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Risk Analysis of Oil and Natural Gas Pipelines Due to Hazards

[1]Prayaal Gautam [2]Rupesh Kumar Khutey, [3]Susanta Kumar Rath,
[4]Akash Srivastava,[5]Vikash Kumar Singh
[1,3,4,5]M.Tech.Scholar, Shri Rawatpura Sarkar University Raipur, Chhattisgarh
[2]Assistant Prof. Shri Rawatpura Sarkar University Raipur, Chhattisgarh

Abstract
Given that natural gas is combustible, the safety of natural gas pipelines has a considerable impact not only on the economy but also on social security. This study proposes a method for cloud inference-based risk assessment that considers a variety of factors, including as ageing, corrosion damage, misuse of variables, design flaws, and third-party harm. First, an evaluation index system is created using a fault tree analysis, which considers the risk factors that could result in an accident (FTA). The index scores and weights are the second.
Risk analysis and risk-based approaches are frequently utilised in the oil and gas pipeline industry to find and create solutions to pipeline collapse occurrences. Even while these strategies and practises can successfully prevent and reduce the concrete loss, such as human loss, productivity loss, asset loss, and environmental loss, the intangible loss, such as reputation damage, is commonly disregarded. This is refuted by numerous recent research in the literature and actual events. To address the aforementioned constraint, this paper selected indicators of reputation loss in pipeline failure events based on pertinent research and the Delphi approach, and the indicators are ranked by group decision-making method and fuzzy analytic hierarchy process (FAHP). Consequently, this paper used its chosen reputation loss indicators in the pipeline failure scenario as its foundation.
In the case study, the investor factor was discovered to be the main element representing reputation damage in the event of an oil and gas pipeline breakdown. Credit rating downgrades and falling stock prices have been recognised as the two most important indications for the efficient improvement of reputation harm in a pipeline failure occurrence.
Oil and gas leaks may occur during transportation for internal or external reasons. If there is a nearby fire source, the concentration of the gas mixture made up of oil/gas and air may approach the limit for burning and/or exploding, which could result in a fire and/or explosion event that results in fatalities and major property loss. As a result, relevant research on the risk analysis and evaluation of the oil and gas pipeline has recently focused on the field of safety engineering. It is crucial to evaluate the fire risk analysis in order to ensure the safety of long-distance oil and gas pipelines. Before analysing the fire risk of the long-distance oil and gas pipeline using quantitative risk analysis, this study first analysed the nature of the long-distance oil and gas pipeline danger (QRA).
This research suggests a novel approach that combines a fuzzy TOPSIS model and an index-based risk evaluation system to control the hazards related to ageing urban oil and gas pipelines. Ranking the risks that have the highest potential to jeopardise pipeline safety is how the methodology is put into practise.
Keywords: *risk assessment, pipeline failure, Fuzzy TOPSIS, oil and gas pipeline.*

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I. INTRODUCTION

World is running help of oil and natural gas. It is very difficult to transport of oil and natural gases to word wise. Pipelines are optimal infrastructure for the transportation of oil and natural gas

Oil and natural gas, on the other hand, are combustible and explosive substances that are typically transported via pipeline networks under high-temperature, high-pressure circumstances. Most accidents, including fires, explosions, and toxic releases, are likely to happen at oil and gas pipelines [1-3], causing casualties, financial losses, and environmental issues. This makes pipeline transportation less sustainable. A sequence of explosions and flames on November 22, 2013, in Qingdao, China, resulted in 8000 people being evacuated, 62 fatalities, 136 injuries, and damage to neighbouring houses and automobiles. When a leak repair procedure ignited evaporated crude oil from a pipeline leak, explosions resulted in a drain . Additionally, natural disasters like earthquakes, floods, and lightning can destroy oil and gas pipelines, which could have negative collateral effects on the populace, the environment, or the industrial activity itself. These incidents—often referred to as Natech events—account for about 5% of serious industrial mishaps [4-5].

The safety of NG and PG pipelines is extremely important because of the frequent leaks from NG and PG pipelines that result in fires and explosions, which cause property losses and human injuries [2]. The NG pipeline leakage tragedy in West Virginia and other locations highlight the risk that NG and PG pipeline leakages could become catastrophic if the right precautions are not taken for their prevention and release mitigation. According to [4], out of 185 mishaps involving natural gas, pipeline accidents accounted for 127 of them, and mechanical breakdown of the pipes was the primary cause of the majority of these accidents.

If there is an accidental leak from a pipeline transporting NG/PG, it may lead to fires and/or explosions impacting adversely the human habitat, property and the environment. Therefore, one has to estimate the release rate of the gas from the pipeline due to its failure. The gas release may be from a small diameter (size) leak, from a hole (of size, do) in the pipeline or the high volume discharge from the pipe-rupture. It has been suggested that a very small pin

hole/crack of size (diameter) _20 mm may lead to a 'leak'; slow release may result from pipeline holes of size 20 mm_do _d; and a rupture may have a diameter of the hole larger than the pipeline diameter, d (EGIG, 1970e2007). Therefore, it is essential to estimate the gas release rate from the pipeline failure for the case of continuous and constant flow rate, and the decreasing flow rate in case of emergency shutdown of the compressor or the valve. It is

also necessary to estimate the area of hazard associated with the habitat, property and environment which will depend on the type of the pipeline failure and associated gas release, the time period of release, ignition time, meteorology and the topography of the area.

II. LITERATURE REVIEW

To find out the main research topics related to the safety and security of oil and gas pipelines,
To investigate the research evolutions and trends in the past decades, the keywords of publications are analyzed by using the cooccurring module in the software of VOSviewer. First, the publications are divided into four parts according to the publication time: (i) before 2005, (ii) 2005-2009, (iii) 2010 2014 and (iv)2015eAugust 2019.To investigate the methods used in safety and security research related to oil and gas pipelines, the research methods used in past research are extracted from keywords. the main safety and security research methods used in each period.

I. Research methods before 2005 As shown infour main research methods are identified before 2005: analytic hierarchy process (AHP), artificial neural networks (ANN), Fuzzy theory, and quantitative risk assessment (QRA). AHP is a multiple attribute decision-making technique that was used to develop a decision support system for inspecting and maintaining oil pipelines [6-7] developed an inverse approach based on ANN for leakage monitoring of pipeline networks. ANN can be used to deal with nonlinear problems with a set of variables by mimicking human brains. However, this method needs large sample data and the behavior of networks is unexplained.[8] applied fuzzy logic in risk assessment to address uncertain input parameters using fuzzy numbers. But it needs subjective evaluation and it is a difficult task to select the exact fuzzy rules and membership functions. A QRA method is established for pipeline route selection in the design stage [9]. The application of the QRA method can obtain a comprehensive result but the result may be not precise and event confusing.

II. Research methods from 2005 to 2009-the main research methods used from 2005 to 2009. QRA is the most frequent method in this period since it is able to quantify the likelihood and consequences of accidents. For example, [10] established a QRA method to determine an optimal inspection and replacement interval. [11] built an individual risk assessment method for highpressure natural gas pipelines. The research results indicated that the risk from a natural gas pipeline is lower than that at the building with a minimum distance from chemical industries. Besides these QRA methods, an event tree approach was used to analyze possible outcomes of an accidental fuel gas release [12]. Event tree analysis can show possible accident scenarios and event sequences but it may be extreme in

size and complexity for an intricate problem. ANN was used for predicting wax deposition [13], ensuring pipeline safety. Multi-attribute utility theory was used in ranking the risk of different sections of natural gas pipelines, incorporating decision-makers' preferences and behavior regarding risk [14]. In this period, advanced tools such as the finite element method (FEM) was used to investigate the failure pressure of corroded pipelines while the computational fluid dynamics (CFD) was applied to model dispersion process of accidental release from pipelines. These advanced tools can obtain more accurate results but they are time-consuming and have higher requirements for operators.

III. Research methods from 2010 to 2014 The main research methods related to the safety and security of oil and gas pipelines in the period 2005e2009, the most frequent methods used in this period are fuzzy theory and QRA. Fuzzy theory combining with other risk assessment tools are usually used to deal with the uncertaintyof input data.[15] combines fuzzy logic theory and expert judgment to address the uncertainty in corrosion risk assessment of natural gas pipelines. [16] used fuzzy logic in a bow-tie model to derive fuzzy probabilities of basic events and to estimate fuzzy probabilities of the consequences of output events. [17] integrated relative risk score (RRS) with fuzzy logic in pipeline risk assessment.[18] demonstrated that the selection of qualitative or quantitative risk assessment methods depends on the available data of the gas pipelines and the precision requirements. [19] used GIS in a QRA to aid pipeline management staff in demarcating high-risk areas. Besides, fuzzy theory, Monte Carlo simulation (MCS) also plays an important role in tackling uncertainty and also in simplifying the computation of analytical methods but it is time-consuming. [20] used MCS to address the uncertainty in damage probability estimation of pipelines subject to earthquakes while [21] applied MCS to simplify the lifetime prediction of corroded pipelines.

IV. Research methods from 2015 to 2019 In the period 2014e2019, the Bayesian network played a dominant role in the research methods related to the safety and security of oil and gas pipelines. Compared with traditional risk assessment tools such as the fault tree, the Bayesian network has obvious advantages in explicitly representing the dependencies of events, updating probabilities, and coping with uncertainties [22-24] used a Bayesian network to assess the internal corrosion hazard of oil & gas pipelines. [25] conducted an accident analysis of natural gas pipeline networks using the Bayesian network. The Bayesian network can also be used to model dynamic risks such as the time-dependent accident risk of subsea pipelines [26]. Besides, fuzzy theory[27], quantitative risk assessment [28] and bow tie [29] are also widely used for assessing the risks of oil and gas pipelines. With the development of computational resources, applying CFD and FEM methods in pipeline safety may become easier and wider in the future. Game theory and attack tree specially used in security risk research.Game theory is a decision-making tool to handle problems that contain intelligent players while it may be inaccurate due to subjective assumptions for attackers. Moreover,
machine learning was also applied in this domain to assist in detecting and sizing of metal-loss defects in oil and gas pipelines. With the rapid development of machine learning techniques, their applications in pipeline safety and security may increase in the future.

Risk-based techniques in pipeline failure event-

Due to many components were subjected to degrading mechanisms such as corrosion, erosion and external interference, the pipelines may lose their structural integrity leading to leakages, bursts and ruptures. These failures can not only cause economic losses to operators in terms of reduced production, clean-up operations, etc., but more importantly pose significant health, environment and safety (HSE) hazards [30]. In order to mitigate the problems associated with failures, many risk-based techniques were widely used in the oil and gas pipeline industry, such as risk-based inspection, risk-based maintenance and risk-based asset integrity [31-34]. Risk-based inspection is a practical technique to assess the likely application of the inspection process and the impact that can appear on pipeline failure, assess the grade of risk and recommend the type of action taken for the development of preventive measures and risk management [31]. Risk-based maintenance is a cost-effective approach to reduce the probability of pipeline failure and associated consequence, which can assist in reducing the cost of maintenance although it does not completely eliminate subjectivity [32-33]. Risk-based asset integrity is a management strategy for maintain the integrity of process facilities, so as to decrease major incident risks. These technologies are based on risk assessment approaches that comprise: an assessment of likelihood of failure, consequence of failure and their combination [34]. For practical applications, Singh and Pokhrel [30] developed a risk-based inspection programs for oil and gas pipelines subjected to microbiologically influenced corrosion. Singh and asserted that the proposed technique is simple to use, flexible enough to be modified according to the requirements of different sections of the plant, and able to incorporate field data. [35] proposed a risk-based maintenance planning of subsea pipelines subjected to fatigue crack growth monitoring. The methodology is able to determine whether the maintenance should be performed or not. [34] presented a hierarchical framework for asset integrity monitoring and assessment, the hierarchical structure is used to characterize the asset and relate it to an organization's strategic goal. The proposed approach uses a risk metric to classify asset integrity through the integration of leading and lagging indicators' outcome. However, although these risk-based techniques take fully account of all kinds of the tangible loss, i.e., human loss, production loss, asset loss and environmental loss, the intangible loss such as reputation loss is often neglected.

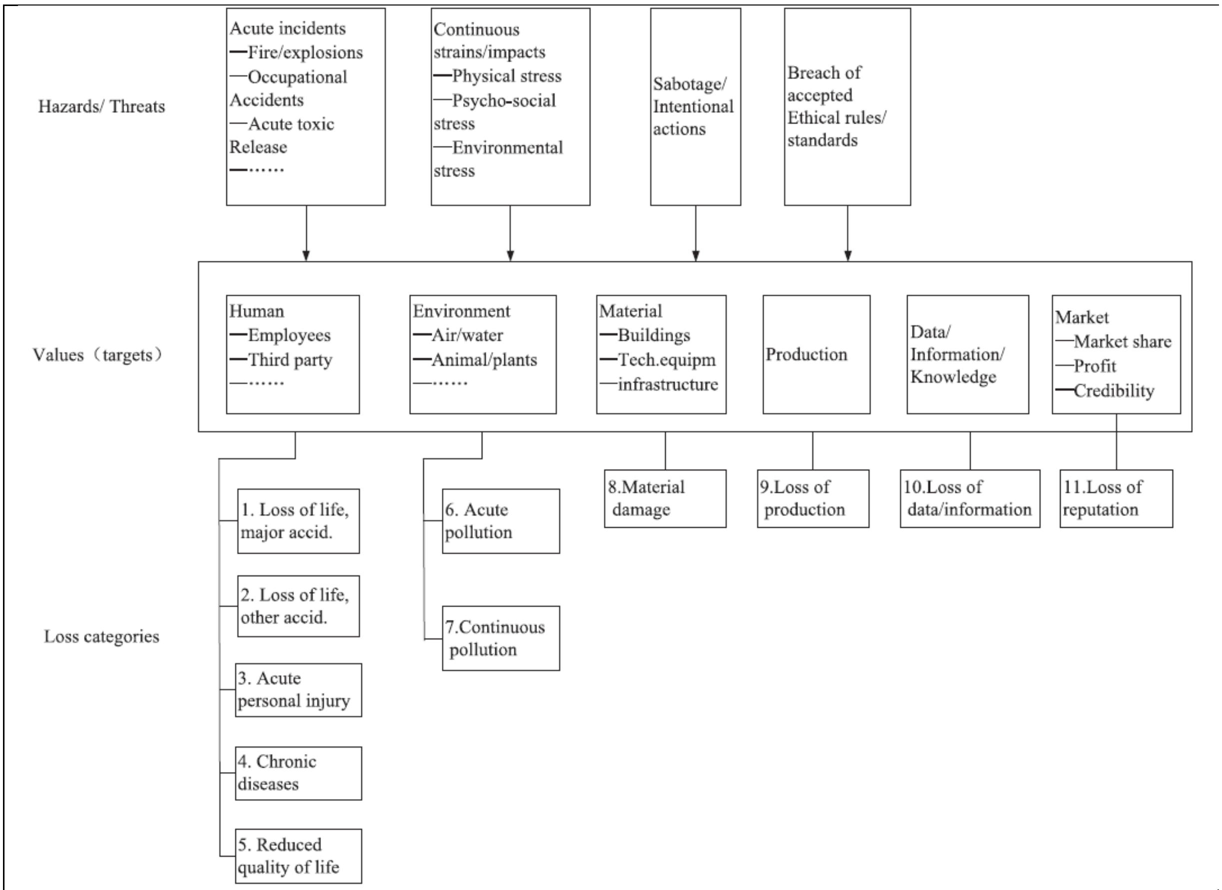

Figure1. Illustration of threats, values and 'loss categories' in risk and vulnerability management.

[35] proposed a risk-based maintenance planning of subsea pipelines subjected to fatigue crack growth monitoring. The methodology is able to determine whether the maintenance should be performed or not. Hassan and Khan [34] presented a hierarchicalframework for asset integrity monitoring and assessment, the hierarchical structure is used to characterize the asset and relate it to an organization's strategic goal. The proposed approach uses a risk metric to classify asset integrity through the integration of leading and lagging indicators' outcome. However, although these risk-based techniques take fully account of all kinds of the tangible loss, i.e., human loss, production loss, asset loss and environmental loss, the intangible loss such as reputation loss is often neglected.

Reputation loss indicators in pipeline failure event According [38], reputation can be expressed by a level of one's belief toward another person or an organization. Thereputation of a company mainly involves the beliefs of the stakeholders toward a corporate and its attributes. There are at least four types of stakeholders in each company, namely investors, customers, employees, and the public. Pipeline failure event impact their stakeholders directly and indirectly. As Oonagh Mary Harpur pointed out [38], if it is failure to meet their stakeholders' expectations and needs without enough reasons, the company will have a bad reputation, in other words, their expectations are greater than their experience [39]. Harpur's definition of reputation can be expressed in the following Eq. (1):

$$\text{Reputation} = \text{Experience} - \text{Expectation} \quad (1)$$

Delphi method (Fig. 2), the structure of the reputation loss factors and indicators in pipeline failure event is proposed. This structure contains 4 factors and 25 indicators. Fig. 5 illustrates the structure of reputation loss factors and indicators in oil and gas pipeline failure event. The structure is neither final nor comprehensive, and new factors and indicators can be added or deleted according to the peculiarities of the oil and gas industry in each country's economic system.

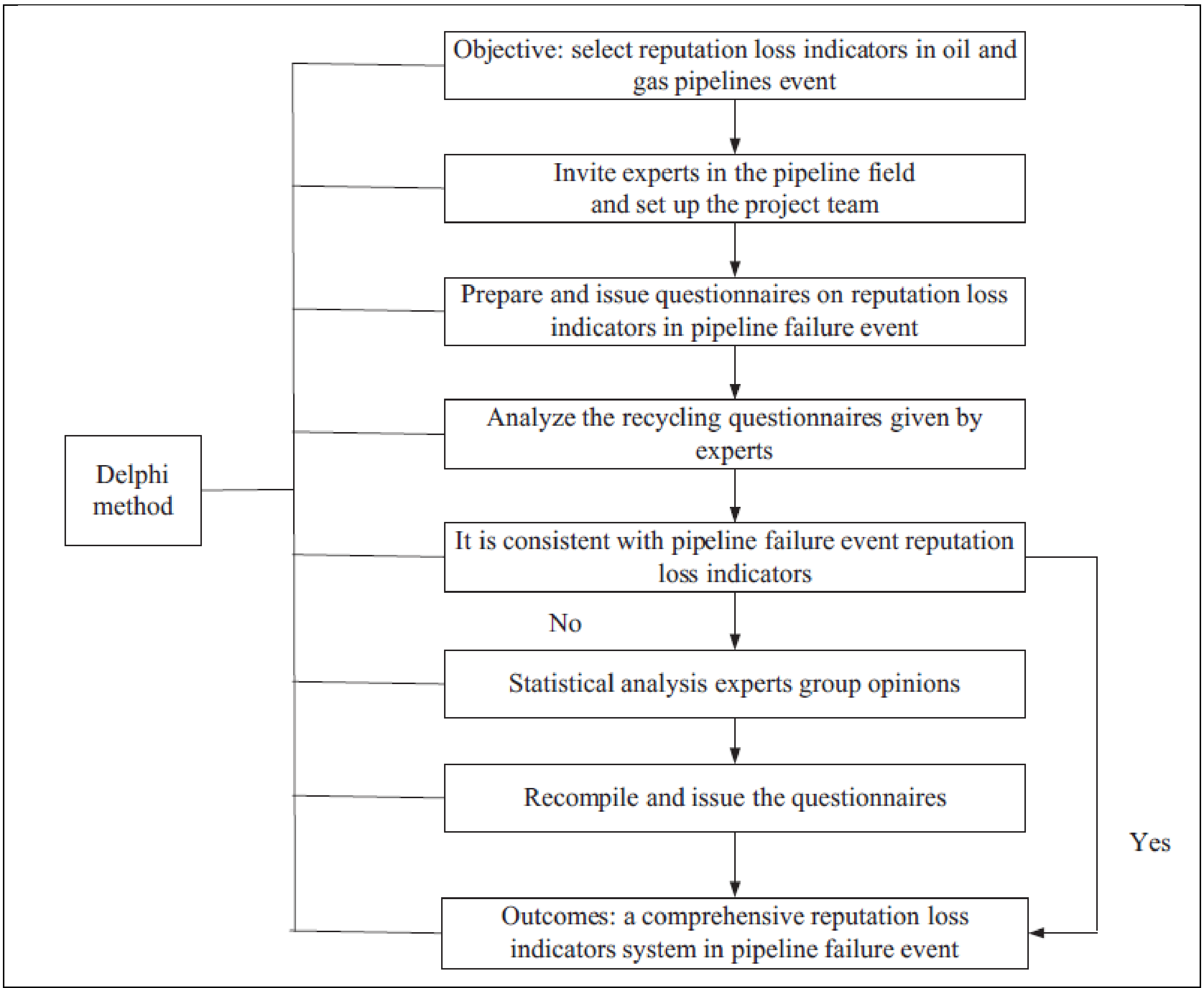

Fig. 2. The flow chart of Delphi method.

III. PROBLEM IDENTIFICATION

I. researcher seen the main regionare pipe failure scale formation inside of pipe. This is one type of corrosion and its very difficult task to remove it.

II. During visual observation of the pipeline at rupture location, it was observed that the failure had initiated from HAZ (Heat Affected Zone) near the weld seam and extended parallel to the seam and finally took a fish-mouth opening shape. The pattern of present failure is same to the earlier three failures. It indicates that the reason of failure may be similar.

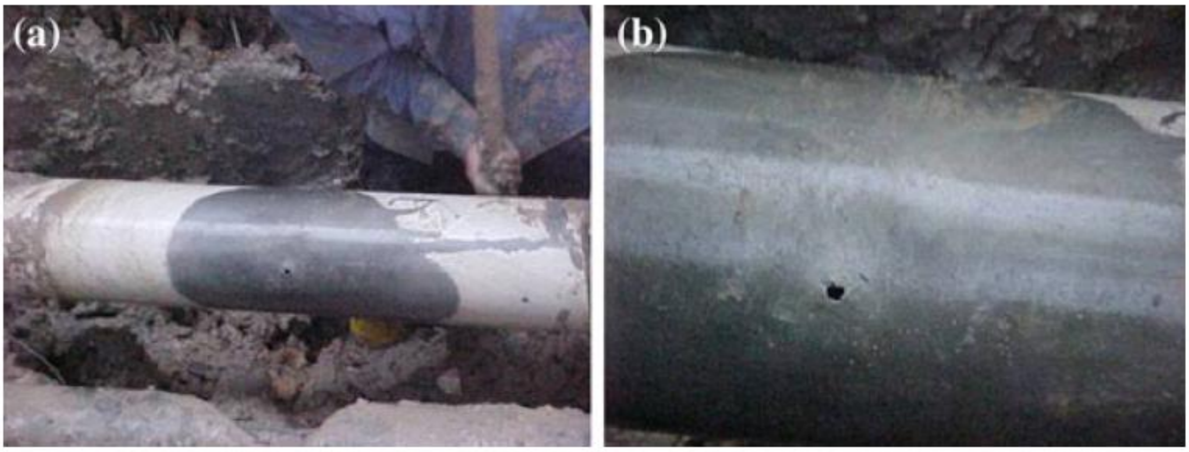

Figure 3. Pipe condition immediately after incident. **a**Exposed condition of NPS 8 pipe, **b** close-up view

III. Repetitive failure of the pipe of similar nature at weld seam establishes that there might be some inherent problem of the pipe related to welding quality at the manufacturing stage and might have been grown during subsequent operations mainly due to cyclic loading in stressed condition.

IV. he failure analysis of the failed pipe collected from the previous failure was carried out by WRI, BHEL Trichy. In the it has been concluded that failure of the pipe took place due to weld failure and there are a few abnormal observations at the weldment like flat weld profile, improperly repair weld, undercut, unfused spots, significant misalignment beyond permissible limit, higher hardness than acceptable limit etc. This indicates that the overall quality of long seam welding joint of the pipes seems to be not satisfactory at the manufacturing stage.

V. Change of service from product transportation to crude oil transportation (high sulphur e.g. MAYA, QTR LS CON + etc.) may also have aggravated the material degradation resulting into failure.

During investigation of the present failure incident, Operator informed that IPS with crack detection tool of the pipeline has already been carried out by an expert agency and the preliminary report provided by the party, which does not reveal any defect between this section of the pipeline. This may be looked into.

REASONS OF FAILURE/ ROOT CAUSE - Based on the above analysis, the following may be the probable causes of this incident: (1) Some inherent problem of the pipe related to weld seam at the manufacturing stage and might have been grown during subsequent operations mainly due to cyclic loading.

(2) Corrosion or other failure mechanism of the pipe due to change of service from product to crude oil.

IV. OBJECTIVES OF THE RESEARCH

I. Safety and security research related to oil and natural gas pipelines to find out the most productive institutions and authors, cooperation networks between countries, institutions and authors, citation and co-citation networks, and research trends in different periods. This section aims to discuss possible research needs for developing a sustainable pipeline transportation system.

II. Safety and security Safety-related incidents are unintentional whereas securityrelated incidents are intentional (the direct objective is to induce undesired incidents) [40]. In terms of oil and gas

III. pipelines, two main categories of security threats exist, i.e., theft and sabotage. Theft has been a long-standing security concern for oil and gas pipelines while the threat of terrorist attacks has become a more pressing priority in some regions [41]. Both theft and sabotage can lead to severe consequences, including public casualties, physical damage to the pipelines, interruption of energy supply, loss of oil and gas, environmental pollution, and the influence on socioeconomic and political stability, etc. [42]. Nonetheless, less than 5% of the 589 publications focused on security issues involving oil and gas pipelines. Given the severe consequences caused by intentional incidents on oil and gas pipelines, safety and security are both important for protecting oil and natural gas pipelines. Therefore, more work on security or integrated safety and security should be carried out in the future, addressing the intelligent and strategic characteristics of attackers and considering the impacts of social, political and economic factors.

IV. **Pipeline system resilience-**The resilience of oil and gas pipeline systems may be defined as the ability to absorb losses and maintain or improve energy supply despite pipeline damages. In light of the accidental hazards, natural hazards and intentional threats to oil and gas pipelines, enhancing the resilience of oil and gas pipeline systems is an important method to ensure the sustainability of the energy supply chain. Once a damage to an oil and gas pipeline is inevitable, a resilient pipeline system can effectively mitigate the consequences of the damage and rapidly recover from the supply interrupt. However, limited research has been done on the resilience of oil and gas pipeline systems. As a result, more attention should be paid to enhance the resiliency of an oil and gas pipeline system, such as formulating a resilient emergency response strategy and developing a robust pipeline system.

For the purpose of determining the significance of reputation loss indicators, and to rank them, it is necessary to take scientific and reasonable weight calculation method. In current literature, AHP is the most popular method used in the determining the indicator weight. This method, developed by Saaty (1980), decomposes a decision problem into a hierarchical elements system.

Compare the importance of each element with a nominal scale. Then, a comparison matrix is established by means of quantitative comparison, and then the eigenvector of the matrix is acquired to represent the comparison weight among the elements of a certain gradation. Finally, the consistency strength of the comparison matrix is evaluated by the eigenvalue and decides whether to accept the information [36-37,43].

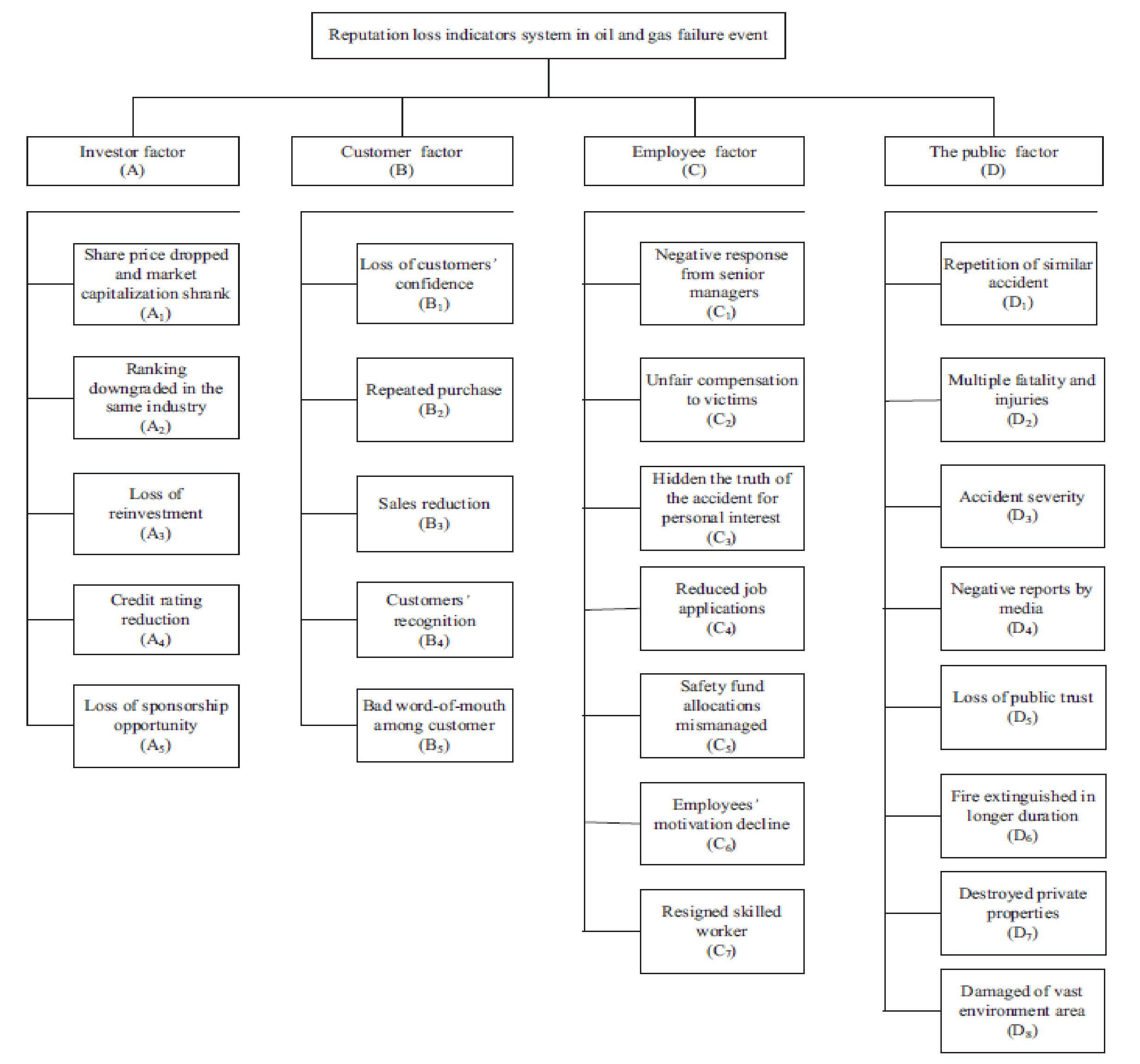

Figure4. The structure of reputation loss factors and indicators in pipeline failure event.

V. METHODOLOGY

I. Risk assessment methods-

The main objectives of risk assessment study is to identify the potential hazards, assess the risk from the individual scenarios and evaluate the risk control measures to reduce the risk to people, plant and environment. Risk are commonly sustained in every industrial activity and accepted to certain level when we do the operations. Risk is descripting in two parameters. For any hazardous event the risk is calculated based on the consequence and product of the frequency of this event. Risk assessment is defined as a mathematical function of the probability and consequence of an incident.

Mathematically,

Risk = F (Frequency of event) * C (Consequence of an event)

Typical quantitative risk assessment flow diagram is followed in this study has shown below (Fig.6.)

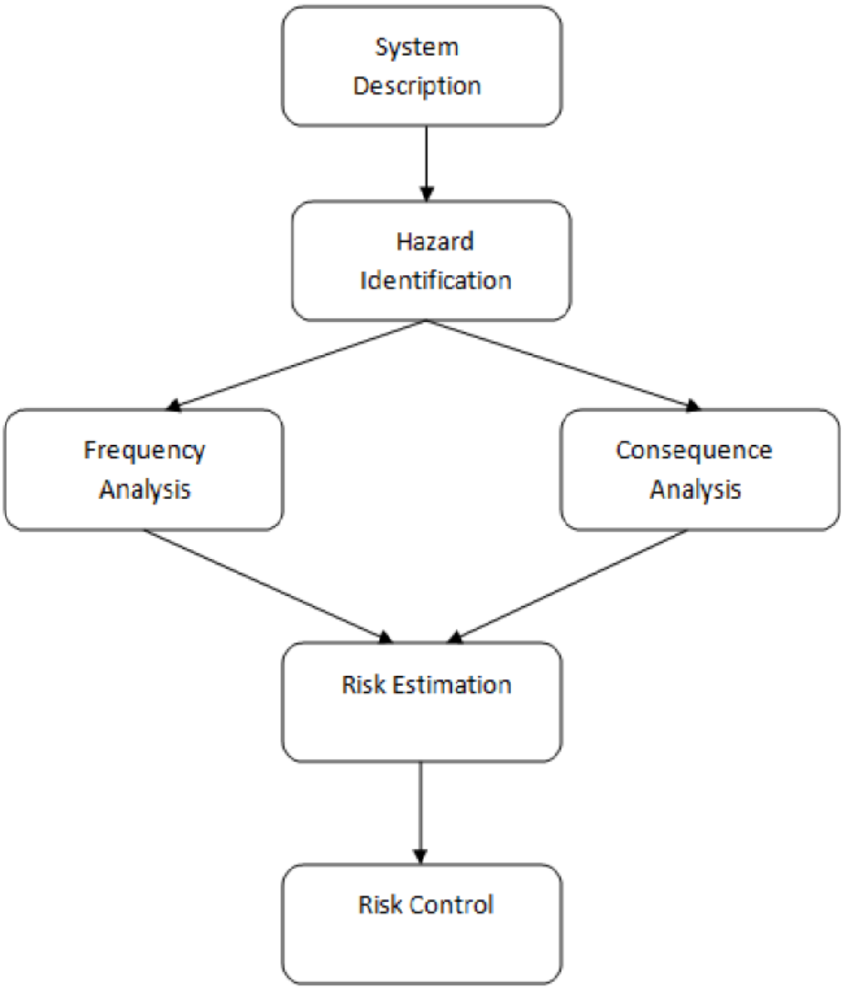

Figure 6 . Typical risk assessment flow diagram.

The methodology for this study involves the following steps -

I. Site visits & collection of data
II. Monitoring the existing natural gas gathering station operation & handling system.
III. Hazard identification through HAZID and HAZOP study
IV. Consequence analysis for hazardous accident scenarios and modelling
V. Review the controls of fire and safety management system
VI. Feedback and recommendations

The following Table-1, shows the key components and equipment's available in the natural gas gathering station and associated pipeline network. This list is used to identify the various potential hazardous event and associated failures.

II. Hazard identification-

Hazard means anything which has the potential that could cause harm or ill health or injury to people or damage to assets or impacts environment. Hazard identification is the fundamental step in risk assessment. Hazard identification and evaluation of major hazards are vital in any safety management system. New oil and gas projects and in some cases modifications of existing oil and gas plants, calls for some element of change and the degree of change is often considerable. The procedure has to identify the hazards systematically arising from normal and abnormal operation of the plant.

Many techniques are available such as experience, engineering codes and standards, checklists, Preliminary Hazard Analysis (PHA), Hazard identification (HAZID), Hazard and operability (HAZOP) study, Job Safety Analysis (JSA), Hazard and effects management process (HEMP) Hazard index, What-if analysis, Failure modes and effect analysis (FMEA), Fire and Explosion Index (F&EI), Mond Index (MI), Construction hazard identification (HAZCON), Electrical hazard and Operability(SAFOP), Layer of protection analysis (LOPA), Fault tree, Event tree etc are implemented by various oil and gas industries now a days. If the hazard is not identified then risk assessment is not cover all the hazards. The unidentified hazard may strike any time

which results in accidents and loss. So it is very important that the hazard identification to be carried out in comprehensive manner. Unidentified hazard negate the risk assessment process; risk cannot be assessed for those hazards and control measures cannot be developed
and implemented. The operators those who involved in the operation are not aware of the hazard in first place. Hazard identification was conducted through employee interview and pipeline hazard identification studies. Interviews are either one to one basis or in groups.
Techniques such as Job Safety Analysis (JSA), Logic diagrams, What-if checklist techniques can be used as qualitative risk assessment techniques for assessment. JSA is method to analyse a job by, step by step process. Nuclear power plants, aerospace industries are using fault tree and event tree as a powerful tools to predict the failure rates. The quantitative tool such fault tree and event tree is used to quantify the risk. Identification and evaluation of major hazards are vital in any safety management system. Checklist approach is used in chemical and process industries to identify the hazards in the process. But checklists are considered as a more generic approach. Layer of protection analysis (LOPA), Failure mode effect analysis (FMEA) are called semi quantitative analysis tools. LOPA is lies in between HAZOP and Quantitative Risk Assessment (QRA) in terms of rigorousness.
HAZID Check list and HAZOP study are used in this study to identify the various hazards and associated potential different hazardous scenarios.
The Table.2, shows the comprehensive checklist used for hazard identification.

III. **HAZOP study-**

HAZOP study is a standardized approach to analysis the process hazards associated with basic operations of the plant which was developed by ICI in UK which is explains "The application of a formal systematic critical examination to the process and engineering intentions of new or modified facilities to assess the hazard potential or mal-operation or malfunction of individual items of equipment and the consequential effects on the facility as a whole". HAZOP study is one of the hazard identification technique can be applied various phases of project development includes in front end engineering and design phase, as a part of detailed design phase and plant operation phase or any modification or alteration of the plant. HAZOP study as a semi quantitative analysis which is applied to upstream oil and gas operations such as offshore drilling operations. HAZOP studies include from original ICI method with required action and now a day's computerized method of HAZOP study wok sheets are employed for analysis.

It is used to identify deviations from the design intent that could lead to hazards or operability problems, and to define any actions necessary to eliminate or mitigate these. Hazard and Operability Study (HAZOP) method is immensely popular for identification of hazards qualitative . HAZOP study requires information such as process data, technical information, process and instrumentation diagram, material balance sheets, process parameters, instrumentation diagram, site plans, line arrangement, list of safety valves etc. HAZOP study has numerous inherent weaknesses in the system. But understanding and having knowledge about the weakness enable the study team to compensate to the extent possible.

For this HAZOP study, a combination of guidewords and process parameters has been used to review the process and instrumentation diagram of the natural gas gathering station. The selected gathering station and associated pipeline network is divided into nodes as per the process flow diagram. Each node the intended function is defined and with the set of guidewords and process parameters are to be applied and deviation and consequences is assessed. If the existing protection system have taken care of the consequences or any additional measures to be provided is established.
From the above HAZID & HAZOP study the following are the four major hazardous event scenarios are identified to do further quantitative risk assessment process.
Scenario 1 - Loss of containment of hydrocarbon from Gas compression in Gathering station.
Scenario 2 – Loss of containment of H_2S from Gas Compression in Gathering station.
Scenario 3 - Loss of containment of hydrocarbon from Pipeline.
Scenario 4 – Loss of containment of $H_2 S$ from Pipeline.

IV. **RESULTS AND DISCUSSION**

As part of this study consequence modelling has been carried out for the hazard sources identified and the results are presented. Radiant heat from fire in Kw/m2 and radiant heat dose from vapour cloud explosion in KJ/m2 and Over pressure from explosions in bar and toxic exposure in ppm levels are evaluated to how the level of injury to the humans.

The findings from the consequence results for the worst case scenarios it should be noted that whilst the consequences can be significant for the large leaks, the likelihood of these events is very low. Statistically, small leaks are more likely to occur. This is also in agreement with the leak frequency analysis carried out for the facilities, which shows that 80% of the leaks are from small hole sizes. Over pressure had created more damage to people, equipment, assets from the past vapour cloud accidents. The risk to the individual are represented as risk contour and called as individual risk. Individual risk contours connects the same risk level in a geographical map. The (Fig-7) shows the location specific individual risk and are mapped with the location drawing.

The Location Specific Individual Risk (LSIR) at gas gathering station associated with the gas compression and evacuation facility has been determined. The highest LSIR has been calculated at the gas recovery compression and compression Area with a value around 1.69E-04/yr. The risk is mainly driven by the fire events (around 80% of total LSIR), however, there are no significant impacts on the existing facilities.

According to the failure statistics of pipelines (Fig.7) and the geographical features along the natural gas pipeline, it is considered that the main causes of pipeline failure in this project include third-party impact, external corrosion and girth weld failure. According to the load analysis of the pipeline, the main load of the pipe includes internal pres- sure load, welding residual stress, third-party external force and geological hazard force. Major hazards to pipelines include inherent factors (pipeline girth weld defects), time-dependent external corrosion, time- independent internal pressure fractures, and third-party impact. Based on the above analysis, it is determined that the limit state equations involved in the failure probability calculation mainly include external corrosion leakage and fracture, third-party mechanical failure leakage and fracture, fault-free fracture and girth weld fracture (Table1). As it is still difficult to quantify the failure probability of geo-hazard, the risk analysis of geo-hazard will be carried out separately. The failure probability calculation is carried out according to the actual parameters of pipeline materials, construction and operation in China, and adopting the mature reliability calculation software at home and abroad (Fig. 5). The calculation of girth weld failure probability is based on the stress analysis results of all weld joints and the defect size data from internal and non-destructive testing.

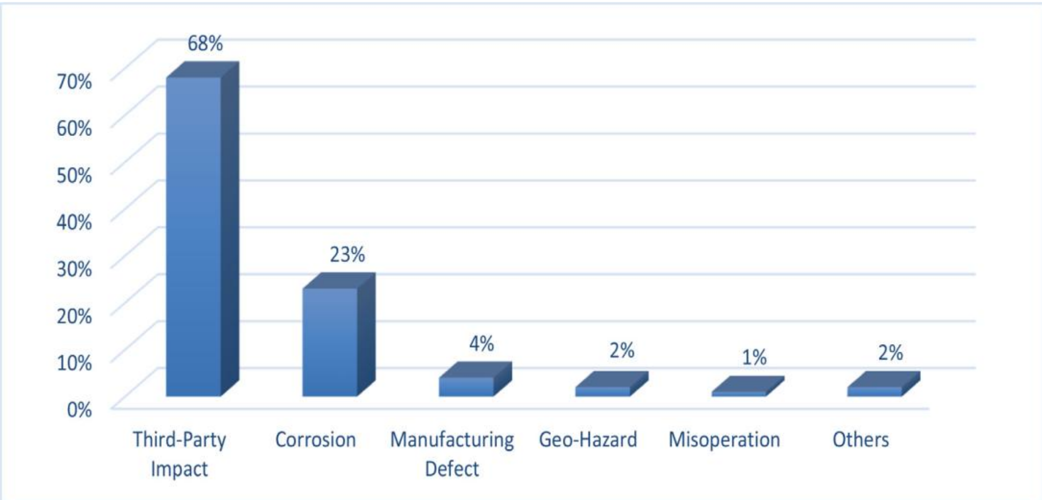

Table-1 Failure statistics of pipelines

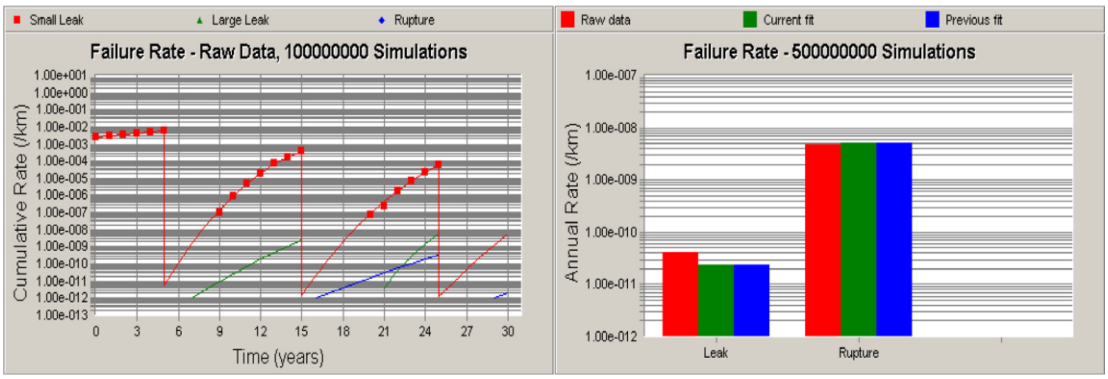

Figure 6. Failure probability calculation results of external corrosion and third-party impact

In addition, welding joint risk assessment and integrity assessment were carried out for the full girth weld of the. The result of welding joint risk assessment shows that the total number of welding joints with high risk is about 6,500. 688 welds failed the integrity evaluation (Fig. 8). Appropriate pipe modification or management measures shall be taken for pipe sections containing welds that fail the integrity evaluation.

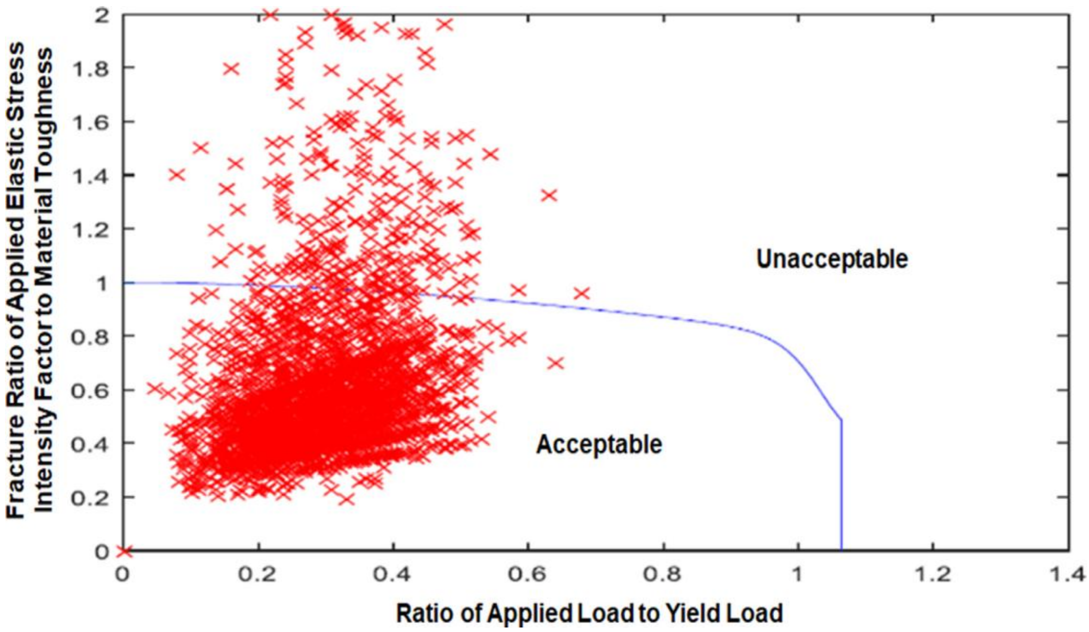

Fig. 8. Integrity evaluation results of the natural gas pipeline

V. CONCLUSION

A fire will occur when leaking oil, gas, and air are combined with an igniting source and transmitted through a long-distance oil and gas pipeline. A jet fire, which happens when handling pressurised or pressure-liquefied combustible materials, is the most challenging of the three fire accidents. For the protection of persons and property, the long-distance oil and gas pipeline fire risk assessment has substantial theoretical and practical ramifications.

Pipeline failure occurrences have resulted in a variety of losses, risk-based methods, and signs of reputation damage. The study showed that intangible loss, such as reputation loss, is commonly ignored even though risk assessment and risk-based approaches are valuable tools for limiting and preventing the tangible loss. However, numerous recent studies contend that when determining the effects of an oil and gas pipeline disaster, reputational harm should be considered. Based on relevant research and the Delphi technique, this work offered a structure for reputation loss factors and indicators in an oil and gas pipeline failure incident, comprising 4 factors and 25 indications. These traits and indicators can help pipeline firms maintain their reputation in the case of a pipeline collapse.

The findings of the present study indicated that risk decision-making and the implementation of preventive measures might be significantly aided by an efficient tool for risk analysis on leakage failure in the oil and gas pipeline business. The study might also be a beneficial educational tool for assessing the risk associated with other ocean oil and gas equipment.

REFERENCES

[1]. Chen, C., Reniers, G., Khakzad, N., 2020. A thorough classification and discussion of approaches for modeling and managing domino effects in the process industries. Saf. Sci. 125, 104618
[2]. Yang, Y., Chen, G., Reniers, G., 2020. Vulnerability assessment of atmospheric storage tanks to floods based on logistic regression. Reliab. Eng. Syst. Saf. 196, 106721
[3]. Wang, B., Li, D., Wu, C., 2020. Characteristics of hazardous chemical accidents during hot season in China from 1989 to 2019: A statistical investigation. Saf. Sci. 129, 104788
[4]. Cozzani, V., Campedel, M., Renni, E., Krausmann, E., 2010. Industrial accidents triggered by flood events: analysis of past accidents. J. Hazard Mater. 175 (1e3), 501e509.
[5]. Huang, K., Chen, G., Yang, Y., Chen, P., 2020. An innovative quantitative analysis methodology for Natech events triggered by earthquakes in chemical tank farms. Saf. Sci. 128, 104744
[6]. Dey, P.K., 2004. Decision support system for inspection and maintenance: a case study of oil pipelines. IEEE Trans. Eng. Manag. 51 (1), 47e56.
[7]. Caputo, A.C., Pelagagge, P.M., 2002. An inverse approach for piping networks monitoring. J. Loss Prev. Process. Ind. 15 (6), 497e505.
[8]. Bonvicini, S., Leonelli, P., Spadoni, G., 1998. Risk analysis of hazardous materials transportation: evaluating uncertainty by means of fuzzy logic. J. Hazard Mater. 62 (1), 59e74.
[9]. Zuniga-Gutierrez, G., Ortega-Rubio, A., 2004. Quantitative assessment for selecting the route for a gas pipeline in Yucatan, Mexico. Human and cological Risk Assessment 10 (2), 451e460.
[10]. Khan, F.I., Haddara, M.M., Bhattacharya, S.K., 2006. Risk-based integrity and inspection modeling (RBIIM) of process components/system. Risk Anal. 26 (1), 203e221.
[11]. Jo, Y.D., Crowl, D.A., 2008. Individual risk analysis of high-pressure natural gas pipelines. J. Loss Prev. Process. Ind. 21 (6), 589e595.

[12]. Sklavounos, S., Rigas, F., 2006. Estimation of safety distances in the vicinity of fuel gas pipelines. J. Loss Prev. Process. Ind. 19 (1), 24e31.
[13]. Obanijesu, E.O., Omidiora, E.O., 2008. Artificial neural network's prediction of wax deposition potential of Nigerian crude oil for pipeline safety. Petrol. Sci. Technol. 26 (16), 1977e1991.
[14]. Brito, A.J., de Almeida, A.T., 2009. Multi-attribute risk assessment for risk ranking of natural gas pipelines. Reliab. Eng. Syst. Saf. 94 (2), 187e198.
[15]. Bertuccio, I., Moraleda, M.V.B., 2012. Risk assessment of corrosion in oil and gas pipelines using fuzzy logic. Corrosion Eng. Sci. Technol. 47 (7), 553e558.
[16]. Shahriar, A., Sadiq, R., Tesfamariam, S., 2012. Risk analysis for oil & gas pipelines: a sustainability assessment approach using fuzzy based bow-tie analysis. J. Loss Prev. Process. Ind. 25 (3), 505e523.
[17]. Jamshidi, A., Yazdani-Chamzini, A., Yakhchali, S.H., Khaleghi, S., 2013. Developing a new fuzzy inference system for pipeline risk assessment. J. Loss Prev. Process. Ind. 26 (1), 197e208.
[18]. Han, Z.Y., Weng, W.G., 2011. Comparison study on qualitative and quantitative risk assessment methods for urban natural gas pipeline network. J. Hazard Mater. 189 (1e2), 509e518.
[19]. Ma, L., Cheng, L., Li, M.C., 2013. Quantitative risk analysis of urban natural gas pipeline networks using geographical information systems. J. Loss Prev. Process. Ind. 26 (6), 1183e1192.
[20]. Omidvar, B., Eskandari, M., Peyghaleh, E., 2013. Seismic damage to urban areas due to failed buried fuel pipelines case study: fire following earthquake in the city of Kermanshah, Iran. Nat. Hazards 67 (2), 169e192.
[21]. Hu, J., Tian, Y.Y., Teng, H.P., Yu, L.J., Zheng, M.S., 2014. The probabilistic life time prediction model of oil pipeline due to local corrosion crack. Theor. Appl. Fract. Mech. 70, 10e18.
[22]. Khakzad, N., Khan, F., Amyotte, P., 2011. Safety analysis in process facilities: comparison of fault tree and Bayesian network approaches. Reliab. Eng. Syst. Saf. 96 (8), 925e932.
[23]. Shaikh, F., Ji, Q., Shaikh, P.H., Mirjat, N.H., Uqaili, M.A., 2017. Forecasting China's natural gas demand based on optimised nonlinear grey models. Energy 140, 941e951.
[24]. Shabarchin, O., Tesfamariam, S., 2016. Internal corrosion hazard assessment of oil & gas pipelines using Bayesian belief network model. J. Loss Prev. Process. Ind. 40, 479e495.
[25]. Wu, J.S., Zhou, R., Xu, S.D., Wu, Z.W., 2017. Probabilistic analysis of natural gas pipeline network accident based on Bayesian network. J. Loss Prev. Process. Ind. 46, 126e136.
[26]. Li, X., Chen, G., Khan, F., Xu, C., 2019. Dynamic risk assessment of subsea pipelines leak using precursor data. Ocean. Eng. 178, 156e169.
[27]. Biezma, M.V., Agudo, D., Barron, G., 2018. A Fuzzy Logic method: predicting pipeline external corrosion rate. Int. J. Pres. Ves. Pip. 163, 55e62.
[28]. Bonvicini, S., Antonioni, G., Morra, P., Cozzani, V., 2015. Quantitative assessment of environmental risk due to accidental spills from onshore pipelines. Process Saf. Environ. Protect. 93, 31e49.
[29]. Chen, M.M., Wang, K., 2019. A bow-tie model for analyzing explosion and fire accidents induced by unloading operation in petrochemical enterprises. Process Saf. Prog. 38 (1), 78e86.
[30]. Maneesh Singh, Marshal Pokhrel, A Fuzzy logic-possibilistic methodology for risk-based inspection (RBI) planning of oil and gas piping subjected to microbiologically influenced corrosion (MIC), Int. J. Press. Vessel. Pip. 159 (2018) 45–54.
[31]. Bernard Kamsu-Foguem, Information structuring and risk-based inspection for the marine oil pipelines, Appl. Ocean Res. 56 (2016) 132–142.
[32]. Gallant Pui, Jyoti Bhandari, Ehsan Arzaghi, RouzbehAbbassi, Vikram Garaniya, Risk-based maintenance of offshore managed pressure drilling (MPD) operation, J. Pet. Sci. Eng. 159 (2017) 513–521.
[33]. W. Alex, T.B. TrafalisDawotola, Z. Mustaffa, P.H.A.J.M. van Gelder, J.K. Vrijling, Risk-based maintenance of a cross-country petroleum pipeline system, J. Pipeline Syst. Eng. Pract. 4 (2013) 141–148.
[34]. Jakiul Hassan, Faisal Khan, Risk-based asset integrity indicators, J. Loss Prev. Proc Indust. 25 (2012) 544–554.
[35]. Ehsan Arzaghi, Mohammad Mahdi Abaei, RouzbehAbbassi, Vikram Garaniya, Christopher Chin, Faisal Khan, Risk-based maintenance planning of subsea pipelines through fatigue crack growth monitoring, Eng. Fail. Anal. 79 (2017) 928–939.
[36]. F. TuncBozbura, Ahmet Beskese, Cengiz Kahraman, Prioritization of human capital measurement indicators using fuzzy AHP, Expert Syst. Appl. 32 (2007) 1100–1112
[37]. Chong Tan, Song Yi, Che Heng, Application of set pair analysis method on occupational hazard of coal mining, Saf. Sci. 92 (2017) 10–16.
[38]. C.J. Fombrun, Reputation: Realizing Value from the Corporate Image, Harvard Business School Press, United States of America, 1996.
[39]. LibriatiZardasti, NorhamimiMohdHanafiah, Norhazilan Md Noor, Nordin Yahaya, Ahmad Safuan A. Rashid, The consequence assessment of gas pipeline failure due to corrosion, Solid State Phenom. 227 (2015) 225–228.
[40]. Chen, C., Reniers, G., Khakzad, N., 2019. Integrating safety and security resources to protect chemical industrial parks from man-made domino effects: a dynamic graph approach. Reliab. Eng. Syst. Saf. 191, 106470 https://doi.org/10.1016/j.ress.2019.04.023.
[41]. Reniers, G.L., Zamparini, L., 2013. Security Aspects of Uni-And Multimodal Hazmat Transportation Systems. John Wiley & Sons.
[42]. Onuoha, F.C., 2008. Oil pipeline sabotage in Nigeria: dimensions, actors and implications for national security. Afr. Secur. Rev. 17 (3), 99e115.
[43]. Saman Aminbakhsh, Murat Gunduz, Rifat Sonmez, Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects, J. Saf. Res. 46 (2013) 99–105.