Risk assessment due to collision between platform PHE-7 and passing vessels

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Abstract. PHE is going to develop seven offshore platforms, one of the platform (PHE-7) is located at particular position that is considered close to access channel to several ports and other under development ports. Considering the mentioned development, a risk assessment study is necessary to ensure that the development would not cause any risk to current marine traffic as well as future traffic. The risk considered here is the collision between platform PHE-7 with vessels operated in that area. This study is aimed to perform risk assessment due to collision between platform PHE-7 and ships and to recommend mitigation should the risk is unacceptable. Three types of collision were developed here were head-on (powered passing vessel) collision, drifting vessel collision, and visiting vessel collision. Each type of collision was then assessed using three main scenarios: by maintaining position of Buoy No.1 and Buoy No.3, by shifting position of Buoy No.1 and Buoy No.3 (to align with the position of MPMT) and by combining those two scenarios. The collision risk assessment found that risk due to collision vessel-platform is in acceptable condition.

1. Introduction

PHE is going to develop seven offshore platforms consist of six wellhead platforms as well as one central processing platform, including subsea pipeline connecting those facilities. One of the platform (PHE-7) that is going to be developed is located at 6°41’ 12.27"S and 112°41’37.85"E that is considered close to access channel to several ports (Port of Tanjung Perak Surabaya, Port of Gresik, and Private companies’ ports) and other under development ports (Port of Teluk Lamong, MISI, BMS, etc).

Considering the above development, a risk assessment study is then necessary to ensure that the development plan provide no risk to current marine traffic as well as future traffic as the result of industrial development at the area. The risks considered here is the collision between Platform PHE-7 with vessels operated in the area.

This study is aimed to perform risk assessment due to collision between platform PHE-7 and ships then give a recommendation about mitigation if the risk is unacceptable.

2. Problem Formulation

Visiting vessels, which approach the platform on legitimate business under their own power including:
• Passing merchant vessels, which pass close to the platform because it lies close to their route between ports.
• Fishing vessels, which may pass close to the platform repeatedly if it lies within fishing grounds.
• Naval vessels, which may conduct exercises near to platforms.
• Offshore tankers, which may load at offshore moorings near to other platforms.
• Other support vessels which are anchored beside platforms for long periods.

As shown in the figure 1, the platform PHE-7 is somehow located in the shipping lane of entrance to Madura Strait. Distance of MPMT buoy to existing PHE-40 Platform is 9800 meters and the distance of MPMT buoy to designed PHE-7 platform is 9400 meters.

Since MPMT is a buoy aimed as a sign of entrance to the port, then logically the ships entering the port will sail towards this buoy and clearly observable that the design position of platform PHE-7 provides risk to marine traffic.

![Figure 1. Location of platform PHE-7](image)

2.1. Visiting Vessel
Collisions between visiting vessels and offshore installations are relatively frequent occurrences, since these vessels work in close proximity to the installation. Most collisions from visiting vessels are low-energy (i.e. bumps against the installation), and cause little more than damaged paintwork and minor denting. However, they may be important for vulnerable equipment, and there is a possibility of high-energy collisions occurring on approach.

The types of vessels involved in collisions are given in (see table 1) based on all reported incidents (Kenny 1988). This shows that visiting vessels dominate the data, although passing vessels (mainly fishing vessels) are also included. It would be desirable to eliminate these, since they are analysed
separately below, but this has not been done in this analysis, partly because the correction would be small, and partly to maintain consistency with the previous work.

**Table 1.** Vessels involved in collision

| Vessel type                  | Number | %  |
|------------------------------|--------|----|
| Supply vessel                | 169    | 70 |
| Stand-by vessel              | 21     | 9  |
| Diving support vessel        | 27     | 11 |
| Other (mainly passing)       | 23     | 10 |
| **Total**                    | 240    | 100|

The AME analysis for the collision uses the following severity categories:

- No damage.
- Fender damage only.
- Minor damage - small scale denting or bending.
- Moderate damage - denting and bending and/or weld fracture (in fixed steel platforms), or denting of stiffeners (on semi-submersibles).
- Severe damage - energy absorbed by the platform exceeding 0.5 MJ.

Collision frequencies are given in table 2, both for all reported incidents and for moderate/severe incidents only, broken down by platform type (Kenny 1988). These are for all vessel types, but can be multiplied by the vessel type probabilities in table 1 (vessel involved in collisions) to give the frequency for any particular vessel type, based on average levels of activity (see Section effect of vessel type).

**Table 2.** Collision frequencies per year for different platform types

| Platform type      | Collision frequency (per platform year) all incidents | Collision frequency (per platform year) moderate / severe incidents |
|--------------------|-------------------------------------------------------|------------------------------------------------------------------|
| Steel              | 0.188                                                 | 0.033                                                            |
| Concrete           | 0.108                                                 | 0.031                                                            |
| Jack-up            | 0.279                                                 | 0.033                                                            |
| Semi-submersible   | 0.390                                                 | 0.156                                                            |
| Overall            | 0.241                                                 | 0.065                                                            |

For fixed platforms, the average number of supply vessel visits has been estimated as 2.5 per week, based on a sample of 29 Norwegian platforms (Technica 1987a). Other vessel visits would increase this, but some fixed platforms would be unmanned, so this is assumed to be a suitable average for all vessel visits to all fixed installations.

These estimates can be used to derive collision frequencies per visit as shown in table 3 for moderate/severe collisions. It may be noted that the above assumptions do not bring the frequency for semi-submersibles into line with that for fixed platforms. A typical overall frequency of moderate/severe collision for all platform types is taken to be per visit.

Collision frequencies for particular vessel types at particular platform types could be estimated by combining the frequencies for platform types with the vessel type probabilities. For example, this would give a moderate/severe collision frequency for a stand-by vessel at a fixed platform of $0.033 \times 0.09 = 3.0 \times 10^{-3}$ per year.
Table 3. Collision frequencies per vessel visit for different platform types

| Platform type     | Visit frequency (vessels/week) | Collision frequency (per visit) moderate / severe incidents |
|-------------------|--------------------------------|----------------------------------------------------------|
| Steel             | 2.5                            | 2.5 x 10^{-4}                                            |
| Concrete          | 2.5                            | 2.4 x 10^{-4}                                            |
| Jack-up           | 5.0                            | 1.3 x 10^{-4}                                            |
| Semi-submersible  | 5.0                            | 6.0 x 10^{-4}                                            |

2.2. Passing Vessel Collision

Collisions that involve passing vessels are relatively rare but are potentially very damaging. It is mainly caused by a watch-keeping failure due to human or sometimes technical factors and are entirely unaware of the platform’s presence. This collision known as powered collision. The other category is drifting vessels that have lost power and are drifting under influence of wind, waves, and current.

Table 4. Collision frequencies per year for different vessel types

| Vessel type                  | Collision frequency (per platform year) all incidents | Collision frequency (per platform year) moderate / severe incidents |
|------------------------------|--------------------------------------------------------|---------------------------------------------------------------------|
| Supply vessel                | 0.170                                                  | 4.6 x 10^{-2}                                                      |
| Stand-by vessel              | 0.021                                                  | 5.7 x 10^{-3}                                                      |
| Diving support vessel        | 0.027                                                  | 7.3 x 10^{-3}                                                      |
| Other (mainly passing)       | 0.023                                                  | 6.2 x 10^{-3}                                                      |
| Overall                      | 0.241                                                  | 6.5 x 10^{-2}                                                      |

When platform is installed offshore, it creates an obstacle to navigation and inevitably influences the traffic pattern in the area. As ships become more aware of the platform’s presence, they will begin to plan their routes to avoid it – in effect moving the lane.

The collision frequency (i.e. the predicted number of collisions per year) is calculated for each shipping lane which passes the platform as:

\[ F_{cp} = N \times F_d \times P_1 \times P_2 \times P_3 \]  \hspace{1cm} (1)

Where \( N \) is total traffic in the lane (vessel movement/year), \( F_d \) is proportion of vessels that are in the part of the lane directed towards the platform, \( P_1 \) is probability that the passage planning stage of the voyage was not carried out successful, \( P_2 \) is probability that the vessel suffers a watch-keeping failure, \( P_3 \) is probability that the platform or stand-by vessel fails to alert the ship in time to prevent a collision.
Figure 2. Powered passing vessel geometry

The collision frequency is proportional to the size of the platform and the ship. The combined size is known as the collision diameter. The collision diameter is defined as the width of that part of the shipping lane cross-section from which the ship would hit the platform unless it changed course. Hence the collision diameter is:

$$D = W_A + B$$

(2)

Where \(W_A\) is the apparent platform width and \(B\) is the ship beam.

If the platform is defined as a rectangular shape of width \(W_P\) and length \(L_P\), and is given an orientation \(\theta\) relative to the shipping lane, the apparent platform width is then:

$$W_A = L_P|\sin\theta| + W_P|\cos\theta|$$

(3)

Figure 3. Collision diameter

If the traffic across the lane follows a normal (or Gaussian) distribution, the probability can be determined accurately by integration of the appropriate part of the distribution, which is usually carried out using published tables. If the collision diameter is small compared to the lane width, a more convenient analytical approximation is:
For the normal distribution, the probability density is:

$$f(A) = \frac{1}{2\sigma} \exp\left(-\frac{k^2}{2}\right)$$

(5)

Where \(d\) is the distance from platform to lane centerline at closest point of approach, \(\sigma\) is standard deviation of traffic distribution across the lane, and \(k\) is \(A/\sigma\) i.e. the number of standard deviations that the platform is from the lane centerline.

The concept of passage planning has been added to ship-platform collision risk models to account for the fact that, as ships become aware of the presence of an offshore installation, they incorporate this knowledge into their pre-voyage passage planning. Thus, the master would normally plan a route that passes in between all known offshore installations, with an allowance for likely deviations due to wind and tide.

Information about new platforms is usually circulated via publications, radio broadcasts, notices to mariners and ultimately updating of nautical charts. As a result, there would be a time following installation of a new platform when mariners became increasingly aware of its presence, and increasingly planned to avoid it.

The probability of failure to plan for merchant ships has been proposed as:

$$P_1(t) = 0.85 e^{-0.75t} + 0.1$$

(6)

Where \(t\) is time since the platform was installed.

2.3. Drifting Vessel Collision

Where a vessel suffers a breakdown (propulsion or steering failure), and drifts under the action of wind and waves into the platform. Such collisions are most likely in severe weather. The vessel drift speeds are relatively low, making precautionary evacuation of the platform possible.

For a ship in a lane to drift and collide with a nearby platform (which may be outside the lane), the following conditions must occur:

- The vessel must suffer a breakdown in its propulsion system.
- The wind direction must be so as to make the vessel drift towards the platform.
- Any attempts to tow the vessel away must be unsuccessful.
- Offshore tankers, which may load at offshore moorings near to other platforms.
- The vessel must fail to repair itself before it reaches the platform.

If the frequency of drifting collisions were calculated rigorously, allowing for all possible breakdown points, wind speeds and directions, locations of towing vessels and self-repair times, the calculation would be time consuming. In practice, drifting collisions are usually a small contributor to overall collision risk, so substantial simplifications can be made.

The developed scenario for drifting passing vessel collision is as follow: while there are any possible passing vessel attempt to collide with platform, there are some possibility of ships machinery or propulsion system breakdown. The possibility of drifting passing vessel collision then is influenced by wind and current direction at the present time. The mathematical equation is presented as follow:

$$F_c D = N_b \times P_b \times P_w \times D/BL$$

(7)

Where \(N_b\) is the total traffic in the box (vessels per year), \(P_b\) is breakdown probability in box, \(P_w\) is probability of wind blowing from box to platform, \(D\) is collision diameter and \(BL\) is the box length perpendicular to wind direction. The map classifies the collision frequencies into the following broad bands:
### Table 5. Collision frequency bands

| Bands     | Frequency   |
|-----------|-------------|
| High      | > per year  |
| Medium    | to per year |
| Low       | < per year  |

#### 2.4. Visiting Vessel/Offshore Tanker Collision

Tankers which load offshore, or are permanently moored offshore as floating production or storage vessels, may suffer several types of collisions, as follows:

- Collision of passing vessel with moored tanker. This can be treated as for collisions of passing vessels with platforms.
- Collision of attendant vessel with moored tanker. This can be treated as for collisions of visiting vessels with platforms.
- Collision of tanker with platform while in transit. This can be treated as for collisions of other passing vessels with platforms.
- Collision of tanker with other vessel while in transit. This is a purely marine issue, and is not addressed in this guide.
- Collision of tanker with its own mooring or with the vessel (FPSO or FSU) it is unloading from. This is considered in.
- Collision of drifting tanker with nearby installations. This may be due to a machinery failure on approach, or due to a mooring failure while in position. Their speeds tend to be low while approaching.

An offshore tanker may become adrift if:

- It suffers mooring/hawser failure while moored or connected.
- It suffers machinery breakdown while approaching or departing from its mooring.
- It suffers machinery breakdown or major DP failure while stationed using dynamic positioning.
- Collision of passing vessel with moored tanker. This can be treated as for collisions of passing vessels with platforms.

It may then collide with nearby platforms if:

- It drifts towards the platform.
- It is unable to restart its machinery (if applicable).
- It is unable to use thrusters to alter its track.
- It is unable to use anchors to stop.
- Attendant vessels are unable to control it, if any.

The general frequency of engine breakdown based on A Guide to Quantitative for Offshore Installations-DNV is $2 \times 10^{-5}$ per hour, based on general merchant ships, and consistent with a repair time of a few shuttle tankers would be expected to have lower frequencies than average due to frequent port visits that provide opportunities for engine inspection as well as low loading on engine while loading offshore.

The drift direction depends on the shape of the vessel’s above-water and under-water form, the wave height and direction, and the wind and current velocities. In most cases, a tanker tends to lie beam-on to the waves and drift on a track at up to $15^\circ$ from the wave direction, depending on the difference between the wind and wave angles (OCIMF 1982).
A probability distribution of wave directions may be obtained from wave climate data for the area. In a simple study, it is often assumed similar to the wind rose, which is more readily available, or even more simply assumed to be uniform. The angle subtended by the platform is estimated as:

\[ A = \arctan \frac{D_1 + D_2}{2L} \]  

(8)

Where \( A \) is angle subtended by platform (rad), \( D_1 \) is width of tanker normal to drift track, \( D_2 \) is width of platform normal to drift track, and \( L \) is initial distance of tanker from platform. For a uniform distribution of wave directions, the probability of drifting on a collision course is then \( \frac{A}{2\pi} \).

The energy level in a ship-platform collision depends on the initial kinetic energy of the ship. This can be estimated as follows:

\[ E = \frac{1}{2} \frac{M}{21000} k \nu^2 \]  

(9)

Where \( E \) is the impact energy (MJ), \( M \) is the vessel mass (tonnes), \( k \) is a hydrodynamic added mass constant, taken as 1.1 for head on (powered impact) and 1.4 for broadside (drifting) impact, and \( \nu \) is vessel speed (m/s).

2.5. Empirical Methods for Consequences Analysis
2.5.1. Pile rupture due to collision. Any impact absorbed by pile would give various effect depend on impact energy given by collision. Ship impact energy is calculated as follow:

\[ E_k = \frac{1}{2} k m \nu^2 \]  

(10)

Where \( k = 1.1 \) for head-on collision and 1.4 for drifting collision, \( m \) is ship’s displacement (weight), and \( \nu \) is ship’s velocity. While pile impact resistance is calculated as follow:

\[ E = 16 \times \left( \frac{2\pi}{9} \right)^{\frac{1}{2}} \times m_p \times \left( \frac{D}{t} \right)^{\frac{1}{2}} \times D \times \left( \frac{\sigma}{D} \right)^{\frac{1}{2}} \]  

(11)
Where $E$ is absorbed energy, $D$ is pipeline outer diameter, $m_p$ is plastic moment capacity, $\sigma$ is dent depth, and $t$ is pipe thickness.

As ship impact energy and absorbed energy is equally same, dent/diameter ratio can be calculated and the result will be summarized on table 6.

**Table 6. Consequence level**

| Dent / diameter(%) | Damage description                  |
|-------------------|-------------------------------------|
| <5 (Level 1)      | Minor damage                        |
| 5 – 10 (Level 2)  | Major damage - no rupture probability|
| 10 – 15 (Level 3) | Major damage - less rupture probability|
| 15 – 20 (Level 4) | Major damage - high rupture probability|
| >20 (Level 5)     | Rupture                             |

2.5.2. **Seabed resistance failure.** In case the platform wont rupture by collision, there are probabilities that seabed wont strong enough to absorb the collision impact. Seabed failure will be occured if below condition is met:

$$SeabedResistanceTorque \leq ImpactTorque$$

While Seabed Resistance Torque ($R_t$) is calculated as follow:

$$R_t = \frac{1}{6} \gamma D H^3$$

(12)

Where $\gamma$ is soil bulk density = 1500 $kg/m^3$, $D$ is pile diameter, and $H$ is pile penetration depth below seabed.

While Ship Impact Torque ($S_t$) is calculated by multiplying the ship impact force and distance from collision point to bottom end point of pile.

3. Methodology

3.1. **Scenario Development**

Three types of collision were developed here. Those type of collision were:

- Head-on collision (powered passing vessel collision) to platform.
- Drifting vessel collision to platform.
- Visiting vessel collision to platform.

Each type of collision above was then assessed by to main scenarios, those were:

1. By maintaining position of Buoy No.1 and Buoy No.3 with respect to:
   a. Existing position of MPMT.
   b. Shifting coordinate of MPMT to 1st mitigating scenario.
   c. Shifting coordinate of MPMT to 2nd mitigating scenario.
2. By maintaining position of Buoy No.1 and Buoy No.3 with respect to:
   a. Existing position of MPMT.
   b. Shifting coordinate of MPMT to 1st mitigating scenario.
   c. Shifting coordinate of MPMT to 2nd mitigating scenario.
3. By combining the above 2 scenarios.
3.2. Vessel Platform Collision

3.2.1. Head-on collision (powered passing vessel collision). The number of traffic in Madura Strait will be increased by considering four factors namely:

- South West Access Channel.
- Madura International Seaport City (MISI).
- Development of Port of Teluk Lamong.
- JICA study report.

It is forecasted that the current annual marine traffic of 14,500 ship’s call (29,000 ship passing) will be doubled in 2030 and become 29,000 ship’s call or 58,000 ship passing.

The scenarios developed for this collision type can be mentioned as follows:

- Scenario Collision 1 (SCC-1): Head-on Collision.
- Scenario Collision 2 (SCC-2): Head-on Collision.
- Scenario Collision 3 (SCC-3): Head-on Collision.
- Scenario Collision 4 (SCC-4): Head-on Collision (Maintain MPMT and Shifting Buoy No.1 and No.3).
- Scenario Collision 5 (SCC-5): Head-on Collision (Shifting MPMT, Buoy No.1, and No.3).
- Scenario Collision 6 (SCC-6): Head-on Collision (Shifting MPMT, Buoy No.1, and No.3).

3.2.2. Drifting passing vessel. The developed scenario for drifting passing vessel collision is as follow; while there are any possible passing vessel attempt to collide with platform, there are some possibility of ships machinery or propulsion system breakdown. The possibility of drifting passing vessel collision then is influenced by wind and current direction at the present time. The scenarios for this following collision type is:

- Scenario Collision 7 (SCC-7) : Drifting Collision, Maintaining MPMT, Buoy No. 1 and Buoy No. 3.
- Scenario 8 (SCC-8): Maintaining Buoy No. 1 and Buoy No. 3, shifting MPMT (1st).
- Scenario 9 (SCC-9): Maintaining Buoy No. 1 and Buoy No. 3, shifting MPMT (2nd).
- Scenario 10 (SCC-10): Shifting Buoy No. 1 and Buoy No. 3, maintaining MPMT.
- Scenario 11 (SCC-11): Shifting Buoy No. 1 and Buoy No. 3, shifting MPMT (1st).
- Scenario 12 (SCC-12): Shifting Buoy No. 1 and Buoy No. 3, shifting MPMT (2nd).

3.2.3. Collision of approaching vessel / visiting vessel (SCC-13). Four models are developed here to assess the risk due to collision of platform and vessels approaching the platform. The methods utilized here are:

1. JP Kenny Model.
2. Lane Geometry Model.
3. Join Probability Model (conservative modelling). Conservative modelling assumed that collision of visiting vessel can be happened with the following scenario:
   a. Watch-keeping failure occurred.
   b. If watchkeeping failure occured, recovery procedure of watchkeeping also failure.
   c. Finally, weather factor consist current and wind caused drifting collision occurred.

3.3. Vessel-Platform Collision Consequences

3.3.1. Computer simulation-FEM method. The models are developed using ANSYS under a Finite Element Method. According to (American Bureau of Shipping 2005), seven basic utilization factors are recommended as load condition for model developed here. The basic utilization factor is provided below as well as the material properties of the platform.
3.3.2. Empirical methods.

- Consequence modelling 1 – pile rupture due to collision.
- Consequences modelling 2 – seabed resistance failure.

4. Case Study

4.1. SCC-1
Model I is developed by assuming that the vessel entering Madura Strait pass the channel towards the existing MPMT buoy located at Coordinate: S; E. Two models are developed here: a) Eastern: By assuming that vessels entering the channel will pass through Eastern side of the platform PHE-7. Five different sub-models are developed by assuming that 0%, 25%, 50%, 75% and 100% of vessels pass through this side, and consequently that 100%, 75%, 50%, 25% and 0% of vessels will pass the Western side of Platform 7 respectively. b) SOUTHERN: using the reciprocal of the scenario mentioned before. The lane width of Eastern access is approximately 5800 meters and 500 meters for the Western access.

4.2. SCC-2
Passing vessel model II is developed as an effort to mitigate model 1 explained previously and carried out by shifting MPMT buoy far to the west. Consequently, the lane width of Eastern access is approximately 5800 meters and 2400 meters for the Western access.

4.3. SCC-3
Passing vessel model III is developed as an effort to mitigate model 2 explained above and carried out by shifting MPMT buoy to the west to a coordinate of S; E. Consequently, the lane width of Eastern access is approximately 5800 meters and 4250 meters for the Western access.

4.4. SCC-4
Passing vessel model IV was developed as an effort to provide another alternative by maintaining the MPMT and shifting the Buoy No.1 and No.3. Consequently, the lane width of Eastern access is approximately 5800 meters and 1600 meters for the Western access.

4.5. SCC-5
Passing vessel model V was developed as an effort to provide other alternative by shifting the MPMT, Buoy No.1 and No.3. Consequently, the lane width of Eastern access is approximately 5800 meters and 4000 meters for the Western access.

4.6. SCC-6
Passing vessel model VI was developed as an effort to provide another alternative by shifting the MPMT, Buoy No.1 and No.3. Consequently, the lane width of Eastern access and western access is approximately 5800 meters and 4250 meters.

4.7. SCC-7
Drifting collision for model I, four different sub-models are developed by assuming that the breakdown probability is 2.5%, 5.0%, 7.5%, and 10%, and further, 3 different probabilities of wind affect the vessel direction are developed: 1%, 3%, and 5%. It is assumed that the vessel will be normally distributed along the access.

4.8. SCC-8
SCC-8 is developed as an effort to mitigate drifting collision model I explained previously and carried out by shifting MPMT buoy to the west. The lane width of Eastern access and western access is approximately 5800 meters and 2400 meters.
4.9. **SCC-9**
This was developed as an effort to mitigate previous model and carried out by shifting MPMT buoy far to the. Approximately of 5800 meters and 4250 meters is the lane width of Eastern access and western access, consequently.

4.10. **SCC-10**
SCC-10 was developed as an effort to provide another alternative by maintaining the MPMT and shifting the Buoy No.1 and No.3. Consequently, the lane width of Eastern access and Western access is approximately 5800 meters and 1600 meters.

4.11. **SCC-11**
SCC-11 was developed as an effort to provide another alternative by shifting the MPMT, Buoy No.1 and No.3 (see Figure below for the new buoy coordinates). Consequently, the lane width of Eastern access is approximately 5800 meters and for the Western access is 4000 meters.

4.12. **SCC-12**
This scenario was developed as an effort to provide another alternative by shifting the MPMT, Buoy No.1 and No.3 (see Figure below for the new buoy coordinates). The lane width of Eastern access is approximately 5800 meters and for the Western access is 4250 meters.

4.13. **SCC-13**

4.13.1. **JP Kenny Model.** Based on this model, if it is assumed that there are twice visit per week, then the collision frequency is . If the visiting vessel frequency toward the platform is set to 3 different numbers (see below) then the collision probability would be 0.02 collision/year. If the number of visiting vessel increase 2 times, in other words there is 208 visit/week, the collision frequency is still far less than one.

4.13.2. **Lane Geometry Model.** Collision would happened in if in the order of visiting vessel approaching the platform, the vessel itself lost control due to machinery breakdown and adrift toward platform.

4.13.3. **Join Probability Model (Conservative Modelling).**
It is assumed that would be extreme values for all the probability of visiting vessel failure.

![Figure 5. Geometry of passing vessel collision (in scale)](image)

4.14. **Consequences**
There would be 15 scenarios for three ship displacement types (2000 tonnes, 5000 tonnes, and 10000 tonnes) and five different ship speeds (2 knots, 4 knots, 6 knots, 8 knots, and 10 knots).

5. **Results and Discussion**
For each scenarios developed above is then analysed and the result is obtained as follows:

5.1. **SCC-1**
At the condition of good visibility, annual collision frequency at all conditions is less than 1. It means that there is expected no collision is going to happen at the Southern side of the platform PHE 7 even though all vessels (29000) will pass through this side (100%). However, in the event of bad visibility, then the annual collision frequency at 25%, 50%, 75% and 100% of cumulative traffic is more than 1. This means that it is expected that 1 collision is occurred at those conditions.

5.2. SCC-2
At the good visibility, annual collision frequency is less than 1 at all conditions. On the other hand, at the bad visibility, the annual collision frequency at 100% of cumulative traffic is more than 1.

5.3. SCC-3
Annual collision frequency at all conditions is less than 1.

5.4. SCC-4
For the eastern scenario the annual collision frequency at all conditions is less than 1. However, the southern scenario (shifting Buoy No.1 and no.3, whilst maintaining the coordinate of MPMT) when the visibility is good, the annual collision frequency at all conditions is less than 1, but in the event of bad visibility, then the annual collision frequency at 50%, 75% and 100% of cumulative traffic is more than 1.

5.5. SCC-5
The annual collision frequency the eastern scenarios at all conditions is less than 1. While the annual collision frequency for the southern scenario (shifting MPMT, Buoy No.1 and no.3) when the visibility is good is less than 1, and in the event of bad visibility, the annual frequency at 100% of cumulative traffic is more than 1.

5.6. SCC-6
Annual collision frequency for eastern side for all condition is less than 1, as well as the southern side.

5.7. SCC-7
Annual collision frequency is less than 1 at the eastern side of the platform for all wind blowing condition, but it will be more than 1 if we set the probability of wind blowing from box to platform is 3% and 5%.

5.8. SCC-8
Annual collision frequency is less than 1 at the eastern side of the platform for all wind blowing condition, but it will be more than 1 if we set the probability of wind blowing to platform is 5%.

5.9. SCC-9
The annual collision frequency is less than 1 for both side of platform for all wind blowing condition.

5.10. SCC-10
Annual collision frequency at all conditions is becoming less than 1 at the eastern side of platform, whilst the annual collision frequency is less than 1 when probability of wind blowing from box to platform is set 1% but if we set the probability of wind blowing from box to platform is 3% and 5%, then then in most cases, it is expected that 1 collision or more is occurred.

5.11. SCC-11
Annual collision frequency at all conditions is becoming less than 1 at the eastern side of platform. However, the annual collision frequency is less than 1 when probability of wind blowing from box to
platform is set 1% or 3% but it will be more than 1 if we set the probability of wind blowing from box to platform is 5%.

5.12. SCC-12
Annual collision frequency at all conditions is less than 1 at the eastern and southern side of the platform for all wind condition.

5.13. SCC-13

5.13.1. JP Kenny Model. The collision probability would be 0.02 collision/year. If the number of visiting vessel increase 2 times, in other words there is 208 visit/week, the collision frequency is still far less than one.

5.13.2. Lane Geometry Model. If the visiting vessel frequency toward the platform is set to 3 different numbers (see below) then for present time probability of ship collision is 0.00021 collision/year.

5.13.3. Join Probability Model (Conservative Modelling).
An extreme value of probability of watch-keeping failure, recovery failure, and weather failure used to calculate the probability of visiting vessel collision in order to ensure that even with extreme value, the probability of ship collision is still negligible.

5.14. Consequences
The result for each modelling consequence is given in table 7.

| Scenario | Ship displacement (t) | Ship speed (knots) | Analysis result |
|----------|-----------------------|-------------------|-----------------|
| 2000     | 2                     | OK                |
| 2        | 2000                  | 4                 | OK              |
| 3        | 2000                  | 6                 | OK              |
| 4        | 2000                  | 8                 | OK              |
| 5        | 2000                  | 10                | OK              |
| 6        | 5000                  | 2                 | OK              |
| 7        | 5000                  | 4                 | OK              |
| 8        | 5000                  | 6                 | OK              |
| 9        | 5000                  | 8                 | OK              |
| 10       | 5000                  | 10                | FAILURE         |
| 11       | 10000                 | 2                 | OK              |
| 12       | 10000                 | 4                 | OK              |
| 13       | 10000                 | 6                 | FAILURE         |
| 14       | 10000                 | 8                 | FAILURE         |
| 15       | 10000                 | 10                | FAILURE         |

The empirical methods for pile rupture due to collision gave results that for each ship class (A-I) based on displacement, each consequence level is calculated by various speed (4-10 knot for head-on
collision and 1-4 knot for drifting collision) and various steel pipe thickness, (80 -120 mm) while recommended value of pile diameter is 27 feet.

The seabed resistance failure showed that seabed failure wont happened with 30 meter pile penetration below seabed. However, seabed failure still occurred if platform get hit by ship with displacement more than 40,000 ton with 20 meter penetration depth.

6. Conclusion and Future Works
Acceptable condition is obtained in SCC-3, SCC-6, and SCC-9. Due to vessel’s ease of maneuverability, the SCC-9 is recommended. Head on collision provide the largest magnitude of impact, especially for vessels having more than 20,000 DWT capacity and speed of more than 10 knots. The drifting collision will only give impact to platform, when the vessels having capacity more than 40,000 DWT and speed of more than 3 knots. Though the possibility of losing platform leg is existed, the risk due to collision is acceptable, since the annual frequency is less than 1 when the MPMT is shifted to the new coordinate. To maintain the safety operation of ship at the platform area the following recommendation is to installing BSNP at every angle of platform’s exclusion zone, installing one Buoy Cardinal West to sign the existence of platform, and installing radar beacon after platform installation.

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