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Research Paper

An Industry Perception and Assessment of Oil and Gas Pipeline Third-Party Interference

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Abstract: The world population is growing at an alarming rate and human needs for technology and easy lifestyles drive dependency on oil energy into excessive demand, resulting in more pipelines, pipelines that are often subjected to various form of abuse. The aim of this research is to investigate the perception of oil and gas pipeline third-party interference from government agencies, professional bodies, academia, pipeline service providers and private companies' representatives. This paper attempts to identify types of third-party interference; the severity of interference; various preventive and detection tools; and examination of how the pipeline industry manage interference. The study population consisted of members of the pipeline industry, including health and safety engineers, pipeline engineers, pipeline service providers, and pipeline project engineers. The methodology for this study was formed by qualitative data, via open-ended questionnaire. The study shows that application of proper standard and procedures; greater awareness campaign to all stakeholders; and more Research and Development are the best procedures in preventing pipeline third-party interference. In organisational procedures to preventing third-party interference during and after pipeline installation, surveillance frequency as determined from risk assessment is the most effective. The study revealed that right-of-way encroachment is the most prevalent activities organisations presently monitor to avoid third-party pipeline damage. The result of the study also showed that communications with all stakeholders is more effective in preventing intentional pipeline interference, and government's social responsibility to communities as the major factor influencing occurrence of intentional pipeline damage; and land use and human activities as the most ranked factor for consideration in mitigating intentional third-party damage. The study also outlined what governments and the industry can and should do to help better manage risk and effectively reduce the risk of pipeline third-party damage.

Keywords: *Content Analysis; Country comparison; Pipeline management*

Introduction

The world population is growing at an alarming rate and human needs for technology and easy lifestyles drive dependency on oil energy into excessive demand. The global energy demand will rise by as much as 54% over the next two decades and oil consumption makes up 40% of this energy demand (EIA, 2007). This increased demand for more oil encourages exploration and production of more petroleum resources and simply means more pipelines (Jing et al., 2013; Yao et al., 2015). This energy infrastructures and maritime transportations (*e.g.* pipelines, truck tankers, refineries and oil and gas terminals) are potential target of terrorists and saboteurs. Third-party interference is a threat in the pipeline industry, and with limited attention within research literature (Hayes & McDermott, 2018; Kraidi, et al., 2021). For example, plenty of studies on pipeline failures have addressed various types of failures such as corrosion and mechanical failures. However, few studies have addressed theoretical and methodological issues of third-party damage, especially intentional pipeline damage (sabotage, theft, and terrorism threats); and many studies and reports have identified this potential (e.g. Nwankwo and Ezeob, 2008; Parfomak, 2008; McKinley, 2007; Houreld, 2007; GAO, 2005; Yao, Xu, Zeng, & Jiang, 2015; Popescu & Gabor, 2021). A considerable amount of literature published on third-party interference suggested it is the leading causes of pipeline failures (CONCAWE, 2007; La & Li, 2005; Parfomak, 2008; Sljivic, 1995; Jager et al., 2002; Re & Colombo, 2004; Palmer-Jones et al., 2004;

Jaffrey et al., 2002; Daco et al., 2000). Cross-country analysis recorded by relevant bodies, for example, UKOPA's Pipeline Fault Database (PFD) covering pipeline loss incidents from 1962, also showed third-party interference as the largest single cause of damage to pipelines in the UK (UKOPA, 2002; UKOPA, 2008).

Technological advancement has made inevitable many companies digging millions of utilities holes across the world (Hayes & McDermott, 2018; Kraidi, et al., 2021). Hence, third party interference becomes inevitable, and the consequences can be devastating for people and the environment. Papadakis (2005) for example, reviewed tragedies that involved twenty-four people who died with several causalities, and others hospitalised with severe burns when a Major Accident Hazard Pipeline (MAHP) near Ghislenghien in Belgium operated at a pressure of 70 bars failed due to third-party activities. Similarly, a third-party damage tragedy occurred in California in 2004 resulting in the death of five utility workers when an excavator digging a ruptured a high-pressure petroleum pipeline. CONCAWE's (1994) detail of how over 500 people died in 1998 when attempting to lift oil product from a pipeline under its jurisdiction failed. Besides this, it also recorded how in 1993 how 51 people were burnt to death when a gas pipeline failed in Venezuela. In the United States, in1994 a 36-inch pipeline in New Jersey failed, resulting in the injuring of more than 50 people (US Department of Transportation, 1995). Parfomak (2008) also reiterated how *"a 1999 gasoline pipeline explosion in Bellingham, Washington, killed two children and an 18-year-old man, and caused $45 million in damage to a city water plant and other property. In 2000, a natural gas pipeline explosion near Carlsbad, New Mexico, killed 12 campers, including four children"*.

The knowledge and understanding of third-party interference is important in pipeline management to overcome the problem of third-party pipeline failures (TRB, 2004; Jaffrey et al., 2002; Gallacher, 1996). Third-party interferences are sometimes due to political instability and socio-economic depravity, where proliferation of arms and ammunitions, militia groups, hostage taking and kidnapping go with this act. For example, rebels have bombed the Caño Limón oil pipeline in Colombia over 600 times since 1995 and similarly detonated several bombs along Mexican natural gas pipelines in July 2007. The U.S President's Commission on Critical Infrastructure Protection (1997) and Parfomak (2008) reports how London police foiled a plot by the Irish Republican Army to bomb gas pipelines and other utilities across the city. In June 2007, the U.S. Department of Justice arrested members of a terrorist group planning to attack jet fuel pipelines at the John F. Kennedy (JFK) International Airport in New York (U.S. Dept. of Justice, 2007).

In Nigeria, militants have repeatedly attacked pipelines and related facilities involving great loss of life and property. Interestingly, the Nigerian National Petroleum Corporation (NNPC) documented over 13,000 cases of vandalism between 2000 and 2008 (Punch, 2008). In 2000 about 250 villagers burned to death in Jesse, Delta State, while scooping fuel from vandalised pipeline. Similarly, in 2003, a foiled attempt of oil theft led to exploding pipelines in a village near *Umuahia*, Abia State; about 125 people died. Another example is the September 2004 third-party interference, where dozens of people died in a pipeline explosion in Lagos after thieves tried to siphon oil product from a pipeline. In May 2006, a pipeline explosion at *Inagbe* Beach on the outskirts of Lagos killed more than 250 people and in December, another 269 recovered burned bodies from the scene of pipeline fire in *Abule Egba*, a suburb of Lagos because of pipeline third-party interference. Recently, Nwankwo and Ezeob (2008) recount how Nigeria has experienced increased pipeline vandalism including a simultaneous bombing of three oil pipelines in May 2007. In addition, on December 26, 2007, over 45 people burned to death in Lagos when fuel they were siphoning from a buried pipeline caught fire. In May 2008, at least 100 people died, and hundreds injured when fuel from a pipeline ruptured by an earthmover explodes in a village near Lagos. Overall, attacks made on the pipeline most time cripples oil production eventually having a multiplier effect on the international oil price. For example, the total destruction of oil pipelines in *Isaka* and *Abonema*, both in Rivers State barely 72 hours after crippling the *Adamakri* crude flow line belonging to Shell Petroleum Development Company (SPDC) affected the price of oil barrel in 2008 (Nwankwo & Ezeobi, 2008). The objective of the study is to gather information from various stakeholders in the oil and gas industry to gain a better understanding of the problem of third-party interference on pipelines. The study aims to assess the perception of the industry towards third-party interference and to evaluate the measures currently in place to prevent, detect, and respond to such incidents.

Materials and Method

Survey Procedure and Sampling

Questionnaires create many nonrespondents, and therefore getting the right people to participate is important. There is need in survey to select the right sample (group) from the population to represent the entire population. Samples are determined using either probability or nonprobability sampling techniques. Nonprobability sampling is nonrandom, and includes systematic sampling, convenience sampling, quota sampling, and snowball sampling (Thomas, 2004). This questionnaire survey utilised the quota recruited nonprobability method of sampling. This method is similar to the stratified probability (random) sampling where identified subgroups (*e.g*. pipeline industry of the oil and gas sector) are sample frame. The recruited sample identifies respondents enlisted from the subgroups via e-mail and are provided with the URL of a web-based questionnaire. The data collection instrument consisted of a self-administered web-based survey to assess respondents' demographic characteristics, opinions, management experience, and perception on pipeline third-party interference from 229 respondents. Thirty-eight (38) countries participated in the study, and many of these responses included opinion and views of representative from DOT and PHMSA, TransCanada PipeLines Limited, SHELL, Subsea7, Exxonmobil, ConocoPhillips, British Pipeline Agency Ltd, and many others.

Coding Open-Ended Questions

Qualitative data, like open-ended questions are nonnumerical records, commentary, description, feedbacks that produce an immediate understanding with further processing. Open-ended questions are unanswerable directly with, for example, a simple "yes" or "no", detail specific comments or answers are required. Coding is therefore the process of converting such qualitative data into numerical records, referred to as multiple response analysis (Kent, 2001). In the study, maximum number of responses to a particular open-ended question was determined from the collated questionnaire after the survey. SPSS statistical software for analysis (version 15) was used for data management and analysis, where responses are defined as variables.

Instrument

The result of this study was part of a larger study on third-party interference using questionnaire survey, and we report here only the open-ended questions about third-party interference. The following were the question's items:

a) Respondents' general opinion about preventing and monitoring pipeline third-party interference.
b) Preferred methods for direct physical protection of pipeline networks
c) Preferences of pipeline damage prevention measures that will mitigate damage cause by third-party activity during and after installation.
d) Suggestion of method most effective for pipeline damage prevention
e) Respondents' opinion about factors influences the occurrence of intentional pipeline damage.

In addition to the above, respondents were asked to select three factors that are most important that could be used to weigh the potential for third-party interference and rank them from 1 to 3 (with 1 as the most important). These items were:

(1) Land use and human activities
(2) Socio-economic conditions of population living near a pipeline
(3) Accessibility to pipeline network (proximity of roads, rivers, streams)
(4) Socio-political factors (*e.g.* literacy rate, political stability, and violence
(5) Depth of pipeline (exposed pipeline provide criminal opportunities)
(6) Other factor in respondents' opinion not mentioned above.

The study is interested in knowing what third-party activities organisations presently monitor, and the items(activities) were: (a) Direct pipeline vandalism; (b) Theft of product and pipeline facilities; (c) Sabotage to pipeline network; (d) Guerrilla attacks; (e) Likelihood of terrorism against pipeline; (f) Intrusion to aboveground facilities; (g) Right-of-way encroachment; and (h) Cyber-attack/potential hijack of network facilities (Muhlbauer, 2004).

Multiple Response Analysis of Open-ended Questions

Multiple response analysis is one of the most used methods of analysing open-ended questions in a questionnaire survey. The goal of using open-ended question in the research is to identify salient theme for analysis by eliciting understanding of the subject from respondents. In addition to closed question in a survey, open-ended questions give respondents the liberty to express replies, comments, and observation from their personal experience. Open-ended questions are qualitative data, and are source of rich description and diagnosable explanations in a context that could generate a research theme (Kent, 2001). The study analysed the patterns of the response to the open-ended questions and frequency from respondents' unique experiences that are organisation specific. The appropriateness of open-ended questions for this research is because of the following (Coakes, 2005; Kent, 2001):

a) The question survey is international, and third-party interference are country specific, hence it was considered inappropriate to *close* some question by specifying only eligible options.
b) Open-ended questions are more engaging and avoid the likelihood of pre-judgement and biasness that might result when responses in a survey is suggested to respondents.
c) An open-ended question captures all view and perception that have not been consider as part of the closed questions of a survey questionnaire.

Results

This study analysed two hundred and twenty-nine (229) responses from 38 countries and was geographically balanced: 50 responses from Africa, 24 from Asia Pacific region, 92 from Europe and 63 from America region. Most respondents (51%) are from the private companies (pipeline consultants and contractors), 17% from government agencies, 8% from the academia, and 4% from professional bodies (Figure 1). Thirty-nine percent (39%) of the respondents are pipeline engineer and 25% are pipeline service providers, also, approximately quarter (25%) of those surveyed are pipeline service providers (Figure 2).

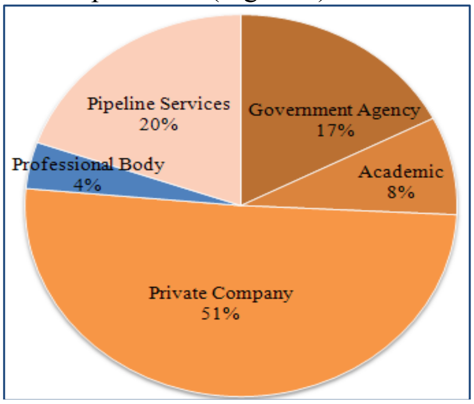

Figure 1. Organisation of Respondents

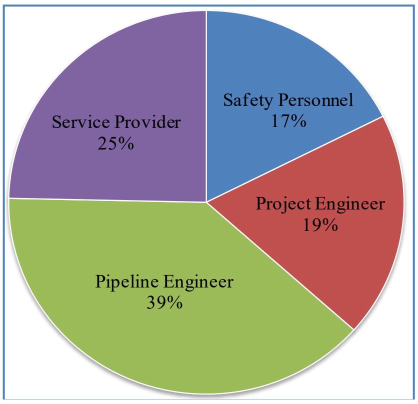

Figure 2. Occupation of Respondents

Preventing and monitoring pipeline third-party interference

Respondents' views about method of preventing and monitoring pipeline third-party interference showed four numbers of maximum responses and twenty possible methods of preventing third-party interference (TPI) identified. Using SPSS, frequency analysis of the multiple responses of respondents' view was examined for distribution. The overall response of the open-ended question showed that 45% of respondents expressed one or more views about preventing third-party interference (Table I).

The frequency table of the multiple responses set indicates that (1) a*pplication of proper standard and procedures* (13.80%); (2) *greater awareness campaign to all stakeholders* (12.20%); and (3) *more Research and Development* (10.60%) are the most frequently referenced view of respondents. In an analysis by location undertaken (Table II), respondents from Africa frequently indicated *use of modern technology* and *evaluation of social and environmental impact*. Respondents from Europe mostly indicated *greater awareness campaign to all stakeholders,* and *application of proper standard and procedures* was frequently indicated by respondents from North America. Similarly, in a cross-tabulation analysis by organisation, respondents from government agencies frequently indicated a*pplication of proper standard and procedures,* while respondents from the professional bodies frequently indicated *more Research and Development.* One participant referred to how more research in third-party interference is necessary: *"In a recent report that was issued by the EU Commission on safety of pipeline transportation systems, the main findings included: Third part damage is the main cause of pipeline incidents and therefore should receive the main focus and the availability of an effective Pipeline Integrity Management system is one of the key elements in controlling the risks".*

Table 1. Frequency table of the multiple responses to preventing and monitoring TPI

Category label from respondents' view	*Responses*		*Percent of Cases*
	N	Percent	
Impact alert system	1	0.50%	1.00%
Greater awareness campaign to stakeholders	23	12.20%	22.30%
Use new Modern technology, e.g. Optical fibre	16	8.50%	15.50%
Enforcement of strict safety requirements	16	8.50%	15.50%
Improve rapid response capability	5	2.60%	4.90%
Address motivations of causes	6	3.20%	5.80%
Accurate collation of pipeline database	5	2.60%	4.90%
Install fence along ROW	1	0.50%	1.00%
Better land use planning guidelines	7	3.70%	6.80%
More Research and Development	20	10.60%	19.40%
Intensive surveillance on Hotspots	9	4.80%	8.70%
Evaluate Social and Environmental Impact	8	4.20%	7.80%
Statutory Punishment to offenders	9	4.80%	8.70%
Increase burial depth	2	1.10%	1.90%
Remote monitoring	8	4.20%	7.80%
Application of proper standard and procedures	26	13.80%	25.20%
Prevent all activities near Pipelines	4	2.10%	3.90%
One-Call Systems	8	4.20%	7.80%
Engage community cooperation	9	4.80%	8.70%
Education on consequences of pipeline failure	6	3.20%	5.80%
Total	**189**	**100.00%**	**183.50%**

Table 2. Open-ended analysis by respondents' location on to preventing and monitoring TPI

		Geographical Location of Respondent						
		Africa	Asia	Europe	North America	South America	Oceania	Total
Impact alert system	Count	1	0	0	0	0	0	1
Greater awareness campaign to	Count	4	1	10	7	1	0	23
Use new Modern technology, e.	Count	7	0	6	3	0	0	16
Enforcement of strict safety	Count	3	1	2	8	0	2	16
Improve rapid response	Count	2	0	1	2	0	0	5
Address motivations of causes	Count	4	0	0	2	0	0	6
Accurate collation of pipeline	Count	0	0	2	2	1	0	5
Install fence along ROW	Count	0	1	0	0	0	0	1
Better land use planning	Count	2	0	4	1	0	0	7
More Research and	Count	5	1	6	7	1	0	20
Intensive surveillance on	Count	3	0	1	3	1	1	9
Evaluate Social and	Count	6	0	1	1	0	0	8
Statutory Punishment to	Count	2	0	2	5	0	0	9
Increase burial depth	Count	1	0	1	0	0	0	2
Remote monitoring	Count	3	0	3	1	0	1	8
Application of proper standard	Count	3	2	9	11	0	1	26
Prevent all activities near	Count	1	0	2	1	0	0	4
One-Call Systems	Count	0	1	1	5	0	1	8
Engage community cooperation	Count	4	0	2	2	0	1	9
Education on consequences of	Count	1	0	1	4	0	0	6
	Count	29	5	32	31	3	3	103

Procedures for Preventing TPI during and after pipeline installation.
Respondents' perceptions were assessed of what damage prevention measures, organisation representative that will mitigate damage cause by third-party activity during and after pipeline installation. The frequency table of the multiple responses analysis indicates that *surveillance frequency by risk assessment* is the most frequently indicated measures. The maximum number of responses obtained from a respondent was two, and the respondent (Table III) identified ten possible methods.

Table 3. Frequency table of responses to procedures for preventing third-party

	Responses		*Percent of Cases*
Responses to open-ended question	N	Percent	N
1. Education of Third parties	2	7.70%	10.00%
2. Fibre optic cable	2	7.70%	10.00%
3. Jet grouting protections to vulnerable portions	3	11.50%	15.00%
4. Material selection against external load	1	3.80%	5.00%
5. Community Investment Strategy	3	11.50%	15.00%
6. One call notification system advertised	3	11.50%	15.00%
7. Coating, possibly concrete	1	3.80%	5.00%
8. Sufficient Burial depth	1	3.80%	5.00%
9. Satellite monitoring	2	7.70%	10.00%
10. Surveillance frequency by risk assessment	8	30.80%	40.00%
Total	**26**	**100.00%**	**130.00%**

Effectiveness of Preventive Methods against Intentional Interference
Respondents were asked what method they would suggest as most effective to prevent pipeline third-party damage from intentional interference. The frequency table of the multiple responses set indicates that *communications with all stakeholders* (16.80%) is the most frequently recommended preventive measure by respondents. *Increase pipe wall thickness* is the least recommended measures (Table 4).

Table 4. Frequency distribution of open-ended question about effectiveness of Preventive Measures

Suggested prevention methods for intentional pipeline. damage by respondents	*Responses*		*Percent of Cases*
	N	**Percent**	**N**
Punishment of offenders to deter others	3	1.90%	3.00%
Maximum pipeline burial with addition protection	19	11.80%	19.00%
Involvement of specialist security organisations	8	5.00%	8.00%
Electromagnetic detection and acoustics	8	5.00%	8.00%
Public education/ Awareness of pipeline location	19	11.80%	19.00%
Direct physical protection of vulnerable segments	13	8.10%	13.00%
Remote and aerial surveillance	21	13.00%	21.00%
Alignment based on Risk/Consequence design	6	3.70%	6.00%
Customised solution tailored to fit the environment	14	8.70%	14.00%
Increase pipe wall thickness	5	3.10%	5.00%
Involve the community to guard pipelines	18	11.20%	18.00%
Communications with all stakeholders	27	16.80%	27.00%
Total	**161**	**100.00%**	**161.00%**

In an analysis by location undertaken (Table 5), respondents from Africa frequently indicated *involve the community to guard pipelines*, while majority of responses from Europe recommended *communications with all stakeholders*. Respondents from North America mostly recommended *public education/ awareness of pipeline location*. Similarly, in a cross-tabulation analysis of respondents' organisation and the open-ended question, respondents from government agencies frequently recommended *communications with all stakeholders.*

Table 5. Cross-tabulation analysis by location

	Geographical Location of Respondent (count)					
	Africa	Asia	Europe	North America	South America	Oceania
Punishment of offenders to deter others	1	0	0	2	0	0
Maximum pipeline burial with addition protection	2	1	7	7	0	2
Involvement of specialist security organisations	2	1	3	1	1	0
Electromagnetic detection and acoustics	1	0	4	2	0	1
Public education/ Awareness of pipeline location	2	1	7	8	0	1
Direct physical protection of vulnerable segments	2	2	5	4	0	0
Remote and aerial surveillance	3	0	9	7	0	2
Alignment based on Risk/Consequence design	0	0	2	3	0	1
Customised tailored solution for the environment	2	1	4	4	2	1
Increase pipe wall thickness	0	0	5	0	0	0
Involve the community to guard pipelines	10	0	5	3	0	0
Communications with all stakeholders	7	1	12	6	0	1
Total	19	4	40	30	2	5

3.4. Factors Influencing Occurrence of Intentional Pipeline Damage

Respondent were asked what factors in their opinion influence the occurrence of intentional pipeline damage. The frequency distribution of responses indicates that *government and social responsibility to communities* (20.60%) is the most frequently commentary factor perceived by respondents that influence the occurrence of intentional pipeline damage (Table 6).

Table 6. Frequency distribution of factors Influencing Occurrence of Intentional Pipeline Damage

	Responses		*%(Cases)*
	N	Percent	N
1) Petroterrorism	17	17.50%	29.80%
2) Political reasons	11	11.30%	19.30%
3) Burial depth of pipeline	4	4.10%	7.00%
4) Strict penalty to offenders	1	1.00%	1.80%
5) Public education and communication	13	13.40%	22.80%
6) Absence of laws for pipeline security	7	7.20%	12.30%
7) Ignorance of the consequences of failure	7	7.20%	12.30%
8) Government and social responsibility to communities	20	20.60%	35.10%
9) Economy situation of a country (*e.g.* theft of product)	17	17.50%	29.80%
Total		**100.00%**	**170.20%**

The next most frequently commentary factor perceived by respondents was *petroterrorism* (all associated activities that interfere with maritime transportation) and *a country's economy*, for example poverty and theft of product. In the more specific comments about occurrence of intentional pipeline damage, the following extracted comment from the survey expresses the opinion of two respondents: *"The reasons for damage can vary by location, e.g. in FSU it is 100% economic (oil theft). In Nigeria, it is a mixture of economic and protest. In Colombia, it was 100% protest. Protest (terrorism) probably cannot be prevented but should be of limited impact. Economic will remain endemic until the political system has the will to stop it as this does not usually seriously damage the pipeline"; and "In Australia intentional interference is not such an issue, rather unintentional interference brought about by deficiencies in the risk assessment in the first instances failing to identify the threat and relevant controls of such interference. I disagree with the any inference that third parties would intentional seek to damage a pipeline; unless of course it is in a politically unstable environment e.g. Iraq and Afghanistan."*

Table 7. Cross-tabulation analysis by location

		Geographical Location of Respondent					
		Africa	Asia	Europe	North America	South America	Oceania
Petro-terrorism	Count	3	1	6	3	1	3
Political reasons	Count	4	1	2	2	1	1
Burial depth of pipeline	Count	0	0	3	1	0	0
Strict penalty to offenders	Count	1	0	0	0	0	0
Public education and	Count	5	1	3	3	0	1
Absence of laws for pipeline	Count	1	0	2	4	0	0
Ignorance of the	Count	1	0	2	4	0	0
Government/Social	Count	7	0	8	5	0	0
Economy situation of a	Count	7	0	5	4	1	0
	Count	15	2	21	14	2	3

In a cross-tabulation analysis by location undertaken (Table VII), respondents from Africa frequently indicated *government/social responsibility to communities* and *economy situation of a country* (*e.g.* poverty and theft of product). In support of the above findings, most comments from Africa (mostly Nigeria) are from respondents' organisation experiencing intentional third-party interference as the following two comments illustrate: "*Failure of government commitment to the people of the oil producing communities in Nigeria, and resentment of government policy implementation expressed as vandalism to company pipeline assets for economic gains",* supported by another respondent, that*: "Poverty/purchasing power of nearby population in relation to value of product in pipelines; and socio-political factors - wealth distribution, employment opportunities, absence of effective community development programs, environmental pollution etc.".* Respondents from Oceania countries mostly indicated *petroterrorism.* Similarly, *petroterrorism* was the most frequently indicated factor by pipeline engineers compared to other profession, for example, pipeline project engineers whose majority indicated g*overnment and social responsibility to communities*.

Ranking of Factors for Potential for Third-Party Interference

Respondents were asked to select the three factors that are most important that could be used to assess the potential for third-party interference and rank them from 1 to 3 (with 1 as the most important). The study shows that *land use and human activities* was the most selected and thus the most ranked factor for consideration in mitigating intentional third-party damage. The second most ranked factor is *depth of pipeline* and followed by *accessibility to pipeline network* (Table 8).

Table 8. Frequency distribution for ranking of factors for potential for TPI

	Land use and human activities		Socio-economic conditions of population living near a pipeline		Accessibility to Pipeline Network (proximity of roads, rivers, streams and rail)		Socio-political factors (e.g. literacy rate, political stability, and violence		Depth of Pipeline (exposed pipeline can often provide criminal opportunities)		Other factor in your opinion not mentioned that influence intentional pipeline	
	Count	%	Count	%	Count	%	Count	%	Count	%	Count	%
None Selected	80	34.9%	118	51.5%	132	57.6%	137	59.8%	105	45.9%	198	86.5%
1st Most Important	86	37.6%	40	17.5%	19	8.3%	30	13.1%	29	12.7%	4	1.7%
2nd Most Important	36	15.7%	42	18.3%	27	11.8%	41	17.9%	52	22.7%	6	2.6%
3rd Most Important	27	11.8%	29	12.7%	51	22.3%	21	9.2%	43	18.8%	21	9.2%
Total	229	100.0%	229	100.0%	229	100.0%	229	100.0%	229	100.0%	229	100.0%

Third-party activities organisations presently monitor to avoid damage.

The survey research examined what activities organisations currently monitor to avoid third-party interference. SPSS multiple dichotomy analysis provided frequencies and percentages for the survey items and determine the most often suggested activities. Analysis of the demographic characteristics of respondents' choice based on occupation, organisation and location were examined using cross tabulation and showed most respondents (97.4%) indicated more than one item, and the frequency distribution showed that *right-of-way encroachment*, followed closely by *direct pipeline vandalism* are the most frequently chosen in the survey (Table 9).

In a cross-tabulation analysis by location, respondents from Africa, North America and Oceania most frequently indicated direct *pipeline vandalism* as the main priority of their surveillance program (Table 9). Respondents from Asia and Europe indicated *right-of-way encroachment*; only South American respondents indicated *theft of product and pipeline facilities*. In likewise manner, frequency analysis by organisation, majority of respondents from the academia and professional bodies indicated *no opinion*, while the respondents from government agencies indicated *direct pipeline vandalism* and *right-of-way encroachment*. Interestingly, respondents from the private companies and pipeline services indicated *right-of-way encroachment* as the most preferred surveillance activities to mitigate intentional third-party interference.

Table 9. Frequency distribution party activities organisations presently monitor to avoid damage.

	Responses		
	N	Percent	Percent of Case
Direct Pipeline Vandalism	108	14.6%	48.4%
Theft of product or facilities	101	13.7%	45.3%
Sabotage to pipeline network	101	13.7%	45.3%
Guerrilla attacks	39	5.3%	17.5%
Likelihood of Terrorism against pipeline facilities	72	9.8%	32.3%
Intrusion to above ground facilities	100	13.6%	44.8%
Right-of-Way Encroachment	116	15.7%	52.0%
Cyber attack and potential hijack of network facilit	32	4.3%	14.3%
No Opinion	69	9.3%	30.9%
Total	738	100.0%	330.9%

Discussion

Standard and procedures, and Research and Development

The study showed that application of proper standard and procedures; greater awareness campaign to all stakeholders; and more Research and Development are most effective in preventing pipeline third-party interference. The findings shows that besides engineering design of pipeline being carried out in line with international best practices, preventing third-party interference also depends primarily in utilising the opportunities created by research and development of pipeline project, for planning, design, installation, and maintenance(Williamson & Daniels, 2008). Education and awareness campaign about the risk and consequences of pipeline failure from third-party interference presented in an accommodating way to stakeholders, youth and communities help prevent third-party interference. One respondent outlined their opinion of preventing pipeline third-party interference:

"The prevention of third party interference is also reliant on the application of standards and procedures by the operating company. In countries where these are regulated it is easier to draw conclusions or state opinions, but in the Middle East for instance, there is a lack of formal regulation and in some cases, this can result in a lack of understanding in the need to enforce and ensure the proper preventative measures are taken".

In the last decades, environmental, political and financial awareness and consciousness about the negative aspects of pipeline failures has led to development of various national policies to reduce such failures. This development have lead to different legal framework and actions taken to promulgate appropriate environmental protection laws; harmonise the existing protection legislation, and make it a constitutional duty of any responsible stakeholders to safeguard petroleum pipeline. Pipeline failures not only impede financial and world energy supply of oil, but also cause death and environmental damage that demean a normal comfortable living environment. Therefore, important effective regulation and legislation for prevention and remediation of pipeline damage from third-party interference cannot be over emphasised.

Table 10. Cross-tabulation of respondents' geographical location

		Geographical Location of Respondent					
		Africa	Asia	Europe	North America	South America	Oceania
s Direct Pipeline Vandalism	Count	27	5	34	29	6	7
	% within $S3_Question	25.0%	4.6%	31.5%	26.9%	5.6%	6.5%
	% of Total	12.0%	2.2%	15.1%	12.9%	2.7%	3.1%
Theft of product or facilities	Count	24	4	35	25	8	5
	% within $S3_Question	23.8%	4.0%	34.7%	24.8%	7.9%	5.0%
	% of Total	10.7%	1.8%	15.6%	11.1%	3.6%	2.2%
Sabotage to pipeline network	Count	28	3	31	28	5	6
	% within $S3_Question	27.7%	3.0%	30.7%	27.7%	5.0%	5.9%
	% of Total	12.4%	1.3%	13.8%	12.4%	2.2%	2.7%
Guerrilla attacks	Count	14	2	10	11	2	0
	% within $S3_Question	35.9%	5.1%	25.6%	28.2%	5.1%	.0%
	% of Total	6.2%	.9%	4.4%	4.9%	.9%	.0%
Likelihood of Terrorism against pipeline facilities	Count	14	3	25	24	3	3
	% within $S3_Question	19.4%	4.2%	34.7%	33.3%	4.2%	4.2%
	% of Total	6.2%	1.3%	11.1%	10.7%	1.3%	1.3%
Intrusion to above ground facilities	Count	18	5	42	26	4	5
	% within $S3_Question	18.0%	5.0%	42.0%	26.0%	4.0%	5.0%
	% of Total	8.0%	2.2%	18.7%	11.6%	1.8%	2.2%
Right-of-Way Encroachment	Count	27	7	43	28	5	6
	% within $S3_Question	23.3%	6.0%	37.1%	24.1%	4.3%	5.2%
	% of Total	12.0%	3.1%	19.1%	12.4%	2.2%	2.7%
Cyber attack and potential hijack of network facilities	Count	5	1	12	12	1	1
	% within $S3_Question	15.6%	3.1%	37.5%	37.5%	3.1%	3.1%
	% of Total	2.2%	.4%	5.3%	5.3%	.4%	.4%
No Opinion	Count	15	6	31	16	3	0
	% within $S3_Question	21.1%	8.5%	43.7%	22.5%	4.2%	.0%
	% of Total	6.7%	2.7%	13.8%	7.1%	1.3%	.0%
	Count	50	15	90	51	11	8
	% within $S3_Question						
	% of Total	22.2%	6.7%	40.0%	22.7%	4.9%	3.6%

Surveillance Frequency

In any procedure for preventing third-party interference after pipeline installation, surveillance frequency determined from risk assessment is the most effective strategy, as also confirmed by this study. Periodic surveillance can help security analysts to assess any unusual trend that could be damaging to the pipeline and identify illegal activities within a pipeline's right-of-way or intrinsic to the pipeline, achievable using GPS mounted helicopter and small wing airplane (Riquetti et al., 1996; Gallacher, 1996). Aerial surveillance could be a reminder to the population beneath, that there is a pipeline on their land and this sometimes could serve as a deterrent. The major reason of disadvantage in high usage frequency and some modes of surveillance (*e.g.* helicopter surveillance) remain the high costs associated with capital, operation, and maintenance.

Communications with Stakeholders

Communications with stakeholders is another organisational representative recommended preventive measure by respondents. Sljvic (1995) recognises third-party interference as the most single probable cause of pipeline failure caused by landowners, utility companies, contractors, and local authorities. He studied relationship between third-party activities and its influence towards pipeline damage, and encouraged increased contact by pipeline operator with potential third parties through quality dissemination of information, this view was supported by Lu and Li (2005). In addition, an earlier companion paper by Hovey and Framer (1993) also confirms the likelihood of a spill along a pipeline is the primary responsibility of the pipeline managers and not the influence of socio-economic factors. He encourages collaborative communication between the operators and the landowners. In all responses to question of preventive, *increase pipe wall thickness* is the least recommended measure compared to education of third parties; installation of fibre optics; jet grouting protections to vulnerable portions, material selection against external load; one call warning systems; and satellite monitoring. This finding was unexpected; an implication of this is the possibility that engineering design with increased thickness of pipeline in vulnerable segment might be unnecessary.

Occurrence Factors of Intentional Pipeline Damage

Another important finding was that governmental social responsibility to communities and *economy situation of a country* (*e.g.* poverty and crime rate) are the most commentary factor perceived by respondents that influence the occurrence of intentional pipeline damage. One participant referred to how governmental social responsibility to communities as a necessary consideration:

"Avoid vulnerable areas, and work with local communities by making them feel responsible for the pipeline"; and "Maintaining excellent and mutually beneficial relationships with the host communities (this is relevant only for prevention of wilful damage), in addition to pipeline surveillance technology for all the pipeline networks, the host communities should continuously be educated about dangers in pipeline vandalization and as well engage them for local surveillance".

This study revealed that the prevalence of third-party interference in Africa is associated with socio-political and socio-economic status of the region. The findings from the survey highlight the need for stakeholders to consider: (1) creation of quality practice with high levels of commitment to communities; (2) development of programs and supports to optimize risk mitigation strategies; and (3) the benefits and understanding of various modern technologies applicable for prevention of third-party interference. Literature suggests that people from poor and deprived area are more likely to damage a pipeline intentionally than those from an area that is more affluent. For example, Bennett (1991) found that theft rate are related directly to gross domestic product per capita of a region, supported by Blau and Blau (1982) who also show how poverty and deprived economic empowerment can result in the frustration, thus leading to higher rates of crime.

Ranked Factors for Potential for Third-Party Interference

The study shows that *land use and human activities* is the most ranked factor for consideration in mitigating intentional third-party damage. The second most ranked factor is *depth of pipeline* and followed by *accessibility to pipeline network* (Table VIII). A participant acknowledged that without proper land use planning, security of pipeline would be a problem: *"...the risk of third-party interference is considered from an unintentional point of view. That is, resulting from poor risk mitigation measures adopted by Pipeline Company such as failing to adequately identify land use and hence put in appropriate and effective controls."* However, the most striking result to emerge from the study about methods of preventing pipeline third-party interference is that *depth of pipeline*; contrary to literature review, is least ranked compared to with *land use and human activities*.

These findings have challenged many study's claim, for example a pioneering study by Knight and Grieve (1974), cited by Mather *et al*., (2001) providing a comprehensive overview of the depth of cover as an influence to damage from third-party. It complements the review by (Neville, 1981), also cited by Mather *et al*., (2001) that incidences to pipeline are low with high depth of cover. Also, the findings of the study do not support previous research that identified depth of pipeline as one of the major dominant factor in third party failures (Muhlbauer, 2004; TRB, 2004; Jager et al., 2002; Taylor et al., 1984; Andersen and Misund, 1983). Therefore increasing pipeline depth of cover could prevent third-party damage, for example, researches have also shown that the probability of damage to a pipeline is reduced by 90% if the pipeline depth is doubled (Hopkins et al., 1999; Hopkins, 1993; Potter, 1985; Taylor et al., 1984). Exposed or shallow pipeline provides criminal opportunities because it is easy to vandalise or create illegal valves for stealing the pipeline content. Brantingham and

Brantingham (1981) term the above scenario as *crime generator*, as they provide places where crimes are likely to happen.

Current Third-party Activities been Monitored by Organisation

It is interesting to note that in all eight cases (Direct pipeline vandalism; Theft of product and pipeline facilities; Sabotage to pipeline network; Guerrilla attacks; Likelihood of terrorism against pipeline; Intrusion to aboveground facilities; Right-of-way encroachment; and Cyber attack/potential hijack of network facilities) *right-of-way encroachment*, followed closely by *direct pipeline vandalism* are the most current activities of intentional third-party interference being monitored by organisations. All participants identified right-of-way and direct pipeline vandalism as one of the factors influencing intentional third-party interference, and recommends regular patrolling on the pipeline right-of-way; for example, two participants outlined their opinion on right-of-way:

> *"Make it difficult to dig into the right of way. Grasscrete grids at the surface make the area look like a green field but make it very difficult to dig. This also spreads out the load of a vehicle driven on the right of way. Cost is an issue and gresscrete can only be used on the highest risk areas*", and *"Public education about pipelines that run through their neighborhood; what activity they might normally see on the ROW, what type of equipment they might see, learn to report any suspicious activity to the local authorities".*

Selected General Remarks about the Questionnaire Survey

The questionnaire survey asked respondents about any feedback or observation about pipeline third-party interference not covered by the survey questionnaire. These are some selected responses:

- *"Industry here held a meeting with various governmental entities to discuss the issue of possible terrorist acts against pipelines, platforms, etc. The lead agency in these discussions was the FBI. FBI recognized that no effective means exists that can prevent a terrorist act. Their desire was that industry set up video surveillance on its facilities with the intent that were such an act to take place that they could retrieve the video for use in investigation of the crime. Industry did not view this favourably in that the approach was tantamount to FBI requesting a "black box" recorder to investigate a disaster after the fact. In other words, FBI accepts the fact that facilities and personnel are in fact helpless to prevent such an attack and as such can only serve to provide possible evidence of the crime after it has been committed. Moreover, even if industry were to set up its own security measures, such measures would not be effective it that no effective counter-response capability exists. Industry representatives even went so far as to suggest that it be allowed the use of firearms to protect it pipeline and associated assets, e.g. offshore platforms. Government did not like this suggestion. Note: it is illegal to possess firearms on such properties. Industry effectively responded that government was powerless to stop industry from arming itself. Government effectively has turned a blind eye to industry's intentions in this regard. As to pipeline yet to be installed; burial, i.e. "hiding" these assets is the most effective means by which to lessen the possibility of their being compromised. Markers are also effective as is membership in a "Dig Alert" organization. Markers however have the disadvantage of advertising placement of pipelines. While your study is very well intentioned and may even provide some positive fruit, it is generally felt here that pipelines are at greatest risk from terrorist activity over which no control or preventative measure is possible. This is not fatalistic viewpoint; it is the reality of the world at this juncture. Joint governmental/industry continued cooperation does exist as regards reacting to reported suspicious activity. However, this is not a pro-active stance. It merely serves the purpose of being able to state that something is being done; no matter how impotent it really is. The recognized truth the matter is the tacit acknowledgement that an attack on a pipeline may be affected with virtual impunity".*
- *"Intentional damage is only likely where there is civil unrest or unhappiness for some reason. Where people wish to vandalize pipelines, there will be little you can do to stop them. There are however many very effective measures that can be taken to avoid accidental pipeline hits, e.g. mapping, One-Call system, legislation, and effective enforcement"*
- *"In Canada we have not seen a large presence of terrorism or other types of activities related to pipeline damage. There have been some pockets of criminal activities within the pipeline community however the greatest threat we face is from within our own ranks. That is a contractor or landowner*

who performs a ground disturbance without calling for locates and hits a pipeline or other buried infrastructure".

- *"The importance of ensuring that Risk assessment is always conducted with the number of increasing events demonstrated the importance of reviewing the pipeline controls for reduction in third-party interference. This is normally by way of neglect in searching land title for easements coupled with no delineation of the pipeline on District Council Maps. With designation secured the pipeline will be shown on District Council Maps and must be reported to any member of the public seeking a LIM (Land Information Management) Report for development or work"*
- *"Third-party damage is typically not an act of sabotage but rather an unintentional interference with the pipeline caused by local activity. The solution is avoidance. Avoidance requires design and construction techniques that identify the pipeline and detection technology on excavating equipment. Where avoidance is not possible then monitoring is required. Solutions must be cost effective".*
- *"Although third-party interference is the single main cause for pipeline damage, the cases of major pipeline incidents (on transmission pipelines) is so rare that additional safety measures are not required at all. Major incidents mainly occur on the distribution networks close to the buildings, mainly caused by manipulation of the supply connection directly. e.g., as an attempt of steeling gas, or due to the design for low pressures (plastic pipes)"*
- *"The cause and solution to the problem of third-party damage to pipelines in Nigeria are well known. There seems to be a reticence on the part of government to address the root causes. The oil companies themselves support local communities in which they work but the government does not support them in the appropriate manner".*
- *"You seem to have overlooked the issue of parochial business interest of some actors, underpinned by corruption. In one of my (field study) interaction with some local people where some Nigeria\'s oil pipelines transverse they argue that some firms or personnel that specialize in repair of pipelines connive with some vandals to puncture these pipes to achieve their mutual interest. The vandals benefit from this through siphoning of the products, while the firms/personnel gain from the award of contracts to effect repairs".*
- *"New technologies to detect buried pipelines and others like Broadband-in-Gas from NETHERCOMM could be more explored".*
- *"For the past 15 years Virginia government has been involved helping our pipeline industry reduce excavation damage to our pipelines. Our efforts have resulted in reducing these damages by more than 50% while miles of underground pipelines have increased by more than 30%. This has been done by effective public education, use of technology and strong and fair enforcement".*
- *"Intentional damage is not a problem in NA at least not yet. Most damage is due to contractors not using one call or facilities not being properly marked (which could go back to good records of the location of the pipeline). We need to make it very convenient for contractors to use first call and very painful if they don't use it".*
- *"Lack of awareness, information and knowledge about the pipeline damage risk, become a major factor of improper design, construction and maintenance, and cause many problems in the field".*

Conclusion

The ability to understand pipeline third party interference (TPI) is a valuable knowledge for stakeholders in the oil and gas industry, and for millions of people who live near petroleum the over two million kilometres of pipelines worldwide. The inadequacy of the usual traditional monitoring via regular patrolling of the rights-of-way, airborne or land-borne is in no doubt (Parfomak, 2008). Therefore, this study recommends that pipeline operator solicits stakeholders' participation at individual and group levels. At the individual level, questionnaires are developed and used for survey of local residents and officials. At group level, public meetings are organised with representatives of the national and local government stakeholders, and local non-governmental organisations. Public meetings held to provide feedback about the scope of the pipeline project, where findings and recommendations of the process will be incorporated into the engineering design (Hopkins et al., 1999; Day, 1998). This strategy will also identify and evaluates the positive and negative impacts likely to result from a pipeline project to enable assigning technical values to curb the impacts. This will enable stakeholders to expectedly recommends practical and cost-effective measures to prevent or reduce significant negative impacts of third-party interference to an acceptable level within a locality (Muhlbauer, 2004).

The study showed that government and social responsibility to communities, petroterrorism and a country's economy are the most frequently commentary factor perceived, that influence the occurrence of intentional pipeline damage. Unfortunately, the limited amount of published literature on intentional pipeline third-party interference makes the questionnaire survey generic. This study has explored the pipeline industry perceptions of third-party interference, and data analysis revealed nine themes: proper standard and procedures; greater awareness campaign to all stakeholders; Research and Development; surveillance frequency as determined from risk assessment; right-of-way encroachment; communications with all stakeholders; government and social responsibility to communities; land use and human activities; and a country's economy. The study would contribute to the development of a more comprehensive and effective approach to preventing and managing third-party interference incidents on oil and gas pipelines, which can enhance the safety and security of pipeline operations and protect the environment and public health.

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References

Andersen T, Misund A, (1983) 'Pipeline Reliability - an Investigation of Pipeline Failure Characteristics and Analysis of Pipeline Failure Rates for Submarine and Cross-Country Pipelines', *Journal of Petroleum Technology,* **35** (4), 709-717. DOI: 10.2118/10467-pa

Bennett RR, (1991) Routine activities: A cross-national assessment of a criminological perspective', *Social Forces,* **70**, 147. https://www.doi.org/10.1093/SF/70.1.147

Blau JR, Blau PM, (1982) 'The cost of inequality: Metropolitan structure and violent crime', *American Sociological Review*, **47,** 114-129. http://www.sciepub.com/reference/61469

Brantingham PJ, Brantingham, P. L. (1981) *Environmental Criminology*. London: Sage: London. https://samples.jbpub.com/9780763755751/55751_ch03_097_148.pdf

Coakes SJ, (2005) *SPSS: Analysis without anguish: Version 12.0 for Windows*. Wiley. https://www.wiley.com › en-cx

CONCAWE. (2007) 'Performance of European crosscountry oil pipelines- Statistical summary of reported spillages in 2005 and since 1971', *CONCAWE Oil Pipelines Management Group's Special Task Force on oil pipeline spillages*. https://www.researchgate.net/publication/294716671_Performance_of_European_crosscountry_oil_pipelines_-_Statistical_summary_of_reported_spillages_in_2010_and_since_1971

Daco I, Dezobry J, Laurens F, Torun S, Zara M, (2000) *Pactole: Un outil d'aide a la conception de canalisations resistant aux agressions de tiers*. Nice, https://rowlandadewumi.com/2021/06/an-industry-perception-and-assessment-of-oil-and-gas-pipeline-third-party-interferencetpi/

Day NB (1998) 'Pipeline Route Selection for Rural and Cross-Country Pipelines. *American Society of Civil Engineers*', ***46*** https://doi.org/10.1604/9780784403457

EIA. (2007) 'Energy in Brief'. http://tonto.eia.doe.gov/energy_in_brief/index.cfm

Gallacher A, (1996) 'Aerial pipeline surveillance in the information age', *Pipes and Pipelines International,* **41**(1), 22-24.

Hayes J, McDermott V, (2018) 'Working in the crowded underground: One call services as a boundary object', *Safety Science*, **110**, 69–79. https://doi.org/10.1016/j.ssci.2017.09.019

Hopkins P, (1993) 'Pipeline Monitoring and Inspection', *IEA International Conference on Natural Gas Technologies*. Kyoto, Japan, 3 November1993. Pipeline Monitoring and Inspection: IEA International Conference on Natural Gas Technologies.

Hopkins P, Fletcher R, Palmer-Jones, R, (1999) 'A method for the monitoring and management of pipeline risk, – A Simple Pipeline Risk Audit *', 3rd Annual Conference on 'Advances in Pipeline Technologies & Rehabilitation.* Abu Dhabi, November 1999. A method for the monitoring and management of pipeline risk, – A Simple Pipeline Risk Audit.

Hovey DJ, Farmer EJ, (1993) 'Pipeline accident, failure probability determined from historical data', *Oil and Gas Journal,* **91**(2), pp. 104-107.

Jaffrey D, Lubbers J, King B, Tapanes EE, (2002) 'An Effective and Proven Technique for Continuous Detection and Location of Third Party Interference Along Pipelines', *4th International Pipeline Conference, Parts a and B*. https://doi.org/10.1115/ipc2002-27046

Jager E, Kuik R, Stallenberg G, Zanting J, (2002) 'The Influence of Land Use and Depth of Cover on the Failure Rate of Gas Transmission Pipelines', *4th International Pipeline Conference, Parts a and B*. https://doi.org/10.1115/ipc2002-27158

Jing XF, Cai ZY, Liu KH, (2013) 'Numerical Simulation of Response of Explosion Ground Shock to Buried Gas Pipeline', *Applied Mechanics and Materials*, **448–453**, 3970–3974. https://doi.org/10.4028/www.scientific.net/amm.448-453.3970

Kent RA, (2001) *Data construction and data analysis for survey research.* Palgrave MacMillan.

Kraidi L, Shah R, Matipa W, Borthwick F, (2021) 'An investigation of mitigating the safety and security risks allied with oil and gas pipeline projects', *Journal of Pipeline Science and Engineering*, **1**(3), 349–359. https://doi.org/10.1016/j.jpse.2021.08.002

Lu H, Li J, (2005) 'Cause and prevention of pipeline third-party interference', *Cause and prevention of pipeline third-party interference,* **25**, (12), 118-120.

Mather J, Blackmore C, Petrie A, Treves C (2001) *An Assessment of Measures in Use for Gas Pipelines to Mitigate Against Damage Caused by Third Party Activity.* HMSO (Report Number: CRR 372/2001).

Muhlbauer WK (2004) *Pipeline Risk Management Manual: Ideas, Techniques, and Resources.* Gulf Professional Publishing. https://www.elsevier.com/books/pipeline-risk-management-manual/muhlbauer/978-0-7506-7579-6

Nwankwo C, Ezeobi O, (2008) 'Nigeria lost N150bn to pipeline vandals in eight years', *The Punch, Nigeria*,

Palmer-Jones R, Hopkins P, Fraser A, Dezobry J, Van Merrienboer H, (2004) *Pipe Line and Gas Industry - Pipes and Pipelines International Pipeline Pigging Conference Proceedings.* Houston, TX.,

Papadakis GA, (2005) 'Overview of pipelines in Europe - advantages and disadvantages.*' Workshop on the Prevention of Water Pollution due to Pipeline Accidents.* Berlin, Germany, 8 and 9 June 2005 Overview of pipelines in Europe - advantages and disadvantages.: UN/ECE, pp.

Parfomak PW, (2008) *Pipeline Safety and Security: Federal Programs.* http://www.fas.org/sgp/crs/homesec/RL33347.pdf.

Potter JC, (1985) 'Effects of vehicles on buried, high-pressure pipe', *Journal of Transportation Engineering,* **111**, (3), pp. 224-236.

Popescu C, Gabor MR, (2021). 'Quantitative Analysis Regarding the Incidents to the Pipelines of Petroleum Products for an Efficient Use of the Specific Transportation Infrastructure', *Processes*, **9**(9), 1535. https://doi.org/10.3390/pr9091535

Re G, Colombo A, (2004) 'TPI Detection on pipeline route by using existing fibre optic cables*', International Gas Research Conference Proceedings.* Vancouver, BC, TPI Detection on pipeline route by using existing fibre optic cables.

Riquetti PV, Fletcher JI, Minty CD, (1996) *Proceedings of the International Pipeline Conference, IPC.* Calgary, Can:ASME.

Sljivic S, (1995) 'Pipeline safety management and the prevention of third-party interference', *Pipes and Pipelines International,* **40**(6), 14-16.

Taylor ME, Lawrence GJL, Carder DR, (1984) *Behaviour of a shallow buried pipeline under impact and abnormal loads.* (03051293 (ISSN)).

Thomas SJ, (2004) *Using web and paper questionnaires for data-based decision making: From design to interpretation of the results.* Corwin Press.

TRB. (2004) 'Transmission pipelines and land use: A risk-Informed approach', *Transportation Research Board - Special Report*, 281.

https://nap.nationalacademies.org/catalog/11046/transmission-pipelines-and-land-use-a-risk-informed-approach-special

UKOPA. (2002) *Pipeline Product Loss Incidents: 2002 2nd report.* UKOPA, United Kingdom Onshore Pipeline Operations Association

UKOPA. (2008) *Pipeline Product Loss Incidents (1962 - 2006).* United Kingdom Onshore Pipelines Operators Association

Williamson J, Daniels C, (2008) *Third party Major Accident Hazard Pipeline (MAHP) infringement.* . Health and Safety Laboratory for the Health and Safety Executive (Research Report RR640.).

Yao A, Xu T, Zeng X, Jiang H, (2015). 'Numerical Analyses of the Stress and Limiting Load for Buried Gas Pipelines under Excavation Machine Impact', *Journal of Pipeline Systems Engineering and Practice*, **6**(3). https://doi.org/10.1061/(asce)ps.1949-1204.0000137.