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TRANSPORTATION IN NIGERIA'S OIL & GAS INDUSTRY: AN ENVIRONMENTAL CHALLENGE

Babatunde Anifowose*, Damian Lawler, Dan Van der Horst, Lee Chapman
School of Geography, Earth & Environmental Sciences (GEES)
The University of Birmingham
Edgbaston, Birmingham, United Kingdom B15 2TT
baa631@bham.ac.uk; DM.LAWLER@bham.ac.uk; d.vanderhorst@bham.ac.uk; l.chapman@bham.ac.uk

Abstract
The Nigerian Niger Delta has in recent years remained a national and international focus for diverse stakeholders not only for its enormous oil and gas resources but for environmental unsustainability, wealth/revenue sharing controversies, civil unrest, and poverty of its inhabitants. To this effect, many innovative individual, corporate and/or joint-government commissioned research projects have been carried out to address the situation. Also, there have been a number of reported cases of interdiction problems (i.e. sabotage or vandalism) along pipeline infrastructure which is one of the key sources of pollution in the area. However, from the Transport Geography perspective (i.e. distance, accessibility, spatial interaction and land use), little work has been done to critically assess individual sources of environmental pollution such as pipeline infrastructure operations within the context of post-project appraisal phases of Environmental Impact Assessment (EIA) protocols or Environmental & Social Impact Assessment (ESIA). This paper identifies some significant limitations in EIA/ESIA protocols in such environments, and proposes a number of improvements to minimize oil industry environmental impacts. In particular, this paper attempts to lay the foundations to enhance EIA/ESIA and reduce the impacts of environmental pollution by (a) the inclusion of GIS and remote sensing, especially for post-project appraisal of pipeline operations and (b) integrating concepts from transport geography models.

Keywords: Transportation, Post-project appraisal, EIA, ESIA, Geographical Information Systems, GIS, Remote Sensing, Oil, Gas

1. Introduction

Pipelines are comparatively more economically viable in terms of accessibility to remote locations, distance coverage, speed and the efficiency with which fluids e.g. water, oil, gas, slurry and other liquids are transported (Lawler 1996, Fricker & Whitford 2001, Degermenci 2001, Oni 2002). Exploration and transport of oil/gas resources commenced in Nigeria's Niger Delta in 1956 with reactive rather than proactive environmental regulations in place. Pipeline transport did not present significant environmental problems until the 1990s (Fig. 1a). Non-maintenance and intentional attacks on an existing supply service system, whether considered as sabotage, vandalism or 'interdiction' (Church et al. 2004), are not just leading to loss of critical infrastructure but also pollutes the environment. Transportation of oil and gas (i.e. hazardous materials, see Douligeris et. al. 1997) has potential for adverse impact on human and environment, especially with oil storage facilities and major oil transport pipelines crossing rivers (Yapa &

Shen 1994). This has been dealt with in a number of environmental and transportation literature but apparently with more emphasis on land (e.g road, rail) and coastal/marine transportation (see Brekke & Solberg 2005, Nwilo & Badejo 2004, Twumasi & Merem 2006).

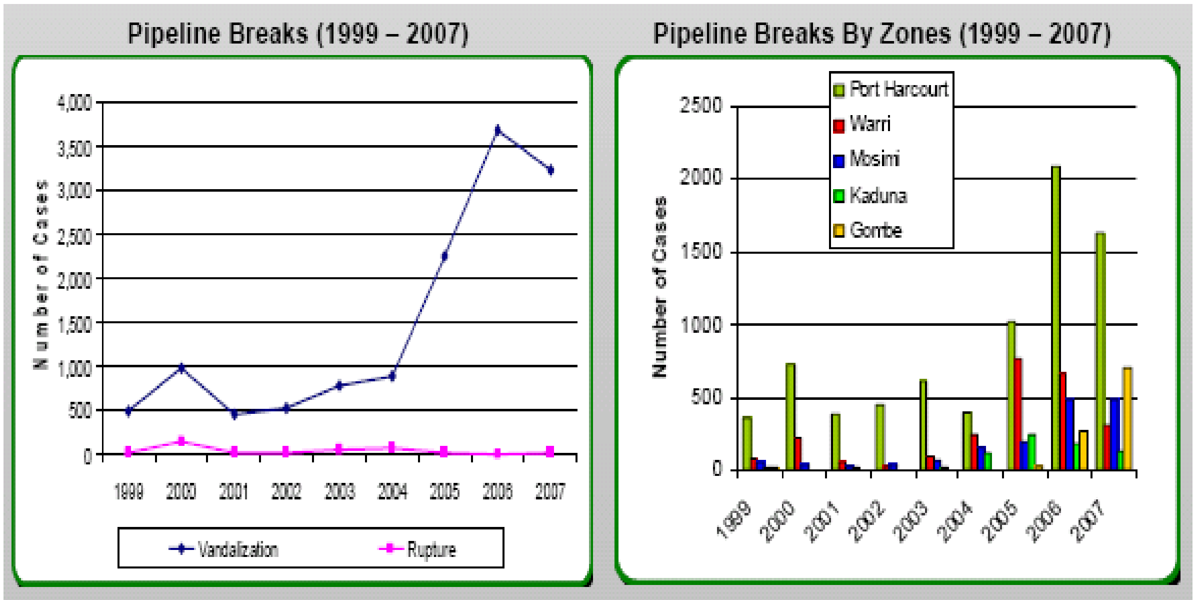

Figure 1a/b: Vandalism/interdiction trend against rupture/corrosion (1999-2007)
Source: Nigeria National Petroleum Corporation (NNPC) Statistical Bulletin 2007
NB: Decline of 11.92% over 2006 figures; 3,244 reported cases, 3,224 due to Vandalism and 20 due to wear & tear

The aim of this work is to lay the basis for an approach that will ensure more environmentally sound pipeline transport operations within an EIA framework which incorporates geospatial technology (i.e. GIS and Remote Sensing) along with integrated use of transport geography model. It also suggests a revised institutional framework to help achieve this aim.

2. Study Area

The geographic coordinates of Nigeria are approximately 4^0 10' - 13^0 50' N and 3^0 5' - 15^0 E (Fig. 2). The Niger Delta Region of Nigeria is the world's third largest wetland, with unique geographic characteristics and is regarded as the world's largest delta (NDRDMP 2006, Marquardt 2006). Oil and gas transport pose environmental challenges to Nigeria as a whole but this paper focuses mainly the Niger Delta (Fig. 2) being the mainstay of oil and gas deposits and energy infrastructure. The greatest proportion of interdiction and degradation is currently recorded in this geographic region (Fig. 1b). There are about 606 oilfields with 355 situated onshore and 251 offshore (Fig. 3a). There are four refineries, three of which are in the Niger Delta region and one in the North central region. There are seven export terminals and a number of floating production vessels. Over 7,000km of oil and gas transport pipelines aid spatial interaction between these point locations (Fig. 3b).

3. Conceptual Framework

This work is guided by two basic conceptual frameworks, i.e. Environmental Impact Assessment (EIA) or ESIA and the Transport Geography model, both of which are applicable to all existing transport modes.

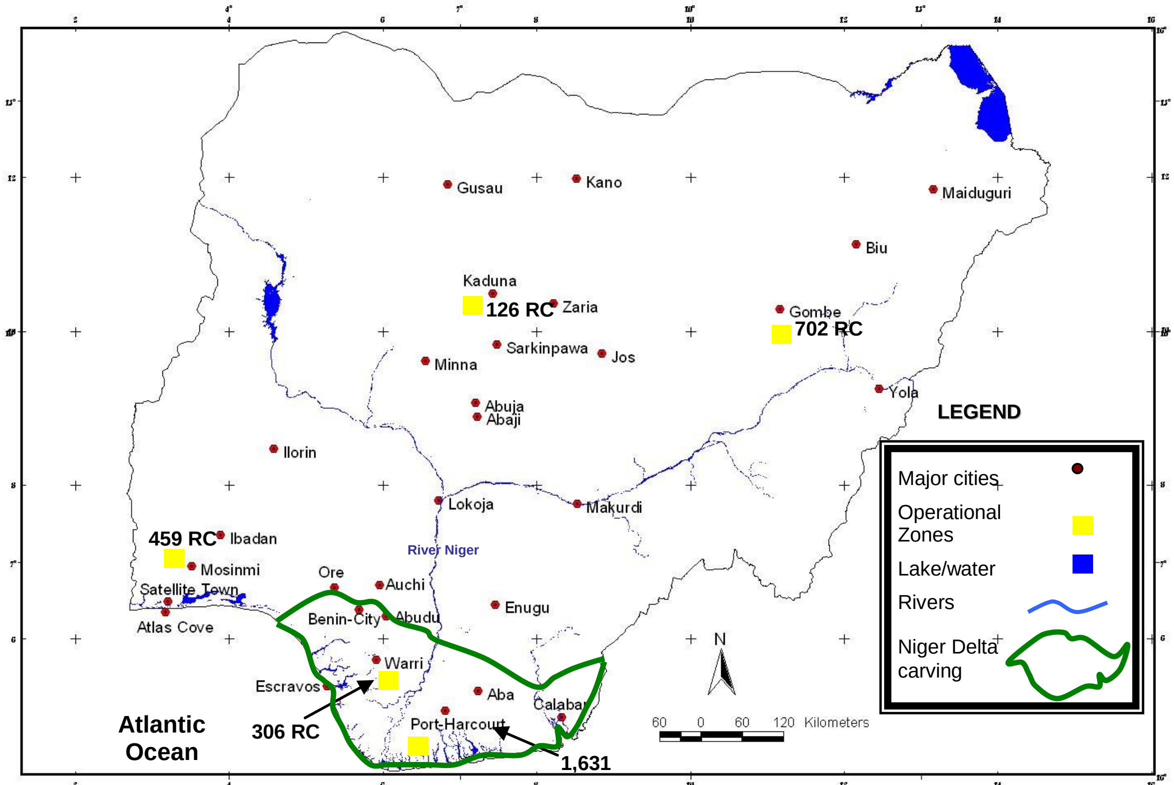

Figure 2: Nigeria showing Niger Delta, major cities & 5 Operational Zones

Source: Anifowose (2006) & NNPC (2007) NB: RC – Reported Cases of pipeline vandalism in 2007

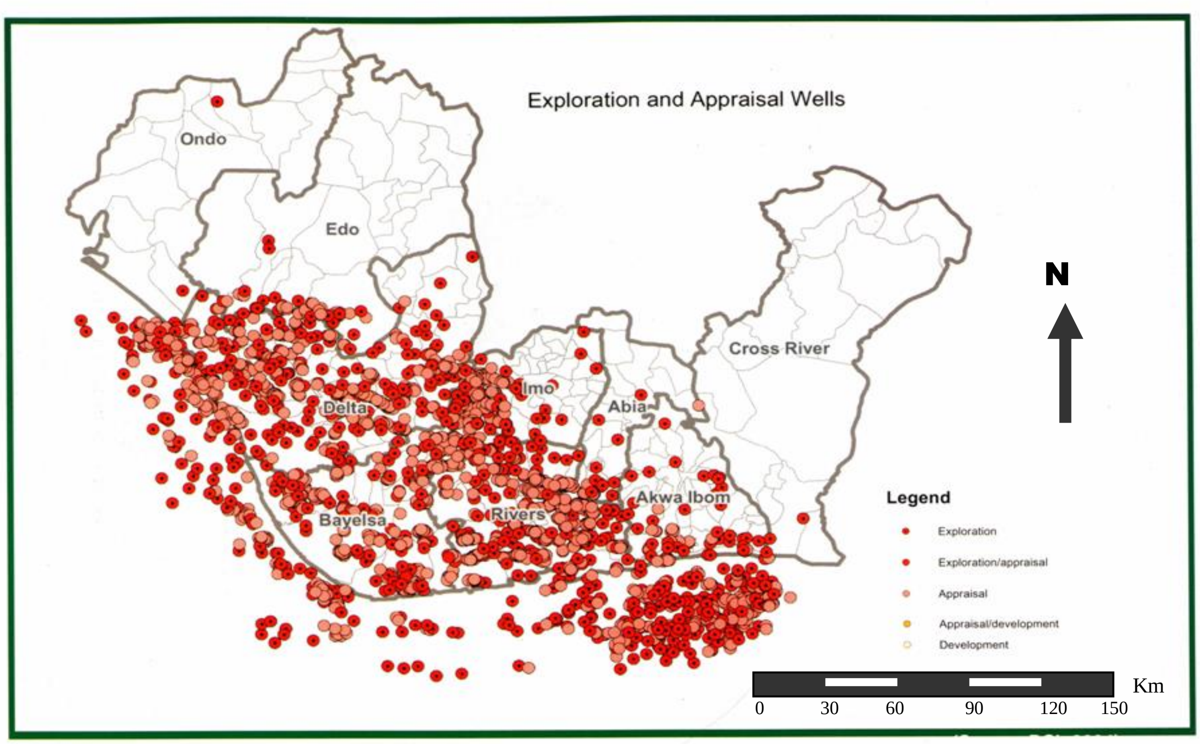

Figure 3a: Niger Delta showing the Distribution of Onshore and Offshore oilfields

Source: NDRDMP, 2006

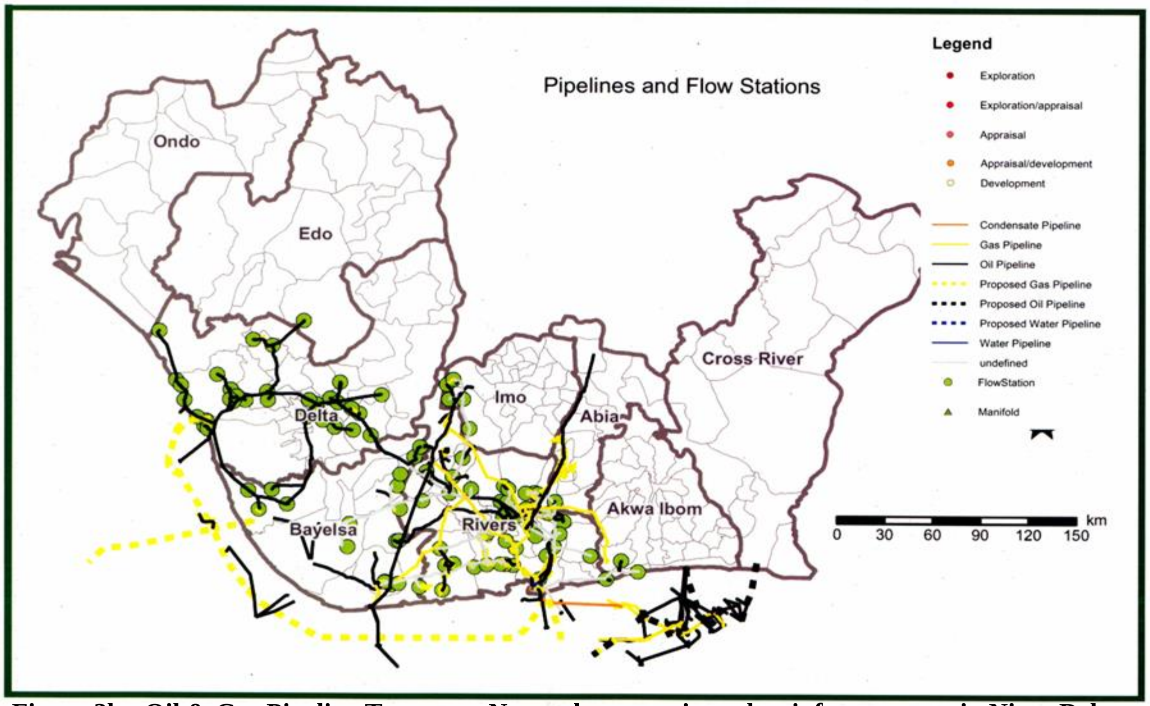

Figure 3b: Oil & Gas Pipeline Transport Network connecting other infrastructure in Niger Delta
Source: NDRDMP, 2006

3.1 Environmental Impact Assessment (EIA)

Munn (1979), defines EIA as the need "*to identify and predict the impact on the environment and on man's health and well-being of legislative proposals, policies, programmes, projects and operational procedures, and to interpret and communicate information about the impacts*" (cited in Glasson et al., 2005, p.3). EIA is an important conceptual framework within which screening, scoping of potential impacts, mitigation, alternatives, monitoring plans and other key issues that may arise from proposed project developments, policies and programmes are identified in advance. EIA for pipeline projects can be broken down into four major stages, viz: construction, hydro-testing, operation (post-project) and decommissioning phases (Lawler, 2003; Lawler et al., 1996). Worldwide, environmental monitoring in the post-project appraisal phase of EIA and concurrent programme appraisal in Strategic Environmental Assessment (SEA) is currently limited, and needs to be developed (e.g. Lawler, 2005).

Patil et al. (2002) identified two main EIA techniques: conventional and geo-spatial. The conventional EIA is where field sampling and analysis are carried out with results presented often in a cause-effect matrix pattern. Geospatial EIA techniques involves mathematical model based on spatial data derived from satellite imagery. In Nigeria, there are numerous statutory frameworks for environmental management currently in operation. Fayiga & Ofunne (2000) and Ogunba (2004) argue that this can lead to a lack of coherence. A recent review of literature shows a gap in the utilization of geospatial technology in EIAs despite its enormous potentials for spatial analysis, temporal resolution and data integration (e.g. Vanderhaegen & Muro 2005). Geospatial technology is also a ready source of environmental data. Ayeni (2006) explores the potential application of remote sensing in EIA as an accurate measurement of environmental degradation using Nigeria's earth observation satellites (i.e. NigeriaSat 1 & 2) as examples. The Disaster Monitoring Constellation (DMC) to which NigeriaSat 1 & 2 belong, is an international initiative that coordinates remote sensing responses and promotes near-real time data to assist mitigation efforts, especially in periods of natural or artificial disasters (Aplin 2005, Wooster 2007).

3.2 Transport Geography Model

Transport Geography investigates spatial interaction of people, freight (dry and wet cargo) or information. Space is however a constraint for pattern of movement including in pipelines. Rodriquez et al. (2006) theorize a framework with which to understand the factors that could impede the free and smooth flow of people and materials in space. The combination of four common interrelated concepts forms the transport geography model namely distance, accessibility, spatial interaction and land use (Fig. 4). Oil & gas resources at a particular location will remain inaccessible and of less value unless the distance (impedance) between such location and the point of consumption is bridged through transport infrastructures like pipelines, trafficable roads and tankers. This model is relevant because distance needs to be overcome for oil and gas resources to serve its purpose. Transport pipelines sabotaged or ruptured could disrupt flow; hence the need for continuous monitoring approaches to enhance oil spill response times and damage prevention.

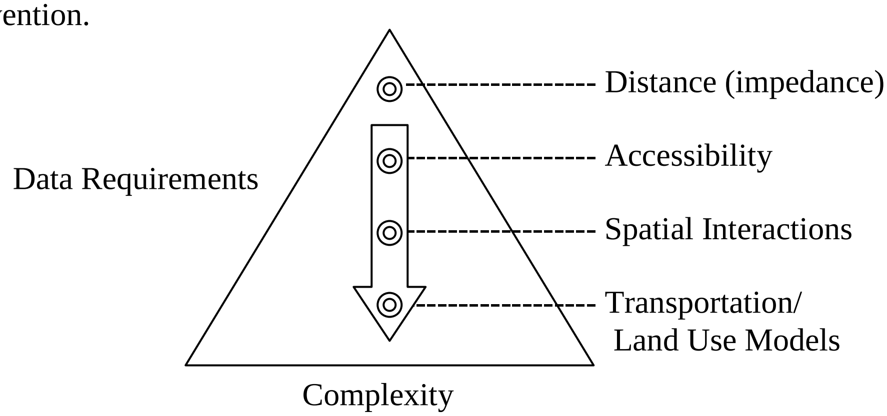

Figure 4: Transport Geography Model showing growing complexity and data requirements.
Source: after Rodrigue et. al. (2006).

Accessibility is another key element as it expresses freight (oil and gas) mobility over a given distance. An ideal transportation system (e.g. pipeline) allows effective accessibility. Hence, locations are not equal as there are varying degrees of accessibility which implies spatial disparity or inequalities (Rodrigue et al. 2006, Kanbur et al. 2006). Accessibility is further dependant on two major concepts.i.e. location and distance. Because transport infrastructures like pipelines and pump/compressor stations serve as means of movement for oil and gas, accessibility or spatial interaction between locations resulting from this inequality estimates the relativity of space in relation to these transport infrastructures. As regards distance, the key issue is connectivity between locations as this is dependent on the likelihood of linking locations through transportation (Rodrigue 2006). Distance in oil and gas transportation is likely best measured in kilometers (km) or in time and connectivity expresses friction of distance in terms of accessibility between locations.

Therefore to measure accessibility, nodes (i.e. point data) e.g. oilfields, export or consumption points and line segments or arcs (i.e. line data) e.g. pipelines, all combine to form a network connectivity logic (i.e. polygon or areal data) represented by connectivity matrix (C1) that expresses the degree of connectivity of each node with its neighbors. The quantity of rows and columns in C1 (also known as *degree of a node*) is equal to the quantity of nodes in the network Rodrigue (2006). For every cell with a connected pair, a value of 1 is assigned and for cells with unconnected pair, a value of 0 is assigned. This matrix measures accessibility and can be expressed mathematically

This paper posits that these variables as represented in the above transport geography model by Rodrigue (2006) are very important in evolving a holistic approach to addressing pipeline transport related pollution problems in the Niger Delta. Specifically, data and information on accessibility, distance, spatial interaction and landuse models are critical ingredients in analyzing risks, oil spill effects, intervention and mitigation efforts, environmental monitoring and ultimately to minimize potential damages from pipelines once they occur, either through sabotage or corrosion. An increasingly important source of these data is derived from geospatial technology capabilities and this potential is yet to be fully tapped especially in EIA post-project appraisal.

4. Key Environmental Variables

Water and air are key environmental variables susceptible to degradation from due to oil and gas exploration activities.

4.1 Water Resources

Water is usually an important theme in most EIAs, and Lawler (2003) proposed Water Impact Assessment within EIA for oil and gas pipelines in order to better monitor and protect water resources from contamination. Rivers, for example, are a key environmental receptor for pollutants in the Niger Delta. There is an urgent need to preserve and protect the Niger River basin, as numerous ecological, economic and social processes are heavily dependent on this water resource. As pointed out by WHYCOS (2006), data on discharge changes and physiochemical parameters at different locations across the length of the Niger river are important. The ever fluctuating flow regimes and the trans-boundary nature of river Niger makes environmental research of key relevance among the member countries. River flow level, discharge and velocity at the time of oil spillage is a key driver of the *impact* of the spill and Lawler (2005) demonstrated the typical magnitude of river flow changes and argued that it is vital to fully quantify river flow temporal and spatial variability within ESIAs, especially in baseline surveys, impact analysis and oil spill response plans. Oil and gas companies in the Niger Delta region have recently been named as major beneficiaries of current sub-regional/international collaborative efforts on a SHARED VISION of the framework for implementation of the Niger River basin Hydrological Observing System designated Niger-HYCOS being supervised by the World Meteorological Organization (WMO). The nine member countries of the Niger-HYCOS which forms the active basin of river Niger have a ‘shared vision’ to jointly manage the resources of the basin. Nigeria is a member and local water resources are managed by eighteen River Basin Development Authorities (RBDA) as parastatals under the Federal Ministry of Water Resources, spread across the six geopolitical zones (Orubu 2006, Akpabio 2007).

4.2 Air quality

It may be possible to address air quality problem in the Niger Delta if a transport-based Gas Development Masterplan is implemented such that it covers pipelines, liquefied natural gas (LNG), gas to liquids (GtL), gas to commodity (GtC), gas to wire (GtW), i.e. generate electricity at the producing field and transport the electricity, by cable, compressed natural gas (CNG), and gas to solids (GtS), i.e. hydrates. See Fig. 5. Hopefully with such plan, gas flaring may gradually become eased-out as more value is likely to be derived from Nigeria’s gas resources. However, current efforts by Federal Government in developing gas resources are laudable and hold great potential for the long clamored environmental sustainability, increased revenue, job opportunities and industrial growth. Niger Delta people should be involved through public-private partnership.

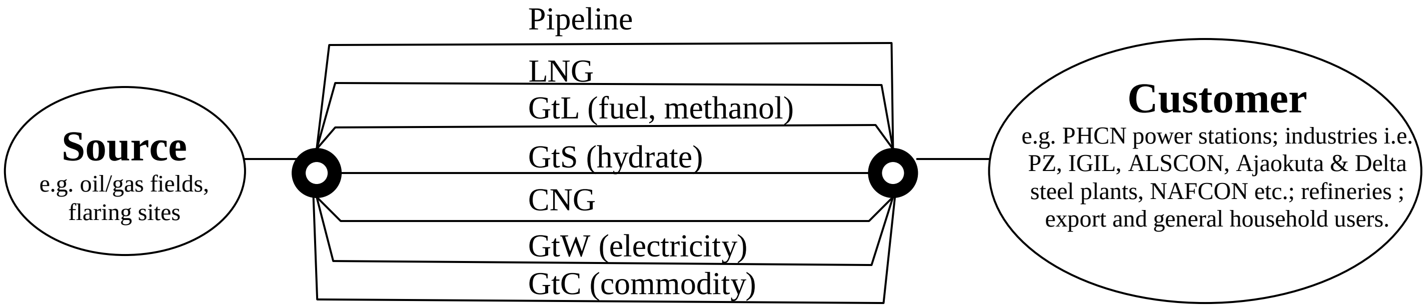

Figure 5: Gas Transport Options
Source: after Thomas S., & Dawe R.A., 2003

5. Recommendations for future research/practice

This section focuses on two key approaches to help reduce environmental damage associated with oil and gas transport in the Niger delta.

5.1 Enhanced EIA methodology and practice

Figure 6 provides a conceptual framework with which to modify existing EIA/ESIA procedures. The EIA process (Glasson et al., 2005) is being redesigned to incorporate geospatial approach at each stage. A geospatial (e.g. RS/GIS) approach is capable of integrating numerous datasets (spatial, attribute, discrete, continuous and temporal) typical of EIAs, co-register (overlay) many diverse datasets, analyze and present results in accessible ways. One major shortcoming of the conventional EIA approach is the subjectivity of impact assessment by individual methods adopted – e.g. Erikstad et al (2008), Kuitunen et al. (2008). Unlike the generic process (see Glasson et al., 2005) which suggests public participation at the first three stages, this enhanced geospatial EIA procedure attempts to involve the grassroots and affected parties through public consultation and participation at all stages of the process. This should result in decisions which are more socially acceptable. Of more relevance to the study area is the final stage of the process which entails the use of satellite data in post-project appraisal phase of EIA. In post-project appraisal, high resolution satellite imagery has the capability to provide unique levels of accuracy at spatial, spectral and temporal dimensions to enable automated change detection that will improve detection of oil spillages or unauthorized intrusion, as found by Roper & Dutta (2006) along pipeline routes.

Some identified impediments to this proposed approach include availability of financial resources to setup the process, software and hardware needs, system maintenance and technical know-how, perception of EIA/ESIA as mere bureaucratic delay in some quarters, human resources and training needs, database management and the political will. All these can be overcome by targeted policy change, dedicated budgetary allocation, enforcement, orientation, enlightenment and training of key stakeholders.

5.2 Changes to institutional frameworks

Major transport modes include road, air, water, rail, pipeline and pedestrian walkways (Chapman 2007). The two conceptual frameworks above are applicable to all of these transport modes. Unfortunately, current systems in Nigeria do not seem to practically recognize pipeline as one of the modes of transportation yet, especially in government infrastructure planning, management and maintenance. Rather, these are left to individual oil and gas companies and the state owned NNPC managed by the Petroleum Pipeline Marketing Company (PPMC). This makes it difficult for the Ministry in charge of transportation matters to effectively address issues emanating from pipeline transport networks. A more integrated solution would be preferable to optimize

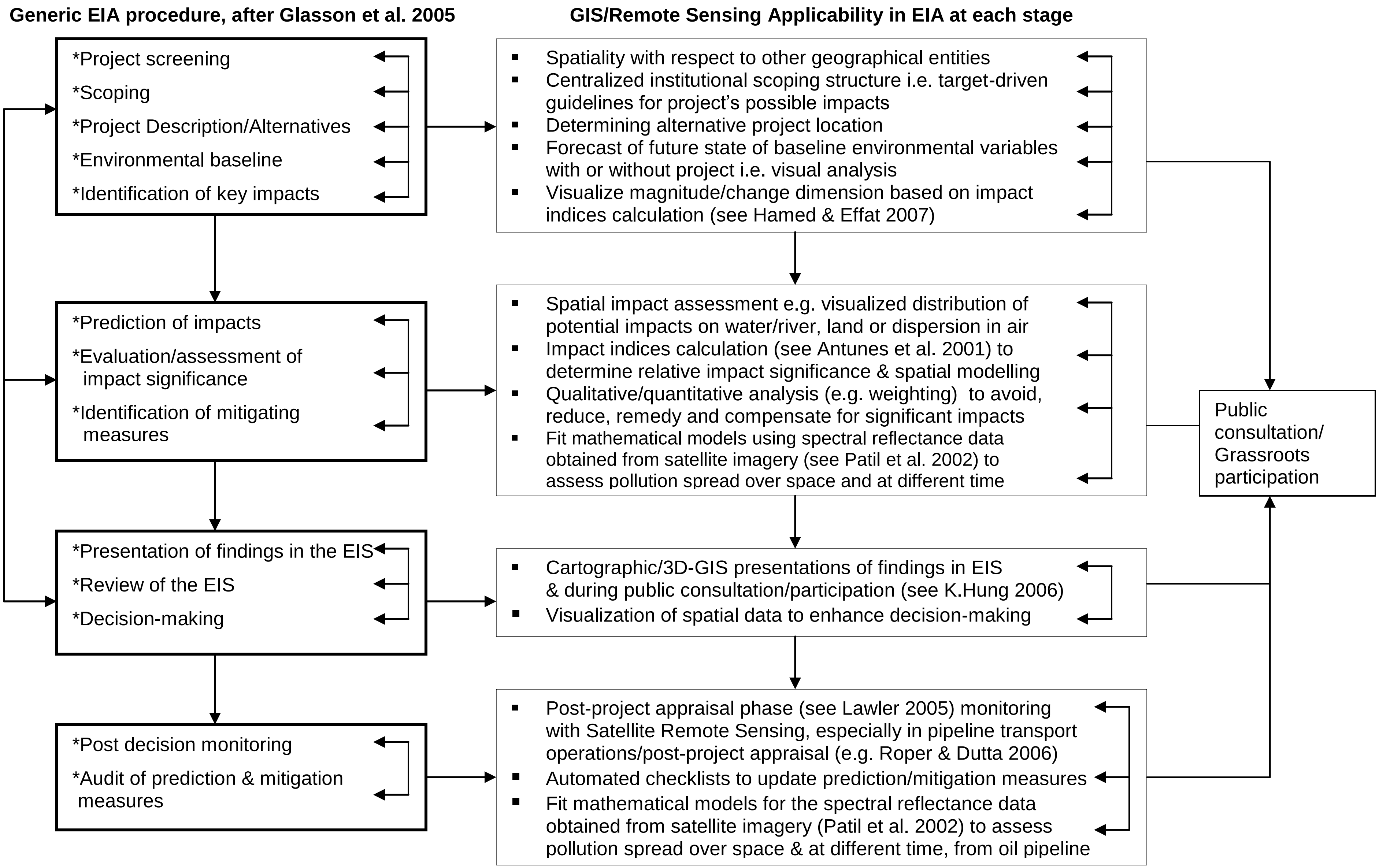

Figure 6: Schematic view of proposed EIA methodology & procedure

environmental protection, resource sustainability, effective coordination and safety concerns and help manage oil spill incidents using the integrated enhanced geospatial EIA approach and the transport geography model. This supposedly may be a better option rather than solitary efforts by individual companies or group of companies.

A case study for best practice is seen in the United States, where the US Department of Transportation (US DOT) - Pipeline & Hazardous Materials Safety Administration (PHMSA) through the Office of Pipeline Safety (OPS) statutorily ensures safe, reliable, and environmentally sound operation of pipeline transport systems all over the USA. The US DOT is the equivalent of Nigeria's Federal Ministry of Transportation; and hazardous materials in this context refer to oil and gas. US DOT PHMSA in collaboration with Transportation Research Board (TRB) through the National Academy of Science develops research needs statements to find solution to problems emanating from gasoline transportation across the USA. The TRB has a standing committee on Transportation of Hazardous Materials (i.e. oil and gas) for this purpose.

The US DOT-PHMSA is working with various stakeholders to develop a reasonably accurate national database of oil and gas pipelines and associated facilities (Roper & Dutta 2006). This collaborative work is to evolve a National Pipeline Mapping System (NPMS), a full-featured Geographic Information System database to contain location, attributes of oil and gas pipelines and onshore/offshore operating facilities in the USA (Roper & Dutta 2006). This is coupled to statutory obligation to ensure safe, reliable and environmentally sound pipeline system. Nigeria could learn from these experiences, develop and integrate its spatial databases, and evolve its institutional frameworks to maximize resource, environmental and social protection.

6. Conclusions

In summary, this paper suggests that:

- A.) The basis for an enhanced EIA methodology in Figure 6 be developed, and then considered by relevant government bodies and stakeholders (including RBDAs);
- B.) The Federal Ministry of Transportation (FMT) and stakeholders explore the advantages of FMT serving as a coordinating body for pipeline transport operations in Nigeria;
- C.) A comprehensive digital database of all pipeline networks and environmental receptors be assembled to enhance mitigation efforts and response operations;
- D.) Government is hereby further encouraged to embrace a transport-based gas utilization framework (Fig. 5*)* and involve mainly unemployed Niger Delta youth/militants preferably through public-private partnership (PPP) arrangement. This will hopefully form part of ongoing efforts to stem restiness in the region.

This paper attempts to lay the foundations of an approach to help manage and mitigate the environmental challenges posed by oil and gas transportation in the Niger Delta region of Nigeria. This approach is characterized by the incorporation of the transport geography model and the enhanced geospatial EIA methodology. These two concepts have one thing in common and that is spatial data. However, distance, accessibility, spatial interaction and Landuse are all critical elements in environmental resource management when planning transport pipeline EIAs. Therefore, transport within geographic boundaries, risk assessment, appropriate technology to enhance intervention and mitigation efforts, minimizing potential damage once occurred and the control of spatial interdiction can be effectively addressed by these two concepts.

There is the urgent need to establish an institutional framework or re-work an existing relevant body e.g. National Oil Spill Detection and Response Agency (NOSDRA) to incorporate these key suggestions into their operations. Nigerian authorities could examine the model provided by US DOT best practices (Roper & Dutta 2006), and adapt this to the country's needs and capabilities. This will require working with all stakeholders, oil companies, PPMC, ministries and parastatals in developing a robust spatial database of all existing pipeline networks and related oil and gas facilities across the country. A ready structure to achieve this is the recently launched National Geospatial Data Infrastructure (NGDI) which incorporates National Geographic Information Systems and allows for data sharing through independent and distributed data sources. The NGDI is currently managed by National Space research and Development Agency (NARSDA) to provide access to and utilize geographic data for comprehensive analysis to assist decision-makers. This would be an effective way to utilize current government investments in satellite data infrastructure and enhance environmental management especially in the oil and gas sector.

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