A Generic Model To Assess Major Incident Frequencies For Offshore Assets

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Quantitative risk assessments (QRAs) for offshore oil and gas exploration and production assets are commonly used in the industry to demonstrate that risks are within tolerable limits. The results of these QRAs are included in an installation's Operations Safety Case, which is prepared in response to the requirements of Regulation 7 of the Offshore Installations (Safety Case) Regulations 2005 [SCR 2005]. These results provide part of the demonstration that the risks are managed to ALARP and are also used as input into the Justification for Continued Operations. A limitation of these assessments, however, is that a realistic comparison between assets is often not possible since methods, input data and assumptions vary from one QRA to another, in some cases quite widely. These variations may include the use of differing leak frequency databases, differing parts count definitions, ignition models, and fatality and impairment probabilities. In addition, QRAs do not focus on potential asset, or environmental consequences which are of significant interest to operators and equity partners.

This paper presents a methodology for assessing Major Incident Frequencies to enable a realistic comparison, on a like for like basis, of a range of asset types, which have been assessed using differing QRA methodologies. The methodology presented within this paper has been applied to various assets including fixed manned and unmanned installations, FPSO's and FSO's. The results indicate that the methodology developed is sufficiently robust to allow a meaningful comparison to be made between different types of assets, and provides an improved estimation of the overall major incident risk frequency compared with that which is typically presented in installation specific safety cases.

Introduction

The need for operators and Joint Venture partners to understand and manage the economic risk of a major incident occurring has been highlighted through a number of recent incidents. However, major incident risk assessment and management has tended to focus on the safety aspects on individual platforms within an operation which could, for example, consist of a number and variety of platforms and subsea structures. A more rational approach to assessing major incident potential is to consider all the major safety, environmental, cost and reputational risks for the entire operation.

Quantitative risk assessments (QRAs) for offshore oil and gas exploration and production assets are commonly used in the industry to demonstrate that risks are within tolerable limits. The results of these QRAs are included in an installation's Operations Safety Case, which is prepared in response to the requirements of Regulation 7 of the Offshore Installations (Safety Case) Regulations 2005 [SCR 2005]. These results provide part of the demonstration that the risks are managed to ALARP and are also used as input into the Justification for Continued Operations. A limitation of these assessments, however, is that a realistic comparison between assets is often not possible since methods, input data and assumptions vary from one QRA to another, in some cases quite widely. These variations may include the use of differing leak frequency databases, differing parts count definitions, ignition models, and fatality and impairment probabilities. In addition, QRAs do not focus on potential asset, or environmental consequences which are of significant interest to operators and equity partners.

This paper presents a methodology for assessing Major Incident Frequencies to enable a realistic comparison, on a like for like basis, of a range of asset types, which have been assessed using differing QRA methodologies. The methodology presented within this paper considers all incidents that may result in any combination of major harm to personnel, damage to the environment or cost impact to the company. It has been applied to various assets including fixed manned and unmanned installations, FPSO's and FSO's.

Scope

The overall objective of the work reported in this paper was to provide the operator with a simplified and consistent methodology that would allow major incident potential to be assessed across its portfolio of operated and non-operated activities. The context within which this activity was carried out is described in previous work [Smith 2013]

The operator's main requirement was that the methodology was based around an EXCEL model which would facilitate the comparison of major incident event frequencies for a range of differing installations and allow changes in the form of the operation and sensitivity to different underlying assumptions to be easily incorporated and assessed. The methodology needed to be able to assess major incident potential for the whole operation (i.e. combine the contributions from the individual assets that form the operation in a rational manner). For Joint Venture operations where a different operator is the Duty Holder, the methodology needed to be able to manage the relatively limited detailed information available compared to the information available for operated assets.

The major incident events, which are defined in the following section, cover events with the potential to impact personnel, the asset and the environment.

The types of installation compared during the assessment covered by this paper were:

- Fixed Manned Installations;
- Normally Unattended Installations (NUI);
- Floating, Production, Storage and Offloading Installations (FPSO);
- Floating Storage and Offloading Installations (FSO);

- Sub-sea completions.

However, it should be noted that the model has been developed such that it is not limited to assessing the installation types listed above.

Major Incidents

Major incidents may be caused by a wide variety of events and again the model was developed in such a way that hazards outside those defined below can be included as required.

The current range of hazards assessed within the model includes the following:

- Loss of personnel;
- TR impairment;
- Major asset damage;
- Major environmental damage;
- Well blowout;
- Helicopter crash;
- Ship collision;
- Structural failure;
- Rotating Equipment;
- Loss of mooring (FPSOs, FSOs only);
- Engine room flooding (FPSOs, FSOs only);
- Engine room, pump room, machinery space and/or cargo oil tank fires (FPSOs, FSOs only).

Unless a detailed assessment was undertaken and reported in the QRAs, generic values were assumed for Ship Collision, Rotating Equipment, Loss of Mooring, Engine Room Flooding, and Engine Room Fire.

A key input for incidents Loss of personnel, TR impairment, Major asset damage, and Major environmental damage was the platform release frequency. The method of assessing for each platform is detailed in Section 4.

Loss of Personnel

Loss of personnel was defined as any event that causes ≥ 1.5 immediate statistical fatalities due to a hydrocarbon release. However, as this is a user defined input it can be modified as required. Immediate fatalities can arise in a populated area due to jet fires, explosions, flash fires and unignited toxic gas (H_2S) clouds. For the latter event a gas concentration of 1000 ppm was applied as the threshold for fatalities.

Fatalities due to evacuation were not assessed within the model as they were considered to be included as part of the TR impairment and asset damage frequencies.

TR Impairment

Events with the potential to impair the TR were considered to be major incidents. In addition TR impairment is considered to result in a requirement to evacuate the installation.

TR impairment was assessed to result from:

- Impairment of the TR boundary due to jet fires, pool fires or explosions. The assessment of this event takes account of the shielding between the event and the TR, and the fire/blast rating of the TR wall, i.e. an A60 wall is considered to fail within 5 minutes of fire impairment
- Failure of the TR supporting structures due to jet fires, pool fires and explosions. In this case the defined capacity of the structure to withstand fire and blast is taken in to account;
- Failure of structures which could impact on the TR, i.e. cranes and drilling derricks. Again this takes account of the capacity of the structures to withstand fire and blast;
- Smoke or gas ingress which reaches the defined impairment criteria within the specified TR endurance time. For this assessment the impairment criteria applied were:
    - Flammable gas – 50% LFL (Lower Flammable Limited). This allows for incomplete mixing of the gas resulting in pockets above 100%;
    - Carbon monoxide (CO) (in smoke from pool fire events) – ≥ 400 ppm;
    - Hydrogen sulphide (H_2S) – ≥ 100 ppm.

Asset Damage

Asset damage was considered to occur for jet and pool fire events which exceed the dimensioning loads summarized in Table 1.

Time (minutes)	Jet Fire Length (m)	Pool Fire Diameter (m)
5	50	30
10	40	20
30	20	10
60	10	5

Table 1 Asset Damage Fire Dimensioning Loads

Explosions were considered to cause significant asset damage if the overpressure within a fire area is ≥ 0.62 bar (9 psi) [Technica 1988]

Environmental Events

For the purposes of this assessment an environmental event is assumed to occur following a large release of a non-volatile or partially volatile (unstabilised) fluid.

In order to determine environmental event frequencies simple rule sets were developed to define both the size of the spill and the duration. The volumes of liquid required for an event to be defined as having an environmental impact were:

- Major spill – 20,000 barrels (3,180 m^3);
- Disastrous spill – 200,000 barrels (31.800 m^3).

Note that for partially stabilised fluids only the non-volatile fraction of the fluid was considered.

For topsides releases a duration of 1 minute was applied during which the fluid would be released at a steady state prior to successful shutdown. For pipeline releases the time for detection and shutdown detailed in Table 2 were assumed. Following shutdown, the isolable volume within then the inventory is considered to be released

Hole Size (mm)	Detection Time
18	12 hours
50	6 hours
100	1 hour
Full Bore	5 minutes

Table 2 Pipeline Release Detection Times

For environmental releases a sensitivity factor can be applied to installations located close to the shoreline or in an environmentally sensitive area.

Blowouts

A blowout is defined as an uncontrolled release of hydrocarbon from a well, which can occur subsea or from the topsides. Only free flowing wells were considered to have the potential to result in a blowout. Wells which require, for example, gas lift or electric submersible pumps to flow were excluded from the assessment. The increased blowout frequency of HPHT (high pressure, high temperature) wells was also factored accordingly

In addition to production blowouts, operations such as development drilling and completion, workover, wireline and coiled tubing were also considered to have the potential to result in a blowout. The type and number of operations assessed is installation specific.

Ship Collision

A ship collision incident may occur where a passing or visiting vessel impacts the installation with sufficient energy to cause major damage. This level of damage was considered to result in significant downtime on the installation while inspections and repairs are made.

The reported risks from ship collision varied by orders of magnitude for similar installations in similar areas. Unless specific detailed ship collision analysis had been performed in the QRA, data was derived solely from the installation size (and thus assumed critical impact energy), and generic impact energy exceedence curves.

Helicopter Crash

Two types of helicopter crash were considered to constitute a major incident as follows:

- Helicopter crashes during the in-flight or take-off and landing phases which result in fatalities;
- Helicopter crash on the installation resulting in asset damage.

To standardize the approach used to calculate helicopter risk, the only installation specific inputs considered as part of the calculation were:

- Travel time to platform;
- Number of journeys / stages;

- Size of platform (for helicopter impact assessment).

Structural Failure.

Structural failure, which results in a major incident, may occur from the following causes:

- Extreme weather;
- Seismic activity;
- General corrosion (lack of structural maintenance);
- Fatigue.

Rotating Equipment

All major turbines on an installation carry the potential risk of turbine failure. Turbine (rotor) failure was considered to be a major incident which could result in fatalities and asset damage, but the primary effect is significant time downtime while the item is replaced or repaired.

Loss of Mooring

This major incident considers multiple mooring chain failure which can result in the installation drifting off location, damage to risers and a release of hydrocarbon fluids.

Engine Room Flooding

Engine room or machinery space flooding considers the ingress of water in to the engine room or machinery space with the potential to cause fatalities or loss of stability. A cause of this event could be a leak from a seawater intake line.

Engine Room Fire

This major incident considers the potential for a fire in the engine room, pump room, machinery space or cargo oil tanks. Fires in these locations have the potential to cause fatalities or to result in asset damage and major downtime on the installation.

Model Development

The model was developed using a series of linked EXCEL spreadsheets supported by VBA code. VBA code was used within the model to facilitate the efficient handling of the large amount of input data required for, and output (results) generated in, each of the individual Major Incident Assessment (MIA) models.

The spreadsheet approach was used to provide an easy to use, transparent model which allows the rapid assessment of any changes. The model comprises a generic input/results workbook and an installation specific major incident assessment workbook. A generic input sheet was developed to make it easier to change input data which was common to all installations, e.g. environmental spill volumes.

Release Frequency Determination.

Due to the high level nature of the assessment the release frequency determination was undertaken using a system count approach based on data given in the HSE's HCR database [HSE HCR] and its associated guidance [HSE 1996]. For each installation assessed the process and fuel gas systems were identified using PFDs (e.g. Flowlines/Oil, Separation/Oil Production etc.). Each system was then broken down in to inventories, where appropriate, to take account of emergency shutdown valves (ESDV), different fluid types, pressure changes and any split between fire areas.

For each system identified the total release frequency, taken from the HCR database [HSE HCR], was split between its associated inventories and fire areas, where applicable, using factors defined in the following rule set (refer to Table 3).

Equipment Item	Frequency Factor
Separator/Scrubbers	Gas section – 2
	Liquid section – 2
Heat exchangers	1
Pumps	1 (1)
Compressors	2 per stage
Metering skid	1
Piping	0.5

Note (1) For 2 x 100% pumps 1 is used (i.e. 1 duty, 1 standby), however, for 2 x 50% pumps 2 is used (2 duty).

Table 3: Equipment Item Frequency Factor Summary

A typical example is presented in Figure 1 for a compression system containing gas (blue) and liquid (green) streams. Using the leak frequency factors presented in Table 3, the proportion of leaks assigned to the gas inventory is calculated as 5/7 = 71%.

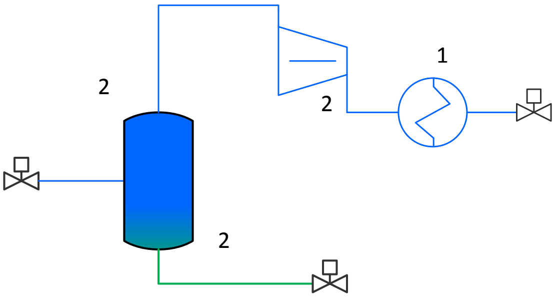


Figure 1: Typical Compression System with Assigned Leak Frequency Factors

The release frequencies for each installation can be modified by a factor if it is felt that a release is more or less likely than the frequency given in the HSE HCR database. This factor can be applied to account for issues such as ageing.

It should be noted that the release frequencies determined using this system count approach showed reasonable agreement (+/-30%) with the majority of reported installation release frequencies presented in the relevant Operations Safety Case.

Results

The frequencies for each of the above major incidents were determined for each of the installations assessed and then summed by Joint Venture. In order to provide a meaningful comparison of the major incident risk associated with each Joint Venture, a range of different approaches to normalization of the risk levels was considered. Here some initial (i.e. pending final verification) results for each Joint Venture are presented, for both the Joint Venture as a whole and for the operator's equity stake in the Joint Venture, in terms of:

- Incidents per 10^9 Barrels of Oil Equivalent (BOE);
- Incidents per £10^9 revenue.
- Incidents multiplied by revenue

An example of the results generated is presented in Table 4 and Figure 2 for a single installation.

Incident Type	Frequency (yr^{-1})
Loss of Personnel	2.092E-3
TR Impairment	8.397E-4
Asset Damage	1.186E-3
Major Env. (Topsides)	0.000E+0
Disastrous Env. (Topsides)	0.000E+0
Major Env. (Pipeline)	9.180E-4
Disastrous Env. (Pipeline)	1.020E-4
Blowout - Topsides	3.819E-4
Blowout - Subsea	3.819E-4
Ship Collision	1.701E-4
Helicopter Crash	4.968E-4
Structural Failure	1.000E-4
Rotating Equipment	1.136E-6
Total	5.654E-03 (1)

Note (1) A single event may cause immediate fatalities, asset damage and impair the TR. For this reason the total frequency of major incidents is less than the sum of the major incident event frequencies by category.

Table 4: Major Incident Frequency Summary

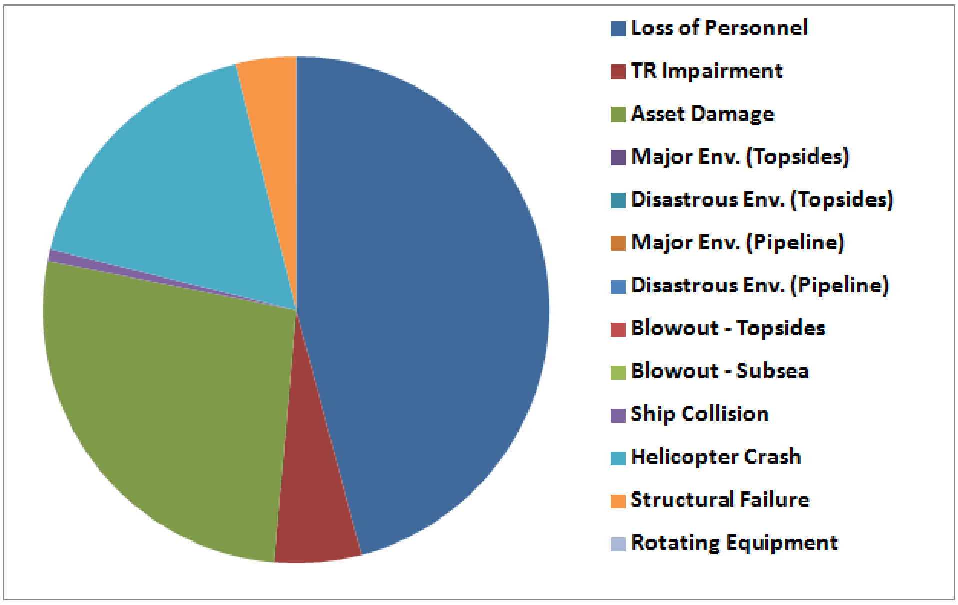
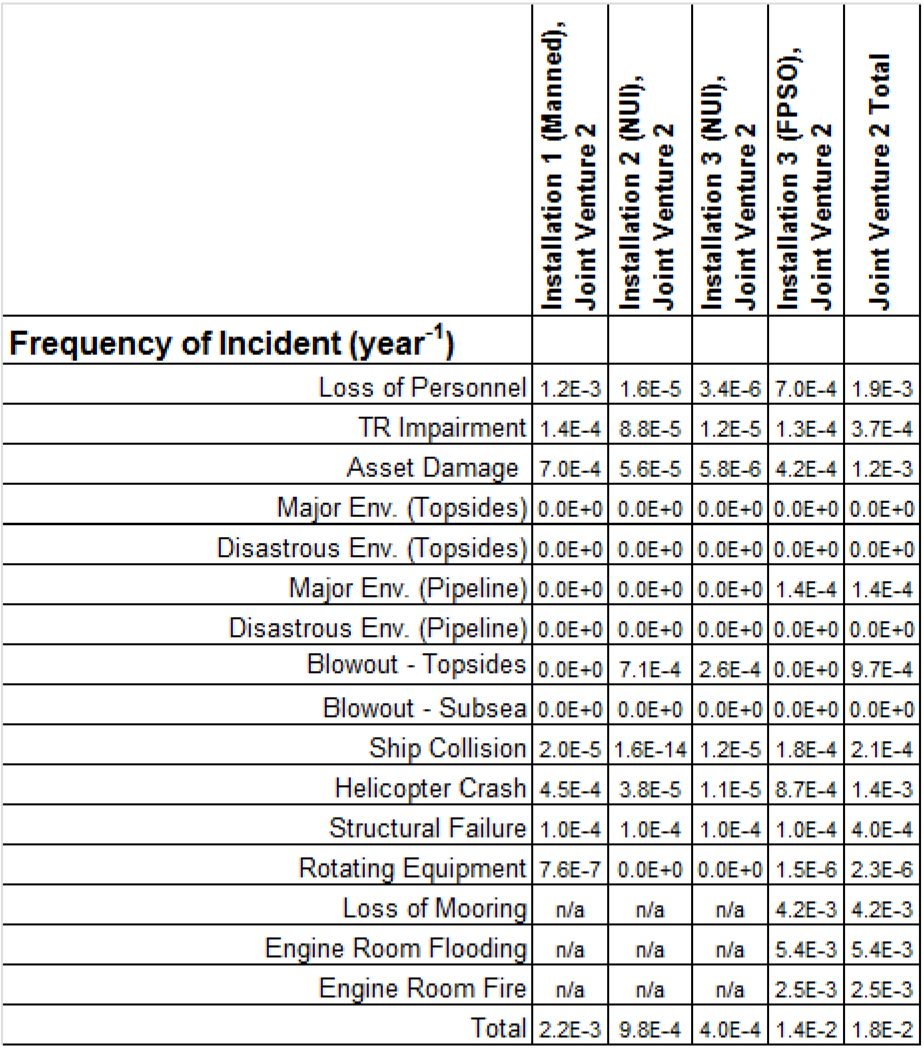


Figure 2: Major Incident Frequency Summary

Table 5 presents a summary of the results for a single Joint Venture including each of the individual installations.

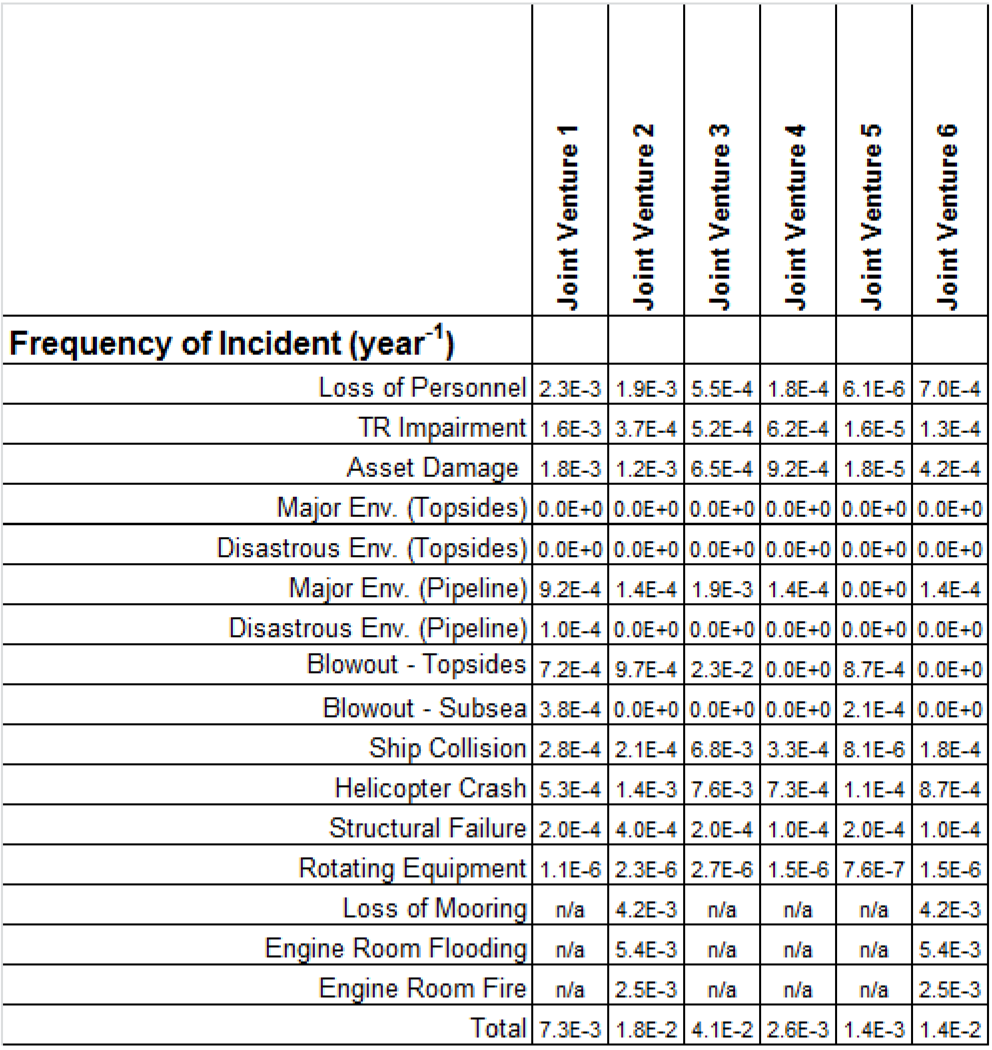


	Installation 1 (Manned), Joint Venture 2	Installation 2 (NUI), Joint Venture 2	Installation 3 (NUI), Joint Venture 2	Installation 3 (FPSO), Joint Venture 2	Joint Venture 2 Total
Frequency of Incident (year^{-1})					
Loss of Personnel	1.2E-3	1.6E-5	3.4E-6	7.0E-4	1.9E-3
TR Impairment	1.4E-4	8.8E-5	1.2E-5	1.3E-4	3.7E-4
Asset Damage	7.0E-4	5.6E-5	5.8E-6	4.2E-4	1.2E-3
Major Env. (Topsides)	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
Disastrous Env. (Topsides)	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
Major Env. (Pipeline)	0.0E+0	0.0E+0	0.0E+0	1.4E-4	1.4E-4
Disastrous Env. (Pipeline)	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
Blowout - Topsides	0.0E+0	7.1E-4	2.6E-4	0.0E+0	9.7E-4
Blowout - Subsea	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
Ship Collision	2.0E-5	1.6E-14	1.2E-5	1.8E-4	2.1E-4
Helicopter Crash	4.5E-4	3.8E-5	1.1E-5	8.7E-4	1.4E-3
Structural Failure	1.0E-4	1.0E-4	1.0E-4	1.0E-4	4.0E-4
Rotating Equipment	7.6E-7	0.0E+0	0.0E+0	1.5E-6	2.3E-6
Loss of Mooring	n/a	n/a	n/a	4.2E-3	4.2E-3
Engine Room Flooding	n/a	n/a	n/a	5.4E-3	5.4E-3
Engine Room Fire	n/a	n/a	n/a	2.5E-3	2.5E-3
Total	2.2E-3	9.8E-4	4.0E-4	1.4E-2	1.8E-2

Table 5: Major Incident Summary for Joint Venture 2

Table 6 presents the results for a range of Joint Ventures which are also presented pictorially as follows:

- Figure 3 – Major Incidents Frequency per year;
- Figure 4 – Major Incidents per 10^9 BOE produced;
- Figure 5 – Major Incidents per £10^9 revenue;
- Figure 6 – Major Incidents multiplied by £10^9 revenue.



Frequency of Incident (year^{-1})	Joint Venture 1	Joint Venture 2	Joint Venture 3	Joint Venture 4	Joint Venture 5	Joint Venture 6
Loss of Personnel	2.3E-3	1.9E-3	5.5E-4	1.8E-4	6.1E-6	7.0E-4
TR Impairment	1.6E-3	3.7E-4	5.2E-4	6.2E-4	1.6E-5	1.3E-4
Asset Damage	1.8E-3	1.2E-3	6.5E-4	9.2E-4	1.8E-5	4.2E-4
Major Env. (Topsides)	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
Disastrous Env. (Topsides)	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
Major Env. (Pipeline)	9.2E-4	1.4E-4	1.9E-3	1.4E-4	0.0E+0	1.4E-4
Disastrous Env. (Pipeline)	1.0E-4	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
Blowout - Topsides	7.2E-4	9.7E-4	2.3E-2	0.0E+0	8.7E-4	0.0E+0
Blowout - Subsea	3.8E-4	0.0E+0	0.0E+0	0.0E+0	2.1E-4	0.0E+0
Ship Collision	2.8E-4	2.1E-4	6.8E-3	3.3E-4	8.1E-6	1.8E-4
Helicopter Crash	5.3E-4	1.4E-3	7.6E-3	7.3E-4	1.1E-4	8.7E-4
Structural Failure	2.0E-4	4.0E-4	2.0E-4	1.0E-4	2.0E-4	1.0E-4
Rotating Equipment	1.1E-6	2.3E-6	2.7E-6	1.5E-6	7.6E-7	1.5E-6
Loss of Mooring	n/a	4.2E-3	n/a	n/a	n/a	4.2E-3
Engine Room Flooding	n/a	5.4E-3	n/a	n/a	n/a	5.4E-3
Engine Room Fire	n/a	2.5E-3	n/a	n/a	n/a	2.5E-3
Total	7.3E-3	1.8E-2	4.1E-2	2.6E-3	1.4E-3	1.4E-2

Table 6: Major Incident Summary by Joint Venture

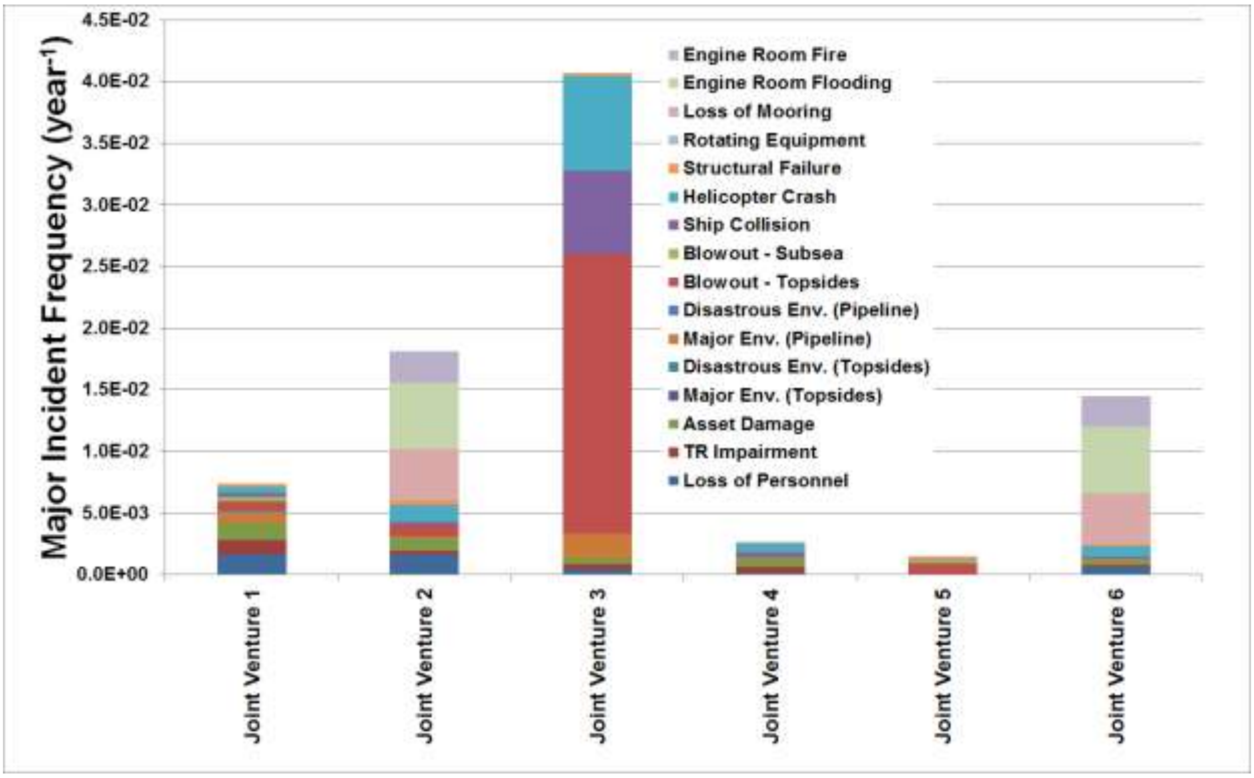


Figure 3: Major Incidents Frequency Per Year

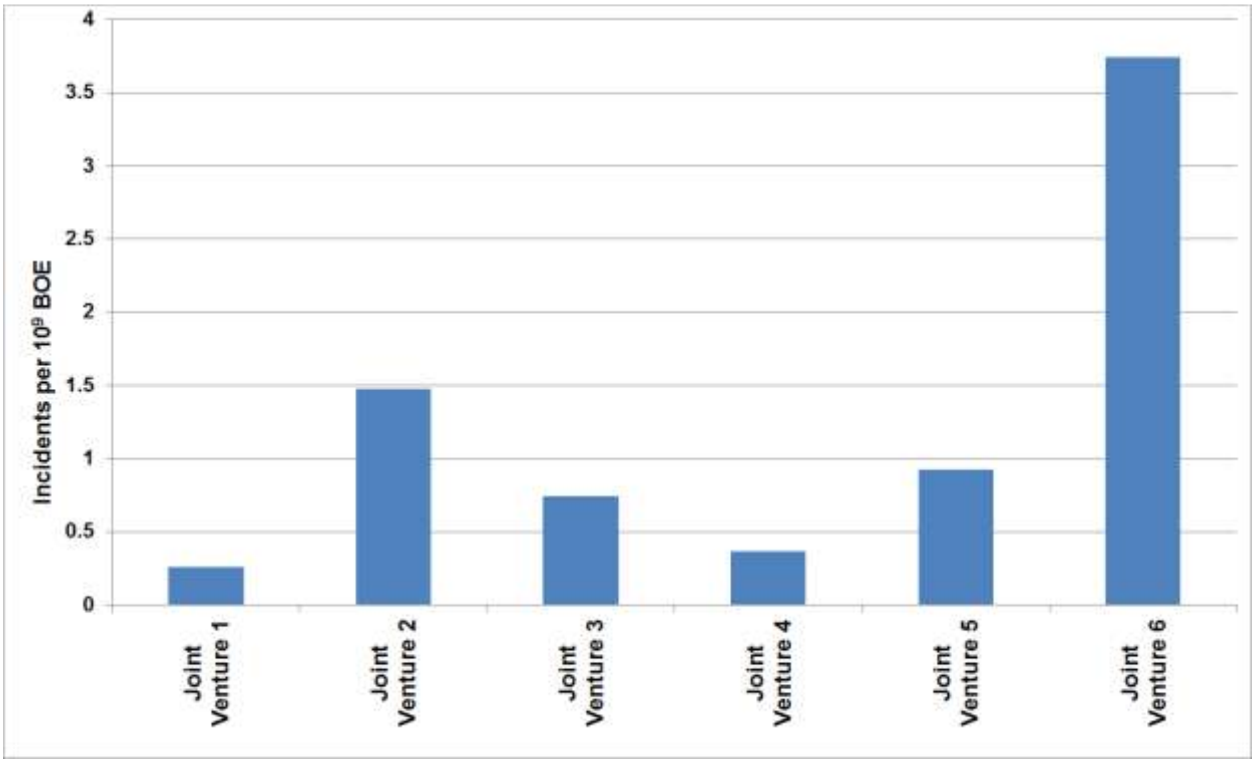


Figure 4: Major Incidents per 10^9 BOE Produced (Overall Joint Venture)

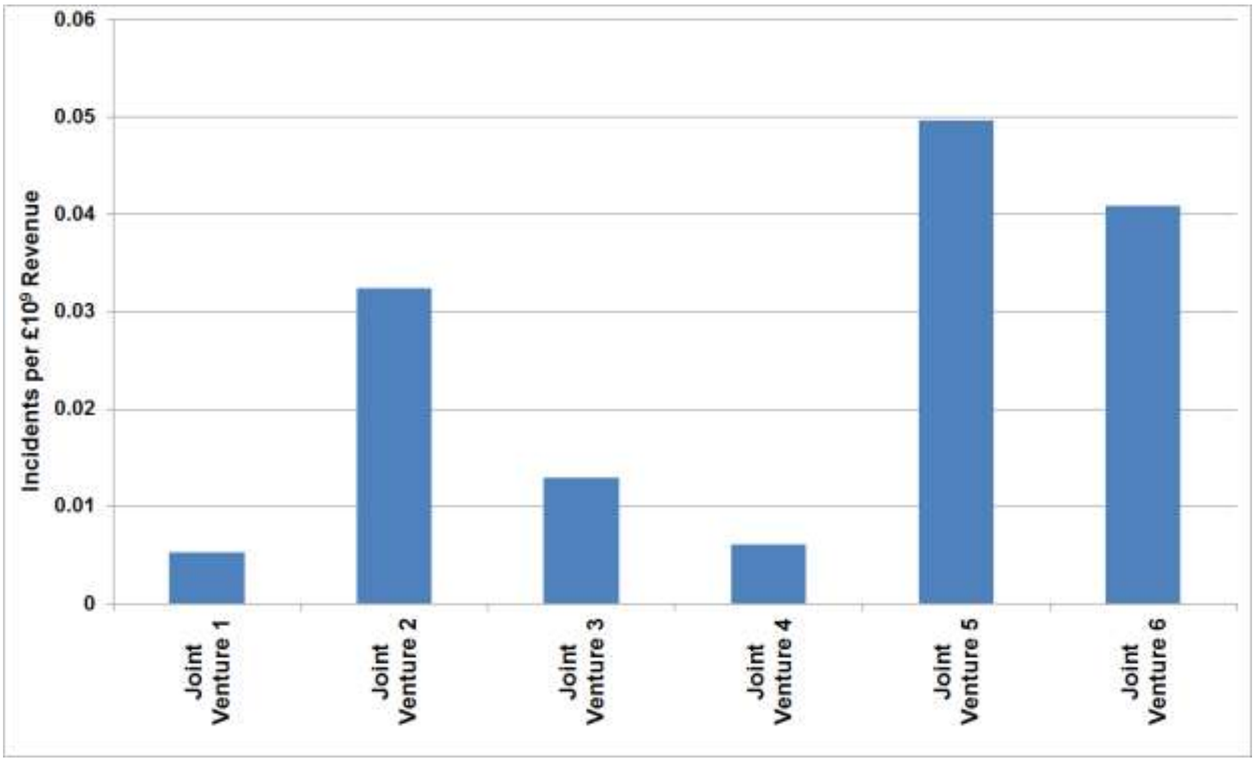


Figure 5: Major Incidents per £10^9 Revenue (Overall Joint Venture)

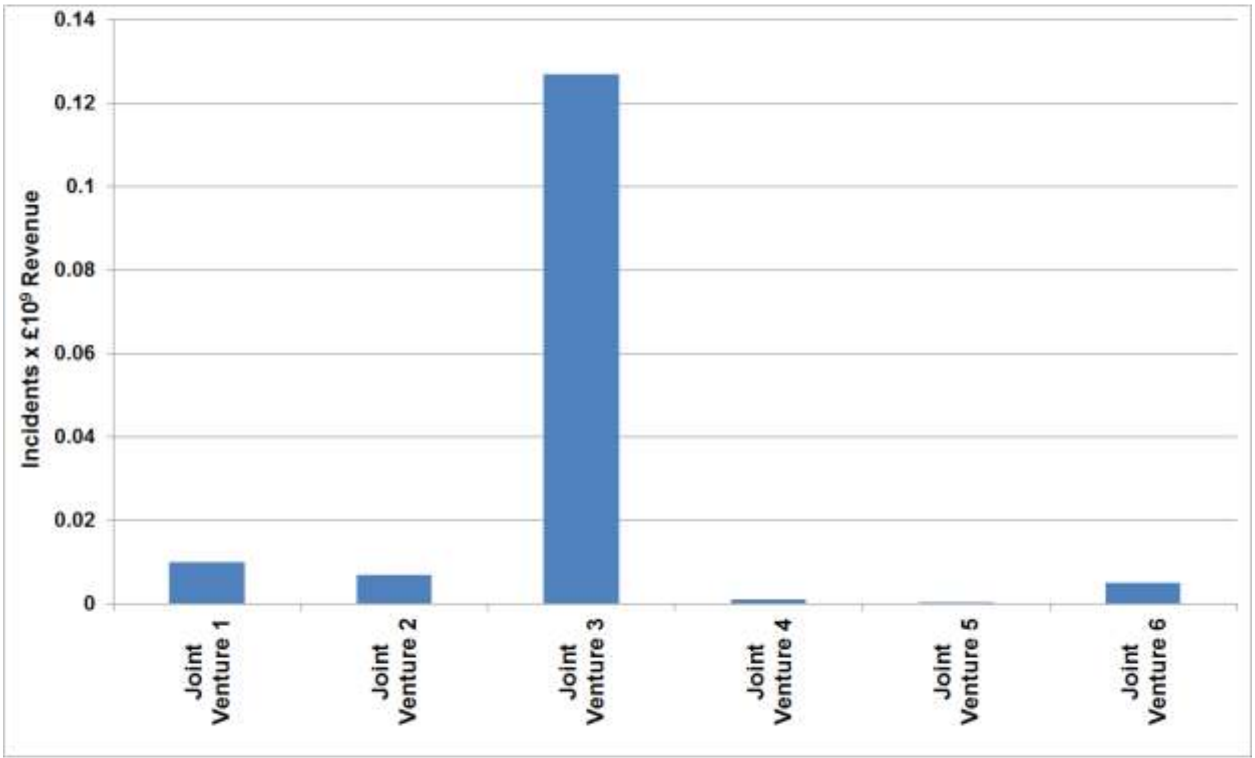


Figure 6: Major Incidents multiplied by £10^9 Revenue (Overall Joint Venture)

Summary

In summary the methodology presented in this paper presents an efficient and transparent methodology for undertaking a high level assessment of risks across a range of installation types. It allows a like for like comparison of the risks across these installations and also provides the operator with a set of results which can guide future discussions of risk and potential liability.

Safety Cases, and the assessment of Major Accident Hazards they contain, are not required to analyze the economic and environmental hazards that may occur. The model presented extends current QRA methodologies to quantify these risks.

Validation of the model is still required to give confidence in calculated leak frequencies and other parameters. Comparisons of existing asset QRAs and their respective Major Incident Assessments carried in this analysis are ongoing. This will include analysis of leak frequencies, probable loss of life calculations (PLL), individual risk calculations (IRPA) and helicopter incident data. The sensitivity of the model to the various assumptions listed throughout this paper will also be investigated.

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