Identification of onboard protective measures against piracy

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Abstract

Ships have adopted various onboard protective measures against piracy and armed robbery against ships for years. The purpose of this article is to objectively identify effective onboard protective measures against such illegal acts. For this purpose, having acquired incident data based on "reports on acts of piracy and armed robbery against ships", from 2001, issued by the International Maritime Organization, we analyze the categorical incident data, applying Hayashi's quantification method type II. We quantitatively indicate the relation between onboard protective measures and severity of consequences. Finally, we identify "Armed Security Guard" and "Evasive manoeuvres" as effective onboard protective measures.

Keywords **:** piracy and armed robbery against ships, Hayashi's quantification method, onboard protective measures, severity of consequence, incident data

1 Purpose and scope of the research

Ships have employed various onboard protective measures for years against "piracy and armed robbery against ships", hereafter called "piracy", due to an increasing number of such illegal acts to ships and seafarers. Figure 1 shows the number of piracy incidents by year and area, based on "Reports on acts of piracy and armed robbery against ships" issued by the International Maritime Organization (IMO), hereafter called "the reports". This figure indicates that the number of piracy incidents has increased since 2007 with the increase of number in Africa. The number of incidents reached its peak in 2011 and after that the number has been decreasing. One of the reasons for the decrease of number of incidents is probably that various onboard protective measures have been adopted since shipping industry had developed, in 2009, "Best Management Practices to Deter Piracy in the Gulf of Aden and off the Coast of Somalia (BMP)", which has been revised three times [1], to avoid, deter or delay piracy attacks in the defined high risk area.

As the effectiveness of the onboard protective measures referred to in the BMP has not been objectively evaluated, Ota et al.[2] attempted to evaluate such effectiveness through the qualitative analysis of incident data in the reports. However, the qualitative analysis was not sufficient for evaluating effectiveness of onboard protective measures objectively.

The purpose of this article is to identify effective onboard protective measures against piracy objectively. For this purpose, we quantitatively analyze the relation between onboard protective measures against piracy and severity of consequences of piracy incidents, while there is a theoretical difficulty in analyzing piracy incident data, which are categorical data such as indices. The countermeasures employed by governments etc., e.g., presence of Naval/Military forces, are excluded from the analysis, since only protective measures taken onboard are referred to as the subject of our analysis.

2 NMRI Piracy Incident Database

2.1 Data sources

We have developed "NMRI (National Maritime Research Institute) Piracy Incident Database" using incident data since 2001 in the reports and "World Register of Ships" issued by IHS Fairplay.

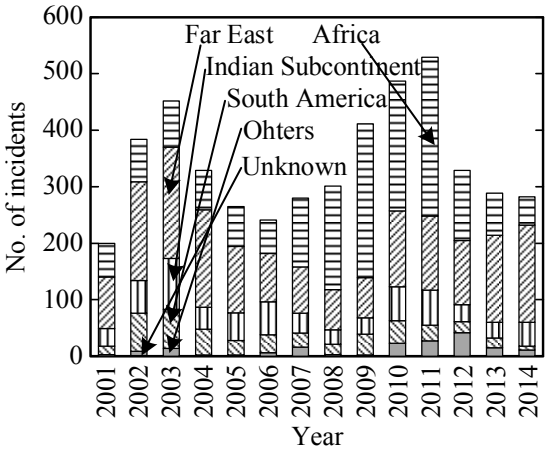

Fig. 1 Number of incidents by year and area

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2.2 Data items and groups

Table 1 shows items and groups of the data contained in NMRI Piracy Incident Database. The data under the groups of "Basic Information", "Criminal Information", "Targeted Ship Information" and "Suffering Information" have been derived from the reports. The data of the items containing the word "index" are categorical and have been classified based on the descriptions of the reports. These indices are expressed in italic font in Table 1. The data under the group of "Suffering Information" indicate the consequences only on "targeted ships" and they do not include casualties of pirates. The data under the groups of "Targeted Ship Specification" have been derived from "World Register of Ships", linked by "IMO number", i.e., item No. 29 in Table 1. StatCode determined by IHS Fairplay is employed as types of targeted ships.

2.3 Classification of severity

Severity of each incident has been classified based on the degree of consequences. "Severity Index (SI)", i.e., item No. 54 in Table 1, is defined as in Table 2. Severity of each incident is judged based on the consequences on persons and/or on ships. "Hijack" has been classified as "very high" severity in conjunction with "Fatalities" and "Abduction", for the reason that ship's personnel are often abducted with their ship in case of a hijack and that the abducted personnel have been killed at a certain frequency, e.g., 3%[3]. The severity of each incident has been classified according to the highest consequence, when plural consequences were reported in the incident.

Table 1 Items and groups of NMRI piracy incident database

Group	No.	Item
Basic Information	1	MSC Circular No.
	2	ID No.
	3	Date
	4	Gross tonnage
	5	Year
	6	Time (local)
	7	Time Difference
	8	Area 1
	9	Area 2
	10	Area 3
	11	Area 4
	12	Position (latitude)
	13	Position (longitude)
Criminal Information	14	Be found?
	15	Robber? Pirates?
	16	Escaped? Arrested?
	17	How to incursion
	18	No. of criminal (Original)
	19	No. of criminal (Figure)
	20	Organization
	21	Using ship?
	22	Type of ship
	23	Mother ship used?
	24	No. of ships
	25	Details of weapons
	26	Weapons
	27	*Weapon category index*
	28	Insider?
Targeted Ship Information	29	IMO No.
	30	Ship status
	31	Ship name
	32	Flag
	33	Ship type I
	34	Ship type II
	35	*Seafarers' action index*
	36	Action taken by seafarers
Suffering Information	37	Hijacked?
	38	No. of assaulted
	39	No. of injuries
	40	Injured?
	41	No. of missing
	42	No. of fate unknown
	43	No. of killed
	44	No. of fatalities
	45	Fatal?
	46	Property loss?
	47	Kidnapped/hostage?
	48	No. of kidnapped
	49	No. of hostage
	50	Sum. of kidnap & hostage
	51	Abducted?
	52	Consequences
	53	Request ransom?
	54	*Severity index *1*
	55	Details of the incident
Protective Measure Index (2008 - 2014)	56	*Alarm*
	57	*Distress message*
	58	*Ship Security Alert System*
	59	*Alert*
	60	*Antipiracy watch*
	61	*Challenging/Chasing pirates*
	62	*Changing anchoring position*
	63	*Mustered crew*
	64	*Citadel/safe room*
	65	*Access control*
	66	*Contacted authority*
	67	*Contacted authority, but failed*
	68	*Evasive manoeuvres*
	69	*Increased speed*
	70	*Whistle/fog horn*
	71	*Starting engine*
	72	*Flares*
	73	*Pressurized water *2*
	74	*Light on/off*
	75	*Long Range Acoustic Device*
	76	*Throwing object*
	77	*Armed Security Guard *3*4*
	78	*Security Guard *4*
	79	*Military on board*
	80	*Anti-piracy measure*
	81	No. of protective measures
Targeted Ship Specification	82	IHSF ship name
	83	Age of ship
	84	StatCode 5
	85	StatCode 3
	86	StatCode 2
	87	StatCode 1
	88	Decoded StatCode 5
	89	Draught
	90	Depth moulded
	91	GRT
	92	DWT
	93	Date of build
	94	Speed
	95	Freeboard *5

Note 1: See Table 2
Note 2: Fire hose/water cannon/water pump/water spray
Note 3: Warning shot/fired/displaying weapon
Note 4: "Security guard" is chosen separately from "Armed Security Guard" in case of unless stated in "the reports".
Note 5: Depth moulded (90) - Draught (89)

Table 2 Definition of Severity & Severity Index (SI)

SI	Severity	Consequence	
		on persons of targeted ships	on ship
0	Low	None (boarded/not boarded)	
1	Medium	Temporary hostage, Threatened	Property loss
2	High	Injuries	
3	Very high	Fatalities, Abduction,	Hijack
X	Unknown	No description about consequence	

2.4 Onboard protective measures

The indices under the group of "Protective Measure Index", i.e., item numbers 56 to 80 in Table 1, have been extracted from the reports from 2008 to 2014, and "No. of protective measures taken", i.e., item No. 81 in Table 1, has been counted. All protective measures described in the reports are represented by the protective measure indices, i.e., item numbers 56 to 80 in Table 1, which are binary data denoting adopted or not. The quantitative analysis is carried out under the assumption that a protective measure is adopted when the measure is referred to in the record of the incident in the reports and a protective measure is not adopted when the measure is not referred to in the record.

2.5 Number of incidents by ship type and severity

Table 3 shows the number of incidents occurred from 2008 to 2014 by types of targeted ships. The total number of incidents of "Cargo Carrying" ships (StatCode 1 = "A") and ships of all types excluding unknown types is 2,214 and 2,425, respectively. Namely, "Cargo Carrying" accounts for 92% of all the targeted ships. Hereafter, those 2,214 incidents on "Cargo Carrying" ships are discussed in this article.

Table 4 shows the numbers of incidents from 2008 to 2014 by severities and types of targeted ships. In this table, "population" means the sum of the numbers of ships all over the world in respective years, where the number of ships in each year is represented as of the end of June.

We used 1959 data other than 255 data with unknown severity (SI = X) for the quantitative analysis. The protective measure "Anti-piracy measure", i.e., item No. 80 in Table 1, is chosen when a kind of crew's actions is stated in the reports, e.g., "security measures", "anti-piracy measures", "preventive measures" or "BMP measures". "Anti-piracy measure" is not included in the analysis, for the reason that this measure and other protective measures are not mutually exclusive owing to its vagueness.

Table 3 Number of incidents by types of targeted ships (2008 to 2014)

StatCode 1			StatCode 2			StatCode 3		
Code	Decode	No. of Incidents	Code	Decode	No. of Incidents	Code	Decode	No. of Incidents
A	Cargo Carrying	2214	A1	Tankers	967	A11	Liquefied Gas	72
						A12	Chemical	443
						A13	Oil	452
			A2	Bulk Carriers	544	A21	Bulk Dry	531
						A22	Bulk Dry/Oil	3
						A23	Self-Discharging Bulk Dry	2
						A24	Other Bulk Dry	8
			A3	Dry Cargo/ Passenger	703	A31	General Cargo	252
						A33	Passenger General Cargo	356
						A34	Refrigerated Cargo	26
						A35	Ro-Ro Cargo	49
						A37	Passenger General Cargo	5
						A38	Other Dry Cargo	15
B	Work Vessel	210	B1	Fishing	19	B11	Fish Catching	18
						B12	Other Fishing	1
			B2	Offshore	65	B21	Offshore Supply	57
						B22	Other Offshore	8
			B3	Miscel-laneous	126	B31	Research	11
						B32	Towing/Pushing	105
						B33	Dredging	1
						B34	Other Activities	3
						B35	Other Activities cont.	6
X	-	1	X1	-	1	X11	Non Merchant Ships	1
Sub-Total		2,425						
Unknown		203						
Total		2,628						

Table 4 Number of incidents by severity and ship type

StatCode 3	Population [ship·year]	No. of Incidents					
		Severity Index					Total
		0	1	2	3	X	
A11	10,880	34	31	1	2	4	72
A12	31,524	159	174	20	52	38	443
A13	54,030	168	158	17	47	62	452
A14	1,108	0	0	0	0	0	0
A21	55,714	180	223	26	32	70	531
A22	628	2	1	0	0	0	3
A23	1,222	1	0	0	0	1	2
A24	7,706	1	6	0	0	1	8
A31	124,744	69	101	14	38	30	252
A32	2,330	0	0	0	0	0	0
A33	33,875	124	182	9	8	33	356
A34	7,977	9	9	2	4	2	26
A35	17,610	15	20	1	4	9	49
A36	18,115	0	0	0	0	0	0
A37	24,530	1	1	0	1	2	5
A38	1,733	7	5	0	0	3	15
Total	393,726	770	911	90	188	255	2,214

3 Method for analysis

3.1 Hayashi's quantification method type II

We analyze relations between onboard protective measures and severity of consequences, using Hayashi's quantification method type II[4]. Hereafter, we call the analysis based on this method "the quantitative analysis". It was reported that distinguishability of this method was as high as that of Neural networks and Bayesian networks in distinguishing a type of disease using CT scanned images[5]. The significant feature of the quantification method is to maximize the extent of separation of groups by assigning continuous values to discrete categories. Those values are called "category scores". Hereafter, we explain how to obtain such continuous values assigned to categories.

3.2 Formulation

The variables are defined below.

$$X_{m,k}(i,j)=\begin{cases}1: & \text{When } m\text{-th case of external criteria } k \text{ belongs to } j\text{-th category of } i\text{-th item.}\\ 0: & \text{When } m\text{-th case of external criteria } k \text{ does not belong to } j\text{-th category of } i\text{-th item.}\end{cases}$$

Here, $X_{m,k}(i,j)$ is called "category value". Equation (1) holds for category values.

$$\sum_{i=1}^{M}\sum_{j=1}^{N_{Ci}} X_{m,k}(i,j)=M \tag{1}$$

where,

M: Number of items,

N_{Ci}: Number of categories of i-th item.

In the quantitative analysis, the number of items M corresponds to the number of protective measures analyzed. The number of categories N_{Ci} of item is always two in the quantitative analysis, because the categories are only "adoption" (ON) and "non-adoption" (OFF) of each protective measure.

$S(i,j)$ is called "category score" assigned to j-th category of i-th item. A case is characterized by its affiliation to categories of items. In the quantitative analysis, a case corresponds to an incident. A case is constituted by a combination of the categories of all respective items. A value "case score" is calculated for each case by Equation (2).

$$Y(m,k)=\sum_{i=1}^{M}\sum_{j=1}^{N_{Ci}} S(i,j)\bullet X_{m,k}(i,j) \tag{2}$$

$Y(m,k)$ denotes a case score of m-th case of a group corresponding to external criterion k. In the quantitative analysis, an external criterion, which is the common term in Hayashi's quantification methods, corresponds to a Severity Index.

Table 5 explains the relations among "item", "category of item", "category score", "category value", "case", "case score" and "external criteria".

The variance between groups (S_B) and the total variance (S_T) are defined as Equations (3) and (4).

$$S_B=\sum_{k=1}^{K}\sum_{m=1}^{N_{Ek}}\left(Y(*,k)-Y(*,*)\right)^2=\sum_{k=1}^{K}N_{Ek}\left(Y(*,k)-Y(*,*)\right)^2 \tag{3}$$

$$S_T=\sum_{k=1}^{K}\sum_{m=1}^{N_{Ek}}\left(Y(m,k)-Y(*,*)\right)^2 \tag{4}$$

where:

$Y(*,k)$: Average of case scores of cases whose external criterion is E_k,

$Y(*,*)$: Average of all cases,

N_{Ek}: Number of cases in k-th external criterion.

S_B and S_T can be rewritten using matrices B, T and vector $\vec{s}$ which are defined as Equations (5) to (7).

$$B\left(\sum_{y=1}^{i_1-1}N_{C_y}+j_1,\sum_{z=1}^{i_2-1}N_{C_z}+j_2\right)=\sum_{k=1}^{K}\frac{g^k(i_1,j_1)g^k(i_2,j_2)}{N_{Ek}}-\frac{n(i_1,j_1)n(i_2,j_2)}{N_{all}} \tag{5}$$

$$T\left(\sum_{y=1}^{i_1-1}N_{C_y}+j_1,\sum_{z=1}^{i_2-1}N_{C_z}+j_2\right)=f(i_1j_1,i_2j_2)-\frac{n(i_1,j_1)n(i_2,j_2)}{N_{all}} \tag{6}$$

$$\vec{s}^{\,t}=\left(\begin{matrix}S(1,1),S(2,1),\cdots,S(1,N_{C1}),\\ \cdots,S(M,1),S(M,2),\cdots,S(M,N_{CM})\end{matrix}\right) \tag{7}$$

where

$g^k(i,j)$: Number of cases which belong to j-th category of i-th item at k-th external criterion,

$n(i,j)$: Number of cases which belong to j-th category of i-th item throughout all external criteria,

$f(i_1j_1,i_2j_2)$: Number of cases which belongs to both j_1-th category of i_1-th item and j_2-th category of i_2-th item,

N_{all}: Number of all cases.

Matrices B and T are positive definite and square matrices having size of N_T by N_T, where N_T is the total number of categories of all items which can be expressed by Equation (8).

Table 5 Explanatory table of the second method of quantification

	Item 1				Item 2					Item *M*				Case score	External Criteria			
	Category(1,1)	Category(1,2)	---	Category(1,N_{C1})	Category(2,1)	Category(2,2)	---	Category(2,N_{C2})	---	Category(M,1)	Category(M,2)	---	Category(M,N_{CM})					
Assigned value $S(i,j)$	S(1,1)	S(1,2)	---	S(1,N_{C1})	S(2,1)	S(2,2)	---	S(2,N_{C2})	---	S(M,1)	S(M,2)	---	S(M,N_{CM})	$Y(m,k)=\sum_{i=1}^{M}\sum_{j=1}^{N_{Ci}} S(i,j)\bullet X_{m,k}(i,j)$	E_1	E_2	---	E_K
Case (1,1)		1			1				---			1		Y(1,1)	1			
Case (2,1)			1			1			---	1				Y(2,1)	1			
---									---					---	1			
Case (N_{E1},1)		1					1		---		1			Y(N_{E1},1)	1			
Average of External Criteria 1														Y(*,1)=ΣY(i,1)/N_{E1}				
Case (1,2)	1					1			---	1				Y(1,1)		1		
Case (2,2)				1		1			---	1				Y(2,1)		1		
---								1	---				1	---		1		
Case (N_{E2},2)	1				1				---					Y(N_{E2},2)		1		
Average of External Criteria 2														Y(*,2)=ΣY(i,2)/N_{E2}				
---									---					---				
Case (1,K)		1					1		---				1	Y(1,K)				1
Case (2,K)	1				1				---		1			Y(2,K)				1
---									---					---				1
Case (N_{EK},K)				1		1			---				1	Y(N_{EK},K)				1
Average of External Criteria K														Y(*,K)=ΣY(i,K)/N_{EK}				
Average of all data														Y(*,*)=$\Sigma\Sigma Y$(i,j)/ΣN_{Ej}				

$$N_T = \sum_{i=1}^{M} N_{C_i} \tag{8}$$

The number of elements of the vector $\vec{s}$ is also N_T. In the quantitative analysis, N_T is twice of number of items M.

Then S_B and S_T are expressed by Equations (9) and (10).

$$S_B = \vec{s}^{\,t} B \vec{s} \tag{9}$$

$$S_T = \vec{s}^{\,t} T \vec{s} \tag{10}$$

Ratio of "variance between groups" to "total variance" (η^2) can be obtained by Equation (11).

$$\eta^2 = \frac{S_B}{S_T} = \frac{\vec{s}^{\,t} B \vec{s}}{\vec{s}^{\,t} T \vec{s}} \tag{11}$$

The vector of case scores $\vec{s}$ is obtained so that it maximize η^2. Equation (11) can be transformed to the eigenvalue problem formulated as Equation (12).

$$\left(B - \eta^2 T\right)\vec{s} = 0 \tag{12}$$

Therefore the vector of category scores $S(i,j)$ can be obtained as the eigenvector corresponding to the eigenvalue which maximize η^2. Because of existence of linear dependencies, the number of non-zero eigenvalues of Equation (12) is the number of external criteria minus one (K-1) or the total number of categories of all items minus the number of items (N_T - M), whichever is less.

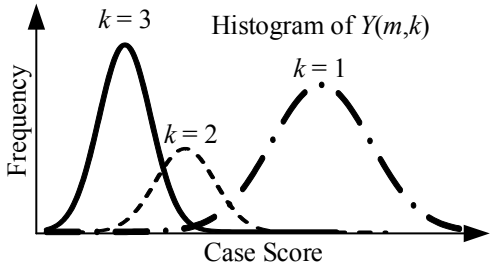

Fig. 2 Illustration of distributions of case score

3.3 Methods for distinguishing relation between categories of items and external criteria

It is possible to distinguish relations between categories of items and external criteria by using case score $Y(m,k)$. In order to distinguish such relations, it is necessary to investigate a distribution of case scores $Y(m,k)$ corresponding to each external criterion calculated from each eigenvector, i.e., the vector of category scores ($\vec{s}$) obtained by Equation (12). A unique one-dimensional distribution of case scores corresponding to each external criterion can be calculated using each vector of category scores. Figure 2 illustrates distributions of case scores. Those distributions overlap each other on the axis of case score. Those distributions can be characterized by their average values and standard deviations. When a distribution of case scores corresponding to an external criterion lies at relatively larger side on the axis of case score, it is considered that categories of items which have relatively

larger category scores have positive relations to the corresponding external criterion. In Figure 2 distribution of $Y(m,1)$ lies at the largest. Therefore, categories of items with large category scores have strong relation with external criterion "$k = 1$".

4 Results of analysis

4.1 Correlation ratio and category score

The eigenvalues, i.e., ratios of "variance between groups" to "total variance" given in equation (11), are 0.286, 0.086 and 0.011, and the correlation ratios, i.e., the square roots of the eigenvalues, are 0.535, 0.293 and 0.104. Hereafter, we discuss only the eigenvector corresponding to the largest eigenvalue, for the reason that the eigenvalue is significantly larger than the other eigenvalues. Table 6 shows the category scores, i.e., the eigenvector, and the numbers of adoption of respective protective measures. Figure 3 shows the histograms of case scores corresponding to the respective severity indices, i.e., the external criteria. This figure clearly shows the tendency that the larger Severity Index corresponds to the smaller average of case scores.

Table 6, Figure 3 and Equation (2) indicate that a protective measure, i.e., an item, has stronger relation with incidents having lower severity when the category score corresponding to category "ON", hereafter we call it "the score(s)", is positive. Similarly, a protective measure has stronger relation with incidents having higher severity when the score is negative.

Table 6 Category score and number of adoption of protective measures

Protective measures (Item)	No. of adoption	Category	
		ON	OFF
Alarm	1,146	2.42×10^{-01}	-3.42×10^{-01}
Distress message	105	-2.42×10^{-01}	1.37×10^{-02}
Ship Security Alert S.	136	-4.92×10^{-02}	3.67×10^{-03}
Alert	277	6.63×10^{-01}	-1.09×10^{-01}
Antipiracy watch	36	3.57×10^{-01}	-6.68×10^{-03}
Challeng/Chasing pirates	45	4.85×10^{-01}	-1.14×10^{-02}
Changing anchoring pos.	*1*	1.44×10^{-01}	-7.38×10^{-05}
Mustered crew	587	1.22×10^{-01}	-5.23×10^{-02}
Citadel/safe room	139	-1.46×10^{-01}	1.12×10^{-02}
Access control	42	7.18×10^{-02}	-1.57×10^{-03}
Contacted authority	294	2.95×10^{-01}	-5.21×10^{-02}
Contact. authority failed	34	1.39×10^{-01}	-2.45×10^{-03}
Evasive manoeuvres	405	1.13	-2.94×10^{-01}
Increased speed	280	2.30×10^{-01}	-3.83×10^{-02}
Whistle/fog horn	94	7.98×10^{-01}	-4.02×10^{-02}
Starting engine	*11*	-6.05×10^{-03}	3.42×10^{-05}
Flares	58	2.25×10^{-01}	-6.87×10^{-03}
Pressurized water	130	4.59×10^{-01}	-3.26×10^{-02}
Light on/off	59	7.98×10^{-01}	-2.48×10^{-02}
L. Range Acoustic Device	*4*	*1.39*	-2.84×10^{-03}
Throwing object	*8*	-5.24×10^{-01}	2.15×10^{-03}
Armed Security Guard	127	1.56	-1.08×10^{-01}
Security Guard	28	5.11×10^{-01}	-7.42×10^{-03}
Military on board	*7*	4.23×10^{-01}	-1.52×10^{-03}
Total	4,053		

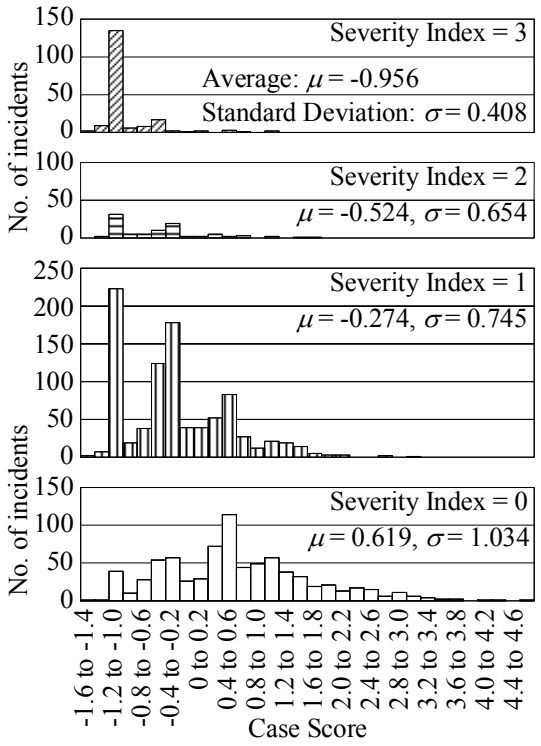

Fig. 3 Histogram of case score

4.2 Discussion

The protective measures in Italic font in Table 6 were adopted 19 times or less, i.e., 1 % of the number of incidents analyzed in paragraph 2.5 (1,959). Hereafter, we discuss 19 protective measures adopted more than 19 times, for the reason that the relation between a protective measure and severity of consequence cannot be evaluated when number of adoption of the protective measure is small.

The average of the scores of these measures is 0.402. The scores of the following 8 protective measures are larger than the average: "Armed Security Guard"; "Evasive manoeuvres"; "Light on/off"; "Whistle/fog horn"; "Alert"; "Security Guard"; "Challenging/Chasing pirates" and "Pressurized water". Therefore, these protective measures have stronger relations with incidents having lower severity than the other protective measures. This implies that the 8 protective measures are relatively effective to reduce severity of consequence. Of the 8 protective measures, "Armed Security Guard" and "Evasive manoeuvres" are considered to be more effective than the others, because the scores of these measures are more than double of the average.

On the other hand, the scores of the following 3 protective measures are negative: "Ship Security Alert System"; "Citadel/safe room" and "Distress message". Therefore, these protective measures have stronger relations with incidents having higher severity. Here, it should be noted that "Citadel/safe room" is often adopted under critical conditions such as boarding of pirates. This fact can lead to the strong relation between "Citadel/safe room" and incidents having

higher severity. Therefore, it cannot be said that the "Citadel/safe room" has adverse effect even though the score is negative. Thus, the effectiveness of protective measures having negative score of category "ON" cannot be evaluated based on the quantitative analysis.

It should be noted that the 3 protective measures cannot be recognized by pirates, while the 8 protective measures may be recognized by pirates. This fact implies that the results of the quantitative analysis can be used only for evaluating effectiveness of protective measures recognizable to pirates.

5 Incidents in "Arabian Sea" and "East Africa"

5.1 Incident data for analysis

As mentioned in section 4.2, the protective measures "Armed Security Guard" and "Evasive manoeuvres" are considered to be effective. "Armed Security Guard" and "Evasive manoeuvres" were adopted in 127 incidents, i.e., 6.5 % (127/1,959), and 405 incidents, i.e., 20.7 % (405/1,959), respectively.

In "Arabian Sea" and "East Africa" areas, "Armed Security Guard" was adopted more frequently than in all areas. We analyze the effectiveness of protective measures in the two areas, in order to confirm the robustness of the evaluation of effectiveness of "Armed Security Guard".

Table 7 shows the numbers of incidents in the two areas from 2008 to 2014 by severities and ship types. Numbers of incidents of unknown severity is 215 of 833 incidents, and 618 incidents are used for the analysis.

5.2 Correlation ratio and category score

The calculated eigenvalues are 0.397, 0.095 and 0.060, and the correlation ratios are 0.630, 0.309 and 0.245. Hereafter, we investigate the eigenvector corresponding to the largest eigenvalue.

Table 8 shows the category scores and numbers of adoption of respective protective measures in the two areas. The protective measures "Changing anchoring position" and "Military on board" are not included in the table for the reason that these measures are not referred to in the 618 incident data.

Figure 4 shows the histograms of case scores, calculated based on the category scores shown in Table 8, corresponding to respective severity indices.

5.3 Discussion

The protective measures in Italic font in Table 8 were adopted 6 times or less, i.e., 1 % of the number of incidents analyzed (618). Hereafter, we discuss the 16 protective measures adopted more than 6 times.

The average of the scores of these 16 measures is 0.313, and the scores of category "ON" larger than the average appear in 7 protective measures, i.e., "Armed Security Guard", "Evasive manoeuvres", "Alert", "Security Guard", "Light on/off", "Contacted authority" and "Mustered crew". The 7 protective measures have stronger relations with incidents having lower severity than the other protective measures. Of the 7 protective measures, "Armed Security Guard" and "Evasive manoeuvres" are considered to be more effective than the others, because the category scores of the measures are more than double of the average. "Armed Security Guard" and "Evasive manoeuvres" were adopted in 105 and 305 incidents, i.e., 17.0 % and 49.4 % in 618 incidents, respectively.

Table 7 Number of incidents by severity and ship type (Area: Arabian Sea & East Africa)

StatCode 3	No. of Incidents					
	Severity Index					Total
	0	1	2	3	X	
A11	19	3	0	2	3	27
A12	65	22	2	29	30	148
A13	70	26	2	15	50	163
A14	0	0	0	0	0	0
A21	85	29	4	29	63	210
A22	1	0	0	0	0	1
A23	0	0	0	0	0	0
A24	0	0	0	0	1	1
A31	36	13	3	32	28	112
A32	0	0	0	0	0	0
A33	62	33	1	5	28	129
A34	2	1	0	1	0	4
A35	11	5	0	4	8	28
A36	0	0	0	0	0	0
A37	1	1	0	1	2	5
A38	3	0	0	0	2	5
Total	355	133	12	118	215	833

Table 8 Category score and number of adoption of protective measures ("Arabian Sea" and "East Africa")

Protective measures	No. of adoption	Category	
		ON	*OFF*
Alarm	274	1.28×10^{-01}	-1.02×10^{-01}
Distress message	55	-1.26×10^{-01}	1.23×10^{-02}
Ship Security Alert S.	69	-1.44×10^{-01}	1.81×10^{-02}
Alert	28	5.17×10^{-01}	-2.45×10^{-02}
Antipiracy watch	*5*	*1.14*	-9.34×10^{-03}
Challeng/Chasing pirates	*2*	*1.04*	-3.39×10^{-03}
Mustered crew	87	3.66×10^{-01}	-5.99×10^{-02}
Citadel/safe room	88	2.09×10^{-01}	-3.47×10^{-02}
Access control	10	1.60×10^{-01}	-2.64×10^{-03}
Contacted authority	143	4.22×10^{-01}	-1.27×10^{-01}
Contact. authority failed	*3*	4.10×10^{-01}	-2.00×10^{-03}
Evasive manoeuvres	305	6.31×10^{-01}	-6.15×10^{-01}
Increased speed	213	2.40×10^{-01}	-1.26×10^{-01}
Whistle/fog horn	24	2.30×10^{-01}	-9.29×10^{-03}
Starting engine	*2*	*1.35*	-4.38×10^{-03}
Flares	51	1.80×10^{-01}	-1.62×10^{-02}
Pressurized water	86	2.76×10^{-01}	-4.47×10^{-02}
Light on/off	12	4.55×10^{-01}	-9.01×10^{-03}
L. Range Acoustic Device	*3*	4.93×10^{-01}	-2.41×10^{-03}
Throwing object	*6*	9.86×10^{-02}	-9.67×10^{-04}
Armed Security Guard	105	9.85×10^{-01}	-2.02×10^{-01}
Security Guard	23	4.69×10^{-01}	-1.81×10^{-02}
Total	1,594		

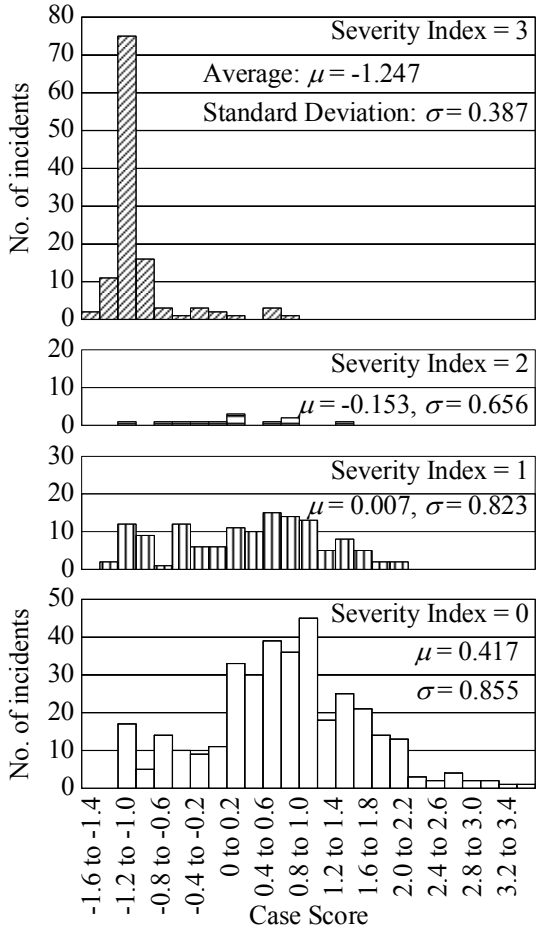

Fig. 4 Histogram of case score ("Arabian Sea" and "East Africa")

The aforementioned two protective measures, i.e., "Armed Security Guard" and "Evasive manoeuvres", are considered to be effective both in all sea areas and in the two areas. Thus, the robustness of these findings are confirmed.

6 Conclusion

We quantitatively analyzed relations between onboard protective measures and severity of consequence using Hayashi's quantification method type II. The results of the quantitative analyses indicate that "Armed Security Guard" and "Evasive manoeuvres" have stronger relations with incidents having lower severity. We also confirmed the robustness of the findings.

In conclusion, "Armed Security Guard" and "Evasive manoeuvres" can be objectively identified as effective onboard protective measures.

7 References

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