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Development of Risk Rating and Index for Coastal Activity Locations

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Abstract : *This paper develops a risk index based on an indicator of risk assessment in terms of coastal activity location and accident type. The risk index is derived from a formula which adds the consequence of failure to a vulnerability value, then subtracts the mitigation value. Specifically, the consequence of failure is the number of casualties in coastal activity locations. An indicator of vulnerability refers to coastal environment elements and social elements. A pointer of mitigation includes managerial and organizational elements that indicate the capabilities of coastal activities. A risk rating of coastal activity location is found from a risk matrix consisting of the accident location and type. The purpose of this study is to prevent accidents at coastal activity locations by allowing the Coastal police guard to monitor effectively and inform visitors of potential risks.*

Key Words : *Risk index, Risk rating, Consequence of failure, Vulnerability, Mitigation*

1. Introduction

Accidents due to coastal activities have continuously increased despite various safety policies. From 2015 to 2019, an average of 128 people died annually at coastal activity locations. Especially in 2018, there were 2180 casualties in coastal activity locations (KCG, 2019a; KCG, 2019b). A regionally customized safety management system can ensure the safety of people engaged in coastal activities. Previous risk assessments to help the coast guard prevent and mitigate accidents consist of excessive qualitative analysis and simple quantitative figures (Kim, 2019a), resulting in risk indices that are unsuitable for application in coastal locations. Chang (2009) called for the development of a total safety management system because of the annual increase in coastal accidents. International research on coastal environmental indicators have evaluated the environmental situation with ecology indicators, including weights for monitoring coastal ecosystems (Nam and Oh, 2012).

This paper develops an improved risk index based on qualitative and quantitative indicators for risk assessment of coastal activity locations.

2. Previous study

The KCG (2018) identified the indicators for coastal risk assessment, categorized by accident locations, types of accident, and safety facilities. Safety hazards are identified according to the accident location and type. For example, the rocks on a seashore could lead to drowning, falling, and isolation. At mud flats, drowning and isolation could occur. A seawall features warnings on drowning and falling, and coastal safety facilities include vehicle screening, safety handrails, safety signs, rescue facilities, night lighting, etc.

The UK Beach Safety Assessment Model is divided into coastal hazards and coastal activities. Coastal hazards include beach scarps, rocks, steep ramps, artificial coast structures, waves, weather, etc. Coastal activities include beach games, walking, rock fishing, surfing, swimming, scuba diving, etc. (Peter, 2013).

Nam and Oh (2012) proposed the indicators of coastal area management to the natural environment, social economics and networks. Kim (2019b) determined the regional factors, accident history factors, and preventive factors of coastal accidents.

The Korean Ministry of the Interior and Safety (MOIS) has developed a regional safety index defined as 100 − (consequence of failure + vulnerability − mitigation), which indicates the safety level of the local government. The safety level includes a consequences of a failure variable, which is the expected number of casualties; a vulnerability variable, which refers to the cause behind the consequence of failure; and a mitigation variable that describes the prevention and response to the consequence of failure (MOIS, 2020).

Satta et al. (2015) reported the Coastal Risk Index in the Mediterranean (CRI-MED), which consists of coastal forcing,

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coastal vulnerability, and coastal exposure. Forcing multiplies hazards by drivers, vulnerability indicates the coastal characteristics, and exposure refers to social and economic factors. It proposes that "Risk = Forcing * Vulnerability * Exposure."

Kim (2019a) showed that the risk assessment of coastal locations can be classified into A, B, and C. The class is determined by the number of accidents and frequency level (low, medium, and high) in the region. The qualitative metrics are different from an estimator's judgement. The NSW Government (2016) has presented a beach hazard rating calculation matrix that consists of beach type and wave height.

3. Risk assessment

3.1 Risk index model

The Korean MOIS has developed a regional safety index, while Satta et al. (2015) reported the CRI-MED. Lee (2011) proposed a simplified risk calculator for beaches: energy (tides + average wave height or flow) + population (in-water population + conflicting activity) +/- UKBSAMP weighting. Peter (2013) used a similar model to calculate the risk rating for any given beach. Various risk analysis models are represented by a few variables, such as hazard, vulnerability, resource, exposure, redundancy, consequence of failure, and capability.

A regional safety index developed by MOIS is currently used in Korea. This research adapted MOIS's and suggest a similar model. The risk index consists of the follosing: Consequence of Failure ($\sum_{i=1}^{n}(w_i \times H_i)$) + Vulnerability ($\sum_{j=1}^{m}(\alpha_i \times V_i)$) - Mitigation ($\sum_{k=1}^{o}(\beta_i \times M_i)$). That is, the risk index model is

$$\sum_{i=1}^{n}(w_i \times H_i) + \sum_{j=1}^{m}(\alpha_i \times V_i) - \sum_{k=1}^{o}(\beta_i \times M_i) .$$

where ω, α and β are the weights. H denotes the hazard factors, V denotes the vulnerability factors, and M denotes the mitigation factors. Each n, m, o, i, j, and k indicates a numerical constant.

The risk index was derived from coastal accident statistics, reports on present conditions (KCG, 2019a; KCG, 2019b), and previous studies (KCG, 2018; Nam and Oh, 2012; KCG, 2016; Satta et al., 2015; Peter, 2013). The variables represent accident situations, marine environment factors, social and economic factors, and managerial and organizational factors. These specific factors were sorted by hazard, vulnerability, and mitigation variables.

3.1.1 Consequence of failure

The consequence of failure variable covers the accidents recorded in the coastal accident statistics of the KCG (2019b). Its metrics are the number of reports, number of occurrences, and number of expected casualties, as listed in Table 1.

Table 1. Factors for the consequence of failure

Accident situation	Report on present conditions	Number of reports
	Occurrence	Number of occurrences
		Number of expected casualties

3.1.2 Vulnerability

The vulnerability variable covers marine environmental factors, such as the weather, seawater, and environment; and socio-economic factors such as community and utilization characteristics. The detailed subfactors are listed in Table 2.

Table 2. Maritime environment and social/economic factors

Risk factor (Level 1)	Risk factor (Level 2)	Risk factor (Level 3)
Environmental factors	Weather	Temperature
		Water temperature (low)
		Wind
		Rainfall
		Sea fog
		Natural disaster (tsunami, storm, wind and waves)
	Seawater/ Sea surface	Tide(tide lever), tide increased speed
		Wave (heaving sea, rip current, wave height)
	Topography/ Environment	Size (area, length)
		Nature (altitude, slope, water level)
		Resource (biological diversity, dispersion)
		Ocean obstacles (rock, seaweed, marine organism)
		Sphagnum
		Shore erosion
Social/ Economic factors	Community character	Coastal population/elderly people/Children
		Fishery size (number of workers, vessels)
		Local industry (tour, festival, experience)
	Use characteristic	Number of tourists
		Number of automobiles
		Ferry service, Fishing boat, Leisure
		Safety consciousness (regulation violation, carelessness, drinking, disobedience)

The vulnerability variable is measured using an ordinal scale (KCG, 2018; Lee, 2011; Peter, 2013). Factors such as the increase in tidal speed, number of rip currents, sphagnum rate, average wave height, height gap between rocks on the seashore, and number of tourists are graded with an ordinal scale ranging from zero to five.

3.1.3 Mitigation

The mitigation variable covers the managerial and organizational factors that indicate the response and management capabilities of the coast guard or local government. The detailed subfactors are listed in Table 3.

Table 3. Managerial and organizational factors

Risk factor (Level 1)	Risk factor (Level 2)	Risk factor (Level 3)
Managerial and organizational factors (Response / Management Capability)	Accident management organization	Response organization (coast guard, local government)
		Medical infrastructure (facility, number of workers)
	Coastal safety capability (Prevention / Mitigation)	Vehicle screen
		Safety handrail
		Safety sign
		Night lighting facility
		Early warning
		CCTV
		Access control (guard fence, buoy)
		Number of patrols
		Education/Training/Campaign
	Institution / Management	Access control area
		Risk management area

The mitigation variable is also measured with an ordinal scale (KCG, 2018; Lee, 2011; Peter, 2013). Factors such as in-water population, conflicting activities, and coastal safety facility are graded using an ordinal scale ranging from zero to five.

3.2 Risk rating

Kim (2019a) proposed the classes A, B, and C as risk ratings to indicate the results of risk assessment in coastal locations. Peter (2013) used a 5 × 5 matrix to describe risk (low, medium, and high) by showing the severity and likelihood levels.

The present study proposes a risk rating of coastal activity locations through a 5 × 5 matrix, which is consists of a risk index describing accident locations and types, as shown in Figure 1. The risk index is categorized into five levels: minor (1 – 20), major (21 – 40), critical (41 – 60), fatal (61 – 80), and multiple fatalities (81 – 100).

A risk rating is produced from the risk index, which is calculated from the assessment sheet for the coastal location and accident type. The risk is rated as class A, B, C, D, or E.

Risk Index		Accident Location: Minor (1~20)	Major (21~40)	Critical (41~60)	Fatal (61~80)	Multiple fatalities (81~100)
Accident Type	Minor (1~20)	A	A	B	B	C
	Major (21~40)	A	B	B	C	C
	Critical (41~60)	B	B	C	C	D
	Fatal (61~80)	B	C	C	D	E
	Multiple fatalities (81~100)	C	C	D	E	E

Fig. 1. Risk ratings in a 5 × 5 matrix.

4. Application of risk assessment

4.1 Selection factor for accident location and type

A sample application of the risk rating and index is shown for the coastal area of Taean. The place called Malipo in Taean is made up of beaches, rocks on the shore, and mud flats. The types of accidents that have occurred include drowning, drifting, falling, and isolation. According to the accident location and type, the partial risk assessment sheet in Table 4 shows the data that was entered into the risk model. The Fall type of accident was excluded in Table 5 because of the margin of this paper.

4.2 Calculating factor values with the risk model

Table 5 shows how the weight is multiplied by the assigned values to calculate the risk index for each type of accident. For the report on the present condition, the grade was obtained with the formula: 0.30 × {Drift (1.00 × 50) + Drowning (1.00 × 30) + Fall (1.00 × 15) + Isolation (1.00 × 96)}. For occurrence, the grade is obtained with the formula: 0.70 × {Drift ((0.40 × 30) + (0.60 × 24)) + Drowning ((0.40 × 25) + (0.60 × 21)) + Fall ((0.40 × 10) + (0.60 × 9)) + Isolation ((0.40 × 90) + (0.60 × 80))}. The value for the accident situation was then calculated with the formula: {0.50 × (value of report + value of occurrence)}.

The value of each factor for the accident situation comes from the KCG's coastal accident statistics. The values for other factors were graded with the ordinal scale ranging from zero to five.

Table 4. Allocated factors for accident location and type on TaeAn location

Factor			Accident location			Type of accident			
Level 1	Level 2	Level 3	Beach	Rock	Mud	Drift	Drown	Fall	Isolation
Accident situation	Report	Number of reports	O	O	O	O	O	O	O
	Occurrence	Number of occurrences	O	O	O	O	O	O	O
		Number of casualty	O	O	O	O	O	O	O
Environmental factor	Weather	Wind	O	O		O		O	
		Fog	O	O	O			O	
		....							
	Seawater	Tide	O	O	O	O	O		O
		Wave	O	O	O	O	O	O	△
	Environment	Size (area, length)	△	△	△				
		Altitude, slope	O	O					
		....							
Social / Economic factor	Community character	Coast population				△	△	△	△
		Fishery size				O	O	O	O
		....							
	Use character	Number of tourist				O	O	O	O
		Number of auto						O	
Managerial and organizational factor	Organization	Response organization	O	O	O				
		Medical Infra	O	O	O				
	Safety Capability	Vehicle screen						△	
		Safety handrail						△	
		....							
	Response Capability	Rescue box	O	△	△				
		Evacuation route	O	△					
		....							
	Management	Access control area	O	O	O				

Ref) O: essential △: option

Table 5. Weights and values for factors of accident types in Taean

Factor			Type of accident						
Level 1	Level 2	Level 3	Drift	score	Drown	score	...	Isolation	score
Accident situation (0.5)	Report (0.3)	Number of reports	1.00	50	1.00	30	...	1.00	95
	Occurrence (0.7)	Number of occurrences	0.40	30	0.40	25	...	0.40	90
		Number of casualties	0.60	24	0.60	21	...	0.60	80
Environmental factors (0.2)	Weather (0.4)	Wind	0.70	3			...		
		Fog			0.40	3	...		
		....							
	Seawater (0.6)	Tide	0.35	3	0.60	3	...	0.80	3
		Wave	0.65	3	0.40	3	...	0.20	3
	Environment	Size (area, length)							
		Altitude, slope							
		....							
Social / Economic factors (0.3)	Community character (0.3)	Coastal population	0.5	3	0.30	3	...	0.70	3
		Fishery size	0.5	2	0.70	2	...	0.30	2
		....							
	Use character (0.7)	Number of tourists	1.00	3	0.80	3	...	1.00	3
		Number of automobiles							
		....							

4.3 Calculating the risk index of the accident location and type

Fig. 2 shows the process for calculating the risk index of the accident location and type. For the beach, the risk index is 75 and calculated from {failure (70) + vulnerability (25) – mitigation (20)}. The maximum value for the beach is 80 points based on the year 2019. For drifting, however, the risk index is 19.6 and was found with {failure (16.7) + vulnerability (2.9)}. The maximum value for drift is 36 points based on the year 2019. The total risk index value of the three accident locations is 263 points, or 90.69 if converted to 100. A single accident location can include several types of accidents. For example, both drowning and drifting can occur at the beach. The total value of the risk index of four accidents is 87.2 points, or 42.5 if converted to 100.

Risk Index Calculation in Malipo (Example)		
Accident Location Risk Index	Beach	70+25-20 = 75/80
	Rock	110+40-10 = 140/154
	Mud	48+10-10 = 48/56
Accident Type Risk Index (except Mitigation)	Drown	12.4+1.3 = 13.7/52
	Drown	16.7+2.9 = 19.6/36
	Drown	5.5+3.4 = 8.9/44
	Drown	43.7+1.3 = 45/73

Fig. 2. Risk index for accident location and type.

4.4 Risk rating for the Malipo location in Taean

The total risk index value for the three accident locations is 90.69. The total risk index value for four accidents is 42.5. Using the 5 × 5 matrix in Figure 1, the risk rating for the Malipo location in Taean is found to be D class.

4.5 Utilization of Risk rating and risk index

It was assumed that the risk ratings of the three accident locations in Malipo will change according to the ebb tide, low water, or high tide, in addition to winds and waves (Fig. 3). Although the risk ratings of A, B, and C are spread out over normal days, the risk ratings of C, D, and E will become more prominent under these conditions. During these times, the role of the KCG will shift to confirmative patrol, guidance and patrol, and emergency work, and will require increased labor. Basic patrol and simple guidance will be conducted during normal days.

Location / Time	Beach	Rock	Mud	Korea Coast Guard Police Box
09:00 (Ebb tide)	B	D	Drift 19.6 Isolation 45.0 Risk Index 46.6 C	Confirmative patrol
12:00 (Low water)	Drown 13.7 Drift 19.6 Risk Index 33.3 C	C	D	Promotion, Guidance, Confirmative patrol
18:00 (High water)	D	Drown 13.7 Fall 8.9 Isolation 45.0 Risk Index 67.6 E	B	Increased manpower arrangement, Emergency work

Fig. 3. Changes in risk rating according to time and different coast guard roles.

5. Conclusion

Accidents due to coastal activities have continuously increased in recent years. Previously proposed risk indices to prevent and mitigate coastal accidents were ineffective because of the limited quantitative variables. This paper developed a risk index based on risk assessment indicators of coastal activity locations and accident types. The risk index was derived from a formula that added the consequence of failure to a vulnerability value, and then subtracted a mitigation value. The factors with each variable are involved in accident situation, environment, social and economic, and organizational and management factor. Different accident locations and types of accident select its appropriate factors. The specific risk index on coastal activity location is calculated based on these factors.

A risk rating of coastal activity locations was obtained with a matrix consisting of accident locations and types. The matrix consists of five risk levels for accident locations and five risk levels for accident types. Finally, the specific risk rating of a coastal activity location is provided to users. With the risk rating, the KCG can efficiently manage high-risk areas. It also helps prevent coastal accidents by enabling the KCG to effectively monitor and inform visitors of risk levels.

Future research demands that the suggested risk factors, ordinal scale, and risk matrix model are maintained continuously through practical use in coastal activity locations.

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