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Analysing the Impact of New Risks on Maritime Safety in Korea Using Historical Accident Data

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사고기록 데이터를 이용하여 국내 해상안전에 새로운 위기가 미치는 영향 분석

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Abstract : *The purpose of this work is to analyse the impact of new accident risks on maritime safety in Korea. The new accident risks have been induced from new/rare or unprecedented events in world maritime transportation, as identified by 46 experts in the previous study. To measure the impact of these new accident risks on maritime safety in Korea, the statistical accident data reported by the Korean Maritime Safety Tribunals (KMST) has been used for calculation, and the concept of Risk Index (RI) = Frequency Index (FI) + Severity Index (SI)established in a Formal Safety Assessment (FSA) by the IMO has also been introduced. After calculating two kinds of weight for FI and SI from the statistical accident data, high ranked scenarios were identified and their relationships between new risks and these scenarios were analysed. The results from this analysis showed, the root cause of the top-ranked scenario to be "developing high technology", which leads to "shorten cargo handling time". These results differed from optimum RCOs such as "business competition" and "crewing problems" which were identified in the previous study.*

Key Words : *Maritime accident, Safety, Risk, Hazard, Risk assessment, FSA, Risk control option*

요 약 : 본 연구의 목적은 새로운 사고의 위기가 국내 해양안전에 미치는 영향을 분석하기 위함이다. 새로운 사고 위기는 세계 해상운송에서 새롭거나 드물게 또는 예측하지 못한 사건들로부터 유추한 것으로 사전 연구에서 46명의 전문가를 통해서 식별한 것이다. 새로운 해양사고의 위기를 식별하기 위하여 해양안전심판원(KMST)의 통계 데이터를 계산에 사용하였고, IMO의 공식안정성평가기법인 위기지수 (RI) = 빈도지수(FI) + 심각성지수(SI)의 개념을 계산에 적용하였다. 통계적인 사고 데이터로부터 FI와 SI의 가중치를 계산한 후 가장 순위가 높은 시나리오를 식별하고 새로운 사고 위기와 시나리오 사이의 관계를 분석하였다. 분석 결과, 가장 순위가 높은 시나리오의 근본적인 원인은 “첨단기술 개발”이었고, 그 결과 “화물 작업 시간 단축”이 발생하는 것으로 나타났다. 이러한 결과는 사전 연구에서 46명의 전문가에 의해 식별한 “영업 경쟁” 및 “선원 문제” 등과 차이가 있음을 보였다.

핵심용어 : 해양사고, 안전, 위기, 위험, 위기평가, FSA, RCOs

1. Introduction

The purpose of this work is to search for the impacts of new accident risks on the maritime safety in Korea (Yim et al., 2015a).

In the previous study (Park et al., 2016a), 45 new accident risks are induced from a new/rare or an unprecedented event in the world maritime transportations (Allianz, 2012; Allianz, 2013; Allianz, 2014; Aliianz 2015) and the several kinds of hazard factors are identified from the response of questionnaires by 46 experts only. Thus the problem of these results are lack of scientific evidence (Hightower et al., 2004; Hightower, 2013; Luketa and Hightower, 2006; Luketa et al., 2008).

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In this work, as succeeding work after the previous study (Park et al., 2016b), the impacts of identified new risk on the maritime safety are carried out using historical accident data in Korea. The three kinds of historical accident data, which are reported in the statistical year book for maritime accidents published by Korean Maritime Safety Tribunals (KMST, 2014), are used.

The key frame of this work is FSA (Formal Safety Assessment) proposed by IMO (International Maritime Organization). According to the FSA, the amount of risk is calculated with the equation form of RI (Risk Index) = FI (Frequency Index) + SI (Severity Index) (IMO, 2001). In this equation, FI and SI are obtained from the historical accident data and it is to keep the scientific evidences in the analysis results of the impacts of identified new risk on the maritime safety in Korea.

2. Study Approaching Procedures

Fig. 1 shows the study procedures to search for the impacts of new risks on the maritime safety in Korea. It is divided into seven steps as followings;

Step 1 : Considering how to calculate the impacts of new risks on the maritime safety in Korea with the concepts of RI = FI + SI in FSA. In this work, we used the two kinds of data; the statistical accident data in Korea and the surveyed response data from questionnaires by 46 experts. The statistical accident data is collected from the statistical year book (from 2010 to 2014) for maritime accidents published by Korean Maritime Safety Tribunals (KMST, 2014). The surveyed response data is obtained from the previous study (Park et al., 2016a).

Step 2 : Compiling the three kinds of statistical accident data; the total number of accidents by each accidents type (herein after Accident data), the total number of accident losses by each accident type (herein after Loss data) and the casualty number by each accident type (herein after Casualty data). Here, Accident data have the dimension of i-by-j (i is 152 scenarios and j is 20 accident cause types).

Step 3 : Calculating the three kinds of reflection weights; the frequency weights α from Accident data, the loss weights β from Loss data and the casualty weights γ from casualty data.

Step 4 : Recalling the response results M of questionnaires which is obtained in the previous study (Park et al., 2016b) and it contained mean values for the 46 respondents.

Step 5 : Calculating M_α which is weighted M by the reflection of frequency weights α. Then after, calculating M_β and M_γ by the reflection of loss weights β and casualty weights γ to M_α.

Step 6 : Summing as $M_T = M_\beta + M_\gamma$ like as the concepts with RI (Risk Index) = FI (Frequency Index) + SI (Severity Index) in FSA.

Step 7 : Finding high ranked scenarios and analyzing their relationships between scenarios, new risks and the type of accident data in Korea.

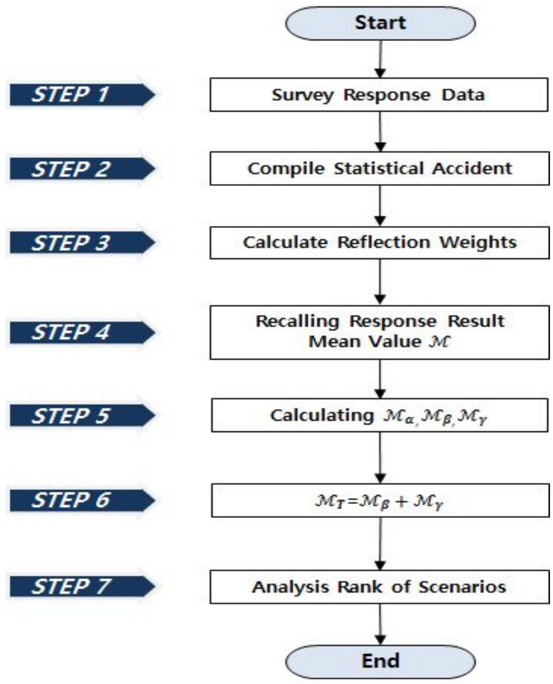

Fig. 1. Procedures to search for the impacts of new risks on the maritime safety in Korea.

3. Evaluation Method of new risks

3.1 Considering Evaluation Methods

In the previous study (Park et al., 2016b), a total of 45 new risks are identified such as human error, crew fatigue, reduced crewing numbers, over-dependence on technology, poor communications and so on. Then after, a total of 152 scenarios was constructed referenced with Influence Diagrams (ID) which are expected from 45 new risks. And the high ranked scenarios are surveyed by 46 experts using questionnaires with 152 scenarios and 20 accident causes as questions. As results from questionnaire survey we can obtain the response results as matrix form M. The response result matrix M of questionnaires have 152 scenarios in row and 20 accident causes in column, thus, M have the dimension of i -by-j (i is 152 scenarios and j is 20 accident causes) as shown in Eq. (1) and the elements $m_{i,j}$ of M are the mean values to 46 respondents (Park et al., 2016a).

$$M = \begin{pmatrix} m_{1,1} & m_{1,2} & m_{1,3} & \cdots & m_{1,j-1} & m_{1,j} \\ m_{2,1} & m_{2,2} & m_{2,3} & \cdots & m_{2,j-1} & m_{2,j} \\ m_{3,1} & m_{3,2} & m_{3,3} & \cdots & m_{3,j-1} & m_{3,j} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ m_{i-1,1} & m_{i-1,2} & m_{i-1,3} & \cdots & m_{i-1,j-1} & m_{i-1,j} \\ m_{i,1} & m_{i,2} & m_{i,3} & \cdots & m_{i,j-1} & m_{i,j} \end{pmatrix}, \quad (1)$$

where

i : Indices of scenarios ($i = 1,2,3,\cdots,I$, I = 152),

j : Indices of accident causes ($j = 1,2,3,\cdots,J$, J = 20).

The basic concept to evaluate new risks, in this work, is to calculate as RI = FI + SI in FSA. To obey this concepts in the calculation procedures, the dimension and variable type of FI and SI are needed to have same matrix formats.

Meanwhile, the dimension and variable types of three kinds of reflected accident data, used in this work, are different with the M. Thus, at first, we consider the features of three kinds of reflected accident data in the calculation process.

The three tables from Table 1 to Table 3 show Accident data, Loss data and Casualty data, respectively. Accident data $A_{j,u}$ in Table 1 have the dimension of j -by-u (j is 20 accident causes and u is 8 accident types). Loss data $L_{p,u}$ in Table 2 have the dimension of p -by-u (p is 3 loss types and u is 8 accident types). Casualty data $C_{v,u}$ in Table 3 have the dimension of v -by-u (v is 3 casualty types and u is 8 accident types). All of accident data are collected from the statistical year book (from 2010 to 2014) published by KMST. And also 8 accident types classified by KMST.

The common features of the three accident data are having the same columns as accident types only but having different rows such as accident causes in Table 1, loss types in Table 2 and casualty types in Table 3. The meanings of each indices of j for 20 accident causes and u for 8 accident types are represented in Table 4.

Table 1. The total number of accidents to accident causes versus accident types during the periods of 2010 to 2014 (j is accident causes and u is accident types)

j \ u	1	2	3	4	5	6	7	8
1	0	0	1	0	0	3	0	0
2	0	1	0	0	0	0	0	0
3	7	0	0	2	0	0	0	0
4	0	4	41	0	0	2	0	0
5	32	16	7	8	0	4	0	4
6	701	14	10	0	0	1	0	3
7	9	2	5	15	0	13	0	1
8	1	0	1	0	0	0	0	0
9	125	1	0	1	0	0	0	0
10	1	0	0	0	1	0	0	1
11	7	2	4	2	0	0	0	0
12	11	9	4	4	1	5	0	4
13	0	0	1	4	2	2	0	67
14	4	3	0	6	47	8	37	1
15	0	0	0	0	23	0	0	0
16	0	0	0	8	3	2	0	1
17	0	0	0	1	0	3	0	3
18	0	0	0	0	0	0	0	0
19	0	1	0	1	0	1	0	0
20	14	1	5	3	8	2	0	1
Sum	923	54	84	58	91	50	37	91

Table 2. Loss data having three kinds loss types from 2010 to 2014 (p is loss types and u is accident types)

p \ u types	year	1	2	3	4	5	6	7
p =1 (Total loss)	2010	9	1	1	16	8	47	0
	2011	4	2	7	22	7	59	0
	2012	2	2	6	5	13	37	0
	2013	3	1	4	6	9	18	0
	2014	1	1	4	5	8	15	0
p =2 (Medium loss)	2010	17	3	59	22	62	1	1
	2011	10	1	46	31	44	2	5
	2012	4	0	44	21	67	1	7
	2013	3	1	45	14	44	1	3
	2014	4	0	24	20	31	4	4
p =3 (Week loss)	2010	182	20	79	0	9	0	560
	2011	196	23	58	4	28	1	644
	2012	156	28	57	12	24	2	482
	2013	144	19	41	9	26	2	285
	2014	125	15	67	9	57	0	333

Table 3. Casualty data having three kinds casualty types from 2010 to 2014 (v is casualty types and u is accident types)

types (v)	year	1	2	3	4	5	6	7	8
v =1 (Death)	2010	22	1	0	10	5	12	0	19
	2011	16	0	2	5	1	2	0	29
	2012	11	4	7	11	5	7	0	26
	2013	9	9	2	8	14	3	0	17
	2014	16	0	1	302	13	29	0	43
v =2 (Missing)	2010	21	1	0	13	1	53	0	12
	2011	19	0	1	22	3	10	1	37
	2012	4	0	10	7	6	1	0	21
	2013	16	2	0	0	6	0	0	14
	2014	11	0	0	10	5	26	0	11
v =3 (Injuries)	2010	63	0	5	3	16	1	3	7
	2011	97	16	5	2	21	0	4	18
	2012	51	24	4	6	34	6	4	13
	2013	131	12	12	2	24	0	2	21
	2014	128	9	13	6	14	3	2	63

Table 4. The meanings of accident causes j and accident type u representing in the three tables from Table 1 to Table 3

Indices	Meanings j	Meanings u
1	Inadequate preparation of departures	Collision
2	Insufficient check for traffic routes	Contact
3	Inadequate keeping course	Grounding
4	Neglection of position checking	Capsizing
5	Bad ship maneuvering	Fire/Explosion
6	Neglecting of watch keeping	Sinking
7	Inadequate preparation/response for bad weather	Eng./Mach.Failure
8	Inadequate anchoring/berthing	Casualties
9	Violation of navigation rules	
10	Neglecting of service supervision	
11	Neglecting of duty	
12	None-compliance of safety regulations	
13	Bad handling of equipment/facilities	
14	Bad handling of fire-fighting facilities	
15	Fault of hull/engine equipments	
16	Inadequate passenger/cargo loadings	
17	Inadequate vessel operating managements	
18	Inadequate crewing placements	
19	Inadequate supporting facilities of route/harbor/traffics	
20	Seaworthiness to abnormal weather/sea states	

3.2 Calculating Weights

To reflect the statistical trends of accidents in Korea into the response scores M of questionnaires, the three kinds of weights, α, β and γ, are calculated from statistical data shown in Table 1, Table 2 and Table 3, respectively.

Let $\alpha \in \{\alpha_{j,u}\}$ in Eq. (2) as accident weights having $\sum \alpha_{j,u} = 1.0$. The elements $\{\alpha_{j,u}\}$ are calculated from the accident data $A_{j,u}$ (20-by-8) as shown in Eq. (3).

$$\alpha = \begin{pmatrix} \alpha_{1,1} & \alpha_{1,2} & \alpha_{1,3} & \cdots & \alpha_{1,u-1} & \alpha_{1,u} \\ \alpha_{2,1} & \alpha_{2,2} & \alpha_{2,3} & \cdots & \alpha_{2,u-1} & \alpha_{2,u} \\ \alpha_{3,1} & \alpha_{3,2} & \alpha_{3,3} & \cdots & \alpha_{3,u-1} & \alpha_{3,u} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \alpha_{j-1,1} & \alpha_{j-1,2} & \alpha_{j-1,3} & \cdots & \alpha_{j-1,u-1} & \alpha_{j-1,u} \\ \alpha_{j,1} & \alpha_{j,2} & \alpha_{j,3} & \cdots & \alpha_{j,u-1} & \alpha_{j,u} \end{pmatrix} \tag{2}$$

$$\alpha_{j,u} = \frac{A_{j,u}}{\sum_{j=1}^{J}\sum_{u=1}^{U} A_{j,u}} \tag{3}$$

where

u : Indices to the type of accidents ($u = 1,2,3,\cdots,U$, U= 8).

Let $\beta \in \{\beta_u\}$ in Eq. (4) as loss weights having $\sum \beta_u = 1.0$. The elements $\{\beta_u\}$ are calculated from Loss data $L_{p,u}$ (3-by-8) as shown in Eq. (5).

$$\beta = (\beta_1 \beta_2 \beta_3 \cdots \beta_{u-1} \beta_u) \tag{4}$$

$$\beta_u = \frac{\sum_{p=1}^{P} L_{p,u}\, b_p}{\sum_{p=1}^{P}\sum_{u=1}^{U} L_{p,u}\, b_p} \tag{5}$$

where

p : Indices to the type of loss ($p = 1,2,\cdots,P$, P= 3)

In Eq. (5), the type of Loss data $L_{p,u}$ (unit: is the number of accidents) divided into three kinds of types such as total loss ($p=1$), medium loss ($p=2$) and week loss ($p=3$) as shown in Table 2. To give different severity level according to the type of losses, weighting values b_p are arbitrary given as b_1 = 100, b_2 = 10 and b_3 = 1, respectively. The amount of severity by loss type is not configured out in the Table 2. Thus, in this work, we estimated the severity of losses referenced with in (Yim et al., 2014).

Let $\gamma \in \{\gamma_u\}$ in Eq. (6) as casualty weights having $\sum \gamma_u = 1.0$. The elements $\{\gamma_u\}$ are calculated from the casualty data $C_{v,u}$ (3-by-8) as shown in Eq. (7).

$$\gamma = (\gamma_1 \gamma_2 \gamma_3 \cdots \gamma_{u-1} \gamma_u) \tag{6}$$

$$\gamma_u = \frac{\sum_{v=1}^{V} F_{v,u}\, c_v}{\sum_{v=1}^{V}\sum_{u=1}^{U} F_{v,u}\, c_v} \tag{7}$$

where

v : Indices to the type of fatalities ($v = 1,2,3,\cdots,V$, $V = 3$)

In Eq. (7), the type of Casualty data $F_{v,u}$ (unit is the number of fatalities) divided into the three kinds of classes such as death ($v=1$), missing ($v=2$) and injury ($v=3$) as shown in Table 3. To give different severity levels according to the type of casualties, weighting values c_v are arbitrary given as c_1 = 100, c_2 = 100 and c_3 = 10, respectively. It can be thought that the death and missing are the same fatalities in the concepts of severity. And injury can be thought as less amount of severity as 1/10 which is induced from RACs (Risk Acceptance Criteria) for casualty class in (Yim et al., 2014). RAC is the group of threshold values to decide the amount of risk levels.

In addition to the three kinds of weights, α, β and γ, the response weight χ is also prepared to deal the response scores M as one of weighting values.

Let $\chi \in \{\chi_{i,j}\}$ in Eq.(8) as response weights having $\sum \chi_{i,j} = 1.0$. The elements $\{\chi_{i,j}\}$ are calculated from the response scores $M \in \{m_{i,j}\}$ (152-by-20) in Eq. (1).

$$\chi = \begin{pmatrix} \chi_{1,1} & \chi_{1,2} & \chi_{1,3} & \cdots & \chi_{1,j-1} & \chi_{1,j} \\ \chi_{2,1} & \chi_{2,2} & \chi_{2,3} & \cdots & \chi_{2,j-1} & \chi_{2,j} \\ \chi_{3,1} & \chi_{3,2} & \chi_{3,3} & \cdots & \chi_{3,j-1} & \chi_{3,j} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ \chi_{i-1,1} & \chi_{i-1,2} & \chi_{i-1,3} & \cdots & \chi_{i-1,j-1} & \chi_{i-1,j} \\ \chi_{i,1} & \chi_{i,2} & \chi_{i,3} & \cdots & \chi_{i,j-1} & \chi_{i,j} \end{pmatrix} \tag{8}$$

$$\chi_{i,j} = \frac{m_{i,j}}{\sum_{i=1}^{I}\sum_{j=1}^{J} m_{i,j}} \tag{9}$$

3.3 Reflecting Weights to M

At first, we obtain the modified response weight w_α (152 scenarios by 8 accident types) in Eq. (10) to reflect the statistical trends of accident weights α (20 accident causes by 8 accident types) into the response weight χ (152 scenarios by 20 accident causes).

$$w_\alpha = \chi\, \alpha \tag{10}$$

Secondly, we reflected β (1 by 8 accident types) in Eq. (4) into the modified response weight w_α in Eq. (10) and get the modified response weight w_β (152 scenarios by 8 accident types) in Eq. (11) to reflect the statistical trends of loss.

$$w_\beta = w_\alpha\, \beta^T \tag{11}$$

where

T : Transpose of matrix

Thirdly, we reflected γ (1 by 8 accident types) in Eq. (6) into the modified response weight w_α in Eq. (10) and get the modified response weight w_γ (152 scenarios by 8 accident types) in Eq. (12) to reflect the statistical trends of casualty.

$$w_\gamma = w_\alpha\, \gamma^T \tag{12}$$

Lastly, we get the w_T as in Eq. (13) with the matrix form in Eq. (14) having the dimension of i (152 scenarios) by u (8 accident types).

$$w_T = (w_\beta + w_\gamma)/2.0 \tag{13}$$

$$w_T = \begin{pmatrix} w_{T_{1,1}} & w_{T_{1,2}} & w_{T_{1,3}} & \cdots & w_{T_{1,u-1}} & w_{T_{1,u}} \\ w_{T_{2,1}} & w_{T_{2,2}} & w_{T_{2,3}} & \cdots & w_{T_{2,u-1}} & w_{T_{2,u}} \\ w_{T_{3,1}} & w_{T_{3,2}} & w_{T_{3,3}} & \cdots & w_{T_{3,u-1}} & w_{T_{3,u}} \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ w_{T_{i-1,1}} & w_{T_{i-1,2}} & w_{T_{i-1,3}} & \cdots & w_{T_{i-1,u-1}} & w_{T_{i-1,u}} \\ w_{T_{i,1}} & w_{T_{i,2}} & w_{T_{j,3}} & \cdots & w_{T_{i,u-1}} & w_{T_{i,u}} \end{pmatrix} \tag{14}$$

The calculation concept of Eq. (13) is RI (Risk Index) = FI (Frequency Index) + SI (Severity Index) as noting in FSA by IMO. w_α in Eq. (10) is correspond to FI, w_β in Eq. (11) and w_γ in Eq. (12) are correspond to FI + SI (severity for loss) and FI + SI (severity for fatality), respectively. Thus Eq. (13) have the concept for RI = FI + SI.

4. Experimental Results and Discussions

4.1 Experimental Results

(1) Ranking of whole accident types

Fig. 2 represents the calculation results for the response of questionnaires to 8 accident types. The x-axis shows the indices of 8 accident types and y-axis is the averaged weights of 152 scenarios to each 8 accident types. Fig. 2 is calculated from Eq. (15) using the elements $\{w_{T_{i,u}}\}$ of $\boldsymbol{w}_T$ in Eq. (13) and, the statistical results are summarized in Table 5.

$$w_{T_u} = \frac{\sum_{j=1}^{J} w_{T_{j,u}}}{J} \tag{15}$$

As shown in Table 5, the ranking order of accident type is the index number of 1 (collision), 8 (Fatality), 6 (Sinking), 4 (Capsizing), 5 (Fire/Explosion), 3 (Grounding), 2 (Contact) and 7 (Eng./Mech. Failure).

The top ranked collision accident takes 56.06 % in total and, it is the combination results with the number of collision accident in Korea and 46 expert's judgements to collision risks. The number of collision accident in Korea is top ranked as shown in Table 1. The three cases of Fatality (13.85 %), Sinking (10.64 %) and Capsizing (9.62 %) are followed.

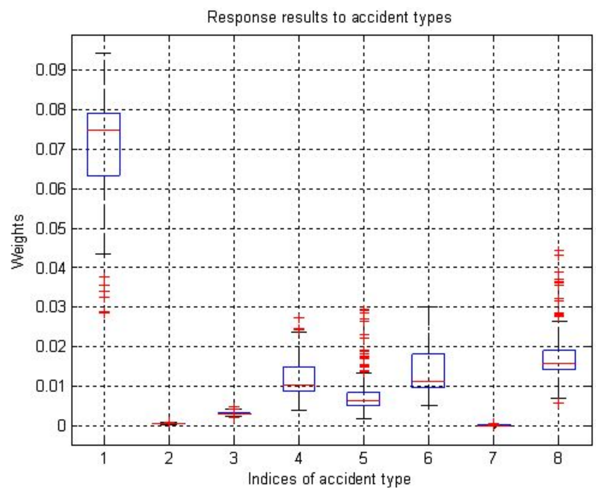

Fig. 2. Summarized calculation results for the response of questionnaires to 8 accident types. The shape of bar graph show 95 % confidence levels of the sample data with mean in the center line, 25 % in the bottom line and 75 % in the top line.

Table 5. Statistical results for the response of questionnaires to 8 accident types

Ranking	Index of accident types u	Mean weights w_{T_u}	Percentile (%)	s.d.	Variation
1	1	0.070542	56.06463	0.012635	0.00016
2	8	0.01742	13.8452	9.49E-05	9E-09
3	6	0.013391	10.64283	0.000402	1.62E-07
4	4	0.012109	9.624003	0.004799	2.3E-05
5	5	0.008346	6.632856	0.005449	2.97E-05
6	3	0.003207	2.549029	0.005441	2.96E-05
7	2	0.000633	0.503419	0.000118	1.38E-08
8	7	0.000174	0.138038	0.00676	4.57E-05

(2) Ranking of whole scenarios

Fig. 2 represents the calculation results for the response of questionnaires to 152 scenarios. The x-axis shows the indices of scenarios having highest ranking with descending orders and y-axis is the averaged weights of 8 accident types. to 152 scenarios.

Fig. 3 is calculated from Eq. (16) using the elements $\{w_{T_{i,u}}\}$ of $\boldsymbol{w}_T$ in Eq. (13).

$$w_{T_i} = \frac{\sum_{u=1}^{U} w_{T_{i,u}}}{U} \tag{16}$$

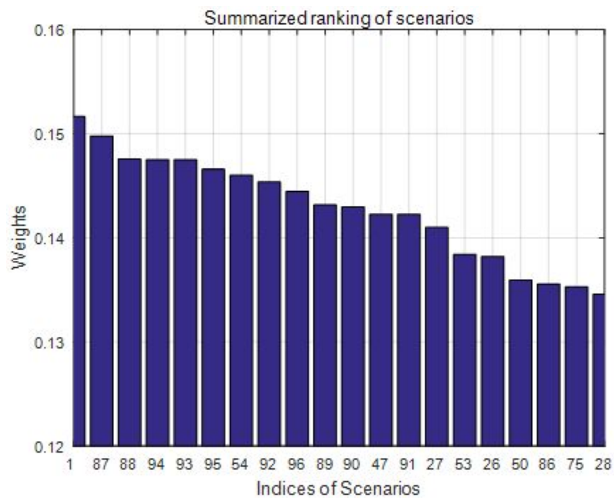

Fig. 3. Summarized calculation results for the response of questionnaires to 152 scenarios. This results show top ranked 20 scenarios.

The meaning of highest ranked scenarios in Fig. 3 are summarized in Table 6 with top 5 highest priority such as the index number of

1, 87, 88, 94 and 93.

In case of top ranked scenario with the index number of 1, the root cause is "developing high technology" in the maritime industries and it led to "shortened cargo handling time". This results are implies that the hazard factors by "shortened cargo handling time" can be propagate into various factors for perils. For examples, the fatigue of crew members or the incomplete ready for departure are can be a result from the "shortened cargo handling time".

In case of the next ranked two scenarios for the index number of 87 and 88 are have same root causes as "Insufficient rules for the dangerous cargo classifications" and it led to "Cargo firing" and "Bad cargo handling". Also, in case of the rest two scenarios for the index number of 94 and 93 are have same root causes as "Ro-Ro Passenger ship" and it led to the "Over heeling" and "Over loading" of a ship.

Table 6. The higher ranked 5 scenarios and its contents

Ran-king	Index of scenario j	Root causes	First transit effects	Second transit effects	Third transit effects
1	1	Developing high-technology	none	none	Shortened cargo handing time
2	87	Insufficient rules for the dangerous cargo classifications	Container ship	Mistakes of loading cargo identifications	Cargo firing
3	88	Insufficient rules for the dangerous cargo classifications	Container ship	Error for loading cargo Identifications	Bad cargo handling
4	94	Ro-Ro Passenger ship	Mistakes of weight display	Inadequate cargo loading places	Over heeling
5	93	Ro-Ro Passenger ship	Mistakes of cargo classifications	Errors of weight display to car/truck	Over loadings

(3) Ranking to each accident types

There are the calculation results for the response of 152 scenarios to 8 accident types separately and, it is calculated from Eq. (14) with the elements $\{w_{T_{i,u}}\}$. The top ranked scenarios in each accident type are summarized in Table 7.

The meaning of highest ranked 8 kinds of accident type scenarios is summarized in Table 7 with the highest priority such as the index number of 106, 55, 49, 54, 48 and 1.

In case of top ranked scenario index number 106 with Collision, the root cause is "Piracy". This result is "Hijacking" cause of lack of preparedness. It has the effect of high weight for neglecting of watch keeping. In case of the contact, the index number 55, the root cause is "Competition pressure" causing to fuel's savings transit to "Poor ship's maneuvering" as the peril. In cases of the Grounding, Fire/Explosion, Eng./Mach. Failure, the index number 49 and 48, the root causes are "Shipbuilding by owner's pressure" causing to poor management and then "Using non-genuine spare parts" or "Representing low quality for shipbuilding". In cases of capsizing and sinking, the index number 54, the root causes are "Ship's characteristic". It transits to vulnerable hull structure and then "Flooding at open deck". For Fatality, Index of scenario 1 is same as Fig. 3 of the highest scenario.

Table 7. The top ranked scenarios in 8 accident types and its contents

Accident type u	Index of scenario j	Root causes	First transit effects	Second transit effects	Third transit effects
1	106	Piracy	Sailing at High Risk Area.	Lack of preparedness	Hijacking
2	55	Competition pressure	Fuel savings	Appearing Slow speed Engine	Poor ship's maneuvering
3	49	Shipbuilding by owner's pressure	none	Poor managements	Low quality for Shipbuilding
4	54	Ship's characteristic	Vulnerable hull structure	Ro-Ro Passenger ship	flooding at open deck
5	48	Ship building by owner's pressure	none	Poor managements	Using non-genuine spare
6	54	Ship's characteristic	Vulnerable hull structure	Ro-Ro Passenger ship	flooding at open deck
7	48	Ship building by owner's pressure	none	Poor managements	Using non-genuine spare
8	1	Developing high-technology	none	none	Shortened cargo handing time

4.2 Discussions

In this work, the impacts of new risks on maritime safety in Korea are searched by the analysis of response results to 152 scenarios created in previous study (Park et al., 2016b). The summarized results are as followings;

In case of accident type, Collision risk is top ranked as part of 56.06 % and then following the order of Fatality 13.85 %, Sinking 10.64 % and Capsizing 9.62 %.

In case of scenarios, the top ranked five scenarios are the index number of 1, 87, 88, 94 and 93. In case of top ranked scenario with the index number of 1, the root cause is "developing high technology" in the maritime industries and it led to "shortened cargo handling time". This results are implies that the hazard factors by "shortened cargo handling time" can be propagate into various factors for perils. For examples, the fatigue of crew members or the incomplete ready for departure are can be a result from the "shortened cargo handling time".

In case of the next ranked two scenarios for the index number of 87 and 88 are have same root causes as "Insufficient rules for the dangerous cargo classifications" and it led to "Cargo firing" and "Bad cargo handling". Also, in case of the rest two scenarios for the index number of 94 and 93 are have same root causes as "Ro-Ro Passenger ship" and it led to the "Over heeling" and "Over loading" of a ship. It is can be thought that the all of these four scenarios are related with cargo loading in the Ro-Ro passenger ship and it is affected by big accident of SEWOL in 2014, Korea.

In case of each 8 accident type, the top ranked scenarios index number are 106, 55, 49, 54, 48, 54, 48 and 1. The root cause is "Piracy". This result is "Hijacking" cause of lack of preparedness. It has the effect of high weight for neglecting of watch keeping. In case of the contact, the index number 55, the root cause is "Competition pressure" causing to fuel's savings transit to "Poor ship's maneuvering" as the peril. In cases of the Grounding, Fire/Explosion, Eng./Mach. Failure, the index number 49 and 48, the root causes are "Shipbuilding by owner's pressure" causing to poor management and then "Using non-genuine spare parts" or "Representing low quality for shipbuilding". In cases of capsizing and sinking, the index number 54, the root causes are "Ship's characteristic". It transit to vulnerable hull structure and then "Flooding at open deck". Regarding of grounding, fire/explosion, eng./mach. failure, capsizing and sinking .It is can be thought that the all of these five scenarios are related in the Ro-Ro passenger ship and it is affected by big accident of SEWOL in 2014, Korea. For Fatality, Index of scenario 1 is same as Fig. 3 of the highest scenario. The result for collision risk, it is known that the highest impact factor is neglecting of the watch keeping. And it can be expected that high score for it from the respondent weights.

In case of scenario index number 55 and 54, They can be thought that it was affected by big accident of SEWOL in 2014, Korea.

5. Conclusions

According to Formal Safety Assessment (FSA) proposed by International Maritime Organization (IMO), the amount of risks calculated with the equation form of RI (Risk Index) = FI (Frequency Index) + SI (Severity Index).

Calculating the three kind of reflection weights and reflection weights to M (Park et al., 2016b), And then finding high ranked scenarios and analyzing their relationship between scenarios, new risks and the type of accident data in Korea. Summarized results are as follows:

1. As a result of the analysis of accident type, collision accident as the top ranked takes 56.06 % in total, and it is the combination results with the number of collision accident in Korea and 46 expert's judgements to collision risks.
2. As a result of the analysis of 152 scenarios, In case of top ranked scenario with the index number of 1, the root cause is "developing high technology" in the maritime industries and it led to "shortened cargo handling time".
3. As a result of the analysis of each accident type, in case of top ranked scenario index number 106 with Collision, the root cause is "Piracy". This result is "Hijacking" cause of lack of preparedness. It has the effect of high weight in collision weight for neglecting of watch keeping.
4. The most important new risk on safety maritime in Korea, "developing high technology" in the maritime industries and it led to "shortened cargo handling time". For examples, the fatigue of crew members or the incomplete ready for departure are can be a result from the "shortened cargo handling time".
5. As results from the analysis of 152 scenarios and each accident type are can be thought that it is affected by big accident of SEWOL in 2014.

Thus, it is clearly known that the optimum Risk Control Options (RCOs) to remove the hazard factors and to mitigate consequences in Korea is the following two factors: "causing risk for shorten cargo handling time" and "neglecting of watch keeping". These results are diffenet with the optimum RCOs such as "business competition" and "crewing problems" which are identified in the previous study by 46 experts only.

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