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Safety Improvement Model in Small Multipurpose Ports

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ABSTRACT

Port safety assessment are primarily conducted only on large ports despite the essential roles of small multipurpose ports for archipelagic areas such as east Indonesia. It is important to note that the increase in the activities of the small port is causing an increased risk of accidents. The study aims to assess the risk of accidents at small multipurpose ports. The safety assessment model applies the Formal Safety Assessment (FSA) method of the International Maritime Organization (IMO) and the use of As Low As Reasonably Practicable (ALARP) with adjusting conditions in a small multipurpose port. The expert judgment method supported by study literature, Focus Group Discussion, interviews, observation, and onboard is carried out to obtain data. Validation of risk identification with Eigen index and risk assessment supported by AHP and FTA weighting methods. This study found that incidents of burning ships and human accidents, i.e. people falling off ships or docks, being hit by vehicles, and being hit by mooring line throws, were the highest risks in small multipurpose ports. Cost-benefit analysis using Cost of Averting Fatality (CAF) that several recommendations are obtained to overcome various accidents at small multipurpose ports, which in essence, is accountable and easy-to-implement system work.

1. INTRODUCTION

The potential resources of Indonesia as an archipelagic country make sea transportation facilities and infrastructure to be very important for the large-scale movement and distribution of goods [1]. The port is one of the main infrastructures in sea transportation [2]. The Indonesian Government has prioritized port construction for the last ten years with a policy of making Indonesia a maritime axis, connecting between islands so that all islands are easier to reach and can increase economic potential through management and distribution [3]. The construction of ports in Indonesia until 2019 has as many as 636 ports consisting of 28 prominent port locations, 164 collection ports, and 444 small ports as regional and local feeders. A large number of small multipurpose ports because reach areas that are difficult to reach by land and air transportation. Serve goods and passengers as well as in the area of domestic sea transportation activities, although in limited quantities, feeders for national ports such as main ports and collection ports, and as a place of origin for destinations for passengers and goods with a range of services within the province especially in Eastern Indonesia [4, 5].

Small multipurpose ports influence the development of an area [6, 7]. However, on the other hand, due to the increased transportation activities at sea, this port must serve various types and sizes of ships. The use of docks does carry out alternately, sometimes without a schedule, depending on the ship that will enter the port. Loading and unloading activities are serving various types of goods in the port with limited equipment causing the risk of accidents to quickly occur and increasing the number of accident events [8, 9]. Accidents issued by Komite Nasional Keselamatan Transportasi (KNKT) in 2019 see Figure 1, the number of accidents at sea has increased yearly. From 2011 to 2018, there were 125 accidents; during that time, 673 victims died or went missing, and 418 victims were injured (Figure 1). The research results on shipwrecks' characteristics in the period 2014-2018 that 47.44% of ship accidents were 'collisions' that occurred in the port [10].

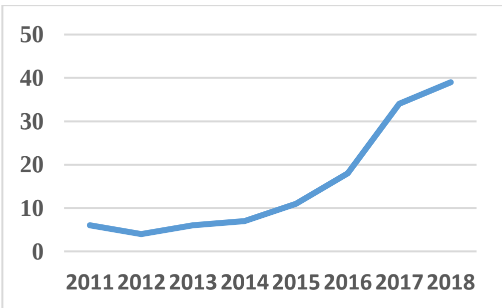

Figure 1. Chart of ship accidents by KNKT investigation 2011-2018 [11]

A small multipurpose port is defined as a port with limited terminals, serving various types of ships and loads flexibly and providing optimum usability, able to accommodate heterogeneous loads from a limited number of general cargo to containers [12]. Various loads are combined, not necessarily in large quantities as in special container terminals. Multipurpose terminals provide adequate load-handling facilities for a considerable period [13]. The technical criteria for this port are a minimum distance of 5–20 miles from other local feeder ports on the same coastline, a maximum dock capacity of 1000 deadweight tonnage, a land area of only one hectare, and loading and unloading equipment according to the type of goods transported. In addition, this port is located in a trading area and city center with limited land for development and is a port that is planning to become a large port [14]. The increased activity, small ports require safe and reliable operational performance. This is essential for protecting human life and health, the environment, and the economy. Therefore, any improper operation can profoundly impact the quality of service, productivity costs, and life [15]. In addition, the effects of accidents or disasters that endanger terminal operations can be controlled, reduced, and eliminated if a suitable risk assessment mechanism is carried out [16, 17]. Modeling safety assessments at ports, almost all carried out at large, primary, unique, congested, and crowded ports with the functions of goods/ cargo, fuel, or passengers, little research effort is devoted to modeling safety assessments on small multipurpose ports [18].

This research aims to fill an important gap in the safety assessment at a small multipurpose port. Measure potential hazards in the port area and factors contributing to risk using the Formal Safety Assessment (FSA) of the International Maritime Organization (IMO) and As Low as Reasonable and Practicable (ALARP) Development to determine the magnitude of the risk reduction and analyze the cost requirements due to the impact of risk. Specifically, the risk analysis model to be developed has primary Indonesian conditions, especially in small multipurpose ports, with case studies at Biak port in West Papua. Some other factors that have yet to be taken into account so far in modeling, such as the multipurpose conditions of small ports, will be another essential part. This study answers how the safety assessment model with the application of FSA and ALARP in small multipurpose ports can do implemented at a cost comparable to the benefits obtained. In addition, this study discusses the importance of systems thinking when using ALARP principles to support decision-making in risk management at small multipurpose ports. In connection with these problems, the research hypothesis is expected to improve the safety of small multipurpose ports by applying the principles of FSA and ALARP in risk management.

2. METHODOLOGY

The Formal Safety Assessment (FSA) method is considered appropriate for port risk assessment [19, 20]. It is a method developed by IMO that aims to improve maritime safety, including protecting life, health, marine environment, and infrastructure, with a structured and systematic methodology that links it between risk analysis and cost assessment [21, 22]. In its development, this method has been used for safety assessment on cruise ships [23], ferries [24], small boats [25], and dry bulk vessels [26] that have a greater risk of accidents than other ships [27, 28]. This method has been used to improve new measures and provisions in the analysis of ship design, operation and control, safety management standards, and regulations. It can be combined according to actual needs [29]. The results of the FSA evaluation identified several improvements, mainly due to the application of incorrect methods according to IMO guidelines, which are not yet transparent [30]. However, the FSA is still better off because it provides a way to be proactive, allowing potential hazards to be considered before severe accidents occur [31]. The FSA can be implemented in five steps (MSC-MEPC.2/Circ.12/Rev.2, 2018) [32]. In Figure 2, In step 1, Hazard identification, all possible risks are established so that significant risks can be selected this step by screening all identified risks. A hazard is a state of a physical situation with the potential for human injury, property, environment, or some combination. Step 1 results in a list of hazards and an assessment of accident scenarios, prioritized by risk level, and step 2 is the identification of the high-risk areas which need to be addressed. Both historical risks and newly identified risks (from steps 1 and 2) should be considered in step 3, for producing a wide range of risk control measures, so that in step 4 identify and compare benefits and costs associated with the implementation of each Risk Control Options (RCOs) in step 3. The result in RCO identified in step 5 for defining recommendations that should be presented to the relevant decision-makers. The recommendations would be based upon the comparison and ranking of risk control options as a function of associated costs and benefits, keeping risks as low as reasonably practicable, and feedback information to review the results generated in the previous steps.

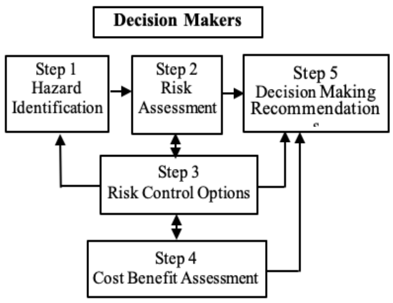

Figure 2. FSA methodology [33]

The level of risk, it is differentiated into unacceptable risks, except in exceptional circumstances (intolerable). Minimal risks do not need further precautions (negligible) for risks between intolerable and negligible levels [34]. A method is introduced As Low As Reasonably Practicable (ALARP), where the concept in Figure 3 is used to describe to what extent A job risk must be lowered by applying various necessary mitigations [35]. "Reasonably" can be interpreted as " accountable." The opposite is "unreasonable" i.e., "absurd" or "far-fetched" whereas "practicable" is often interpreted as "practical" or rather "easily enforceable" [36, 37]. Usually, the reference is the availability of current technology and available resources [38]. This is to ensure that safety resources can be maximized for the analysis of the estimated number of lives saved, as the ALARP criteria result in more substantial minimum requirements for life safety investments [39, 40].

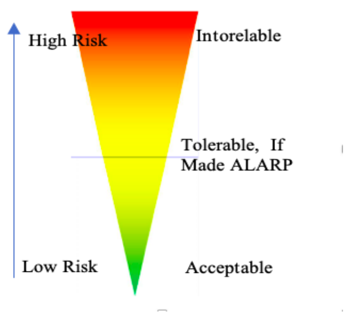

Figure 3. ALARP concept [41, 42]

Hazard identification starts from the main clues [43], namely accident data [44, 45], then continues with the field visits and finally with experts' opinions on accidents that can occur at small multipurpose ports. Qualitative research instruments at the hazard identification stage use the opinions of experts directly involved in operations in small multipurpose ports to use content validity tests from Aiken with the Aiken V index. The content validity test shows the extent to which the questions in the questionnaire can fully and proportionally represent the behavior of the sample given the test [46]. The validation results are said to be valid in terms of content if the analysis of the V index (expert agreement index) is obtained> 0.3 [47]. The item can be used if the V index > 0.3 is declared valid. Experts were asked about the possibility of some accident occurring in a small multipurpose port with a choice of yes or no answers and given a column if there are additional types of accidents—the validity of Aiken content with Aiken V index. The validation results are said to be valid in terms of content. If the analysis of the V index (expert agreement index) is obtained > 0.3, then it is declared valid so that the type of accident can use.

$$V = \frac{S}{ni(c-1)} \tag{1}$$

where, S is the score difference ($S = R\text{-}Lo$); ni is the number of experts; Lo is the lowest rating number; c is the highest appraisal rate; R is the number given by experts [48]. Furthermore, in risk assessment, using the formula for Risk index [49]:

$$Risk\ index = F \times C \tag{2}$$

In this study, objective weighting is carried out using the Analytical Hierarchy Process (AHP) method. This method can help decision-making obtain the best alternative by displaying the order of ranking priorities [50]. In this study, the AHP method was used to select the highest risk on small multipurpose ports with the following stages:

(1) Calculation of Weighting Average:

$$G = \sqrt[n]{X1, X2, \ldots .Xn} \tag{3}$$

where, n is the number of respondents and Xn is the respondents' Answers.

(2) Calculate the average of the four entries ($\lambda\ max$):

$$\lambda\ max = \sum_{i=0}^{n} \frac{vector\ consistency}{n} \tag{4}$$

(3) Calculate index consistency (CI):

$$CI = \frac{\lambda max - n}{n-1} \tag{5}$$

(4) Calculating Consistency Ratio (CR):

$$CR = \frac{CI}{RI} \tag{6}$$

where, RI is Random Index (RI) table with n = 4, RI = 0.90, the value is acceptable, or the respondent is consistent if the CR is smaller than 10% [51].

The risk value weighting above for the human, environmental, infrastructure, and corporate components, then multiplying by the previous initial risk value, with the weighting value for that component [52, 53].

Furthermore, to determine whether the existing risk management options are the best with a cost-benefit analysis, it can be seen from the Cost of Averting Fatality (CAF) with Net of CAR (NCAF) and Gross of CAF (GCAF). This is based on the fact that the smaller the NCAF or GCAF value, the better the effectiveness of risk management to reduce the risk of unavoidable accidents [54]:

$$GCAF = \frac{\Delta\ C}{Risk\ Reduction} \tag{7}$$

$$NCAF = \frac{\Delta\ C - \Delta\ B}{Risk\ Reduction} \tag{8}$$

where, ΔC = Risk control costs; ΔB = economic benefits of implementing risk control; Risk Reduction is obtained by the magnitude of the Reduction of high-risk and very high conditions of ALARP (moderate risk).

Risk Assessment was identified by utilizing FTA Fault Tree Analysis (FTA) methods. System failures caused by various combinations of faults can be analyzed graphically with FTA. This technique helps describe and assess events within the system [55]. This Fault Tree Analysis method effectively finds the problem's core because it ensures that an unwanted event or loss caused does not originate at one point of failure. Fault Tree Analysis identifies the relationship between causal factors and is displayed as an error tree involving a simple logic gate [56].

The qualitative analysis combines the accident data results, observation time, and judgment experts. Data collection is carried out through direct observation at selected ports, Focus Group Discussion (FGD), and interviews in port and on board. There were 22 respondents, spread across various agencies and involved in safety-related activities at the port, i.e., The Harbourmaster, Port Authority Office (HMPA), Port of management (PM), Port Health Office (PHO), Port Area Police, and Labor Organization. Respondents from passengers and cargo ship's Captain, Chief Officer, Third Officer, and Quarter Master. Respondents were chosen to adjust to face-to-face restrictions due to health protocols due to the COVID-19 pandemic. The interview outcome will likely remain the same if more people are involved because of the same respondent agency or organization and the same port characteristics [57]. The same was in the study of the ship captain's perspective on ship safety due to port activities with 25 respondents. Therefore, the number of people interviewed did not significantly affect the study's results [58].

3. RESULT

3.1 Research site

Port of Biak is in Eastern Indonesia (Figure 4) and feeder port, with port authorities and harbormaster levels III. The one pier to serve passengers and goods (Table 1) is located in the city center, with free community access to the port area [59]. The function of the port as other multipurpose small ports, in addition, to ship berthing activities, and unloading of the ship is also used for non-port activities, such as sports, recreation, religion, and trade. The Indonesian port company (PT. Pelindo) carries out port operations, employing approximately 200-300 workers. Biak Papua Port was chosen because it will be developed into a logistics distribution center in West Papua.

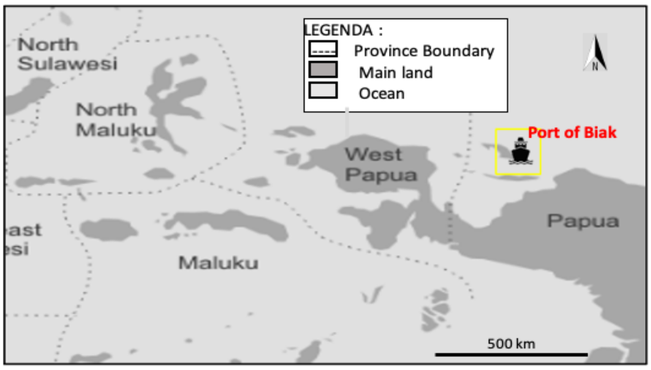

Figure 4. Location Port of Biak
(Coordinates: 1.1844° S, 136.0764° E)

Table 1. Data hydro oceanography and facilities Biak Papua Port

Hydro Oceanography	size
Shipping Lanes Length	3.7 mile
Shipping Lanes width	380 m
Minimum Depth	16 MLWS
Minimum Harbor Depth	12 MLWS
Wind Speed	11 Knot
Current Speed	1.7 Knot
Wave Height	1.5 Meter
Seawater Tidal (HWS)	10 MLWS
Facilities	
Wharf Area	3.542 m^2
Warehouse	3.800 m^2
Container Yard	6000 m^2
Pilot boat	1 Unit
Container Crane (CC)	2 Unit
Reach Stacker (RS)	4 Unit
Forklift 32 & 7 Ton	1 Unit
Head Tractor (HT)	4 Unit
Tronton 20 Feet	7 Unit
Clean Water	100 Tn/h.

Source: Generated by authors based on https://pelindo.co.id/operasional?regional=4#ports

3.2 Hazard identification

At this stage, the required data is accident data in the form of frequency criteria. However, there needs to be a solution to collecting data, namely the unavailability of accident data documented by related parties at the port. The results of the FGD show that this is due to the unavailability of the platform as a guiding tool for port operators and individuals dealing with safety issues to support the *FSA* risk assessment as recommended by the IMO. Therefore, activities to identify potential hazards that can cause accidents are carried out by judgment experts, and interviews at port locations and on board. From obtaining 32 items (Table 2), Validation with V Index Eigen, 27 items reliable.

3.3 Risk assessment

The consequences scale (Table 3), frequency scale (Table 4), and matrix risk assessment (Table 5) of the identified hazards adaptation to standard adjustments AS/NZS 4360-2004 [60, 61] with Descriptions:

1 - 5 : Very Low Risk
6 - 11 : Low Risk
12 – 15 : Medium Risk (Alarp)
15 – 19 : High Risk
20 – 25 : Very High Risk

The results of risk assessment on some potential hazards at each location in the port are in Table 6.

Then the next step, Through the Analytis Hierarchy Process (AHP) of Eqns. (3), (4), (5), and (6), is the weighting of component human, environment, infrastructure, and corporate, see Table 7.

Furthermore, the results of the risk assessment by adjusting the component weights in Table 7, and the ranking of the types of accident events are obtained in Table 8.

Table 2. The estimated Hazard Identification results of the validation with V index Eigen from Eq. (1)

Area	Hazard Type	V
Waters in front of the port	A Man falls from a ship into the sea	0,955
	A Man being Trap between a ship	0,455
	The Collision between ships	0,591
	The Collision between a ship with a wharf	0,818
	The Capsized Ship	0,364
	A ship aground	0,409
	Fire on Ship	0,818
	Spills of Hazardous Material from Ship	0,318
	Cargo Leakage	0,500
Wharf/ Terminal/ container yard	A Man falls into the sea	0,955
	Slip or Fall on the floor	0,818
	Fallen from a height	0,545
	Stumbles on his feet	0,500
	A Man gets hit by a vehicle	0,727
	A Man hit the hatch cover	None*
	A Man falling into the hatch	0,364
	Fallen containers had struck a Man.	None*
	A man trapped between containers	None*
	The Collisions between vehicles	0,636
	The vehicle falls into the sea	0,500
	A vehicle crashes into the facility	0,545
	Crane does not move	0,318
	Load from Container falls	0,636
	Reverse Truck Crane	None*
	Load Leakage	0,364
	Oil Spill	0,545
	Dangerous goods spills	None*
	A mooring line throw hit a man	0,818
	Man crushed by cargo	0,588
	Man falling from a height	0,471
	Fire Facilities	0,353
	Oil Spill	0,529

Notes: None* (Not related to the study area)

3.4 Fault tree analysis for risk assessment development

It can be seen that of the two types of events, one fire on the ship in Figure 5, four types of events have a direct impact on humans, namely: people are hit by the end of the mooring lines, people fall into the sea from the ship, people fall into the sea from the dock, and people are hit by vehicles, so these four types of events are simplified into human accidents in Figure 6. The results of the risk assessment after weighting with *fault trees* i.e.

Table 3. Consequences scale

Category (Scale)	Human	Infrastructure	Environment	Corporation
C1 (1) Insignificant	the wound is very small or scratched	the surface of peeled non-structural elements	meaningless damage	work activities take place as usual
C2 (2) Small	one minor injury needs local, first aid	small cracks of part structural and non-structural elements.	slight spills do not spread	work is interrupted, still can working.
C3 (3) Medium	multiple minor injuries or one significant injury, road treatment	large cracks in most structural and non-structural components and, if repaired, can still function properly	spill spreads in the port area	part of the work stops and can function again after the repair.
C4 (4) Large	severe injuries & hospitalization)	occurs in some structural and non-structural components, and if a repair does not work correctly, can collapse if the hazard repeats	pollution out of the port area that has the potential for environmental damage	the whole work stops, it can function again after the repair is made
C5 (5) Fatal, Disaster	permanent disability or death	collapse most structural and non-structural components of the building cannot be used)	large-scale oil spills which are very damaging to the environment)	the ship is completely damaged and cannot be reused.

Source: Generated by authors based on AS/NZS 4360:2004

Table 4. Frequency scale

Frequency (Scale)	Definitions
F1 (1) Rare	An event once in 10 years of operation or rarely occurs.
F2 (2) unlikely	An event occurs once in 5 years of operation. Sometimes occurs under certain conditions.
F3 (3) Moderate	An event occurs once a year. Occurs under certain conditions (can occur occasionally)
F4 (4) Likely	An event occurs once in 10 operations.
F5 (5) Almost certain	It always happens in every condition (every time). An event can happen at least once a week.

Source: Generated by authors based on AS/NZS 4360-2004

Table 5. Matrix risk assessment

Consequences	C5	15	19	23	24	25
	C4	8	14	18	21	22
	C3	5	11	13	17	20
	C2	3	7	10	12	16
	C1	1	2	4	6	9
Frequency		F1	F2	F3	F4	F5

Source: Generated by authors based on AS/NZS 4360-2004

Table 6. Initial risk assessment results from Eq. (2)

Variable	Average Frequency (F)	Average Consequences (C)	Risk Rating (F) * (C)
Fire on ship	4,89	4,15	Very High
A Man gets hit by a vehicle on the wharf	3,69	4,69	High
A man falls into the sea from the wharf	4,46	3,85	High
A man falling into the sea from the ship	4,31	4,00	High
A mooring line throw hit a man	4,15	3,85	High

Table 7. Impact component weighting value

Component	Weight
Human	0,5
Infrastructure	0,1
Environment	0,2
Corporate / Management	0,2

Table 8. Ranking results after weighting

Rank	Accident events	Estimated Consequences Most Likely to Occur				Estimated worst Consequences Most Likely to Occur				
		Human	environment	Infrastructure	Corporation	Human	environment	Infrastructure	Corporation	Result
1	Fire on Ship	5,9	1,8	1,2	3,2	10,8	2,0	1,4	3,4	29,7
2	A Man was hit by vehicles	7,4	1,8	0,9	1,8	9,3	1,2	0,6	2,4	25,4
3	A Man falling into the sea from the ship	7,4	1,8	0,9	1,8	9,3	1,2	0,6	1,2	24,2
4	A Man falls into the sea from the wharf	4,4	1,8	0,9	1,8	11,8	1,2	0,6	1,2	23,7
5	A mooring line throw hit a man	7,4	1,8	0,9	1,8	7,9	1,2	0,6	1,2	

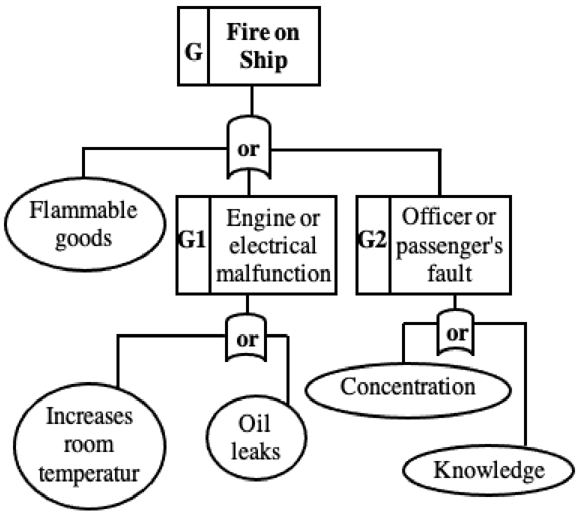

Figure 5. Fault tree analysis fire on a ship

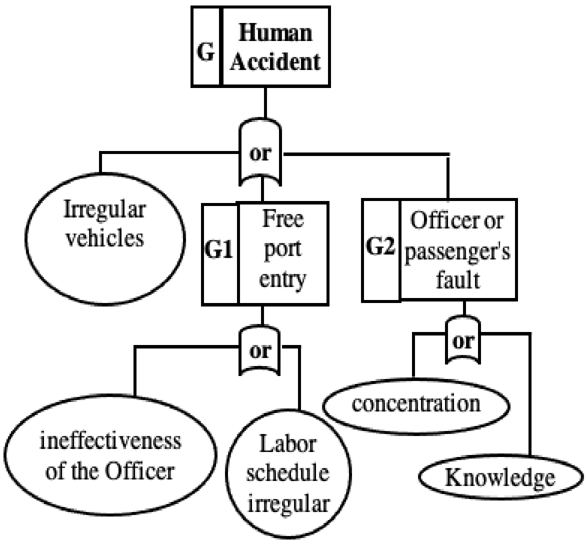

Figure 6. Fault tree analysis human accident

The cause of ship fires at the wharf can occur due to flammable cargo carried by ships, electrical disturbances, problems with auxiliary engines, wrong actions of crew members, rising temperatures in rooms adjacent to bunkers and overheated bulkheads, actions of passengers disposing of materials that cause fires and goods on ships carrying fuel such as cars or motorcycles.

The FTA found that the causes of human accidents at ports such as people being hit by vehicles were due to the irregularity of the vehicles entering the port, both private, public, and cargo vehicles. In addition, due to the mistakes of officers or passengers, there are no restrictions on people who are not related to the port and the unfavorable work schedule of workers causes the port to become congested, as a result, people can fall from the pier or ships and can be hit by tross ropes.

3.5 Risk Control Options (RCOs)

FTA analysis found the main problem is that accidents can occur, so efforts were made to carry out a systemized, adequate, and practical RCO see Table 9. Focusing on water areas and port docks, where there are one very risky and four high risks.

3.6 Alarp analysis in the cost-benefit calculation

Assuming the ship burned at the port is a pioneer ship with a capacity of 1200 GT cargo passenger type, this ship is widely used in eastern Indonesia 56 percent of the number of ships for the implementation of sea tolls, the price is around IDR. 54,000,000,000 [62]. There was one fatality at the port in a year. The average person who experiences an accident is 40 years old, and income and age data are based on BPS [63]. Compensation funds are based on the provisions of the 2020 employment BPJS [64]. Shiploads are daily necessities such as rice, estimated at 100 tons at a price of IDR.10,000/ kilogram. So the results of the analysis can be seen in Table 10. Furthermore, the price for the risk control plan in the Table 11. is set based on the unit price of goods and services in the regions.

The subsequent analysis is to determine the comparison of cost benefits between if done and if not mitigated / preemptive risks in Table 12. In this analysis, it is planned that the lifetime period is one year because based on the results of risk control, the average frequency of controlling accident events is one year.

Table 9. Identify actions RCO to control risk

RCO	Risk Control Options	Parties involved
RCO 1 & 2	Training and certification, and mandatory use of personal protective equipment.	- Master Harbour & Port Authority,
RCO 3, 4 & 5	Tighten restrictions on port entry, controls the number of labor, and improve periodic inspections	- Shipping Company, - Loading and Unloading Company
RCO 6, 7, 8 & 9	Maintenance of ship engines, preservation of vehicles, provisions for ladders moving from port ships and between ships, and installation of safety information	- Transportation Management Services
RCO 10	Optimizing the use of information technology to support port safety (Inaportnet)	

Table 10. Estimated cost fire ship and fatality at port

Casualties	Total cost
Total cost due to fire 1 ship	IDR 55.100.000.000
Total loss of death per person/year	IDR 1.102.000.000
Total Losses of ships burned with death tolls	IDR 56.202.000.000

Table 11. Risk mitigation financing plan

Countermeasures	Total Cost
Training and Certification	IDR 137.871.000
Procurement of personal protective equipment and work protective equipment	IDR 111.552.000
Tighten entry restrictions, control labor schedules, and periodic inspections	IDR 71.300.000
Installation of safety information and arrangements for ladders between ships	IDR 20.167.000
Vehicle maintenance/year	IDR 74.220.000
Ship engine maintenance/year	IDR 2.124.000.000
Optimizing the use of information technology to support port safety, for example, Inaportnet (IT)	IDR 37.450.000

Table 12. Estimated costs - benefits of mitigating risk

Cost Component	Ship on Fire (SF)	Human Accidents (HA)
Losses from accidents (a)	IDR 56.202.000.000	IDR 1.102.000.000
Ship revenue (b)	IDR 1.197.000.000	-
Port operating revenue (c)		IDR 64.382.298.230
Training and certification financing (d)	IDR 71.200.000	IDR 137.871.000
Personal protective equipment Financing (e)	IDR 43.560.000	IDR 111.552.000
Financing Tightens Access Restrictions, Labor Schedule controls, and periodic inspections (f)	-	IDR 71.300.000
Installation of Safety information (g)	-	IDR 20.167.000
Ship engine maintenance (h)	IDR 2.124.000.000	-
Vehicle maintenance (i)	-	IDR 74.220.000
Optimizing the use of information technology to support port safety (j)	IDR 22.067.000	IDR 393.950.000
Advantages of mitigation are carried out (k**SF**)=(a)+(b) or (k**HA**)= (a)+(c)	IDR 57.399.000.000	IDR 65.484.298.230
The advantages of mitigation are not carried out (l**SF**) = (b) or (l**HA**)=(c)	IDR 1.197.000.000	IDR 64.382.298.230
△B = (a)	IDR 56.202.000.000	IDR 1.102.000.000
Financing if mitigation is carried out (m**SF**)=(d)+(e)+(h)+(j) or (i**HA**)=(d)+(e)+(f)+(g)+(i)+(j)	IDR 2.260.827.000	IDR 809.060.000
Financing if mitigation is NOT carried out (n**SF**)=(a)+(h) or (n**HA**)=(a)	IDR 58.326.000.000	IDR 1.102.000.000
△C	IDR -56.065.173.000	IDR-292.940.000

Notes ΔB = Total Economic Benefits of Risk Management
ΔC = total risk reduction costs

3.7 Recommendations for decision making

Following the research objectives related to the Safety assessment model, FSA, and ALARP, this model determines how much risk reduction will decrease due to the impact of various alternatives to controlling the risk of accidents at multipurpose ports [65]. ALARP is obtained from the risk matrix to reduce the risk from very high to medium risk. So that the recommendations for the benefits of risk control will be more extraordinary because these activities are carried out jointly between the government, port operators, port business entities, and ship owner companies.

In a fire ship accident at the port, if mitigation and preventive activities are carried out, there are many benefits obtained by ship owners. In this case, the government or shipping companies make a profit of IDR 57,399,000,000 compared if they do not carry out risk mitigation which only gets a smaller profit of IDR 1,197,000,000. In addition, if they carry out activities to overcome the risk of additional financing issued, it is smaller, namely IDR 2,260,827,000, compared to if they do not overcome the risk, it can cost IDR 56,202,000,000 is estimated. Furthermore, for human accidents in ports, for PT. Pelindo, if risk mitigation is carried out, benefits in the form of profits are obtained of IDR 68,790,298,230, with additional costs incurred of IDR 809,060,000. Furthermore, do not carry out risk mitigation. The benefits are in the form of smaller profits of IDR 64,382,298,230 with costs of IDR 4,408,000,000.

Based on the results above, the recommendations are given i.e.

(1) The Government needs to increase joint training by involving firefighters, port operators, port business entities, ship captains, ship crews, port health services, port police, and workers in safety-related activities and awarding and improving organizational policies on recruitment, selection, training, education, and appearance levels, as well as competency assessment. Development of appropriate training for regional, language, and cultural safety conditions.

(2) For ports in the Eastern region, the issue of indigenous workers vs. migrants and the desire for independence is often the main reason for the difficulty of implementing policies related to port safety. Therefore there is always a need for cooperation from all parties, especially involving local communities through religious and customary institutions, to get the best solution. Improving the quality of human resources in the local community through educational training and socialization on the importance of safety must always be sought so that the community slowly understands and understands port safety. It needs to be socialized that access restrictions are preventive and responsive efforts related to safety to avoid danger to ships, crew, passengers, officers, and communities around the port.

(3) Installation and maintenance of signs and safety information need to be improved. The company or relevant agency is obliged to sign a safety consensus. In addition, the mandatory use of Personal Protective Equipment (PPE) is ported with strict supervision and, if necessary, sanctions for violations of its use.

(4) Optimize the use of Information Technology (IT) to support port security. The use of various Android applications

in controlling fires. The Android-based Raspberry Pi' provides preliminary information about fires, such as detecting fires, fire smoke, and room temperatures that are high enough, can directly cut off electricity and spray water on fire sources to prevent early fires. In addition to accident documentation, it is necessary to develop an Inaportnet that can be used to document accidents in detail because it has a section for reporting when there is a delay in the service of ship arrival or ship departure due to an accident. This data from Inaportnet can be used to assess, reduce, or control risks.

4. DISCUSSIONS

In small multipurpose port, Human Resources (HR) related to safety experts are still lacking. Many small ports cannot be monitored, many accidents are not reported or recorded, Incompleteness of equipment such as safety signs on ships and in ports, so there are often problems in the service of passengers and goods simultaneously (potential hazards). Public access cannot be restricted to the port area, Handling accidents at the port are more often handled directly by the police, not the port operator. The results of these various problem, generally provide a common understanding of the need to make policies related to safety assessments that will use for risk assessment. The above problems are almost the same as those experienced in some countries in Europe and Asia. Economic and cultural considerations in an area must be considered in formulating safety policies at the port.

Figure 7. Examples of risk events in small multipurpose ports in Indonesia (a). Attractions from the ship [66]; (b). irregular vehicles in the port (observation, 2021); (c). fire on a ship in port [67]; (d). Labor scrambled to board the ship (Observation,2021); (e). rare items (observation, 2022); (f). The density of the environment in the port area [68]

The results of Hazard Identification on small multipurpose found some potential that we had not found in previous studies, namely people falling into the sea either intentionally or accidentally, people falling from docks, and people being hit by the end of the mooring line. Some types of accidents generally occur in ports i.e. falling from a ship into the sea, Collision, Capsized Ship, Grounding, Fire in the ship, Ships sinking, and Cargo Leake. Subsequently, in the wharf area, people slip or fall on the floor, fall from a height, is hit by a vehicle, is struck by fallen containers, and stumble on their feet. Load from Container falls, Load from Container falls, and Load Leakage. There is a potential danger that does not relate to the study area, ships sinking, People hitting the hatch lid, being hit by fallen containers, being trapped between containers, and dangerous goods (hazardous and toxic substances). So, the potential danger is eliminated. People being hit by hatch lids never happens because freighters that carry out hatch opening activities doing automatically, or the storage of hatch covers are placed in a particular place separate from the ship's hatch, while people are trapped between containers and exposed to containers that fall is rare because there are still a small number of containers and easy to place in this port area. Truck cranes have yet to be used in small multipurpose ports. There is an assessment related to the four activities above because it is the experience of respondents who have previously worked at larger ports in small multipurpose port areas, activities related to B3 management do not exist. Figure 7 has some examples of risk activities in small multipurpose ports.

In addition, several potentials were found that were not found in previous studies: people falling into the sea intentionally or accidentally from ships, falling from docks, and being exposed to mooring line discharges.

The results of the Fault Tree Analysis for the Human Accident Risk Assessment found that many People coming into the port area, although not all of them are interested in the port, can cause a man to be hit, fall into the sea from the dock or ship, and be hit by the end of the troop mooring lines. People go up and down ships, laborers, sellers, and public and private vehicles are free to enter, which ultimately interferes with loading and unloading activities, which indeed do not have separate vehicle lanes from pedestrians. When the ship enters the port, the Officer on the ship can fall when preparing the ship's ladder on one side of the ship because it is done manually. Passengers can fall due to gathering and crowding on the ship or standing outside the guardrail when transferring people between ships. There is no facility for passengers to move between ships when the ship does not dock directly at the port but berths on other ships. When the ship leaves the port, many are forced or deliberately jump off the ship because many are not passengers as laborers, children, merchants, and delivery people on the ship. Laborers because they are waiting for wages that passengers have not paid, sellers because they do not hear information about the ship's departure, and children. After all, they deliberately want to jump off the ship as entertainment because they get paid by passengers. Falling from the dock can also occur when going up and down the ship due to shifting stairs, not using a good ladder, or deliberately jumping off the pier as an entertainment/attraction. The worst consequences can occur if people fall on their belonging, the side of the dock, or parts of the ship. It can cause death, and such events can occur once a year, so it is a high risk.

Furthermore, the potential for danger with high risk is most abundant in the wharf area. Results observations in the field, other than many parties involved in this area, their use equipment. In this area, there are many activities from the ship's stage entering the port area, carrying out movement, throwing mooring lines, berthing at the port, passengers disembarking, laborers, and ports boarding ships. Unloading activities from the ship and in the next stage, passengers boarding the ship, cargo is raised to the ship until the ship leaves the dock, there is still a potential danger.

5. CONCLUSIONS

It is improving safety at small multipurpose ports is very important in archipelago regions. This port connects the farthest areas with the center of Government and distributes goods to and from the region. IMO and the Government have issued various policies to improve the security of this port, especially regarding safety assessments. Implementing these various policies has encountered obstacles, especially when dealing with local conditions.

Safety assessment model with FSA application on small multipurpose ports using expert opinion with Aiken validation index, Hazard identification found 27 types of accidents. Primarily due to the result of free access for people to enter.

The use of ALARP begins with a Risk Assessment which finds ship fires are the highest risk events at the port, followed by a Cost-benefit Assessment using adjustments to central and regional financing policies. Furthermore, the Risk Control Assessment is carried out by emphasizing system cooperation between various parties, no longer alone, prioritizing improving human resources, especially for communities around the port through training, education, and socialization. Ultimately, it is easy to budget with a risk control financing plan that can be accounted for and implemented with the cost benefits obtained and used as recommendations for policymakers.

The main obstacle to the use of FSA is related to inadequate data documentation. In the future, policymakers must perform obligations, especially those required to collect data properly. For island nations, Risk Assessments for safety improvements at small multipurpose small ports should always be conducted periodically to avoid and prevent more significant losses.

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