

A Study on the Selection of Core Technology in Maritime Safety Field for Fourth Industrial Revolution Era - Focusing on Ship Inspection Agency -

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ABSTRACT

The 'fourth industrial evolution' brings lots of changes to industries. Digital technologies based on ICT and convergences are changing in society and economy. Even in maritime industry, fourth industrial revolution is bringing many changes, such as ICT technology application to shipbuilding, navigation and maritime transport. Especially, a maritime safety technology is the key technology for keeping and developing of current maritime industry. Thus, Ship inspection authority which has main role in maritime safety field should react promptly to these changes comes from fourth industrial revolution.

So, a series of interview and an AHP questionnaire survey, the importance of evaluation criteria are ranked and 30 selected core maritime safety technologies which have high relevance with 'Ship Inspection Authority' and these are ranked by Multi Criteria Analysis. Also selected core maritime safety technologies were analyzed by BCG Matrix with core competencies of Ship inspection authority (Ship inspection, Ship safety management, Environment-Friendly).

Keyword: Fourth industrial revolution; Ship inspection authority; Maritime safety technology; BCG Matrix; AHP analysis

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1. Introduction

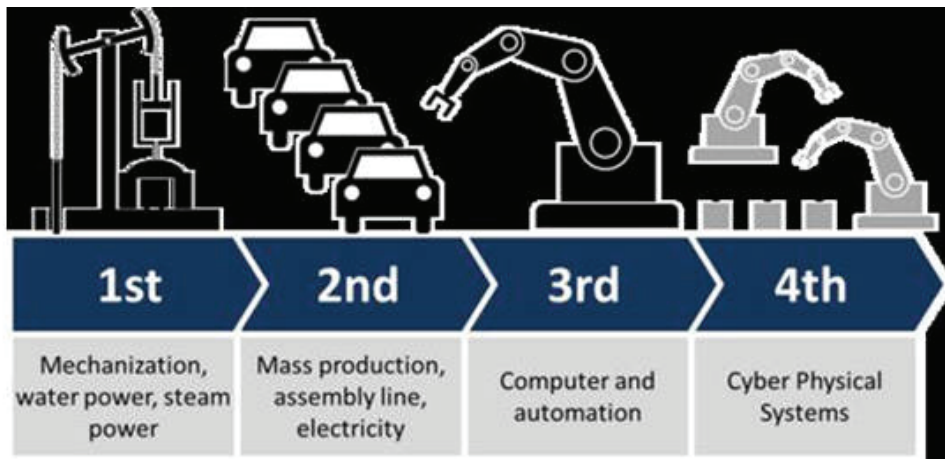
1.1 Background

Since the concept of the 'fourth industrial revolution' was laid out at the World Economic Forum 2016, an interest about this concept is growing on the whole society and it is expected to transform the entire human race with its rapid development. The fourth industrial revolution is a revolution that combines offline and online unlike the conventional industrial revolution, and it is a completely different mix of virtual and physical systems, rather than a particular technology shift in the conventional industrial revolution. (Kagermann, 2013)

Major technologies in the fourth industrial revolution include innovative ICT, cyber-physical systems, network communications, simulation, big data analytics, cloud computing, robots, augmented reality and intelligent devices(EPRS, 2015)

Especially, the fourth industrial revolution, especially based on the digital revolution, takes place at the beginning of the 21st century. It represents the ubiquitous mobile internet, information center, artificial intelligence and machine learning.

Figure 1. Four stages of the industrial revolution



Source: Internet of Things(www.heat-processing.com)

Fourth industrial revolution in Figure 1 was initialized at the Hanover Exhibition in 2011. To explain how technology fundamentally changes the structure of the global value chain, the fourth industrial revolution has made virtual machines available worldwide by introducing the 'Smart Factory'. Through this, it became possible to produce products fully customized and a new operating model was created.

The fourth industrial revolution predicted that ICT technologies accumulated in the third industrial revolution will have a significant impact on the progress and innovation of mankind by the process of 'increasing usage' and 'condensed adaptation

periods'.(Paul Krugman, 1998)

Although the definition of the fourth industrial revolution is unclear, it is possible to conciliate the various points discussed so far in three dimensions: technology, industry and systems

In the aftermath of the fourth industrial revolution, the concept of 'Smart Automation' which interacts with machines-machines-humans is spreading. Also these major technologies from fourth industrial revolutions will likely play a role in the maritime safety field and contribute to the development of related technologies.

In the field of ship inspection and ship management, lots of technologies related to fourth industrial revolution will be developed in the near future. But, the overall response to these developments is costly and time consuming and the rationalization through selection and focus is necessary.

1.2 Literature Review

Some previous studies related to maritime safety technology have been made. Oh et al. (2010) were carried out evaluation maritime technologies that require international cooperation. They selected high-priority technologies in maritime safety and developing countries and evaluated their priorities by deriving evaluation factors. The valuation factors were divided into three groups as the maturity of maritime safety technology, the promotion probability of projects and the degree of importance of technology, and the detailed factors of each group were drawn. Significantly evaluated maritime safety technologies included electronic chart technology, ship monitoring technology, and oil spill diffusion prediction and countermeasures. Cho(2011) studied about the present status and future direction of Maritime Safety Audit(MSA). He evaluated the achievements and implementation problems of MSA through define the fundamental problems of MSA by conceptualizing and analyzing MSA limits. Kang(2018) applied this method to the entire process of smart disaster safety management based on the fourth industrial revolution to minimize human, social, economic and environment damage from accidents and disasters of general industry part. And he also proposed virtual reality and augmented reality disaster safety management decision support system intelligent robot for recovery, disaster, discovery, reconnaissance relief and so on.

In the previous study, some studies on maritime safety technology were conducted. However, few studies have examined the importance and priority of maritime safety technology based on the fourth industrial revolution technology. In some studies, there are only cases that apply to the field of safety management in general industry. Therefore, this study can be said that it is different from the fourth industrial revolution Technology as an important research to identify what important technology is required in maritime safety field and what technology should be developed first.

1.3 Scope of Research

In Korea, a ship inspection is carried out under related law (Ship Safety Law)

to check competency of ship's structure and equipment for securing sea-worthiness of ship and human life. This inspection for the government has been carried out by two authorities, one is a classification society in Korea and the other is a quasi-government authority. In this study, the core technologies in maritime safety for the authority. Because it was difficult to collect data for analysis from classification society.

1.4 Research methodology

There are two methodologies for this study. Firstly, the concept and trends of fourth industrial revolution and technologies related to fourth industrial revolution are examined by desk research. Secondly, the maritime safety technologies which have highly related with core competency of ship inspection authority using quantitative techniques.

The final objectives of this study are the screening of maritime safety technology which has a close correlation with fourth industrial revolution and also the selection of maritime safety technology for ship inspection authority as a future growth engine for the authority

To achieve the objective of this study, the trends and kinds of technologies related to fourth industrial revolution in the maritime safety field are figured out. A number of technologies which have close relationship with Ship Inspection Agency A are identified by using desk research and interview with experts.

Especially, a questionnaire survey is carried out to the group of maritime safety experts (Ship inspector, Research institute, Shipbuilder, Shipping Company and etc.) to enhance the objectivity of survey result and analyze the survey result with AHP (Analytic Hierarchy Process) and MCA (Multi Criteria Analysis).

Also, the BCG Matrix method is using to decide the prior maritime safety technologies which are related with the core competency of Ship Inspection Agency A.

2. Ship Inspection Agency "A"

2.1 Overview of Ship Inspection Agency "A"

Ship Inspection Agency A established under the law of Ship Safety Act (Article 45) in 1979, as a semi-government body is supposed to be a safeguard of people's life and property at sea through excellent ship inspection, passenger ship, safety operations and develop & research the technologies in the areas of ship and its equipment, as well as maritime sectors.

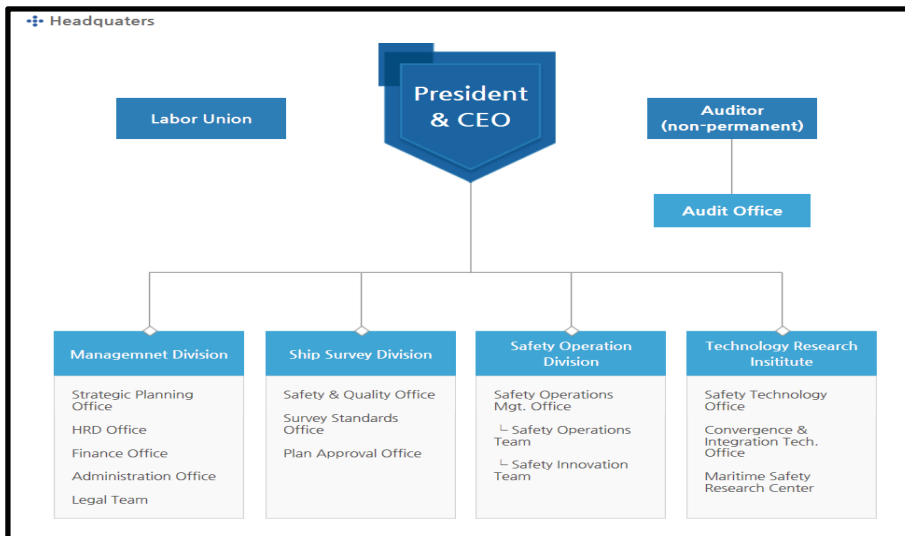
The Main services of Ship Inspection Agency A are 'Ship inspection for securing ship's safety', ' R&D and distribution of technologies for ship and ship's facilities' and 'Passenger ship Safe Operation Management', the details of services are as below;

- Approval of plan for ship construction and ship borne materials

- Inspection of ship & ship borne materials
- Confirmation for ship borne materials or small ship made or altered by accredited manufactures
- Status survey for container
- Approval for cargo stowage, lashing and other related activities
- R&D for securing of seaworthiness of ship and human life at sea
- Research and analysis of international standards for ship safety
- Consigned tasks for supervision throughout whole process of ship construction
- Research, education and public relations for preventing maritime accidents
- Consigned tasks from government and municipality by law
- Passenger ship safety operation management
- Other services declared by CEO for achievement of the goal

Ship Inspection Agency A has three (3) divisions and one (1) research institute and 15 branch office. One of the core competencies of authority, ‘Ship Inspection’ is charged in the ‘Ship Survey Division’, ‘Ship Safety Management’ is charged in ‘Safety Operation Division’ and ‘Maritime Safety Technology and Environment-Friendly Technology Development’ is charged in ‘Technology Research Institute’ in the Figure 3.

Figure 2. Organization of ‘Ship Inspection Agency A’



Source: Korea ship safety authority(www.kst.or.kr)

2.2. Technologies in Ship Inspection Agency A

The majority of technology development has been carried out by the ‘Technology Research Institute’ in the Ship Inspection Agency A. The Vision of ‘Technology Research Institute’ is that realization of “Leading authority for ship safety” and market creation through “HIGH-SAFETY-TRUST” and “Year- Round” Technologies and objectives

are dealt with fourth industrial revolution related technology development.

For the realization of authority's VISION, the institute sets 6 objectives as below;

- 1) Standardization of maritime safety assessment technology: Pursuing international standardization of maritime traffic safety assessment technology and best marine industry technologies.
- 2) Development of the equipment to prevent human accident: Localization of life saving appliance and navigation safety facilities
- 3) ICT based marine convergence technology: Development the marine convergence technologies through the analysis of marine safety information
- 4) Climate change response technology: Operation of comprehensive information center for GHG mitigation and development of GHG Mitigation technologies
- 5) Environment-friendly technology certification: Development of certifying technology of electronic propulsion system and navigational performance for the NON-SOLAS Coastal passenger ship
- 6) Development of ship safety technology: Self-Dependency on core engineering technology for securing ship's sea-worthiness and structure performance

Meanwhile, 'Technology Research Institute' sets 6 Core strategies for development of technology as below;

- (Strategy 1) Build the 'Integrated assessment system for ship's safety': Development of navigation loads detection & analysis and DB system, Development of status monitoring and operation system for car-ferry vessel. Development of program for assessment of aged ship's hull fatigue strength
- (Strategy 2) Development of Safety device for prevention of human loss in marine accident; Development of performance evaluation technology for life saving appliance with high-end material, Development of core technology for prevention of fire safety on ship, Development of evacuation facilities suitable for maritime environment condition.
- (Strategy 3) Development of environment-friendly ship technology and its adoption to international standard: Verification technology for electronic propulsion system, Development of environment-friendly propulsion system satisfied with international standard, Development of environment-friendly navigation system for coastal ship.
- (Strategy 4) Development of technology for response to climate change: Build a comprehensive information center for GHG mitigation, Development of GHG Mitigation Technology, Development of Policy for GHG reduction.
- (Strategy 5) Development of marine convergence technology based on ICT: Development of SMART e-Navigation system, Development of high value-added technology for creation of new growth engine in the maritime industry, Development of marine convergence technology for securing maritime traffic safety.

- (Strategy 6) Research on maritime safety policy and internationalization of maritime industry technology : Build a system for applying local best maritime technology to the international standards, Development of optimal navigation route for passenger ship, Development of New Concept Technology for assessment of Maritime Traffic status and Port safety.

3. Selection of Core Maritime Safety Technologies for the ‘Ship Inspection Agency A’

3.1 Selection of Core Maritime Safety Technologies

In the process of core maritime safety technologies selection for the Ship inspection agency A to accommodate with fourth industrial revolution, the importance of evaluation indices was identified by ‘Hierarchy method’ to enhance the objectivity.

The maritime safety technologies are categorized with consideration of the correspondence the technology with authority’s core competencies and evaluated the importance of each technology by multi criteria analysis method then picked the core technologies out

The selected core maritime safety technologies were analyzed by BCG Matrix in a view of Growth rate and market possession after development of technologies.

Total 108 maritime safety technologies were identified in a relation with the core technologies of the fourth industrial revolution and 30 technologies were classified as shown in the Table 1 by experts in a view of correlation with the core competency of ship inspection agency A

Table 1. Pool of the ‘Core Maritime Safety Technology’

Rank	fourth Industrial revolution Core Tech.	Maritime Safety Tech.	Details of Tech.	Score (10 point)
1	BIG Data	Ship Safety Management	Optimal navigation route proposal for vulnerable ship	9.0
2	BIG Data	Ship Safety Management	Enhancing the Safety management for mid/small cargo ship and passenger ship	9.0
3	Internet of Things, BIG Data	Ship Safety Management	Comprehensive managing and monitoring system for ship’s safe and environment-friendly navigation	9.0
4	Internet of Things, BIG Data	Ship Safety Management	Pre-alarms and accident prevention system for the risky situation (Fire, Flooding)	8.8
5	Augmented Reality	Ship Safety Management	Simulator for workers’ safety education	8.8
6	BIG Data	Ship Safety Management	Detecting and response system for maritime accidents	8.5
7	BIG Data	Ship Safety Management	Safe route for Passenger ship	8.3
8	BIG Data	Ship Safety Management	New Concept Technology for assessment of Maritime Traffic status and Port safety	8.3

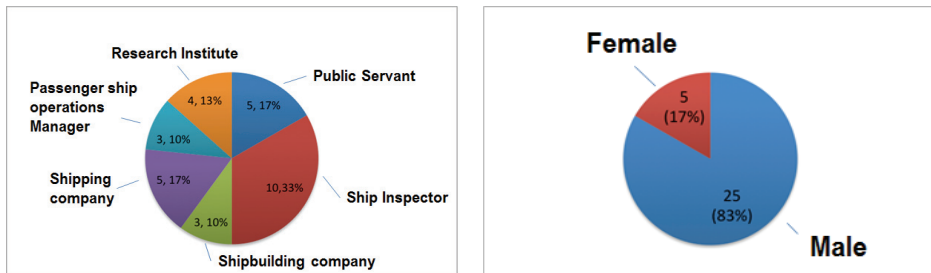
Rank	fourth Industrial revolution Core Tech.	Maritime Safety Tech.	Details of Tech.	Score (10 point)
9	High-Tech Manufacturing	Ship Inspection	Performance evaluation of Life saving device made with High-Tech Material	8.3
10	Clean Energy	Ship Inspection	Electric Propulsion system Tech.	8.3
11	High-Tech Manufacturing	Ship Inspection	Integrated Control system for ship's equipment	8.1
12	High-Tech Manufacturing	Ship Inspection	Customized Safety device for small/mid ship	8.1
13	Clean Energy	Ship Inspection	Environment-Friendly propulsion system in accordance with international standard	8.1
14	Clean Energy	Environment Friendly	Comprehensive management system(DB) of GHG from ship	8.1
15	BIG Data	Ship Inspection	Ship's life cycle management Tech,	7.8
16	BIG Data	Ship Inspection	Tech. for enhancement of ship's maneuverability and stability	7.8
17	Internet of Things, BIG Data	Ship Inspection	Ship status monitoring and managing system for Car-Ferry	7.8
18	Internet of Things, BIG Data	Ship Inspection	Monitoring Tech. for ship's equipment	7.8
19	Clean Energy	Environment Friendly	GHG Mitigation Technology	7.8
20	Augmented Reality	Ship Inspection	Ship Inspection and Monitoring Tech. with VR/AR	7.6
21	High-Tech Manufacturing	Ship Inspection	Development of standard hull shape for fishing boat	7.6
22	High-Tech Manufacturing	Ship Inspection	Development of standard hull shape of Deep-sea fishing vessel for enhancing the catching efficiency and declining of fuel	7.6
23	BIG Data	Ship Safety Management	Optimized Navigation system based on Big Data	7.4
24	Internet of Things, BIG Data	Ship Inspection	Automatic response system for engine failure with diagnostic result	7.4
25	Augmented Reality, BIG Data	Ship Safety Management	Optimal Nav. Information process and management technology based on Augmented Reality	7.4
26	High-Tech Manufacturing	Environment Friendly	Ballast Water Management Tech.	7.4
27	Clean Energy	Ship Inspection	Environment-Friendly navigation system for coastal ships	7.4
28	Clean Energy	Environment Friendly	Safe navigation of LNG-Fueled ship	7.4
29	Internet of Things	Ship Inspection	Water Ingression detecting sensor for small ship	7.4
30	Internet of Things, BIG Data, Cloud	Ship Safety Management	SMART e-Navigation System Tech.	7.1

The classification of marine safety technologies, priority of assessment items, and assessment by technology were performed by organizing a group of experts.

The expert group consists of people who engage the maritime safety area or who has knowledge and a questionnaire survey was carried out to ship's inspector(10 person), Public servants in maritime safety field(5 person), shipbuilding company(5

person), Passenger ship operation manager(3 person) and Research institute(4 person) in the Figure 4.

Figure 3.. Composition of Respondents

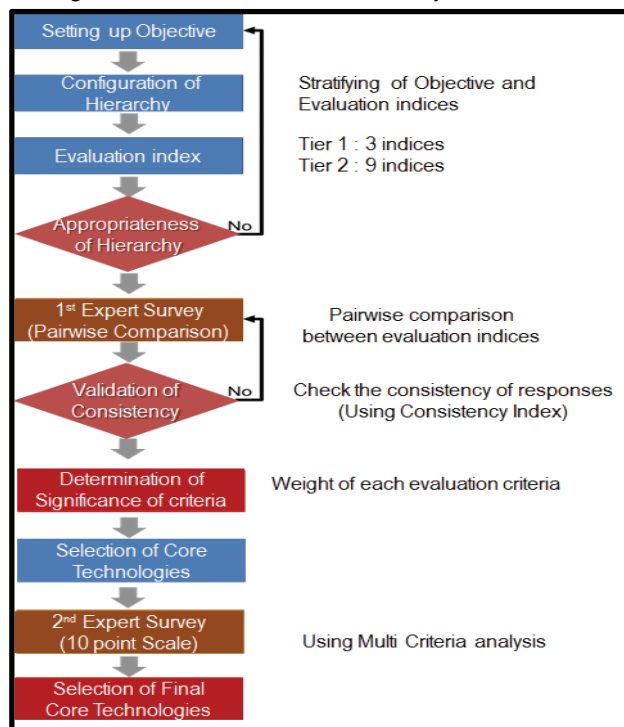


The detailed method to get the rank of core maritime safety technologies for ship inspection agency A' through the survey is as a Figure 5.

Especially, the objective for evaluation is setting up clearly and each evaluation indices is stratified with AHP method and a pair-wise comparison between the 'Evaluation Indices' is using for getting its importance between indices.

After calculation of each evaluation index's importance, classified top 30 technologies are ranked with using 'Multi Criteria Analysis' method.

Figure 4. Process for 'Core Maritime Safety Tech.' selection



In this study, evaluation indices which are using in national R&D budget review process are applied to evaluate the importance of each index and it is classified the 'Tier 1' & 'Tier 2' evaluation index in the Table 2.

It is classified three 'Tier 1' indices and nine 'Tier 2' indices as the evaluation index. The indices of 'Tier 1' are 'Validity', 'Necessity' and 'Economic feasibility'.

The index of 'Validity' consists of 3 'Tier 2' indices; 'Clarity of Technology', 'Appropriateness of Technology', 'Possibility of Technology'.

The next index of 'Necessity' also consists of 3 'Tier 2' indices; 'Urgency of Technology', 'Consistency of Technology', 'Potential of Technology' and the last 'Tier 1' index 'Economic Feasibility' has 3 'Tier 2' indices; effect of technology to the Science, Economy and Society.

Table 2. Evaluation Indices to rank 'Core Maritime Safety Technology' for fourth Industrial Revolution

Tier 1	Tier 2	Details
Validity	Clarity of Technology	Concreteness of Core technology's objective, Measurability of Objective, Attainability of Objective
	Appropriateness of Technology	Development of Core technology's appropriateness with the fourth industrial revolution technologies
	Possibility of Technology	Possibility for success of Core technology
Necessity	Urgency of Technology	Necessity of Core technology development and its urgency
	Consistency of Technology	Match for Government's existing policy for R&D and fourth Industrial revolution technology
	Potential of Technology	Growth potential after development of core technology
Economic feasibility	Scientific effect of Technology	Creation of Scientific output(Research paper, Patent), Ripple effect to other R&D Project
	Economical effect of Technology	Creation of added value through core technology development and increasing of export volume
	Social impact of Technology	Enhancement of Public Safety and job creation through core technology development

With result of questionnaire survey, the importance of evaluation indices in Tier 1 is 'Necessity', 'Economic feasibility', 'Validity' in a row. In 'Tier 2', 'Possibility of Technology', 'Urgency of Technology' and 'Social impact of technology' are ranked in a row.

The final result of analysis showed 'Urgency of Technology (0.1672)', 'Potential of Technology (0.1557)' and 'Consistency of Technology (1.448)' are ranked as the most important index for selection.

Table 3. Result of importance between the Evaluation Indices

Tier.1	Weight	Tier.2	Importance	Total	Rank
Validity	0.2615	Clarity of Technology	0.2847	0.0745	9
		Appropriateness of Technology	0.3566	0.0932	6
		Possibility of Technology	0.3587	0.0938	5
Necessity	0.4678	Urgency of Technology	0.3575	0.1672	1
		Consistency of Technology	0.3096	0.1448	3
		Potential of Technology	0.3329	0.1557	2
Economic feasibility	0.2707	Scientific effect of Technology	0.2963	0.0802	7
		Economical effect of Technology	0.2903	0.0786	8
		Social impact of Technology	0.4135	0.1119	4

The 2nd questionnaire survey is carried out for 30 technologies which have high relevance with ‘Ship Inspection Agency A’ and these are ranked by Multi Criteria Analysis in the Table 4.

The results of the Multi Criteria analysis about each evaluation index are as below table. Such as ‘Safe navigation of LNG-Fueled ship’, ‘Detecting and response system for maritime accidents’, ‘Pre-alarming and accident prevention system for the risky situation (Fire, Flooding)’ are preferred by that result.

Table 4. Evaluation result for core maritime safety technologies

Rank	fourth Industrial revolution Core Tech.	Maritime Safety Tech.	Details of Tech.
1	Clean Energy	Environment Friendly	Safe navigation of LNG-Fueled ship
2	BIG Data	Ship Safety Management	Detecting and response system for maritime accidents
3	Internet of Things, BIG Data	Ship Safety Management	Pre-alarming and accident prevention system for the risky situation (Fire, Flooding)
4	Augmented Reality	Ship Inspection	Ship Inspection and Monitoring Tech. with VR/AR
5	BIG Data	Ship Inspection	Tech. for enhancement of ship’s maneuverability and stability
6	Clean Energy	Environment Friendly	GHG mitigation technology
7	BIG Data	Ship Safety Management	Optimized Navigation system based on Big Data
8	Internet of Things, BIG Data, Cloud	Ship Safety Management	SMART e-Navigation System Tech.
9	High-Tech Manufacturing	Ship Inspection	Integrated Control system for ship’s equipment
10	High-Tech Manufacturing	Ship Inspection	Development of standard hull shape of Deep-sea fishing vessel for enhancing the catching efficiency and declining of fuel
11	Clean Energy	Ship Inspection	Environment-Friendly navigation system for coastal ships
12	BIG Data	Ship Safety Management	Enhancing the Safety management for mid/small cargo ship and passenger ship
13	High-Tech Manufacturing	Ship Inspection	Development of standard hull shape for fishing boat
14	BIG Data	Ship Safety	Safe route for Passenger ship

Rank	fourth Industrial revolution Core Tech.	Maritime Safety Tech.	Details of Tech.
		Management	
15	Clean Energy	Environment Friendly	Comprehensive management system(DB) of GHG from ship
16	Internet of Things, BIG Data	Ship Inspection	Ship status monitoring and managing system for Car-Ferry
17	High-Tech Manufacturing	Ship Inspection	Customized Safety device for small/mid ship
18	Internet of Things, BIG Data	Ship Inspection	Automatic response system for engine failure with diagnostic result
19	Internet of Things, BIG Data	Ship Safety Management	Comprehensive managing and monitoring system for ship's safe and environment-friendly navigation
20	High-Tech Manufacturing	Ship Inspection	Performance evaluation of Life saving device made with High-Tech Material
21	BIG Data	Ship Safety Management	Optimal navigation route proposal for vulnerable ship
22	Clean Energy	Ship Inspection	Environment-Friendly propulsion system in accordance with international standard
23	BIG Data	Ship Safety Management	New Concept Technology for assessment of Maritime Traffic status and Port safety
24	Clean Energy	Ship Inspection	Electric Propulsion system Tech.
25	High-Tech Manufacturing	Environment Friendly	Ballast Water Management Tech.
26	Internet of Things, BIG Data	Ship Inspection	Monitoring Tech. for ship's equipment
27	Augmented Reality	Ship Safety Management	Simulator for workers' safety education
28	Augmented Reality, BIG Data	Ship Safety Management	Optimal Nav. Information process and management technology based on Augmented Reality
29	BIG Data	Ship Inspection	Ship's life cycle management Tech,
30	Internet of Things	Ship Inspection	Water Ingression detecting sensor for small ship

3.2. Core Maritime Safety Technologies for 'Ship Inspection Agency A'

Considering technology possession and growth rate of technology for future public safety, it is essential for the ship inspection agency A when they will develop the core maritime safety technologies.

The core maritime safety technologies are mostly incomplete. So, it's difficult to predict the development status and possessions of technologies for public safety when the technologies will be developed. However, 'Choice and Concentration strategy' is the best strategy for the ship inspection agency A with enhancement of their own core competencies and preoccupation in maritime safety technology market through the grasp of high potential technologies preferentially.

So, BCG Matrix analysis which was introduced by Boston Consulting Group in USA is applied in this study to find the best strategy for the ship inspection agency A.

In this study, normal terms on BCG Matrix are avoided and redefine the terms with consideration of authority's characteristics as below and in the Figure 6.

- Market Growth Rate → Growth Rate of Public Safety Technology Development

- Relative Market Share → Public Safety Technology possession
- Emerging Market → Superb Public Safety Technology
- Profit Creation Market → Essential Public Safety Technology
- Developing Market → Required Public Safety Technology
- Declining Market → Basic Public Safety Technology

The ‘Superb Public Safety Technology’ means that the technology which is must-develop for the public safety. The ‘Essential Public Safety Technology’ means that the technology which is lower growth rate but it is using for public safety. So, this technology is important for keeping public safety.

A term of ‘Required Public Safety Technology’ means that technology which has higher growth rate and lower possession. But, this technology is only developed by strong demand because of its high degree of dependence upon foreign technology. The ‘Basic Public Safety Technology’ has a lower growth rate of public safety technology development and lower public safety technology possession, but it is the required technologies basically to keep the public safety.

Figure 5. Typical BCG Matrix

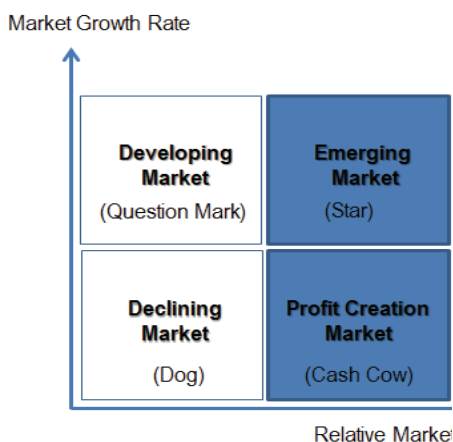
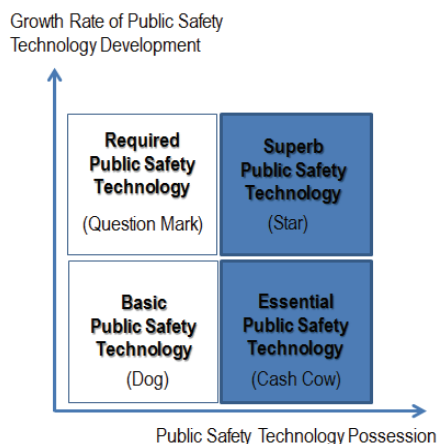


Figure 6. Redefinition of BCG Matrix



However, the core maritime safety technologies are still in developing and the market for these technologies didn't exist yet. So, the opinion about ‘Public Safety Technology Possession’ and ‘Growth rate of Public Safety Technology Development’ after completion of development of technology are analyzed through the survey from maritime safety experts.

It is defined that the x-axis is as a ‘Public Safety Technology possession’ and the y-axis is as a ‘Growth Rate of Public Safety Technology Development’ and also set the mean value of each survey as a median. Using this median, divide 4 quadrants with x-axis and y-axis and define each quadrant as ‘Superb Public Safety Technology (Star)’, ‘Essential Public Safety Technology (Cash Cow)’, ‘Required Public Safety Technology (Question Mark)’, ‘Basic Public Safety Technology (Dog)’

The technologies in Quadrant 1(Star) have over-average value in both ‘Public Safety Technology possession’ and ‘Growth Rate of Public Safety Technology

Development'. So, it is also expected that these technologies will bring the profit to market in near future.

The technologies in Quadrant 2(Question Mark) have below-average value in 'Public Safety Technology possession' and over-average value in 'Growth Rate of Public Safety Technology Development'. So, it is expected that market will be grown if these technologies will be developed in near future.

The technologies in Quadrant 3(Dog) have below-average value in both 'Public Safety Technology possession' and 'Growth Rate of Public Safety Technology Development'. So, the technologies in here are essential for securing the public safety.

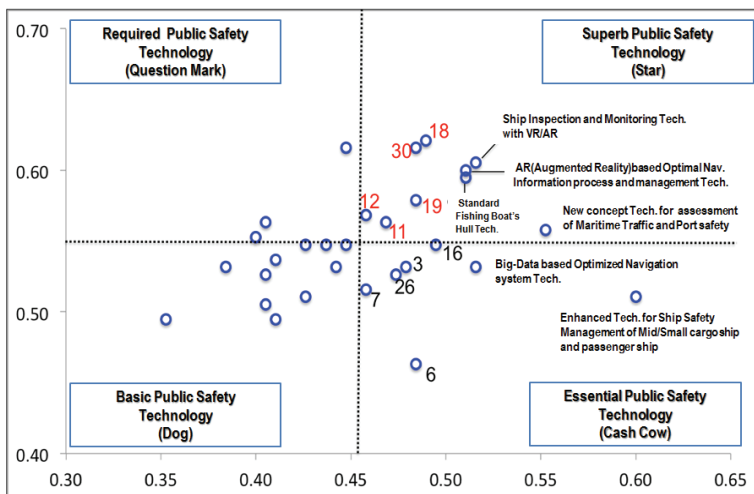
The technologies in Quadrant 4(Cash Cow) have above-average value in 'Public Safety Technology possession' and below-average value in 'Growth Rate of Public Safety Technology Development'. So, the technologies in here will be expected to have large percentage of possession in the market, but the possession will be paused or decreased due to the declining growth rate

With above circumstances, the technologies which are settled in Quadrant 1(STAR) and Quadrant 4(Cash Cow) could be the core technologies for the Ship Inspection Agency A to have strong point with development of these technologies.

The result of BCG Matrix analysis for 30 core maritime safety technologies are Figure 8, the superb public safety technologies in quadrant 1 are 'Ship Inspection and Monitoring Tech. with VR/AR,' Optimal Nav. Information process and management technology based on Augmented Reality', 'New Concept Technology for assessment of Maritime Traffic status and Port safety' and 'Development of standard hull shape for fishing boat'.

The essential public safety technologies in quadrant 4 are 'Optimized Navigation system based on Big Data', 'Enhancing the Safety management for mid/small cargo ship and passenger ship', 'Comprehensive managing and monitoring system for ship's safe and environment-friendly navigation' and Ballast Water Management Tech.'

Figure 7. BCG Matrix (Total Technologies)



With the result of BCG Matrix analysis, 9 technologies are ‘Superb Public Safety Technology (Star)’ and 7 technologies are ‘Essential Public Safety Technology (Cash Cow)’ in the Table 5.

The estimated development years for these technologies are expected minimum 7.63 years and maximum 9.47 years according to the survey result from maritime experts. For ‘Superb Public Safety Technology’ will take minimum 6.84years to 9.47 years as maximum and for ‘Essential Public Safety Technology will take minimum 5.79 years to 9.21 years as maximum.

Table 5. Result of BCG matrix analysis(Total Technologies)

Market	No.	Core Technologies	Est. Development Years(Yr)
Superb Public Safety Tech. (Star)	8	New Concept Technology for assessment of Maritime Traffic status and Port safety	8.42
	11	Integrated Control system for ship's equipment	8.68
	12	Customized Safety device for small/mid ship	7.63
	18	Monitoring Tech. for ship's equipment	8.42
	19	GHG Mitigation Technology	8.42
	20	Ship Inspection and Monitoring Tech. with VR/AR	8.16
	21	Development of standard hull shape for fishing boat	6.84
	25	Optimal Nav. Information process and management technology based on Augmented Reality	8.95
	30	SMART e-Navigation System Tech.	9.47
Essential Public Safety Tech. (Cash Cow)	2	Enhancing the Safety management for mid/small cargo ship and passenger ship	5.79
	3	Comprehensive managing and monitoring system for ship's safe and environment-friendly navigation	9.21
	6	Detecting and response system for maritime accidents	8.16
	7	Safe route for Passenger ship	6.32
	16	Tech. for enhancement of ship's maneuverability and stability	8.42
	23	Optimized Navigation system based on Big Data	9.21
	26	Ballast Water Management Tech.	7.63
Required Public Safety Tech. (Question Mark)	13	Environment-Friendly propulsion system in accordance with international standard	7.89
	14	Comprehensive management system(DB) of GHG from ship	8.42
	22	Development of standard hull shape of Deep-sea fishing vessel for enhancing the catching efficiency and declining of fuel	8.68
Basic Public Safety Tech. (Dog)	1	Optimal navigation route proposal for vulnerable ship	7.37
	4	Pre-alarmed and accident prevention system for the risky situation (Fire, Flooding)	6.84
	5	Simulator for workers' safety education	7.89
	9	Performance evaluation of Life saving device made with High-Tech Material	7.37
	10	Electric Propulsion system Tech.	9.21
	15	Ship's life cycle management Tech,	8.95
	17	Ship status monitoring and managing system for Car-Ferry	7.37
	24	Automatic response system for engine failure with diagnostic result	8.95
29	Water Ingression detecting sensor for small ship	7.11	

3.3 BCG Matrix Result for Ship inspection related Technologies

The BCG Matrix result of technologies for ship inspection, one of the core competencies, is a Figure 9 and Table 6. The technologies which are settled in Superb Public Safety Technology (STAR) are 5 technologies such as ‘Integrated Control system for ship’s equipment’, ‘Customized Safety device for small/mid ship’, ‘Monitoring Tech. for ship’s equipment’. The technology which is settled in Essential Public Safety Technology (Cash Cow) is ‘Tech. for enhancement of ship’s maneuverability and stability’

Figure 8. BCG Matrix(Ship Inspection related Technologies)

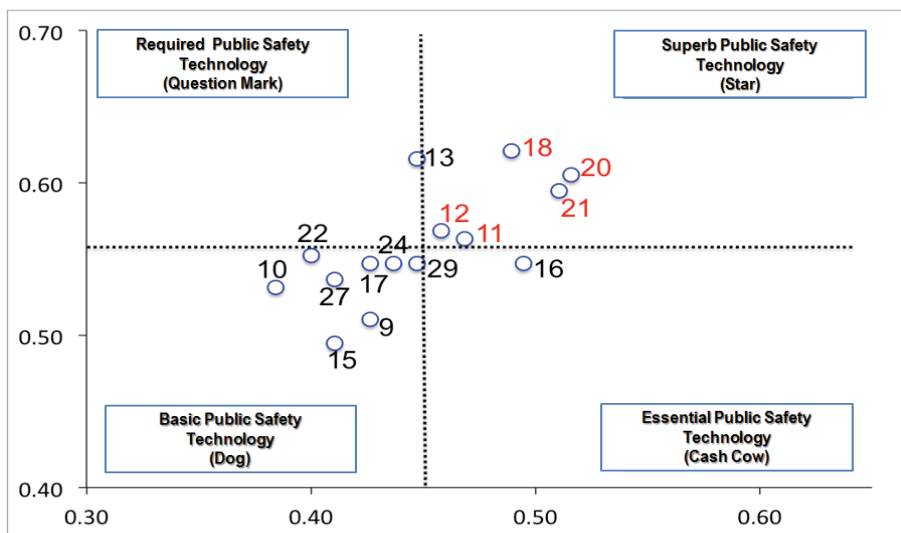


Table 6. Result of BCG matrix analysis(Ship Inspection related Technologies)

Market	No.	Core Technologies	Est. Development Years(Yr)
Superb Public Safety Tech. (Star)	11	Integrated Control system for ship’s equipment	8.68
	12	Customized Safety device for small/mid ship	7.63
	18	Monitoring Tech. for ship’s equipment	8.42
	20	Ship Inspection and Monitoring Tech. with VR/AR	8.16
	21	Development of standard hull shape for fishing boat	6.84
Essential Public Safety Tech. (Cash Cow)	16	Tech. for enhancement of ship’s maneuverability and stability	8.42
Required Public Safety Tech. (Question Mark)	13	Environment-Friendly propulsion system in accordance with international standard	7.89
Basic Public Safety Tech. (Dog)	9	Performance evaluation of Life saving device made with High-Tech Material	7.37
	10	Electric Propulsion system Tech.	9.21
	15	Ship’s life cycle management Tech,	8.95

Market	No.	Core Technologies	Est. Development Years(Yr)
	17	Ship status monitoring and managing system for Car-Ferry	7.37
	22	Development of standard hull shape of Deep-sea fishing vessel for enhancing the catching efficiency and declining of fuel	8.68
	24	Automatic response system for engine failure with diagnostic result	8.95
	27	Environment-Friendly navigation system for coastal ships	8.16
	29	Water Ingression detecting sensor for small ship	7.11

3.4 BCG Matrix Result for Ship Safety Management related Technologies

The BCG Matrix result of technologies for Ship Safety Management, one of the core competencies, is a Figure 10. & Table 7. The technologies which are settled in Superb Public Safety Technology (STAR) are 5 technologies such as ‘Comprehensive managing and monitoring system for ship’s safe and environment-friendly navigation’, ‘New Concept Technology for assessment of Maritime Traffic status and Port safety’, ‘Optimized Navigation system based on Big Data’, ‘Optimal Nav. Information process and management technology based on Augmented Reality’ and ‘SMART e-Navigation System Tech.’.

The technologies which are settled in Essential Public Safety Technology (Cash Cow) are ‘Enhancing the Safety management for mid/small cargo ship and passenger ship’ and ‘Detecting and response system for maritime accidents’

Figure 9. BCG Matrix (Ship Safety Management Technologies)

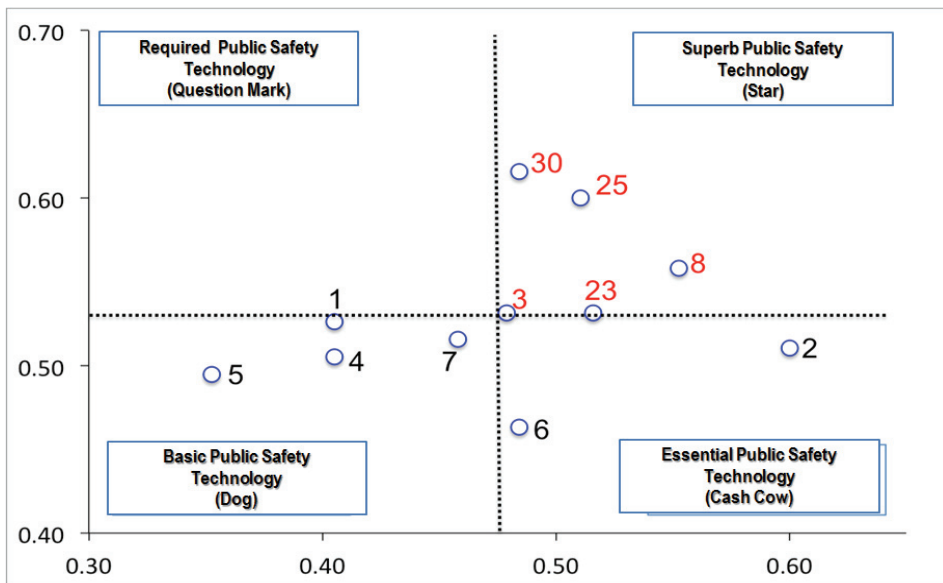


Table 7. Result of BCG matrix analysis(Ship Safety Management Technologies)

Market	No.	Core Technologies	Est. Development Years(Yr)
Superb Public Safety Tech. (Star)	3	Comprehensive managing and monitoring system for ship's safe and environment-friendly navigation	9.21
	8	New Concept Technology for assessment of Maritime Traffic status and Port safety	8.42
	23	Optimized Navigation system based on Big Data	9.21
	25	Optimal Nav. Information process and management technology based on Augmented Reality	8.95
	30	SMART e-Navigation System Tech.	9.47
Essential Public Safety Tech. (Cash Cow)	2	Enhancing the Safety management for mid/small cargo ship and passenger ship	5.79
	6	Detecting and response system for maritime accidents	8.16
Basic Public Safety Tech. (Dog)	1	Optimal navigation route proposal for vulnerable ship	7.37
	4	Pre-alarming and accident prevention system for the risky situation (Fire, Flooding)	6.84
	5	Simulator for workers' safety education	7.89
	7	Safe route for Passenger ship	6.32

3.5 BCG Matrix Result for Environment-friendly related Technologies

The BCG Matrix result of technologies for Environment-friendly, one of the core competencies is a Figure 11. & Table. 8. The technology which is settled in Superb Public Safety Technology (STAR) is 'GHG Mitigation Technology' and the technology which is settled in Essential Public Safety Technology (Cash Cow) is 'Ballast Water Management Tech.'

On the other hands, the technology which is settled in Required Public Safety Technology (Question Mark) is 'Comprehensive management system (DB) of GHG from ship' and the technology which is settled in Basic Public Safety Technology (Dog) is 'Safe navigation of LNG-Fueled ship.'

Figure 10. BCG Matrix (Environment-Friendly related Technologies)

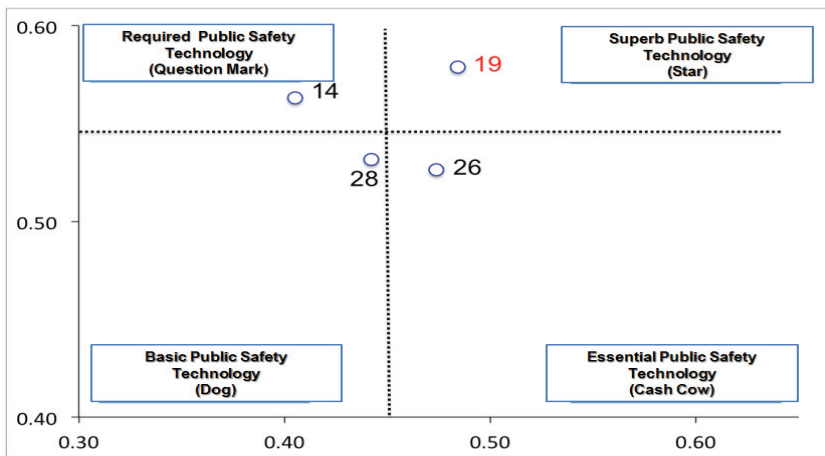


Table 8. Result of BCG matrix analysis (Environment-Friendly Technologies)

Market	No.	Core Technologies	Est. Development Years(Yr)
Superb Public Safety Tech. (Star)	19	GHG Mitigation Technology	8.42
Essential Public Safety Tech. (Cash Cow)	26	Ballast Water Management Tech.	7.63
Required Public Safety Tech. (Question Mark)	14	Comprehensive management system(DB) of GHG from ship	8.42
Basic Public Safety Tech. (Dog)	28	Safe navigation of LNG-Fueled ship	8.16

4. Conclusion

The fourth industrial revolution is expected to spread rapidly across all areas of human life and is expected to bring about many changes. Major technologies that will lead this fourth industrial revolution are artificial intelligence, robotics, Internet of Things, self-driving cars, 3D printing, nanotechnology, biotechnology and energy storage technologies and etc.

The changes in the fourth industrial revolution will also affect marine safety and will play a major role in the development of related technologies. So, the authority who has a role in maritime safety field, especially in ship inspection, ship safety management and other. So, it is the essential to identify the core technologies to prepare for fourth industrial revolution and its effects to Ship Inspection Authority which has a main role on the ship inspection and ship safety management.

For preparation for the fourth industrial revolution, many countries and industries are responding to it. It is found that the demand for eco-friendly ships, high value-added ships, and marine leisure ships is high and as strengthening of the regulations for marine environment protection, the technologies for that are strengthened.

Each country shows great interest in maritime safety technologies in advanced maritime countries, and has established practical national strategies to secure global standards for maritime safety technologies and to gain market dominance.

Korean government also set the implementation plan for development of maritime safety, selection of core technology and conduct many researches such as ‘e-navigation technology’, ‘High-end(IT Convergence) navigation aids’, ‘Navigation system technology’, ‘Safe navigation technology for arctic route and polar area’, ‘Maritime salvage technology’, ‘Mitigation technology for maritime accidents’.

This study discusses the selection of core maritime technologies for ship inspection Agency A with its core competencies (Ship inspection, Ship safety management, Environment-friendly).

As a result of the selection process with BCG Matrix, the Superb Public Safety technologies (Star) in ship inspection are ‘Integrated Control system for ship’s equipment’ and others, the Essential Public Safety technologies (Cash Cow) in ship inspection are ‘Tech. for enhancement of ship’s maneuverability and stability’.

The 'Star' technologies in Ship safety management are 'Integrated Control system for ship's equipment' and other 4 technologies, the 'Cash Cow' technologies in Ship safety management 'Enhancing the Safety management for mid/small cargo ship and passenger ship' and 'Detecting and response system for maritime accidents'.

Lastly, the 'Star' technology in Environment-friendly is 'GHG Mitigation Technology' and the 'Cash Cow' technology in Environment-friendly is 'Ballast Water Management Tech.'

In preparation for the fourth Industrial Revolution era, the core maritime safety technologies for the Ship Inspection Agency A that should be implemented first and prioritize them and it also analyzed the classification of maritime safety technologies, importance of items in technology development, and priority of development of public safety technologies using quantitative techniques.

4.1 Acknowledgement

This study is a part of the results of the planning study on maritime safety for the fourth industrial revolution, which supported by Korea Ship Safety Authority.

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