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Prioritization of the human health and safety loss factor subject to offshore pipeline accidents

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Prioritization of the human health and safety loss factor subject to offshore pipeline accidents

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Abstract. Accidents at the offshore platform are unavoidable due to un[illegible] reasons. The nature of its operations involves unstable materials sometimes under extreme pressure in aggressive environments lead to increase in risk thus accidents and tragedies can cause higher severity to platform's workers. Risk assessment in oil and gas (O&G) industry are essential to protect human and ecosystem from damages as it helps to create awareness and identify if existing control measure are adequate enough or vice versa for hazards and risks before accident happens. Consequence of failure (CoF) is a part of risk assessment process consists of four categories which are people loss, asset loss, environmental loss and reputation loss. In the current standard using by O&G industry in Malaysia which is PETRONAS Technical Guideline (PTG), CoF are being generally classified as incomprehensive because it does not consider many factors. Identifying more factors leads to better risk assessment as it helps in reducing unnecessary inspection or maintenance that could lead to excessive allocation of money for risk assessment. The objective of the study is to identify human health and safety loss threat factors. This study focuses on CoF of people loss or also known as human health and safety loss for offshore platform facilities damages. The information and identification of parameters related to human health and safety loss of offshore platform facilities damage are determined from case studies and literature review. All the information gathered are then being verified by O&G PETRONAS experts through survey and interviews. As a result, it is determined that the threat factors for human health and safety loss are fatality, injuries, disabilities and illness. In conclusion, identification of these threat factors as agreed by experts is more realistic as the severity levels of the accident are unique thus the factors should be more various.

1. Introduction

Accidents due to any possible reason at the offshore platform are foreseeable with offshore developments. The reason, scale and severity of the effects of the accident are unique depend on the situation on the site. It relies on a combination of many natural, technical, and technological factors. The most popular causes of offshore accidents are equipment failures, staff errors, and extreme environmental impacts such as seismic activity, field ice, typhoon and etc. The spills and explosives of oil, gas and other chemical compounds are the main threats of offshore accident. The nature of its operations involves unstable materials sometimes under extreme pressure in aggressive environments lead to increase in risk thus accidents and tragedies happen regularly. Since 2001 to 2010, 69 offshore deaths, 1349 injuries and 858 fires and explosions accidents in the Gulf reported, according to the Federal Minerals Management Service.

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Oil and gas (O&G) industry are the main source of world's fuel consumption. Most of the O&G product is being transported by pipelines from one location to another. Due to natural pipeline characteristics i.e. ageing, aggressive environmental factors, inadequate design, improper protection and maintenance, existing pipelines around the world susceptible to deterioration [1]. In order to ensure optimal performance of existing pipeline, extensive maintenance, repair and renewal practices or even replacement of certain components is highly encouraged. In case of system failure, the pipeline integrity is of main interest of the O&G companies, government-owned agencies, [illegible] and other stakeholders so that potential harmful consequences related to public health, safety and heavy financial liabilities is predicted to be reduced [1]. The pipeline failures are unavoidable; thus risk reduction can be done by selecting efficient risk management strategies.

The fall of oil prices has led to the reduction of annual profit margin, as well as an inflated cost base in many O&G companies. It urges the companies to revise the cost allocated for operating purposes and investment budgets need to be rationalized without jeopardizing efficiency of operation. The reduction in cost will eventually affect the risk management as operation and maintenance are crucial for any companies as well as O&G industry. The nature of O&G operations involve unstable material worked under extreme pressure in unpredictable environment lead to increase in risk hence accidents and tragedies happen mostly have high severity level.

In order to increase human and ecosystem protection from damages, risk assessment is the main concern in O&G industry [2]. As the oil price dropped has cause the increase in cost for any cost related to O&G industry, the companies cannot depend only on production of O&G to generate companies' income. Therefore, it is crucial for owners to minimize the inspection, maintenance and repair cost without jeopardizing the integrity management. The inspection frequencies for the pipelines have traditionally been driven by [illegible]ve inspection practices, usually at time-based intervals. However, these inspection practices do not consider the possibility of failure of a component under its operating and loading conditions, or the consequence of failure [3]. Every asset is unique which are being placed in different location, with different [illegible] and different in design life. Therefore, every component have different behavior and dealing with various surrounding. Risk-based inspection is a means to design and optimize an inspection strategy based on the performance or a risk assessment progress.

In Malaysia, pipeline risk consequence has practicing the PETRONAS Technical Guideline for Pipeline Operational Risk Assessment (PTG 11.36.04) over the years [4]. There are four consequences of factors stated in the guideline consists of people loss, asset loss, environmental loss and reputation loss. [illegible] four factors of the consequence of failure (CoF) addressed, people factor or also known as human health and safety loss (HHSL) factor is considered as too general because not a single attempt to calculate the loss in monetary value based on the person individual values. O&G sector is believed as an industry that left behind others in embracing change and integrating HHSL factors because [illegible] unethical to value ones death. HHSL factors in monetary value in the O&G industry [illegible] usually unacknowledged and below the standard of other sectors such as nuclear sector and railway. Furthermore, current risk assessment value are semi quantitative, thus the realism of the value [illegible] questionable.

As mentioned earlier, the crisis of crude oil price drop has affect the risk management as the cost needs to be revised in order to sustain in the industry. The lack of the way companies managing risk and hazards was highlighted as one of the major issues regarding accidents occurred in offshore platform over the last 20 to 30 years. The existing pipeline condition monitoring require the whole pipeline to be inspected periodically, thus it is time-consuming and might be over estimate or under estimate [5]. The need to minimize the cost has urges the owner to have a better decision-making process before the accidents happen. This paper aimed is to identify human health and safety loss threat factors. It focuses on identification of human health and safety loss threat factors based on case studies. The information and identification of parameters related to human health and safety loss of pipeline damage was gathered from case studies report, literature review, surveys and interviews with experts in O&G industry. It focuses on offshore area around the world.

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2. Literature Review

2.1. Oil price dropped

The Malaysia's O&G industry has succeeded to become among the country's most active owners of O&G assets and becoming among the world's major producers or liquefied natural gas over a century ago. National oil company Petroliam Nasional Berhad (PETRONAS) has becoming the custodian for country's O&G resources since its formation in 1974. PETRONAS now has succeeded to [illegible] among the largest corporations on Fortune's Global 500 list. However, the current global O&G industry is going through big crisis largely due to chronic oversupply situation which led [illegible] reduction of crude oil prices.

PricewaterhouseCoopers reported Petroliam Nasional Berhad (PETRONAS) registered [illegible] billion MYR of after tax profits on the back of 248 billion MYR of revenues in 20[illegible] compared to [illegible] billion MYR of after tax profits from 329 billion MYR of revenues chalked up in the previous year. It is clear that the prolonged lower oil prices affect the company. In spite of the challenges presented by low oil prices, Malaysia remains one of South East Asia's most [illegible] own[illegible] O&G reserves as shown in Figure 1.

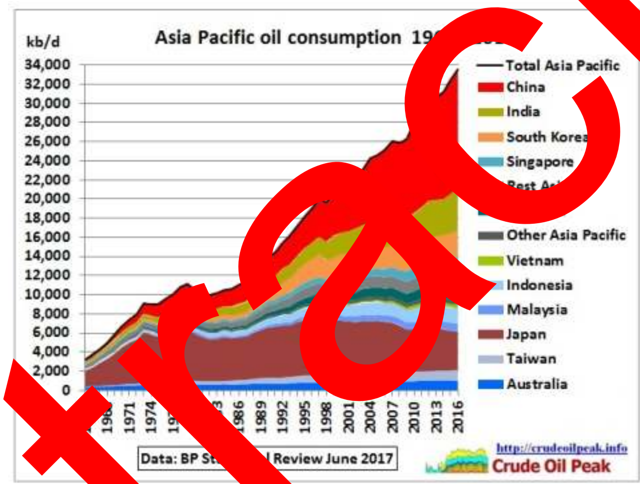

Figure 1. Production of oil in Southeast Asia from 1965 until 2016

In spite of low prices in global crude oil, O&G industry still remain important to the country as it contributes 20 to 30 percent to the country's Gross Domestic Product (GDP). With the presence of over 3[illegible] O&G companies in Malaysia including both international and local companies, the multiplier effect generated by this sector is still sizable and recognized by PETRONAS, the National Oil Company) and the Government of Malaysia as a strategic and priority sector.

Many exporting countries rely on tax revenue from oil production to fund government spending. For example, Russia gains 70% of all tax revenues from O&G. Falling oil prices leads to a government budget deficit and requires either higher taxes or government spending cuts. Other oil exporters like Venezuela are relying on oil revenues to fund generous social spending. A fall in oil prices would lead to a significant budget deficit and social problem [6].

Historical loss trends reveal a potential correlation between significant falloffs in oil prices and increased energy losses. Energy companies must exercise caution when implementing cost-cutting measures designed to oppose or offset the effects of low oil prices to ensure to avoid loss. The cost for the upcoming projects is deducted by the industry operators from, industry operators are trying to drive down the cost of new projects by 20-30 percent [7]. Hence, there is a concern, from the point of view of process safety and loss control that lower revenues from O&G production and falling demand could potentially result in reductions in investment in risk-control measures; the reduction in maintenance and inspection activity could result in a higher rate of accidents.

In order to protect human and ecosystem from damages, risk assessment is a crucial concern in O&G industry [2]. As the drop of crude oil prices forces the industry to cut the operation co[illegible] the risk assessment will be affected. This issue has become a bigger concern to the industry itse[illegible] the performance of the companies should not be taken carelessly. There is a needed for the indus[illegible]o revise the cost without neglecting the safety issues of employees and stakeholders. The [illegible] consequence estimation that commonly used nowadays involves time-based risk assessme[illegible]as led to the unnecessary inspection thus results in increased of unnecessary costing as well.

2.2. Risk Assessment

Risk assessment is defined as overall process of risk analysis and risk evalua[illegible]. Acc[illegible]ng to [illegible] 11.36.04, the risk definition for pipeline risk assessment is can be simplified i[illegible]s sho[illegible]n Equation 1 [4].

$$Risk = Probability\ of\ Failure\ x\ Consequence\ [illegible]\ re \tag{1}$$

Risk of pipeline damage is a product of Probability of Failure (PO[illegible]nd Conse[illegible]e of Failure (CoF); where the CoF is evaluated based on people loss, envi[illegible]ntal lo[illegible]asset loss and reputation loss (PAER). Basically, risk can be defined as relationship [illegible]etween two fac[illegible]ch are probability of accidents will occur and the consequences of accid[illegible]ts. PTG 11.[illegible].04 provide guideline and recommendations to conduct Pipeline Operational Risk A[illegible]ssment [4]. [illegible]ble 1 show an example of currently used risk matrix as the end-product of a risk asse[illegible]ent proced[illegible]e. This 5x5 risk assessment matrix is currently used in pipeline integrity ma[illegible]nt in [illegible] perform risk assessment for operating pipeline, the asset owner is requ[illegible]d to d[illegible]ine the expected events that might affect pipeline integrity during operational stage.

Table 1. Risk Assessment M[illegible]ix Model [illegible] O&G [illegible]peline Integrity Management [4]

Consequence of failure (COF)	People (P)		Slight Injury	[illegible]y	Major	Single Fatality	Multiple Fatalities
	Asset (A)		Slight [illegible]mage	Minor Damage	Local Damage	Major Damage	Extensive Damage
	Environment (E)		Sli[illegible]fect	Minor Effect	Localized Effect	Major Effect	Massive Effect
	Reputation (R)		Slig[illegible] Impact	Local Impact	Industry Impact	National Impact	International Impact
	S[illegible]ity rating		1 Negligible	2 Minor	3 Moderate	4 Major	5 Catastrophic
Probabilit[illegible] failure (P[illegible])	E [illegible]y li[illegible] [illegible]d	Happ[illegible]everal times [illegible]ear at lo[illegible]n	Moderate	High	High	Very High	Very High
	[illegible] Like[illegible] happened	Ha[illegible]s several [illegible] per year in company	Low	Moderate	High	High	Very High
	C [illegible]o happ[illegible]ed	Incident has occurred in company	Low	Low	Moderate	High	High
	B Unlikely to happened	Heard of incident in industry	Very Low	Low	Low	Moderate	High
	A Very unlikely to happened	Never heard of in industry	Very Low	Very Low	Low	Low	Moderate

Risk assessment is simply a method of identifying the seriousness of a risk. Identified risks can be analyzed by two approaches which are qualitative and quantitative methods. In order to create a successfully sustainable business in hazardous industries, an organization needs to manage risk comprehensively across its operations in routine and efficient way [8]. Some adjustment in the

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dynamic between safety and productivity where safety is not set against production and risk mitigation becomes a fundamental part of efficient and effective operations.

Malaysia is currently practicing the standards provided by PETRONAS. However, the risk assessment can be considered as simple without complex mathematical model which relies o[illegible]xpert's judgment and based on readily developed models of pipeline integrity assessment. It is ess[illegible]l to involve stakeholders' opinion in risk assessment. There are significant inequities in resources a[illegible]g stakeholders such as large pipeline companies and nongovernmental organizations [9].

2.3. Consequence Assessment

Consequence assessment is defined as the product or process of identifying or evaluating t[illegible]otential or actual effects of an event, incident, or occurrence. It is the process involving t[illegible]antifi[illegible]n of CoF as the outcome of a failure based on the assumption that such failure wil[illegible]ccur [4[illegible] is d[illegible] for all consequences that are of importance to pipeline operator, such as safet[illegible]econo[illegible]environment and reputation. CoF is divided into safety, environment and eco[illegible]mic. It is [illegible]alyz[illegible]respe[illegible]vely by quantitative assessment, which consists of personnel such as the [illegible]al of [illegible]d or dea[illegible] caused by explosion, blowout, ignition, pipeline failure or hazardous t[illegible]appen, [illegible]ronm[illegible]l as the damage of wildlife creature, ecosystem, soil water; can be short or l[illegible]term e[illegible]and financial consequence such as the potential of business loss in product[illegible]rrupt[illegible]nd the cost of repairing and recovering the failed pipeline component. CoF have fo[illegible] components w[illegible]people loss, asset loss, environmental loss and asset loss [4]. People loss or [illegible]tter-to-use te[illegible]n Human Health and Safety Loss (HHSL) is yet to be identified monetarily and it is [illegible] major focu[illegible]f this paper to identify the influencing factors prior to the previously mentioned intent[illegible]

2.4. People Loss

The weaknesses in managing risk and haz[illegible]s was [illegible]ghl[illegible]ed as one of the major issues regarding accidents occurred in offshore platform[illegible]ve[illegible]e la[illegible]20 to [illegible]rs [5]. The loss of human life as well as the amount of damages and the i[illegible]act on en[illegible]onmen[illegible]l will affect the degree of severity of the accident [10]. All of four compo[illegible]of conseq[illegible]ce [illegible]ailure (CoF), people loss or also known as human health and safety[illegible]s is one [illegible]e factor tha[illegible]ng generally assessed in PTG standards. O&G sector is believed as an i[illegible]ry that [illegible]behind others in embracing change and integrating human factors. The human factor[illegible]e O&G in[illegible]try is usually below the standard of other sectors such as nuclear sector and railways. T[illegible]mpact to [illegible]ople or details definition of CoF in term of harm to people are tabulate[illegible]le 2.

Table 2. Impact to people [4]

Sev[illegible]		Definition
[illegible]le	[illegible]rms	
Ins[illegible]ficant	[illegible] inj[illegible]	[illegible]t aid injury or slight health effects not affecting work performance or causing disability e.g first aid injury, exposure to non-hazardous dusts.
[illegible]	Minor [illegible]ury	Medical Treatment Case Restricted Work Case, Lost Time Injury or minor health effects (invoicing health hazards capable of minor health effect which are reversible, e.g. irritant agents, defatting agents, food poisoning bacteria) affecting work performance, such as restriction to work activities or a need to take a few days to fully recover
3 Moderate	Major injury	Permanent Partial Disability, significant health effects (capable of irreversible health damage without loss of life e.g. noise, poor manual handling tasks, hand/arm vibration chemicals causing systemic effects, sensitizers), exposure to possible human or animal carcinogens, or results of injury/illness in the lower categories (category 1 & 2 above) which affect performance in the longer term such as prolonged absence from work for more than 4 days.
4 Major	Single fatality	Permanent Total Disability, single fatality from accident or occupational illness or major health effects caused by health capable or irreversible damage with serious disability or death e.g. exposure to corrosives, probable human carcinogens, extreme heat and cold, psychosocial risk factors.
5 Catastrophic	Multiple fatalities	Multiple fatalities or Multiple Permanent Total Disability from accident or occupational illness caused by health hazards with the potential to cause multiple fatalities, e.g. chemical with acute toxic effects (hydrogen sulphide, carbon monoxide), known human carcinogens.

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Table 2 shows that even single fatality has considered as major severity thus it proved that all this while the people loss has been seriously looked into. However, the severity level being identified only by numbers which is from 1 to 5 which indicates insignificant to catastrophic severity. Offshore platform involves many people either permanent workers or contract workers, from managers, engineers to the diver, each of them has its own experiences and level of qualification come from different background. The more factors identified to conduct the risk assessment is better to estimate more realistic value for human health and safety loss. Throughout the study, some factors were proposed in questionnaire and some of it was be identified through interviews with experts. It is important for the factors to not being too general in term of defining the factor for people. In fact, human health and safety loss are crucial in risk assessment. Therefore, it is better if the risk assessment could be more realistic by converting the loss of life value according to identified factors into monetary unit.

3. Methodology

An overview of the research design to satisfy the objectives of this paper is illustrated in Figure 2.The information was gathered through literature reviews, interviews and questionnaires to identify the HHSL indicators using the primary source to extract the date i.e. literature review and with the assistance of case studies of offshore pipeline failures related to explosion. The identified factors through interviews are designed into questionnaires for preliminary survey to obtain the responses from respondents from experts or employees of Pipeline Integrity Management to gather more information and get the different stakeholders' point of views, specifically for O&G pipeline companies.

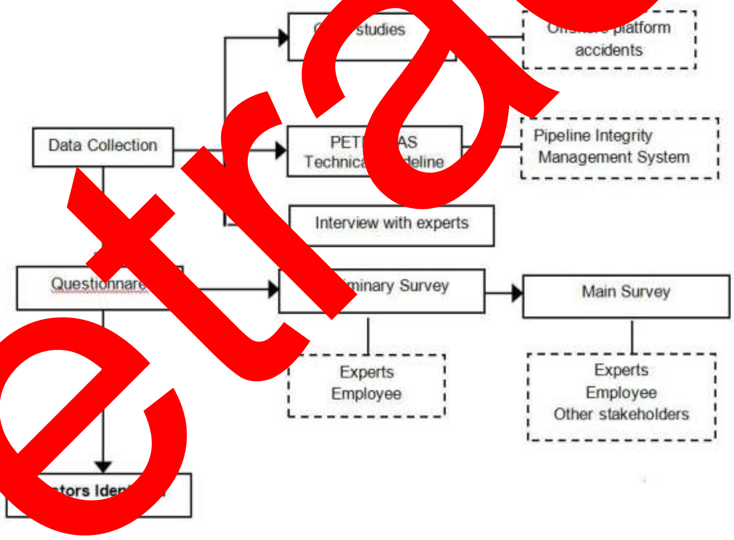

Figure 2. Research design

Several interview sessions was conducted to obtain the opinions from experts regarding the identification of human health and safety loss factor. A set of questionnaires that contain the factors identified from the initial interview, literature reviews and case studies were distributed to the experts to verify the factors and parameters relevant for research purposes. Returned questionnaire was analyzed to determine the sample return rate, demographic analysis and reliability analysis. The demographic analysis consists of frequency and percentage of age, sex, level of education, position and years of working experience. An average index was used to obtain the average score of each factor according to the respondents' preferences.

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Case studies was thoroughly investigated to gather more information regarding the human health and safety loss threat factors and the parameters that should be count in risk assessment. The case studies were found from the online resources such as newspaper website and journalist reports. A number of 12 offshore accident cases were gathered was listed in Table 3. Through the ca[illegible]tudies, the human health and safety threat factors were identified and occurred repeatedly in sever[illegible]ses; others unavailable due to source limitations. The factors were summarized into Table 4 for [illegible]r observations.

Table 3. List of case study of offshore accidents

Case No.	Event Date	Venue	Pipeline operator	HHSL Fatality	[illegible]	M[illegible]
1	27 March 1980	Campeche, Mexico	Phillips Petroleum	12[illegible]	NA	NA
2	15 February 1982	Norwegian North Sea	Mobil Oil's *Ocean Ranger*	[illegible]	NA	NA
3	March 1983 - May 1985	Persian Gulf, Iran	Nowruz oil	[illegible]	[illegible]	[illegible]A
4	16 August 1984	Newfoundland, Canada	Petrobas' Enchov[illegible]	[illegible]	NA	[illegible]A
5	6 July 1988	North Sea	Occidental Petroleu[illegible] Piper Alpha	16[illegible]	NA	NA
6	3 November 1989	Gulf of Thailand	Unocal Corporation	91	[illegible]	NA
7	11 April 1991	Italy	MT *Have*[illegible]	[illegible]	NA	NA
8	28 May 1991	Ulsan, South Korea	ABT S[illegible]mer	5	NA	4
9	20 March 2001	Genoa, Italy	Petroba[illegible]36	11	17	NA
10	27 July 2005	Mumbai offshore, India	Oil and [illegible]l Gas [illegible]poratio[illegible]GC)	22	NA	NA
11	21 August 2009	Gulf of Mexico, United S[illegible]s	[illegible]Deepwate[illegible]	11	17	NA
12	16 January 2012	Africa	C[illegible]Nigeria Limited	2	NA	NA

NA : Not available

4. Results and Discussion

Sample size of minimum 30 per[illegible] is require[illegible]n sta[illegible]ard practice of conducting a survey. The adequacy of return rate [illegible]uld be 5[illegible]nd above. [illegible]otal sample size and return rate for the survey is shown in Table 4 belo[illegible]e retur[illegible]e is calculated based on the percentage of collected survey divided by the total distri[illegible]survey. T[illegible]e are three divisions within PETRONAS and employees from various technical discipl[illegible] (project [illegible]anagement, piping and pipeline) were involved. The O&G industry's em[illegible] were d[illegible]ed into two categories: experts and employees.

T[illegible]le 4. Result of sample size and return rate of survey

Person[illegible]	Distribu[illegible]	Collected	Return Rate (%)	Return Rate Adequacy Level
[illegible]erts	33	24	100	Very good
[illegible]loyees	[illegible]	16	100	Very good
[illegible]TAL	[illegible]49	40	82	Very good

[illegible]e: Return rate adequacy level for reporting purposes (<50: Inadequate; 0-59: Adequate; 60-69: Good; 70-100: Very good)

[illegible]emographic [illegible]alysis gives insight into the age, gender, working experience, position and [illegible]ademic qualification of a population. The demographic of 24 experts and 16 employees of other [illegible] company are tabulated in the following Table 5 and Table 6, respectively. In Table 5, there are mo[illegible]n half of the experts are 30 years and above. Most of the experts have bachelor degree. More than 5[illegible] of the respondents are engineers. Most of them have more than five years of experience in pipeline integrity management. On the other hand, in Table 6, there are more than half of the employees are 30 years and above. All respondents have bachelor degree and almost 70% of respondents are engineers. Most of them have more than five years of experience in O&G industry.

Table 5. Respondent's demographic of survey (Experts)

Criteria	Category	Frequency	Percentage (%)
Gender	Male	14	58.3
	Female	10	41.7
Age	Below 30	5	20.8
	30-39	14	58.3
	40-49	3	12.5
	50 and above	2	8.3
Years of working experience	Less than 5	4	16.7
	5-10	9	37.5
	11-15	5	20.8
	More than 15	6	25.0
Years in pipeline integrity management	Less than 5	5	20.8
	5-10	13	54.2
	11-15	3	12.5
	More than 15	3	12.5
Job position	Custodian	1	4.2
	Executive	3	12.5
	Manager	1	[illegible]
	Engineer	13	[illegible]
	Technical Support	1	[illegible]
	Others	5	[illegible]
Highest academic qualification	Certificate	0	0.0
	Diploma	1	4.2
	Degree	23	95.8
	Master	0	0.0
	PhD	0	0.0

Table 6. Respondent's demographic of survey (Employees)

Criteria	Category	Frequency	Percentage (%)
Gender	Male	[illegible]	68.8
	Female	5	31.3
Age	Below 30	2	12.5
	30-39	10	62.5
	40-49	[illegible]	25.0
	50 and above	0	0.0
Years of working experience	Less than 5	3	18.8
	5-10	5	31.3
	11-15	5	31.3
	More than 15	3	18.8
Years in O&G industry	Less than 5	4	25.0
	5-10	5	31.3
	11-15	5	31.3
	More than 15	2	12.5
Job position (current)	Custodian	0	0.0
	Executive	0	0.0
	Manager	3	18.8
	Engineer	11	68.8
	Technical Support	1	6.3
	Others	1	6.3
Highest academic qualification	Certificate	0	0.0
	Diploma	0	0.0
	Degree	16	100.0
	Master	0	0.0
	PhD	0	0.0

In order to identify reliability of the survey, minimum 0.70 Cronbach's alpha value is required. From this study, result show 0.911 value of Cronbach's alpha, which considered the survey was in an excellent stage of reliability level. Result for the hypothesis testing for offshore survey is tabulated in the Table7. It can be concluded that there is no significant difference between respondent in the rating of the factors, regardless of the types of the respondents e.g. combined, expert only, or employee only. In short, the prioritization of factor can be done without considering the difference of years of working experience, years of involvement in pipeline integrity management, current job position nor its highest academic qualification among the respondents, either experts or employees of other O&G companies.

Table 7. Summary of the hypothesis testing

Demographic	Hypothesis Testing	Respondent	Reject Null Hypothesis
Working Experience (Year)	Kruskal-Wallis	Combined	No
		Expert only	No
		Employee only	No
Involvement in Pipeline Integrity Management (Year)	Kruskal-Wallis	Combined	No
		Expert only	No
		Employee only	No
Job Position (Current)	Kruskal-Wallis	Combined	No
		Expert only	No
		Employee only	No
Highest Academic Qualification	Mann-Whitney	Combined	No
		Expert only	No
		Employee only	No comparison (all employees [illegible]er)

5. Conclusion

This paper has shown its ability to identify the HHSL factor of offshore pipeline accident based on an in-depth literature search in journal, reports and online data, which are the number of fatality, number of injury and number of missing people. These items was identified via a thoroughly reviewed 12 offshore accident case study occurred around the globe for the sake of data collection purpose. It is highly encourage to study more offshore O&G accident case study in the future for a better observation of HHSL factor.

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