8-24-2014

Application of Grey Theory in mandatory Flag State audit on STCW Convention implementation

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Application of Grey Theory in Mandatory Flag State Audit on STCW Convention Implementation

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

MASTER OF SCIENCE

(MARITIME SAFETY AND ENVIRONMENTAL MANAGEMENT)

2014

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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Acknowledgments

This paper was prepared as part of my studies applying for the master degree of Maritime Safety and Environmental Management (MSEM) jointly held by World Maritime University and Dalian Maritime University. I would like to acknowledge and extend my sincere appreciation to the following persons without whom this research paper could not be completed.

In the first place, I would like to express my thanks from the bottom of my heart to Dalian Maritime University, which gave me the opportunity to study this program. Especially, the other three masters from Marine Engineering academy who have broad and profound mathematical knowledge always help me with my studies and give me very useful advice.

In the second place, I would like to extend my special thanks to Professor Dang Kun of DMU and Zheng Yuxin from Guangdong MSA , for not only their contribution of sharing their experience and knowledge about this research paper with me, but also for their advice on this paper. Once I finished my draft and sent to Professor Dang Kun, he would immediately check it and correct for me, for which I am very grateful.

Last but not least, my deepest gratitude goes to my family, my beloved parents, whose love, encouragement and continuous support are always precious and will remain cherished in my entire life.

Abstract

Title: **Application of Grey Theory in Mandatory Flag State Audit on STCW Convention Implementation**

Degree: **MSc**

This Research paper contains mainly five parts: Convention Foundation for Obligations and responsibilities of Flag State, Overview of Grey Theory, Establishment of Mandatory Audit Index System of STCW Convention Implementation, Effectiveness assessment based on Grey Theory.

In this research, the author first illustrates the instrument system in the maritime regime and structure of STCW Convention. Furthermore, the author introduces that the IMO audit actually consists of Voluntary Audit and Mandatory Audit, and highlights the necessity of Mandatory Audit.

Secondly, this paper introduces the basic conception of Grey Theory and its application area. After the analysis of the reasons why Grey Theory can be applied in mandatory flag state audit of STCW Convention, in part 3, a general index system is established.

Thirdly, based on references and statistics collected by the author, the research paper establishes an index system which consists of four performance sides.

Finally, with the index system already having been established in the last part, the author proposes a set of hypothetical data and uses the Grey Theory to compute the

effectiveness of flag state A in implementation of STCW Convention. In addition, the result is verified in the case study.

KEYWORDS: Implementation, STCW Convention, Grey Theory, Index

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List of Abbreviation

FSC	Flag State Control
ICAO	International Civil Aviation Organization
IMO	International Maritime Organization
INC	International Navigation Congress
INFA	Importance, Necessity and Feasibility Analysis
ILO	International Labour Organization
ISM Code	International Management Code for the Safe Operation of Ship and for pollution prevention
JWG	Joint Working Group
MARPOL	International Convention for the Prevention of Pollution from Ships
MEPC	Marine Environment Protection Committee
MLC	Maritime Labour Convention
MSC	Maritime Safety Committee
SOLAS	International Convention for the Safety of Life at Sea
STCW	Standards of Training, Certification and Watchkeeping
UNCLOS	United Nations Conference on the Law of the Sea
VIMSAS	Voluntary IMO Member State Audit Scheme
VTS	Vessel Traffic Service

Chapter 1

Introduction

1. 1 Motivation of the Research

Since the IMO was founded in 1959, conventions and amendments formulated by IMO have exerted much influence on ship safety, marine environment, compensation, anti-terrorist, anti-piracy operation and shipping transportation. However, major marine accidents never stop. For example, people all over the world have witnessed “ERIKA” oil spill in European waters and “Prestige” shipwreck. Therefore, the international society doubts about the effectiveness of conventions. Based on statistics and rational analysis, we find that the reason for this phenomenon is not due to the convention itself, but the implementation attitude and control system of contracting parties. Thus, in the year of 2014, the topic of the day of World Maritime Day is “IMO conventions: effective implementation”.

The major content of the audit is paper works and whether activities acted by Flag states are in accordance with IMO instruments. However, the interval among the unqualified, qualified and excellent is a blind area, and there is no specific standard that auditors can comply with. Briefly, at present, the methodology of audit is lack of quantification support. Auditors always use their jurisdiction right based on their

subjective experiences, therefore, different auditors would obtain various results in the same convention audit team. Obviously, in order to overcome this obstacle, it is necessary for auditors to use methods and thoughts in mathematics.

All in all, the purpose of this research paper is to improve the accuracy of audit result which is obtained from the mandatory audit index system already established before. With the Grey Theory, it limits human influences to a low level and helps the IMO mandatory audit team to make objective assessment to STCW Convention implementation.

1.2 Definition of Implementation

"Implement something (formal)" means to "make something that has been officially decided start to happen or be used". (Oxford Advanced Learner's Dictionary, 2013a) As for the implementation of Convention, the explanation can be found in Resolution A.1054 (27), "Code for the Implementation of Mandatory IMO Instruments, 2011"(You, 2013, p.6). According to the Code, "When a new or amended IMO mandatory instrument enters into force for a State, the Government of that State must be in position to implement and enforce its provisions through appropriate national legislation and to provide the necessary implementation and enforcement infrastructure. This means that the Government of the State must have: .1 the ability to promulgate laws which permit effective jurisdiction and control in administration, technical and social matters over ships flying its flag and…"(IMO, 2011).

In other words, the State's tragedy should be communicated, records "of conformity

to requirements and of the effective operation" of the state should be "established and maintained", and some measures should be taken to continuously improve the performance of the state "in maritime safety and environmental protection activities" (IMO, 2011).

1.3 Scope and methodology of the thesis

The present study focuses on how to put forward implementation of STCW Convention related issues and Mandatory Audit, and aims at finding some countermeasures concerning the seafarers' development. However, specialists might ignore the way to assess the effectiveness of the convention implementation.

The methodology used in the thesis is importance, necessity and feasibility analysis (INFA). In the light of past Grey Theory application contributed by the specialists in other fields, the effectiveness of STCW Convention implementation taken by Flag State is analyzed from a mathematical view.

Chapter 2

Convention Foundation for Obligations and Responsibilities of Flag State

2.1 Instruments System in the Maritime Regime

Generally, the instruments system in the maritime sector can be divided into treaty and non-treaty parts. Both treaty instrument and non-treaty instrument are the forms of the international standards and regulations. Treaty instruments are legally binding on states that agreed to be bound by it. Treaty instruments include the conventions of IMO, the related Codes and Protocols, such as SOLAS convention, STCW convention, and MARPOL73/78 convention. Besides, a number of conventions cover a wide range of maritime safety, security and marine pollution issues that have been adopted by IMO all belong to treaty instruments, such as Maritime Labor Convention, 2006; International Convention on Load Lines, 1966; Convention for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation, 1988; International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004; International Convention on Salvage, 1989; Athens Convention relating to the Carriage of Passengers and their Luggage by Sea, 1974;

International Convention on the Establishment of an International Fund for Compensation for; Oil Pollution Damage, 1971(Mukherjee, 2014).

Non-treaty instruments, however, are not legally binding on any states. States may choose to apply it in whole or in part, modify it to suit their requirements, or completely disregard it. Non-treaty rules and regulations are adopted by the IMO Assembly on the recommendation of the relevant Committee. Occasionally, a Diplomatic Conference may adopt a non-treaty regulation. A non-treaty regulation may subsequently achieve 'treaty statuses' by incorporation in a treaty instrument. IMO standards contained in non-treaty instruments may take the form of Codes, Standards, Practices, Guidelines, Manual or Recommendations. Despite the lack of formal commitment or legal obligation, there is nevertheless an implied obligation on States not to act contrary to the spirit and terms of such instruments, and this obligation is usually complied with (Mukherjee, 2014).

In order to ensure the safety shipping and lives for seafarers, the pillars of instruments system mainly conclude:

1. SOLAS Convention. The main objective of the SOLAS Convention is to specify minimum standards for the construction, equipment and operation of ships, compatible with their safety. Flag States are responsible for ensuring that ships under their flag comply with its requirements, and a number of certificates are prescribed in the Convention as proof that this has been done.

2. MARPOL73/78 Convention. The MARPOL73/78 Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It is a combination of two treaties

adopted in 1973 and 1978 respectively and updated by amendments through the years.

3. STCW Convention. The convention is the first to establish basic requirements on training, certification and watch-keeping for seafarers on an international level. STCW Convention has been amended for many times during recent years, and among which are the most important amendments namely 95Amendment and 2010 Manila Amendment.

4. MLC, 2006. It can be separated into three levels architecturally, namely the Articles, Regulations and the Technical Code. The Code is divided into Part A mandatory standards and Part B recommendatory guidelines. In order to ensure the effective implementation of the convention, it establishes the provision of responsibilities of the flag state inspection and certification, implementation and oversight responsibility for implementing port state to ensure seafarer recruitment and placement responsibility of providing social security.

All conventions are considered as the pillars of the international regulatory regime, complementing the key Conventions of the International Maritime Organization (IMO) for quality shipping to enhance maritime safety.

2.2 Structure of STCW Convention

By June 2013, the STCW 1978 had 157 Parties, representing 99.23 percent of world fleet tonnage. Based on the statistics, the great importance of STCW Convention can

be easily identified, and therefore, to be compatible with the specific condition, the STCW Convention has been amended for many times. The most important amendments are 95Amendments and 2010 Manila Amendments. Compared to the STCW 78, the structure of STCW 78/95 is much more different. As illustrated in Figure 1, the content of STCW 78/95 is consists of the Convention, Annex and Code. Annex and Code are equivalent to the body of Convention; The Annex is the general stipulations, while the specific standards are included in the Code. Part A in Code includes the mandatory standards and regulations concerning the specific requirements on seafarers' knowledge and skills, and Part B is the recommendatory guidelines corresponding to Part A.

The 95 Amendment has adopted a drastic revision on STCW 78. The technical provisions have tremendous influence on standards of Training, Certification and Wacthkeeping. Undoubtedly, its enforcement and implementation push the seafarer management towards a new starting line.

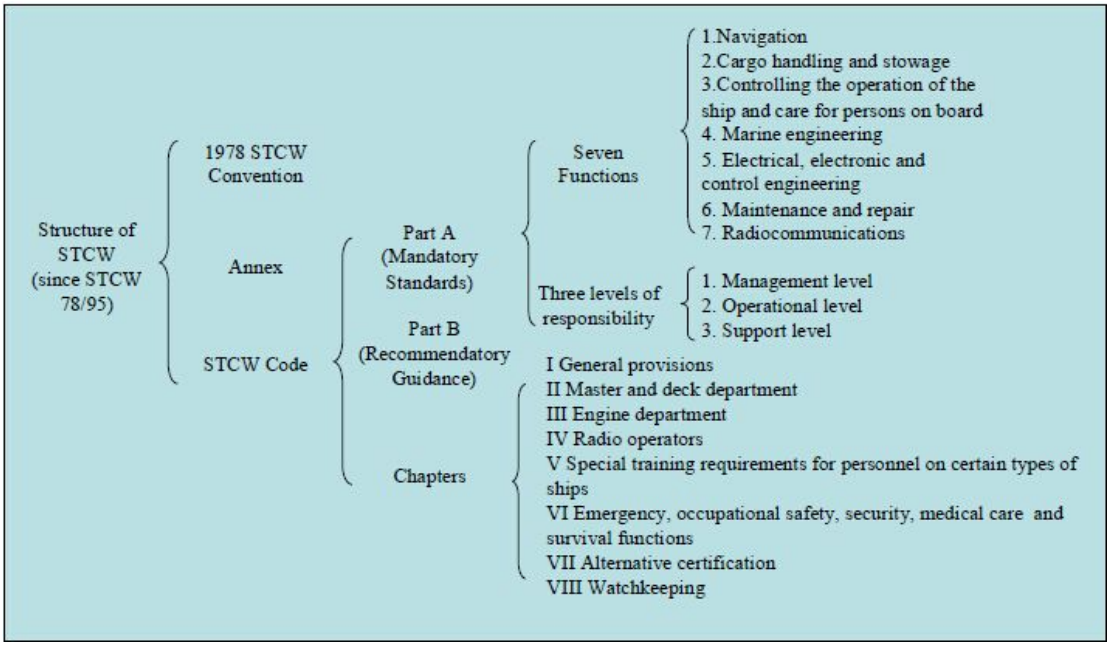

Figure 1 - Structure of the Convention (since STCW78/95)

Source: You, J.(2013). *Study on the influence of evolution of IMSAS in implementation of STCW Convention and related issues*. Unpublished master's thesis, World Maritime University, Dalian, China.

For 78/10 Manila Amendments, the main structure is the same as that of 95 Amendment. However, in compliance with technical development in modern shipping, some provisions have been revised. At the same time, implementation has been improved to a higher level. For Maritime Administration, maritime colleges and training schools, shipping companies and seafarers, specific obligations and responsibilities are provided in the implementation of STCW Convention.（You，2013，p.20）

As the principal part of the STCW Convention implementation, seafarers should accept higher standards of their competency，and as spirit of human factor, leadership and teamwork attitude of seafarers are regarded as an fundamental role in implementation.

2.3 Obligations and Responsibilities of Flag State Specified in STCW Convention

In IMO regime, the inter-relationship and responsibility among factors are as illustrated in Figure 2. Centered on the "Shipping Industry", the role played by different factor is different from each other, and when it comes to the convention implementation, the IMO, Governments, Recognized Organizations (RO), Ship owners/Shipping Companies, and Seafarers consist of an organic whole, and the figure shows that Flag State is of great importance in the responsibility network.

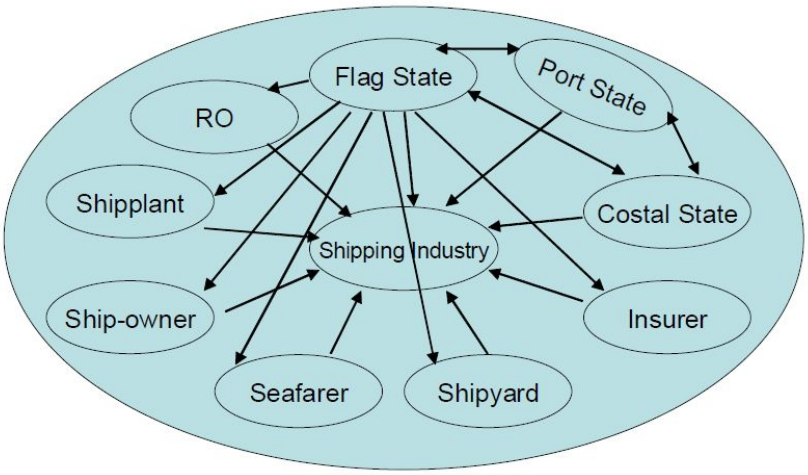

Figure 2 - Responsibility Chain under IMO Regime
Resource: Yu, Q. W. (2009). Discussion on enhancing the efficiency of the Flag State Control in China.*China MSA, (Maritime Workshop)*, 43-45.

As for the flag state, it is important for us to make sure that implementation is not just a particular task for a specific department, and implementation of Conventions can be easily found in marine activities, such as the port state control inspection, oil spill response, vessel traffic service (VTS), dangerous cargo management and crew management. Besides, since the effective implementation can help build a state with more competitive power in marine activities and state governance, it is necessary for the maritime administration to call on the parties to comply with the corresponding regulations. Take the STCW Convention for an example, the maritime administration plays a role as a leader in convention implementation, however, without participation of maritime universities/colleges, training schools/entities, companies and single seafarer for their own sake, the implementation of STCW convention might be a paper talk.

Generally, for the purpose of maritime safety and pollution prevention, UNCLOS and IMO instruments establish maritime law structure. According to the article 94 of

UNCLOS, and combined with regular management, the main responsibilities of flag states in details are as follows:

1. Ratification and accession of related IMO and ILO conventions;
2. Changing the international law into native law;
3. Building up administrations that correspond with ships;
4. According to the A.789(18), IMO, the flag state should build up a recognized quality control system;
5. Building up and maintaining a professional team which is able to make ship design audit and technology policy decision;
6. In order to keep the genuine link between flag state and ships, the flag states should interval flag state inspections;
7. Based on types of ships, training ship surveyors and maritime investigators;
8. Maintain statistics of fleets and crews;
9. Making reaction to inquiry from the port state and coastal state;
10. Building up approval the crew training system which is based on STCW 2010;
11. Making investigations for transportation accidents and pollution cases.
12. Making reports to IMO according to the regulations.

(UN, 1982)

As for STCW Convention, more details are concluded in the CODE FOR THE IMPLEMENTATION OF MANDATORY IMO INSTRUMENTS, 2011(Resolution A.1054 (27)), it establishes the specific obligations and responsibilities for flag state on STCW Convention, is illustrated in Table 1:

Table 1- Special Flag State Obligations

STCW Convention	**Content**
Art. VI	Certificates

Art. VIII(3)	Dispensation – reporting
Art. IX(2)	Equivalents – reporting
Reg. I/2	Certificates and endorsements
Reg. I/10	Recognition of certificates
Reg. I/11(5)	Revalidation of certificates
Reg. I/14	Responsibilities of companies
Reg. IV/1.3	Application
Reg. V/1.4	Mandatory minimum requirements for the training and qualification of masters, officers and ratings on tankers
Reg. V/2.9	Mandatory minimum requirements for the training and qualification of masters, officers, ratings and other personnel on ro-ro passenger ships
Reg. V/3.9	Mandatory minimum requirements for the training and qualification of masters, officers, ratings and other personnel on passenger ships other than ro-ro passenger ships
Reg. VIII/1	Fitness for duty
Reg. VIII/2	Watchkeeping arrangements and

	principles to be observed

Source: International Maritime Organization. (2011, December 20) *Code for the Implementation of Mandatory IMO Instruments, 2011* (A 27/Res.1054 (27)). London: Author.

Responsibilities are consistent with obligations. When the flag state gives its flag to a ship, the flag state has to maintain this ship to comply with requirements in IMO conventions, and keep the "genuine link" with this ship. The flag state should take measures to ensure safety of ships with its flag. The main measures that flag state takes to implement responsibilities are as follows: certifications for registered ships, crew training and certification, supervision and control, regular inspection, punishment, litigation, detention, report to the IMO, collection of data, response to the defects, assessment, cooperation and communication, culture and improvement of the public safety culture and environmental consciousness, etc. Therefore, for an effective and responsible flag sate, simple certification is not enough.

2.4 Necessity of Mandatory Audit

Section 7 of Article 2 of the Charter of the United Nations stipulates that "Nothing contained in the present Charter shall authorize the United Nations to intervene in matters which are essentially within the domestic jurisdiction of any state..." (UN, 1945), therefore, the IMO just helps some contracting countries with technology support and STCW "White List", without any practical control of implementation. Due to the lack of enforcement, it is hard for IMO to establish a complete management system. Thus, IMO has learned the experience from "Universal Safety Oversight Audit Program", which was established by ICAO, and released audit scheme.

2.4.1 Discussion between "Voluntary" and "Mandatory"

Due to the feature of voluntariness, the VIMSAS has the following drawbacks (Li & Qiu, 2007, p.41):

1. If some member states are not willing to apply for audit, them might not finish convention implementation work as much as possible, as a result, the experience shared by IMO is not capable of being digested by other member states;
2. Without enforcement, the audit system will maintain the paperwork condition as ISM Code;
3. Voluntariness will bring unfairness to all member states, which go against the nature of the convention.

However, the merits of mandatory audit mechanism eclipse with the drawbacks of VIMSA:

1. The principle of international law: all states must uniformly comply with international convention;
2. Mandatory Audit mechanism will enhance relationship among flag states, coastal states, port states, and RO all over the world;
3. Mandatory Audit will exert the same mount of pressure on member states.
4. Only by Mandatory Audit, can the safety and pollution prevention is desired to be improved effectively. The international requirement of marine environment claims that all member states should implement international convention without exception;
5. The IMO needs a mandatory mechanism to suppress criticism from INC.

2.4.2 Institutionalization History and Tendency of IMO Member State Audit Scheme

In order to achieve implementation of the audit scheme timely, IMO should develop guidelines and manuals for the operation of the audit scheme. The guideline should include the principles, scope and responsibility. At the same time, IMO should prepare the budget for the training of auditors and conduct of the training of auditors. Finally, the fund should be established to help developing countries, since some developing countries do not have adequate capital to carry out audit. Because of financial reasons, they do not like accepted audit. It is necessary to hold conference timely to share the lessons and experiences with member state. In general, that the IMO and member states take the relevant responsibilities of audit scheme is a necessary measure to push the audit scheme.

Table 2 - Time Frame and Schedule of Activities to Institutionalize the IMO Member State Audit Scheme

IMO	Timing	Action
MSC and MEPC	First half of 2010	Consider how to make the Code for the implementation of mandatory IMO instruments mandatory, including provisions for auditing
MSC and MEPC	Second half of 2010	Identify mandatory IMO instruments through which the Code and auditing should be made mandatory
Council	End 2010	Establish Joint Working Group of MSC, MEPC, FAL and TCC to review the Framework and

		Procedures for the Scheme
MSC and MEPC	2011 and 2012	Develop provisions to make the Code mandatory through the identified mandatory IMO instruments
Council	Second half of 2011	Approve a progress report for submission to A27
Assembly 27	November 2011	Receive a progress report and decide as appropriate
JWG	2011 and 2012	Receive the Framework and Procedures for the Scheme
JWG	2013	Finalize the Framework and Procedures, taking into account the finished product of the Code and the related amendments to mandatory IMO instruments
Council	First half of 2013	Approve the Framework and Procedures for the Scheme, for submission to A28 for adoption
Committees	2013	Adopt amendments to the mandatory IMO instruments concerned for entry into force on 1 January of 2015
Assembly 28	November 2013	Adopt resolution on the Framework and Procedures for the Scheme and amendments to those mandatory instruments under the purview of the Assembly
Council, Committees and Secretariat	2014	Preparatory for the commencement of an institutionalized audit scheme

Source: International Maritime Organization. (2010, January 18) *Future development of the Voluntary IMO Member State Audit Scheme* (A 26/Res.1018). London: Author.

After the institutionalization of audit scheme being raised, related committees and Sub-committees have started to plan for the possible time frame and member states have begun to prepare for the new era of the audit scheme (You, 2013, p.12).

2.4.3 Feature of Mandatory Audit

1. Equality. The audit must comply with Code for the Implementation of Mandatory Instruments, Resolution A.973 (24). In this way, it is readily available to achieve equality both on procedure and structure.
2. Continuity. For unqualified content, IMO should review the key points continuously; therefore, the contracting countries are able to correct their drawbacks.
3. Transparency. The transparency between the audit team and the state being audited should be acceptable on both sides, the state being audited has to provide documents, records, files, and interviews; and the audit team also should tell the state being audited what noncompliance issues are.
4. Privacy. Except the audit report, the Secretary-General should consider any information, materials and notes as the privacy.

Chapter 3

Overview of Grey Theory

3. 1 Brief Introduction to Grey Theory

Grey System theory was initiated in 1982. As far as information is concerned, systems which lack of information, such as structure message, operation mechanism and behavior document, are referred to as Grey Systems. For example, the human body, agriculture, economy, etc., are Grey Systems (Deng, 1989, p.1).

Scientific and reasonable mandatory assessment is not only the foundation of flag state implementation audits but also the developing requirements of shipping management all over the world. Historical experience showed that not only general qualified assessment, but also quantified and specified statistics consist of crucial part of audits. In order to reduce audit mistakes and specify the audit, a lot of improvement was made in operator training and management. However, the lack of behavior instructions and instruction assessment methodology is obvious. These parameters in instructions reflect the comprehensive quality and professional competency of the people involved in the audit.

Grey theory is an important method to catch essence and natural laws for science and management. It makes use of objectives' Grey information fully, observes internal relation among elements. Besides, it builds up Grey models, which are give rational conclusions for projects. It happens to solve the dilemma encountered in audits or decision-making of operator behavior in management of flag state. This study introduces a new application of grey theory in mandatory audits of flag state, providing an ideal in realizing scientific implementation of effectiveness assessment.

In the system and control theory, people divide the system into three categories based on their understanding: the white systems in which all the system features are known, the black system in which all the system features are unknown, the grey system which some system features are known while others are unknown. For the understanding of the human develops gradually, the objective things are grey system in fact. The grey theory studies the uncertain object, and it extracts valuable information through the generation and development of the some known information. Its feature is making full use of the already occupied "minimum information". In the practical engineering applications many systems are known limited and grey evaluation model provides effective method for the evaluation of these systems (Wang& Li & Shi, 2005).

3. 2 Basic Principles of Grey Theory

3.2.1 Principle of "Information Difference"

“Difference” is among information; all information is bound to differ. We usually call “Objective A is different from objective B.” Compared to objective B, objective A has specific content, which is related to objective B (Du, 2012, p.19). It is the existence of widespread “differences” in the objective world that provides us with basic information on the perception of the world. We have to change the perception of the world or awareness through new information, differences between new information and the original perception of objectives. It is major breakthroughs in scientific research work that provides people with some important differences with the previous cognitive information. The more information contained in new information, the difference is more obvious from the original information.

3.2.2 Principle of “non-uniqueness of the solution”

The solution of much uncertain or incomplete information is not unique. To solve practical problems, the Grey system theory complies with the principle of “non-uniqueness of the solution,” the basic criteria, in which flexibility is very important. “Non-uniqueness of the solution” reflects the thought that the goals and constraints can be combined with the grey target in a multi-objective decision-making. There are many examples in life. For example, a graduate from senior high school, when she applies for colleges, she considers “A University” as the only choice, however, when her test score is not in the dominant position, and it is difficult to achieve her dream; If she is willing to accept other choices, she will have more chances to step into higher education.

There are some specific performances of “non-uniqueness of the solution”. For example, targets can be accessed, relationships can be coordinated, programs can be improved, understanding can be deepened, construction can be optimized, and the way of thinking can be multi-directional. In the face of a variety of possible solutions and determine a more satisfactory solution. Therefore, the “non-uniqueness” is a better way to combine the quantitative with the qualitative analysis.

3.2.3 Principle of “Least Information”

Another major feature of the Grey system theory is that it is capable of taking full advantage of the least known information which has already been controlled. Least information principle is a unity of more and less. The target of Grey system is to study the small sample uncertainty, poor information, and it is based on the limited information space. Least information is also a basic principle of Grey Theory. Leverage that occupies minimal information has been developed to solve the fundamental problem of grey system theory in order to get an amount of information to determine how many grey and non-grey standards there are.

3.2.4 Principle of “Acknowledgment and Basement”

Acknowledgment is based on the amount of information and information itself. Without information, it is difficult to be cognitive. Comparatively, with complete information, it is able to obtain certain acknowledgment, by contrast, only able to get incomplete grey acknowledgment.

3.2.5 Principle of “Endless Grey”

As a wide connotation and extension system, grey system is an objective and absolute system. Incomplete information is comparatively common. Instead, the complete information is completely opposite and in changeable condition. Accurately, there is no system that all the factors are certain. It would be impossible for someone to complete each system and gives it quantified value. Therefore, there is no absolute white system. Even though the original information is certain, new uncertainties will appear immediately. By constantly replenishing themselves, human beings continuously keep the perception of the objective world. Information is endless, acknowledgment is also endless. Of course, in practical practice, we can also assume that the system is white based on the typical situation, and the grey system theory provides us with a good method to solve the problem.

3.3 Feasibility Study on Grey Theory in Convention Implementation Area

Firstly, the mandatory audit itself is an abstract system, but not an entity. Its structure, boundaries, status and so can not be accurately described. As for the operation mechanism system, people do not very understand. Secondly, whether the relationship between the mandatory audit of internal subsystems, among various factors, or between the upper and lower positions, all kinds of relationships are complex, ambiguous. A quantitative description is quite difficult.

Mandatory audit can be considered as a changeable and dynamic system, in which various factors are in constant change. And changes are random and there are no principles to be followed, as in case of the emergence of machine failures during the audit process, unsafe behavior onboard, etc. When the unqualified behavior that happened during audit process is random, it can be viewed as a random process, which is a distinctive feature of Grey (Du, 2012, p.20).

STCW Convention implementation has a feature of uncertainty. The description of its content, property and function can be considered as an index system which consists of kinds of factors and indices. Actually, many quantitative indices in STCW Convention implementation are white values among Grey intervals. Due to human factors and influence of the technical methods, there are a variety of shortages, error, and even false phenomena in statistical data and observations. In some accidents, besides the economic loss that we can see, some indirect loss is hard to be judged, and can only be estimated through calculation.

Our data are limited as to when to audit the STCW Convention implementation, and the method of probability is not appropriate. As for this kind of complex issue, based on the specific condition, we choose the Grey Theory to analyze it.

This chapter 3 makes a detailed introduction to Grey Theory; the Grey Theory is a kind of mathematical method in academic data analysis. For the complex inter-relationship, this paper believes that Grey Theory is capable of making a better explanation to mutual correlation among factors in STCW Convention implementation.

In other decision fields, Grey Theory has many successful precedents, and many scholars make use of Grey Theory to analyze complicated system. However, that kind of analysis is not mature in the area of convention implementation assessment, and I hope this ground breaking choice can draw the attention of the maritime sector. Although the Grey Theory in this paper is not mature enough, the purpose of this paper is to play a role as a pilot and prompt other scholars to put forward a more complete application in convention implementation assessment area. The chapter 4 will mainly focus on Grey Correlation analysis and Clustering method, and take Flag State A as an example to use Grey Theory.

Chapter 4

Establishment of Mandatory Audit Index System of STCW Convention Implementation

4.1 The Principles of Establishment of Mandatory Audit Index System

4.1.1 The Principle of Reflection

For the indices which are capable of indicating the implementation effect, they should be included in the mandatory audit index system, thus, the system can comprehensively and fully reflect the effectiveness of implementation.

4.1.2 The Principle of Feasibility

The indices that reflect the effectiveness of STCW Convention implementation are numerous, and the ways to obtain those indices are also complicated. In reality, it is hard to obtain them all. But when we consider the first principle, we should pay attention to feasibility. Otherwise, the theory will run against implementation practice.

4.2 Classification of Initial Indices

Based on the above principles, and combined with the analysis of STCW Convention, this paper initially considers the classification of mandatory audit indices of STCW Convention implementation as follows:

Main contents and basic requirements shall include the following aspects:

1. For crews, the familiarity of methods to ensure ship safety and pollution prevention;
2. The procedure to ensure that safety of ship operation and environmental protection in accordance with relevant international conventions and the native laws and regulations;
3. The respective permission for shore-based managers and people onboard, and the information connection between them;
4. Records for casualties and unqualified actions;
5. The familiarity of operations within crew's own duty;
6. Internal audit and management for review process;
7. The feedback and correction to update the program.

4.2.1 Flag State Authority Mandatory Audit Index

a. General audit index for flag state authorities in high-level:

1. The domestic legislative indemnification, as well as the feasibility;
2. Acknowledgment of the implementation of the STCW and STCW operation;
3. The measure to ensure safety and environmental protection policy to be implemented;

4. The rationality of implementation management structure, whether it is in accordance with documents and system operations;
5. Designated personnel appointments and the role they play;
6. Systematic management of crews' certificates;
7. Delegation of roles in emergency conditions (emergency response);
8. Administrative review procedures and implementation.

b. The designated personnel mandatory audit indices:

1. It requires that the designated personnel shall totally be familiar with the latest convention and execute effective monitor on implementation;
2. Guaranty measures of special communication channels between ships and shore-based companies;
3. The shore-based support resources from companies provided for the designated personnel;
4. Guaranty that the ship has adequate resources and shore-based support;
5. Punishments for unqualified designated personnel;
6. Internal audit and effectiveness evaluation.

c. Policy and Regulation Division and FSC mandatory audit indices:

1. Assistance of the designated personnel to monitor convention implementation;
2. The STCW Convention content knowledge training and assessment;
3. Formulation of convention internal audit plan and the data collection;
4. The effectiveness evaluation, the organization and implementation of management after identifying markers;
5. Document control and daily management.

d. Personnel management mandatory audit indices in general:

1. Qualifications of key positions, and whether qualifications are satisfied;

2. New hires and job-transfer training onboard, and update training or assessment for person who has already been on position;

3. Daily training and examination for person onboard and on-shore;

4. Health guarantee after casualties, and treatment of conditions which are not in conformity with the provisions of the processing.

e. Mandatory audit indices for deck department management taken by Maritime Administrations:

1. The qualification of captain and ship-drivers, and tracking capability of investigation business;

2. Onboard inspection and guidance to key operation of bridge department;

3. Preparedness, training, response for emergency conditions;

4. Navigation security which includes sea charts, navigation books and security information, besides, special routes and cargo security information are involved;

5. Treatment to casualties, dangerous and unqualified conditions which are related to deck.

f. Mandatory audit indices for engine department management taken by Maritime Administration

1. Evaluation and tracking for individual engine officer ability;

2. Onboard inspection and guidance to key operation of engine department;

3. The ship equipment maintenance management, technical condition of ship equipments;

4. Ship spare equipments and the material supply;

5. Treatment to casualties, dangerous and unqualified conditions which are related to machinery;

6. Management of technical statistics and ship certificates.

g. Shore-based attendance room mandatory audit indices:

1. Ship movement control;

2. Business guidance for carriage of dangerous goods;

3. Response velocity in emergency condition.

h. Logistic management mandatory audit indices:

1. Resource security perception and actual practices;

2. The control of various kinds of documents.

4.2.2 Representative Ship Mandatory Audit Indices

a. General mandatory audit indices among departments onboard:

1. Implementation of company's safety and environmental protection policy and safety management objectives;

2. Guaranty of latest STCW Convention information for each departments;

3. The crew should be capable of keeping internal and external language communication;

4. Emergency condition response training, familiarity of own duty in emergency condition;

5. Inspection of the ship equipment’s technical condition and its maintenance plan;

6. Effectiveness inspection of STCW Convention documents equipped with the ship;

7. Schedule of ship STCW Convention implementation audit inspection.

b. Captain mandatory audit indices:

1. Management of certificates and daily audit condition;

2. Implementation of company's safety and environmental policy and safety management objectives;

3. Reports to the company's designated personnel;

4. Inspection of various commands of captain and its implementation;

5. Records of validation of the ship’s key operation;

6. Supervision of new hires and transferred personnel (the first mate, chief engineer, director of the passenger, etc.) for the proper familiar training;

7. Update training task.

c. Deck department audit indices:

1. Safety operation of cargo handling;

2. Safety operation of the ship arrival and departure;

3. Watchkeeping of sailing and anchoring;

4. Deck equipment maintenance condition;

5. The maintenance records of emergency and rescue equipment taken by the third mate;

6. GMDSS equipment maintenance plan and its implementation.

d. Engine department mandatory audit indices in general:

1. Chief engineer familiarity extent with the STCW Convention and its annex;

2. Records of engineering key operation;

3. The specific duty that the engineer takes in charge, and the management of key equipment maintenance;

4. Maintenance records of the fire extinguisher, life-saving equipment, experimental conditions;

5. Ship electrical equipment, emergency power system, and the alarm system circuit inspection (inspection cycle, records);

6. Pollution prevention equipment maintenance;

7. Refueling process (plans, matters).

e. Section of passenger ships audit items

1. The passenger safety management, fire control, and the life-saving knowledge introduction (including jackets wearing process);

2. Safety management of special passengers;

3. Emergency response, fire control facilities and the familiarity of emergency arrangement for waiters onboard;

4. Passenger control and population crisis management.

4.3 Secondary Classification of Indices

Firstly, this research paper considers “General audit indices for flag state authorities in high-level”, “The designated personnel mandatory audit index(except 4.2.1.b.2)”, “Policy and Regulation Division and FSC mandatory audit indices”, “Personnel management mandatory audit indices in general”, “Logistic management mandatory audit indices”, “Mandatory audit indices for deck department management taken by Maritime Administrations(except 4.2.1.e.4)” and part of “Mandatory audit indices for engine department management taken by Maritime Administration” as the general mandatory audit indices in administrative level, as the representative items which

indicate the administrative level, those indices are the reflection of STCW Convention implementation effectiveness.

Secondly, in technical view, technical indices in deck department and engine department are professional, and deck department and engine department which are connected with each other tightly, are an organic whole. Therefore, technical management mandatory audit indices are mainly concluded 4.2.1.e.2, 4.2.1.e.4, 4.2.1.f.2, 4.2.1.f.3 and 4.2.1.f.4.

Thirdly, another kind of indices is the communication guaranty, which ensures the "Genuine Link" between the flag state and ships.

Finally, the management result mandatory audit indices participate into the system as a whole. The shore-based implementation effectiveness is mainly exemplified by shipping activities; therefore, indices concluded in this part are onboard.

Table 3 – Secondary Index Classification

1	General mandatory audit indices in administrative level	4.2.1.a 4.2.1.b(except 4.2.1.b.2) 4.2.1.c 4.2.1.d 4.2.1.e(except 4.2.1.e.4) 4.2.1.f.1 4.2.1.f.5 4.2.1.f.6 4.2.1.h

2	Technical management mandatory audit indices	4.2.1.e.2 4.2.1.e.4 4.2.1.f.2 4.2.1.f.3 4.2.1.f.4
3	Communication guaranty mandatory audit indices	4.2.1.b.2 4.2.2.a.2 4.2.2.b.3 4.2.1.g
4	Management result mandatory audit indices	4.2.2.a 4.2.2.c 4.2.2.d 4.2.2.e

Source: the Author

4.4 Validation of Mandatory Audit Index System

4.4.1 A Systematic Cycle of Mandatory Audit

The implementation plan of Mandatory Audit can be generally split into four steps:

1. Determine the auditors;
2. Audit cycle and audit methods;
3. Audit feedback, namely that staffs involved into the convention implementation should admit existed problems and find out the reason;
4. Plan revision, according to the condition of proposed targets and the next implementation mission.

And so forth, the four steps consist of a systematic cycle.

4.4.2 Critical Factors for Validation of Mandatory Audit Index System

1. Supports from all aspects in IMO

   Firstly, auditors should obtain the support from administrators in high-level. The attitude of administrators in high-level would directly affect the Mandatory Audit power and results; secondly, other departments which are able to provide auditors with related documents and statistics are also the key point of the whole plan.

2. The establishment of audit team and division of labour

   In IMO, MSC, which undertake the work of Mandatory Audit, is the supreme technical committee, whose members in MSC are from IMO leader group and secondary departments, every mature audit team needs an experienced leader who is able to manage other teammates as a whole.

3. Information collection in Mandatory Audit process

   The Mandatory Audit is a long-term and complicated project. As the foundation evidence of assessment, the accuracy timeliness of information and statistics is the pro-condition for successful Mandatory Audit. In the audit team, auditors should firstly collate various indices, the information concluded in the log book, on-site inspection, and casualty report are the reflection of indices which are evidence and foundation Mandatory Audit.

4. Feedback and communication of Mandatory Audit

   The feedback and communication before the Mandatory Audit and during the process both are key points to accurate assessment, only by controlling error during the audit process and taking precaution plan to deal with emergency condition, are auditors capable of limiting the risk to a minimum level. Besides, it is important to focus on communication method and feedback skills.

5. Statistical analysis and complaint to the audit result

   According to the quantitative results, auditors should classify the convention implementation. Besides, in order to comply with fairness and openness, complaint procedure plays an important role in ensuring the right of member state. Administrators in IMO ought to face the complaint prudently and treat the complaint as a chance to complete the Mandatory Audit system.

Chapter 5

Grey Correlation Analysis and System Clustering Calculation

5.1 Grey Correlation Analysis of STCW Convention Implementation

5.1.1 Grey Correlation Analysis

The development direction of the system depends on different factors. In the process of analyzing factors, people always concentrate on the main factor and secondary factor, or what factors contribute more to the system more and we also pay attention to whether the impact improves the development or weaken the development. The degree of impact among factors is weighted as correlation degree. When the correlation degree is secured, we obtain the weight of each factor.

The following introduces the basic steps to compute Grey Correlation Analysis:

1. Determine the amount of system behavior characteristics and factors set. At the

beginning of conducting Grey Correlation analysis, indirect data or reference sequence which represents systematic behaviors should be selected first, besides, data or reference sequence of relevant factors which affect main systematic behavior should also be selected.

2. Preprocess the above data. Grey correlation analysis was conducted by a quantitative research, so it is necessary to dispose with behavior feature mapping volume, and make them into a substantially similar magnitude dimensionless data sequence, at the same time, making negative factors into positive factors. Dimensionless method is divided into the following categories: initial treatment, the mean treatment, the relative value of the range. Based on practices, this paper uses the initial treatment and specific treatment methods are as follows:

   Set up comparative sequence:

   $$X_i = \{x_i(1), x_i(2), x_i(3), x_i(4)\}$$

   Initial treatment on the above sequence, get dimensionless sequence as follows:

   $$Y_i = \{y_i(1), y_i(2), y_i(3), y_i(4)\}$$
   $$= \left\{ \frac{x_i(1)}{x_i(1)}, \frac{x_i(2)}{x_i(1)}, \frac{x_i(3)}{x_i(1)}, \frac{x_i(4)}{x_i(1)} \right\}$$

3. Compute correlation coefficient

   The grey correlation coefficient is a quantitative reflection among sequence curves. During the application process, different scholars have shown various methods of calculating correlation coefficient based on their actual research. The method taken by this thesis is as follows:

   $$\xi_i(k) = \frac{\min_i \min_k \left| x_0(k) - x_i(k) \right| + \rho \max_i \max_k \left| x_0(k) - x_i(k) \right|}{\left| x_0(k) - x_i(k) \right| + \rho \max_i \max_k \left| x_0(k) - x_i(k) \right|} \qquad (5.1)$$

Where ρ must be from 0 to 1. The difference between correlation coefficient is larger and differentiation capability is stronger if ρ is smaller. Usually, ρ is equal to 0.5.

4. Compute correlation degree

   Actually, correlation coefficient is evaluation result for each other. Correlation degree is defined as weighted summation of correlation coefficients giving comprehensive evaluation result for each factor.

5.1.2 Case study of Grey Correlation Analysis

Let us take Flag State A as an example and use Grey Correlation theory to analyze implementation effectiveness of STCW Convention. A number of 200 ships, which consist of VLCC, containers and passenger ships, are registered in Flag State A, the Flag State A became a member in IMO and agreed to comply with STCW Convention in 2009. Flag State A has already accepted annual audit, and the past audit reveals that there were not any severe drawbacks during its implementation process. However, ship detention happened twice in the year of 2010 and 2011due to the reason of certificates. Therefore, it is necessary to take an implementation effectiveness audit for STCW Convention. Based on the audit items mentioned above, suppose that the IMO get the following table:

Table 4 –Unqualified Index Review of Flag State A

	2010	2011	2012	2013
General mandatory audit index in administrative	2	4	3	1

level				
Technical management mandatory audit index	3	2	2	1
Communication guaranty mandatory audit index	3	2	1	2
Management result mandatory audit index	5	3	3	2

Source：the Author

And use Grey correlation analysis is used to conduct a systematic analysis,

The first step is to preprocess the above data

Table 5 – The processed data list

	2010	2011	2012	2013
Management result mandatory audit index X_0	1	0.6	0.6	0.4
General mandatory audit index in administrative level X_1	1	2	1.5	0.5
Technical management mandatory audit index X_2	1	0.66	0.66	0.33
Communication guaranty mandatory audit index X_3	1	0.66	0.33	0.66

Source：the Author

Then, we take the 'General audit index in administrative-level' as the comparative sequence x_0, and the other reference sequences are x_i(i=1, 2, 3), analyzing the

correlation, differencing the sequences and the result is in the following table:

Table6 - The Reference Sequence and Comparative Sequence Difference

j	1	2	3	4
$\lvert x_0 - x_1 \rvert$	0	1.4	0.9	0.1
$\lvert x_0 - x_2 \rvert$	0	0.06	0.06	0.07
$\lvert x_0 - x_3 \rvert$	0	0.06	0.27	0.26

Source：the Author

From the table, minimum difference is equal to 0, maximum difference is equal to 1.4;

And then put those figures into the formula and compute the correlation coefficient:

Table7 - Correlation Coefficient

j	1	2	3	4
$x_0(j)$ and $x_1(j)$	1	0.33	0.4375	0.875
$x_0(j)$ and $x_2(j)$	1	0.9211	0.9211	0.9091
$x_0(j)$ and $x_3(j)$	1	0.9211	0.7216	0.7292

Source：the Author

Next, the correlation degree is computed, as is illustrated in the table below:

Table8 - Correlation Degree

i	1	2	3

r_i	0.6606	0.9378	0.8430

Source：the Author

Obviously, $r_2 > r_3 > r_1$

Therefore, in the implementation effectiveness audit of STCW Convention, the correlation between technical management audit items and management result audit items is the much stronger, and then the correlation between ship movement supervision audit items and General audit items in high-level. However, the correlation degree differences are not tremendous; therefore, the result audit items and the ship movement supervision audit items are also important elements which are related to management result.

Based on the data above, the weights of each kind of index are:

The weight of General mandatory audit index in administrative level:

$$\mu_1 = \frac{r_1}{1 + r_1 + r_2 + r_3} = \frac{0.6606}{1 + 0.6606 + 0.9378 + 0.8430} = 0.1920$$

The weight of technical management mandatory audit index:

$$\mu_2 = \frac{r_2}{1 + r_1 + r_2 + r_3} = \frac{0.9378}{1 + 0.6606 + 0.9378 + 0.8430} = 0.2725$$

The weight of communication guaranty mandatory audit index:

$$\mu_3 = \frac{r_3}{1 + r_1 + r_2 + r_3} = \frac{0.8430}{1 + 0.6606 + 0.9378 + 0.8430} = 0.2450$$

The weight of Management result mandatory audit index:

$$\mu_4 = \frac{r_4}{1 + r_1 + r_2 + r_3} = \frac{1}{1 + 0.6606 + 0.9378 + 0.8430} = 0.2906$$

5.2 Grey Clustering Calculation of STCW Convention Implementation

5.2.1 Method of Grey Clustering

According to the type of clustering objectives, Grey Clustering can be divided into Grey Correlation Clustering and Whiteness Weight Function Clustering. When we deal with the classification of similar factors, usually the Grey Correlation Clustering is readily available, and it can simplify the complicated system. By the method of Grey Correlation Clustering, researchers are able to identify whether there is frequent relationship among factors and it can maintain information from the original index. Whiteness Weight Function Clustering is mostly used to observe whether the objective belongs to the category that has already been set.

Considering the feature of objective, this paper mainly utilizes the method of Whiteness Weight Function Clustering. With the foundation of index system, this paper creates Whiteness Weight Function based on the average value. Besides, indices are classified into three levels: excellent, qualified, and unqualified, whereby, the method of Whiteness Weight Function Clustering can be employed to assess the STCW Convention Implementation for Flag State A.

Next, a brief introduction is made to the method of Whiteness Weight Function Clustering:

Assume Ⅰ, Ⅱ, Ⅲ...as Clustering objectives,

Assume 1*,2*,3*, ... as Clustering index,

Assume 1, 2, 3,...as the Grey number of Clustering,

Assume d_{ij} as the number of Clustering Whiteness,

$$d_{ij} \quad , \quad j \in \{1^*, 2^*, ...\}$$

$$I \in \{\mathrm{I}, \mathrm{II}, \mathrm{III}...\} \quad ,$$

d_{ij} is one of the Clustering Objectives, for the number of Whiteness which is owned by Clustering index j , the Grey numbers of Clustering are "excellent", "qualified", and "unqualified", d_{ij} refers to the value of index j in the year of i.

The six steps of Grey Clustering are as follows:

Step 1: give the number of Clustering Whiteness d_{ij} ;

Step 2: define the Grey Whiteness Function;

If Clustering indices are 1*, 2*, 3*, ..., n*, and the Grey number of Clustering is 1, 2, 3, ..., m, given

$f_{kj}(x)$, $k \in \{1^*, 2^*, ..., \mathrm{n}^*\}$,

$$j \in \{1, 2, ..., m\}$$

is Whiteness Function to λ_{kj}.

The given $f_{kj}(x)$ is one of the conditions in picture A, B, C (Kun &Yi, 2005):

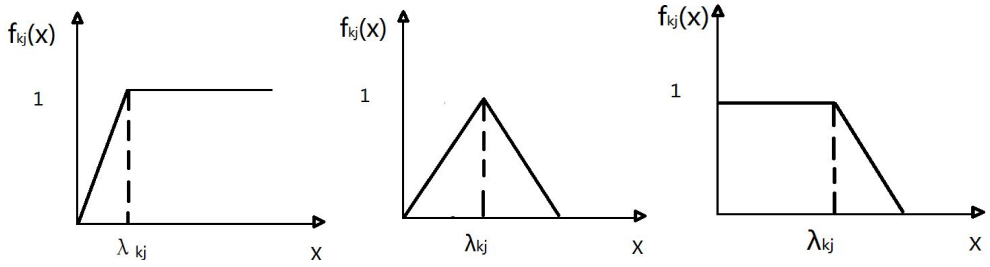

Figure 3 - Whiteness Function

Source：the Author

Step 3: compute the weight of Clustering:

$$\eta_{kj} = \frac{\lambda_{kj}}{\sum_{i=1}^{n} \lambda_{ij}} \quad j = 1,2,...,m \tag{5.2}$$

Step 4: compute the Clustering Coefficient:

$$\sigma_{ij} = \sum_{k=1}^{n} f_{kj}(d_{ik}) \eta_{kj} \mu_k \tag{5.3}$$

Step 5: form the Clustering vector:

$$\sigma_i = [\sigma_{i1}, \sigma_{i2}, ..., \sigma_{im}] \tag{5.4}$$

Step 6: Clustering:

If $\sigma_{ik} = \max\{\sigma_{i1}, \sigma_{i2}, ..., \sigma_{im}\}$, then the Clustering objective *i* belongs to the category *k*.

5.2.2 Application of the Method of Grey Clustering in Mandatory Audit of STCW Convention Implementation of Flag State A

Step 1: give the data matrix:

In Matrix D, the first subscript of each element represents different years, the second subscript represents different indices,

$$D = \begin{matrix} 2 & 4 & 3 & 1 \\ 3 & 2 & 2 & 1 \\ 3 & 2 & 1 & 2 \\ 5 & 3 & 3 & 2 \end{matrix}$$

Step 2: determine the Whiteness Weight Functions:

Due to the lack of statistics in reality, this paper makes some assumptions: the average value of unqualified general mandatory audit index in administrative level is 3.20; the average value of unqualified Technical management audit index is 3.18; the average value of unqualified Communication guaranty mandatory audit index is 1.66; the average value of unqualified Management result mandatory audit index is 5.42.

In the year of 2011, the average value of unqualified General mandatory audit index in administrative level is 3.20; therefore, according to the average value, the implementation effectiveness is separated into three levels, $[0,1.60]$ is excellent, $[1.60,3.20]$ is qualified, $[3.20,\infty]$ is unqualified.

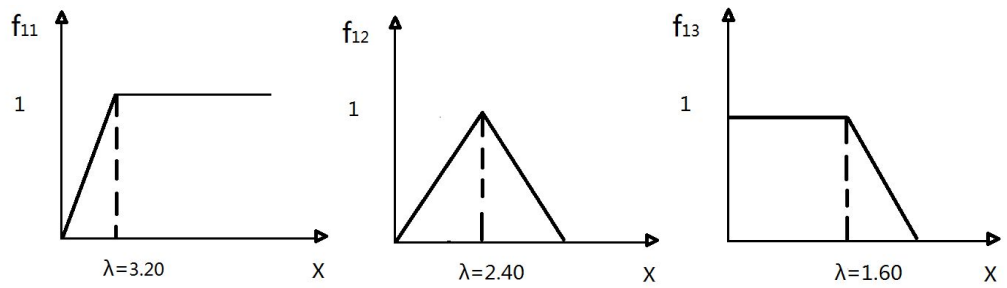

Figure 4 - Whiteness Function of Unqualified General Mandatory Audit Index in Administrative level

Source：the Author

In the year of 2011, the average value of unqualified Technical management mandatory audit index is 3.18; therefore, according to the average value, the implementation effectiveness is separated into three levels, $[0,1.59]$ is excellent, $[1.59,3.18]$ is qualified, and $[3.18,\infty]$ is unqualified.

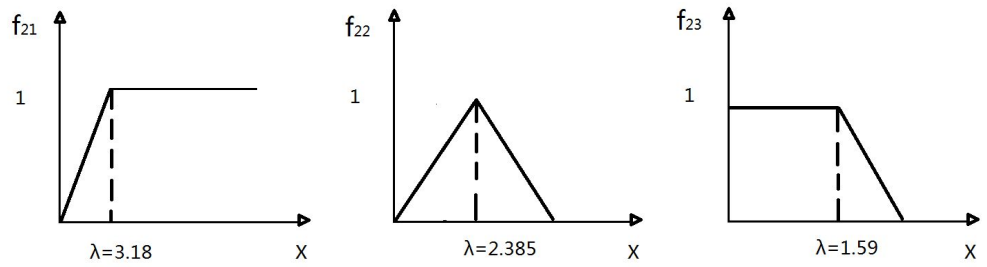

Figure 5 - Whiteness Function of Unqualified Technical Management Mandatory Audit Index

Source: the Author

According to the assumptions, it is found that the average value of unqualified Communication guaranty mandatory audit index is 1.66, therefore, the implementation effectiveness is separated into three levels, $[0,0.83]$ is excellent, $[0.83,1.66]$ is qualified, $[1.66,\infty]$ is unqualified.

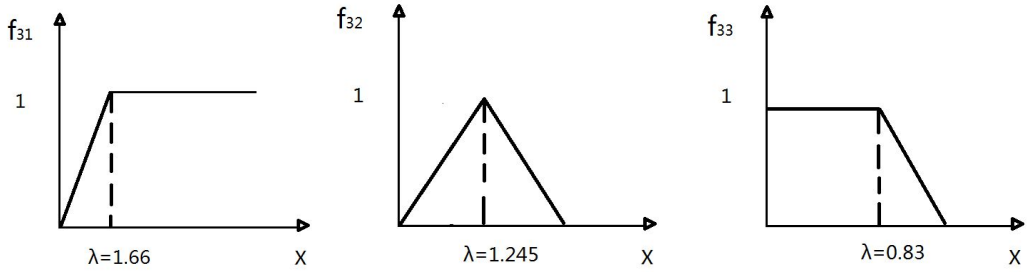

Figure 6 - Whiteness Function of Unqualified Communication Guaranty Mandatory Audit Index

Source: the Author

In the year of 2011, the average value of unqualified Management result mandatory audit index is 5.42; therefore, according to the average value, the implementation effectiveness is separated into three levels, $[0,2.71]$ is excellent, $[2.71,5.42]$ is qualified, $[5.42,\infty]$ is unqualified.

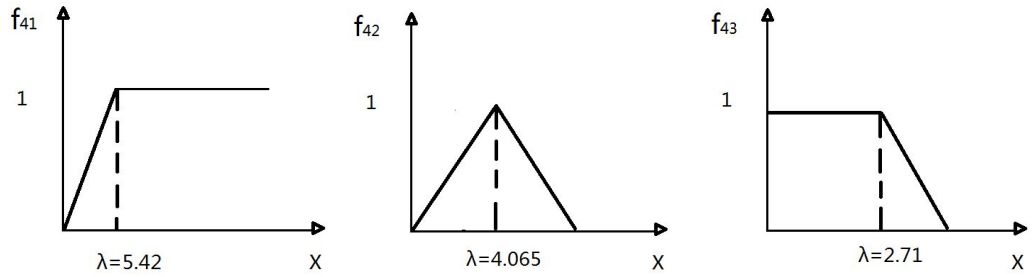

Figure 7 - Whiteness Function of Unqualified Management Result Mandatory Audit Index

Source: the Author

Step 3: compute the weight of the clustering:

As for Grey factor j, the weight of the index k is described as η_{kj}:

$$\eta_{kj} = \frac{\lambda_{kj}}{\sum_{i=1}^{4} \lambda_{ij}} \tag{5.5}$$

For different indices, the weight of unqualified effectiveness is described as $\eta_{k1}(k=(1,2,3,4),$

$$\eta_{k1} = \frac{\lambda_{k1}}{\sum_{i=1}^{4} \lambda_{i1}} \tag{5.6}$$

In the set of all unqualified index, the weight of unqualified general mandatory audit index in administrative level is described as η_{11}

$$\eta_{11}=\frac{\lambda_{11}}{\sum_{i=1}^{4}\lambda_{i1}}=\frac{\lambda_{11}}{\lambda_{11}+\lambda_{21}+\lambda_{31}+\lambda_{41}}=\frac{3.20}{3.20+3.18+1.66+5.42}=\frac{3.20}{13.46}=0.2377$$

In the set of all unqualified indices, the weight of unqualified Technical management mandatory audit index is described as η_{21}

$$\eta_{21}=\frac{\lambda_{21}}{\sum_{i=1}^{4}\lambda_{i1}}=\frac{\lambda_{21}}{\lambda_{11}+\lambda_{21}+\lambda_{31}+\lambda_{41}}=\frac{3.18}{3.20+3.18+1.66+5.42}=\frac{3.18}{13.46}=0.2363$$

In the set of all unqualified indices, the weight of Unqualified Communication guaranty mandatory audit index is described as η_{31}

$$\eta_{31}=\frac{\lambda_{31}}{\sum_{i=1}^{4}\lambda_{i1}}=\frac{\lambda_{31}}{\lambda_{11}+\lambda_{21}+\lambda_{31}+\lambda_{41}}=\frac{1.66}{3.20+3.18+1.66+5.42}=\frac{1.66}{13.46}=0.1233$$

In the set of all unqualified indices, the weight of Unqualified Management result audit index is described as η_{41}

$$\eta_{41}=\frac{\lambda_{41}}{\sum_{i=1}^{4}\lambda_{i1}}=\frac{\lambda_{41}}{\lambda_{11}+\lambda_{21}+\lambda_{31}+\lambda_{41}}=\frac{5.42}{3.20+3.18+1.66+5.42}=\frac{5.42}{13.46}=0.4027$$

Explanation: when it comes to the weight of Grey number of Clustering, this research paper takes the method of Equipartition, therefore, the weight of excellent, qualified, unqualified in the type of index is the same, in other words, $\eta_{11}=\eta_{12}=\eta_{13}=\eta_{14}$, $\eta_{21}=\eta_{22}=\eta_{23}=\eta_{24}$, $\eta_{31}=\eta_{32}=\eta_{33}=\eta_{34}$, $\eta_{41}=\eta_{42}=\eta_{43}=\eta_{44}$.

Step 4: compute the Clustering Coefficient σ_{ij}

In the year of i, the coefficient of Grey factor j is described as σ_{ij}:

$$\sigma_{ij} = \sum_{k=1}^{4} f_{kj}(d_{ik})\eta_{kj}\mu_k \tag{5.7}$$

In the year of 2010, the clustering coefficient of unqualified implementation is:

$$\begin{aligned}
&\sigma_{11} = \sum_{k=1}^{4} f_{k1}(d_{1k})\eta_{k1}\mu_k \\
&= f_{11}(d_{11})\eta_{11}\mu_1 + f_{21}(d_{12})\eta_{21}\mu_2 + f_{31}(d_{13})\eta_{31}\mu_3 + f_{41}(d_{14})\eta_{41}\mu_4 \\
&= f_{11}(2)\times 0.2377\times 0.1920 + f_{21}(3)\times 0.2363\times 0.2725 + f_{31}(3)\times 0.1233\times 0.2450 \\
&+ f_{41}(5)\times 0.4027\times 0.2906 \\
&= 0.2278
\end{aligned}$$

In the year of 2010, the clustering coefficient of qualified implementation is:

$$\begin{aligned}
&\sigma_{12} = \sum_{k=1}^{4} f_{k2}(d_{1k})\eta_{k2}\mu_k \\
&= f_{12}(d_{11})\eta_{12}\mu_1 + f_{22}(d_{12})\eta_{22}\mu_2 + f_{32}(d_{13})\eta_{32}\mu_3 + f_{42}(d_{14})\eta_{42}\mu_4 \\
&= f_{12}(2)\times 0.2377\times 0.1920 + f_{22}(3)\times 0.2363\times 0.2725 + f_{32}(3)\times 0.1233\times 0.2450 \\
&+ f_{42}(5)\times 0.4027\times 0.2906 \\
&= 0.1759
\end{aligned}$$

In the year of 2010, the clustering coefficient of excellent implementation is:

$$\begin{aligned}
&\sigma_{13} = \sum_{k=1}^{4} f_{k3}(d_{1k})\eta_{k3}\mu_k \\
&= f_{13}(d_{11})\eta_{13}\mu_1 + f_{23}(d_{12})\eta_{23}\mu_2 + f_{33}(d_{13})\eta_{33}\mu_3 + f_{43}(d_{14})\eta_{43}\mu_4 \\
&= f_{13}(2)\times 0.2377\times 0.1920 + f_{23}(3)\times 0.2363\times 0.2725 + f_{33}(3)\times 0.1233\times 0.2450 \\
&+ f_{43}(5)\times 0.4027\times 0.2906 \\
&= 0.0228
\end{aligned}$$

Step 5: construct row vector of clustering and clustering

In the year of 2010, the row vector of clustering is described as:

$$\sigma_1 = [\sigma_{11}, \sigma_{12}, \sigma_{13}] = [0.2278, 0.1759, 0.0228],$$

Obviously, σ_{12} is the maximum, therefore, in the year of 2010, the implementation of Flag State A is unqualified.

In the year of 2011, the clustering coefficient of unqualified implementation is:

$$\sigma_{21} = \sum_{k=1}^{4} f_{k2}(d_{2k})\eta_{k2}\mu_k$$
$$= f_{12}(d_{21})\eta_{12}\mu_1 + f_{22}(d_{22})\eta_{22}\mu_2 + f_{32}(d_{23})\eta_{32}\mu_3 + f_{42}(d_{24})\eta_{42}\mu_4$$
$$= f_{12}(4)\times 0.2377\times 0.1920 + f_{22}(2)\times 0.2363\times 0.2725 + f_{32}(2)\times 0.1233\times 0.2450$$
$$+ f_{42}(3)\times 0.4027\times 0.2906$$
$$= 0.1675$$

In the year of 2011, the clustering coefficient of qualified implementation is:

$$\sigma_{21} = \sum_{k=1}^{4} f_{k1}(d_{2k})\eta_{k1}\mu_k$$
$$= f_{11}(d_{21})\eta_{11}\mu_1 + f_{21}(d_{22})\eta_{21}\mu_2 + f_{31}(d_{23})\eta_{31}\mu_3 + f_{41}(d_{24})\eta_{41}\mu_4$$
$$= f_{11}(4)\times 0.2377\times 0.1920 + f_{21}(2)\times 0.2363\times 0.2725 + f_{31}(2)\times 0.1233\times 0.2450$$
$$+ f_{41}(3)\times 0.4027\times 0.2906$$
$$= 0.1811$$

In the year of 2011, the clustering coefficient of excellent implementation is:

$$\sigma_{23} = \sum_{k=1}^{4} f_{k3}(d_{2k})\eta_{k3}\mu_k$$
$$= f_{13}(d_{21})\eta_{13}\mu_1 + f_{23}(d_{22})\eta_{23}\mu_2 + f_{33}(d_{23})\eta_{33}\mu_3 + f_{43}(d_{24})\eta_{43}\mu_4$$
$$= f_{13}(4)\times 0.2377\times 0.1920 + f_{23}(2)\times 0.2363\times 0.2725 + f_{33}(2)\times 0.1233\times 0.2450$$
$$+ f_{43}(3)\times 0.4027\times 0.2906$$
$$= 0.1232$$

In the year of 2011, the row vector of clustering is described as:

$$\sigma_2 = [\sigma_{21}, \sigma_{22}, \sigma_{23}] = [0.1811, 0.1675, 0.1232]$$

Obviously, σ_{21} is the maximum, therefore, in the year of 2011, the implementation of State A is unqualified.

In the year of 2012, the clustering coefficient of unqualified implementation is:

$$\sigma_{31} = \sum_{k=1}^{4} f_{k1}(d_{3k})\eta_{k1}\mu_k$$
$$= f_{11}(d_{31})\eta_{11}\mu_1 + f_{21}(d_{32})\eta_{21}\mu_2 + f_{31}(d_{33})\eta_{31}\mu_3 + f_{41}(d_{34})\eta_{41}\mu_4$$
$$= f_{11}(3)\times 0.2377\times 0.1920 + f_{21}(2)\times 0.2363\times 0.2725 + f_{31}(1)\times 0.1233\times 0.2450$$
$$+ f_{41}(3)\times 0.4027\times 0.2906$$
$$= 0.1663$$

In the year of 2012, the clustering coefficient of qualified implementation is:

$$\sigma_{32} = \sum_{k=1}^{4} f_{k2}(d_{3k})\eta_{k2}\mu_k$$
$$= f_{12}(d_{31})\eta_{11}\mu_1 + f_{22}(d_{32})\eta_{22}\mu_2 + f_{32}(d_{33})\eta_{32}\mu_3 + f_{42}(d_{34})\eta_{42}\mu_4$$
$$= f_{12}(3)\times 0.2377\times 0.1920 + f_{22}(2)\times 0.2363\times 0.2725 + f_{32}(1)\times 0.1233\times 0.2450$$
$$+ f_{42}(3)\times 0.4027\times 0.2906$$
$$= 0.1982$$

In the year of 2012, the clustering coefficient of excellent implementation is:

$$\sigma_{33} = \sum_{k=1}^{4} f_{k3}(d_{3k})\eta_{k3}\mu_k$$
$$= f_{13}(d_{31})\eta_{13}\mu_1 + f_{23}(d_{32})\eta_{23}\mu_2 + f_{33}(d_{33})\eta_{33}\mu_3 + f_{43}(d_{34})\eta_{43}\mu_4$$
$$= f_{13}(3)\times 0.2377\times 0.1920 + f_{23}(2)\times 0.2363\times 0.2725 + f_{33}(1)\times 0.1233\times 0.2450$$
$$+ f_{43}(3)\times 0.4027\times 0.2906$$
$$= 0.1503$$

In the year of 2012, the row vector of clustering is described as:

$$\sigma_3 = [\sigma_{31}, \sigma_{32}, \sigma_{33}] = [0.1663, 0.1982, 0.1503]$$

Obviously, σ_{32} is the maximum, therefore, in the year of 2012, the implementation of State A is qualified.

In the year of 2013, the clustering coefficient of unqualified implementation is:

$$\sigma_{41}=\sum_{k=1}^{4} f_{k1}(d_{4k})\eta_{k1}\mu_k$$
$$=f_{11}(d_{41})\eta_{11}\mu_1+f_{21}(d_{42})\eta_{21}\mu_2+f_{31}(d_{43})\eta_{31}\mu_3+f_{41}(d_{44})\eta_{41}\mu_4$$
$$=f_{11}(1)\times 0.2377\times 0.1920+f_{21}(1)\times 0.2363\times 0.2725+f_{31}(2)\times 0.1233\times 0.2450$$
$$+f_{41}(2)\times 0.4027\times 0.2906$$
$$=0.1080$$

In the year of 2013, the clustering coefficient of qualified implementation is:

$$\sigma_{42}=\sum_{k=1}^{4} f_{k2}(d_{4k})\eta_{k2}\mu_k$$
$$=f_{12}(d_{41})\eta_{12}\mu_1+f_{22}(d_{42})\eta_{22}\mu_2+f_{32}(d_{43})\eta_{32}\mu_3+f_{42}(d_{44})\eta_{42}\mu_4$$
$$=f_{12}(1)\times 0.2377\times 0.1920+f_{22}(1)\times 0.2363\times 0.2725+f_{32}(2)\times 0.1233\times 0.2450$$
$$+f_{42}(2)\times 0.4027\times 0.2906$$
$$=0.1148$$

In the year of 2013, the clustering coefficient of excellent implementation is:

$$\sigma_{43}=\sum_{k=1}^{4} f_{k3}(d_{4k})\eta_{k3}\mu_k$$
$$=f_{13}(d_{41})\eta_{13}\mu_1+f_{23}(d_{42})\eta_{23}\mu_2+f_{33}(d_{43})\eta_{33}\mu_3+f_{43}(d_{44})\eta_{43}\mu_4$$
$$=f_{13}(1)\times 0.2377\times 0.1920+f_{23}(1)\times 0.2363\times 0.2725+f_{33}(2)\times 0.1233\times 0.2450$$
$$+f_{43}(2)\times 0.4027\times 0.2906$$
$$=0.2270$$

In the year of 2013, the row vector of clustering is described as:

$$\sigma_4=[\sigma_{41},\sigma_{42},\sigma_{43}]=[0.1080,0.1148,0.2270]$$

Obviously, σ_{43} is the maximum, therefore, in the year of 2013, the implementation of Flag State A is excellent.

From the assessment results, in the years of 2010 and 2011, the implementation of Flag State A is unqualified; in the year of 2012, the implementation of State A is qualified; in the year of 2013, the implementation of State A is excellent. In the year of 2011, the difference between 0.1811 and 0.1675 is small; therefore, the implementation of Flag State A is approximately qualified.

Chapter 6

Conclusion

Since the IMO was founded in 1959, convention implementation audit has been mainly maintained at the subjective jurisdiction level. Although scholars have already introduced many mathematical methodologies to make assessment effective, the related auditors attach little importance to the type of method, and management departments did not take the mathematical theory into practical audit. By making Grey Correlation Analysis and Grey Clustering calculation to important index, this research paper obtains the convincing effectiveness result from the perspective of statistics. At the same time, it opens a new scope of quantified thought in convention implementation area.

With the foundation of analysis for STCW Convention implementation audit, and combined with the practical condition, this research paper selects four types of index ,which conclude General mandatory audit index in administrative level, Technical management mandatory audit index, Communication guaranty mandatory audit index, and Management result mandatory audit index. By means of correlation analysis for index, the paper determines the weight and effect degree for each index in the whole STCW Convention implementation audit. On the one hand, the index provides flag state with an implementation reference; on the other hand, it establishes a guideline for auditors in details.

When auditors carry out mandatory audit to STCW Convention implementation, according to the index mentioned above and the method of Grey Clustering, it is readily available for auditors to make a rational effectiveness assessment to implementation result during a period of time. This paper takes Flag State A as an example, in the years of 2010 and 2011, the implementation of Flag State A is unqualified; in the year of 2012, the implementation of State A is qualified; in the year of 2013, the implementation of State A is excellent. Due to the different index weights in calculation, this paper makes a revision to general Grey Clustering Analysis formula, and the calculation result is closer to reality.

Assuredly, due to the lack of historical statistics, when determining Whiteness Weight Functions, this paper makes some assumptions in the average value of unqualified index. Besides, my ability is limited, and there are many drawbacks and incomplete information that need to be improved, such as the accuracy of calculation results. In addition, as for index selection in STCW Convention implementation, the secondary classification standard might not be proper. “Mandatory Audit” itself is a complicated system full of uncertainty, the Grey Theory used in this paper is only an attempt of study, which may need to be further improved and amended.

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