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Comparison of Two Different Technical Solutions in Mitigating Pipeline Vandalism in Nigeria's Niger Delta

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ABSTRACT

Pipeline vandalization in the Niger Delta area of Nigeria has assumed a bigger threat to the economic and corporate image of Nigeria. Oil and gas exploration is the mainstay of the Nigerian economy and has been the main source of foreign direct investment into the country over the years. Coupled with loss of income, vandalization also comes with security threats that have drained the confidence and faith of Nigeria's partners in investing in the country. The Department of Petroleum Resources (DPR) in its annual reports from 2014 - 2018 showed that spills attributed to sabotage or vandalizations were 65.1%, 63%, 44%, 52.4%, 46.2% of total spill for 2014, 2015, 2016, 2017, and 2018 respectively. In the year 2019 alone, Nigeria recorded a loss of about 22 million barrels of crude oil valued at about $1.00 billion for the half year and about $2.7 billion for the full year at $60.0 per barrel. This paper posits that only technical solutions in addition to existing social solutions will bring an end to pipeline vandalization. An extensive study of two technical solutions was done. The two methods are most suitable for land terrain. This paper compares the economic, technical, and social implications of these methods and leaves the construction engineer with the option on which to adopt, depending on varying environmental and social conditions.

Keywords: Pipeline Integrity; Integrity Management; Pipelines Vandalism.

1.0 INTRODUCTION

Oil and gas provides the main source of energy for industrial, commercial, and domestic use. These energy sources are often concentrated in areas other than where they would be needed. Pipelines transport oil & gas over long distances, from producing wells and regions to export terminals, refineries, and fuel depot. Pipelines fail in operation because of defects such as cracks, corrosions, dents, puncture, etc. The biggest of them all is vandalization. Vandalization accentuates other form of defect, leading to damage and leaks on the pipeline, resulting to huge downtime, cost, and environmental hazards / challenges. Different form of defects lead to Pipelines failure in operation.

1.1 Pipeline Vandalism

A major cause of pipeline rupture arises from premeditated damage of producing pipeline for illegal economic reasons. This is so true in Nigeria. Our primary focus in this paper is to compare two different technical solutions to eliminate pipeline vandalization, as a significant contribution to pipeline integrity management. Olalekan (2020) reporting in Nairametrics informed that the Nigerian National Petroleum Corporation (NNPC) group managing director lamented that over 45,000 incidents of pipeline vandalism were recorded on NNPC pipelines over an 18 year period. According to the 2013 annual report of Nigeria Extractive Industry Transparency Initiative (NEITI), Nigeria lost $10.9 billion to oil theft from 2009 to 2011. Over the years there has been notable occurrence of pipeline failures/incidents around the world and in Nigeria which has led to oil/gas leakages and spills. The Department of Petroleum Resources (DPR) in its annual reports for 2014, 2015 ,2016, 2017 and 2018 showed that spills attributed to sabotage or vandalism were 65.1%, 63%, 44%, 52.4%, and 46.2% of total spill for 2014, 2015, 2016, 2017 and 2018 respectively. Kadafa (2012), quoting the Punch newspaper of February 2012 reported thus: "a total of 2,796 oil spill incidences were recorded between the periods of 1976 – 1990 leading to 2,105,393 barrels of oil spilled". Kadafa (2012) further reported that: "The UNDP 2006 report stated that there was a total of 6,817 oil spills between 1976 and 2001, leading to 3 million barrels of oil lost". Spills that occur in areas that are populated often have huge environmental impacts as they spread out over vast area, destroying aquatic life and agricultural products that are valuable to man for his survival. Umar et al (2017) lamented the frequent attacks by Niger Delta militants on oil and gas pipelines, describing it as worrisome, "due to its devastating effects on the environment". They stressed that: "Factors such as poor management, poor governance, weak legal system, and environmental degradation are among factors that encourage crude pipeline vandalization in the Niger Delta". Babatunde (2020) stated that "Oil exploration and pollution harms water resources and fuels conflict in the Niger Delta region". Weli (2019 sought the support of all stakeholders to curb pipeline vandalism, informing that "Since 2017, sabotage spill rate has risen steeply and crude oil theft from Shell Petroleum Development company of Nigeria (SPDC) JV's pipeline network averaged 11,000 barrels per day in 2018, an increase of about 20% over previous year. Ofualagba et al (2020) informed that: "Between 2010 and 2012, about 2,787 line break were reported on pipelines belonging to the Nigerian National Petroleum Corporation (NNPC) resulting in loss of 157.81 metric tons of petroleum products worth about 12.53 billion Naira".

Nigeria according to the Nigeria National Petroleum Corporation (NNPC) has a maximum production capacity of 2.5million barrels of crude oil per day with a larger capacity for gas and non-associated gas. Nigeria ranks as Africa's largest oil producer and the 6th largest oil producing country in the world. She is therefore not immune the Quality, Health, Safety and Environment (QHSE) concerns in the industry today. A large percentage of QHSE concerns derive from integrity or lack of it of Nigeria's oil and gas pipeline systems.

There has been a constant concern with regards to the level of integrity of oil and gas pipelines in Nigeria, which impinges on the quality, health, safety, and environmental well-being of the country. This is especially so because oil and gas pipeline crisscross the length and breadth of the entire country transporting crude, gas, and refined petroleum products, usually at high pressure. This concern has made it important that more innovative ways be found for the management of the integrity of our oil and gas pipelines.

1.2 The Challenge

One of the biggest problems facing the pipeline industry is the fact that the world's pipeline infrastructure is ageing. According to Achebe et al (2012), 41% of Nigeria's pipeline network are more than 30 years old. The widespread of pipelines combined with their multifarious range of operations, sizes, materials, age, and environmental effects contribute to the hazards associated with the pipeline industry. Often, these cumulative hazards make oil and gas pipeline safety a very complex process. Tragic onshore and offshore accidents attributed to the failure of pipelines are major concerns for operating companies, regulators, and the public- Peekema, (2013).

Vandalism of pipelines has assumed alarming dimension and has become the most critical source of pipeline failures in Nigeria. Several lives have been lost to incidents including pipeline explosions attributable to vandalism. Pipelines are spread in many places, used for many services, and come in several sizes. These factors contribute to the hazards associated with the pipeline industry. According to Igbal H. (2018): "These cumulative hazards make oil and gas pipeline safety a very complex process". "Tragic onshore and offshore accidents attributed to the failure of pipelines are major concerns for operating companies, regulators, and the public". These problems have huge environmental, economic, safety, and security implications. While Nigeria had about 2,787 pipeline breaks between 2010 and 2012, the figure is analyzed to be at about 15,685 between 2002 and 2012 - Okoli (2019). These pipeline incidences translate to huge economic loss and massive environmental pollution. On many occasions they have resulted in loss of lives for workers and host communities with over 2,500 lives lost in a period of 10 years - Okoli (2019). Most of these pipelines have been subjected to deterioration due to vandalization, aging, aggressive environmental factors, inadequate design and improper protection and maintenance Ogwu (2014); Shahriar et al 2012; Anifowose et al 2011). Oil companies need to carry out proper hazard identification of the operation they perform whether these are man-made or natural, and manage their risks using appropriate technology to ensure safe working practices. Ipingbemi (2009) stated that oil spill which has occurred in several areas of the Niger Delta has impacted negatively on both pH value of the soil and hydrocarbon content of water, the consequence of which is the migration of people to other areas for greener pasture. Ugochukwu et al (2012) discussed the various impacts that oil production has had on the biodiversity of the Niger Delta. Okolo et al (2010) reiterated that the discovery of oil in the Niger Delta in 1956 did not and has not ushered in the needed sustainable development in the region. On the contrary, they posited that the activities of the Multinational oil and gas companies' operation in the region has continued to pollute and degrade the environment, so much so that it disarticulated the local economy of the people, leading to unmet expectations and consequent anger and frustration. They identified this as what led youths of the region to vandalize oil and gas pipelines. The need to stamp out pipeline vandalism can therefore not be over emphasized. It is imperative to do this both for the economic, quality, health, safety, and environmental wellbeing of Nigeria. The following incidents among so many others are worth pointing out:

1. From information contained in the 2013 annual report of Nigeria Extractive Industry Transparency Initiative (NEITI), $10.9 billion was lost to oil theft from 2009 to 2011 (Onoja, 2013).

2. The Nigerian National Petroleum Corporation (NNPC) reported in June 2019 that 106 points were vandalized in its network of pipelines, representing a 79% rise in cases of pipeline vandalism over the figure for May of the same year (60 points).

3. Shell Petroleum Development Company of Nigeria (SPDC) reported 17 vandalized points on some of its pipelines n June 2020.These are:
    a) 28” Bomu – Bonny pipeline -1 point
    b) 14’’ OkodiaRumuekpe -5 points
    c) 28” Nkpoku – Bomu – 1 point
    d) 20’’ Kolocreek – Rumuekpe -2 points
    e) 12’’ Imo river – Ogale – 5 points
    f) 36’’ Nkpoku – Ogale – 1 point

4. According to Obaseki (2019) NNPC reported that Nigeria in 2019 recorded a loss of 22.64 million barrels of crude oil valued at $1.35 billion for the half year and $2.7 billion for the full year at $60.0 per barrel. “The Nembe-Cawthone Channel Trunkline (NCTL) suffered the most vandalism attack during this period”. Huge loses were also recorded on the following pipelines in the period:

a) Nembe – Cathone Channel Trunkline (NCTL) – 9.2 million barrels
b) Trans Niger Pipeline (TNP) – 8.6 million barrels
c) Trans Forcados Pipeline (TFP) – 3.96 million barrels
d) Trans Excravos Pipeline (TEP) – 877,000 barrels

Products pipeline vandalism has resulted to several explosions in the past, leading to preventable loss of lives and environmental degradation. The following are worth mentioning:

a) March 2019 Warri pipeline explosion)
b) March 15 2020 Abule Ado in Lagos Nigeria
c) 2008 Ijegun pipeline explosion Lagos
d) 2020 Abule Egba pipeline explosion Lagos
e) 2020 pipeline explosion at Soba area of satellite town Lagos.

In January 2020, NNPC General Manager public affairs (business news – Nairamarics, April 23rd, 2020) reported that vandalism of its pipeline network across the country rose by a phenomenal spike of 50%. Furthermore, at the 2019 Nigeria Extractive Industry and Transparency Initiative (NEITI) inaugural dialogue NNPC managing director (Business news – Nairamatrics 21st January 2020) reported that between 2001 and 2019, an 18-year period about 45,347 vandalism incidents were recorded on its pipeline network. Okoli et al (2013) wrote that “vandalism mostly take place in poor courtiers because international oil companies often fail to bury or protect their pipelines as they would have to by law in rich countries”. “The easily accessible pipes which often run through slums and informal settlements are tempting to desperately poor communities”. They recommended stringent penalties for perpetrators as well as adequate protection and surveillance.

According to DPR annual reports (2010 to 2018), spills attributed to sabotage or vandalizations were 65.1%, 63%, 44%, 52.4%, and 46.2% of total spill for 2014, 2015, 2016, 2017, and 2018 respectively. The reports also showed that spills attributed to Yet-to-be-determined (YTBD) factors were 17.3%, 13.5%, 23.0%, 15.85%, and 26.88% for 2014, 2015, 2016, 2017, and 2018 respectively. Data for causes of spill from 2010 to 2013 are not available. We have relied on the spill summary only for this period. Data is available for both spill summary and cause of spill for 2014 to 2018.

2.0 TECHNICAL SOLUTIONS

The fast-changing nature of the problem and the increasing sophistication of pipeline vandals have necessitated the application of measure that will not only discourage pipeline vandalism but can lead to its long-term elimination. Three methods deep burial, horizontal directional drilling and Pipe-in-pipe are discussed.

estimates of achieved depth. This will be followed by both longitudinal and cross echo sounding of the completed trench to accurately determine the depth and width of the trench-bottom, respectively.

2.1 Horizontal Directional Drilling (HDD)

2.1.1 Philosophy

Godwin et al (2001) defined HDD as a trenchless method of installing underground pipelines, typically used in river or large open water pipeline crossings. HDD construction is no longer limited only to river or large water body crossings but is now used to lay oil and gas pipelines as well. It is very suitable in densely populated areas. The original objective is to safely lay the pipeline with little or no obstruction or disturbance of life of the populace. There is minimal disturbance of the eco system and access to the pipeline is limited. HDD was conceived by Martin Cherrington in 1963 (How the HDD began – Martin Cherrington) He conceived it while working for a contractor in Los Angele California USA. It was originally conceived and used to overcome large natural obstacles, such as river crossings. It has since become popular as a major construction methodology in installation of underground facilities in major urban cities as well as large diameter and long-distance pipeline installation. As informed by Godwin et al (2001), HDD was successfully used for the Antioc – Pittsburg California 16 inches and 24 inches natural gas pipelines. HDD was used for this project to overcome environment, engineering, as well as major route selection challenges arising from limited right-of-way size, obstructions, high density living area as well as rail track and moving train obstructions.

For this paper, we are recommending it as an alternative pipelay method, to limit access to the pipeline to prevent vandalization as well as achieve environmentally friendly construction.

2.1.2 Design

Soil Condition: HDD Installation is most suitable for soft soil such as clay and compacted sand. However, advanced technology has enabled the manufacture and use of drilling tools to install pipeline in varied soil conditions. It is important to carry out pre-construction inspection of the Right-Of-Way (ROW) to establish the soil condition along the ROW. This will enable the equipment of the HDD drilling rig with the most appropriate drilling tool suitable for the soil type. It will also enable the contractor to plan for the type of back reamer and mud mixture to use.

Site Condition: Establish and ensure there is sufficient room at the site for entrance and exit pits and all other equipment. Also review the site and ROW for evidence of substructures such as manhole covers, valve box covers, meter boxes, electrical transformers, conduit, or drop lines from utility poles.

Sufficient cover dept: This should be ensured to prevent heaving and hydraulic fracture of the soil during and after pipeline installation.

Alignment: Drill path must be aligned, to minimize the fracture resistance during pull back and maximize the length of the pipe that can be installed during a single pull.

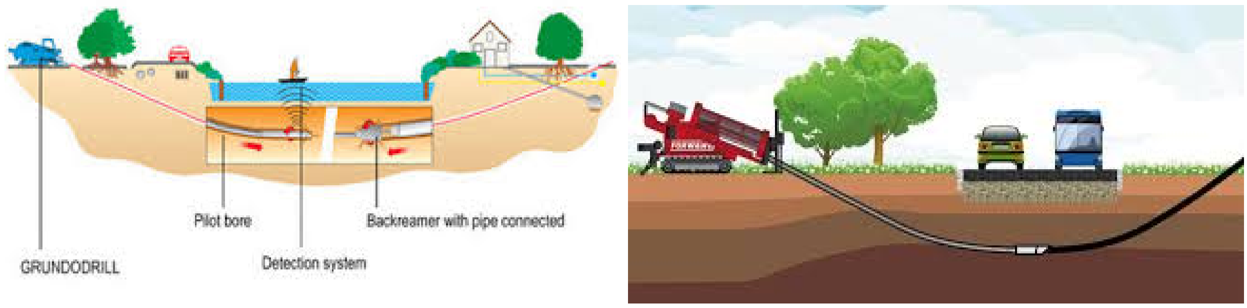

Figure 1 HDD Profile

Installation of pipelines using HDD methodology is done in three (3) steps, as shown in figure 2

1. Pilot Hole. This basically consists of drilling an initial hole along the drill path of the proposed crossing or pipeline ROW. This initial hole is drilled along a pre-determined alignment. The entry and exit points are located using traditional survey methods. Pilot hole drilling also enables the acquisition of requisite data for a successful installation of pipeline. Such data includes rate of penetration and confirmation of geotechnical strata.
2. Reaming. Reaming consists of one or more hole opening passes. Two types of tools- fly cutter and rock hole opening tools are used to enlarge the pilot hole.
3. Pull back. This is the installation or pulling of the pre-welded or fabricated pipe string into the reamed hole. This is the most critical stage in HDD installation.

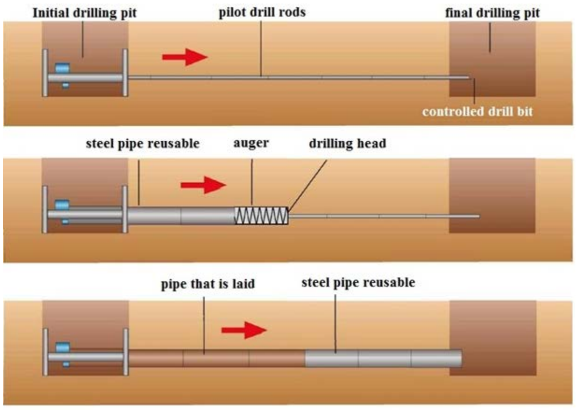

Figure 2 Steps in HDD Pipe Lay

2.1.4 Cost

Vilfrant (2010) posits that the construction market in general, including HDD follows the trend and patterns of society and is affected by the amount of spending, the capacity and experience of contractors and complexity of projects. In comparing the cost of HDD versus open-cut construction method, Langan (2003) advocated that we must adopt the term "comparing apple for apply" in comparing the costs. Comparing apple for apply implies the need to compare alternatives fairly before deciding. Langan (2003) opined that it is often difficult to estimate construction costs as this might only depend on materials, labour and profit, but also driven by market conditions such as availability of experienced construction contractors for all methods. Using the "apple for apple" comparison philosophy, Langan (2003) compared "the cost of HDD and open cut construction for the installation of sanitary sewer pipeline". The tendering for the project required contractors to quote using the HDD and or open-cut construction methods. All conditions were equalized to get a total project cost for both methods. Both tenders contained the typical tender items and same requirements, thereby leveling the playing field. All factors were known by the contractors during the tendering stage allowing them to make strategic decisions prior to submitting their bids. According to Lagan, during tender evaluation, it was decided that the bid with the lowest total project construction cost would be awarded the project. After comparing apple to apple, the lowest total construction prize was realized by the HDD method. For this project, the potential cost saving was determined by comparing the average prize for the three lowest bids for each construction method. A saving of 46% was achieved with the HDD method. However, in some cases HDD costs are higher especially using a less experienced contractors and depending on the sophistication of the society. Atalah et al (2009) investigated "The cost of HDD versus open-cut construction methods for the installation of pressure water lines in Nairobi Kenya". They concluded that: "The cost HDD was about 12.5% more expensive than open-cut".

Table 1 Cost Comparison Breakdown for Open-cut and HDD Methods (In Kenyan Shillings)

Cost Category	Open Cut		HDD	
	Amount (Ksh)	Percentage of total cost	Amount (Ksh)	Percentage of total cost
Labor Cost	775,4492	4.81%	915,714	5.04%
Burden	1,380	0.01%	7,367	0.04%
Permanent Material	5,306,867	32.93%	8,394,449	46.20%
Construction Material	700,927	4.35%	1,108,504	6.10%
Equipment Cost	7,353,853	45.64%	4,780,545	26.31%
Site Expenses	494,848	3.07%	760,328	4.18%
Project Markup	706,925	4.39%	1,064,460	5.86%
General Expenses	706,925	4.39%	1,064,460	5.86%
Bond	67,283	0.42%	75,510	0.42%
Total Cost	16,114,500	100%	18,171,337	100%

Doing a cost comparison in Nigeria, the cost of laying a 20" pipeline over 15 kilometers using HDD and normal open cut was done. Because of the relative newness of the method and the less sophistication of construction contractors, the cost was marginally higher than in the Nairobi project investigated by Atalah et al (2009). This is shown in table 2

Table 2. Cost of HDD Construction for a 20" x 15km Pipeline

SUMMARY OF TRUNCKLINE COST FOR 20" x 15KM		
Horizontal Directional Drilling		
S/N	**ITEM DESCRIPTION**	**AMOUNT (N)**
1.	Allow provisional sum for Engineering works	280,000,000.00
2.	Procurement (15km 20" PE Coated pipes)	4,128,000,000.00
3.	Personnel	190,807,344.30
4.	Equipment	4,160,961,856.07
5.	WELDERS & FITTERS Cost Per Joint for 15KM	131,040,000.00
6.	Allow provisional sum for Community Stipend	135,000,000.00
7.	Allow provisional sum for NDT	126,000,000.00
8.	Allow provisional sum for HYDRO-TEST	120,257,061.30
9.	Allow provisional sum for Tie-In	60,008,569.71
	TOTAL	**9,332,074,831.38**

From Tables 1 and 2, HDD is about 22.8% more expensive than normal traditional open cut shallow burial.

2.1.5 Benefits

By quarter 2 of 2002, when China achieved an unprecedented annual GDP growth of nearly 10.0% Carlin (2014). The need for massive infrastructural development arose, with attendant social implication like the need to maintain sane human activities while not hampering ongoing developments in infrastructure, transportation system and rural-urban migration. There became a need for major underground facilities installation such as gas, oil, water and sewage pipelines, electrical ducts, telecommunication facilities, etc. HDD technology was utilized to achieve a balance between construction inconveniences, safe co-habitation of humans and facilities, and social harmony. The following advantages therefore prevail for HDD pipeline construction:

i) Less manpower is required, thereby contributing to project cost saving.
ii) Reduced ground excavation
iii) Reduced engineering and construction time; it does not require the robust buoyancy calculations, concrete coating/curing.
iv) Affords the construction team a site that is almost independent of weather condition.
v) Elimination of need for site restoration activity
vi) Reduced negative social impact and cost.
vii) Reduced negative environmental impact and cost.
viii) Ability to install pipeline with extreme accuracy in congested urban areas.

2.1.6 Challenges

1) Limitation regarding soil conditions
2) Stability problem when encountering loose sand.
3) Available space at the lunching and receiving ends.

4) Less manpower is needed. Reduced employment opportunity may lead to community or social agitation.
5) Adoption of HDD for pipe laying at national level may lead to "start-up'' cost challenges.
6) Massive local training will be required, with attendant cost implication.
7) Capital flight issues will arise. The initial manpower and equipment requirement are not available locally.
8) Maintenance of the pipeline at the depth buried will be more difficult than for normal burial. However, maintenance frequency will also be drastically reduced because vandalization accentuates other forms of failure such as corrosion damage. When pipelines are vandalized and oil stolen, the point of puncture becomes susceptible to initiation of corrosion because the pipeline becomes exposed to the environment, as the protective coating is removed, and the bare steel is exposed.

HDD pipe lay technology has been used successfully in Nigeria to lay the 20'' X 67km Amukpe-Escravos Pipeline. The pipeline was installed between 6meter and 45meter below ground level. The aim was to secure the pipeline against external interference and vandalism.

2.2 Pipe-in-Pipe Concept

This is essentially designed to have an inner pipe inside an outer pipe covering. It is made up of an inner pipe and an outer pipe cover. It is not new in pipeline construction as it has been applied over time at road crossing and pipe intersections, where it is estimated that there will be higher pressure at 60 those points. In this case it is extended beyond road crossing points, to cover the entire pipeline right of way. The inner pipe is the designed line pipe, putting into consideration the fluid to be conveyed, internal pressure containment as well as the area classification. "The inner pipe is insulated with thermal insulation material to achieve the required arrival temperature as well as for corrosion prevention". It is suitable for application in the construction of land lines Design: The Inner pipe is coated with materials to insulate against corrosion and to achieve the arrival temperature of the conveyed fluid. The outer pipe is designed to protect the inner pipe insulation material against hydrostatic pressure as well as mechanical damage. The two pipes are separated for some space at the end of each joint to achieve thermal insulation. Construction: The aim is to provide added protection against vandalization, for the pipe carrying the petroleum product, by making access difficult. The construction methodology can be same open cut and bury system. The pipe is buried at normal depth. The added protection is provided by the outer pipe. Figure 3 shows the profile of a typical pipe-in-pipe design for a crossing, showing the inner pipe, thr end seperstion and the outer pipe that provides protection for the inner pipe. Figur 4 shows the pipe-in-pipe profile for a concrete coated outer pipe.

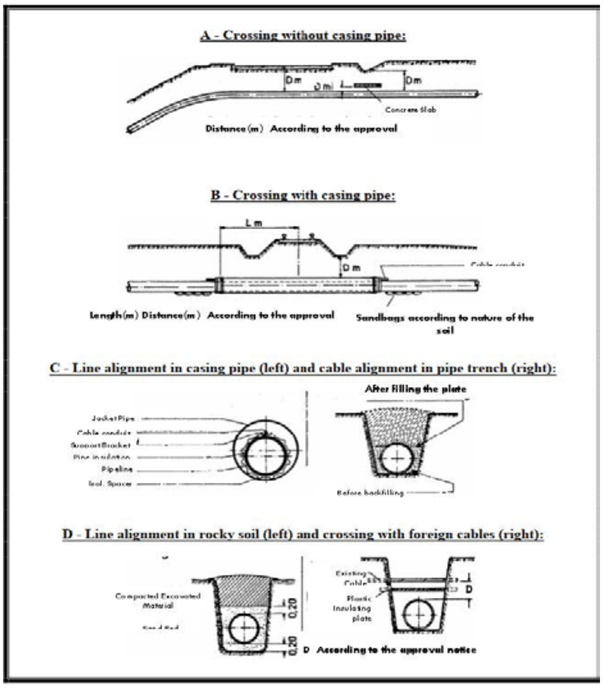

Fig 3 Pipe-in-pipe Profiles and Line Allignment

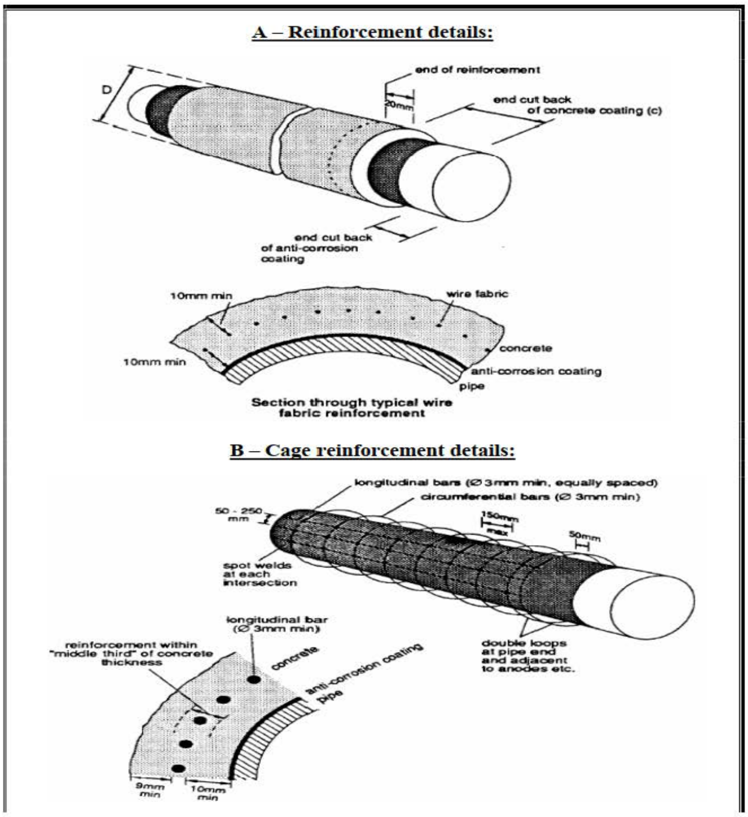

Fig 4 Concrete Coating of Pipe outer surface

3.0 COMPARISON OF TECHNICAL SOLUTIONS

3.1 Cost Comparison

Table 3. Cost of Normal Open -Cut Construction for a 20” x 15km Pipeline

SUMMARY OF TRUNCKLINE COST FOR 20" x 15KM		
NORMAL OPEN CUT CONSTRUCTION WORKS		
SN	**ITEM DESCRIPTION**	**AMOUNT (N)**
1	Allow provisional sum for Engineering works	280,000,000.00
2	Procurement (15km 20" PE Coated pipes)	4,128,000,000.00
3	Personnel	244,255,947.38
4	Equipment	2,372,601,800.00
5	WELDERS & FITTERS Cost Per Joint for 15KM	131,040,000.00
6	Allow provisional sum for Community Stipend	135,000,000.00
7	Allow provisional sum for NDT	126,000,000.00
8	Allow provisional sum for HYDRO-TEST	120,257,061.30
9	Allow provisional sum for Tie-In	60,008,569.71
	TOTAL	**7,597,163,378.39**

Table 4 Cost of HDD construction for a 20" x 15km pipeline

SUMMARY OF TRUNCKLINE COST FOR 20" x 15KM		
Horizontal Directional Drilling		
S/N	**ITEM DESCRIPTION**	**AMOUNT (N)**
1.	Allow provisional sum for Engineering works	280,000,000.00
2.	Procurement (15km 20" PE Coated pipes)	4,128,000,000.00
3.	Personnel	190,807,344.30
4.	Equipment	4,160,961,856.07
5.	WELDERS & FITTERS Cost Per Joint for 15KM	131,040,000.00
6.	Allow provisional sum for Community Stipend	135,000,000.00
7.	Allow provisional sum for NDT	126,000,000.00
8.	Allow provisional sum for HYDRO-TEST	120,257,061.30
9.	Allow provisional sum for Tie-In	60,008,569.71
	TOTAL	**9,332,074,831.38**

Table 5 Cost of Pipe-in-Pipe Open -Cut Construction for a 20" x 15km Pipeline

SUMMARY OF TRUNCKLINE COST FOR 20" x 15KM		
PIPE-IN-PIPE CONSTRUCTION WORKS		
S/N	**ITEM DESCRIPTION**	**AMOUNT (N)**
1.	Allow provisional sum for Engineering works	280,000,000.00
2.	Procurement (15km 20" PE Coated pipes)	4,128,000,000.00
3.	Procurement (15km 24" PE Coated pipes) OUTER PIPE COVER	4,985,000,000.00
4.	Personnel	290,807,344.30
5.	Equipment	3,135,344,800.00
6.	WELDERS & FITTERS Cost Per Joint for 30KM	262,080,000
7.	Allow provisional sum for Community Stipend	135,000,000.00
8.	Allow provisional sum for NDT	126,000,000.00
9.	Allow provisional sum for HYDRO-TEST	120,257,061.30
10.	Allow provisional sum for Tie-In	60,008,569.71
	TOTAL	**12,870,451,378.3**

The cost of Item 1, 2, 6, 7, 8, and 10 are constant in all methods while Item 2, 3 and 4 varies as shown in table 3, 4 and 5 above
The cost comparison for variable items for the Normal Open Cut, HDD and Pipe-In-Pipe methods are shown in Table 6 and chart analysis shown in figure 3, 4 and 5 below.

Table 6 Cost Comparison for Variable Cost Item Using Normal Open Cut, HDD And Pipe-In-Pipe for a 20" x 15km Pipeline

SUMMARY OF TRUNCKLINE COST FOR 20" x 15KM				
S/N	ITEM DESCRIPTION	AMOUNT(₦)		
		NORMAL OPEN CUT	HDD	PIPE-IN-PIPE
1	Personnel	244,255,947.38	190,807,344.30	290,807,344.30
2	Equipment	2,372,601,800.00	4,160,961,856.07	3,135,344,800.00
3	Welders & Fitters Cost Per Joint for 15KM	131,040,000.00	131,040,000.00	262,080,000.00

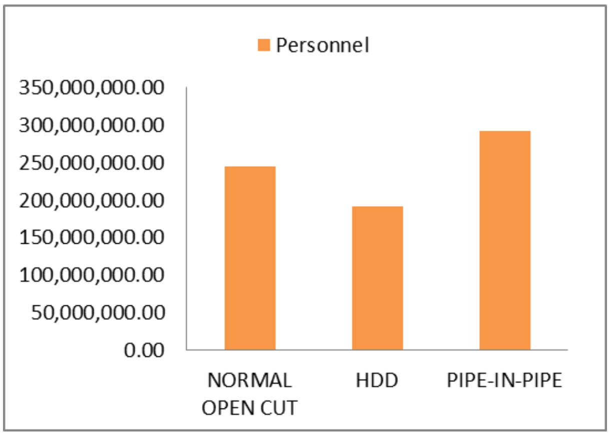

Fig 5 Cost Comparison for Personnel Using Normal Open Cut, HDD and Pipe-In-Pipe for a 20" x 15km Pipeline

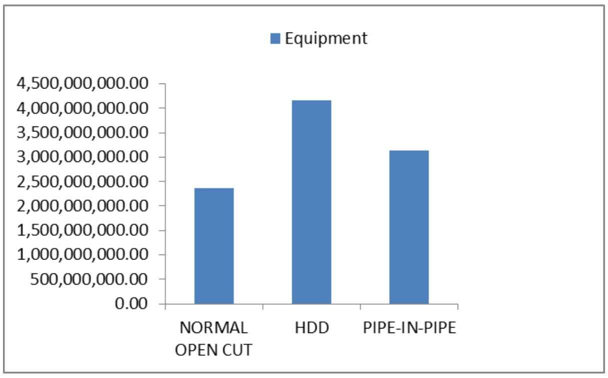

Fig 6 Cost Comparison for Equipment's Using Normal Open Cut, HDD And Pipe-In-Pipe for a 20" x 15km Pipeline

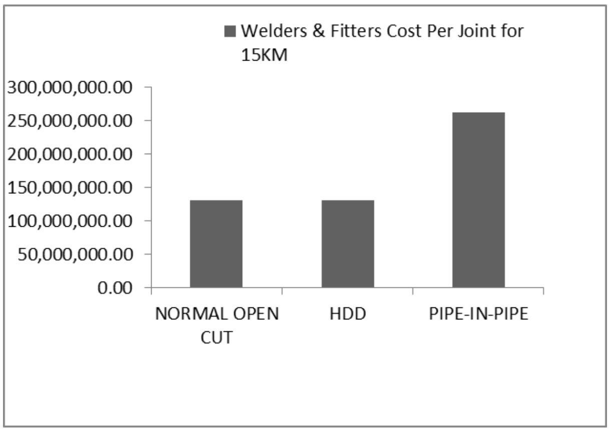

Fig 7 Cost Comparison for WELDERS & FITTERS Cost Per Joint for 15KM Using Normal Open Cut, HDD and Pipe-In-Pipe for a 20” x 15km Pipeline

Table 7 Cost Comparison of Normal Burial with HDD, Pipe-in-Pipe, Deep burial

NORMAL BURIAL	HDD	PIPE-IN-PIPE
7,597,163,378.39	**9,332,074,831.38**	**12,870,451,378.3**
Cost above normal burial	**22.8%**	**69.4%**

For apple-to-apple cost comparison (table 6), HDD is about 22.8% higher, translating to about N1.7b (One billion, seven hundred million Naira) additional cost; Pipe-in-pipe is about 69.4% higher, translating to about N5.2b (Five billion, two hundred million Naira) additional construction cost.

Comparing the additional costs of the HDD and Pipe-in-pipe construction methods, pipe-in-pipe is more expensive. This basically arises from the additional cost of procurement of the outer prospective pipe. Both methods are suitable for land terrain, but HDD is technically more complicated than pipe-in-pipe because of its newness and the lack of local experienced manpower and equipment outlay. However, deeper burial can be achieved with HDD than pipe-in-pipe construction.

3.2 Construction and Technical Comparison

Table 8 Technical Comparison of Deep Burial, HDD, and Pipe-in-Pipe Methods

HDD	PIPE-IN-PIPE
Most suitable on land	Most suitable on land
Less manpower is required, thereby contributing to project cost saving	Engages a lot of manpower
Equipment outlay is more technical and expensive.	Same equipment as for normal shallow burial
Risk of failure is higher due to sophisticated equipment and skilled manpower required.	Risk of failure is relatively low
Reduced negative social impact and cost	Social and environmental impact is high
There is no need for site restoration activity	Site restoration is required
As Less manpower is needed, reduced employment opportunity may lead to community or social agitation.	More employment opportunity is created
Reduced engineering and construction time;	More construction time needed
There is limitation regarding soil conditions. Adoption of HDD for pipe laying at national level may lead to “start-up’’ cost challenges	Less limitation regarding soil conditions No start-up issues. methodology is not sophisticated
Massive local training will be required, with attendant cost implication	Methodology is not sophisticated
Ability to install pipeline with	Urban congestion is still

extreme accuracy in congested urban areas. Adverse safety and environmental issues are averted.	a huge challenge to achieve pipe lay by this method
There is stability problem when encountering loose sand	There is less problem regarding excavation of areas with loose sand and slurry.
limited ground excavation, hence, no issue regarding management of excavated materials	Same volume of excavated material as in normal burial construction.

4.0 CONCLUSION

In terms of cost, it is worthy of note that In 2019 Nigeria recorded a loss of 22.64 million barrels of crude oil valued at $2.7 billion (Two Billion Seven Hundred Million Dollars) at $60.0 per barrel**.** That year 2019, the following pipelines suffered serious incidents of vandalizm:

a) Nembe – Cathone Channel Trunkline (NCTL) – 9.2 million barrels
b) Trans Niger Pipeline (TNP) – 8.6 million barrels
c) Trans Forcados Pipeline (TFP) – 3.96 million barrels
d) Trans Excravos Pipeline (TEP) – 877,000 barrels

If an additional cost of ₦5.2 billion (using the highest additional cost scenario) incurred to construct a pipeline with a lifespan of about 25 years will save a possible loss of N21.5 billion (Twenty one billion five Hundred Million naira) annually, this additional cost pales into insignificance. Note that we have used the least possible case of oil spillage; using Trans Excravos Pipeline (TEP). This pipeline lost 877,000 barrels. At $60.0 per barrel with exchange rate at ₦410/$, the loss amounted to **₦21,574,200,000.00(Twenty One Billion Five Hundred and Seventy Four Million Two Hundred Thousand) naira only.**

This paper therefore strongly recommends the adoption of technical solutions to the elimination of pipeline vandalization.

Fig 8 Percentage Cost Comparison of HDD method, Pipe-In-Pipe Method and Loss due to Oil Spillage from Sabotage/Vandalization Using Normal Burial Method

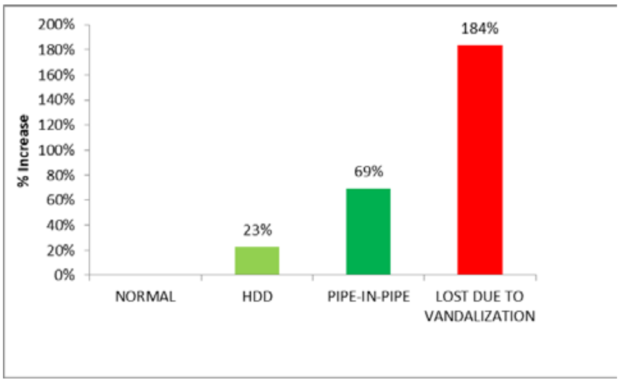

Figure 6 above shows that the percentage loss recorded using the least case of spillage as a result of sabotage/vandalism from normal burial method is 115% above the cost of Pipe-In-Pipe method and 151% above the cost of HDD method in constructing a pipeline with a lifespan of over 20years. This shows that the incurred cost in both the HDD method and Pipe-In-Pipe method is of no significnce when compared to the huge loss from oil spillage due to sabotage/vandalization using the existing normal burial method.

The two construction methods outlined are geared to solve the problem of pipeline vandalization. Each method where adopted will save huge cost and solve a vast percentage of the environmental and safety issues associated with pipeline operations. Certainty and stability in pipeline operations will improve the integrity management of pipelines, improve corporate image, and encourage foreign direct investments in Nigeria's oil & gas sector.

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