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Risk Analysis on Ship Wreck and Container Cargo to Ship Navigation

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ABSTRACT: Wreck of a ship is an incident that must be avoided. Ship accidents are generally caused by a several cases, such as human error, natural disaster, technical errors, missed communication, poor condition of the ship, and many more. Ship wreckage have huge impact for ship navigation, environment, economics, and others. Those impact have many disadvantages for the shipowners, and also for environment. For examples the fuel spills that pollute the environment, make disturbance to sailing ship because the track for those navigation is blocked by the ship wreck and their cargo especially on shallow location (<50 m). These research will discuss the effect the container when it is floats on the sea and its interference other ships. The main objective of this study is to present a risk assessment on the environmental impact of the wreck and container cargo. Wrecks on the seabed is likely to pose a risk to passing ships. container and its contents as well as the possibility of refloat, and also their environmental risks emanating from the wreck and container cargo, such as fuels, lubricants, and chemical cargo. Variations scenario is a collision between ships that pass by floating containers. The frequency of refloating container, and the consequences of the passing ship depends on several factors, which will be the subject of research. However, because of the frequency of refloating containers is unlikely, then the risk is low and does not pose a danger to navigation. These risk assessment using risk matrix 5x5 which is the combined value of the frequency and consequences of the incident. The results of this study indicate the level of risk, whether the risk is accepted, not accepted or received by considering the costs and benefits (ALARP). To consequence, there are two parameters which energy is absorbed and the penetration occurs. The absorbed energy is divided into two, namely the energy absorbed by ship and the energy absorbed by containers. In this study were taken 5 groups based on the size of the vessel. In this cases any 5 size group of vessels is based on the size of the ships that pass in the shipping lanes at the site of the sinking. Assumed these vessels have speed 10 knots at the location. As well as speed drifting containers having 0 to 3 knots.

1 INTRODUCTION

Security and Maritime Safety is a very important factor to support marine transportion and prevent accidents where the establishment of shipping lanes are intended to ensure the security and safety of navigation by providing a route for ships sailing through the waters, followed by tagging for navigational hazards. Implementation shipping routes which includes the program, structuring, development, operation and maintenance is intended to be able to provide services and guidance to the parties in the marine transportation services to attention to the capacity and capability groove associated with the weight of the ship going through that route in order to sail safely, smooth and comfortable.

According to H. Landquist research in 2013, shipwrecks deteriorate and the probability of a release of oil increases with time on the sea floor. The potential leakage is a risk to the marine environment and may also have social and economic consequences. The purpose of this study was to evaluate existing methods for risk assessment of shipwrecks and suggest a generic risk assessment framework. A risk assessment is necessary for providing decision support on remediation actions and thus enabling an efficient use of available resources. Existing risk assessment methods aimed for assessing shipwrecks were evaluated by comparison to relevant parts of an international standard on risk management. The comparison showed that existing methods lack several key components of risk assessment procedures. None of the evaluated methods provide a comprehensive risk assessment for potentially polluting shipwrecks and few take into account uncertainty and sensitivity. Furthermore, there is a need to develop risk assessment methods considering long-term effects of continuous release of oil into the marine environment. Finally, a generic comprehensive framework for risk assessment of shipwrecks is suggested.(11)

Potentially polluting shipwrecks containing oil or other hazardous substances may pose a threat to the marine environment. This is a global problem and many shipwrecks stem from the Second World War and have been deteriorating on the sea floor since then. Only in Swedish waters there are more than 2,700 wrecks that warrant further investigation and 31 of these are given a very high priority due to the environmental threat they pose. These wrecks are together estimated to contain between 1,000 and 15,000 tonnes of bunker oil. Every shipwreck poses a unique threat depending on, for example, the type of vessel, cause of sinking and environmental preconditions. Currently, there is no comprehensive method for assessing the environmental risk posed by shipwrecks and providing necessary support to decision-makers. The generic framework for risk management of shipwrecks clearly shows the important steps that need to be performed and how they are linked. It also emphasizes the need of proper assessments to facilitate an efficient resource allocation for these types of environmental threats. The tool for probabilistic risk assessment of shipwrecks enables uncertainty analysis and is a first step towards a holistic risk assessment method for shipwrecks. (12)

Wreck of a ship is an incident that must be avoided. Ship accidents are generally caused by a several cases, such as human error, natural disaster, technical errors, missed communication, poor condition of the ship, and many more. Ship wreckage have huge impact for ship navigation, environment, economics, and others. Those impact have many disadvantages for the shipowners, and also for environment. For examples the fuel spills that pollute the environment, make disturbance to sailing ship because the track for those navigation is blocked by the ship wreck and their cargo especially on shallow location (<50 m). (7)

2 ANALYSIS OF SHIP WRECK

2.1 *Risk Acceptance Criteria*

Risk acceptance criteria in the study are using Semi Quantitative Analysis with Risk Acceptance Criteria. This study combines the probability and consequences of an event based on the Risk Acceptance Criteria. This protocol uses the Risk Matrix 5 x 5 to determine the level of risk as shown in Figure 1Figure. Risk categories occurred are shown in Table 1. The criteria probability of occurrence and the consequences on the ship are shown in Table 2 and Table 3, respectively. (9)

PROBABILITY						
	LEVEL 1	1	2	3	4	5
	LEVEL 2	2	4	6	8	10
	LEVEL 3	3	6	9	12	15
	LEVEL 4	4	8	12	16	20
	LEVEL 5	5	10	15	20	25
		LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
		CONSEQUENCY				

Figure 1. Risk Matrix

The risk value of 1-4 can be considered low and acceptable, without further control measures or actions. Risk value of 5-9 can be considered ALARP (as low as reasonably possible) if appropriate control measures or mitigation is implemented.

Table 1. Description of the Risk Matrix

Value	Classification	Description
1-2	*Slight*	No action required
3-4	*Minor*	No additional control measures are required. Monitoring for changes
5-9	*Moderate*	Actions can be performed under the supervision of a responsible person. Mitigation is required in order to qualify as ALARP
10-14	*High*	Actions can be performed after the risk assessment. Mitigation is required in order to qualify as ALARP
15-25	*Intolerable*	Further mitigation and risk assessment are required

Table 2. The criteria probability of occurrence

Level	Description
1	*Unlikely*
2	*Rare*
3	*Moderate*
4	*Likely*
5	*Most likely*

Table 3. The consequences on the ship

Level	Description
1	No damage to the ship and structures
2	Minor damage to the ship and structures
3	Damage on the ship and structures, ship repair required
4	Mayor damage on the ship and structures, ship repair required
5	The damage is very serious, the ship mostly damaged

2.2 *Frequency Analysis*

2.2.1 *Frequency Analysis of Passing Ship Colliding with the Wreck*

The vessel was sunk on the sea bed in approximately 70-80 metres depth of water (sea in Indonesia) while ships passing to the area approximately having draught 6.4 metres (biggest ship passing the location). The possibility of passing ships colliding with the wreck is impossible. Therefore, it is not necessary to conduct a risk analysis.

2.2.2 *Frequency Analysis of Collision between Ship with Container*

A passing ship will only collide with a container from the ship only if the container refloats from its location on the seabed, or on the wreck. The collisions ilustration is shown in Figure 2.

The likelihood that a container would float free and up from the wreck of the sunken vessel, is unlikely (Level 1).

All containers within the wreck and within the location of the wreck site would now be fully waterlogged (ie filled with water), in the process of sinking within the seafloor and possibly in the process of breaking up in the process. Therefore we can firmly state, that the sunken containers from the ship, would not float free and thus would not become a hazard for shipping, therefore the frequency analysis of a collision between ship and container below, is generally only for information and guidance on consequence should a collision had happened at the time of sinking of the ship with the floating containers and a passing ship.

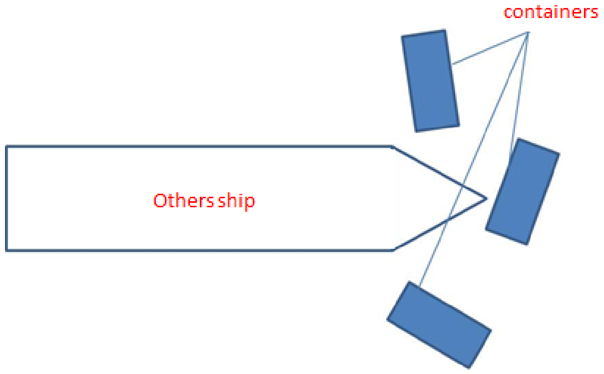

Figure 2. Assumption of a collision between ships with containers

Based on the observations and some ship accident, there are some parts of the ship containing trapped air (bubbles). The only likely way air can now be trapped in a container is if there is perishable cargo within the container that decomposes, causing carbon dioxide and other gases to accumulate within the container. The accumulation of these gases, which are less dense than seawater, may cause buoyancy if the air is trapped within the container. It is very unlikely that there is any perishable cargo remaining within the containers to be further decomposed.

Although unlikely, even if air did get released into a container, it will be released through air vents; it will not be trapped to the extent that it causes a container to refloat. Containers are weathertight, not watertight, and therefore seawater has already entered the containers and flooded them and it is very unlikely that sufficient air can get trapped within a container to cause it to float.

Furthermore, given that the container bindings are nickel plated and much stronger than the containers themselves, it is highly unlikely that corrosion of the bindings will be an issue before the containers themselves corrode. Therefore there is very little chance of the container itself corroding and breaking free of its binders and re-floating. In any event, the weight of the water above the container makes it very unlikely for it float even if it corroded away from its bindings. As the container corrodes, the walls and sides would collapse before the container bindings would effectively corrode. As it collapses, there is no way it would float to the surface, as the container would just break apart and sink into the sea floor, if it had not already done so.

The negligible risk is demonstrated by the fact that except for containers that remained afloat immediately after sinking (and have now been recovered), there has been no container that has re-floated since sinking more than 10 months ago.

Based on the regulation of ABS (American Bureau of Shipping) and GL (Germanischer Lloyd), a container must be certified before used to meet the safety standards. Therefore, to obtain the certificate, containers should perform a series of tests in order to match with the classification standard. There are many tests, but there are no watertight test. However, there is a weathertight test. Therefore, there are no watertight containers so that when the container is submerged in the water, the water will get into the container. Therefore the container can not float due to be filled with sea water.[1][4]

In containers the corner post and locking bar, which are of stronger material than the container walls and sides and thus would take a much longer time to corrode. Aluminum corrosion rate is 0.034 mm/year and steel corrosion rate is 0.1 ~ 0.17 mm/year.

So, the frequency of container floats is unlikely (Level 1) and almost certainly the case in this incident. Therefore, based on the acceptance criteria of the frequency of container float is currently on Level 1 which is Unlikely.

2.3 *Consequency Analysis*

2.3.1 *Consequency Analysis of Collision*

The categories of accident i.e. a collision between a passing ship with the wrecks or cargo containers. This could cause a passing ship be damaged or leakage of the hull.

2.3.2 *Impact Energy*

Impact energy that occurs when the collision between ships that pass with containers are as follows. The collision marked by several parameters. The following are the main parameters that influence the level of damage.[5]

- Structural characteristics of ship that bumped.
- Structural characteristics of container.
- Mass of ship that bumped.
- Mass of container that was hit.
- The speed of the ship that bumped.
- Speed of containers that was hit.
- The distance between the wreck and the container.
- Location of collision on the ship.

The illustration when the collision occur as shown in Figure 3.

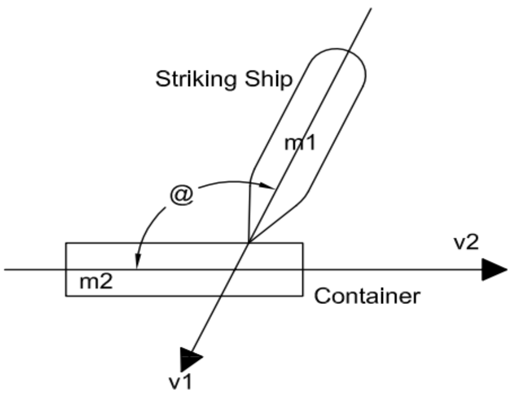

Figure 3. The illustration when the collision occur

From the collision scenario above then we obtained an equation as followst:

$$\Delta Ek = \frac{M1(M2+\Delta M)}{2M2+M1+\Delta M}\left(V1\sin\alpha^2\right) \quad (1)$$

where:

ΔEk = absorb energy

M1 = mass of ship that bumped.

M2 = mass of container or wrecks that was hit.

V1 = The speed of the ship that bumped.

ΔM = additional mass coefficient of container or wrecks that was hit.

Based on equation (1), the absorbed energy by ship and the absorbed energy by container are given in Table 6 up to Table 9.

Table 6. The absorbed energy by ship (container speed is 0.5 knots)

Container	Absorbed Energy (ton.knot²)			
	Ship A	Ship B	Ship C	Ship D
C20	4.992	4.827	4.985	4.994
C40	3.496	3.415	3.493	3.497
CR20	2.248	2.215	2.247	2.249
CR40	3.122	3.057	3.119	3.123

Table 7. The absorbed energy by ship (container speed is 1 knot)

Container	Absorbed Energy (ton.knot²)			
	Ship A	Ship B	Ship C	Ship D
C20	19.968	19.308	19.942	19.976
C40	13.984	13.660	13.971	13.988
CR20	8.994	8.861	8.989	8.995
CR40	12.488	12.230	12.478	12.491

Table 8. The absorbed energy by ship (container speed is 1.5 knots)

Container	Absorbed Energy (ton.knot²)			
	Ship A	Ship B	Ship C	Ship D
C20	44.928	43.442	44.869	44.946
C40	31.464	30.735	31.436	31.473
CR20	20.236	19.937	20.224	20.239
CR40	28.097	27.516	28.075	28.104

Table 9. The absorbed energy by container (ship speed 10 knots)

Container	Absorbed Energy (ton.knot²)			
	Ship A	Ship B	Ship C	Ship D
Ship A	4058.353	2871.671	1879.380	2574.377
Ship B	3557.403	2612.493	1765.652	2364.456
Ship C	4036.363	2860.691	1874.708	2565.565
Ship D	4064.997	2874.981	1880.786	2577.033

Note:
Assumed the angle formed by the ship and the container is 90°.
Assumed additional mass coefficient (Ch / ΔM) is 0.85 when sway.

Table 4. Ship Group

Ship group	L (m)	B (m)	H (m)	D (m)	Cb	Displacement (m3)	Displacement (ton)	Vs (knot)
A	126.50	19.80	8.40	6.40	0.75	12022.56	12323.12	10.00
B	44.30	9.00	3.60	2.30	0.58	531.87	545.16	10.00
C	98.00	16.50	7.80	5.40	0.75	6548.85	6712.57	10.00
D	134.00	26.40	11.00	5.40	0.84	16046.55	16447.72	10.00

A : Medium ship size; B : Smallest size of the ship that pass in the shipping lanes at the site of sinking ; C : Size of the ship between 44m-134m that pass in the shipping lanes at the site of sinking; D : Largest size of the ship that pass in the shipping lanes at the site of sinking

Table 5. Container Group

Container Group	L (m)	B (m)	H (m)	Weight (ton)	Drifting Speed 0.5 knot	1 knot	1.5 knot
C20	6.10	2.44	2.59	40.00	0.50	1.00	1.50
C40	12.20	2.44	2.59	28.00	0.50	1.00	1.50
CR20	6.10	2.44	2.59	18.00	0.50	1.00	1.50
CR40	12.20	2.44	2.59	25.00	0.50	1.00	1.50

C20 : Container 20-feet (lightweight 2930 kg)
C40 : Container 40-feet (lightweight 3764 kg)
CR20 : *Reefer container* 20-feet (lightweight 3400 kg)
CR40 : *Reefer container* 40-feet (lightweight 4900 kg)

2.3.3 *Depth of Penetration*

The absorbed energy of an object due to the collision can result in deformation or penetration. The following is a deformation or penetration that occurs based on the number of energy absorbed in the calculation of the energy absorbed in the previous discussion. The penetration on the ship and container can be seen in Table 10 up to Table 13. Besides using equation (2) and (3), also can be used Figure 4.

1 $0 \le \Delta Ek \le 218$ ton.knot^2 :

$$Rt = \Delta Ek/145 \quad (2)$$

2 $218 \le \Delta Ek \le 744$ ton.knot^2:

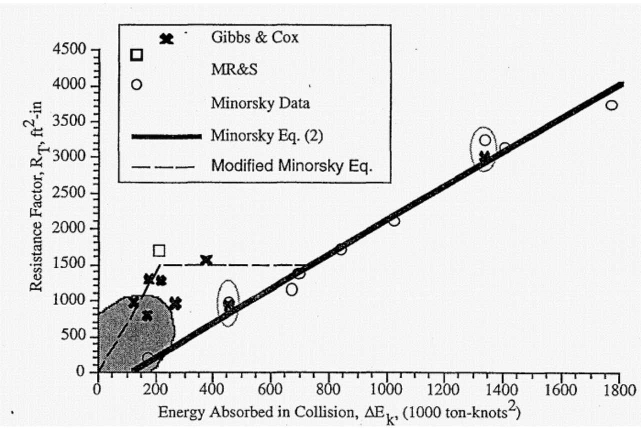

Figure 4. Minorsky Curve

3 $\Delta Ek \ge 744$ ton.knot^2:

$$Rt = (\Delta Ek - 121.9) / 0.4145 \quad (3)$$

Table 10. Penetration on the ship (container speed 0.5 knots)

Container	Depth of Penetration (ft^2.in) Ship A	Ship B	Ship C	Ship D
C20	0.0344	0.0333	0.0344	0.0344
C40	0.0241	0.0236	0.0241	0.0241
CR20	0.0155	0.0153	0.0155	0.0155
CR40	0.0215	0.0211	0.0215	0.0215

Table 11. Penetration on the ship (container speed 1 knot)

Container	Depth of Penetration (ft^2.in) Ship A	Ship B	Ship C	Ship D
C20	0.138	0.133	0.138	0.138
C40	0.096	0.094	0.096	0.096
CR20	0.062	0.061	0.062	0.062
CR40	0.086	0.084	0.086	0.086

Table 12. Penetration on the ship (container speed 1.5 knots)

Container	Depth of Penetration (ft^2.in) Ship A	Ship B	Ship C	Ship D
C20	0.310	0.300	0.309	0.310
C40	0.217	0.212	0.217	0.217
CR20	0.140	0.137	0.139	0.140
CR40	0.194	0.190	0.194	0.194

Table 13. Penetration on the container (ship speed 10 knots)

Container	Depth of Penetration (ft^2.in) Ship A	Ship B	Ship C	Ship D
Ship A	9496.871	6633.946	4240.000	5916.712
Ship B	8288.307	6008.668	3965.625	5410.267
Ship C	9443.819	6607.457	4228.730	5895.452
Ship D	9512.901	6641.933	4243.393	5923.119

2.3.4 *Risk Matrix and Acceptance Criteria*

Risk acceptance criteria in the study are using Semi Quantitative Analysis with Risk Acceptance Criteria. This study combines the probability and consequences of an event based on the Risk Acceptance Criteria. This protocol uses the Risk Matrix 5 x 5 to determine the level of risk. For each case (ship hit into container and container hit into the ship because drifting) at the ship A until ship D are shown in Figure 5 up to Figure 32.

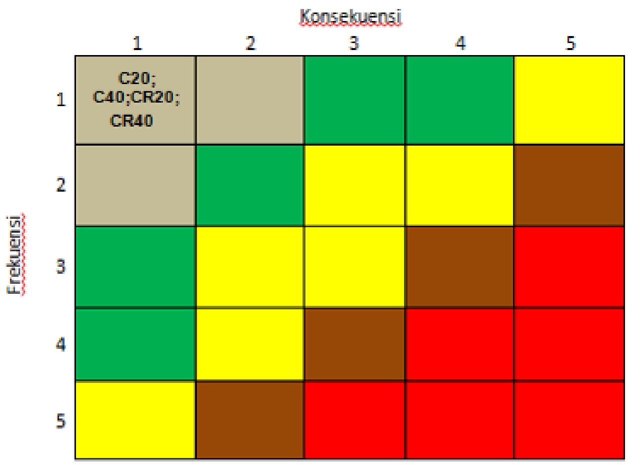

Figure 5. Container hit into midship of ship A-B-C-D (*drifting* 0.5 knots)

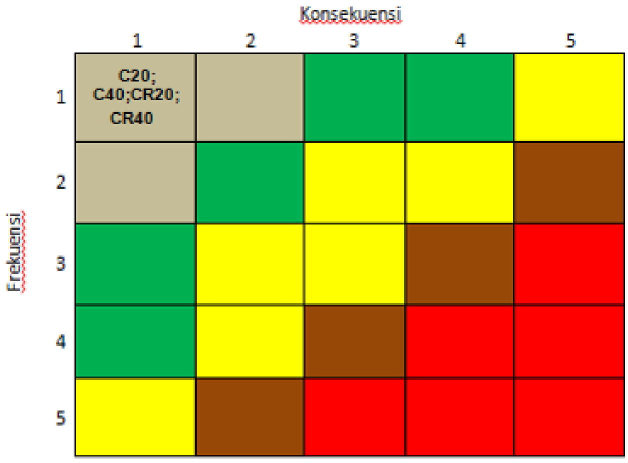

Figure 6. Container hit into midship of ship A-B-C-D (*drifting* 1 knots)

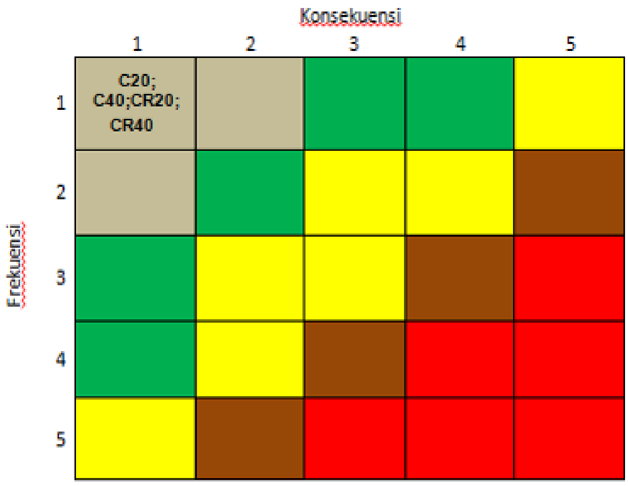

Figure 7. Container hit into midship of ship A-B-C-D (*drifting* 1.5 knots)

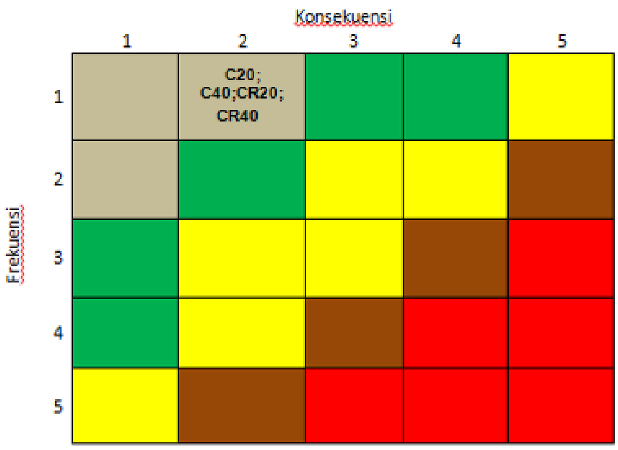

Figure 8. Ship A-B-C-D hit into container 0 knot (vessel speed 10 knots)

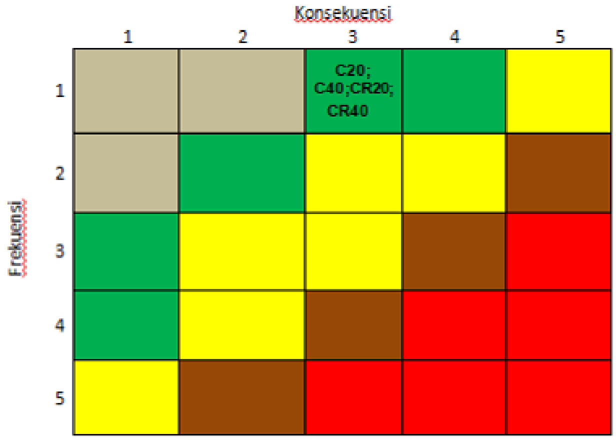

Figure 9. Ship A-B-C-D hit into container 0.5 knot (vessel speed 10 knots)

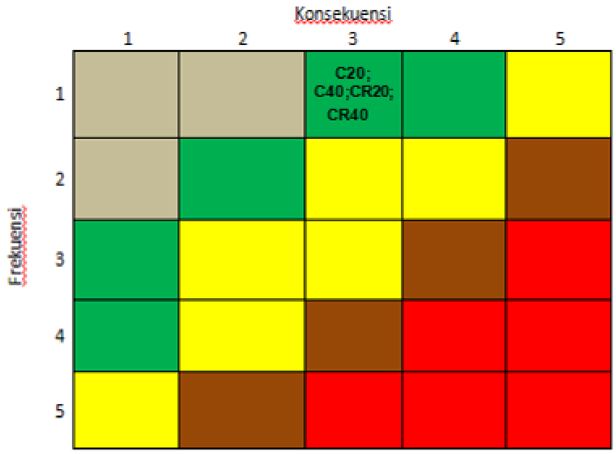

Figure 10. Ship A-B-C-D hit into container 1 knot (vessel speed 10 knots)

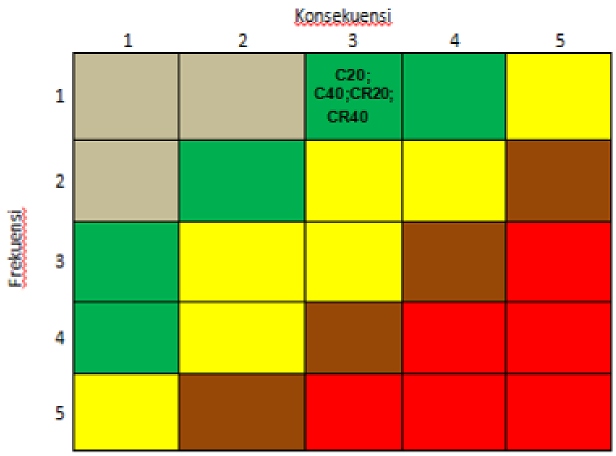

Figure 11. Ship A-B-C-D hit into container 1.5 knot (vessel speed 10 knots)

3 CONCLUSIONS AND FUTURE WORKS

Based on the results of risk assessment of the ship wreck and container cargo to ship navigation can be summarized as follows:

1 Risk of wreck interference to ships navigation and damage to environment is non-existent and not required to be assessed further.

2 The container re-floating is unlikely and the risks to safe navigation/shipping in the area are low and acceptable.

- Based on the risk matrix, for the scenario of container hit into the ship at the speed 0.5 knots, 1 knot, and 1.5 knots, the ship either A, B, C and D, does not caused the deformation on the ship structures. So the risk matrix shows the acceptable area (low risk) for all types of containers.
- Based on the risk matrix, for the scenario of the ship hit into the container at speed 10 knots, the ship either A, B, C and D, for container 0 knot, does not caused the deformation on the ship structures. So the risk matrix shows the acceptable area (low risk) for all types of containers.
- Based on the risk matrix, for the scenario of the ship hit into the container at speed 10 knots, the ship either A, B, C and D, for container 0.5 knot, 1 knot, and 1.5 knots, does not caused the deformation on the ship structures. So the risk matrix shows the acceptable area (low risk) for all types of containers.

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