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A study on vessel deficiency risk assessment based on PSC inspection data from Tokyo MOU

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A STUDY ON VESSEL DEFICIENCY RISK ASSESSMENT BASED ON PSC INSPECTION DATA FROM TOKYO MOU

By

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The People's Republic of China

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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.

Signature: ……XXXX…..

Date: ………...July 3rd 2017……..

Supervised by: XXXX

XXXX

Assessor: ………………………………………

Co- Assessor: …………………………………..

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ABSTRACT

Title: **A** Study on Vessel Deficiency Risk Assessment Based on PSC Inspection Data from Tokyo MOU

Degree: Master of Science (M.Sc)

The rapid development of the shipping industry has brought great challenges to ship supervision for the Maritime Safety Department in every country or region. The increase in the number of ships, as well as the implementation of the new maritime conventions, have created a contradiction between the limited regulatory resources and the growing number of regulatory objects. At this stage of the mechanism for ship selection, it narrows down the number of target ships to a certain range, but it is still difficult to meet the growing regulatory requirements. Therefore, seeking a more optimized risk assessment of ship deficiencies has become an inevitable problem for Port State Inspection for all States.

This paper introduces the 5-year PSC inspection data from Tokyo Memorandum, and analyses the quantity and distribution of ship deficiencies and detainable deficiencies in detail. And based on the Tokyo Memorandum PSC inspection data, the method of cluster analysis is used to find out the relationship between the ship's deficiency risks and the inherent factors of the ship, thus greatly reducing the number of target ships.

The result of cluster analysis can further screen the ships at berth within the scope of the competent authorities, and provide the corresponding reference for PSCOs targeting the ships. However, it is unavoidable that the objects of this analysis may be omitted. Besides, due to the limitation of the author's expertise, the result may not reflect the actual ships completely. But some rules that are obtained are surely helpful in PSC inspection.

KEY WORDS- Deficiency; PSC; Tokyo MOU; ship risk

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1 Introduction

1.1 Research Background

With the development of science and economy, the shipping industry (e.g.: the increasingly large-scale, specialization and high-speed of ships) plays an increasingly important role in the development of the national economy. However, the frequent maritime accidents not only cause a huge loss of economic property and casualties, but also lead to a huge damage to the environment. So, each country or region have adopted a series of measures to reduce ship accidents, and to improve the level of safety management for the shipping industry. Among these, Port State Control (PSC) inspection is one of the very effective methods.

The background of the Port State Control originated from the issue of the AMOCO CADIZ with Liberia flag in March 17, 1978, which is grounded at Portsall Reef at 3 miles from the Brittany Peninsula in France, resulting in a serious oil pollution of 230,000 tons of crude oil leakage (Ai Yazhao, 2003). The convenience flag makes the traditional shipping countries a sharp decline in the shipping industry, coupled with the rising oil spill accidents. As a result, there are big problems in the implementation of the International Maritime Conventions. Thus, PSC inspection comes into being.

China is one of the 20 member states of the Tokyo Memorandum and has played an active role in fulfilling the goals of International Marine Organization—"Safe, Secure and Efficient Shipping on Clean Oceans". If China wants to change from a big shipping country to a country with more power on shipping, it is important to develop the maritime technology and strengthen the supervision of ships and oceans as well. PSC inspection is a significant part of China's implementation of the International Maritime Conventions, and it is the last line of defense for the maritime security and pollution prevention. In recent years, more and more attention is paid to PSC inspection by many countries.

1.2 Purpose of this paper

The author is one of PSC officers in Lianyungang Maritime Safety Administration, who has an in-depth contact with the PSC inspection work. It is very technical in content, which not only needs a wealth of experience in the sea of PSCOs, but also needs the PSCOs familiar with the International Maritime Conventions. However, due to the increasing number of International Maritime Conventions coming into force, it is hard for PSCOs to know all of these conventions. For example, there is one maritime convention—the POLAR CODE and five amendments entering into force (Xu Chunsong, Han Jialin, 2017). The content of PSC inspection has developed from the initial concerning of ship navigation safety and marine environmental protection to concerning the interests and wellbeing of the seafarers. Due to the large content of International Maritime Conventions, there is more time and strength needed in the process of PSC inspection, which leads to the dropping of the inspection on some sub-standard ships because of the tight sailing date. For example, Lianyungang, where the author works, has such a phenomenon that the D.P.R. of Korea flag or other convenience flag with Korean crew ships reach the port during the weekends when the PSC inspection station is not on duty under ship agency's arrangements in order to escape from the PSC inspection. This is clearly contrary to the original intention of the PSC inspection.

I believe that the inspection of the ship does not need to be exhaustive. While maintaining the normal inspection coverage, it is urgent to improve the efficiency of inspection. In this paper, I will analyze the data of Tokyo MOU PSC in recent 5 years, and analyze the inherent points of the ships, such as the flag, the management company, the classification society, the ship type, tonnage, etc. Through the analysis of these elements, results will be obtained as for where the ship deficiencies exists and what ships should be inspected thoroughly, achieving a targeted PSC inspection and changing the drawbacks of current PSC inspection.

2 *Introduction of Asia Pacific Region PSC inspection*

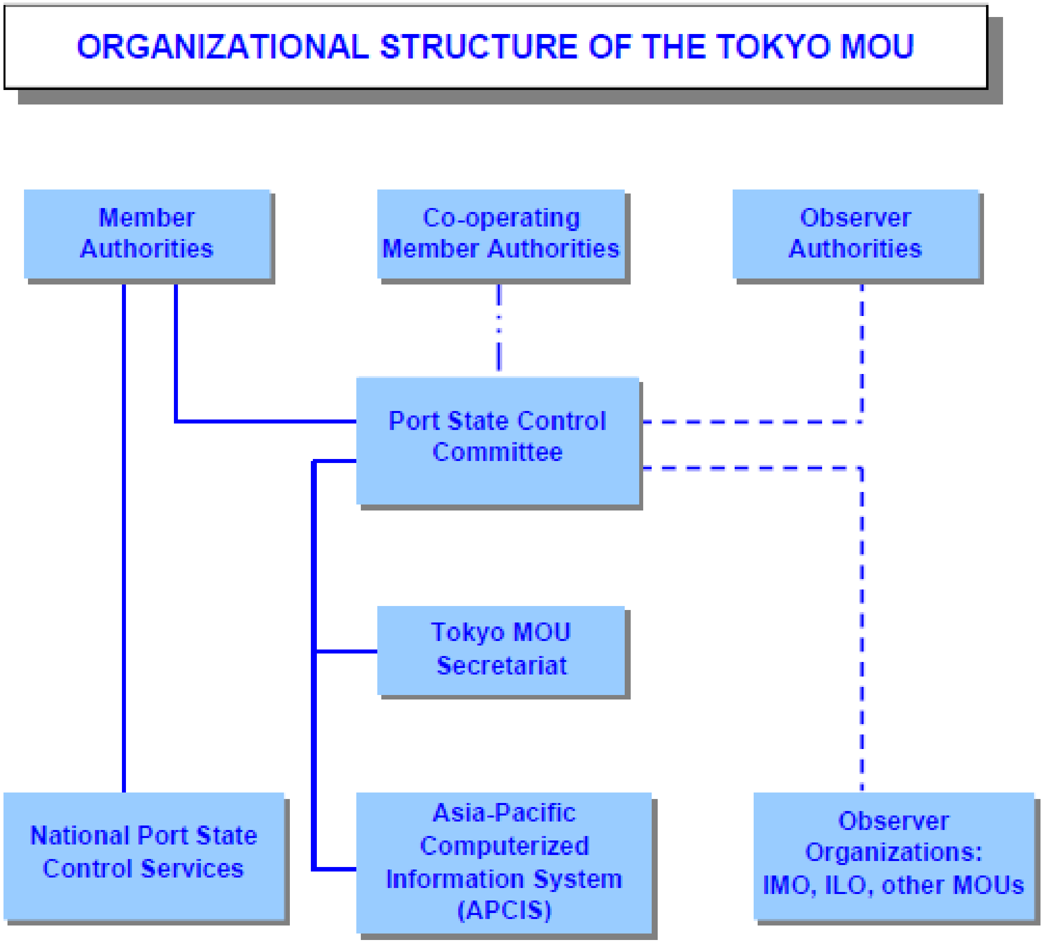
2.1 Brief introduction of Tokyo-MOU organization

The Tokyo Memorandum began operation on 1 April 1994 and now has 20 member States, five observer States and seven international observing organizations (Annex 1). “The Tokyo MOU is one of the most active regional port State control (PSC) organizations in the world. The organization consists of 20 member Authorities in the Asia-Pacific region. The main objective of the Tokyo MOU is to establish an effective port State control regime in the Asia-Pacific region through co-operation with its members and agreement of their activities, to eliminate substandard shipping so as to promote maritime safety, to protect the marine environment and to safeguard working and living conditions on board.

Tokyo MOU strives to:

- develop and maintain effective and efficient PSC system in the region;
- enhance the status and performance of the MOU;
- promote joint initiatives and co-operation with other regional PSC regimes; and
- improve transparency, communication and relationship with the industry.” (Tokyo MOU website)

Picture 2-1: Tokyo MOU organizational structure



Source: Tokyo MOU website http://www.tokyo-mou.org/organization/organizational_structure.php

2.2 Tokyo Memorandum New Inspection Regime (NIR) general introduction

The past inspection regime of Tokyo MOU is based on the ship's target factor and risk to determine the priority inspection of the PSC. The New Inspection Regime of Tokyo MOU highly draws on the Paris MOU target ship selection mechanism and now the Tokyo MOU NIR divides the ship into 3 groups: low-risk ships, medium-risk ships and high-risk ships. The inspection window were 9 to 18 months, 5 to 8 months, 2 to 4 months separately (Table 2-1). When the ship's inspection window is open, PSCOs may carry out PSC inspection for the target ship. In other words, ships may be inspected because they are within the time window of inspection (Priority II). When the date is beyond the inspection window period, PSC must implement PSC inspection which means the ship must be inspected because the time window has been closed (Priority I). If the inspection widow is not open, in principle, the PSCO cannot carry out PSC inspection unless some specialized situation occurs (Tokyo MOU NIR, 2014).

Table 2-1: Time Windows

Ship Risk Profile	Time Window since previous inspection
Low Risk Ships	9 to 18 months
Standard Risk Ships	5 to 8 months
High Risk Ships	2 to 4 months

Source：Tokyo MOU New Inspection Regime, 2014

The following Table.2-2 is Ship Risk Profile made by Tokyo MOU. In Tokyo MOU NIR, the ship's risk is significantly concerned with the ship's type, age, flag, classification society, company performance, deficiency quantity and condition of detainment. Under the New Inspection Regime, Tokyo MOU has paid closer attention to specific types of oil tankers, chemical tankers, gas carriers, passenger ships and bulk carriers, with an initial score of 2. In addition, the performance of ship management companies also greatly affect the value of the ship, which requires the ship management company to increase the safety management of ships to avoid the ship from getting into a high risk level. It is worth mentioning that when counting deficiencies each ISM related deficiency is weighed at five points, while other deficiencies are valued at one point (Tokyo MOU NIR, 2014).

Table 2-2: Ship Risk Profile

Parameters	Profile			
	High Risk Ship (HRS) (When sum of weighting points >=4)		Standard Risk Ship (SRS)	Low Risk Ship (LRS)
	Criteria	Weighting points	Criteria	Criteria
Type of Ship	Chemical tanker,	2	Neither LRS	-

		Gas Carrier, Oil tanker, Bulk carrier, Passenger ship		nor HRS	
Age of Ship		All types > 12y	1		-
Flag	BGW-list[1]	Black	1		White
	VIMSAS[2]	-	-		Yes
Recognized Organization	RO of TokyoMOU[3]	-	-		Yes
	Performance[4]	Low Very Low	1		High
Company performance[5]		Low Very Low	2		High
Deficiencies	Number of deficiencies recorded in each inspection within previous 36 months	How many inspections were there which recorded over 5 deficiencies?	No. of inspections which recorded over 5 deficiencies		All inspections have 5 or less deficiencies (at least one inspection within previous 36 months)
Detentions	Number of Detention within previous 36 months	3 or more detentions	1		No detention

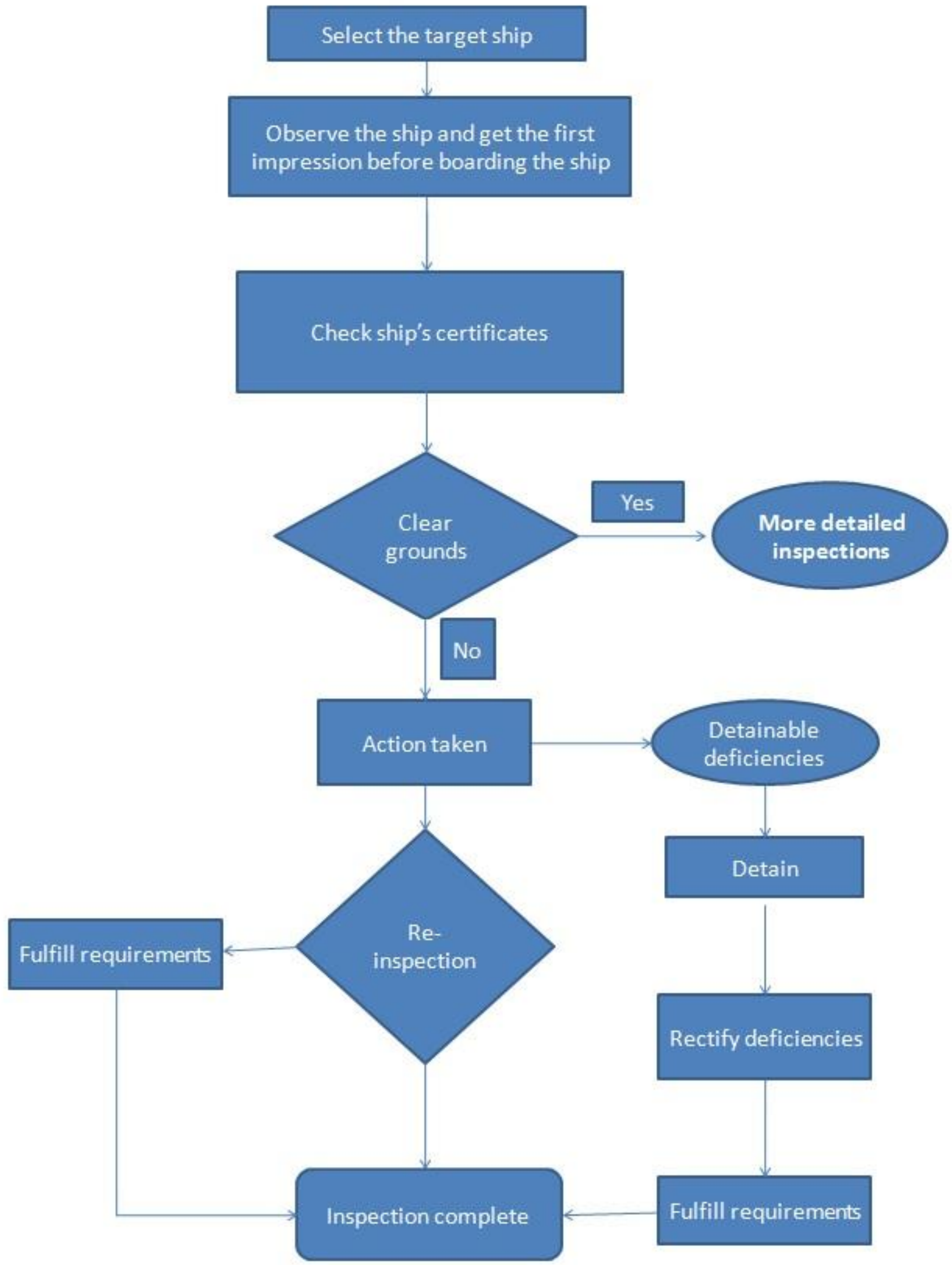
Source：Tokyo MOU New Inspection Regime, 2014

The classification of ship risk factors is the main basis for PSC selecting target ships. Through the Asia-Pacific Computerized Information System (hereinafter referred to as APCIS), PSCOs select the ships which are on the port one by one finding target ships for PSC inspection. In actual work, the PSCOs do not inspect every foreign ship on port, and the requirement of number of inspection for each memorandum is also different. In “Work objectives of China Maritime Safety Administration, 2016” issued by China MSA, PSC inspection rate should reach that ships with Priority I inspection rate should be more than 18% and ships with Priority II rate should be more zhan 8% (China MSA, 2016). "People's Republic of China Ship Safety Inspection Regulations" stipulates that every ship's law enforcement activities requires two persons. Take Lianyungang MSA for example, there are six PSCOs in PSC inspectors station. Each time, they can be divided into only three groups to carry out PSC inspection. Apart from half an hour's drive from workplace to port, one PSC inspection will take about four hours to complete. Overall speaking, a complete PSC inspection takes about one business day from selecting the target ship to the PSC report entry. If the ship is detained, the period of time required will be longer.

2.3 Working procedures of PSC inspection

On November 30, 2011, the International Maritime Organization (IMO) adopted Resolution A.1052 (27)—"Port State Control Procedure, 2017" in the 27th general assembly agenda, which invites all Contracting Governments to implement these Port State Control procedures when carrying out PSC inspections. The full text of the procedure replaces "Port State Control Procedure, 1995" ,which is the customary use. It is the second procedure relating to the implementation process of Port State Control since the Global Port State Surveillance Regional Organization established (Hu Ronghua, 2013). Before PSCOs board the ship, they will give a general look to the appearance of the ship, such as paint conditions, rotten candles or pitting, rusty spot, etc., to obtain the initial impression of the ship. After boarding, PSCOs will check the ship's certificate and the relevant documents at first. If all the certificates of the ship are valid, and the basic impression and the visual situation of the ship are in good condition, PSCOs will believe that this ship is managed well, PSC inspection activity will stop and clear report will be issued to the ship; Otherwise, PSCOs has clear grounds to believe that the equipment onboard or ship crews does not meet the requirements of the conventions, a detailed inspection will be carried out. Finally, a PSC report with actions taken will be issued to the ship according to the inspection results. Picture 2 is the general process of PSC inspection procedure.

Picture 2-2: PSC inspection flow chart



Source: the Author's drawing according to Resolution A.1052(27), IMO

It should be noted that, in the actual PSC inspection work, despite the fact that there are rules stated in Resolution A1052 (27) and in "People's Republic of China Ship Safety Inspection Regulations", yet basically there is no initial inspection for the ship, and in most cases, more detailed inspection would be carried out. We can see that there are 66 certificates that require PSCOs to inspect in “Procedures for Port State Control, 2011” (see Annex 2). These do not include the MLC conventions and polar rules that have come into force in recent years, and BWM convention which is coming into effect. As a result, it is more likely that PSCO will need to inspect more certificates on the horizon.

In addition, the Annexes that are given by Resolution A.1052 (27) refer to MARPOL, SOLAS, STCW, Tonnage, Load Line conventions, the ship’s documents, anti-pollution equipment, ship structures, life-saving, fire fighting, minimum manning, drills, crew operations and procedures, etc. In the implementation of international conventions, PSCOs need to face different types of ships, different ship ages, crews from different nations, diverse types of ship equipment. So many inspection items mentioned above make PSCOs exhausted and unable to inspect the ship from all aspects in the inspection process.

2.4 Applicable Conventions for PSCOs

The laws and regulations for PSC inspection are mainly based on the relevant provisions of the international conventions, while the states are the parties to these conventions. In accordance with the provisions of the applicable conventions, the PSC officers may inspect the foreign vessels arriving at their port. Most of the international conventions come from two organizations: the International Maritime Organization (IMO) and the International Labour Organization (ILO). Relevant convections are listed as follows:

“– the International Convention on Load Lines, 1966;

– the Protocol of 1988 relating to the International Convention on Load Lines, 1966, as amended;

– the International Convention for the Safety of Life at Sea, 1974, as amended;

– the Protocol of 1978 relating to the International Convention for the Safety of Life at Sea, 1974;

− the Protocol of 1988 relating to the International Convention for the Safety of Life at Sea, 1974;

− the International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978 relating thereto, as amended;

− the International Convention on Standards for Training, Certification and Watchkeeping for Seafarers, 1978, as amended;

− the Convention on the International Regulations for Preventing Collisions at Sea, 1972;

− the International Convention on Tonnage Measurement of Ships, 1969;

− the Merchant Shipping (Minimum Standards) Convention, 1976 (ILO Convention No. 147);

− the Maritime Labour Convention, 2006;

− the International Convention on the Control of Harmful Anti-fouling Systems on Ships, 2001; and

− the Protocol of 1992 to amend the International Convention on Civil Liability for Oil Pollution Damage, 1969." （Tokyo MOU, 2015）

Due to the development and renewal of the maritime convention, the PSC inspection of the ship is constantly changing with the modifications of conventions, but there is one standard that the PSC inspection always obeys —"Old ships apply to old rules, new ships comply with new regulations". This means that the PSCOs should not only be familiar with new conventions, but also know about ancient regulations. This situation traps PSCOs in trouble. For example, there are two important amendments (81 Amendments, 2000 Amendments), FSA code, FSS code, and ISM, ISPS code in SOLAS convention. PSCOs should know all about them. Although some of the conventions seem to be the same, yet in fact there are big differences. All these make it difficult for PSCOs to remember all the conventions.

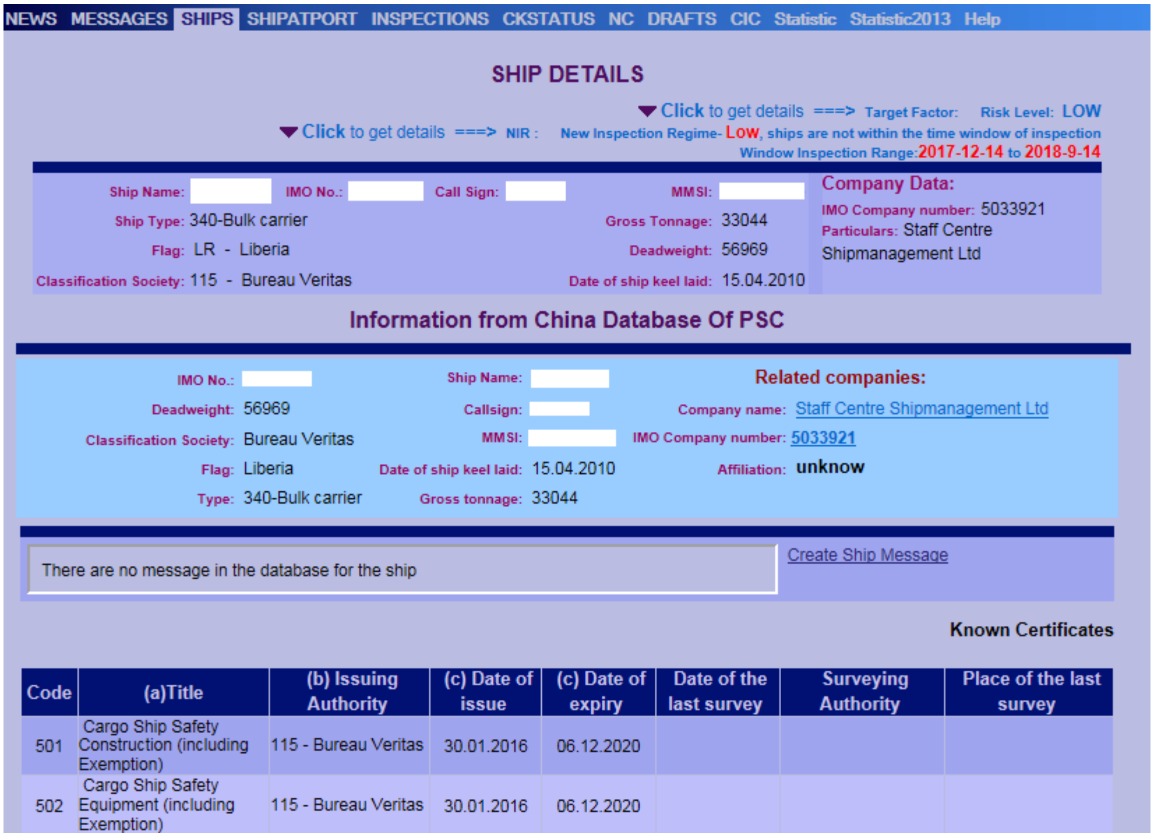
3 Analysis of PSC Data in Asia-Pacific Region

3.1 Introduction of target ship selection system

Asia Pacific Computerized Information System (APCIS) is an independent computer information center in Vladivostok, Russia, which was officially launched on January 1, 2000. The data for the database is provided by the members of Tokyo MOU and all data is available for the members to review to enhance the transparency of the information (Xu, R.et al., 2007). China PSC Computerized Information System refers to the Chinese port state monitoring computer information system, the main data from APCIS. The system can provide PSC inspection report entry, checking and data statistics functions. In PSC inspection, the selection of target ships is done through this system.

When PSCOs begins working, firstly, PSCOs will locate all ships in port via Geographic Information System. Ship name, IMO number, call sign, MMSI number, ship status (mooring or sailing), ship length, width, depth and other basic ship information will be grasped. Then, entering the China PSC Computerized Information System and inputting ship IMO number, PSCOs will get more detailed ship information, including ship flag, classification societies, ship risk, inspection window open or not etc. (Picture 3-1). After determined the target ship inspection window is open , PSCO can check ship import and export plan released by the Vessel Traffic Service centre to make sure whether the target ship has a plan to leave the port. Generally, when the ship leaves the harbor in 2 hours, PSC inspection will not be carried out to avoid delay of sailing date.

Picture. 3-1: CPCIS window



NEWS MESSAGES SHIPS SHIPATPORT INSPECTIONS CKSTATUS NC DRAFTS CIC Statistic Statistic2013 Help

SHIP DETAILS

Click to get details ===> Target Factor: Risk Level: LOW

Click to get details ===> NIR : New Inspection Regime- Low, ships are not within the time window of inspection

Window Inspection Range:2017-12-14 to 2018-9-14

Ship Name: IMO No.: Call Sign: MMSI:

Ship Type: 340-Bulk carrier Gross Tonnage: 33044

Flag: LR - Liberia Deadweight: 56969

Classification Society: 115 - Bureau Veritas Date of ship keel laid: 15.04.2010

Company Data:

IMO Company number: 5033921

Particulars: Staff Centre Shipmanagement Ltd

Information from China Database Of PSC

IMO No.: Ship Name:

Deadweight: 56969 Callsign:

Classification Society: Bureau Veritas MMSI:

Flag: Liberia Date of ship keel laid: 15.04.2010

Type: 340-Bulk carrier Gross tonnage: 33044

Related companies:

Company name: Staff Centre Shipmanagement Ltd

IMO Company number: 5033921

Affiliation: unknow

There are no message in the database for the ship

Create Ship Message

Known Certificates

Code	(a)Title	(b) Issuing Authority	(c) Date of issue	(c) Date of expiry	Date of the last survey	Surveying Authority	Place of the last survey
501	Cargo Ship Safety Construction (including Exemption)	115 - Bureau Veritas	30.01.2016	06.12.2020			
502	Cargo Ship Safety Equipment (including Exemption)	115 - Bureau Veritas	30.01.2016	06.12.2020			

Source: CPCIS, available from: http://218.25.179.238:7001/pscchina/LoginAction.do?action=login

3.2 Analysis of PSC data from Tokyo MOU

3.2.1 Overview on PSC inspections in Asia-Pacific region

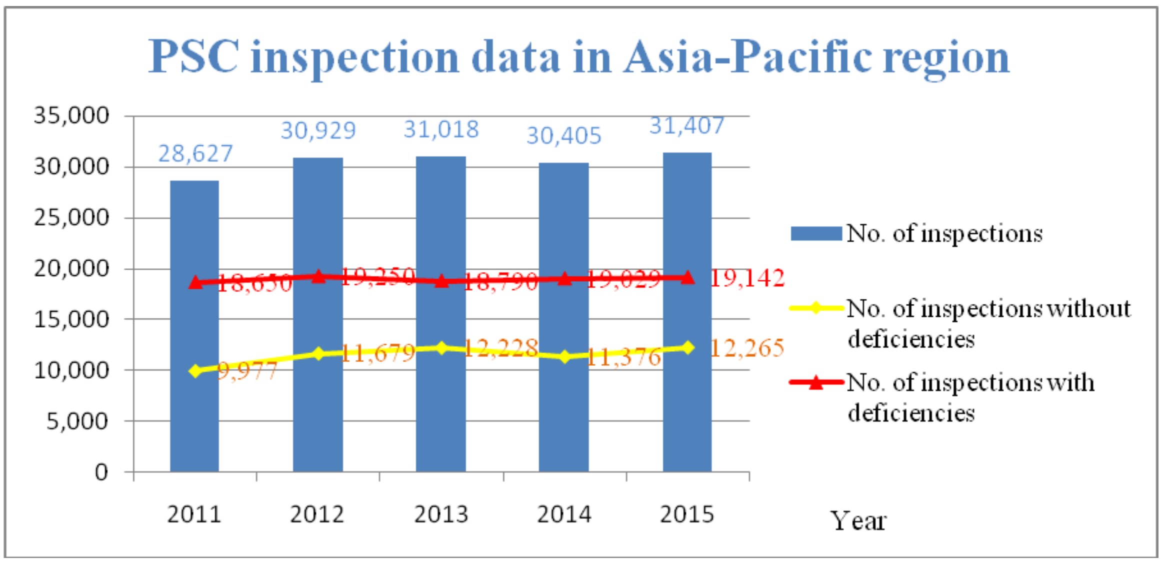
Every PSC inspection generates an inspection report that, inter alia, contains detailed information on the deficiencies noted (including 0 for no deficiency) together with relevant vessel particulars such as the flag of registry, IMO vessel number, vessel type, year built, and date of inspection (Cariou, P., Jr, M. Q. M., & Wolff, F. C., 2008). Although there are a lot of conventions mentioned in Item 2.3, it is impossible that all these conventions are the key points of PSC inspection. Seven of the most important conventions in the international regulatory framework for maritime safety serve as the bases upon which the regime of PSC has been institutionalized. (Domijan-Arneri, M., 2002). These are SOLAS, MARPOL, Load Lines, STCW, COLREG, TONNAGE, Minimum Standard Convention (ILO 147) (Ademuni-Odeke, 1997). According to the Tokyo-MOU PSC Annual Report (2011～2015), this paper will give a brief introduction on the distribution data of ship deficiencies and detainable deficiencies.

Table 3.1: PSC inspection data statistics in Asia-Pacific Region, 2011-2015

Inspection time (year)	2011	2012	2013	2014	2015
No. of inspections	28,627	30,929	31,018	30,405	31,407
No. of inspections with no deficiencies	9,977	11,679	12,228	11,376	12,265
No. of inspections with deficiencies	18,650	19,250	18,790	19,029	19,142
No. of deficiencies	103,549	100,330	95,263	89,560	83,606
No. of detentions	1,562	1,421	1,395	1,203	1,153

Source: the author's calculation, data from the Tokyo MoU (2011–2015).

Picture 3.2: PSC inspection data in Asia-Pacific region, 2011～2015

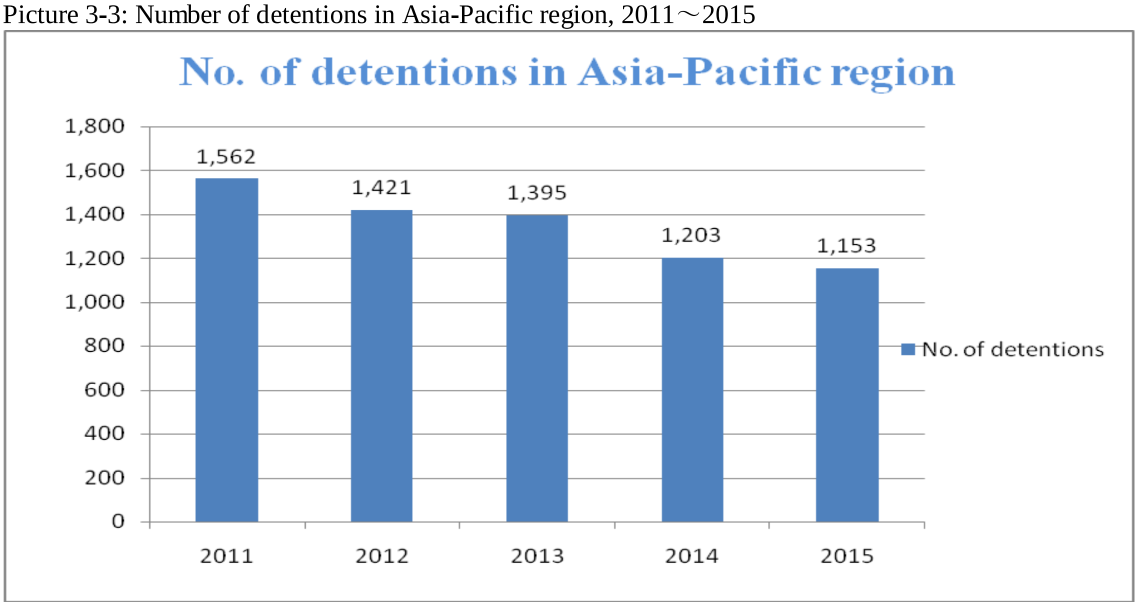


Source: the author's drawing, data from the Tokyo MoU (2011–2015).

In the past five years, there has been an upward trend in PSC inspection number in the Asia-Pacific region. The number of inspections rose from 28,627 in 2011 to 31,407 by 2015, and the number of ships with deficiencies and ships without deficiencies also increased accordingly. In the situation of an increase trend in the number of ship PSC inspections, we should pay attention to two aspects. On the one hand, from the view of global economic situation, the world economic growth rate is extremely slow, and there may even be a trend of economic recession. Shipping economy itself is a kind of staple commodity, which has been seriously influenced by the trend of global economic conditions (Qin Junwei, 2016). From 2013 onwards, there is an obvious decrease in the number of ships arriving at port. However, because of the weak economic situation, the shipping market is speeding up to weed out the old age ships. For example, among the 251 ships inspected by the Lianyungang MSA PSC station in 2016, 130 ships are under 10 years old, accounting for 51.8 percent of the total number of PSC inspections, and there are even 37 ships which has been used for less than 5 years (keel laid after 2012), taking up to 14.7 percent of the total number of inspected ships. There is a relatively large advantage for these ships in the PSC inspection, and a large quantity of them would pass PSC inspection without any deficiencies (Authors' calculation, 2017). On the other hand, the Tokyo Memorandum's old inspection mechanism is that all ships (except special circumstances) should receive a PSC inspection every 6 months, while the New Inspection Regime has a greater change in target ship's selection system. The Tokyo MOU NIR came into effect in January 1, 2014 (Sun Yujie, 2013). This also shows that, in the past five years, more frequent ships are inspected in Asia-Pacific region.

3.2.2 Detainable ships in Asia-Pacific region

Picture 3-3: Number of detentions in Asia-Pacific region, 2011～2015



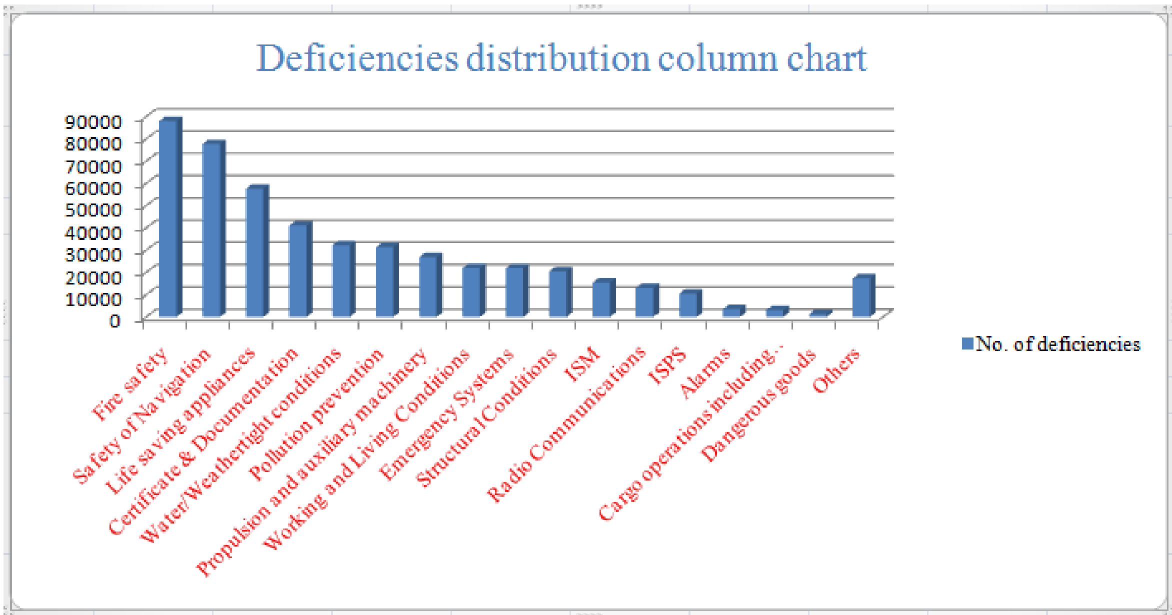
Source: Author's drawing, data from the Tokyo MoU (2011–2015).

Different from an upward trend in the total number of PSC inspection, from 2011 to 2015, the number of ship detention is declining. There are more than 1,500 ships detained in 2011, and then an obvious decreasing trend is seen from then on. Approximately 100 detained ships are reduced each year, and in 2015, there are only

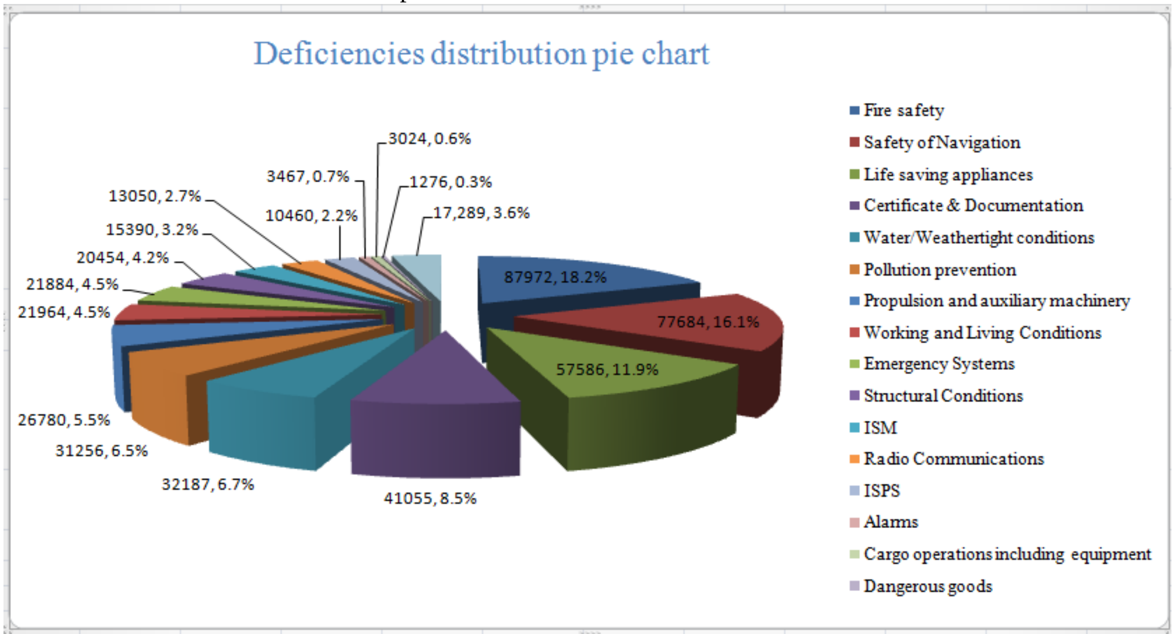
1,153 ships detained. As for the reason, I suppose there are 2 points. As mentioned in Item 3.2.1, ships with old ages have no competitors in the current shipping market. And the Tokyo MOU NIR pays more attention to the safety management system of both ships and ship management companies, which means the seafarers on board and ship management company should continuously strengthen the safety management in order to have a better performance to the company.

3.3 Deficiencies distribution

Picture. 3-4 :deficiencies distribution column chart 2011-2015



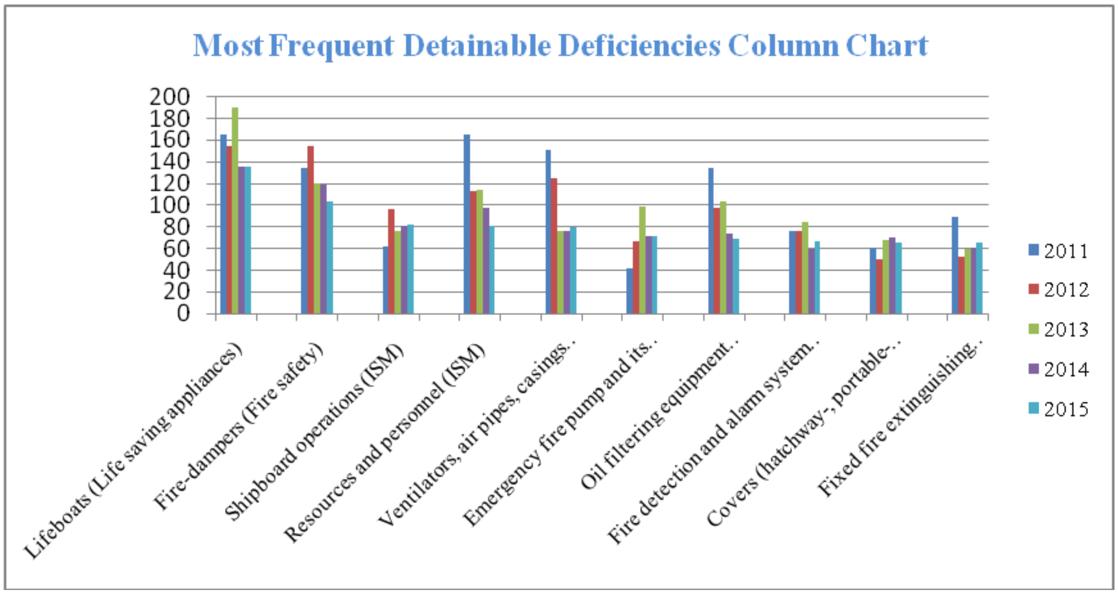
Picture 3-5 :deficiencies distribution pie chart 2011-2015



Source : Picture 6 7, Authors's caculation, data from the Tokyo MOU (2011-2015).

The column chart and pie chart compares figures for deficiencies of different categories in Tokyo MOU PSC inspection data statistics from 2011 to 2015. It is clear that Fire Safety is the most concentrated area than any other deficiencies, with 87,972 items accounting for 18.2 percent of PSC deficiencies. Safety of Navigation occupies the second place that 77,684 items were found in this 5-year period time, about 2 percent lower than Fire Safety. Life-saving apparatus is also significant with 11.9% of the total number of deficiencies. As for Certificate & Documentation, there are plenty of deficiencies because every convention has its provision about issuing certificates. Therefore, this item ranks the 4th position (41,055, 8.5%). In terms of Water/Watertight conditions, 32,184 deficiencies were found in 5 years, accounting for 6.7%. Pollution prevention (MARPOL) has always drawn PSCOs' attention, especially the oil pollution prevention (MARPOL Annex I) and sewage water pollution prevention (MARPOL Annex IV), the number of this item is a little smaller than Water/Watertight conditions, with 31,256 deficiencies, followed by Propulsion and auxiliary machinery. This is because there is plenty of hydraulic equipment in the engine room which may easily leak. When PSC inspection is carried out, if the engine room could be kept clean, it will leave a better impression on PSCOs, and the possibility of clear report will be greater. Although there are only 15,390 ISM deficiencies were found, that is about 5,000 on average, more attention still needs to be paid to this item. PSCOs is very careful about writing ISM deficiencies on report because once there are ISM deficiencies, there are problems in safety management of the ships. As a consequence, when ISM deficiency is issued, the ship will be detained in all probability. Worse still, the ship management company will be affected and additional audit might be carried out for company to make sure SMS runs well. MLC convention came into effect on August 20, 2013, so there is hardly any figure for this item. Other items, such as ISPS, Radio Communication, Alarms and so on, occupied less proportion. Here, we will not discuss them one by one.

Picture 3-6: Most frequently detainable deficiencies column chart



Source : Authors's caculation, data from the Tokyo MOU (2011-2015)

Picture 3-6 is the column chart that illustrates the most frequently detainable deficiencies from 2011 to 2015. It is clear that Lifeboats (Life saving apparatus), ISM, Fire-dampers (Fire safety) and Oil filter equipment are in the detainable deficiencies concentrated area. These items are mainly related to SOLAS convention Chapter II-1，II-2，III & IX and MARPOL convention Annex I.

From the Tokyo-MOU's PCS inspection data statistics (2011～2015), Life-saving apparatus is the most important. Although in PSC inspection, the number of Life-saving apparatus deficiencies found were less than the figure of Fire safety and Safety of Navigation yet among a total number of 6,734 detained ships, there are 782 ships detained because of Life-saving deficiencies, accounting for 11.6 percent and is higher than any others. Especially in some cold area, the lifeboat engine is difficult to be started because of poor maintenance. Fire safety ranks the second place: 632 ships were detained due to fire fighting deficiencies. In the PSC inspection in the Asia-Pacific region, the requirements for engine room fire dampers are very stringent. According to SOLAS CII / R47, R38 (b), R69 (a), all the main inlets and outlets of ventilation systems should be able to be closed outside the ventilated area; the operating position of the closing device should be easily accessible and there should be obvious permanent marks indicating whether the closing device is in the open position or in the closed position. The requirement is very clear that the ventilation system should be able to be closed outside the ventilated area. If not, detention is inevitable. Statistics also show that the Emergency system is the key point in PSC inspection. The main defective aspects of Emergency system are: emergency generator failure, emergency fire pump malfunction, emergency illumination out of order, emergency escape trunk blockage, no signs or emergency lighting, no emergency steering drills, life saving, fire fighting, failure of oil spill to meet the requirement of convections, and so on. It is worth mentioning that, "the rest time of crews" currently draws PSCOs' attention, especially after MLC convention came into effect (Wang Qi, 2014). In 2014, Paris MOU and Tokyo MOU jointly held the "STCW Convention crew rest time Concentrated Inspection Campaign". According to the Paris MOU announced the CIC result, there were 16 ships that are severely detained during the campaign (14% of the total number of detention) and 11 of the 16 detained ships were general cargo ship / multi-purpose ship (70%), 3 bulk carrier ships (19%), 1 container ship and 1 ship of other type (Bao Junzhong, 2015). In July 2010, a total number of 293 foreign ships received Australia Maritime Safety Administration's (AMSA) PSC inspection, of which 23 ships were detained (Huang Zhi, 2011). Among the detained ships, there were eight ships that were given the deficiencies: "SMS's failure to ensure watch keeping hours are correctly recorded; Masters unable to ensure watch keepers are rested as per STCW". The rest time of the seafarers is not only related to the implementation of the STCW and MLC Convention, but also related to provisions of the ISM. Therefore, in the situation that the ship is detained due to the rest time of crews, usually coupled by the SMS-related deficiencies .

It is true that the ship is a dynamic system with many elements (Raphael Baumler, 2017). Via analyzing the Tokyo-MOU PSC inspection data, there is no doubt that dealing with big data is conducive to finding objective laws. In the 251 ships inspected by the Lianyungang Maritime Safety Administration in 2016, the most frequent deficiencies were 10-Safety of Navigation,07-Fire safety,11-Life saving appliances, with the figure 227, 225, 154 respectively (Author's statistics, 2017). This result is highly consistent with the result analyzed in Chapter 3.3. This shows that the inherent factors of the ships can be qualitatively analyzed to find the internal rules of these data. The author believes that the three important elements are: ship' Flag, classification societies and ship type determine the number of ship deficiencies and defect-free pass rate. In the next chapters, this paper will discuss the relationship between the ships' defects and the three elements through cluster analysis.

4 Cluster analysis

4.1 Benefit of cluster analysis

A ship has many properties, and in many cases, we cannot predict the status of the ship management. In the area where the author works, excellent management can make the ship obtain excellent performance in the PSC inspection. For example, ships under the management of some famous shipping management company, such as, Maersk Line Swiss Mediterranean Shipping, France Dafei Shipping, China Taiwan Evergreen Shipping, Germany Habar Laoard Shipping, China CSCL and other world-renowned management companies. Because of its ISM system running in place, even if the ship has an old age, the ship still maintains excellent operating conditions. However, there are plenty of world's shipping companies whose management quality we cannot control, which makes the analysis of ship management situation impossible.

However, cluster analysis can classify the ships into different groups according to the similarity of ship properties to find the relationship between ship property and ship management. Clustering analysis is better at classifying fuzzy data than other data analysis methods. In the case of seemingly less relevant data, the relationship between elements is found. It is more intuitive in the selection of ships when the ship's management situation and its inherent factors is linked.

4.2 K-means cluster analysis

Cluster analysis is one of the most important data analysis methods that has been widely used in many applications, including pattern recognition, data analysis, image processing, and market research (Han, J., Kamber, M., & Chiang, J.，1997). Clustering divides a group of data objects into multiple classes or clusters. There is a high degree of similarity for the object in the same class or cluster, and there are huge differences in different clusters of objects and the optimal number of clusters is unknown beforehand. This belongs to an unsupervised learning method.

At present, many domestic and foreign scholars have proposed a variety of clustering methods. Typical clustering methods include: Partitioning Method, Hierarchical Method, Grid-based Method, Density-Based Method and Model-based Method (Xiang, P. S., 2011). Among so many clustering algorithms, the k-means algorithm is one of the most widely used algorithms. Compared with other algorithms, the k-means algorithm has the characteristics of simple algorithm, fast and stable clustering effect. The algorithm is relatively scalable and efficient. K-means algorithm is widely used in a wide range of applications, including image and voice data compression (Chinrungrueng, C., 1993; Lloyd, S., 1982)， data preprocessing of system modeling by radial basis function network (Moody, J., & Darken, C. J., 2008)， task decomposition in heterogeneous neural network structures (Chinrungrueng, C., 1993), bioinformatics (Jiang, D., Tang, C., & Zhang, A., 2004) and other emerging areas. Therefore, it is necessary to study the optimization of k-means algorithm.

The K-means algorithm divides M data objects into k clusters, where k is the number of clusters previously set by the user. Let X = { k clusters of M data objects divided by K-means algorithm }. Suppose X = $\{x_1, x_2, \cdots, x_m, \cdots, x_M\}$ is a set of M data objects. The N features of each data object are represented by F = $\{f_1, f_2, \cdots, f_n, \cdots, f_N\}$, then each data object can be expressed as $x_m = \{x_{m1}, x_{m2}, \cdots, x_{mn}, \cdots, x_{mN}\}$, where x_{mn}

is the n^{th} attribute value of the m^{th} object. C = { c_1, c_2,⋯, c_k,⋯, c_K } denotes the k^{th} clustering center, c_{kn} is the set of K clustering centers. c_k ={ c_{k1}, c_{k2},⋯, c_{kn},⋯, c_{kN} } represents the k^{th} cluster center of the n^{th} attribute. The dissimilarity measure between the data object x_m and the clustering center c_k is called diss(x_m,c_k). The smaller the diss(x_m,c_k) value is, the greater the likelihood that the data object x_m belongs to the clustering center c_k. In general, the Euclidean distance diss(x_m,c_k) is:

$$\mathrm{diss}(x_m, c_k) = \sum_{n=1}^{N} \mathrm{diss}(x_{mn}, c_{kn}) \tag{1}$$

Where diss(x_m, c_k)=$|x_{mn}, c_{kn}|^2$ is the dissimilarity of x_m and c_k on the n^{th} attribute f_n.

According to Eq. (1), the optimal clustering result is found for any data object x_m and its corresponding clustering center c_k in the data set, so that the sum of the distance between the whole data set and the clustering center on its clustering is the smallest:

$$\mathrm{Minimize}\ S(U, c) = \sum_{m=1}^{M} \sum_{k=1}^{K} \sum_{n=1}^{N} u_{mk} \times d(x_{mn}, c_{kn}) \tag{2}$$

Clustering center：

$$c_{kn} = \frac{\sum_{m=1}^{M} u_{mk} \times x_{mn}}{\sum_{m=1}^{M} u_{mk}}, \quad k=1,2, \cdots, K;\ n=1,2, \cdots, N \tag{3}$$

After several iterations, until the clustering center tends to be stable, it shows that when the clustering reaches all or local stability, the clustering process is terminated.

5 Evaluation of ship deficiencies risk via cluster analysis

This paper analyzes the safety management status of ships through 5 years' inspection data, and explores the relationship between the ship flag, the classification society and the ship's type with the number of deficiencies. Three indexes (i.e.: the defect-free rate, the average number of deficiencies and the detention rate) are used to evaluate the ship's deficiency situation.

The ship without deficiency rate indicates that the ship is in good condition and that the index is obtained by the number of defect-free ships divided by the initial number of inspected ships. The higher the value of this rate, the better managed the ship occupy the number of inspected ships. The number of mean defects also reflects the quality of the ship. The data is obtained by dividing the total number of deficiencies by the number of defective ships. The smaller the number of average deficiency, the better the ship's condition. Besides, the average number of defects is also a reflection of the management situation; The detained ships indicate poor quality and the detention rate is obtained by dividing the detained ships by the total number of inspected ships. The smaller the value of this index is, the better quality the ships are of.

5.1 Analysis of Flag State - Cluster Analysis

Adopting zero defect rate, the average deficiencies per ship and the detention percentage (%) are taken as the variables of the cluster analysis. The zero defect pass rate is the derived field, which is calculated as (No. of inspection -No of inspection with deficiencies) / No. of inspection. The case marker variable is the categorical variable for the "Flag". Utilizing k-means clustering analysis algorithm, set k = 3, the analysis results are as follows:

Table 5-1: Initial clustering center

	Cluster		
	1	2	3
Average deficiencies per ship	11.43	13.00	4.00
Detention percentage (%)	85.71	.00	50.00
Defect-free rate	.13	.00	.00

The table represents the initial cluster center, it is a case in general.

Table 5-2 : Iteration history[1]

Iteration	Changes in the cluster center						
	1	2	3		1	2	3
1	.000	10.852	14.193	4	.000	.499	2.477
2	.000	.557	4.406	5	.000	.602	2.222
3	.000	.256	1.597	6	.000	.000	.000

The clustering analysis is a process of iteration and convergence. The default number of iterations is 100, and it can be seen from Table 5 that the number of iterations of the clustering process is 6 and the clustering center is provided after each iteration.

Table 5-3: Clusters of Flags

Case NO.	Flag	Cluster	Distance	Case NO.	Flag	Cluster	Distance	Case NO.	Flag	Cluster	Distance
1	Panama	2	1.698	42	United States	2	3.003	83	United Arab Emirates (UAE)	2	2.557
2	Hong Kong, China	2	3.063	43	Bangladesh	2	6.809	84	Solomon Islands	2	2.743
3	Liberia	2	1.811	44	Vanuatu	2	1.987	85	New Zealand	2	3.814
4	Singapore	2	2.497	45	Togo	2	6.73	86	Bahrain	2	4.745
5	Marshall Islands	2	0.647	46	France	2	4.718	87	Samoa	3	5.865
6	Cambodia	2	10.112	47	Portugal	2	0.871	88	Brazil	3	1.64
7	Korea, Republic of	2	4.448	48	Belgium	2	1.784	89	Chile	2	5.445
8	China	2	4.349	49	Saudi Arabia	2	3.182	90	Falkland Islands (UK)	2	5.514

[1] The convergence is achieved due to the absence of changes or small changes in the cluster center. The maximum absolute coordinate of any center is changed to .000. The current iteration is 6. The minimum distance between the initial centers is 36.475.

9	Malta	2	2.363	50	Moldova	3	8.302	91	Colombia	3	14.431
10	Viet Nam	2	3.38	51	Saint Kitts and Nevis	2	7.155	92	Spain	3	3.835
11	Bahamas	2	0.851	52	Switzerland	2	1.624	93	Equatorial Guinea	2	9.443
12	Antigua and Barbuda	2	4.416	53	Iran	2	3.197	94	Libya	2	5.557
13	Cyprus	2	2.217	54	Croatia	2	3.809	95	Ecuador	2	7.294
14	Belize	2	4	55	Luxemburg	2	1.251	96	Lithuania	2	5.287
15	Greece	2	1.871	56	Tanzania	3	3.781	97	Ukraine	2	7.542
16	Thailand	2	4.253	57	Curacao	2	1.156	98	Ship's registration withdrawn	1	0
17	Russian Federation	2	0.7	58	Sweden	2	4.464	99	Argentina	3	6.371
18	Sierra Leone	3	7.243	59	Barbados	2	3.951	100	Libyan Arab Jamahiriya	2	5.305
19	Malaysia	2	0.616	60	Cook Islands	3	8.763	101	Mauritius	2	5.694
20	Norway	2	1.243	61	Jamaica	2	4.226	102	Ireland	2	6.326
21	United Kingdom (UK)	2	1.139	62	Niue	3	7.268	103	Tunisia	2	5.306
22	Kiribati	2	6.484	63	Kuwait	2	0.32	104	Finland	2	5.831

23	Germany	2	0.457	64	Egypt	3	6.807	105	Mexico	2	6.331
24	Korea, Democratic People's Republic	3	9.23	65	Dominica	2	6.651	106	Algeria	3	24.412
25	Philippines	2	4.532	66	Papua New Guinea	3	1.411	107	Canada	2	5.315
26	Indonesia	3	8.48	67	Saint Kitts and Nevis	2	8.41	108	Estonia	3	25.059
27	Isle of Man (UK)	2	0.987	68	Georgia	3	3.977	109	Jordan	2	6.058
28	Japan	2	2.668	69	Tonga	3	3.483	110	Bolivia	3	24.581
29	Saint Vincent and the Grenadines	2	1.664	70	Pakistan	2	2.077	111	Fiji	2	6.948
30	Denmark	2	0.684	71	Sri Lanka	2	2.245	112	Nigeria	2	6.651
31	Netherlands	2	1.392	72	Maldives	2	5.704	113	Bulgaria	2	8.405
32	Italy	2	2.952	73	Myanmar	2	7.938	114	Faroe Islands	2	6.948
33	Tuvalu	2	2.09	74	Israel	2	1.677	115	Gambia	2	6.966
34	Mongolia	3	7.119	75	Palau	2	9.844	116	Iceland	2	5.841
35	Cayman Islands (UK)	2	1.66	76	Ethiopia	2	2.146	117	Lao, People's Democratic Republic	2	6.948
36	Taiwan, China	2	2.205	77	Comoros	3	5.669	118	Lebanon	2	5.319

37	India	2	5.824	78	Brunei Darussalam	3	5.02	119	Montenegro	2	6.329
38	Bermuda (UK)	2	3.242	79	Honduras	3	3.079	120	Romania	2	6.948
39	Vanuatu	2	3.818	80	Australia	2	5.922	121	Saint Helena (UK)	2	10.038
40	Gibraltar (UK)	2	2.117	81	Peru	3	8.022	122	South Africa	2	6.948
41	Turkey	2	3.374	82	Qatar	2	9.099				

From Table5-3 above, it can be seen in different types of flag countries. The first column stands for the flag country number, the second column for the flag country, the third column for the classification of the name, and the fourth column for the distance to the cluster center.

Table 5-5: Final cluster center

	Cluster		
	1	2	3
Average deficiencies per ship	11.43	4.47	7.50
Detention percentage (%)	85.71	5.28	25.67
Defect-free rate	.13	.36	.16

Table 5-5 represents the center value of the final cluster for each category. Through this table, we can see that the second class of defect-free pass rate is high, the average number of deficiencies and detention rate are low, so this group is an excellent group compared with others; the first class of defect-free pass rate is low, the average number of deficiencies and detention rate are higher, so this group is an inferior group; the third category is in between the first class and the second class, so it is the medium group.

Table.5-6: The final distance of cluster centers

Cluster	1	2	3
1		80.731	60.168
2	80.731		20.615
3	60.168	20.615	

Table.8 represents the distance between the different categories.

Table5-7: The number of cases in each cluster

Cluster	1	2	3	Effective	Missing
Number	1	97	24	122	0

Table 5-7 represents the number of Flags in each category.

5.1.1 Correlation analysis between parameters and variables in cluster analysis

Table 5-8: Correlation

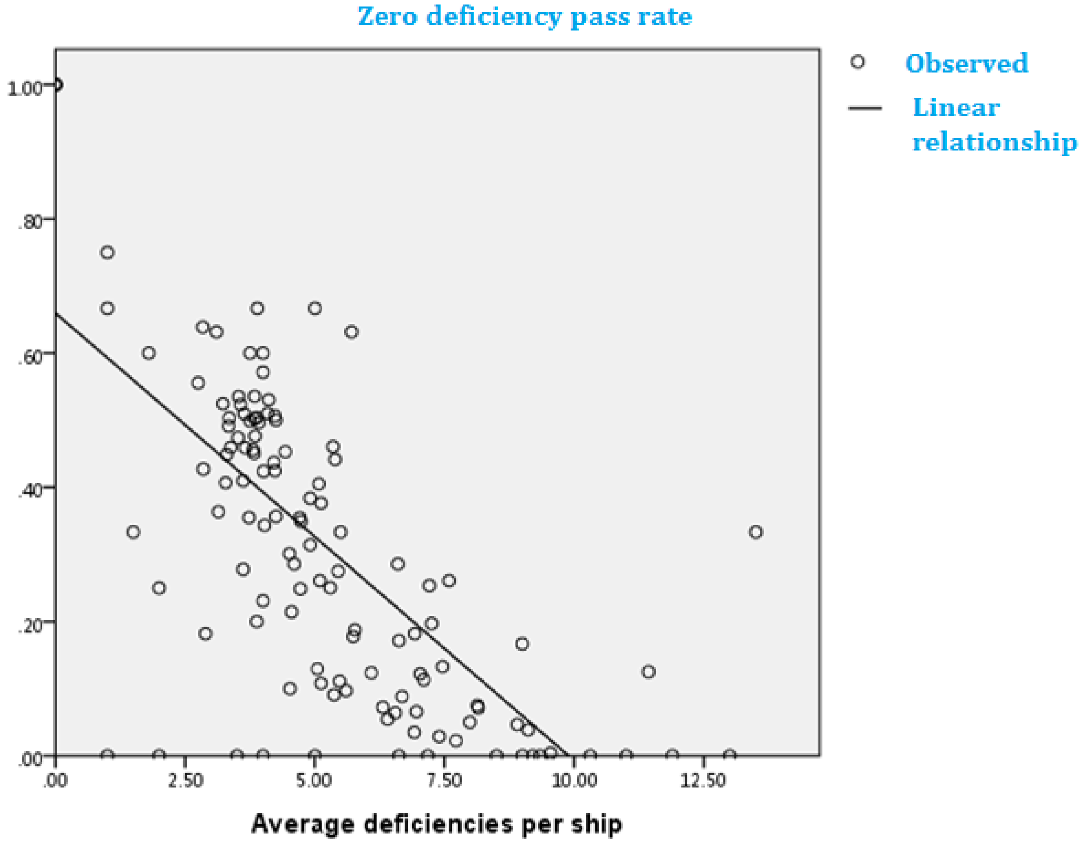
		Defect-free pass rate	Average deficiencies per ship	Detention percentage (%)
Defect-free pass rate	Pearson correlation	1	-.699**	-.349**
	significance (two-side test)		.000	.000
	N	122	122	122
Average deficiencies per ship	Pearson correlation	-.699**	1	.540**
	significance (two-side test)	.000		.000
	N	122	122	122
Detention percentage (%)	Pearson correlation	-.349**	.540**	1
	significance (two-side test)	.000	.000	
	N	122	122	122

**. Significant correlation at .01 level (bilateral)

Table 5-8 shows that the defect-free rate is negatively correlated with the number of average deficiencies, with the negative correlation coefficient being -0.699, and the coefficient significant decreasing when p<0.01; The zero defect-free rate is also negatively correlated with the detention rate, with the negative correlation coefficient being -0.349, and the coefficient significant decreasing when p<0.01; The average number of deficiencies is positively correlated with the detention rate, with a 0.54 of the the correlation coefficient, and the coefficient significant decreases when p<0.01.

5.1.2 Regression analysis of parameters and variables in cluster analysis

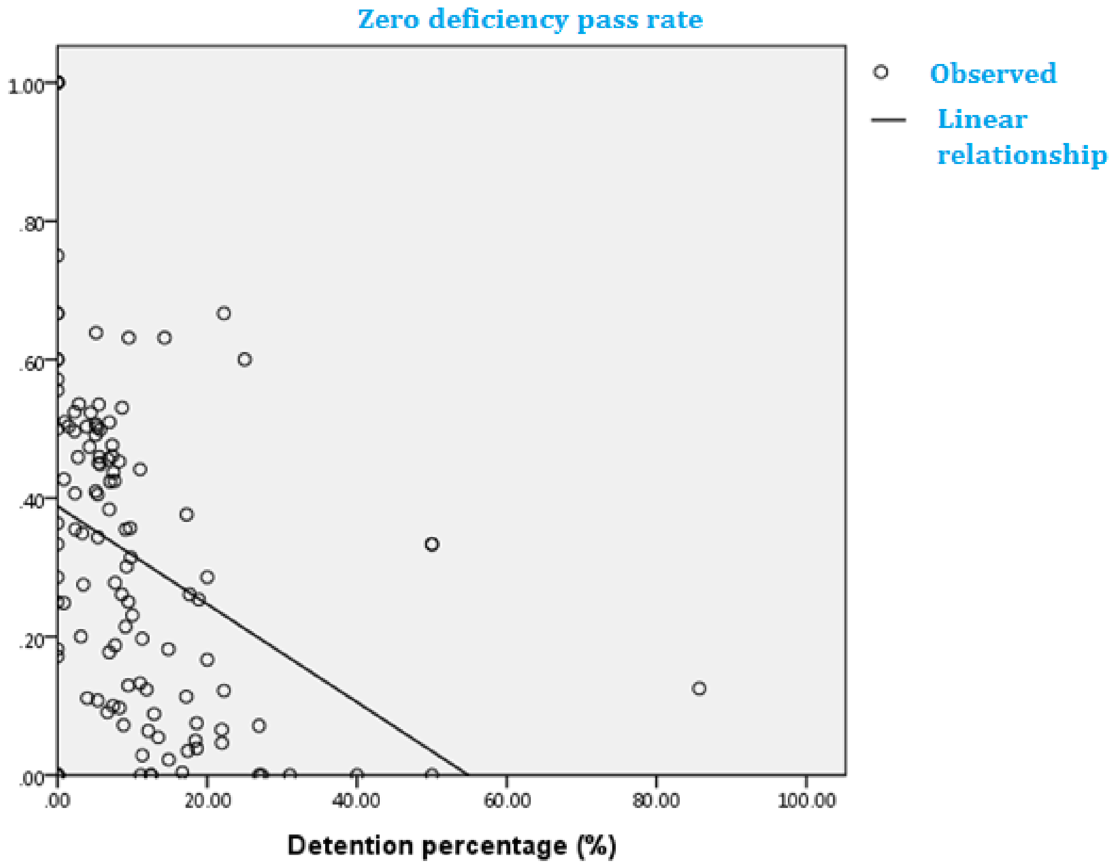
Picture 5-1: Relationship between the number of average deficiencies and zero defect pass rate.



From this figure, the relationship between the zero defect rate and the number of average deficiencies can be seen via linear regression, and the regression equation is:

Y=-0.067x+0.66，where X is the number of average deficiencies, and Y is the zero defect pass rate.

Pictrue5-2 :Relationship between the detention rate and zero defect pass rate



From this figure, we can see that the relationship between the zero defect rate and the detention rate through linear regression, and the regression equation is:

Y=-0.007z+0.388， where X is the detention rate, and Y is the zero defect pass rate.

5.2 Analysis of classification society - Cluster Analysis

Using the detention rate (%) and the Relevant Organization (RO) responsibility percentage (%) as the variables of the cluster analysis, the case variable is the "classification society". Using k-means clustering analysis algorithm, set k = 3, the analysis results are as follows:

Table.11: Initial clustering center

	Cluster		
	1	2	3
Detention percentage (%)	.00	50.00	66.67
RO responsibility percentage (%)	.00	50.00	11.11

Table 5-9 : Iteration history[2]

Iteration	Changes in the cluster center		
	1	2	3
1	7.553	.000	13.355
2	.307	.000	5.633
3	.000	.000	.000

Table 5-10: Clusters of classification

Case NO.	Classification society	Cluster	Distance	Case NO.	Classification society	Cluster	Distance	Case NO.	Classification society	Cluster	Distance
1	Alfa Register of Shipping	1	7.247	31	Honduras Bureau of Shipping	1	7.247	61	Overseas Marine Certification Services	1	4.692
2	American Bureau of Shipping	1	4.624	32	Honduras International Surveying and Inspection Bureau	1	7.247	62	Panama Bureau of Shipping	1	4.806

[2] The convergence is achieved due to the absence of changes or small changes in the cluster center. The maximum absolute coordinate of any center is changed to .000. The current iteration is 3. The minimum distance between the initial centers is 42.312.

3	American Register of Shipping	1	1.083	33	INCLAMAR (Inspection y Classification Maritime, S. de. R.L.)	1	9.447	63	Panama Marine Survey and Certification Services, Inc.	1	1.706
4	Asia Classification Society	1	0.638	34	Indian Register of Shipping	1	0.622	64	Panama Maritime Documentation Services	1	2.729
5	Belize Maritime Bureau Inc.	1	2.487	35	Indonesian Classification Bureau	1	13.684	65	Panama Maritime Surveyors Bureau Inc	1	5.146
6	Bulgarski Koraben Registar	3	2.778	36	Intermaritime Certification Services, S.A.	1	0.844	66	Panama Register Corporation	1	0.802
7	Biro Klasifikasi Indonesia	1	7.734	37	Marconi International Marine Company Ltd.	1	7.247	67	Panama Shipping Certificate Inc.	1	1.907

8	Bulgarski Koraben Regista r	3	2.778	38	International Maritime Register	1	5.285	68	Panama Shipping Registrar Inc.	1	2.519
9	Bureau Securit as	1	2.023	39	International Naval Surveys Bureau	1	3.003	69	Phoenix Register of Shipping	1	1.425
10	Bureau Veritas	1	3.196	40	International Register of Shipping	1	6.713	70	Polski Rejestr Statkow	1	0.987
11	C.T.M. Inspection and Classification Company, S. de R.L	3	18.637	41	International Ship Classification	1	3.382	71	R.J. Del Pan	1	7.247
12	Ceskoslovensky Lodin Registe r	1	7.247	42	Iranian Classification Society	1	0.777	72	Registro Brasileiro de Navios de Aeronaves	1	7.247

13	China Classification Society	1	6.299	43	Isthmus Bureau of Shipping	1	1.919	73	Registro Internacional Naval S.A.	1	3.343
14	China Corporation Register of Shipping	1	1.109	44	Isthmus Maritime Classification Society S.A.	1	7.247	74	Registro Italiano Navale	1	2.935
15	Compania Nacional de Registro e	1	7.247	45	Korea Classification Society (former Joson Classification Society)	1	8.515	75	RINAVE Portuguesa	1	0.608
16	Compania Nacional de Registro e Inspeccion de Naves	1	7.247	46	Korea Ship Safety Technology Authority	1	6.798	76	Russian Maritime Register of Shipping	1	1.458
17	Cosmos Marine Bureau	1	5.285	47	Korean Register of Shipping	1	5.609	77	Russian River Register	1	7.247

18	CR Classification Society	1	2.529	48	Libyan Surveyor Mr. Sif Ennasar	1	7.247	78	Ship Classification Malaysia	1	5.033
19	Croatian Register of Shipping	1	6.095	49	Abdulhamid Giahmi	.	.	79	Shipping Register of Ukraine	1	7.258
20	Cyprus Bureau of Shipping	1	7.247	50	Lloyd's Register	1	4.3	80	SingClass International Pte Ltd	1	14.897
21	Det Norske Veritas	1	4.678	51	Macosnar Corporation	1	3.096	81	Sing-Lloyd	1	13.771
22	DNV GL AS（2014年合并）	1	4.371	52	Maritime Lloyd Ltd, Georgia	1	3.096	82	Turkish Lloyd	1	0.719
23	Dromon Bureau of Shipping	1	14.993	53	Maritime Lloyd Ltd, Georgia	1	9.447	83	Turkish Lloyd	1	7.247
24	Ferriby Marine	3	16.9	54	Maritime Technical Systems and Services	1	3.224	84	Union Bureau of Shipping	1	8.163

25	Fidenav is SA	1	1.064	55	National Cargo Bureau Inc.	1	0.456	85	Union Marine Classificat ion Society	2	0
26	German ischer Lloyd	1	3.087	56	National Shipping Adjusters Inc	1	0.93	86	Universal Maritime Bureau	1	5.68
27	Global Marine Bureau	1	6.68	57	New United Internatio nal Marine Services Ltd	1	13.824	87	Universal Shipping Bureau	1	2.439
28	Global Shippin g Bureau	1	9.633	58	Nippon Kaiji Kyokai	1	3.945	88	Venezuela n Register of Shipping	1	1.909
29	Helleni c Registe r of Shippin g	1	2.802	59	NV Unitas	1	7.247	89	Vietnam Register	1	0.615

30	INCLAMAR (Inspection y Classification Maritime, S. de. R.L.)	1	7.247	60	Novel Classification Society S.A.	1	7.247	90	Other	1	4.352

Table 5-11: Final cluster center

	Cluster		
	1	2	3
Detention percentage (%)	7.23	50.00	50.00
RO responsibility percentage (%）	.45	50.00	2.78

Table 5-12: The final distance of cluster centers

Cluster	1	2	3
1		65.457	42.830
2	65.457		47.223
3	42.830	47.223	

Table 5-13:The number of cases in each cluster

Cluster	1	2	3	Effective	Missing
Number	84	1	4	89	1

With reference to Chapter 5.1, the initial cluster center, the number of iterations, the final cluster center, and the number of cases per class in the process of clustering can be seen. Utilizing the rate of detention as a reference standard, the first category is an excellent group. On the basis of RO responsibility percentage (%) as a reference index, the second category is the medium group, and the third category is the inferior group.

5.3 Analysis of type of ships - Cluster Analysis

Using the detention rate (%) and the average number of deficiencies as the variables of the cluster analysis, the case variable is the "type of ship". Using k-means clustering analysis algorithm, set k = 3, the analysis results are as follows:

Table 5-14: Initial clustering center

	Cluster		
	1	2	3
Average deficiencies per ship	8.78	5.27	.00
Detention percentage (%)	22.22	8.90	.00

Table 5-15 : Iteration history[3]

Iteration	Changes in the cluster center		
	1	2	3
1	3.406	1.879	2.961
2	.000	.192	.738
3	.000	.185	.556
4	.000	.000	.000

Table 5-16: Clusters of type of ships

Case NO.	Type of ships	Cluster	Distance	Case NO.	Type of ships	Cluster	Distance
1	NLS tanker	2	1.832	12	Woodchip carrier	2	2.486
2	Combination carrier	2	.914	13	Livestock carrier	2	4.956
3	Oil tanker	2	2.642	14	Ro-Ro passenger ship	2	3.078
4	Gas carrier	2	1.715	15	Passenger ship	3	1.233
5	Chemical tanker	3	1.781	16	Factory ship	1	3.406
6	Bulk carrier	2	.943	17	Heavy load carrier	2	.880
7	Vehicle carrier	3	2.224	18	Offshore service vessel	2	.274

[3] The convergence is achieved due to the absence of changes or small changes in the cluster center. The maximum absolute coordinate of any center is changed to .000. The current iteration is 4. The minimum distance between the initial centers is 10.343.

8	Container ship	2	2.494	19	MODU & FPSO	1	3.406
9	Ro-Ro cargo ship	2	.779	20	High speed passenger craft	3	1.774
10	General cargo/multi-purpose ship	2	2.595	21	Special purpose ship	2	1.072
11	Refrigerated cargo carrier	2	1.359	22	High speed cargo craft	3	3.917
12	Woodchip carrier	2	2.486	23	Tugboat	2	1.215
13	Livestock carrier	2	4.956	24	Others	2	1.511

Table 5-17: Final cluster center

	Cluster		
	1	2	3
Average deficiencies per ship	6.81	4.83	3.11
Detention percentage (%)	19.45	7.45	2.39

Table 5-18: The final distance of cluster centers

Cluster	1	2	3
1		12.152	17.455
2	12.152		5.354
3	17.455	5.354	

Table5-19: The number of cases in each cluster

Cluster	1	2	3	Effective	Missing
Number	2	17	5	24	0

With reference to Chapter 5.1, we can see the initial cluster center, the number of iterations, the final cluster center, and the number of cases per type of ships in the process of clustering. The first category is the excellent group; the second category is the medium group, and the third category is the inferior group.

Although it is not possible to actually predict the ship's defeceiencies during the ship's PSC selection process, yet we can determine the high-risk ship preferably by screening the inherent attributes of the ship and the ship's priority. The results of the ship's inherent attributes in the cluster analysis are given the value of 1, 2 and 3 respectively, expressed as $Flag_x$=(1,2,3), RO_x=(1,2,3), $Type_x$=(1,2,3). For simplicity, we obtain the ship's inherent property matrix expressed as N = (3, 4, 5, 6, 7, 8, 9). The ship's priority is given the value of 0,1 and 2, where 0 means the inspection window is not open yet, expressed as $P=\begin{matrix}0\\1\\2\end{matrix}$. In the next step, we multiply the two matrices, getting the result of P * N. And we can use the table to indicate the performance of the ship which is going to be inspected.

Table 5-20: Evaluation grade classified by the grade

0～5	6～10	10～15	16～20
Inspection unavailable	Low-risk	Medium-risk	Hight-risk

The more detailed the evaluation grade, the more accurate the evaluation, the higher credibility of the evaluation, and correspondingly the more complex the corresponding assessment process is (Wang Yong, & Li Zan, 2012). In the process of target ship selection, PSCOs may add three values of inherent attributes of the ship added and multiply the ship's priority level to obtain the prediction of the target ship's performance in PSC inspection. For example, if the ship gets a score of 0 in the risk assessment, which means the ship's inspection window is not open, the PSC inspection should not be carried out. If the ship gets a score of 9 in the risk assessment, it indicates that the inherent value of the ship is large, but the ship's inspection priority is not high; if the ship risk assessment value is greater than 10, that indicates the ship has a higher risk of ship property and it is Priority II ship. In this case,PSCOs should give more attention to these kind of ships. After risk process, plenty of ships will be screened out, which will surely reduce PSCOs' workload.

6 Conclusion

There is no doubt about the importance of the PSC inspection of the ship, and how to better carry out the PSC inspection is also a key issue for each country to protect the crew, ensuring the ship's safety and maintaining the marine environment. Based on the analysis of PSC data of Tokyo-MOU 2011-2015, this paper summarizes the distribution of ships' deficiencies and the detention in the ship PSC inspection, and then finds out the nature of the inherent attributes of the ship by cluster analysis to assess the ship's performance under PSC's inspection.

However, the situation of ship's deficiencies is not entirely determined by the ship's inherent properties. In the author's statistics on the PSC inspection data of Lianyungang ships in 2016, apart from the fact that most of the conclusions are consistent with this paper, it is found that the deficiencies issued in the PSC reports are related to different PSCOs to a certain extent. Every PSCO has different academic backgrounds, some of them are experienced ocean-going captains, some are engineers, but they all have their own characteristics and professional judgment when issuing the PSC report. Besides, human factors could not be ignored. For example, PSC inspection result may be different when the seafarers are changed. All these will have an impact on the assessment results. However, the analysis of large data will help PSC lock sub-standard ships to carry out key inspections and improve the efficiency of PSC inspection.

Maritime accidents are caused by the interactions of human factors, ship factors, environmental factors and many other factors, among which the virtues or defect degree of the ship's management are directly reflected by the number of ship's deficiencies or detonable deficiencies in PSC inspection(Zhong Simiao，2011). As a PSCO, the author deeply feels the responsibility of this work. To improve the efficiency of PSC inspection, inspection skills is the goal that the author has always dreamed of achieving. Due to the time limitation as well as personal ability, the author cannot fully detect the various factors affecting the ship's defects. The assessment of ships' deficiencies is also within a certain range. However, the author still sincerely hope that this article can have some implications for the PSC inspection work in the future.

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Annex I: **The structure of Tokyo MOU organization**

There are 20 member authorities: Australia, Canada, Chile, China, Fiji, Hong Kong (China), Indonesia, Japan, Republic of Korea, Malaysia, the Marshall Islands, New Zealand, Papua New Guinea, Peru, the Philippines, theRussianFederation, Singapore, Thailand, Vanuatu and Viet Nam;

One co-operating member Authority: Panama;

5 Observer authorities: Democratic People's Republic of Korea, Macao (China), Solomon Islands, Kingdom of Tonga and United States Coast Guard; and

7 Observer organizations: the International Maritime Organization (IMO), the International Labour Organization (ILO), the Paris MOU, the Viña del Mar Agreement, the Indian Ocean MOU, the Black Sea MOUand Riyadh MOU.

Source: Tokyo MOU website http://www.tokyo-mou.org/organization/organizational_structure.php

Annex 2: List of certificates and documents

List of certificates and documents which are to some extent applicable should be checked during the inspection referred to in paragraph 2.2.3 (as appropriate):

1 International Tonnage Certificate (1969);

2 Reports of previous port State control inspections;

3 Passenger Ship Safety Certificate (SOLAS reg.I/12);

4 Cargo Ship Safety Construction Certificate (SOLAS reg.I/12);

5 Cargo Ship Safety Equipment Certificate (SOLAS reg.I/12);

6 Cargo Ship Safety Radio Certificate (SOLAS reg.I/12);

7 Cargo Ship Safety Certificate (SOLAS reg.I/12);

8 Special Purpose Ship Safety Certificate (SOLAS reg.I/12, SPS Code reg.1.7);

9 For ro-ro passenger ships, information on the A/A-max ratio (SOLAS reg.II-1/8-1);

10 Damage control plans and booklets (SOLAS reg.II-1/19);

11 Stability information (SOLAS reg.II-1/5-1 and LLC 66/88 reg.10);

12 Manoeuvring Booklet and information (SOLAS reg.II-1/28);

13 Unattended machinery spaces (UMS) evidence (SOLAS reg.II-I/46.3);

14 Exemption Certificate and any list of cargoes (SOLAS reg.II-2/10.7.1.4);

15 Fire control plan (SOLAS reg.II-2/15.2.4);

16 Fire safety operational booklet (SOLAS reg.II-2/16.3.1);

17 Dangerous goods special list or manifest, or detailed stowage plan (SOLAS reg.II-2/19 and ILO Convention No.134 art.4.3(h));

18 Document of compliance Dangerous Goods (SOLAS reg.II-2/19.4);

19 Ship's logbook with respect to the records of drills, including security drills, and the log for records of inspection and maintenance of life-saving appliances and arrangements and fire-fighting appliances and arrangements (SOLAS regs.III/19.5 and 20.6);

20 Minimum Safe Manning Document (SOLAS reg.V/14.2); Refer to Resolution 1 of the 1995 SOLAS Conference.

21 SAR coordination plan for passenger ships trading on fixed routes (SOLAS reg.V/7.3);

22 LRIT Conformance Test Report;

23 Copy of the Document of compliance issued by the testing facility, stating the date of compliance and the applicable performance standards of VDR (voyage data recorder) (SOLAS reg.V/18.8);
24 For passenger ships, List of operational limitations (SOLAS reg.V/30.2);
25 Cargo Securing Manual (SOLAS reg.VI/5.6);
26 Bulk Carrier Booklet (SOLAS reg.VI/7.2);
27 Loading/Unloading Plan for bulk carriers (SOLAS reg.VI/7.3);
28 Document of authorization for the carriage of grain (SOLAS reg.VI/9);
29 INF (International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on Board Ships) Certificate of Fitness (SOLAS reg.VII/16 and INF Code reg.1.3);
30 Copy of Document of Compliance issued in accordance with the International Management Code for the Safe Operation of Ships and for Pollution Prevention (DoC) ISM Code (SOLAS reg.IX/4.2);
31 Safety Management Certificate issued in accordance with the International Management Code for the Safe Operation of Ships and for Pollution Prevention (SMC) (SOLAS reg.IX/4.3);
32 High-Speed Craft Safety Certificate and Permit to Operate High-Speed Craft (SOLAS reg.X/3.2 and HSC Code 94/00 reg.1.8.1);
33 Continuous Synopsis Record (SOLAS reg.XI-1/5);
34 International Certificate of Fitness for the Carriage of Liquefied Gases in Bulk, or the Certificate of Fitness for the Carriage of Liquefied Gases in Bulk, whichever is appropriate (IGC Code reg.1.5.4);
35 International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk, or the Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk, whichever is appropriate (IBC Code reg.1.5.4 and BCH Code reg.1.6.3);
36 International Oil Pollution Prevention Certificate (MARPOL Annex I reg.7.1);
37 Survey Report Files (in case of bulk carriers or oil tankers) (SOLAS reg.XI-1/2);
38 Oil Record Book, parts I and II (MARPOL Annex I regs.17 and 36);
39 Shipboard Marine pollution emergency plan for Noxious Liquid Substances (MARPOL Annex II reg.17);
40 (Interim) Statement of compliance Condition Assessment Scheme (CAS) (MARPOL Annex I regs.20.6 and 21.6.1);

41 For oil tankers, the record of oil discharge monitoring and control system for the last ballast voyage (MARPOL Annex I reg.31.2);

42 Shipboard Oil Pollution Emergency Plan (MARPOL Annex I reg.37.1);

43 International Pollution Prevention Certificate for the Carriage of Noxious Liquid Substances in Bulk (NLS) (MARPOL Annex II reg.9.1);

44 Cargo Record Book (MARPOL Annex II reg.15);

45 Procedures and Arrangements Manual (chemical tankers) (MARPOL Annex II reg.14.1);

46 International Sewage Pollution Prevention Certificate (ISPPC) (MARPOL Annex IV reg.5.1);

47 Garbage Management Plan (MARPOL Annex V reg.9.2);

48 Garbage Record Book (MARPOL Annex V reg.9.3);

49 International Air Pollution Prevention Certificate (IAPPC) (MARPOL Annex VI reg.6.1);

50 Logbook for fuel oil change-over (MARPOL Annex VI reg.14.6);

51 Type approval certificate of incinerator (MARPOL Annex VI reg.16.6);

52 Bunker delivery notes (MARPOL Annex VI reg.18.3);

53 Engine International Air Pollution Prevention Certificate (EIAPPC) (NOx Technical Code 2008 reg.2.1.1.1);

54 Technical files (NOx Technical Code 2008 reg.2.3.6);

55 Record book of engine parameters (NOx Technical Code reg.6.2.2.7.1);

56 International Load Line Certificate (1966) (LLC 66/88 art.16.1);

57 International Load Line Exemption Certificate (LLC 66/88 art.16.2);

58 Certificates issued in accordance with STCW Convention (STCW art.VI, reg.I/2 and STCW Code section A-I/2);

59 Table of shipboard working arrangements (STCW Code section A-VIII/1.5 and ILO Convention No.180 art. 5.7);

60 Mobile Offshore Drilling Unit Safety Certificate (MODU Code 2009 chapter I section 6);

61 Certificate of insurance or any other financial security in respect of civil liability for oil pollution damage (CLC 69/92 art.VII.2);

62 Certificate of insurance or any other financial security in respect of civil liability for

Bunker oil pollution damage (BUNKERS 2001 art.7.2);

63 International Ship Security Certificate (ISSC) (ISPS Code part A/19.2);

64 Record of AFS (AFS 2001 Annex 4 reg.2);

65 International Anti-Fouling System Certificate (IAFS Certificate) (AFS 2001 Annex 4 reg.2); and

66 Declaration on AFS (AFS 2001 Annex 4 reg.5).

For reference:

1 Certificate of Registry or other document of nationality (UNCLOS art.9.1.2);

2 Certificates as to the ship's hull strength and machinery installations issued by the classification society in question (only to be required if the ship maintains its class with a classification society);

3 Cargo Gear Record Book (ILO Convention No.32 art.9.2(4) and ILO Convention No.152 art.25);

4 Certificates loading and unloading equipment (ILO Convention No.134 art.4.3(e) and ILO Convention No.32 art.9(4));

5 Medical certificates (ILO Convention No.73); and

6 Records of hours of work or rest of seafarers (ILO Convention No.180 part II art. 8.1).

Source: PROCEDURES FOR PORT STATE CONTROL, 2011 APPENDIX 12

Annex 3: **Comparison of Deficiencies by Categories**

Nature of deficiency		Number of deficiencies				
		2011	2012	2013	2014	2015
Certificate & Documentation	Crew Certificates	4,502	1,275	1,074	1,534	1,593
	Documents		5,359	5,345	6,416	4,500
	Ship Certificates		2,754	2,348	2,445	1,910
Structural Conditions		8,257	3,593	3,511	2,671	2,422
Water/Weathertight conditions		8,139	6,753	5,899	5,812	5,584
Emergency Systems		N/A	5,628	5,392	5,093	5,771
Radio Communications		3,073	2,987	2,500	2,259	2,231
Cargo operations including equipment		661	675	575	613	500
Fire safety		18,114	20,522	17,539	16,654	15,143
Alarms		704	798	754	634	577
Safety of Navigation		17,435	17,124	16,275	14,231	12,619
Life saving appliances		12,281	12,070	11,507	10,515	11,213
Dangerous goods		284	241	216	183	352
Propulsion and auxiliary machinery		7,166	5,470	5,458	4,549	4,137
Working and Living Conditions	Living Conditions	459	672	620	529	349
	Working Conditions	2,952	4,496	4,887	4,134	2,866
Labour Conditions	Minimum requirements for seafarers	N/A	N/A	11	74	35
	Conditions of employment	N/A	N/A	33	363	515

	Accommodation, recreational facilities, food	N/A	N/A	199	1017	998
	Health protection, medical care, social security	N/A	N/A	66	983	1,699
Pollution prevention	Anti Fouling	24	16	21	7	13
	MARPOL Annex I	5,643	2,335	2,037	1,679	1,607
	MARPOL Annex II	53	27	40	13	17
	MARPOL Annex III	37	17	14	33	30
	MARPOL Annex IV	996	1,013	1,070	1,199	1,301
	MARPOL Annex V	1,580	981	2,618	1,587	1,252
	MARPOL Annex VI	680	796	915	758	847
ISM		3,497	3,292	3,099	2,699	2,803
Other		7,012	1,436	1,240	876	722
Total		**103,549**	**100,330**	**95,263**	**89,560**	**83,606**
ISPS		2933	2,490	2,033	1,615	1,389
Grand total		106,492	102,820	97,296	91,175	84,995

Source: Author’s calculation, Data from
Annual Report on Port State Control in The Asia-pacific Region 2011 Table 6
Annual Report on Port State Control in The Asia-pacific Region 2014 Table 13
Annual Report on Port State Control in The Asia-pacific Region 2015 Table 14[4]

[4] ASIA-PACIFIC PORT STATE CONTROL MANUAL will be updated regularly, the old and new code table is different, which leads to the missing of some data in 2011, 2012 ship deficiencies.

Annex 4: **Comparison of most frequently reserved deficiencies**

No.	Most frequent deficiencies	Year					
		2011	2012	2013	2014	2015	Total
1	Lifeboats (Life saving appliances)	165	155	190	136	136	782
2	Fire-dampers (Fire safety)	135	155	120	119	103	632
3	Shipboard operations (ISM)	62	96	76	81	82	397
4	Resources and personnel (ISM)	165	113	114	98	81	571
5	Ventilators, air pipes, casings (Water/Weathertight conditions)	151	125	76	76	80	508
6	Emergency fire pump and its pipes (Emergency Systems)	42	67	99	71	72	351
7	Oil filtering equipment (MARPOL Annex I)	134	98	104	74	69	479

8	Fire detection and alarm system (Fire safety)	**76**	**76**	**85**	**60**	**67**	**364**
9	Covers (hatchway-, portable-, tarpaulins, etc.) (Water/Weathertight conditions)	**61**	**50**	**68**	**70**	**66**	**315**
10	Fixed fire extinguishing installation (Fire safety)	**89**	**52**	**59**	**61**	**66**	**327**
11	Others	**482**	**434**	**404**	**357**	**331**	**2008**
Total		**1562**	**1421**	**1395**	**1203**	**1153**	**6734**

Source: Author's calculation Data from

Annual Report on Port State Control in The Asia-pacific Region 2013 Table 13

Annual Report on Port State Control in The Asia-pacific Region 2015 Figure 13, Table 15

Annex 5: PORT STATE INSPECTIONS PER FLAG

	Flag	No. of inspection	No of inspection with deficiencies	No. of deficiencies	No. of detetions	Average deficiencies per ship	Detention percentage (%)
1	Algeria	3	2	11	1	5.50	50.00
2	Antigua and Barbuda	2597	1671	7096	162	4.25	9.69
3	Argentina	7	5	23	1	4.60	20.00
4	Australia	25	10	18	0	1.80	0.00
5	Bahamas	3493	1751	6558	100	3.75	5.71
6	Bahrain	13	10	40	1	4.00	10.00
7	Bangladesh	259	227	1383	27	6.09	11.89
8	Barbados	93	65	293	6	4.51	9.23
9	Belgium	155	77	258	3	3.35	3.90
10	Belize	2213	2053	12964	181	6.31	8.82
11	Bermuda (UK)	368	175	565	4	3.23	2.29
12	Bolivia	2	2	8	1	4.00	50.00
13	Brazil	11	11	79	3	7.18	27.27
14	Brunei Darussalam	27	9	35	2	3.89	22.22
15	Bulgaria	1	1	11	0	11.00	0.00
16	Cambodia	7632	7461	57626	1108	7.72	14.85
17	Canada	3	1	5	0	5.00	0.00
18	Cayman Islands (UK)	537	194	551	10	2.84	5.15
19	Chile	11	7	22	0	3.14	0.00
20	China	4320	2116	8656	20	4.09	0.95
21	Colombia	10	10	92	4	9.20	40.00
22	Comoros	29	29	271	9	9.34	31.03
23	Cook Islands	93	58	297	10	5.12	17.24
24	Croatia	133	66	256	1	3.88	1.52
25	Curacao	116	59	197	3	3.34	5.08
26	Cyprus	2471	1391	5853	104	4.21	7.48
27	Denmark	728	400	1531	22	3.83	5.50
28	Dominica	66	53	384	6	7.25	11.32
29	Ecuador	8	8	28	1	3.50	12.50
30	Egypt	71	53	382	10	7.21	18.87
31	Equatorial Guinea	9	9	107	1	11.89	11.11
32	Estonia	3	2	27	1	13.50	50.00
33	Ethiopia	30	27	122	2	4.52	7.41
34	Falkland Islands (UK)	11	9	26	0	2.89	0.00
35	Fiji	2	0	0	0	0.00	0.00
36	Finland	4	3	6	0	2.00	0.00
37	Faroe Islands	1	0	0	0	0.00	0.00
38	France	206	118	336	1	2.85	0.85
39	Gambia	1	1	9	0	9.00	0.00
40	Georgia	43	41	365	9	8.90	21.95
41	Germany	1043	685	2763	37	4.03	5.40
42	Gibraltar (UK)	340	178	686	13	3.85	7.30
43	Greece	1700	834	3032	58	3.64	6.95
44	Honduras	26	26	268	7	10.31	26.92
45	Hong Kong, China	14253	7178	28121	163	3.92	2.27
46	Iceland	1	1	2	0	2.00	0.00
47	India	487	272	1465	30	5.39	11.03
48	Indonesia	918	814	5779	140	7.10	17.20
49	Iran	134	121	677	10	5.60	8.26

50	Ireland	6	2	2	0	1.00	0.00
51	Isle of Man (UK)	897	417	1471	23	3.53	5.52
52	Israel	33	30	161	2	5.37	6.67
53	Italy	711	389	1725	32	4.43	8.23
54	Jamaica	85	74	374	7	5.05	9.46
55	Japan	876	474	1735	13	3.66	2.74
56	Jordan	3	2	3	0	1.50	0.00
57	Kiribati	1077	934	6967	103	7.46	11.03
58	Korea, Democratic People's Republic	1042	1038	9904	173	9.54	16.67
59	Korea, Republic of	6972	5238	24711	44	4.72	0.84
60	Kuwait	79	39	165	2	4.23	5.13
61	Lao, People's Democratic Republic	1	0	0	0	0.00	0.00
62	Lebanon	1	1	5	0	5.00	0.00
63	Liberia	11038	6358	25489	447	4.01	7.03
64	Libyan Arab Jamahiriya	7	3	12	0	4.00	0.00
65	Libya	9	4	11	0	2.75	0.00
66	Lithuania	8	4	17	0	4.25	0.00
67	Luxemburg	127	70	231	4	3.30	5.71
68	Malaysia	1254	746	3786	40	5.08	5.36
69	Maldives	35	29	192	0	6.62	0.00
70	Malta	3963	2280	9651	174	4.23	7.63
71	Marshall Islands	8170	4067	15633	215	3.84	5.29
72	Mauritius	7	5	33	0	6.60	0.00
73	Mexico	4	1	1	0	1.00	0.00
74	Moldova	143	138	955	24	6.92	17.39
75	Mongolia	547	506	4115	94	8.13	18.58
76	Montenegro	1	1	1	0	1.00	0.00
77	Myanmar	34	31	207	4	6.68	12.90
78	Netherlands	713	375	1320	16	3.52	4.27
79	New Zealand	14	11	50	1	4.55	9.09
80	Nigeria	2	2	17	0	8.50	0.00
81	Niue	80	76	607	14	7.99	18.42
82	Norway	1227	585	2091	26	3.57	4.44
83	Pakistan	40	29	158	1	5.45	3.45
84	Palau	33	27	187	4	6.93	14.81
85	Panama	43960	27091	133042	1874	4.91	6.92
86	Papua New Guinea	56	52	424	14	8.15	26.92
87	Peru	23	17	129	3	7.59	17.65
88	Philippines	1028	705	3459	69	4.91	9.79
89	Portugal	166	98	355	5	3.62	5.10
90	Qatar	19	7	40	1	5.71	14.29
91	Romania	1	0	0	0	0.00	0.00
92	Russian Federation	1381	1232	6314	66	5.13	5.36
93	Saint Helena (UK)	1	1	13	0	13.00	0.00
94	Saint Kitts and Nevis	141	132	864	16	6.55	12.12
95	Saint Vincent and the Grenadines	792	704	3860	28	5.48	3.98
96	Samoa	12	10	90	2	9.00	20.00
97	Saudi Arabia	145	86	282	2	3.28	2.33
98	Sierra Leone	1269	1220	11114	227	9.11	18.61
99	Singapore	9997	4642	17806	133	3.84	2.87
100	Solomon Islands	16	13	75	1	5.77	7.69
101	South Africa	1	0	0	0	0.00	0.00
102	Spain	10	4	15	1	3.75	25.00

103	Sri Lanka	40	32	124	1	3.88	3.13
104	Saint Kitts and Nevis	55	52	333	7	6.40	13.46
105	Sweden	114	42	130	4	3.10	9.52
106	Switzerland	136	74	282	5	3.81	6.76
107	Taiwan, China	508	274	1466	20	5.35	7.30
108	Tanzania	122	114	793	25	6.96	21.93
109	Thailand	1510	1132	6004	107	5.30	9.45
110	Togo	209	203	1503	23	7.40	11.33
111	Tonga	41	36	253	8	7.03	22.22
112	Tunisia	5	2	8	0	4.00	0.00
113	Turkey	296	139	571	12	4.11	8.63
114	Tuvalu	614	505	2900	35	5.74	6.93
115	Ukraine	8	8	53	1	6.63	12.50
116	United Arab Emirates (UAE)	18	13	47	1	3.62	7.69
117	United Kingdom (UK)	1158	626	2119	35	3.38	5.59
118	United States	262	169	631	4	3.73	2.37
119	Vanuatu	232	151	714	5	4.73	3.31
120	Vanuatu	341	220	1037	20	4.71	9.09
121	Viet Nam	3745	2768	14107	238	5.10	8.60
122	Ship's registration withdrawn	8	7	80	6	11.43	85.71

Source: Author’s calculation Data from
Annual Report on Port State Control in The Asia-pacific Region 2011, 2012, 2013 and 2014, Table 3
Annual Report on Port State Control in The Asia-pacific Region 2015 Table 4

Annex 6: PORT STATE INSPECTIONS PER RECOGNIZED ORGANIZATION

	Classfication	No.of overall inspections	No.of overall detentions	No.of Roresponsible detentions	Detention percentage (%)	RO responsibility pecentage (%)
1	Alfa Register of Shipping	8	0	0	0.00	0.00
2	American Bureau of Shipping	15949	418	23	2.62	0.14
3	American Register of Shipping	73	6	0	8.22	0.00
4	Asia Classification Society	13	1	0	7.69	0.00
5	Belize Maritime Bureau Inc.	62	6	0	9.68	0.00
6	Bulgarski Koraben Registar	2	1	0	50.00	0.00
7	Biro Klasifikasi Indonesia	381	57	3	14.96	0.79
8	Bulgarski Koraben Registar	4	2	0	50.00	0.00
9	Bureau Securitas	38	2	0	5.26	0.00
10	Bureau Veritas	16452	666	26	4.05	0.16
11	C.T.M. Inspection and Classification Company, S. de R.L	9	6	1	66.67	11.11
12	Ceskoslovensky Lodin Register	18	0	0	0.00	0.00
13	China Classification Society	13453	128	2	0.95	0.01
14	China Corporation Register of Shipping	960	59	2	6.15	0.21
15	Compania Nacional de Registro e	2	0	0	0.00	0.00
16	Compania Nacional de Registro e Inspeccion de Naves	2	0	0	0.00	0.00
17	Cosmos Marine Bureau	64	8	0	12.50	0.00
18	CR Classification Society	593	28	1	4.72	0.17
19	Croatian Register of Shipping	176	2	1	1.14	0.57
20	Cyprus Bureau of Shipping	18	0	0	0.00	0.00
21	Det Norske Veritas	17321	446	14	2.57	0.08
22	DNV GL AS	4248	122	8	2.87	0.19
23	Dromon Bureau of Shipping	18	4	0	22.22	0.00
24	Ferriby Marine	6	2	0	33.33	0.00
25	Fidenavis SA	61	5	0	8.20	0.00
26	Germanischer Lloyd	15250	634	24	4.16	0.16
27	Global Marine Bureau	1933	268	25	13.86	1.29
28	Global Shipping Bureau	42	7	1	16.67	2.38
29	Hellenic Register of Shipping	10	1	0	10.00	0.00
30	INCLAMAR (Inspection y Classification Maritime, S. de. R.L.)	11	0	0	0.00	0.00
31	Honduras Bureau of Shipping	4	0	0	0.00	0.00
32	Honduras International Surveying and Inspection Bureau	7	0	0	0.00	0.00
33	INCLAMAR (Inspection y Classification Maritime, S. de. R.L.)	162	27	0	16.67	0.00
34	Indian Register of Shipping	515	35	0	6.80	0.00
35	Indonesian Classification Bureau	110	23	1	20.91	0.91
36	Intermaritime Certification Services, S.A.	2234	143	13	6.40	0.58

37	Marconi International Marine Company Ltd.	4	0	0	0.00	0.00
38	International Maritime Register	16	2	0	12.50	0.00
39	International Naval Surveys Bureau	206	21	2	10.19	0.97
40	International Register of Shipping	1507	209	22	13.87	1.46
41	International Ship Classification	1468	154	20	10.49	1.36
42	Iranian Classification Society	127	10	0	7.87	0.00
43	Isthmus Bureau of Shipping	2564	234	19	9.13	0.74
44	Isthmus Maritime Classification Society S.A.	4	0	0	0.00	0.00
45	Korea Classification Society (former Joson Classification Society)	1115	175	15	15.70	1.35
46	Korea Ship Safety Technology Authority	221	1	0	0.45	0.00
47	Korean Register of Shipping	14304	235	4	1.64	0.03
48	Libyan Surveyor Mr. Sif Ennasar	1	0	0	0.00	0.00
49	Abdulhamid Giahmi	0	0	0	#DIV/0!	#DIV/0!
50	Lloyd's Register	20287	598	15	2.95	0.07
51	Macosnar Corporation	120	5	0	4.17	0.00
52	Maritime Lloyd Ltd, Georgia	24	1	0	4.17	0.00
53	Maritime Lloyd Ltd, Georgia	6	1	0	16.67	0.00
54	Maritime Technical Systems and Services	115	12	1	10.43	0.87
55	National Cargo Bureau Inc.	14	1	0	7.14	0.00
56	National Shipping Adjusters Inc	87	7	0	8.05	0.00
57	New United International Marine Services Ltd	57	12	0	21.05	0.00
58	Nippon Kaiji Kyokai	48574	1603	73	3.30	0.15
59	NV Unitas	1	0	0	0.00	0.00
60	Novel Classification Society S.A.	1	0	0	0.00	0.00
61	Overseas Marine Certification Services	1803	215	12	11.92	0.67
62	Panama Bureau of Shipping	216	26	1	12.04	0.46
63	Panama Marine Survey and Certification Services, Inc.	393	35	3	8.91	0.76
64	Panama Maritime Documentation Services	1788	178	10	9.96	0.56
65	Panama Maritime Surveyors Bureau Inc	89	11	0	12.36	0.00
66	Panama Register Corporation	291	23	0	7.90	0.00
67	Panama Shipping Certificate Inc.	96	6	2	6.25	2.08
68	Panama Shipping Registrar Inc.	523	51	3	9.75	0.57
69	Phoenix Register of Shipping	17	1	0	5.88	0.00
70	Polski Rejestr Statkow	111	9	1	8.11	0.90
71	R.J. Del Pan	2	0	0	0.00	0.00
72	Registro Brasileiro de Navios de Aeronaves	2	0	0	0.00	0.00
73	Registro Internacional Naval S.A.	102	4	0	3.92	0.00
74	Registro Italiano Navale	4018	174	1	4.33	0.02
75	RINAVE Portuguesa	44	3	0	6.82	0.00
76	Russian Maritime Register of Shipping	2274	132	4	5.80	0.18
77	Russian River Register	1	0	0	0.00	0.00
78	Ship Classification Malaysia	90	2	0	2.22	0.00
79	Shipping Register of Ukraine	13	1	1	7.69	7.69
80	SingClass International Pte Ltd	258	57	4	22.09	1.55
81	Sing-Lloyd	450	94	10	20.89	2.22

82	Turkish Lloyd	15	1	0	6.67	0.00
83	Turkish Lloyd	2	0	0	0.00	0.00
84	Union Bureau of Shipping	4956	760	74	15.33	1.49
85	Union Marine Classification Society	2	1	1	50.00	50.00
86	Universal Maritime Bureau	1620	208	22	12.84	1.36
87	Universal Shipping Bureau	290	28	2	9.66	0.69
88	Venezuelan Register of Shipping	11	1	0	9.09	0.00
89	Vietnam Register	3955	262	19	6.62	0.48
90	Other	1136	131	13	11.53	1.14

Source: Author's calculation Data from
Annual Report on Port State Control in The Asia-pacific Region 2011, 2012, 2013 and 2014, Table 5
Annual Report on Port State Control in The Asia-pacific Region 2015 Table 6

Annex 7: PORT STATE INSPECTIONS PER SHIP TYPE

	Type of ship	No. of inspections	No. of inspections with deficiencies	No.of deficiencies	No.of detentions	Average deficiencies per ship	Detention percentage (%)
1	NLS tanker	292	130	570	12	4.38	9.23
2	Combination carrier	220	92	362	7	3.93	7.61
3	Oil tanker	9649	4342	18795	211	4.33	4.86
4	Gas carrier	3289	1531	6353	90	4.15	5.88
5	Chemical tanker	10278	5314	23083	195	4.34	3.67
6	Bulk carrier	52486	29994	135934	1968	4.53	6.56
7	Vehicle carrier	4093	1713	5289	79	3.09	4.61
8	Container ship	23379	13825	55046	707	3.98	5.11
9	Ro-Ro cargo ship	906	703	3693	57	5.25	8.11
10	General cargo/multi-purpose ship	36622	29582	185057	2846	6.26	9.62
11	Refrigerated cargo carrier	3711	2699	14221	236	5.27	8.74
12	Woodchip carrier	1169	628	2312	33	3.68	5.25
13	Livestock carrier	282	212	1280	26	6.04	12.26
14	Ro-Ro passenger ship	434	384	2541	19	6.62	4.95
15	Passenger ship	1140	698	2961	20	4.24	2.87
16	Factory ship	7	6	29	1	4.83	16.67
17	Heavy load carrier	538	330	1308	25	3.96	7.58
18	Offshore service vessel	721	436	2214	32	5.08	7.34
19	MODU & FPSO	22	18	158	4	8.78	22.22
20	High speed passenger craft	142	128	494	1	3.86	0.78
21	Special purpose ship	274	165	746	14	4.52	8.48
22	High speed cargo craft	1	0	0	0	0.00	0.00
23	Tugboat	1201	785	3824	49	4.87	6.24
24	Others	1530	1146	6038	102	5.27	8.90

Source: Author's calculation Data from
Annual Report on Port State Control in The Asia-pacific Region 2011, 2012, 2013 and 2014, Table 4
Annual Report on Port State Control in The Asia-pacific Region 2015 Table 5