Jurnal Kejuruteraan 37(5) 2025: 2231-2242
https://doi.org/10.17576/jkukm-2025-37(5)-16

Drone Technology Improves Personnel Safety in Offshore Working Environment Via Quantitative Risk Assessment (QRA) Analysis

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Received 9 January 2025, Received in revised form 19 May 2025
Accepted 20 June 2025, Available online 30 August 2025

ABSTRACT

Personnel safety in offshore environments is a critical concern due to the high-risk operations involving oil and gas extraction. Quantitative Risk Assessment (QRA) provides a systematic approach to identify, analyse, and mitigate potential hazards in these challenging settings. This paper explores the application of QRA in assessing offshore safety risks, focusing on evaluating accident scenarios such as hydrocarbon leaks, explosions, fires, occupational hazards, and structural failures. Incorporating statistical models and historical incident data into the analysis, QRA quantifies the likelihood and consequences of hazardous events, offering a clear perspective on individual risk per annum (IRPA) and potential loss of life (PLL) for offshore personnel. Integrating drones into offshore operations significantly enhances safety and risk management, especially for Remote, Normally Unmanned Offshore Production Platforms (RNUOPP). Using drones is theoretically foreseen to reduce the PLL and lower the IRPA. Drones provide real-time, high-resolution data that improve the accuracy of QRA models by facilitating frequent and detailed inspections of critical infrastructure, such as pipelines, flare stacks, and other hard-to-reach areas, without exposing personnel to hazardous conditions. By enabling early detection of equipment deterioration, corrosion, or structural issues, drones help prevent accidents before they escalate, significantly reducing the likelihood of catastrophic events like explosions or spills. This proactive approach minimises the potential for accidents and decreases PLL by reducing worker exposure to high-risk tasks. Furthermore, by automating inspections and eliminating the need for personnel to conduct dangerous manual tasks, drone usage directly lowers IRPA, enhancing overall offshore safety.

Keywords: Quantitative Risk Assessment (QRA); Individual Risk Per Annum (IRPA); Potential Loss of Life (PLL); unmanned offshore platform; drone

INTRODUCTION

Safety is a crucial factor in offshore oil and gas production facilities. A low-risk event may severely impact the company's workers' safety, assets, environment, and reputation if not properly addressed. Since an oil and gas company has a considerable risk of accidents, a risk assessment should be applied, and actions should be taken to address the identified risks.

To prevent accidents that might affect the safety of personnel, facilities, environments, or the company's reputation, an oil and gas company should implement the operation safety case (OSC) contained in a risk assessment. The OSC will identify and quantify any risks involved in the operations, thereby revealing the risk level. Depending on the risk value, the risks can be controlled or reduced by several activities to make the risk acceptable as low as reasonably practicable (ALARP) (Kumaraningrum et al. 2019).

Using drones in various industries has revolutionised safety protocols by minimising personnel exposure to hazardous environments.

The use of drones for offshore or upstream oil and gas facilities has developed rapidly in the past decade. One of the primary benefits of using drones for oil and gas industry operations is the significant reduction in human exposure to dangerous environments. Drones can perform inspections in high-risk areas, such as offshore platforms, flare stacks, and pipelines, without putting personnel at risk (Equinox Drones 2024).

Remote inspection of hazardous areas, for example, drones are increasingly employed to inspect areas that are dangerous or difficult for human workers to access. Drones can be deployed to perform inspections of oil rigs, pipelines, or power plants, reducing the need for workers to enter these potentially dangerous areas physically. Workers can also avoid dangerous scaffolding or high structures by using drones to check progress, inspect high-mounted equipment, or monitor for structural integrity. For example, by using aerial drones to undertake routine and tailored inspections, companies can decrease the time and money that typically goes into the process. On the Block Island Wind Farm Installation (Rhode Island, USA), the ULC Custom-Developed Hexacopter UAS has been in use since September 2019. This drone was able to obtain photographic data on all key inspection points in only 25% of the time that it would typically take to manually inspect the same areas (Seagard 2020). This equates to a 100% reduction in human exposure time to the task by replacing it with drones and a 75%-time reduction to complete the same task.

In disaster situations like fires, chemical spills, gas, or radiation leaks, drones can assess the damage and identify dangers before human investigation or rescue teams enter. By reducing the number of workers sent into dangerous environments, drones drastically cut the risk of injury or fatality.

The drone can also enhance surveillance and monitoring. Drones equipped with high-definition cameras and sensors can provide real-time data on working conditions, improving the ability to monitor safety compliance at construction sites, large industrial facilities, and, in this case, offshore oil and gas production facilities. The drone can track environmental conditions such as gas leaks, chemical spills, air quality, and signs of dangers like structural weaknesses or weather changes. This proactive approach allows management to make informed decisions and take preventive action before accidents occur.

In terms of emergency response, drones can improve the response and decision-making. In emergency scenarios such as fires, earthquakes, or chemical spills, drones can be deployed quickly to assess the scale of the incident, identify potential hazards, and locate trapped or injured personnel without putting first responders in immediate danger. Recently, drone capabilities have been developed to deliver medical supplies or communication devices to remote or hazardous areas. Drones may also guide rescue teams with precise real-time imagery, reducing the need for personnel to take unnecessary risks. These capabilities ensure that emergency responders are better informed and can act more safely and efficiently.

Using drones for offshore oil and gas production facilities is also foreseen to reduce human fatigue and risk exposure. Certain tasks traditionally performed by personnel, such as preventive maintenance, visual inspections, and data collection, can now be carried out by drones, and workers no longer need to travel great distances in potentially hazardous environments, reducing accidents due to fatigue. Drone usage will minimise the risk exposure when drones can be deployed to operate in extreme weather, such as monsoon season with high windspeed, high swells, or dangerous terrain, meaning that human workers are not put in harm's way.

The drone can provide accurate data collection and risk management. Drones equipped with advanced sensors and artificial intelligence can gather precise data on environmental hazards. This includes thermal imaging to detect heat sources in industrial sites or, in this case, for offshore oil and gas facilities and minimising fire risks. Gas detection sensors mounted on drones will enable the capability to measure dangerous chemical levels, ensuring that personnel are not exposed to toxic gases.

Regarding training and simulation, drones are also used for safety training in construction, mining, or oil and gas industries. Drone technology can simulate risky environments or disaster scenarios, allowing workers to practice safety protocols without facing real danger. This prepares personnel for emergencies while reducing the chances of error in actual dangerous situations.

In conclusion, through the proper management of change (MoC) process to implement drone technology offshore, these risks may be brought down to ALARP and demonstrated by using quantitative methods such as Quantitative Risk Assessment (QRA) or Bowtie (Syazarudin et al. 2022). Drone technology is transforming safety standards across multiple industries, and this research focuses on personnel safety improvement for offshore oil and gas production environments. By taking over tasks that traditionally involved significant risk to human personnel, drones reduce the likelihood of accidents and improve the overall efficiency of operations. This can be demonstrated using Quantitative Risk Assessment (QRA) with Individual Risk Per Annum (IRPA) and Potential Loss of Life (PLL) as the tangible results to support this research.

OBJECTIVES

This research's main objective is to quantitatively demonstrate how drones' use at RNUOPP improves personnel safety using the QRA method by analysing IRPA and PLL comparisons between conventional human approaches and the latter.

This objective can be achieved by identifying the following at the initial stage:

1. Identify and improve major risk contributing factors.
2. Identify areas where drone technology can be introduced to reduce the personnel safety risk As Low as Reasonably Practicable (ALARP). Subsequently, risk levels will be compared and evaluated before and after the implementation of drone technology.

RESULTS PRESENTATION

The results of this personnel safety QRA method will be represented by two main parameters, which are:

1. Individual Risk Per Annum (IRPA) and
2. Potential Loss of Life (PLL).

INDIVIDUAL RISK PER ANNUM (IRPA)

IRPA is the annual fatality risk of one specific individual from a selected category depending on the probability of presence in an area. The IRPA considers how much time each worker spends at the field facilities, including normal transportation between the facilities. The formula for IRPA calculation is given in Equation 1 below.

IRPA
*=Number of hours per day (**a** hours)*
*×Number of working days per year (**b** days)*
×Location Specific Individual Risk

Note: LSIR is the risk that will be exposed to a person who is present at that location 24 hours and 365 days.

EQUATION 1. Individual Risk Per Annum (IRPA) Equation
Source: How to Calculate Individual Risk Per Annum (IRPA) in *Safeti* using PLL, Det Norske Veritas, 2024

The IRPA is the sum of risk contributions from process risks (hydrocarbon release events from topsides, risers, pipelines, and blowouts) and non-process risks (ship collision, transportation, structural failure, and occupational risks). The acceptable categories of IRPA for workers and the public are in Figure 1 and Table 1 below.

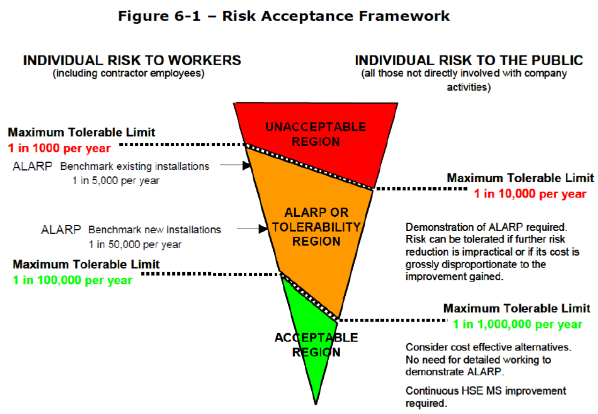

FIGURE 1. Individual Risk Per Annum (IRPA) Acceptance Framework Example
Source: Drilling Safe Wells Through Efficient, Rapid and Site-Specific Planning to Manage Risks & Improve Performance, Abu Dhabi International Petroleum Exhibition & Conference, 2016

TABLE 1. Individual Risk Per Annum Tolerance Criteria

Individual Risk Per Annum (IRPA) Value per Year	Tolerance Category
$> 1\times10^{-4}$	Intolerable for the public.
$> 1\times10^{-3}$	Intolerable for workers.
$< 1\times10^{-6}$	It can be considered broadly acceptable without further expenditure on risk reduction measures, as it is comparable to everyday risks that people consider insignificant.
$1\times10^{-3} < IRPA < 1\times10^{-6}$	Tolerable, provided all practical measures to reduce risk have been considered and implemented if cost-effective. This is referred to as the ALARP region.

Source: IChemE Hazards 30, Symposium Series No 167, Confusion Over Risk Criteria, 2020

IRPA is a useful measure because it considers the proportion of time personnel spend working in each platform location based on the job function and is independent of the number of people exposed.

This will assist in developing an enhanced safety protocol or system that accurately calculates Individual Risk per Annum, allowing companies to identify high-risk areas and implement preventive measures. This solution will integrate advanced technologies like drones, sensors, and real-time analytics to monitor, predict, and reduce individual risk throughout the year.

POTENTIAL LOSS OF LIFE (PLL)

Potential Loss of Life (PLL) is another risk assessment parameter used to estimate the number of fatalities that could result from hazardous events or accidents in a particular environment, industry, or operation over a specific period. It helps organisations quantify the potential human cost of safety failures or high-risk activities. The equation for PLL is demonstrated in Equation 2 below.

$$PLL_{event} = IRPA_{event} \times N \times N_s$$

N = Number of personnel.
N_s = Number of workdays per year.

EQUATION 2. Individual Risk Per Annum (IRPA) Equation
Source: How to Calculate Individual Risk Per Annum (IRPA) in Safeti using PLL, Det Norske Veritas, 2024

HYPOTHESIS

This research's initial hypothesis anticipates that drones' deployment at remote and normally unmanned offshore production platforms (RNUOPP) to perform routine preventive maintenance, surveillance, and data gathering will reduce the requirement for human deployment, direct physical involvement, or movement from central platforms to RNUOPP, subsequently reducing the risk and exposure to the associated hazards.

This reduction in hazard exposure and improvement in personnel safety can be tangibly demonstrated through QRA analysis.

METHODOLOGY

The main steps in conducting QRA are as follows and can be demonstrated in Figure 2 below:

1. Identify the site or location to be assessed.
2. Location hazard identification.
3. Location hazard event frequency estimation.
4. Location fatality estimation.
5. Location Risk summation and ranking.
6. Risk (IRPA and PLL) analysis.

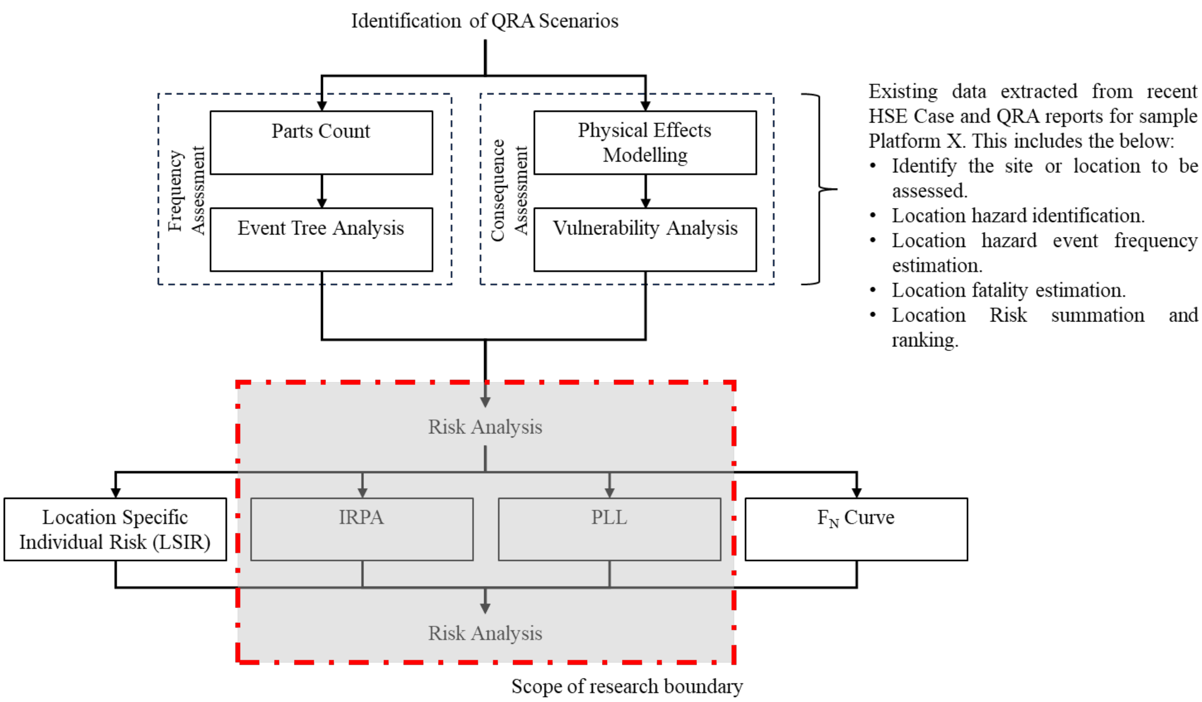

FIGURE 2. QRA Methodology Process Flow with Scope of Research Boundary Demarcation
Source: Introduction to QRA, TÜV Rheinland, Risktec, 2025

SITE OR LOCATION IDENTIFICATION

This study will use one (1) sample remote and normally unmanned offshore production platform from Company X, operating in Malaysia. This platform faces monsoon season logistical challenges, such as transporting workers or personnel from the central platform to these remote, normally unmanned production platforms by boats, as depicted in Figure 3 below.

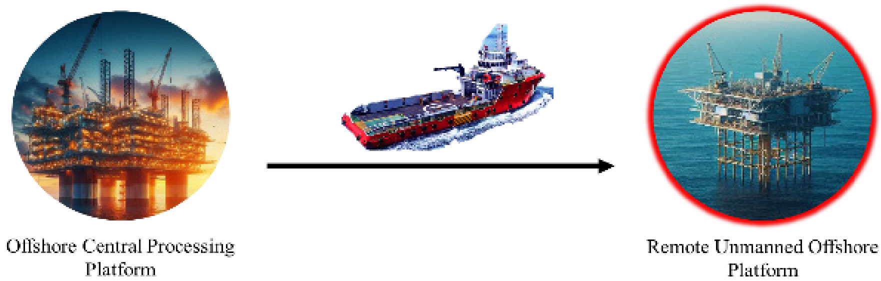

FIGURE 3. Personnel Normally Deployed to Remote Unmanned Offshore Platform by Boat

LOCATION HAZARD IDENTIFICATION

The hazards for RNUOPP for Company X can be divided into two (2) categories:

1. Hydrocarbon associated hazards.
2. Non-hydrocarbon Associated hazards.

Hydrocarbon-associated hazards are typically process-related and may cause an explosion or fire event. An example is gas release, which accumulates, reaches critical gas cloud size, ignites, and subsequently causes overpressure and thermal radiation, which may cause injury or fatality.

Other non-hydrocarbon-associated hazards are non-process-related. Examples include lifting incidents, dropped objects, boat collisions, and men overboard.

LOCATION HAZARD EVENT FREQUENCY ESTIMATION

Frequency is the likelihood of an event occurring per year for each hazard. The probability outcome of each specific hazard event is based on historical trends, industry data, and simulations. The final frequency of a hazard event is estimated by combining probabilities of the appropriate branches from the hazard event tree analysis (ETA).

LOCATION FATALITY PROBABILITY ESTIMATION

In fatalities estimation, the probability of fatalities in the pre-identified or to be-studied area, by combining fatality probability in one (1) year, based on consequence modelling outcome for each hazard event related to RNUOPP (i.e., operating heavy machinery, managing chemicals, working at heights, boat transfer, etc.)

Combining frequency and consequence, the formula for risk (R) to estimate the fatality potential is given in Equation 2 below:

$$Risk = P_{event} \times P_{fatality\text{-}event}$$

P_{event} = Probability of hazard event occurrence in a year
$P_{fatality\text{-}event}$ = Probability of fatality from a hazard event

EQUATION 3. Location Fatality Probability Estimation Equation
Source: How to Calculate Individual Risk Per Annum (IRPA) in *Safeti* using PLL, Det Norske Veritas, 2024

LOCATION RISK SUMMATION AND RANKING

These frequencies and consequences of the various hazard event outcomes will be integrated to quantify the non-hydrocarbon and hydrocarbon risk levels at the location using the process hazard analysis software (PHAST) software. The hydrocarbon and non-hydrocarbon risk contributors will then be summarised, and subsequent personnel, overall risk rankings to personnel, will be demonstrated.

LOCATION RISK ASSESSMENT

The last step of the QRA will be the risk assessment. The estimated risk levels will be compared with the organisation's risk acceptance criteria to determine if additional risk reduction intervention is required to reduce the risks to ALARP.

PLATFORM X QUANTITATIVE RISK ASSESSMENT (QRA) AT NORMAL OPERATING CONDITION

This QRA study for Platform X, which is foreseen to implement drone technology for routine activities, will assess the risks from hydrocarbon-associated and non-hydrocarbon-associated hazards identified on this platform.

This study assumes Platform X is an RNUOPP with the below manning under normal operations.The next assumption is that the personnel listed in Table 2 will be working on a rotational basis, with two weeks on duty (14 days) and two weeks off duty. This means they will work approximately 182 days per year, N_s value.

TABLE 2. Manning Level During Normal Operations Per Day on Platform X

Personnel Trade	Number of Personnel, *N*
Electrical & Instrumentation Technician	2
Mechanical Technician	1
Production Technician	1
Crane Operator	1
Total	5

By default, the offshore personnel will be working a 12-hour shift per day. The productive time is estimated to be 10 hours, with 2 hours allocated for travelling (since Platform X is RNUOPP), work preparation, and resting time. The productive time at Platform X is demonstrated in Table 3 below.

TABLE 3. Time Spend (hours) at Platform X Working Areas Per Day

	Main Deck *Note 2*	Mezzanine Deck *Note 2*	Lower Deck Zone 1 *Note 1*	Lower Deck Zone 2 *Note 1*	Lower Deck Work & Tooling Room *Note 1*	Jacket Deck- Well *Note 1 & Note 2*	Jacket Deck - Riser Leg *Note 2*	Total (hours)
Electrical & Instrumentation Technician	1.0	2.0	1.0	2.0	3.0	0.0	1.0	10.0
Mechanical Technician	1.0	2.0	1.0	2.0	3.0	0.0	1.0	10.0
Production Technician	1.0	1.0	2.5	1.0	3.0	0.5	1.0	10.0
Crane Operator	0.0	8.0	0.0	0.0	0.0	1.5	0.5	10.0

Note:

1. Area identified to be exposed to hydrocarbon-associated hazards (i.e., explosion, flash fire, jet fire, etc.).
2. Area identified to be exposed to non-hydrocarbon-associated hazards (i.e., dropped objects, occupational hazards, boat transportation, etc.)

The Platform X Fire and Explosion Risk Assessment (FERA) report is assumed to provide an in-depth analysis of the consequences and frequencies of hydrocarbon-associated hazards. This is a typical intensive report or analysis for a specific work location that considers hydrocarbon leak frequencies, varied sizes of leaks, operating conditions, inventory sizes, critical gas cloud sizes, types of fire and explosion events, and impairment frequencies.

The risks from hydrocarbon-associated hazards and non-flammable hazards are assumed to be from the below listed:

1. Well hydrocarbon unintentional release or blow-out at Platform X.
2. Platform X topside facilities unintentional hydrocarbon release.
3. Pipeline riser at topside, unintentional hydrocarbon release at Platform X.

These values from each hydrocarbon hazard event's estimated frequencies and probabilities will be used to generate the hydrocarbon-associated Location Specific Individual Risk (LSIR), which for this study is 1.34×10^{-7}.

The non-hydrocarbon associated hazards for Platform X are assumed based on *Petronas Technical Standard for Quantitative Risk Assessment (QRA), Document No: EP HSE SG 04 14, February 2014* guidance. The applicable hazards are listed:

1. Boat transportation.
2. Occupational hazards.
3. Structural failure.

INDIVIDUAL RISK PER ANNUM (IRPA) FOR PLATFORM X UNDER NORMAL OPERATING CONDITIONS

The pre-calculated non-hydrocarbon Location, Specific Individual Risk for Platform X for this study, is 7.73×10^{-7}. Based on the information provided for Platform X at normal operating conditions, which considering the monsoon season, the value of IRPA for hydrocarbon-associated hazards is calculated from Equation 1 and demonstrated in Table 4 below.

TABLE 4. Hydrocarbon Associated Hazards IRPA for Each Worker (Trade) Under Normal Operating Condition

	Hours Working at Hydrocarbon Risk Areas	Hours Working at Hydrocarbon Risk Areas, *a* (converted into day)	Expected Working Days per Year, *b*	Estimated IRPA at Normal Working Condition
Electrical & Instrumentation Technician	6.0	0.3	182	6.08×10^{-6}
Mechanical Technician	6.0	0.3	182	6.08×10^{-6}
Production Technician	7.0	0.3	182	7.09×10^{-6}
Crane Operator	1.5	0.1	182	1.52×10^{-6}

Next are the IRPA values for non-hydrocarbon-associated hazards, calculated from Equation 1 and demonstrated in Table 5 below.

TABLE 5. Non-Hydrocarbon Associated Hazards IRPA for Each Worker (Trade) Under Normal Operating Condition

	Hours Working at Non-Hydrocarbon Risk Areas	Hours Working at Non-Hydrocarbon Risk Areas, *a* (converted into day)	Expected Working Days per Year, *b*	Estimated IRPA at Normal Working Condition
Electrical & Instrumentation Technician	4.0	0.2	182	2.34×10^{-5}
Mechanical Technician	4.0	0.2	182	2.34×10^{-5}
Production Technician	3.5	0.1	182	2.05×10^{-5}
Crane Operator	10.0	0.4	182	5.86×10^{-5}

Adding hydrocarbon IRPA (Table 4) and non-hydrocarbon IRPA (Table 5) for each worker will give the overall IRPA values under normal operating conditions, as summarised in Table 6.

TABLE 6. Overall IRPA for Each Worker Category for Platform X Under Normal Operating Condition

	Overall IRPA
Electrical & Instrumentation Technician	2.95×10^{-5}
Mechanical Technician	2.95×10^{-5}
Production Technician	2.76×10^{-5}
Crane Operator	6.01×10^{-5}

POTENTIAL LOSS OF LIFE (PLL) FOR PLATFORM X UNDER NORMAL OPERATING CONDITION

The total potential loss of life (PLL) for Platform X under the hydrocarbon-associated hazards scenario is calculated from previously provided Equation 2, data from Table 2 and Table 4, and demonstrated in Table 7 below.

This assumes each worker category works 182 days per year and a maximum of ten productive hours per day on Platform X.

TABLE 7. Hydrocarbon Associated Hazards PLL for Each Worker (Trade) Under Normal Operating Condition

	Estimated IRPA at Normal Working Condition	Estimated PLL at Normal Working Condition
Electrical & Instrumentation Technician	6.08×10^{-6}	5.53×10^{-4}
Mechanical Technician	6.08×10^{-6}	2.76×10^{-4}
Production Technician	7.09×10^{-6}	3.76×10^{-4}
Crane Operator	1.52×10^{-6}	1.73×10^{-5}
Total		1.22×10^{-3}

Next, the total PLL for Platform X for non-hydrocarbon associated hazards is also calculated from previously provided Equation 2, data from Table 2 and Table 5, and demonstrated in Table 8 below.

The same assumptions of the number of days per year and working hours used to calculate the previous PLL are used.

TABLE 8. Non-Hydrocarbon Associated Hazards PLL for Each Worker (Trade) Under Normal Operating Condition

	Estimated IRPA at Normal Working Condition	Estimated PLL at Normal Working Condition
Electrical & Instrumentation Technician	2.34×10^{-5}	1.42×10^{-3}
Mechanical Technician	2.34×10^{-5}	7.11×10^{-4}
Production Technician	2.05×10^{-5}	5.44×10^{-4}
Crane Operator	5.86×10^{-5}	4.44×10^{-3}
Total		7.12×10^{-3}

Adding PLL values from hydrocarbon-associated hazards (1.22×10^{-3}) and non-hydrocarbon-associated hazards (7.12×10^{-3}) will give Platform X a potential loss of life, PLL, under normal operating conditions of 8.34×10^{-3}.

PROJECTED PLATFORM X QUANTITATIVE RISK ASSESSMENT (QRA) WITH DRONE PROJECT

This section will assume the drone project is deployed and only used during monsoon season, when deploying personnel will be challenging.

However, routine preventive maintenance and surveillance still need to be done. The monsoon season assumption is based on typical Malaysian weather trends. The monsoon starts in October, continues throughout the year, and ends in February at the beginning of the year for five months (*Jabatan Meteorologi Malaysia*. 2024).

The next assumption is that each worker category can only work 7 days for each 2-week on-duty rotation. That brings the total number of days each worker category cannot go to Platform X to thirty-five (35) throughout the monsoon season, or only one hundred forty-seven (147) days per year working, instead of one hundred eighty-two (182) days under normal operating conditions.

The rest of the parameters, such as the number of personnel or workers visiting Platform X, worker categories, and hazards for hydrocarbon and non-hydrocarbon, will remain the same per normal operating conditions. This reduction in the number of days working per annum is expected to reduce workers' exposure to the risk of hazards on Platform X, both hydrocarbon and non-hydrocarbon-associated. This assumes drones will be deployed during monsoon season to perform the minimum preventive maintenance, surveillance, and data gathering requirement and revert the data through the existing communication system (either wireless or hard subsea cables).

INDIVIDUAL RISK PER ANNUM (IRPA) FOR PLATFORM X WITH DRONE PROJECT IMPLEMENTED

Based on the assumptions from the previous section, different sets of IRPAs for hydrocarbon and non-hydrocarbon-associated hazards for Platform X with the drone project implemented can be generated as per Table 9 and Table 10, respectively.

TABLE 9. Hydrocarbon Associated Hazards IRPA for Each Worker (Trade) With Drones Implementation

	Total Hours Working at Hydrocarbon Risk Areas (hours)	Total Hours Working at Hydrocarbon Risk Areas, *a* (converted into day)	Expected Working Days Per Year, *b* with Drone (Monsoon Season)	Estimated IRPA with Drone Deployment
Electrical & Instrumentation Technician	6.0	0.3	147	4.91×10^{-6}
Mechanical Technician	6.0	0.3	147	4.91×10^{-6}
Production Technician	7.0	0.3	147	5.72×10^{-6}
Crane Operator	1.5	0.1	147	1.23×10^{-6}

TABLE 10. Non-Hydrocarbon Associated Hazards IRPA for Each Worker (Trade) With Drones Implementation

	Total Hours Working at Non-Hydrocarbon Risk Areas (hours)	Total Hours Working at Non-Hydrocarbon Risk Areas, *a* (converted into day)	Expected Working Days Per Year with Drone (Monsoon Season)	Estimated IRPA with Drone Deployment
Electrical & Instrumentation Technician	4.0	0.2	147	1.89×10^{-5}
Mechanical Technician	4.0	0.2	147	1.89×10^{-5}
Production Technician	3.5	0.1	147	1.66×10^{-5}
Crane Operator	10.0	0.4	147	4.73×10^{-5}

Adding hydrocarbon IRPA (Table 9) and non-hydrocarbon IRPA (Table 10) for each worker will give the overall IRPA values with the drone project implemented, as summarised in Table 11.

TABLE 11. Overall IRPA for Each Worker Category for Platform X With Drones Project Implemented

	Overall IRPA
Electrical & Instrumentation Technician	2.38×10^{-5}
Mechanical Technician	2.38×10^{-5}
Production Technician	2.23×10^{-5}
Crane Operator	4.86×10^{-5}

POTENTIAL LOSS OF LIFE (PLL) FOR PLATFORM X WITH DRONE PROJECT IMPLEMENTED

Similarly to the previous exercise, with the drone project implemented, the total PLL is calculated from previously provided Equation 2, data from Tables 2 and 9, and demonstrated in Table 12 below.

TABLE 12. Hydrocarbon Associated Hazards PLL for Each Worker (Trade) With Drones Implementation

	Estimated IRPA with Drone Deployment	Estimated PLL with Drone Deployment
Electrical & Instrumentation Technician	4.91×10^{-6}	3.61×10^{-4}
Mechanical Technician	4.91×10^{-6}	1.80×10^{-4}
Production Technician	5.72×10^{-6}	2.45×10^{-4}
Crane Operator	1.23×10^{-6}	1.13×10^{-5}
Total		7.98×10^{-4}

Next, the same steps are applied to calculate the total PLL for Platform X for non-hydrocarbon-associated hazards based on Equation 2, data from Table 2 and Table 10, and demonstrated in Table 13 below. The same assumptions of the number of days per year and working hours are used to calculate the previous PLL under normal operating conditions.

Adding PLL values from hydrocarbon-associated hazards (7.98×10-4) and non-hydrocarbon-associated hazards (4.65×10-3) will give Platform X potential loss of life, PLL with a drone project implemented at 5.44×10-3.

TABLE 13. Non-Hydrocarbon Associated Hazards PLL for Each Worker (Trade) With Drones Implementation

	Estimated IRPA with Drone Deployment	Estimated PLL with Drone Deployment
Electrical & Instrumentation Technician	1.89×10^{-5}	9.28×10^{-4}
Mechanical Technician	1.89×10^{-5}	4.64×10^{-4}
Production Technician	1.66×10^{-5}	3.55×10^{-4}
Crane Operator	4.73×10^{-5}	2.90×10^{-3}
Total		4.65×10^{-3}

RESULTS ANALYSIS AND COMPARISON

Figure 4 demonstrates that drone deployment to perform routine activities at RNUOPP, especially during logistically challenging periods such as monsoon season, will improve the overall IRPA for each worker's trade.

Workers do not need to be deployed to Platform X (RNUOPP) to perform these activities, reducing the exposure to hydrocarbon and non-hydrocarbon risks.

From Figure 4 below, the Crane Operator is identified to have the highest IRPA among other worker categories. This is because most contributions are from non-hydrocarbon-associated hazards for crane operators. Crane operators handle lifting equipment, working at height at crane pedestals, and climbing vertical monkey ladders, which takes most of their time.

The Crane Operator from Table 4 has the least IRPA related to hydrocarbon hazards due to his job nature, which does not require him to use hydrocarbon processing equipment. However, the combination of hydrocarbon and non-hydrocarbon IRPAs still indicates that the Crane Operator has the highest exposure, as indicated in Figure

From Table 4, Production Technicians demonstrate the highest IRPA for hydrocarbon-associated hazards due to the nature of their job, which requires them to deal with process parameters such as flow, pressure, and temperature daily to optimise oil and gas production safely.

However, when combined with the non-hydrocarbon-associated IRPA, the Production Technician indicates the lowest overall IRPA due to the nature of the job, which exposes it to fewer occupational hazards, as demonstrated in Figure 4.

Based on Figure 1, even though the existing IRPAs for each worker's category under normal operating conditions are already within the ALARP region, drone technology implementation is foreseen to improve this ALARP further and push down the workers' IRPAs towards an acceptable region, which is one (1) case for every 100,000 years.

Consistent with IRPA trends, the PLL for each work category also demonstrates improvement with the implementation of drone technology. This can be visualised in Figure 5 below.

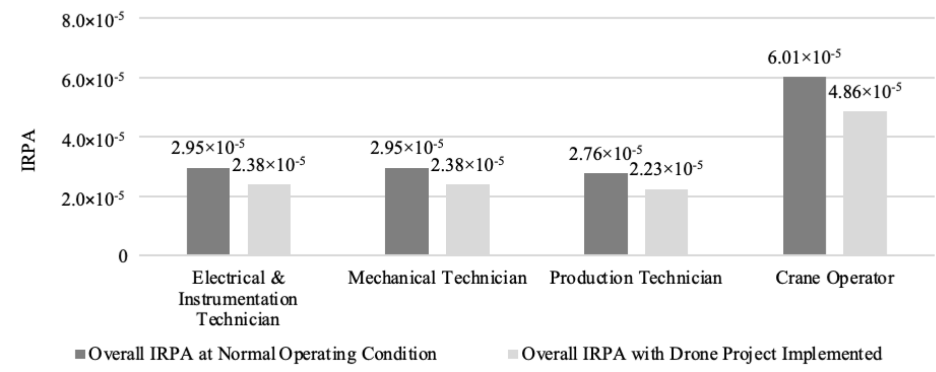

FIGURE 4. Platform X Individual Risk Per Annum (IRPA) Comparison

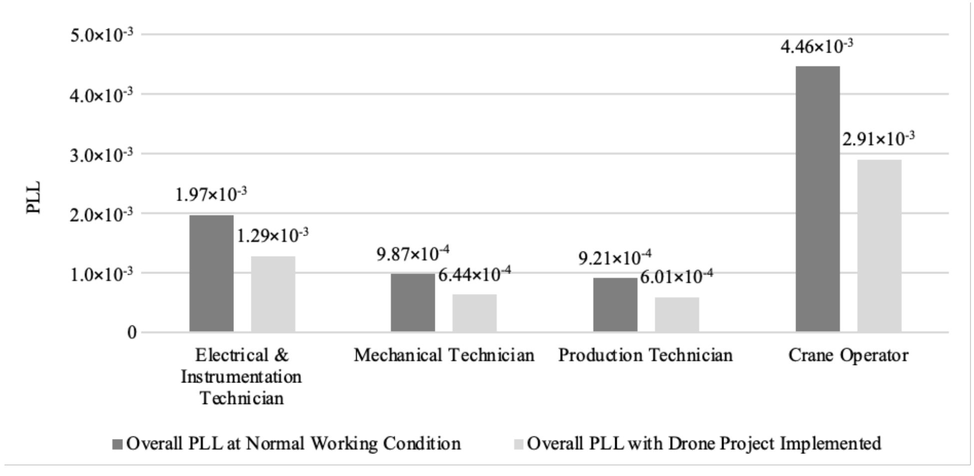

FIGURE 5. Platform X Potential Loss of Life (PLL) Breakdown by Work Trade Category Comparison

Overall PLL for Platform X is expected to improve approximately by 35%, reducing the potential of one (1) fatality case for every 120 years (8.34×10^{-3}) to one (1) fatality case for every 184 years (5.44×10^{-3}), with the implementation of drone technology for routine RNUOPP activities. This can be demonstrated in Figure 6 below.

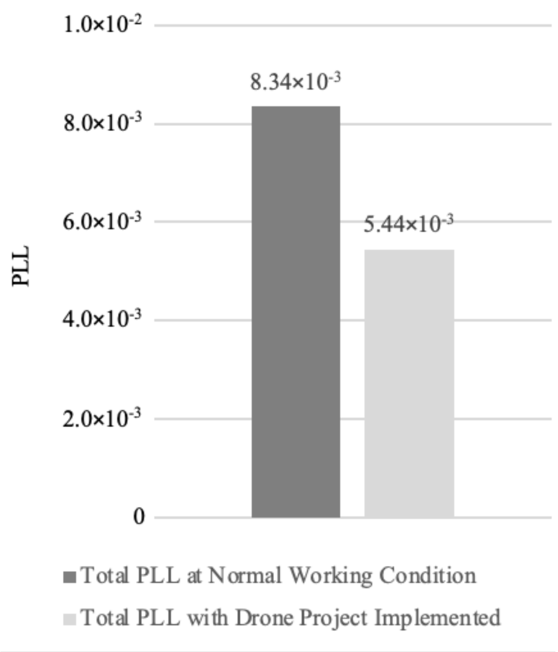

FIGURE 6. Platform X Overall Potential Loss of Life (PLL) Comparison

CONCLUSION

Using drones at remote, normally unmanned offshore production platforms (RNUOPP) is expected to further improve the safety of working personnel, reduce the potential loss of life, and directly provide a better and safer working environment.

This study's example is based only on one (1) RNUOPP, Platform X. If the drone project can be deployed to all other RNUOPPs surrounding a central processing platform, the overall IRPA and PLL values for the offshore oil production facilities are expected to improve significantly.

Not all activities at RNUOPP can be executed using drones. Extensive corrective maintenance, in-depth investigation, and pipeline inspection gauge (PIG) deployment will still require human intervention and presence. However, with the rapid advancement of drones, human capabilities are being duplicated in a more articulated approach, which opens the opportunity further to minimise human exposure to hydrocarbon and non-hydrocarbon hazards risks.

Multiple types of robots and drones with various sensors (payloads) enable acquiring data, including photographs, from diverse locations without disrupting operations while minimising personnel exposure to hazardous locations and confined spaces (SLB 2024). Drones are also expected to improve workflow and reduce cost, keeping people safe by replacing humans in higher-risk tasks (Petronas 2021). Regarding disaster or incident emergency response, drones are particularly useful in hazardous or contaminated areas where human access is restricted or dangerous, such as toxic gas leaks and explosive environments.

In summary, drones are expected to significantly reduce human risk, especially in dangerous environments such as offshore oil exploration and production. The offshore oil and gas industry is in the race to pursue unmanned solutions to increase efficiency, reduce costs, improve safety, meet regulatory requirements, and differentiate themselves in a competitive market. These factors make unmanned technologies or drones an attractive option for offshore oil and gas operations and a wide range of sectors, including manufacturing, logistics, agriculture, construction, healthcare, and defence.

ACKNOWLEDGEMENT

The authors would like to acknowledge the funding from the Universiti Kebangsaan Malaysia via Dana Impak Perdana to support this study (Reference: DIP-2023-010).

DECLARATION OF COMPETING INTEREST

None.

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