Passenger Ship Evacuation Analysis with Fire Risk Assessment Approach Using NFPA 551

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Abstract. Based on ship accident data by Indonesian National Transportation Safety Committee (NTSC) from 2018 to 2019, there was 773 ship accidents and 21 of those accidents caused by fire ,evacuation process when accident occurred is very important. When it is not working, the number of fatalities will be high. The more number of passengers, the more number fatalities if the evacuation process is not good. Evacuation failure are generally caused by trapped passengers in rooms aboard. Therefore an analysis of passenger evacuation is carried out to determine the risk level of the evacuation route has been created by the designer. The method used in this study uses a model analysis Fire Risk Assessment based on NFPA 551 with a qualitative checklist method. The analysis shows the evacuation route for this research object has not met the passenger safety criteria (SOLAS) related to the number of escape routes both primary and secondary which is lacking and inappropriate and subsequently for evacuation routes passengers pass through areas with a high level of fire risk ranking is 5, therefore re-arrangement of evacuation routes is needed to avoid areas of high fire risk or by re-arrangement of the galley location, especially on the 3rd deck.

1. Introduction

Some accident on passenger ships are currently taking a lot of attention because of the many events. Ships are subject to accidents which may culminate due to several causes; majorly due to capsizing/ foundering, stranding, collision, fire/explosion, structural failure etc. Such accidents can typically lead to total loss or serious damage to the ship as well as injuries/fatalities of the crew and passengers [1]. Based on ship accident data by the NTSC from 2018 to 2019, there was 773 ship accidents and 27 % of those accidents caused by fire on passenger ships resulting in casualties of 62 person [2]. Important things are needed to make safety measures on board in terms of design and operation to prevent injury/ fatality on-board consequent to the accidents, such as conducting a safety plan arrangement on the passenger rescue evacuation route, because if wrong in determining the evacuation route on the ship it will be fatal. Evacuation routes are to be designed accordance with IMO regulation and other international regulations such as SOLAS for Hazard Identification of critical locations on-board [3] and evaluating the appropriateness and execution of a fire risk assessment by Guide for the Evaluation of Fire Risk Assessments (NFPA 551) [4]. IMO has recognized the importance of evacuation and mandatory evacuation analysis for all Passengers and Ro-Pax vessels on 1 January 2020 [5]. Therefore to avoid many fatality numbers, an analysis of the evacuation routes with fire risk assessment approach is needed. In this research, the object of research is passenger ship with the type of pioneer ship (perintis) 2000 GT, Length of ship is 68.5 m and Breadth is 14 m, consist of 5 (five) deck and with a capacity is 514 passengers and 36 crew members.

2. Research methodology

The methodology used in this study is all steps of the activities carried out to resolve the problem and ultimately produce a conclusion. The first stage is the collection of safety plan data arrangements for passenger ships that are the object of research with parameters is deck number, on-board space, number of passengers, escape route and source of fire space, the second step is conducting a literature study of previous studies and regulations related to maritime safety, the third step is conducting a review of safety plan arrangements to determine the condition of safety planning on the ship regarding evacuation routes, type and location of fire extinguishing system and the fourth step is to identify hazards based on 14 types of spaces as critical locations (fire hazard locations) on the ship according to SOLAS (3) Ch. II-2, Regulation 9, and finally the evaluation of conditions in the third and fourth step with NFPA 551.

3. Ship safety plan reviewing

3.1. Evacuation Route Plan

The evacuation route for passengers is very important when designing a ship, therefore it is necessary to evaluate the evacuation routes on the ship. The review of the evacuation route is based on the safety plan (Figure 1.) by identifying the evacuation routes for each deck to the assembly point.

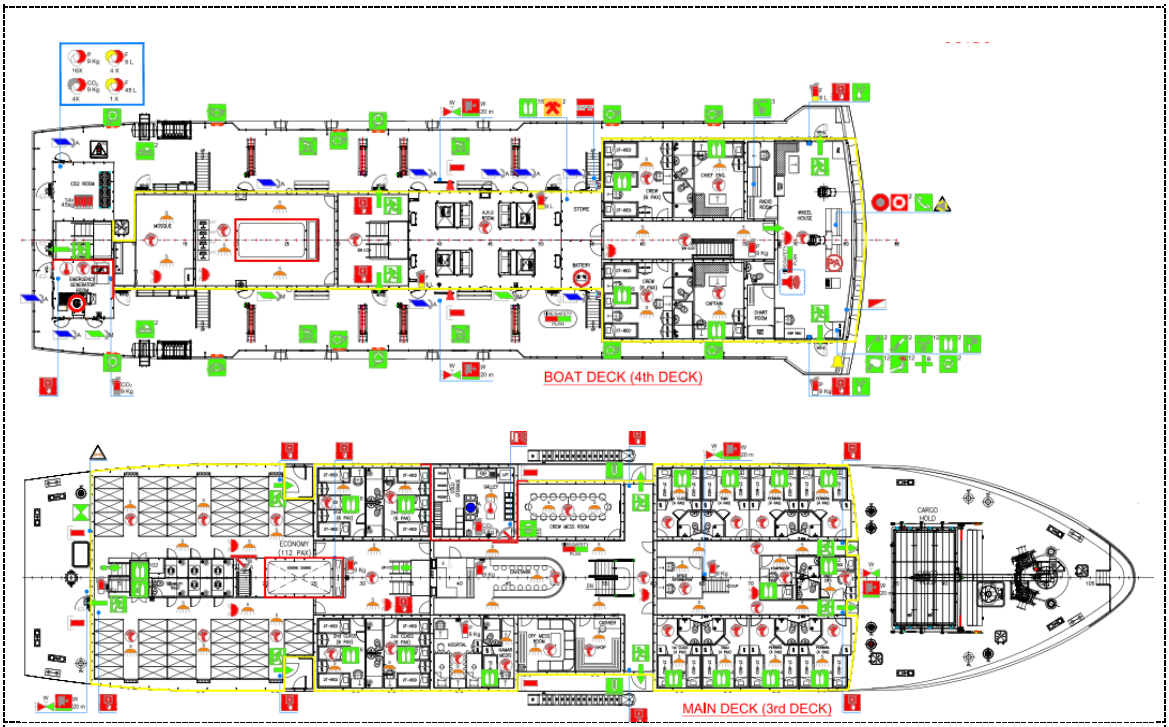

Figure 1. Fire Safety Plan on Main Deck and Boat Deck

The identification evacuation routes of passengers on board based on:

- the kind of the onboard space (based on the function of space),
- the number of passengers on each deck and each room (based on general arrangement),
- number of escape route consist of primary escape route is the quickest and easiest way to the assembly/ muster station or survival craft and Secondary Evacuation Route is a specially designated exit route for use when the Primary route is unusable.
- fire source space is a room on a ship that has a source of fire

The data is shown in table 1 below

Table 1. Evacuation route identification each deck

No	Deck Number	On-board Space	Number of Passenger	Number of Escape route		Fire source space	Remark
				Primary	Secondary		
1	1st deck (tank top)	Accommodation space (pax)	192	2	N/A	Machinery space	Engine room bulkhead
2	2nd deck (tween deck)	Accommodation space (pax)	168	1	N/A	Pantry, restaurant, Machinery space	-
3	3rd deck (main deck)	Accommodation space (pax+crew)	172	N/A	2	Machinery space, galley	Engine casing
4	4th deck (boat deck)	Accommodation space (pax+crew)	14	5	N/A	Emergency generator, Machinery space	Engine casing
5	Top deck	Open deck space	-	-	-	-	-

3.2. Type and Location of Fire Extinguisher

The evacuation route for passengers is very important when designing a ship, therefore it is necessary to evaluate the evacuation routes on the ship. The review of the evacuation route is based on the safety plan (Figure 1.) by identifying the evacuation routes for each deck to the assembly point.

Table 2. Type and Location of Fire Extinguisher on Evacuation route

No	Deck Number	On-board Space		Fire Extinguisher (FE)	
				Type	Number
1	1st deck (tank top)	Accommodation space (pax)	Economy I	Portable FE Sprinkler	1 (powder type) 9 point
			Economy II	Portable FE Sprinkler	1 (powder type) 9 point
			Economy III	Portable FE Sprinkler	1 (powder type) 9 point
2	2nd deck (tween deck)	Accommodation space (pax)	Economy VI	Portable FE Sprinkler	2 (powder type) 22 point
3	3rd deck (main deck)	Accommodation space (pax+crew)	Economy V	Portable FE Sprinkler	2 (powder type) 16 point
			Crew I	Portable FE Sprinkler	1 (powder type) 14 point
4	4th deck (boat deck)	Accommodation space (pax+crew)	Crew II	Portable FE Sprinkler	1 (powder type) 6 point
5	Top deck	Open deck space	-	Portable FE Sprinkler	-

4. Fire risk identification and ranking

In determining the ship evacuation route of passengers should be consider to critical locations based on SOLAS regulations (3) Chapter II-2, Regulation 9 is 14 locations of critical location and risk ranking based the frequency of ignition as follows in Table 3.

Table 3. Occurrence of fire frequency and risk ranking for ship spaces based on fire accident data

No.	SOLAS Space Category	Number of Occurrence	Frequency of Ignition/ s-y	Risk Ranking
1	Control station	0	0	1
2	Stairways	23	0.5	3
3	Corridors	52	0.112	2
4	Evacuation stations and external escape route	11	0.024	1
5	Open deck spaces	72	0.155	2
6	Accommodation spaces for minor fire risk	315	0.68	4
7	Accommodation spaces for moderate fire risk	19	0.041	2
8	Accommodation spaces for greater fire risk	192	0.415	3
9	Sanitary and similar spaces	55	0.119	2
10	Tanks, voids and auxiliary machinery spaces	10	0.022	1
11	Auxiliary machinery spaces, cargo spaces, cargo and other oil tanks	0	0	1
12	Machinery spaces and main galleys	642	1.386	5
13	Store rooms, workshops, pantries	126	0.272	2
14	Other spaces in which flammable liquids are stowed	4	0.009	1

Note:
1 = Negligible, 2 = Marginal, 3 = Critical, 4 = Serious, 5 = Catastrophic

5. Risk evaluation with NFPA 551 (checklist method)

After identifying the evacuation route based on the risk ranking for each accident on the ship, the risk evaluated according to NFPA 551 using the qualitative checklist method in Table 4.

Table 4. Risk Evaluation with NFPA 551 - Qualitative Method checklist

No	Deck Number	On-board Space		Fire source address	Dangerous possibility	Risk ranking	Current safeguard	Recommendation
1	1st deck (tank top)	Accommodation space (pax)	Economy I Economy II Economy III	Machinery space	Heat radiation if any ignition	3	Engine room bulkhead A-60, 3 FE (Powder type) and 27 sprinkler, and 2 primary escape route	To add secondary escape route
2	2nd deck (tween deck)	Accommodation space (pax)	Economy IV	Pantry, Machinery space	Heat radiation and explosion if any ignition	2	Engine room bulkhead A-60, 2 FE (Powder type) and 22 sprinkler, and 1 primary escape route	To add more primary & secondary escape route
3	3rd deck (main deck)	Accommodation space (pax+crew)	Economy V & Crew Room I	Galleys, engine room tunnel	Heat radiation and explosion if any ignition	5	3 FE (Powder type) and 30 sprinkler, and 1 primary escape route	To add primary escape route, re-arrange galley position

Table 4. Risk Evaluation with NFPA 551 - Qualitative Method checklist *(continued)*

No	Deck Number	On-board Space	Fire source address	Dangerous possibility	Risk ranking	Current safeguard	Recommendation
4	4th deck (boat deck)	Accommodation space (pax+crew)	Crew Room II	Engine room tunnel	Heat radiation and explosion if any ignition	1	1 FE (Powder type) and 6 sprinkler , and 5 primary escape route	-

6. Discussion

Based on the analysis in Sections 3, 4, and 5, the evacuation route is not optimal refers to the global risk condition of evacuation route on all decks in ship. In this ship, there are 4 evacuation routes that are designed in all decks. When there is one evacuation route that is not smoothly done, it will affect to the whole evacuation process and will have an effect on evacuation time becomes longer. Passengers coming from the 1st deck to get to the assembly point only go through tween decks, therefore to takes more than 1 primary escape route direct to the assembly point. And then on the main deck (third deck) which is a deck with a high risk level with risk ranking 5, the high risk level caused by the evacuation route area of the main deck there is a galley which is a source of fire and is a critical location based on SOLAS regulations (3) Chapter II-2, Regulation 9. And the primary escape route for passengers on the main deck not directed towards the assembly point and it is not in accordance with the SOLAS provisions that the escape route shall be arranged so as to provide the most direct route possible to the assembly point [6]. Eventhough in the table 4 the number of risk level in 4th deck (where the assembly point is placed) is 1 (small), the high risk level of 3rd deck makes a possibility become an obstacle of the evacuation process.

7. Conclusions

Fire Risk Assessment based on NFPA 551 with a qualitative checklist method shows the evacuation route for this research object has not met the passenger safety criteria in accordance with the above discussion related to the number of escape routes both primary and secondary which is lacking and inappropriate and subsequently for evacuation routes passengers pass through areas with a high level of fire risk ranking is 5, therefore re-arrangement of evacuation routes is needed to avoid areas of high fire risk or by re-arrangement of the galley location, especially on the 3rd deck.

Acknowledgment

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