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# Quantifying reputation loss of pipeline operator from various stakeholders' perspectives – Part 1: Prioritization

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ABSTRACT

Quantifying reputation loss (RL) due to pipeline damage is commonly generalized based on the owner's definition. This one-way perspective of portraying RL is unfair and unrealistic and consequently miscalculates the impact assessment of pipeline damage; hence, inaccurate risk prediction. It is crucial to develop a model to quantify qualitative RL to avoid unpredicted risk. Thus, this article provides a framework for a procedure to calculate RL by utilizing the factors identified in a previous study. In this paper (Part 1), the prioritization of factors based on the stakeholders' perspectives is presented. The factors were grouped into stakeholder-influenced categories and prioritized by a fuzzy analytic hierarchy process based on the feedback gained from the stakeholders, i.e., investors, customers, employees and the public. The result shows that factor D3, "Accident severity", was ranked highest by all stakeholders. The priority vector for each factor obtained was assigned as a weight of the factor. The pipeline owner's reputation loss model (RLM) is developed by applying the obtained priority vectors in the subsequent paper (Part 2). The developed model was verified by experts as a comprehensive, clear, objective, practical and moderately reliable model. The model was applied to a case study and eventually produced a lower risk value when compared with the currently used model. It is proven that RL factors can be quantitatively measured and can simultaneously improve pipeline damage impact assessment. Thus, a risk-based inspection schedule can be managed comprehensively.

## 1. Introduction

A minor or major accident in oil and gas (O&G) industry results in financial and reputation losses (Amir-Heidari et al., 2016; Renjith et al., 2018). A comprehensive Pipeline Integrity Management Programme (PIMP) is vital for the maintenance of a safe and reliable O&G pipeline. A PIMP consists of a foundation of pipeline inspection, assessment, mitigation and communication aimed at minimizing the risk of a pipeline failure to "as low as reasonably practicable". PIMPs have experienced significant changes since the early 2000s. A well-planned PIMP is necessary to avoid pipeline damage and reduce the impact of failure events. A PIMP secures the annual profit margins of pipeline owners and protects their reputations.

The time-based inspection previously used in PIMPs has been improved by the implementation of a risk-based inspection (RBI). An RBI allows pipeline owners to choose the most cost-effective pipeline inspection scheme, optimizing maintenance scheduling and reducing unnecessary inspections. As a part of an RBI module, risk of pipeline damage is defined as the product of the likelihood or frequency of pipeline damage and the impact or consequence of such an event. The existing consequence assessments are quite effective in evaluating the monetary loss caused by pipeline failure, such as the number of fatalities and injuries, cost of asset damage, cost of production loss, and cost of environmental pollution fines. However, as a part of the critical assets of a company, quantifying the loss of its reputation in dollars and cents is quite difficult (Gavious et al., 2009; Kim et al., 2012; Khakzad et al., 2017). Despite its qualitative nature, the actual cost of pipeline damage cannot be determined while neglecting the contributing factors of reputational loss.

There are many challenges encountered in estimating the cost of a company's RL, including its time dependency, difficulties in quantifying the reputational threat factors in terms of monetary values, and a lack of the identification of the impact of RL towards the company's local conditions, e.g., the stakeholders of the company. Onshore pipelines

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buried underground are laid across various types of geographical surfaces with different demographics and populations. These varying conditions lead to different impacts on a company's reputation in the event of a pipeline failure. For example, the impact of a pipeline failure causing an explosion in Europe is different from that of a similar event in Nigeria due to their different public education levels. Public awareness of safe and reliable pipeline operations also varies between countries.

The risk assessment for pipeline damage practice currently includes an assessment of the failure event's effects on an owner's reputation. However, most industry members choose to exclude the post-accident RL due to its qualitative nature and the subjectivity of its factors. The characteristics of factors affecting RL of a company are as follows: (1) time dependent (Dunbar and Schwalbach, 2000; Bie, 2006), (2) multidimensional (Fombrun, 1996), (3) behaviour dependent (Bie, 2006), and (4) highly influenced by stakeholders' past experience with the company's services (Spence, 2011; Tanabe and Miyake, 2012; Ale et al., 2017). To simplify the assessment procedure, the current practices for pipeline risk assessment assume that the cost of RL is equivalent to the business interruption costs (Muhlbauer, 2004; Silva and Lopes, 2018). Likewise, in previous studies, the loss of a company's reputation is calculated based on fluctuations in the share price over a period of time (Vergin and Qoronfleh, 1998; Money and Hillenbrand, 2006; Tonello, 2007; Scandizzo, 2011; Villa et al., 2017). This method of quantifying RL is time dependent but affects only a single stakeholder, e.g., the investors of the company. Ironically, the expectations of the other stakeholders have similar impacts, i.e., jeopardizing the reputation of the company and significantly influencing company operations (Macnamara, 2006). Public perception prior to a pipeline damage event is crucial, as it forces pipeline operators to apply immediate mitigation measures. This public pressure insisting for a safe pipeline differs by geographical location and the status of the pipeline owner.

Although efforts to quantify RL for pipeline owners has been initiated by previous research (E&P 6.54/246, 1996; Muhlbauer, 2004; PTG 11.36.04, 2015), none of the available models rank the factors influencing the company's RL for reacting to the most severe factors from the perspectives of the various company's stakeholders. Furthermore, a model to quantify RL specifically tailored for onshore pipeline damage is currently unavailable. However, there are existing models of RL found in other industries such as banking and retail (Muller and Vercouter, 2008; APCO Insight, 2010; Li et al., 2010; Cherchiello, 2011; He and Wu, 2013).

The prediction of pipeline COF in publications is scarcely available (De Cunha, 2016). If RL has a significant contribution to the total cost of a failure event and is commonly neglected in the monetary COF assessment, inaccurate assessment can occur due to the negligence. Additional cost may be imposed due to unnecessary inspections initiated by errors in pipeline inspections and maintenance. Hence, a pipeline company's annual profit margins are affected. If a RLM is well developed, reasonable increments in the inspection frequency can prevent pipeline damage by focusing on the higher-risk pipelines. Since the RL factor is qualitative, it is difficult to quantify it in a monetary manner. Thus, an initiative to quantify RL from different perspectives of the pipeline operator's stakeholders, e.g., investors, customers, employees and the public, is highly recommended.

Thus, this study aims to evaluate the impact of RL on pipeline owners and is the subject of two companion papers. In this paper (Part 1), prioritization of the reputation-threat factors according to different stakeholders' perspectives is presented. In the subsequent paper (Part 2), the stakeholder-oriented priority vectors for reputation-threat factors of pipeline damage are evaluated, including the prediction and validation of the model via interviews with experts and implementing case studies in Malaysia. The outcomes may contribute to the consequence assessment of pipeline damage by exploring a selection of RL factors for pipeline owner's RL modelling purposes in future.

## 2. Literature review

Pipelines are the safest means of transporting natural gas and hazardous liquids according to the Pipeline Hazardous Materials Safety Administration (PHMSA) (Dziubínski et al., 2006; Carvalho et al., 2008; Brito and Almeida, 2009; Brito et al., 2010; Furchtgott-Roth, 2013). Pipelines are prone to failure due to third-party damage, corrosion, natural forces, and other causes. To maintain safety when transporting high-risk products such as O&G, implementation of PIMPs is crucial. A PIMP is a set of controls and activities related to pipeline design, operation, inspection, maintenance and assessment intended to minimize the risk of a pipeline failure to "as low as reasonably practicable" (ALARP).

### 2.1. Pipeline Integrity Management Programmes (PIMP)

The United States Department of Transportation (USDOT) launched a PIMP in the early 2000s to improve safety measures for old and new pipelines and reduce the impact of pipeline damage. The rules for gas transmission pipelines issued in late 2003 require operators to identify high consequence areas (HCA), identify threats within an HCA, prioritize segments based on the identified threats, replace or repair segments requiring remediation, reassess segments every seven years, and develop a written PIMP to improve pipeline safety (Feldman, 2015). Since these rules were enforced, the trend in increasing pipeline incidents between 1994 and 2004 has plateaued (NTSB SS-15/01, 2015). To prioritize pipeline inspections, pipeline operators and owners must forecast the likelihood of a pipeline failure and its possible impact on internal and external stakeholders. This stage is known as pipeline risk assessment, and the measuring tool used to evaluate risk by assessing the probability and consequences of a pipeline failure to plan pipeline maintenance and inspections is known as an RBI.

Pipeline risk assessment in the O&G industry has evolved over time due to the need for better PIMP to guarantee safe and reliable operations that are used as the basis for economic-friendly decisions (Paez and Roy, 2010; Denis et al., 2013). It allows the documentation and categorization of pipeline segments' vulnerabilities to identify risks in an organized manner. It integrates various stages of reliability and consequence analysis for the purpose of answering the following questions (Muhlbauer, 2004): (1) What is the cause of a pipeline failure? (2) How can the failure occur? (3) How frequently does the failure occur? (4) What are the consequences of the failure? The efficiency of a pipeline risk assessment can be evaluated by its capability to characterize and calculate all pipeline-related risks (Sulaiman and Tan, 2014). A smart pipeline risk assessment uses common sense tactics to create a meaningful, logical and structured approach that integrates all available information into a robust evaluation, permitting situation-specific solutions that are concise yet flexible (Muhlbauer, 2012).

Risk assessment is currently a common practice in many industries; it permits the owner to prepare contingencies for any unwanted event that may occur in the future. It can be defined as the verification of the qualitative or quantitative risk value associated with a particular situation and an identified hazard or threat (Muhlbauer, 2004). It is performed by compiling the estimated risks into a risk matrix in which the risks are evaluated by a specific number derived from estimates of the frequency or likelihood and severity or consequence. This matrix describes the levels of tolerable risks by a ranking procedure. The company's tolerable risks are defined according to the ALARP region established by the company, so that the available options to mitigate the identified risks are cost and benefit friendly.

The assessment of pipeline failure consequence includes the failure impact on humans, loss of company assets, environmental damage and RL. The risk of pipeline damage increases linearly with the impact severity rating (i.e., 1 – negligible to 5 – catastrophic). The current consequence assessments of pipeline losses track individual and combined losses. A combined loss uses an index for the consequences of failure (PTG 11.36.04, 2015). For example, the business service interruption costs are considered a loss of reputation for a pipeline owner due to difficulties in quantifying the reputation numerically (Muhlbauer, 2004). This is insufficient for portraying the actual losses to a pipeline owner's reputation; the reputation is the belief of the company's stakeholders towards an owner (Fombrun, 1996). A comprehensive consequence assessment model is needed to help operators forecast possible losses and plan an effective and cost-effective PIMP to secure the pipeline owners' annual profit margins.

### 2.2. Consequence assessment

The assessment of the consequence of failure (COF), or simply the consequence assessment, involves the quantification of the likely damage or loss as a result of any possible eventuality (Pula et al., 2005). The COF is assessed as the outcome of a failure based on an assumption that such a failure will occur. The consequences can be categorized into two types: short-term consequences (losses at the time of failure, e.g., the cost of hospitalization for employees and members of the public) and long-term consequences (future losses that occur in subsequent years, e.g., the costs of production losses and costs of environment treatment/decontamination) (Dziubínski et al., 2006). According to the Petronas Technical Standards (PTS) of Pipeline Operational Risk Assessment, the COF is defined for all consequences that are of importance to the pipeline operator, i.e., safety, economic, environmental and reputation (PTG 11.36.04, 2015).

Losses resulting from pipeline accidents cause a wide-ranging set of consequences. COFs are commonly assessed by measuring the people, environmental, and economic losses that will be borne by the asset owner (Brandsæter, 2002; Brito et al., 2010; DNV-RP-F107, 2010; Guo et al., 2018). The economic loss is considered the loss of the pipeline owners' production and/or assets, depending on the term they prefer to use in their assessment. The level of measurable harm or damage is described in terms of a monetary value or number of fatalities (Muhlbauer, 2006). The monetary value is determined by the willingness to pay for every scenario of consequences (Jonkman et al., 2003; Park et al., 2004). The fatality rate is the preferred measure, as it is the most important, but other pipeline failure consequences require the same amount of attention (Jo and Jong, 2005; Brito and Almeida, 2009).

The effects of human and environmental losses on the pipeline consequence analysis are an active field of research, as they directly affect the trust of the external stakeholders, which subsequently affects the owner's credibility in pipeline integrity management (Khan and Haddara, 2004; Arunraj and Maiti, 2009; Han and Weng, 2011). The asset loss can be calculated by referring to the stored asset inventory database of the company. These three losses can be easily quantified, in numerical or monetary terms or as time-based disruptions. On the other hand, the reputation COF has yet to be measured by these means. Currently, RL is measured based on concerns broadcast on mass and/or electronic media or pressure from parties who have a personal or corporate interest in the company, from the lowest (local) to the highest level (international) (PTG 11.36.04, 2015). A company's reputation is the belief of stakeholders towards a company and its attributes (Fombrun, 1996). This technical standard partially assesses the RL for a pipeline owner because it focuses primarily on the public impact; the investors, customers and employees are neglected. This qualitative assessment is a self-centred assessment; an assessor's preferences vary depending on his/her experience in assessing the risk of pipeline damage. In addition to reputation, other types of loss, e.g., people, assets, environmental and production, are assessed quantitatively. There is a need to express the reputation in a quantitative manner, or at least using a combination of quantitative and qualitative measurements, i.e., a semi-quantitative assessment, to simplify the assessment process. This process leads to inconsistencies in assessing the RL as part of a consequence assessment, which affects the total risk value of the pipeline. A comprehensive PIMP is unsuccessfully executed if the RL impacts on a pipeline's risk value are proven to be significant.

In addition to PTG 11.36.04, other technical standards can be utilized to assess the consequence of pipeline damage, such as the Integrity Management of Submarine Pipeline Systems recommended practices (DNV-RP-F116, 2015). According to Det Norske Veritas (DNV), the recommended practice of risk assessment of pipeline protection standard, the pipeline COF is assessed based on human safety, environmental impact and economic loss (DNV-RP- F107, 2010; DNV-RP-F116, 2015). However, another recent DNV standard for the verification of onshore pipelines suggests that an additional impact of loss be measured in addition to those suggested in the previous standards, i.e., regulatory and political consequences (DNV-DSS-316, 2013).

PTG 11.36.04 (2015) determined RL by the summation of three main losses, namely, human, economic and environment. DNV-RP-F116 (2015) suggests that company reputation can be considered by types of impact in the COF assessment. In addition to political consequences and loss of share value, reputation is considered one of the elements that damages the environment (DNV-RP-F116, 2015). Thus, loss of company reputation is included in the environmental impact assessment. In contrast, in the American Petroleum Institutes (API) Risk-Based Inspection recommended practice, loss of reputation is assumed to be the loss of market share (API-RP-580, 2009). These three different standards have their own ways to assess the impact of RL; hence, different results are obtained. The pipeline operator may use any standard that suits the company objective as long as the pipeline can be operated safely.

### 2.3. Loss categories

Hokstad and Steiro (2006) introduce 11 categories of overall losses for vulnerability management. The first nine losses are combined and categorized into four major losses, including production loss, asset loss, human health and safety loss, and environmental loss, to create an individual or overall consequence model (Khan and Haddara, 2003; Arunraj and Maiti, 2009; Hanafiah et al., 2015). This directly calculated loss is also called the tangible assets loss. An effort to quantify the RL is required because earning a reputation is more difficult and takes longer than losing it and it is one of the indicators of a company's long-term success. Referring to the loss costing guidelines for O&G exploration and production, the quantification of an O&G company's RL is simply not impossible (E&P 6.54/246, 1996).

### 2.4. Identifying factors from various databases

The media reports of pipeline failures, such as the pipeline explosions in Kaohsiung, Taiwan, Andhra Pradesh in India, and Sarawak, Malaysia, in 2014, have been common in recent years. The impact from a pipeline accident is tremendously horrible, particularly when numerous fatalities and injuries are involved, and immediate coverage in the mass or electronic media is unavoidable. In general, these reports generate different perceptions among the stakeholders; negative impressions are obviously expected. These perceptions may directly or indirectly degrade the company's reputation.

The RL factor cannot be identified from any currently available online pipeline accident event databases for public reference because these databases commonly record only the cause of the accident and the quantifiable losses, i.e., human, environmental, and asset. Furthermore, the accident documentation method, types of recorded historical data, and the definition of the accident vary among countries. Three different bodies of pipeline safety are used as examples, including the European Gas Pipeline Incident Data Group (EGIG), the Transportation Safety Board (TSB) of Canada, and the Pipeline Hazardous Materials Safety Administration (PHMSA) of the United States Department of Transportation (USDOT). These three regulatory bodies have recorded pipeline accident events since the 1970s.

The EGIG was established in 1982 by European gas transmission system operators as an initiative to record unintentional gas releases from their pipelines, aimed at providing pipeline safety performance assessments for the purpose of forecasting incident frequencies and probabilities (EGIG, 2014). Its database covers incidents for the years between 1970 and 2013, involves 17 operators, and records incidents that meet the following conditions: an unintentional gas release incident; the pipeline must be made of steel with a maximum operating pressure greater than 15 bar; and the pipeline must be located onshore but outside of gas installation fences (EGIG, 2014). Production lines, equipment or component-related incidents are not included in the database.

The TSB has been responsible for providing an annual summary of pipeline safety data since 1970, stating that "*the types of facilities involved in accidents and incidents such as compressor station, gathering line, injection or delivery facility, meter station, gas processing plant, pump station, storage facility, terminal, transmission line and others*" (TSB, 2014). The report offers a statistical summary of accidents and incidents by different analysis categories (TSB, 2014), including type, province, facility type, product type and quantity released.

The PHMSA has recorded all reported incidents related to pipelines in the country since 1970 and provides a statistical summary with trend lines for the previous 20 years of pipeline incidents; they are categorized into the two groups of significant and serious incidents (PHMSA, 2015). The PHMSA database consists of recorded incidents pertaining to onshore and offshore pipelines in various types of systems as such gas transmission, gas distribution, gas gathering, liquefied natural gas (LNG) and hazardous liquid (PHMSA, 2015). The raw data concerning a pipeline incident can be retrieved from PHMSA and the United State Department of Transportation Office of Pipeline Safety as well.

These three regulatory bodies have introduced different definitions of pipeline accidents. EGIG (2014) defines an incident simply as any unintentional gas release from a transmission pipeline. However, the TSB and PHMSA each divide pipeline accidents into two groups, incident and accident and significant incident and serious incident, respectively. For example, TSB (2014) mentioned that it is considered "*a commodity pipeline incident if any of these conditions are fulfilled: an uncontained and uncontrolled release of a commodity occurs; a pipeline is operated beyond its design limits; a pipeline causes obstruction to vehicles as a result of a* supporting *environment disturbance; the structural integrity of the pipeline reduces under its design limits by any abnormality; any local activity near the pipeline poses a threat to the pipeline structural integrity; any part of the pipeline has a shutdown due to a hazard to secure commodity transportation*". In contrast, a commodity pipeline accident is "*a direct effect from a commodity pipeline operation, where a person is exposed to fire, ignition, explosion or release that causes fatality or serious injury necessitating hospitalization; the commodity pipeline withstands damage due to contact with another object or* supporting *environment disturbance, or sustains an explosion, or a fire or ignition that is not associated with normal operating circumstances, or endures damage resulting in the release of any commodity*".

According to PHMSA (2015), "*an incident is considered significant if any of the following occur: fatality; personal injury requiring hospitalization; property damage, including clean-up costs, the value of lost product, and the damage to the property of the operator or others, or both, estimated to exceed $50,000; release of five gallons or more of a highly volatile and hazardous liquid (any petroleum or petroleum product) or carbon dioxide; and an explosion or fire not intentionally set by the operator*". An incident that meets the first two criteria is considered a serious incident (PHMSA, 2015). The differences in these definitions of a pipeline accident are due to different regulations imposed by each country. It is vital for a government to provide a safe and sound living environment for citizens; public safety is a government priority.

Fig. 1 shows the annual number of incidents between 1970 and 2013 based on EGIG reports. The incident data between 2004 and 2013 was extracted from the TSB and PHMSA database reports, as shown in Figs. 2 and 3. To obtain the number of similar cases within a selected time frame, the onshore natural gas transmission pipeline cases from between 2004 and 2013 recorded in all of the abovementioned databases are observed. The total numbers of cases reported within the 10-year in all databases are as follows: 209 incidents are reported by the EGIG (EGIG, 2014); the TSB reported 233 cases, of which 19 are considered accidents, while the remaining cases are categorized as incidents (TSB, 2014); and 606 cases are documented by the PHMSA, of which 43 are serious incidents and the others are significant incidents (PHMSA, 2015).

A total of 1048 gas transmission pipeline cases are reported in the selected databases within a ten-year period (between 2004 and 2013) in Europe, Canada and the US. There are other countries that may also have similar databases; an interested party can purchase them in a customer-centred customized format (EGIG, 2014). The number of cases increases as there is a possibility for any natural and hazardous liquid pipeline to experience failure at any location and time, either documented or ignored, depending on the regulations of its respective country, specifically for an onshore pipeline (PHMSA, 2015).

The lives of innocent people are in danger, and in recent years, the

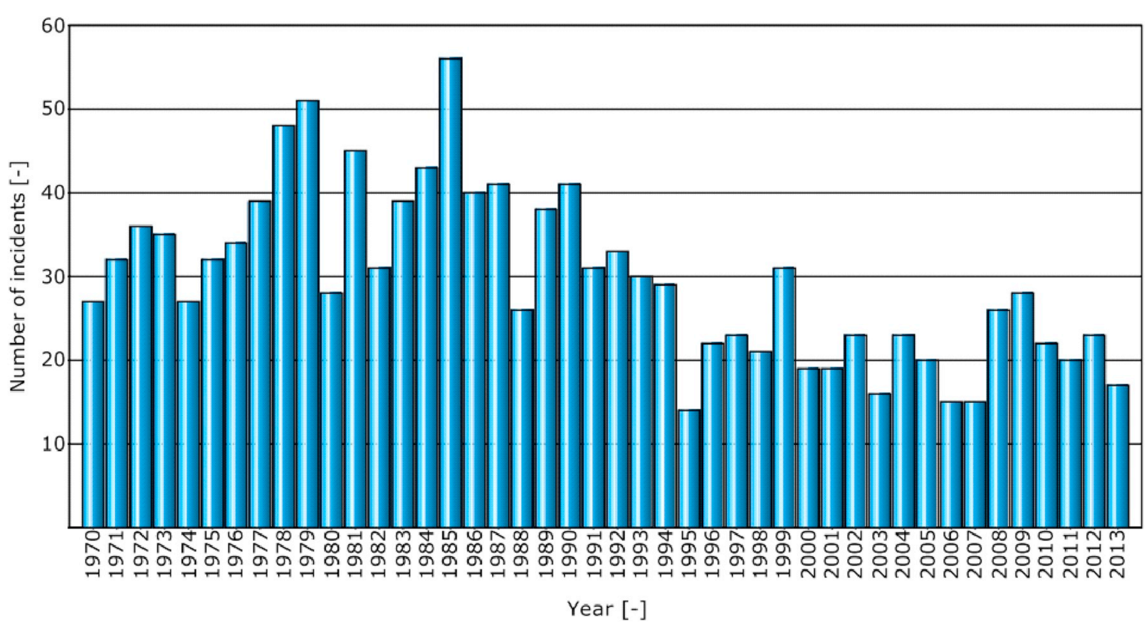


**Fig. 1.** Annual number of incidents (1970–2013) (Source: EGIG, 2014).

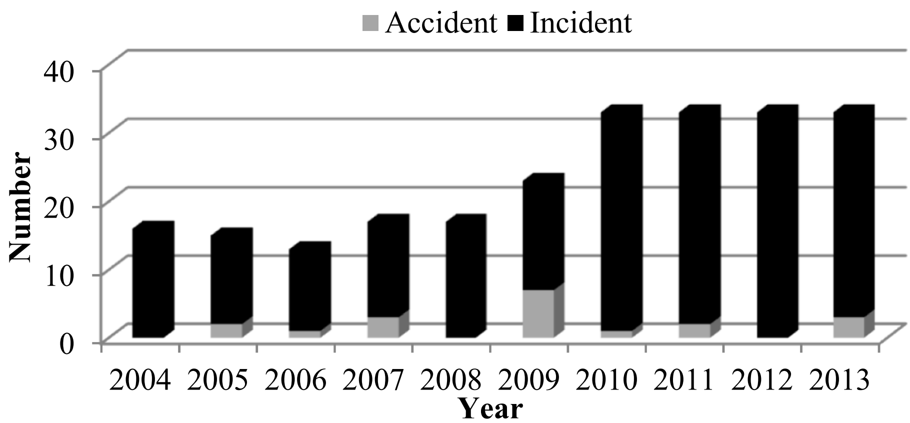


**Fig. 2.** Annual number of accidents and incidents in TSB (2004–2013) (Source: TSB, 2014).

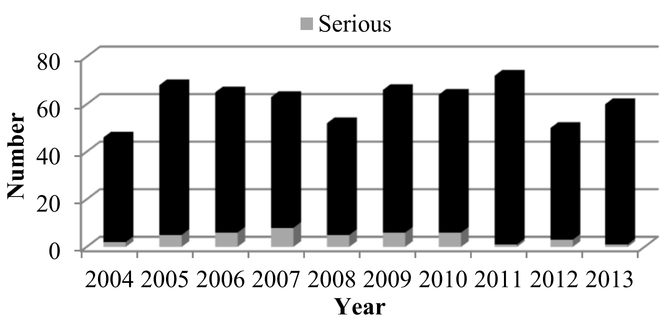


**Fig. 3.** Annual number of serious and significant incidents in PHMSA (2004–2013) (Source: PHMSA, 2015).

demands for safety precautions have become greater. This urges pipeline owners to evaluate their pipelines' reliability to compensate for the trust from the stakeholders. The reason behind the reduction in the number of gas transmission pipeline incidents in the last 20 years shown in Fig. 1 is not found in the database (EGIG, 2014). In addition, the documentation of pipeline damage from each database rarely reports the analysis of the COF of the events. Even if available, only tangible monetary-based losses, e.g., number of injuries and fatalities, cost of assets, and production losses, are included.

Of all the database records on the frequency of pipeline failure events and causes of failure mentioned, only the PHMSA provides statistics for the consequence analysis of the number of fatalities, injury costs, industry costs and public loss. The TSB and PHMSA were established by the Canadian and US governments, respectively, while the EGIG was developed by the 17 major operators of gas transmission in Europe. Their records for pipeline systems differ; the EGIG reports unintentional natural gas releases from transmission pipelines, the TSB records failure events in federally regulated pipelines, and the PHMSA records all pipeline damage in the US. Zardasti et al. (2017) successfully identified 30 RL factors indicating stakeholders' negative perceptions based on an in-depth review of 30 case studies of pipeline failure during the period between 1965 and 2014. However, the prioritization of these multiple factors is an issue that has been raised for future research.

### *2.5. Prioritization of reputation loss (RL) factors*

Identifying RL factors is pointless unless they are prioritized. Many factors have been identified; it is fruitless to focus on all factors at once. Moreover, it is an ineffective way to overcome the loss of reputation practically, specifically for a pipeline operator. Thus, there is a need to prioritize the identified RL indicators to assist pipeline operators or owners in focusing on which factor is to be addressed first. There are several factor prioritization techniques available. The analytic hierarchy process (AHP) and fuzzy analytic hierarchy process (FAHP) are appropriate methods to prioritize factors because they segregate the weighting of each factor based on respondents' preferences. In addition, these methods have successfully interpreted respondents' preferences and transform a linguistic rating scale into a numerical fuzzy scale. This allows the result of a RLM to be designed quantitatively.

The AHP method was developed by Thomas L. Saaty in 1980 (Kiris, 2013). It is an effective tool to solve complex decision making by allowing respondents to prioritize the importance levels of factors (Torfi et al., 2010; Nilashi and Janahmadi, 2012; Hossain et al., 2014). A higher weight factor is an indication of a highly important factor, and vice versa. In a general framework of the AHP method, *Criterion* and *Sub-Criterion* are the factors identified to achieve the *Goal*, while *Alternative* is the choice of solutions available corresponding to the *Goal*. AHP consists of four steps (Coulter et al., 2006): (1) the hierarchical breakdown of a problem into a *Goal*, *Criterion*, and *Sub-Criterion*, (2) the practice of a pairwise comparison procedure to define respondents' preferences, (3) the scaling of the attribute values for each alternative, and (4) the alternative ranking. The root of the AHP method is the determination of the relative importance of the *Criteria* and *Sub-Criterion* to rank the *Alternatives* via the pairwise comparison method (Arunraj and Maiti, 2010). The pairwise comparison is challenging when $n(n\text{-}1)/2$ pairwise comparisons must be completed, where $n$ is the number of predetermined criteria. Moreover, respondents can easily become bored during a survey questionnaire session, regardless of the questionnaire design (Sato, 2005). This issue can be overcome by implementing the pair-wise judgement data transformation process (Chen, 2010).

In addition to solving the subjective qualitative attributes, AHP is applicable to make objective judgements from the quantitative attributes or a mixture of both. It is one of the best ways for deciding among complex criteria structures on different levels (Özdağoğlu and Özdağoğlu, 2007). However, Yang and Chen described the limitations of a pure AHP method (Toosi and Kohanali, 2011): (1) it is mainly used in the applications of nearly crisp-information decisions, (2) it generates uneven judgement scales and excludes uncertainties in human judgement, (3) it produces inaccurate rankings, and (4) AHP output is significantly influenced by the perceptions and other subjective judgements based on decision makers' preferences.

Fuzzy logic was primarily introduced by Lotfi Asker Zadeh in 1965 (Zadeh, 2008). It is an attempt to formalize two types of human capabilities: (1) to converse reason and make rational decisions in imperfect information environments, and (2) to perform various physical and mental tasks without any measurements or computations (Zadeh, 2008). The FAHP is a synthetic extension of the classical AHP method in which the fuzziness of the decision makers is considered (Özdağoğlu and Özdağoğlu, 2007; Kabir and Hasin, 2011). Several researchers have integrated fuzzy theory with the AHP method to eliminate the uncertainty and vagueness in the judgement of the decision makers (Aydin and

Pakdil, 2008; Chuang et al., 2009; Li and Poh, 2010; Toosi and Kohanali, 2011; Javanbarg et al., 2012; Pandey et al., 2013; Aqlan and Ali, 2014; Sa'idi et al., 2014; Urbina and Aoyama, 2017). FAHP was applied to determine the relative weights of the criteria (Chuang et al., 2009; Torfi et al., 2010; Li and Poh, 2010; Amini and Jochem, 2011; Zeynali et al., 2012; Noor et al., 2012; Pandey et al., 2013). This helps in prioritizing the factors and attributes of the predetermined factors (Mikhailov and Tsvetinov, 2004; Kong and Liu, 2005; Bozbura and Beskese, 2007; Sevkli et al., 2007; Lee et al., 2009; Junior et al., 2014) and ranking the available choices to achieve an objective (Celik et al., 2009; Das, 2010; Dalalah et al., 2010; Gharakhani et al., 2014). Both the AHP and FAHP methods are able to derive the resulting weights of the predetermined factors. Hence, the identification of the comparison between weights in both methods is necessary (Özdağoğlu and Özdağoğlu, 2007; Kordi, 2008; Kabir and Hasin, 2011).

### 2.6. Remarks

The literature search presented explained the need to develop a RLM for onshore pipeline failure involving an explosion. Previous explosion events show that the pipeline owner's reputation was jeopardized due to the impact of the accident on their stakeholders, which justifies that the stakeholders' expectations were unable to be achieved. Hence, the pipeline owner suffers RL. The reputation of a company is relative to the stakeholders' expectations, and it differs depending on their concerns with respect to a company. Therefore, to develop a quantitative RLM of a

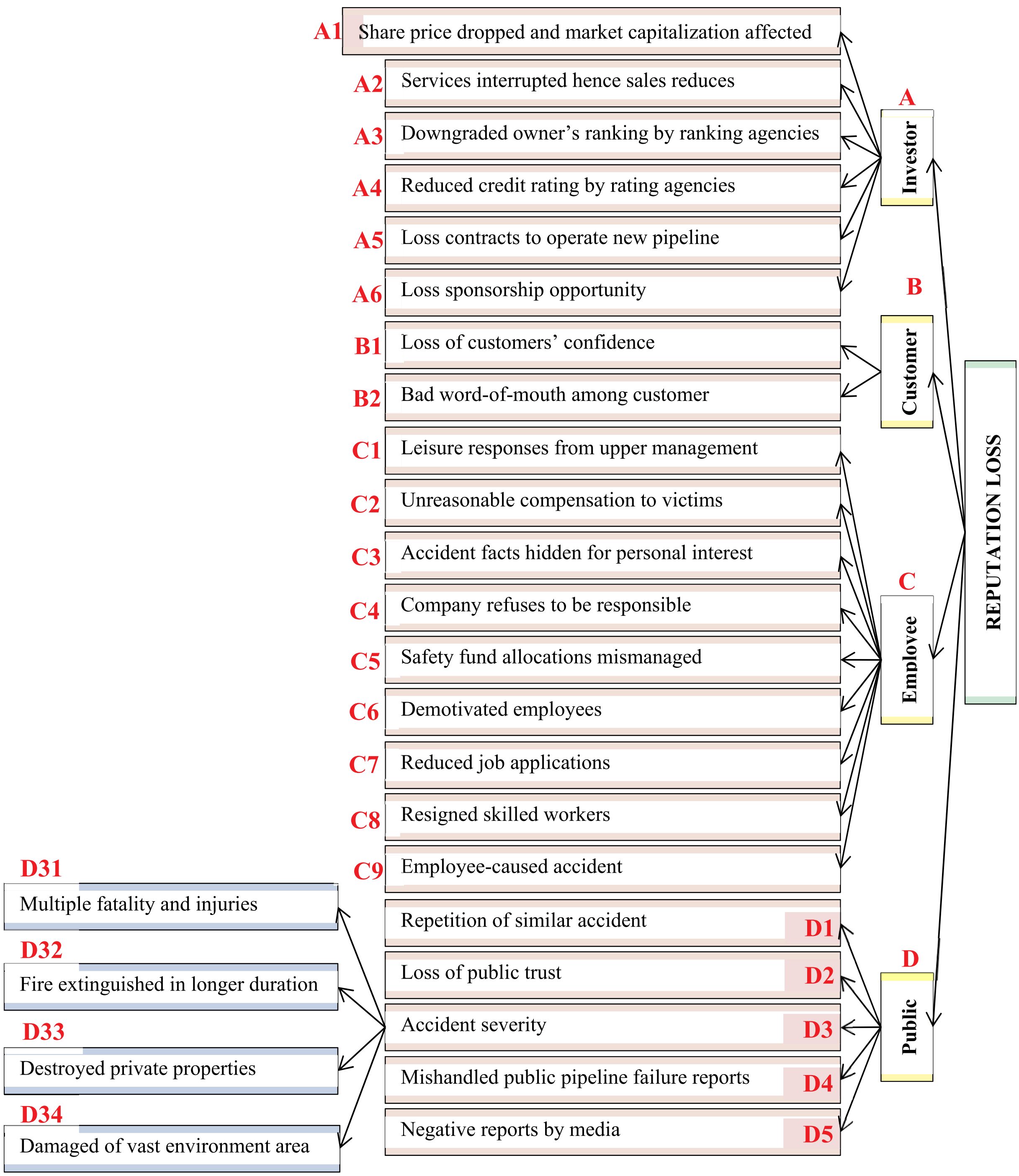


**Fig. 4.** Hierarchical breakdown of proposed RLM framework.

pipeline owner prior to an explosion event, the identification of 30 RL indicators of onshore pipeline damage reported in the past 50 years (between 1965 and 2014) was accomplished using an event study method for 30 case studies (Zardasti et al., 2017). These multiple factors are troublesome without being prioritized to allow the owner to respond to the factors that show a higher impact. The currently available reputation models assess the reputation level of a company based on a single stakeholder or a combination of several stakeholders.

## 3. Methodology

The AHP and FAHP were utilized to weight the RL factors and determine the relationship between the identified factors and the pipeline operators' RL prior to the event. Statistical analysis was implemented for the verification of the data hypotheses. The evaluation of the RL impact was performed by the establishment of a reputation loss index (RLI) incorporating the RL severity rating, which was built into the risk matrix to assess the consequences of pipeline failure; simultaneously, the risk value is obtained. The RLI of the selected pipeline explosion events discussed in Zardasti et al. (2017) is obtained as part of the evaluation process. Finally, a RLM to assess the pipeline consequence failure following an explosion is developed quantitatively.

### *3.1. Framework of the reputation loss model (RLM)*

Based on the identified RL factors obtained from Zardasti et al. (2017), the factors were arranged into a proposed RLM framework as shown in Fig. 4. This arrangement was inspired by the work of Cravens et al. (2003), and in the later analysis work, the AHP method will be used for factor prioritization purposes. Since the identification of the RL factors is highly dependent on the stakeholders' perceptions, the identified factors were arranged according to the impact to a specific stakeholder. For example, the RL factors "Share price dropped and market capitalization affected", "Services interrupted hence sales reduces", "Downgraded owner's ranking by ranking agencies", "Reduced credit rating by rating agencies", "Loss contracts to operate new pipeline", and "Loss sponsorship opportunity" are factors that may influence the trust of the investors towards the company. Thus, these factors are sub-factors for the pipeline operator's stakeholder "Investor". This arrangement was created for "Customer", "Employee" and "Public" as well.

Since most of the factors have quite long names, they were given codes for simplicity by implementing the AHP hierarchical breakdown, as shown in Fig. 4, indicating that the stakeholders "Investor", "Customer", "Employee" and "Public" are criterion coded as A, B, C, and D, respectively; the Sub-criterion are the RL factors coded as A1, A2, A3, A4, A5, and A6 for each factor under stakeholder "Investor". The sub-subcriteria "Multiple fatality and injuries", "Fire extinguished over longer duration", "Destroyed private properties", and "Damaged vast environment area" are under the sub-criterion "Accident severity" coded as D3 under the stakeholder "Public", and thus they were coded as D31, D32, D33, and D34, respectively.

To support the findings, experts were interviewed, and the relative importance of RL factors was identified. The identified factors are designed as questionnaires to undergo a preliminary survey to obtain responses from respondents regarding their feasibility and understanding, including the questionnaire's layout and design.

### *3.2. Interviews*

Several interview sessions were completed to obtain expert opinions regarding the identification of the RL factors and the feasibility of the RLM. Initially, ten O&G pipeline integrity management employees were selected to participate in each interview session, which had different objectives: agreements on the RL factors and questionnaire validation. The experts involved in the interviews were selected from different sectors of O&G companies with headquarters in Malaysia, such as private-limited petroleum exploration and production companies, pipeline technical solution providers and publicly listed gas transmission pipeline companies. These local companies were selected because they have a better understanding of the local conditions of pipeline damage failure probabilities and consequences. The majority of the experts have a minimum of five years of working experience in pipeline integrity management in an O&G company.

The first session was conducted to gain the experts' agreement on the identified factors of RL collected through literature reviews and case studies. The overall idea of the research was presented prior to the interview to provide an overview and scope of the work to be executed. The interview sessions were performed individually to allow direct two-way conversations and reduce misinterpretations and misconceptions of the factors. This allowed no bias between experts' points of view against each identified factor. From the interview sessions, all experts agreed with all identified factors, and several suggestions were raised for consideration, such as the following: pipeline location, e.g., onshore pipelines, must be stated so that the RL factors will be directly interrelated; the term "responsibility" is sensitive to O&G companies as the industry is a well-known high-risk industry, and responsibility is their main focus to deliver a safe and sound project for a good reputation; and the factors associated with employees' attitudes are important as each employee is both an internal stakeholder and an agent of the company's first impression towards the external stakeholders.

The next interview sessions aimed to validate the constructed survey to satisfy the minimum requirements of O&G industry members. A trial questionnaire survey was distributed and answered during the interview sessions. This hands-on session was held with all experts simultaneously at each of their companies, and they were allowed to ask any questions regarding the survey at the midpoint of the session so that their understanding of the questions could be observed. At the end of the sessions, several suggestions were made to improve the questionnaire from the experts' perspectives as employees of O&G companies, including the following: the rating scale of 1–10 is considered a large range, and people in the industry are easily confused, so it is best to use a 1 to 5 rating scale; a given scenario of a pipeline explosion event that includes the failure cause and impact is the best way to avoid too much writing in the questionnaire survey, as words simply bore participants faster than figures; and a short and concise questionnaire survey is better as a shorter duration is needed to complete the survey. These suggestions were taken into consideration in the construction of the preliminary and subsequent questionnaires.

### *3.3. Questionnaire and survey*

In addition to collecting data via the literature review, case studies and interviews with experts, a questionnaire is another instrument applied in this study. Based on the data collected and suggestions noted from the previous research instruments, the questionnaire was constructed to obtain responses from particular experts of this study. Two surveys were conducted: (1) a preliminary survey and (2) a main survey. These surveys were intended to obtain the perception on the RL factor from the panel of experts, both pipeline integrity management employees and researchers, with several purposes: (1) the level of influence, (2) the level of importance, and (3) the impact of the factors towards each stakeholder, i.e., investors, customers, employees and the public. Subsequently, each stakeholder was asked to provide their responses regarding the influence of the RL factors towards pipeline owners in a different questionnaire. As a general rule for most research, a sample size of more than 30 but less than 500 is considered appropriate, as suggested by J.T. Roscoe (Kumar et al., 2013). Depending on the method of analysis to be used, the number of respondents may differ. For example, the AHP and FAHP methods require at least ten respondents due to the complexity of the analysis, and the number of respondents is considered satisfactory for further analysis.

For the preliminary survey, ten people were considered adequate to answer the survey regardless of their knowledge background. A research student is a good example of a respondent for this preliminary study, incorporated with several pipeline integrity management experts with at least five years of pipeline integrity management working experience. This survey was done to test the reliability of the data obtained from the returned survey. The Cronbach's alpha for this survey should be at least 0.70 for a new construct to show that the internal consistency of the questionnaire is above an acceptable level, and consequently further analysis of the survey can be executed. The preliminary questionnaire was prepared to obtain responses from the respondents regarding the suitability of the questionnaire layout, including the instructions and questions, understanding of the questions, and answer methods. This stage allows the respondents to suggest any improvements to be made to minimize the level of misunderstanding of respondents to the main questionnaire later.

There are two types of preliminary questionnaire designs in this study, Type 1 and Type 2. The preliminary survey, Type 1, was designed to identify the factors that influence the O&G pipeline operator's loss of reputation due to a pipeline explosion event. This survey was handed to the selected respondents in person and retrieved immediately once it was completed (within 10 min). However, to create a respondent-friendly questionnaire survey, an online survey is the latest and easiest method to gain respondent interest to complete a survey with good instructions laid out in the survey design. There is a significant amount of current research that implements this method with the help of online forms due to its simplicity for data collection. The responses from the respondents were later automatically recorded once the submit button was clicked. The Type 1 survey designed previously was corrected and upgraded into an online version with several modifications. The preliminary survey Type 2 design aimed to gain the perceptions of the stakeholders (investors, customers, employees and the public) towards a pipeline operator who was involved in an onshore pipeline accident related to an explosion.

The main surveys were designed online based on the lessons learned from the preliminary survey. For this study, there are five types of surveys with different objectives to be achieved: Type 1, Type 2, Type 3, Type 4 and Type 5. These surveys were distributed via electronic mail and shared on social media related to the O&G company stakeholders in Malaysia, as follows: (1) Type 1 surveys all stakeholders, (2) Type 2 for investors, (3) Type 3 for customers, (4) Type 4 for employees, and (5) Type 5 for the public. The objective of the Type 1 main survey was to evaluate the perceptions of the stakeholders towards a pipeline operator after an onshore pipeline accident related to an explosion. The Type 2 main survey design was expanded from the main questionnaire design of the Type 1 version. This survey was intended to allow an investor to assess the RL level of a pipeline company according to the RL indicators provided, accompanied with a structured worst-case scenario for assessment purposes. Meanwhile, the Type 3, Type 4 and Type 5 main survey formats and objectives were somewhat similar to the Type 2 main survey design and were used to obtain responses from customers, employees and the public, respectively.

### 3.4. Data analysis

Prior to modelling the O&G pipeline company RL specifically designed for pipeline consequence assessment, the collected data from the literature review, case studies, interviews with experts and questionnaire surveys were analysed using a relevant and appropriate method to answer all the objectives at the end of the study. Initially, the number of factors extracted from the literature review, case studies and interviews with experts was calculated using frequency analysis, including the number of factors that occurred in each case study. As soon as the sample size was determined, the main survey was distributed to the respondents online. The data obtained from the designed preliminary survey had to be subjected to a reliability analysis before the main survey could be distributed to the identified respondents. The reliability of the survey data was analysed using the computer-aided statistical analysis software known as Statistical Package for the Social Sciences (SPSS), and the data sampling for each survey was analysed by frequency analysis and percentages. It is crucial to perform hypothesis testing to determine the significant differences between samples to confirm that the samples are not different in terms of ratings before further analysis can be executed. The Mann-Whitney U test and the Kruskal-Wallis H test were utilized for this purpose due to the non-parametric nature of the survey data.

To determine the relationship between the identified factors and the exploded pipeline owner's reputation, the prioritization of the factors was analysed using the AHP and FAHP methods, and then the factors were ranked by rearranging the factor weights in a descending manner (i.e., highest weight ranked first). The factor priorities were also ranked according to the respective stakeholders' perceptions to observe the impact level of each factor on the stakeholders.

### 3.5. Statistical analysis

Through the literature review, case studies and interviews with experts, the number of RL factors initiated by an event of an onshore O&G pipeline was retrieved (Zardasti et al., 2017). The number of factors that occurred in each selected case study was calculated using frequency analysis and was presented in a table. The number of factors that occurred in all case studies was also included in the table. The frequency of an observation is the number of times the observation occurs in the data. Frequency analysis measures the central tendency of the data and its dispersion, which is portrayed in tables or graphs. This analysis is used for all types of surveys and consists of multiple choice and ordinal questions. The responses were analysed by the numbers of frequency or percentages using Microsoft (MS) Excel and SPSS software; the highest value shows the most preferred answer among the respondents. The calculation of frequency percentage is shown in Equation (1).

$$Percentage(\%) = \frac{f}{N} \times 100 \tag{1}$$

where $f$ is the frequency of an observation and $N$ is the number of respondents.

Generally, a sample size for research activities can be determined by Equation (2) (Krejcie and Morgan, 1970).

$$SS = \frac{X^2NP(1-P)}{d^2(N-1) + X^2P(1-P)} \tag{2}$$

where $SS$ is the required sample size; $X^2$ is the table value of Chi-square for 1-degree of freedom at the desired confidence level; $N$ is the population size; $P$ is the population proportion (assumed to be 0.50 since this would provide the maximum sample size); and $d$ is the degree of accuracy expressed as a proportion (0.05). A population is an entire group of people, while a sample is a portion that represents the population. For an unknown and outnumbered population, as a general rule, a sample size of 30 respondents is needed, as well as for a sample that is broken into sub-samples, e.g., by race or gender, as proposed by J.T. Roscoe in 1975 (Kumar et al., 2013). For the return rate of the questionnaire, an indication of adequacy is used. This statement of adequacy justifies that the questionnaire is acceptable to be further analysed for documentation purposes (Miller, 1991).

Information on perceptions and opinions normally involves Likert-scaled questions, as the qualitative data are unable to be measured directly; this assessment of attitude was introduced by Rensis Likert in 1931 (Gliem and Gliem, 2003). It is necessary to calculate and report the Cronbach's alpha coefficient for determining the internal consistency reliability when a Likert scale is used (Brown, 2011). The Cronbach's alpha reliability coefficient ranges between 0 and 1 (Gliem and Gliem, 2003); the internal consistency of the scale increases as the value is closer to 1. The reliability analysis was done on all preliminary and main surveys to obtain the internal consistency so that it achieves a Cronbach's alpha reliability coefficient of at least 0.70 and the internal consistency is acceptable.

A Likert-scale survey must be analysed as ordinal data instead of intervals, although the difference between scales is somewhat similar to that of interval data. Ordinal data are generally used for categorical data. These ordinal-scaled data are called non-metric data (Kumar et al., 2013). The Mann-Whitney U test is a non-parametric test that is suitable to be used for this type of data, where the significance of the difference between two groups is to be observed. The Mann-Whitney U test, which is also known as the Wilcoxon rank sum test, was used to determine the significant difference between samples in terms of the ratings given in all surveys. It is crucial to perform this hypothesis testing to investigate differences among the respondents regarding the factors before a RLM can be developed. It tests the significant differences of the ratings of the RL factors between two independent groups of samples, such as the level of education, years of work experience, and type of stakeholder.

This study indicated that the null hypothesis should not be rejected, which means that the ratings do not differ between groups. The test statistics can be determined by the sum of the ranks for each of the two groups. The significance of the ranks' sums can be obtained by transforming the score to a standard normal deviate value, $Z$. The significance level for this study was established to be 0.05, for which the level of confidence of 95% was selected. If the value of significance is greater than 0.05, the test does not reject the null hypothesis, which means there is no significant difference between the two groups of samples in terms of rating the RL factors.

On the other hand, the Kruskal-Wallis H test is another non-parametric test for non-metric data. The difference between these two tests is the number of groups of samples to be tested for the significance of their differences. This test is implemented on a sample with more than two groups, denoted as $K$. The sum of the ranking can be performed by summing the ranks for each of the $K$ groups. The Kruskal-Wallis $H$ statistic is computed from these sums, and it has a distribution similar to a chi-square distribution. Briefly, the critical value of $H$ can be determined from a chi-square distribution table. As the level of confidence of 95% was selected and the significance level for this study was established to be 0.05, the test does not reject the null hypothesis if the value of significance is greater than 0.05. In conclusion, there is no significant difference between $K$ groups of samples in terms of rating the RL factors.

### 3.6. Prioritization of reputation loss (RL) factors

Initially, all the criteria presented in Fig. 4 were included in the survey to obtain the respondents' preferences according to the fundamental scale of the AHP method. The retrieved survey responses then underwent a procedure called the pairwise comparison method with the aid of the Super Decisions software. This method is used to obtain the relative weight of each criterion. However, the logical grouping of the nodes and clustering of the RL factor framework must be decided first, because each criterion has a local and global priority, whereby each level of criteria was scored with respect to its parent criterion by comparing one choice to another. As shown in Fig. 5, the clusters are made for factors under the parent criteria of the *Goal*, the *Criterion* and the *Sub-criterion,* e.g., factors A, B, C, and D, and the *Sub-subcriterion*, such as factor D3. The nodes are located within the clusters. This process was used to obtain the normalized weight for each factor, and subsequently the priority of each factor for the parent criterion and the criteria within the cluster can be obtained. The sum of all the criteria under a given parent criterion in each layer of the hierarchy must be equal to 1.

Data from the surveys were input into the Super Decisions software prior to the completion of a manual calculation on the data transformation scheme for the pairwise judgement suggested by Chen (2010), which overcomes the complexity in the analysis as the number of

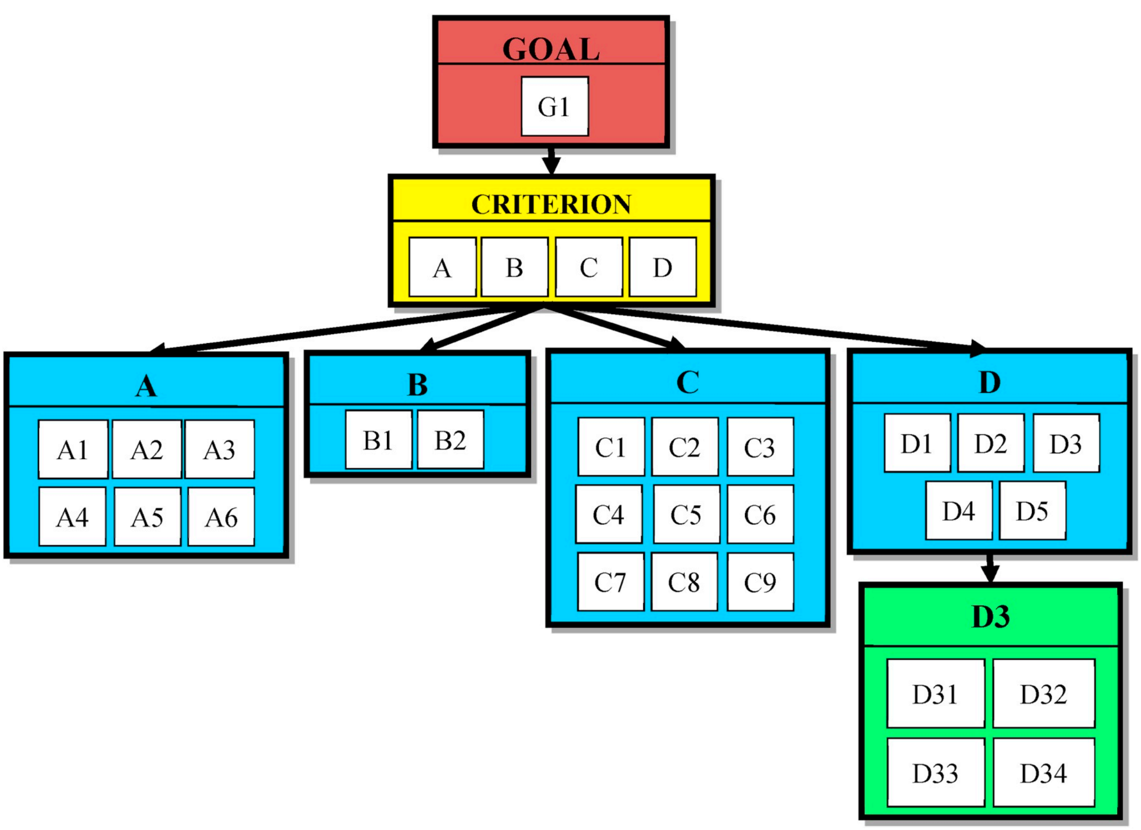


**Fig. 5.** AHP framework in the Super Decisions' main window.

variables increases and the number of survey questions simultaneously decreases. The *Pairwise Comparison* command is available in the drop-down menu of the *Assess/Compare* tab in the software. A popup window appears, and data entry can be performed. In the same window, the inconsistency, which is limited to 10% or 0.10 to validate the inconsistency of the rating by the respondent, is provided in the top right corner of the window. Similarly, the priorities of the factors are available just below the inconsistency value in the form of graphs and numbers. The overall priorities for all factors can be observed via the *Computation* tab dropdown menu of the *Priorities* command.

The results given by the Super Decisions software can be obtained using the MS Excel software as well. The comparison between both factors was done to validate the results provided by the Super Decisions software. Hypothesis testing between the results is implemented to obtain the significant differences between both factors using non-parametric testing, e.g., the Mann-Whitney U test or the Kruskal-Wallis H test. The data retrieved from the Likert-scale survey are entered into a worksheet in MS Excel, and the calculation of the priority for each factor is performed. The pairwise comparisons are applied to factors within the same level in the AHP framework, namely, *Criterion*, *Sub-criterion* and *Sub-subcriterion*. Among all of the FAHP methods, the Chang's extent analysis method is considered the simplest. This method is similar to previous methods; the difference is in the scale used (Lee et al., 2009). FAHP uses a triangular fuzzy scale (TFN) defined based on the AHP fundamental scale. The procedures to prioritize the RL are similar to those presented in Libriati et al. (2018).

## 4. Results

### 4.1. Statistical analysis

The Cronbach's alpha value for all questionnaires ranges between 0.886 and 0.958, with a good to excellent reliability level, showing that the questionnaire design successfully achieves the minimum internal consistency value of 0.70 prior to collecting the responses as primary data. The return rates for the Type 1 and Type 5 surveys are adequate at 91% and 50%, respectively, in contrast with the other surveys, due to several reasons. The Type 2 survey was distributed to investors despite the short research duration. A minimum of 30 respondents were contacted, but only two responded, leading to a 6.7% return rate.

Nevertheless, the responses were recorded to gain the differences in perspective between stakeholders. For the Type 3 and 4 surveys, the return rate was slightly below the minimum 50% return rate, 47% for both surveys, yet they met the minimum sample size of 30 persons. It is a general rule that surveys can be divided into sub-samples. Hence, all of the main surveys can be further analysed statistically. Table 1 shows a summary of the demographic analysis of all respondents calculated in terms of the frequency and percentages.

Prior to determining the relationship between the factors of RL and their impact on an operator, hypothesis testing needs to be executed to avoid significant differences between the ratings of factors by the different groups of stakeholders. For example, there are two groups of customers, such as retailers and end users, involved in this analysis. It is hypothesized that there is no significant difference in the RL factors' ratings between retailers and end users, for which the significance levels, $p$, for all factors must be more than 0.05 so that the null hypothesis cannot be rejected. If so, it shows that there is a 5% chance that the results falling in the critical region have occurred by chance.

Initially, the hypothesis testing was applied to different types of customers, customer awareness of pipeline accidents, years the product has been purchased by the customers, and customers' current product brand used. The result shows that the null hypothesis is not rejected based on the $p$-value, except for the following factors: A, C, A2, A4, D3, and D32. Similarly, the significance of the difference of employees' years of work experience, employees' level of job position (level of management) and sector of O&G company were tested. The factors C,

**Table 1**
Respondents' demographics for all main surveys.

| Type of Main Survey | Criteria | Category | Frequency | Percentage (%) |
|---|---|---|---|---|
| 1 (All stakeholders) Objective: To gain the perceptions of the stakeholders towards a pipeline operator after an onshore pipeline accident related to an explosion | Gender | Male | 37 | 60.7 |
| | | Female | 24 | 39.3 |
| | Age (years) | 21–30 | 37 | 60.7 |
| | | 31–40 | 20 | 32.8 |
| | | 41–50 | 3 | 4.90 |
| | | >51 | 1 | 1.60 |
| | Aware of pipeline accident | Yes | 59 | 96.8 |
| | | No | 2 | 3.20 |
| | Type of stakeholder | Investor | 2 | 3.30 |
| | | Customer | 8 | 13.1 |
| | | Employee | 31 | 50.8 |
| | | Public | 20 | 32.8 |
| 2 (Investor) Objective: To allow the investor to assess the reputation loss level of the oil and gas company according to the reputation loss indicators provided | Gender | Male | 2 | 100 |
| | | Female | 0 | 0.0 |
| | Age (years) | 21–30 | 1 | 50.0 |
| | | 31–40 | 1 | 50.0 |
| | | 41–50 | 0 | 0.0 |
| | | >51 | 0 | 0.0 |
| | Aware of pipeline accident | Yes | 2 | 100 |
| | | No | 0 | 0.0 |
| 3 (Customer) Objective: To allow the customer to assess the reputation loss level of the oil and gas company according to the reputation loss indicators provided | Gender | Male | 2 | 100 |
| | | Female | 0 | 0.0 |
| | Age (years) | 21–30 | 1 | 50.0 |
| | | 31–40 | 1 | 50.0 |
| | | 41–50 | 0 | 0.0 |
| | | >51 | 0 | 0.0 |
| | Aware of pipeline accident | Yes | 2 | 100 |
| | | No | 0 | 0.0 |
| 4 (Employee) Objective: To allow the employee to assess the reputation loss level of the oil and gas company according to the reputation loss indicators provided | Gender | Male | 17 | 73.9 |
| | | Female | 6 | 26.1 |
| | Age (years) | 20–29 | 7 | 30.4 |
| | | 30–39 | 9 | 39.1 |
| | | 40–49 | 6 | 26.1 |
| | | >50 | 1 | 4.30 |
| | Aware of pipeline accident | Yes | 23 | 100 |
| | | No | 0 | 0.0 |
| | Years of working experience | <5 | 9 | 39.1 |
| | | 5–10 | 3 | 13.0 |
| | | >10 | 11 | 47.8 |
| | Job position | Executive | 5 | 21.7 |
| | | Manager | 5 | 21.7 |
| | | Engineer | 12 | 52.2 |
| | | Others | 1 | 4.30 |
| | Company sector | Owner | 9 | 39.1 |
| | | Service provider | 13 | 56.5 |
| | | Fabricator | 1 | 4.30 |
| 5 (Public) Objective: To allow the public to assess the reputation loss level of the oil and gas company according to the reputation loss indicators provided | Gender | Male | 7 | 9.70 |
| | | Female | 65 | 90.3 |
| | Age (years) | 20–29 | 58 | 80.6 |
| | | 30–39 | 13 | 18.1 |
| | | 40–49 | 1 | 1.40 |
| | | >50 | 0 | 0.0 |
| | Aware of pipeline accident | Yes | 67 | 93.1 |
| | | No | 5 | 6.90 |
| | Highest level of education | PhD | 5 | 6.90 |
| | | Master | 23 | 31.9 |
| | | Degree | 35 | 48.6 |
| | | Diploma | 0 | 0.0 |
| | | Certificate | 9 | 12.5 |

A2, C1, and C9 reject the null hypothesis, while the others accept it. Furthermore, the hypothesis tests are applied on the public factors concerning the awareness of pipeline accidents, highest level of education, product purchase history, and current product brand use, and only factors B1 and B2 obtained less than a 0.05 $p$-value. Thus, it can be concluded that we do not reject the null hypothesis; therefore, the ratings for the RL factors do not differ significantly within the same group of stakeholders, e.g., customers, employees and the public.

Since the difference in the RL factor ratings between investors cannot be evaluated due to the inadequate number of respondents, the comparison of the factor ratings for all types of stakeholders, e.g., investors, customers, employees and the public, is implemented to identify the significant differences among the ratings given by the various stakeholders. It is hypothesized that the null hypothesis is to be rejected, as the ratings differ among the types of stakeholders. Out of the 30 factors, 14 have significance levels less than 0.05; hence, the null hypothesis was rejected as expected. It can be concluded that there are significant differences in the ratings by types of stakeholders, and it is suggested that the factor RL impacts by the stakeholders are analysed individually, rather than generalizing them as a single value for all stakeholders. As expected, the same result was found in the hypothesis testing on the different types of survey.

It is predicted that the RL factor ratings differ between the multiple (Type 1) and single (Types 2, 3, 4 and 5) stakeholder surveys. Nine factors had rejected null hypotheses, with significance level values less than 0.05. This shows that each type of survey holds individual rankings of RL factors, i.e., all stakeholders (Type 1), investors (Type 2), customers (Type 3), employees (Type 4) and the public (Type 5). Consequently, it is important to identify the priority of the RL factors according to single-stakeholder perceptions rather than a generalization of the factors' ranking by various stakeholders due to the differences of perceptions and expectations among the stakeholders towards the pipeline operator.

### 4.2. Prioritization of factors

The result of the priority vector for all RL factors according to the investors', customers', employees' and public's perceptions is evaluated using various methods of analysis. It is hypothesized that there are significant differences between the priority vectors obtained from various stakeholders, as their expectations towards the O&G company vary. On the other hand, there is no significant difference between the priority vectors calculated by the AHP and FAHP methods using various computer-aided software, e.g., MS Excel and Super Decisions software, as expected. The significances of the differences in priority vectors among stakeholders have shown that factors B, C and C5 have significance levels below 0.05; thus, the null hypothesis is rejected. Each stakeholder has different views on these factors compared to the other factors of RL. In contrast, the null hypothesis cannot be rejected, as there is no significant difference between the priority vectors calculated using the various analysis methods.

It is best to extract the ranks of the factors rather than the numerical values of the weights of the factors, due to the differences in the weight of each factor of each stakeholder depending on the analysis method used. The results show that factor A6 is the only factor that had a similar ranking from all stakeholders using the different types of analysis methods; it was generally ranked as having the least influence on the pipeline owner's RL prior to pipeline explosion events. Factor D3 appears to be ranked as the first factor in the public-influenced category.

If the first ranked for all factors' influence categories is to be observed in the stakeholder-influenced category, both the customers and employees agreed that factor A had the most influence on the pipeline owner's reputation, while the public selected factor C, and the investors chose factor B. The customers and the public have a common view of the factor B2, with both agreeing that this factor of the customer-influenced category has a greater impact on the pipeline owner's reputation compared to factor B1; the employees and investors opined the opposite. In the employee-influenced category, factor C9 ranked as the first reason for the pipeline owner to lose reputation by the employees and public, while the customers perceived that factor C1 is the most influential factor of RL, and the investors chose factor C3.

On the other hand, all stakeholders have different opinions of the investors' influences on the pipeline owner's RL. The investors and customers believed that factor A3 is the greatest reason for RL; the employees chose factor A1; and the public selected factor A5. Similarly, all stakeholders have different opinions of the consequence-influenced factors of RL on the pipeline owner's reputation. The investors and customers chose factor D34, the employees selected factor D33, and the public chose both factors D31 and D34.

The inconsistency in the perceptions between stakeholders should be acknowledged, and it is generally impossible to gain a single priority vector of RL factors to represent all stakeholders. In addition, the sole analysis method to obtain the priority vector has to be selected as well as the value to be implemented in the creation of the RL calculation formula. The FAHP method of analysis is selected due to its robustness in the pairwise comparison process with the assistance of the data transformation process. Combined with the TFN, it extrapolates the Likert-scale data into a linguistic scale and the fuzzy synthetic extent method for determining the weight vectors of the RL factors. Further analyses of this study utilized the weights of the RL factors obtained from the FAHP method as the chosen method.

The local and global weights for all RL factors based on the perceptions of the investors, customers, employees and public are obtained, as shown in Table 2. The local weight is the normalized weight vector obtained from the previous analysis, while the global weight is the product of the factor's weight and the parent criterion. For example, the global weight for factor A1 is calculated by multiplying the local weight of factor A by the local weight of factor A1. In summary, the local weight for factor A is the total of the global weights for the investor-influenced factors of RL (A1, A2, A3, A4, A5 and A6). These weights are later used in the formulation of the RL calculations, the development of the RLI, and the model as a pipeline consequence assessment.

### 4.3. Validation of priority vectors

To validate the priority vectors and rankings of the RL factors, experts were interviewed and simultaneously answered a survey for the importance of the RL factors and the individual stakeholders' influence. The profiles of the ten participating experts in the validation processes are as follows: eight are pipeline engineers, one is a pipeline inspector, and the last is a pipeline technical authority. Their work experience in the O&G industry specifically on pipelines ranges between eight and 33 years. Seven of the ten experts who participated in this validation stage work for O&G producer companies, one for a supplier, another for a fabricator, and the last is a consulting company's employee. Most of the experts interviewed worked for the pipeline integrity consultancy owned by the Malaysia oil giant PETRONAS. Eight of them have worked in the O&G industry for at least ten years, particularly on PIMPs. The selection of the experts considers company factors other than the business point of view to avoid bias in the analysis.

From the results, both the experts and the respondents weighed nearly equal or approximate values of priority vectors for the RL factors as follows: A2, D33, D31 and D1. The percentages of difference are 0.24%, 0.08%, 0.32% and 2.37%, respectively. An agreement in preferences between the experts and respondents, i.e., investors, customers, employees and the public, can be seen from these results, which support the characteristics of a company's reputation suggested by Fombrun (1996), investors are the company's capital suppliers; hence, service interruption is the investor's undesired event. The destruction of private property due to an explosion event tarnishes the reliability of the company entrusted by the customer. Employees are concerned with health and safety at work, and the responsibility of the owner is the public's highest concern, including the avoidance of the repetition of a similar event. On the other hand, the largest differences between RL factors in percentage weights by the experts and respondents are 31.15%, 45.87%, 35.10% and 39.38% for factors A, A2, D2 and C7, respectively.

**Table 2**
Local and global weights for factors from investors.

| Stakeholder | Criterion | | Sub-criterion | | | Sub-subcriterion | | |
|---|---|---|---|---|---|---|---|---|
| | Factor | Local | Factor | Local | Global | Factor | Local | Global |
| Investor | A | 0.2489 | A1 | 0.1789 | 0.0445 | | | |
| | | | A2 | 0.1657 | 0.0412 | | | |
| | | | A3 | 0.1794 | 0.0447 | | | |
| | | | A4 | 0.1675 | 0.0417 | | | |
| | | | A5 | 0.1529 | 0.0381 | | | |
| | | | A6 | 0.1557 | 0.0388 | | | |
| | B | 0.2694 | B1 | 0.5336 | 0.1438 | | | |
| | | | B2 | 0.4664 | 0.1257 | | | |
| | C | 0.2306 | C1 | 0.1131 | 0.0261 | | | |
| | | | C2 | 0.1135 | 0.0262 | | | |
| | | | C3 | 0.1212 | 0.0279 | | | |
| | | | C4 | 0.1212 | 0.0279 | | | |
| | | | C5 | 0.1053 | 0.0243 | | | |
| | | | C6 | 0.1141 | 0.0257 | | | |
| | | | C7 | 0.1070 | 0.0247 | | | |
| | | | C8 | 0.0993 | 0.0229 | | | |
| | | | C9 | 0.1079 | 0.0249 | | | |
| | D | 0.2511 | D1 | 0.2103 | 0.0528 | | | |
| | | | D2 | 0.1959 | 0.0492 | | | |
| | | | D3 | 0.2125 | 0.0534 | D31 | 0.2645 | 0.0141 |
| | | | | | | D32 | 0.2439 | 0.0130 |
| | | | | | | D33 | 0.2271 | 0.0121 |
| | | | | | | D34 | 0.2645 | 0.0141 |
| | | | D4 | 0.1993 | 0.0500 | | | |
| | | | D5 | 0.1820 | 0.0457 | | | |
| Customer | A | 0.2604 | A1 | 0.1709 | 0.0445 | | | |
| | | | A2 | 0.1631 | 0.0425 | | | |
| | | | A3 | 0.1731 | 0.0451 | | | |
| | | | A4 | 0.1656 | 0.0431 | | | |
| | | | A5 | 0.1693 | 0.0441 | | | |
| | | | A6 | 0.1580 | 0.0412 | | | |
| | B | 0.2448 | B1 | 0.4776 | 0.1169 | | | |
| | | | B2 | 0.5224 | 0.1279 | | | |
| | C | 0.2480 | C1 | 0.1153 | 0.0286 | | | |
| | | | C2 | 0.1082 | 0.0268 | | | |
| | | | C3 | 0.1154 | 0.0286 | | | |
| | | | C4 | 0.1126 | 0.0279 | | | |
| | | | C5 | 0.1110 | 0.0275 | | | |
| | | | C6 | 0.1141 | 0.0283 | | | |
| | | | C7 | 0.1072 | 0.0266 | | | |
| | | | C8 | 0.1052 | 0.0261 | | | |
| | | | C9 | 0.1110 | 0.0275 | | | |
| | D | 0.2468 | D1 | 0.1917 | 0.0473 | | | |
| | | | D2 | 0.1903 | 0.0470 | | | |
| | | | D3 | 0.2106 | 0.0520 | D31 | 0.2534 | 0.0132 |
| | | | | | | D32 | 0.2449 | 0.0127 |
| | | | | | | D33 | 0.2481 | 0.0129 |
| | | | | | | D34 | 0.2536 | 0.0132 |
| | | | D4 | 0.2026 | 0.0500 | | | |
| | | | D5 | 0.2048 | 0.0505 | | | |
| Employee | A | 0.2557 | A1 | 0.1807 | 0.0462 | | | |
| | | | A2 | 0.1744 | 0.0446 | | | |
| | | | A3 | 0.1767 | 0.0452 | | | |
| | | | A4 | 0.1556 | 0.0398 | | | |
| | | | A5 | 0.1616 | 0.0413 | | | |
| | | | A6 | 0.1510 | 0.0386 | | | |
| | B | 0.2510 | B1 | 0.5029 | 0.1262 | | | |
| | | | B2 | 0.4971 | 0.1247 | | | |
| | C | 0.2396 | C1 | 0.1080 | 0.0259 | | | |
| | | | C2 | 0.1047 | 0.0251 | | | |
| | | | C3 | 0.1099 | 0.0263 | | | |
| | | | C4 | 0.1058 | 0.0253 | | | |
| | | | C5 | 0.1061 | 0.0254 | | | |
| | | | C6 | 0.1173 | 0.0281 | | | |
| | | | C7 | 0.1180 | 0.0283 | | | |
| | | | C8 | 0.1111 | 0.0266 | | | |
| | | | C9 | 0.1190 | 0.0285 | | | |
| | D | 0.2537 | D1 | 0.1800 | 0.0457 | | | |
| | | | D2 | 0.1869 | 0.0474 | | | |
| | | | D3 | 0.2459 | 0.0624 | D31 | 0.2482 | 0.0155 |
| | | | | | | D32 | 0.2337 | 0.0146 |
| | | | | | | D33 | 0.2598 | 0.0162 |
| | | | | | | D34 | 0.2583 | 0.0161 |

(*continued on next page*)

**Table 2** (*continued*)

| Stakeholder | Criterion | | Sub-criterion | | | Sub-subcriterion | | |
|---|---|---|---|---|---|---|---|---|
| | Factor | Local | Factor | Local | Global | Factor | Local | Global |
| | | | D4 | 0.1717 | 0.0436 | | | |
| | | | D5 | 0.2155 | 0.0547 | | | |
| Public | A | 0.2548 | A1 | 0.1687 | 0.0430 | | | |
| | | | A2 | 0.1630 | 0.0415 | | | |
| | | | A3 | 0.1691 | 0.0431 | | | |
| | | | A4 | 0.1668 | 0.0425 | | | |
| | | | A5 | 0.1707 | 0.0435 | | | |
| | | | A6 | 0.1616 | 0.0412 | | | |
| | B | 0.2321 | B1 | 0.4724 | 0.1096 | | | |
| | | | B2 | 0.5276 | 0.1224 | | | |
| | C | 0.2638 | C1 | 0.1118 | 0.0295 | | | |
| | | | C2 | 0.1038 | 0.0274 | | | |
| | | | C3 | 0.1111 | 0.0293 | | | |
| | | | C4 | 0.1091 | 0.0288 | | | |
| | | | C5 | 0.1121 | 0.0296 | | | |
| | | | C6 | 0.1139 | 0.0300 | | | |
| | | | C7 | 0.1102 | 0.0291 | | | |
| | | | C8 | 0.1113 | 0.0294 | | | |
| | | | C9 | 0.1167 | 0.0308 | | | |
| | D | 0.2494 | D1 | 0.1902 | 0.0474 | | | |
| | | | D2 | 0.1817 | 0.0453 | | | |
| | | | D3 | 0.2206 | 0.0550 | D31 | 0.2513 | 0.0138 |
| | | | | | | D32 | 0.2468 | 0.0136 |
| | | | | | | D33 | 0.2483 | 0.0137 |
| | | | | | | D34 | 0.2535 | 0.0139 |
| | | | D4 | 0.2026 | 0.0505 | | | |
| | | | D5 | 0.2050 | 0.0511 | | | |

## 5. Discussion

For a better understanding of the stakeholders' expectations and the identification of the major contributing factor to RL, the priority vector was rearranged ascendingly and summarized in Table 3. From the result, factor D3 was chosen by all the stakeholders as the first factor that impacts the reputation of a pipeline owner prior to the failure event of a pipeline explosion, while the influences of the other factor categories differ among all respondents of the surveys. The investors were of the opinion that factors D31, "Multiple fatalities and injuries", and D34, "Damaged vast environment area", are equally important to the loss of a pipeline owner's reputation, while the customers and public agreed that factor D34 has more impact than factor D31. The employees suggested that factor D33, "Destroyed private properties", has the highest impact on the reputation.

**Table 3**
Ranking of reputation loss factors by stakeholder.

| Factor | Ranking | | | |
|---|---|---|---|---|
| | Investor | Customer | Employee | Public |
| A | 3 | 1 | 1 | 2 |
| B | 1 | 4 | 2 | 4 |
| C | 4 | 2 | 4 | 1 |
| D | 2 | 3 | 3 | 3 |
| A1 | 2 | 2 | 1 | 3 |
| A2 | 4 | 5 | 3 | 5 |
| A3 | 1 | 1 | 2 | 2 |
| A4 | 3 | 4 | 5 | 4 |
| A5 | 6 | 3 | 4 | 1 |
| **A6** | **5** | **6** | **6** | **6** |
| B1 | 1 | 2 | 1 | 2 |
| B2 | 2 | 1 | 2 | 1 |
| C1 | 4 | 2 | 6 | 4 |
| C2 | 3 | 7 | 8 | 9 |
| C3 | 2 | 1 | 4 | 6 |
| C4 | 2 | 4 | 7 | 8 |
| C5 | 8 | 6 | 9 | 3 |
| C6 | 5 | 3 | 3 | 2 |
| C7 | 7 | 8 | 2 | 7 |
| C8 | 9 | 9 | 5 | 5 |
| C9 | 6 | 5 | 1 | 1 |
| D1 | 2 | 4 | 4 | 4 |
| D2 | 4 | 5 | 3 | 5 |
| **D3** | **1** | **1** | **1** | **1** |
| D4 | 3 | 3 | 5 | 3 |
| D5 | 5 | 2 | 2 | 2 |
| D31 | 2 | 2 | 3 | 2 |
| D32 | 3 | 4 | 4 | 4 |
| D33 | 4 | 3 | 1 | 3 |
| D34 | 2 | 1 | 2 | 1 |

The investors place greater emphasis on the influence of factor B "Customers" in contributing to the loss of the pipeline owners' reputation than the other major stakeholders. Conversely, the customers selected factor A, "Investors", which is similar to the choice of the stakeholders and employees. Ironically, the public chose factor C, "Employees", because they demand responsibility for pipeline safety. The investors who participated in the survey may have similar perceptions to first-time buyers of company shares, focusing on the financial behaviour of the company (Helm, 2007). This is confirmed when factor B1, "Loss of customers' confidence", is chosen by investors, clarifying the reason behind the selection of customers as the major reason for pipeline owners' RL. This factor was selected by the employees as well. Instead of selecting factor B1, both the customers and public agreed that factor B2, "Bad word-of-mouth among customers", contributes the most to the pipeline owners' RL. Customer loyalty depends on the like ability of the company rather than the company's competence (Zhang, 2009).

The reputation of a company is more than merely a financial issue; it includes non-financial aspects such as "commitment to social and charitable issues" according to the investors (Helm, 2007). The company's performance affects its ranking over time, and changes in perception are an indicator of how the company is perceived by the public (Fombrun, 2007). Various surveys of investors focus on lists of the most and least admired firms and annual rankings (Rourke, 2011). Thus, factor A3, "Downgraded owner's ranking by ranking agencies", is the investors' aim, and it influences the pipeline owner's reputation more than the second highest factor, A1, "Share price dropped and market capitalization affected". A short-term share price deviation does not affect investors' attitude towards a company in which they are emotionally invested (Helm, 2007).

However, the employees suggest different factors than the investors and customers. The highest RL factor selected by employees is factor A1, "Share price dropped and market capitalization affected", due to the expectations of the investors for the future growth and earnings prospects of the company, followed by factor A3, "Downgraded owner's ranking by ranking agencies" (Cordeiro and Schwalbach, 2000). A company's stock price may suffer a substantial depreciation due to its inability to sustain credibility in the company's management (Rose and Thomsen, 2004). Investors' loyalty is determined by their decisions to sell or hold their company shares, which impacts the RL of the company (Helm, 2007). The public, in contrast, selected factor A5, "Loss contracts to operate new pipeline", as making the highest contribution to the pipeline owner's RL, while the company's financial performance is not of public interest (Helm, 2007).

Furthermore, a company has to tolerate a loss of investor confidence if management is incapable of persuading them in a credible way (Rose and Thomsen, 2004). This is certainly the reason for equal election between factors C3, "Accident facts hidden for personal interest", and C4, "Company refuses to be responsible", of the internal stakeholders' or employees' behaviour. In contrast, the customer chose only factor C3, "Accident facts hidden for personal interest", as the main reason for a pipeline owner's reputation. The stakeholders follow the behaviour of the executives to investigate the sincerity of a company's intentions (Rourke, 2011). On the other hand, both employees and the public voted for factor C9, "Employee-caused accident", as the major reason of pipeline owner RL; the employees hope for the trustworthiness of the company, while the public requests responsibility (Fombrun, 1996).

All stakeholders who participated in the survey agreed that factor D3, "Accident severity", has a great impact on a pipeline owner's reputation, and it was ranked first in the public-influenced category. The post-accident impact had an extreme influence on internal and external stakeholders, as both parties are at a loss by the tragic event (Chai et al., 2011). In contrast, factor A6, "Loss sponsorship opportunity", ranked the least influential in the RL of pipeline owners prior to failure events, excluding the investor who chose factor A5, "Loss contracts to operate new pipeline". In summary, it can be concluded that all stakeholders believe that this factor is not in the stakeholders' interest.

The AHP method was used to prioritize the factors of RL given by the respective stakeholders of pipeline owners via a pairwise comparison between factors with the assistance of the fuzzy triangular number that transformed the AHP fundamental scale value into a linguistic scale. The fuzzy synthetic extent method simplifies the process of obtaining the weight vector. This is the reason for choosing the FAHP method to select the priority vectors for this study. Future research to prove that FAHP method is the best way to prioritize factor rather than AHP is highly encouraged; highly consistent pairwise comparison matrix is an indicator that the triangular FAHP is best to be used (Chan et al., 2019). The priority vectors or weights of the RL factors are inconsistent between stakeholders; thus, the RL evaluation should consider all stakeholders' perceptions because a good reputation is the outcome when the company's performance exceeds the stakeholders' requirements and expectations (Rayner, 2003; Trotta and Cavallaro, 2012).

## 6. Conclusion

This article has successfully discussed the prioritization of the RL factors of a pipeline operator for onshore pipeline damage. Please be reminded that all factor values are considered independent. In conclusion, both internal and external stakeholders agreed that the pipeline owner's RL is highly influenced by factor D3, "Accident severity", while factor A6, "Loss sponsorship opportunity", was considered the least influential. The ranking method determines a factor's priorities; the highest vector has the highest rank of RL factors. The effort to model the RL formulation can be designed based on the weights obtained from the points of view of four different pipeline operator stakeholders, namely, investors, customers, employees and the public. This prioritization of the RL factor process can assist the pipeline operator in determining the most influential post-accident reputation threat. Identifying the risk to the owner's reputation is part of a risk-based inspection that can optimize maintenance scheduling and reduce unnecessary inspections. Hence, the owner's annual profit margins can be secured.

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## Appendix A. Supplementary data

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