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A systematic quality assessment of Environmental Impact Statements in the oil & gas industry

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Abstract

The global economy relies heavily on oil and gas resources. However, hydrocarbon exploitation projects tend to cause significant impacts on the environment. But despite numerous Environmental Impact Statements (EISs) to identify/mitigate such impacts, no study has specifically assessed the quality of EISs for both onshore and offshore oil and gas projects to evaluate strengths and weaknesses which can be disseminated to encourage and share best practices. To address this research gap, this paper develops a modified Lee and Colley evaluation model to assess the quality of 19 sampled oil and gas project EISs produced (1998-2008) in Nigeria. Our findings show that project description and communication of results are the main areas of strength. However, Mann-Whitney tests suggest that there is no evidence that the quality of EISs for the latter period (2004-2008) is higher than that of the earlier period (1998-2004). Environmental impact prediction and decommissioning were among the key areas requiring enhanced attention. We suggest that periodic systematic review of the quality of submitted/approved EISs (c. every 3-5 years) should be established to monitor EIS quality trend. This would enhance continual improvement in both the EIA processes and the resultant EISs of technical engineering projects. Such reviews have the potential to illuminate some of the underlying problems of, and solutions to, oil and gas exploration, production and transportation related environmental impacts. This suggested change would be useful internationally, particularly for the burgeoning unconventional exploration and production of resources.

Keywords: Oil and gas projects; Project decommissioning; Environmental Impact Assessment (EIA); Environmental Impact Statement (EIS); Lee and Colley review model; environmental impacts; Nigeria.

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1. Introduction

1.1 Importance of the Problem

Much of the world economy is underpinned by the international oil and gas industry which is moving into a new phase of unconventional resources and competition from renewables (e.g. see Torres et al., 2016; Moustafa, 2016). However, environmental impacts of oil and gas activities on air, water, soil and ecosystems have been well documented (e.g. Lawler, 2005; Skierszkan et al., 2013; Anifowose and Odubela, 2015; Barcelo and Bennett, 2016; Landis et al., 2016).

On the international scene, Lawler (2005) found that poorly defined environmental changes, relevance and data quality issues were the major problems facing water resource management in oil-rich Azerbaijan and Georgia. A study of contaminants from Canada’s Alberta heavy oil revealed some metal (i.e. arsenic, cadmium, nickel, vanadium) enrichment in soil samples within 20 km of oil facilities in the Cold Lake area (Skierszkan et al., 2013). In the US state of Colorado where active shale wells as of March 2015 are about 53,288, it is estimated that a minimum of 500 million m^3 of water is required for hydraulic fracturing; and in 2013, up to 600 spills of produced water chemicals were reported (Barcelo and Bennett, 2016). Though, health impacts studies linking environmental health hazards with shale gas activities lack methodological rigour (Werner et al., 2015). New data have suggested that macroinvertebrate communities in north-central Arkansas are impacted by different levels of gas activity thereby prioritising the need for quantitative analyses of cumulative freshwater-impacts from oil and gas projects (Johnson et al., 2015). In Cyprus, a study on liquefied natural gas (LNG) and pipeline network found key environmental impacts to include the release of particulate matter, odour/smell, noise and declining soil conditions as well as job opportunities (Papadopoulou and Antoniou, 2014).

In Nigeria, the case study country for this paper, an examination of 200 locations, 122km of pipelines and heath records of 5,000 community members found significant environmental and health impacts following inadequate maintenance and decommissioning of oil and gas facilities in Ogoniland (UNEP, 2011). Giwa et al., (2014) report that communities adjacent to gas flaring sites in Nigeria often utilise the heat generated from the flare to dry farm produce and cloths; and to roast fish and maize. This increases the exposure of local people to noxious gases and other by-products emitted through the flaring processes which can result in environmental impacts and health problems including asthma, cancer, blood disorder and bronchitis, amongst others (see Davoudi et al., 2013). Nigeria has a long history of oil exploitation, spillage and pollution, particularly in the Niger Delta (UNDP, 2006; UNEP, 2011; Webb, 2011; Anifowose et al., 2012a). In addition, human injury and fatalities resulting from pipeline incidents are common here (e.g. Onuoha, 2007; Jasper, 2009; Aroh et al., 2010; Anifowose et al., 2012a). Ma'anit (2011) and Webb (2011) estimated that 9-13 million barrels of oil were spilt in the Niger Delta over the past 50 years (equivalent to one Exxon Valdez oil spill every year).

Environmental Impact Assessment (EIA) is a proactive methodical process that investigates and predicts the potential direct, indirect and cumulative impacts of proposed project activities on environmental receptors, ideally from project initiation to decommissioning, and offers mitigation strategies. Produced as part of an EIA process, the Environmental Impact Statement (EIS) is a key document for reporting anticipated impacts of oil and gas projects, their mitigation and management plans. In most countries, the EIA process is part of the project permit or project approval procedure stipulated by the relevant authorities. Financial institutions like the World Bank, European Bank for Reconstruction and Development and the International Finance Corporation also require the submission of a detailed EIS as part of environmental due diligence for project financing (e.g. Lawler and Milner, 2005).

Over the years, significant awareness of environmentally sound processes and sustainable development have been promoted by EIA practice in large-scale infrastructural projects (Gilbuena et al., 2013; Cesar et al., 2014). However, EIS appraisal studies show that quality is not always satisfactory (e.g. European Commission, 2009). Lawrence (1997) and Cashmore (2004) found that EIA practice has evolved without coherent conceptual theoretical and methodological foundation. Backlund (2009) stated that the quality of impact assessments in the EU suffered from applications of overly simple methodologies, and incomplete assessment of environmental impacts. Eilperin (2010) and the National Commission (2011) found that major oil and gas projects (e.g. BP’s Macondo well drilling) were exempted from environmental impact analysis.

The effectiveness of the EIA system can be evaluated against the quality of EISs (Heinma and Poder, 2010), and/or regulatory compliance, adequacy of information and methodology, presentation of information and communication, objectivity, fairness and transparency (HMSO, 1996; Glasson et al., 1997; EC, 2001). A systematic quality review of EISs involves the sampling and methodical evaluation of several approved project EIS documents, using a set of review criteria (see section 2.1). Such quality reviews are common in non-oil and gas project sectors such as road construction, power and dam installations, mining activities and green-field developments. Performance review of EISs can help to strengthen quality control within EIA systems (e.g. Lee and Colley, 1992; UNEP, 2002; European Commission, 2009) especially when evidence-based methods are used (Backlund, 2009). There is a strong link between EIA process and EIS quality (Zhang et al., 2013).

Therefore, if the full strengths of EIA processes are to be realised, we suggest here that critical independent periodic reviews of the quality of EIA report (i.e. EIS) samples are essential. This should identify strengths and weaknesses which can be disseminated to encourage and share best practices in oil and gas developments. However, such reviews for the oil and gas industry are still rare today.

1.2 Research Gap

Several EIS quality review studies have been reported for non-oil and gas project sectors (see Table 1). Following periodic EIS quality review (at country or sector-level), a common feature of these studies is the hypothesis that project EISs tend to show improvement in quality over time.

However, the only known evaluation of EIS quality for oil and gas projects is the useful study of Barker and Jones (2013), commissioned by the then UK Department for Business Enterprise and Regulatory Reforms (DBERR). This focused solely on UK *offshore* petroleum production. Based on literature search from publicly accessible databases, our study here is believed to be only the second study which focuses on EIS quality for the oil and gas sector, and the only study anywhere which includes both onshore and offshore projects. In addition, none of the above cited studies in Table 1 apparently utilised inferential statistical analysis to evaluate their suggested EIS quality improvement. Hence, our study presented here.

1.3 Study Aims and Objectives

This paper has three unique aims. First, we address this international research gap by presenting a systematic analysis of the quality of EISs for both onshore and offshore oil and gas projects. Second, to our knowledge, this is the first assessment of its kind to examine the effectiveness with which decommissioning impacts are assessed within EISs of both oil and gas projects. Third, and again novel to our knowledge, this paper tests the hypothesis that EIS quality of onshore and offshore oil and gas projects improves over time by using the 1998 to 2008 era (Table 2).

The study objectives are to:

a. Develop an EIS quality review model for oil and gas projects, based partly on a review of methodologies adopted in previous studies of EIS quality review (see Table 3);

b. Apply this model to assess the quality of 19 EISs produced between 1998 and 2008 covering *both* onshore and offshore projects (Table 2);

c. Test the hypothesis that EIS quality for hydrocarbon projects in Nigeria has improved over the 1998-2008 period; and

d. Make recommendations for future EIA practice in the Nigerian oil and gas industry, and in similar international contexts.

1.4 Environmental Regulation in the Nigerian Oil and Gas Industry

1.4.1 EIA Governance Structure

The evolution of EIA policy, practice and environmental awareness in Nigeria is closely tied to the oil and gas industry (Olokesusi, 1998; Ogunba, 2004). Understandably, when commercial oil and gas exploration began in the 1950s (Steyn, 2009), only simple environmental protection protocols and policies existed (Anifowose et al., 2014). To date, there are two main EIA governance structures in Nigeria's oil and gas industry; and we summarise below their evolution.

First, the inadequacies of reactive environmental control measures (e.g. the Petroleum Act of 1969), and the need for Nigeria to progress towards sustainable environmental practices, led to the establishment of the Federal Environmental Protection Agency (FEPA) by Decree 58 of 1988. FEPA had responsibility for the overall protection and sustainable use of Nigeria's environmental resources until its functions were transferred to the newly created Federal Ministry of Environment (FME) in 1999. Afterwards, FEPA ceased to exist and the FME was further empowered to formulate and review the National Policy on the Environment. Meanwhile, Nigeria's EIA decree 86 was enacted in 1992 and it mostly mirrors the US NEPA Act of 1969.

Second, the Petroleum Act of 1969 is the major regulatory framework in Nigeria that empowers the Department of Petroleum Resources (DPR) – a parastatal of the Federal Ministry of Petroleum Resources – as the responsible agency for environmental protection and pollution management in the oil and gas industry. The DPR also possesses the statutory responsibility for ensuring 'compliance to petroleum laws, regulations and guidelines' including those relating to health, safety and environment in conformity with national and international standards.

EIA consultants / preparers are often registered by both the DPR and FME. Any oil company or proponent seeking to undertake large scale project(s) in Nigeria's oil and gas industry has to seek EIA permit or approval from both the FME and DPR. This is in line with extant regulations such as the EIA decree 86 of 1992 and the Petroleum Act of 1969. This requirement appears to have inadvertently contributed to the widely reported frictions in environmental regulatory duties in Nigeria's oil and gas industry. For example, these two agencies, though set up for a common goal, have been adjudged duplicative, overlapping and at times conflicting in their responsibilities (Olokesusi, 1998; Ogunba, 2004). However, in theory this double review could make for a more robust process since both agencies are expected to approve or disapprove projects based on the quality of EISs. Multijurisdictional approaches are not limited to Nigeria. For example in Canada both Federal and Provincial authorities have legislated EIA requirements which subject projects to multiple EIA processes (Leboeuf et al., 2010).

1.4.2 Other Regulatory Instruments

Apart from the EIA decree 86 of 1992 and the Petroleum Act of 1969, there are about 16 other regulatory controls that support EIA practice in Nigeria's oil and gas industry (see Agha et al., 2002). The major instruments are operated as follow:

1. *Federal Ministry of Environment (FME*): The sectoral Guidelines for Oil and Gas Industry Projects (FEPA, 1995). These outline approaches for conducting EIAs in compliance with the requirements of the Nigerian EIA Decree 86 of 1992 which commits Nigeria to international best practices (Ameyan, 2008).
2. *Department of Petroleum Resources (DPR):* The Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN, 2002). Between 2000 and 2002, the DPR upgraded its EIA process to allow a systematic integration with project engineering

design and continuous monitoring of especially the implementation of designed mitigation (Agha et al., 2002).

3. The States and the Local Government Authorities are encouraged by the amended FEPA decree 59 of 1992 to establish environmental protection bodies. This has further complicated the EIA process, leading to State Environmental Protection Agencies (SEPAs) seeking to be involved at key EIA stages rather than just at the final review stage.

Indeed, Eneh (2011) has reported rivalries and jealousies at different levels of government while Emeseh (2012) found that conflict exists amongst federal and state parastatals over unclear jurisdiction on oil activities.

There are different versions of the Petroleum Industry Bill (PIB) and it is currently being replaced by the Petroleum Industry Governance Bill 2016 which passed its first reading in Nigeria’s national assembly in April. The PIB sought to establish for the oil and gas industry a comprehensive legal framework which includes the protection of health, safety and environment (PIB, 2012).

To improve the enforcement of environmental regulations in Nigeria, an Act establishing the National Environmental Standards and Regulations Enforcement Agency (NESREA) was signed into law in 2007. Sections 7(g), (h), (j), (k), (l) and 8 (k), (l), (m), (n), (s) clearly exclude oil and gas from the purview of the Act but section 7(c) appears to have a contrary view. The removal of the phrase ‘oil and gas’ from section 7(c) has been advocated by many (e.g. Ladan, 2012) as it appears to have been added in error.

2. Materials and Methods

2.1 Adaptation of the EIS quality review model

Past EIS quality review studies evaluated key performance criteria such as the completeness of information contained in each EIS; compliance with local, national and international standards; veracity and acceptability of approach(es) to impact analyses; and assessment of alternative options amongst others. In the past 20 years, these performance criteria have evolved as major yardsticks for grading the quality of EISs and the most widely used model criteria are Lee and Colley (Lee et al., 1999); the European Commission checklist (EC, 2001); and the IAU Oxford Brookes (HMSO, 1996). More details about these can be found in Table 3. We modelled our study on the Lee et al. (1999) framework because it is comprehensive, robust and widely used (see Table 1). To help adapt the Lee et al. (1999) model, we:

(a) assessed the methods and structure of oil and gas project EISs housed at the European Bank for Reconstruction and Development (EBRD) in London;

(b) ran a pilot application of the Lee et al. (1999) model on three representative Nigerian EISs and reviewed the results;

(c) adapted and enhanced the Review Areas, Categories and Sub-Categories, including adding a new Review Area (RA) on ‘Decommissioning/abandonment’ (Fig. 1, Table 4) as informed by the pilot run. This addition to the EIS quality review model is important given the environmental problems following the abandonment of oil facilities in Ogoniland Nigeria (UNEP, 2011), and also because international best practices for oil and gas project EIAs now include decommissioning (see FEPA, 1995; World Bank, 1999; DPR, 2002; Lawler, 2003; 2005; Ekins et al., 2006). Rising environmental standards make decommissioning a major challenge for oil companies (Strutt et al., 2006; Boothroyd et al., 2016).

(d) reconciled the model with the basic requirements of Nigerian policy frameworks including the two main national environmental regulatory instruments guiding the oil and gas industry (section 1.4); and,

(e) informed the model from international best practices, including HMSO (1996), Glasson et al. (1997), and World Bank Environmental Assessment Sourcebook (1999) for Energy and Industry Projects.

A summary of all modifications to the Lee et al. (1999) model is provided in Table 5.

2.2 EIS submissions and sample selection

Before EGASPIN in 1991, there were fewer than ten environmental study reports in the Nigerian oil and gas industry, including two pre-project EIAs and five post-impact assessment reports (Agha et al., 2002). However, between 1990 and 2001 about 130 EIA studies/EISs were recorded for the upstream sector alone as shown in Agha et al. (2002). During a field visit to Nigeria in April 2009, 19 EISs (~150-300 pages each) were selected: 14 through customized stratified random sampling from an EIA repository, and five directly from some Energy companies. The customised stratified random sampling was done by picking EISs from the four directions of the repository. The EISs were not arranged or listed in any specified order therefore a gauged top, middle and lower strata were identified. Then simple random samples were taken from each stratum at the top, middle and lower piles.

Though there is hardly any oil or gas field development project without pipelines built into it, the customised stratified sampling approach ensured that the final sample contained pipeline projects and others alike. This approach took advantage of *a priori* knowledge of data access situation including how the EISs were emplaced, thereby improving the efficiency of the sampling design (e.g. see Claggett et al. 2010, p.338-9). Under such situation, a simple random sampling or any other sampling technique was not considered as useful as this customised stratified approach. Seawright and Gerring (2008) stated that choosing small sample in a completely random manner without prior stratification can lead to serious problems.

This sample represents approximately 9% of the estimated total submission at that time, and each sampled Project EIS is listed in Table 2. The depth and richness offered by this single-unit research design combined with the comparability of the 19 cases provide some useful trade-off regarding the limited representativeness of the study (Gerring, 2004). However, it is widely recognised that a truly representative case is difficult to identify (Seawright and Gerring, 2008). Nevertheless, large scale research with higher sample sacrifices depth for reliability (Gorard, 2006).

2.3 Applying the adapted Lee et al. (1999) model

We followed the 'advice for reviewers' in Lee et al. (1999, p.31) which contain the recommended systematic steps in the review process. The expanded version of the model is shown in Fig. 1. Figure 2 provides a schema of the process followed in applying the revised model to the 19 EISs listed in Table 2. The scoring of each EIS is based on how the criteria in Table 4 are adhered to or performed; and this scoring follows a similar approach used in the evaluation of design and safety engineering documents (e.g. see Strutt et al., 2006). The grading and scoring criteria used here are given in Table 6 and follow a similar principle to the tiered-classification (e.g. Excellent to Very Poor) reported in Boriani et al., (2010). The scoring approach is, no doubt, constrained by ontological and epistemological underpinning typical of many research studies. Table 6 explains the justification for the allocation of grades to EIS components or tasks. The enhanced result collation sheet (supplementary_folder_1) contains a translation script of the numerical equivalents to the grading symbols (A to F) (Table 6).

Typically, a 'satisfactory' EIS is awarded a grade of A, B or C depending on the extent to which the performance criteria (Table 4) have been met. For example, an EIS can be deemed 'satisfactory' if it clearly addresses the points below, amongst other things:

- evident prediction of impacts as deviation from baseline condition
- states confidence limits and uncertainties in data, and demonstrates quality control and quality assurance – these are rarely done in EISs

- provides clear evaluation criteria, technical and environmental justification for project alternatives
- balanced view e.g. considering not just negative impacts but also the positive ones and vice versa
- adherence to extant policy requirements (section 1.4) in the oil and gas industry; and application of international standards like the ISO 14000 series and World Bank Assessment Sourcebook for Energy Projects
- rigorous analyses and quantitative impact modelling (e.g. oil spill trajectory simulation and hydrodynamic modelling, sediment plume dispersion modelling, pipeline leak modelling using historical data) where necessary – less often done in EISs
- anticipates the level of success for the proffered mitigation measures
- field data collection, where relevant, adequately covers seasonal and inter-annual variability.

On the other hand, an ‘unsatisfactory’ EIS is awarded a grade of D, E or F depending on the extent to which the performance criteria have not been met. For example, an EIS can be deemed ‘unsatisfactory’ if it has some or all of the following, amongst others:

- lack of evidence to suggest that impacts have been defined as deviation from baseline condition;
- little or no indication of confidence limits, uncertainties or data gaps;
- the absence of quantitative modelling where this would have been beneficial;

- application of simple/basic impact prediction methods where more advanced methods would be most appropriate;
- none declaration of residual impacts;
- lack of justification for any unmitigated impacts;
- limited adherence to laid down policies and protocols on key project aspects such as decommissioning;

Strict privacy restrictions on access to these confidential EISs in this developing nation meant that only one reviewer could be used in this study. However, similar ‘one-reviewer’ approaches have been used widely and successfully e.g. Guilanpour and Sheate (1997), Gray and Edward-Jones (2003), and part of Peterson (2010). In common with usual practice, six (~32%) of the 19 EISs were re-reviewed four weeks after their initial review (Fig. 2). Re-reviews of EISs generally show repeatable results (e.g. Guilanpour and Sheate, 1997). For the occasional difference in grades here, EISs were re-reviewed once more to produce a final grade.

The Lee et al. (1999) model, as shown in Fig. 1, is hierarchical and consists of Review Areas (RAs), Review Categories (RCs) and Review Sub-Categories (RSCs). The quality assessment of RSCs determines the grading of RCs and RCs in turn determine the grading of the RAs. The five RAs represent the major areas of EIA activities considered necessary for oil and gas projects while the RCs are categories of activities that must be accomplished under each RA. The RSCs are the detailed basic level tasks that must be accomplished within each RC. Details of RAs, RCs and RSCs are in Table 4.

Assessment of these hierarchical topics and the overall EIS scores are then recorded using the revised score sheet shown in supplementary_folder_1.

2.4 Testing the hypothesis of EIS quality improvement over time

A Mann-Whitney *U* test at $p = 0.05$ was used to test the hypothesis that EIS quality has improved over time, based on the samples in Table 2. To do this, we compared the earlier half of the sampled EISs (1998-2004: n = 10) with the later half (2004-2008: n = 9). The difference in quality between the two periods was measured by the number of EISs which achieved at least 'satisfactory' grades in the EIS overall, and in all individual Review Areas. Apart from the 14 EISs selected through customised stratified sampling, the five EISs retrieved from other sources (section 2.2) are not expected to significantly influence the statistical analysis here. Normally, the probabilities generated from statistical tests are estimates and the alpha (α) level (e.g. 0.05) for retaining or rejecting a null hypothesis has no mathematical or empirical relevance (Gorard, 2006). Effectively, statistical analyses rely on personal judgement in a way not different from qualitative data analysis. According to Field (2009), an attempt to understand the representativeness of a given sample and how much variability there is between sample means requires approximations of the standard error. This is because, in reality, collecting hundreds or thousands of samples to construct a sampling distribution is only better imagined. More so, the basis of inference in randomisation models is the random assignment of cases to groups (e.g. lower, middle and upper), hence random sampling from certain population with specified distribution is not necessary (Ernst, 2004). Therefore, inferences should be limited to the cases in the study. It is impossible to completely eliminate errors and bias in conducting research (Gorard, 2006; Field, 2009) and in rare occasions where errors are known, calculating their precise impact is often not feasible (Gorard, 2006).

3. Results

3.1 Overall Assessment for the Environmental Impact Statements

A key finding is that almost half (47%) of the 19 sampled EISs for the Nigerian oil and gas industry were rated as unsatisfactory in quality (i.e. grades D to F) (Fig. 3A). About three-quarters of the unsatisfactory EISs were graded D and the rest graded E. Ten EISs were satisfactory (i.e. grades A to C). Just 26% of these were graded 'Very Good' (all rated as B). Two EISs (11%) were scored as Poor (grade E) (Figure 3A). No EISs were graded in the extreme categories of A and F.

3.2 Quality of individual Review Areas (RAs)

Table 7 shows a full matrix of results for all the Review Areas (RAs) and Review Categories (RCs). Figure 3B presents grading for each Review Area across the 19 EISs. Clearly, the most successful area is RA 4 (Communication of Results), where satisfactory grades were achieved in 95% of the EISs. This is followed by RA 1 (Project Description/Baseline Environment) and RA 3 (Alternatives and Mitigation) where satisfactory ratings were returned for 63% and 58% of EISs respectively. The 'Identification and Evaluation of Key Impacts (RA 2)' – one of the most important aspects of EIA – was found to be unsatisfactory in 58% of the sampled EISs. Importantly, the Decommissioning/Abandonment aspect of EISs (RA 5), a newly added Review Area (see Fig. 1), was scored as 'unsatisfactory' in 15 of the 19 EISs (see section 3.2.5).

3.2.1 Review Area 1 – Project Description and Baseline Environment

Analysis of the five Review Categories within RA 1 (Table 7) shows that *'Environment Description'* was handled most successfully of all categories (and rated satisfactory in 95% of EISs), followed by *'Description of the Project Development'* (79%). The *'Baseline Environment Condition'* was satisfactorily described in 63% of the EISs, while *'Site Description'* was satisfactory in 42% of them. *'Wastes and Residuals'* were satisfactorily addressed in just 37% of the EISs.

3.2.2 Review Area 2 - Identification and Evaluation of Key Impacts (during site preparation, construction, operation)

Review Area 2 is crucial, but the *'Definition of Impacts as Deviation from Baseline Condition'* (RC 2.1) was the weakest category in 74% of the EISs (Table 7). Also, 63% of the EISs unsatisfactorily addressed *'Impact Prediction'* with only 11% of the EISs scoring very good grades while *'Impact Significance'* was unsatisfactory in 68% of them. However, *'Impact Identification'* was satisfactorily addressed in 74% and *'Scoping'* was satisfactorily addressed in 68% of the EISs.

3.2.3 Review Area 3 - Alternatives and Mitigation

Table 7 shows that the *'Alternatives'* RC was generally handled satisfactorily in 95% of EISs, and 68% received very good grades. However, the *'Scope and Effectiveness of Mitigation'* category was scored as unsatisfactory in 63% of the 19 EISs. Also, '*Commitment to Mitigation'* was satisfactory in 63% of them, though this does not guarantee actual adherence to mitigation measures after project approval.

3.2.4 Review Area 4 - Communication of Results

The *'Layout'* and *'Presentation'* categories were satisfactory for all EIAs, with grades falling between A and C, although about only half (58%) of the former could be classed as very good (Table 7). In only 53% of the EISs was the *'Emphasis' RC* scored as 'Very Good'. Most EISs (89%) included satisfactory sections for the '*Non-technical Summary',* and 79% were 'Very Good' (Table 7).

3.2.5 Review Area 5 – Decommissioning, Closure or Abandonment

In the Category of *'Addressing the Positives'* only 21% of EISs were rated as satisfactory (Table 7). This is despite the potential for oil and gas engineering structures to be recycled, or serve as artificial reefs, such as the 'rigs-to-reef' program in the Gulf of Mexico (Schroeder and Love, 2004) where about 93% of the 3000 decommissioned platforms has been removed completely and 7% already made into artificial reefs (Vedachalam et al., 2015). Similarly, the *'Addressing the Negatives'* category was scored as unsatisfactory in 79% of the EISs.

3.3 Change in EIS quality over time

Mann-Whitney *U* test on the number of 'Satisfactory' EISs does not provide statistically significant evidence (at $p < 0.05$) of an improvement in the overall quality of EISs between the earlier period (1998-2004: n = 10) and the later period (2004-2008; n = 9). The result was similarly non-statistically significant when the central break-point of the sample was adjusted to reduce the earlier period to 9 EISs. Moreover, the same test on the number of 'Satisfactory' individual *Review Areas* shows no evidence of an increase in quality over time. However, for the case with 9 EISs in the 1998-2004 period, a statistically significant increase in quality over time emerged for just one Review Area, namely 'Alternatives and Mitigation' ($p = 0.019$). In both cases of overall EIA quality and Review Areas, there is an assumption that any observed difference is partly explained by sampling variability (e.g. Sullivan and Feinn, 2012).

4. Discussion

4.1 Implications of the overall results

The trends on Figure 3 show that undertaking EIS quality review for oil and gas projects could be beneficial by unveiling areas needing adequate attention. For example, the non-oil and gas UK study by Glasson et al. (1997) revealed that EIA preparers and other stakeholders have learnt from experience. The overall results in Fig. 3 may not be unconnected with, amongst others, the absence of full scoping, unfocused assessment, inadequate baseline data and poor coverage of mitigation methods as found by Gray and Edwards-Jones (1999). In South Africa, a similar study suggested that the quality of EISs in the North-West province is at par with international standards though not without some shortcomings (Sandham and Pretorius, 2008). Barker and Jones (2013) found that a number of EISs were unsatisfactory and cited a concern that the EIA process may have been driven by regulatory compliance instead of best practices. The overall EIS quality review results for this Nigerian study, as demonstrated in Fig. 3, is not any different. However, it is unclear if an empirically positive correlation exists between a country's national policy implementation compliance and its resultant environmental performance.

4.2 Drilling down into the quality of individual Review Areas

Interestingly, the level of satisfactory grades recorded for RAs 1 and 4 are reasonably consistent with findings of past EIS quality review studies for non-oil and gas projects (e.g. McMahon, 1996; Barker and Wood, 1999; Sandham and Pretorius, 2008; Sandham et al., 2008a; Kabir et al., 2010; Sandham et al., 2010). We discuss below the assessments of Review Categories within each individual Review Area.

4.2.1 Project Description and Baseline Environment

'Environment Description' and '*Description of Project Development'* are more straightforward tasks (i.e. more descriptive than analytical and less technical) for EIA teams and this explains the high ratings for these categories. For the *'Wastes and Residuals'* category, however, most EISs mentioned likely waste types but gave little or no information on the quantities of wastes to be generated or the timing and nature of waste generation. Also, the methods by

which waste quantity was derived, and their uncertainties and confidence limits were often unsatisfactorily addressed. Clearly, communication of uncertainty is important in environmental impact assessment (e.g. Wardekker et al., 2008; Butt et al., 2014).

Majority of the EISs demonstrated some evidence of biological and chemical data collection covering the wet and dry seasons. However, very little physical data (e.g. hydrological and hydraulic) were presented even when substantial water bodies were clearly at risk e.g. at pipeline river crossings (see Anifowose et al., 2012b; Anifowose et al., 2014; Lawler and Wilkes, 2015). In addition, most sampled EISs did not describe the 'Baseline Environment' as it could be expected to evolve should the project *not* proceed – despite 'baseline' being crucial in environmental risk assessment (Butt et al., 2014). Unsurprisingly therefore, this problem also resurfaced under impact identification and prediction (section 3.2.2). As for *'Site Description'*, more than 50% of sampled EISs lacked a clear land-use map of the project environment. This is likely to hinder the study of the impacts of scale (spatial or detail) on the accuracy of impact prediction (e.g. Joâo, 2002).

4.2.2 Identification and Evaluation of Key Impacts

With respect to RC 2.1, the absence of predictive modelling of impacts in most EIAs, as also previously noted by Ogunba (2004), weakens a score. Only five of the 19 EISs applied some predictive modelling (e.g. atmospheric dispersion of released gases; numerical simulation of sediment plume and oil spill; land-subsidence modelling due to hydrocarbon withdrawal etc.). Similar problems, including non-testable and non-auditable predictions, have also been reported in the UK (Floater 2002), parts of Europe (Glasson et al. 2005), Australia (Buckley 1991, Warnken and Buckley 1998) and Canada (Bernard et al. 2001, Noble and Storey 2005). Impacts in the sampled EISs were not evidently determined as deviation from a baseline condition, therefore the ability to adequately predict future environmental impacts is compromised. This led to unsatisfactory grades in the *'Impact Prediction'* RC (Table 7). This supports similar findings in the Barker and Jones (2013) study and a British forest sector study by Gray and Edward-Jones (2003).

The majority of sampled EISs relied on 'expert' opinion and past experience in assessing impact significance, and lack a convincing or objective rationale. This largely makes the process subjective, as Sadler (1996) found in an international study of EIA effectiveness. Russo (1999) posited that over-reliance on experience is a major problem facing the conduct of energy sector EIA because the environment is constantly changing. Also, Glasson et al. (2005) argued that expert opinion, though useful, cannot provide totally defensible and flawless foundations for EIA impact prediction and significance evaluation. However, sophisticated predictive techniques may provide alternatives to this problem, but such advanced methodologies could restrict active participation of key stakeholders in the EIA process (Weston, 2004; Glasson et al., 2005).

4.2.3 Alternatives and Mitigation

For oil and gas exploration, *'Alternative'* options arguably are restricted in location but several options exist for the process technologies, especially extraction, and oil and gas transportation. Some of the EISs focused more on economic than environmental issues when examining alternatives.

A key point, however, is that residual impacts and uncertainties of *'Mitigation Effectiveness'* were hardly addressed. Such confirmation of '*Mitigation Effectiveness'* requires, of course, detailed post-project monitoring, although this can be difficult to achieve (e.g. Noble and Storey, 2005; Nasen et al., 2011). There is some international recognition of the need for better implementation of mitigation measures for energy-related projects (e.g. E&P Forum/UNEP, 1997; Russo, 1999; Khadka and Khanal, 2008; Klevas et al., 2009). Indeed, Wawryk (2002) and Marazza et al., (2010) suggest that Environmental Management Systems (EMS) (*an environmental protocol often voluntarily adopted by multinational oil companies*) could help here given their focus on change over time and the monitoring of mitigation plans and environmental impacts. Perhaps, implementation of mitigation is where the rather controversial NESREA Act (see Ladan, 2012; Ambituuni et al., 2014) detailed in section 1.4 could become useful. Fortunately, Nigeria's DPR has already enhanced its EIA process to allow a systematic integration with project engineering design and continuous monitoring of the implementation of designed mitigation. This, with similarly robust complements from the FME, could mean that the exclusion of oil and gas activities from NESREA Act is apt.

4.2.4 Communication of Results

Review Area 4 was the strongest part of the EISs examined, perhaps because it is a simpler task and less technical unlike impact prediction. Nevertheless, many environmental baseline chapters were disproportionately lengthy, yet none of the EISs presented clear chapter summaries. Also, many of the EISs cited largely old references (e.g. 1960s-1980s) relative to their submission dates.

4.2.5 Dealing with project decommissioning impacts

This was the worst performed of the five Review Areas (see Table 7; Fig. 3B). The project decommissioning sections in 79% of the EISs did not apparently follow requirements set out by, for example, FEPA (1995). Very few EISs provided clear outlines of how contaminated environmental receptors would be remediated or replaced. Instead, most EISs only made reference to the relevant sections of the DPR EGASPIN (2002) or its earlier version; or to FME FEPA (1995) with promises of adherence. This is unfortunate, given the UNEP (2011) report which demonstrated that inadequate handling of oil and gas asset decommissioning contributed to environmental problems in Ogoniland – a similar point reinforced by Schroeder and Love (2004) in the Gulf of Mexico. Similarly, a recent study found high concentrations of soil gas methane above decommissioned oil and gas wells in the UK and suggested that this could be due to well integrity failure where facilities have been inappropriately decommissioned (Boothroyd et al., 2016). Clearly, asset decommissioning in Nigeria (and possibly elsewhere) needs more thorough attention in EISs including a step-change that involves the integration of EMS and project-level HSE Management Systems (see Wawryk, 2002).

The rather weakly assessed decommissioning impacts is not surprising given the misconception about project decommissioning in EIAs. Russo (1999) stated that there are uncertainties about the necessity for an anticipation of possible environmental impacts of decommissioning in EIAs of energy projects since such project lifespans are substantial. But a potential solution to this problem is to treat EISs as ‘living documents’ which will allow updates to relevant aspects (e.g. decommissioning) as technology and science evolve. In the Desire Oil Plc. exploratory drilling project in the UK (Palframan, 2010; p.3), the EIS through its Environmental Management Plan (EMP) was integrated with the ISO 14001 EMS and the HSE Management System. Recent studies have emphasised the significance of EIA-EMS integration as a fundamental step-change towards addressing such project environmental concerns (e.g. Palframan, 2012; Perdicoulis et al., 2012; Raissiyan and Pope, 2012).

4.3 Discussing the hypothesis of EIS quality improvement (1998-2002)

The lack of statistically significant improvement in EISs quality is surprising. It was hypothesised that EIS quality would rise over time as per the previous studies (sections 1.2, 1.3), and driven by at least four temporal changes like: (a) emerging environmental/EIA legislation e.g. the EIA Decree of 1992 and EGASPIN (2002); (b) emerging analytical methods and improved Information Technology through time, including software availability, enhanced instrumental/remote sensing platforms (e.g. NigeriaSat-1) for data collection;

(c) greater availability of longer and more representative datasets of enhanced quality through time; and (d) increased experience with EIA analytical and reporting methods within oil and gas companies.

This result is intriguing, given the improvement over time suggested for non-oil and gas project EISs, albeit without statistical analysis (e.g. see Table 1). Based on our study sample (section 2.2), one explanation for the lack of statistically significant improvement over time in Nigerian oil and gas EISs is perhaps the absence of independent monitoring/periodic EIS quality review. With this, independent review feedback into the EIA system can enhance the practices and processes of EIA (Lee and Brown, 1992; Glasson et al.,1997). However, the increase in quality over time observed in the 'Alternatives and Mitigation' Review Area could have been driven by the fact that 'alternatives' are mostly restricted to specific locations (e.g. hydrocarbon reservoir sites). And alternative processes and designs adopted are dependent upon evolving technologies. Our analyses and key findings did not support the popular hypothesis regarding EIS quality improvement over time. Nevertheless, our study reported herein, and those of the non-oil and gas projects cited above, provide some empirical basis for potential evolution of a theory of EIS quality change over time.

Finally, though not all EISs may be suitable for full online access due to commercial confidentiality, technical reasons and security concerns, studies of EIS quality review should be encouraged for the benefit of the industry and on-line availability of EIS is consistent with a drive towards greater transparency and public accountability. Notwithstanding alleged criticism by some government regulators (Webb, 2011), we were pleased to find that since 2011, some Nigerian oil and gas project EISs have become available online.

5. Conclusion

In this paper we present the first ever study of EISs quality for both onshore and offshore oil and gas projects. As further novel elements, the study tests the hypothesis of improvement over time and critically reviews the degree to which project decommissioning impact is assessed within EISs.

The main study findings are: (a) project description and communication of results are main areas of strength; (b) of the 19 sampled EISs, almost half (47%) were scored as unsatisfactory; (c) environmental impact prediction and decommissioning were among the areas requiring enhanced attention; (d) Mann-Whitney tests suggest that there is no evidence that EISs for the latter period (2004-2008) were of a higher quality than those of the earlier period (1998-2004) – a finding that is contrary to common expectation.

Based on the findings of this study, we argue for National Environmental Policy in Nigeria to mandate a systematic, independent, periodic quality review of EISs every 3 to 5 years in the oil and gas industry, for the explicit purpose of improvement in good practice. Secondly, project decommissioning should henceforth be explicitly addressed in all future EISs in line with regulatory frameworks.

Beyond the case study sector and country, this study provides a robust demonstration that a systematic quality review reveals important areas needing adequate attention in EISs. Furthermore, this review could be used to target the dissemination of good practice/s and verify if EIA approval processes are sufficiently robust and adhered to.

Periodic systematic quality review of EISs, as described in this article, is part of wider responsible actions that would encourage transparency, stewardship or accountability and integrity – all of which are key principles of environmental sustainability. It would be useful to test our findings and hypothesis in other oil and gas producing countries, and in other extractive industries which carry a significant environmental risk.

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New enhanced result collation sheet for Environmental Impact Statement (EIS) quality review

Overall EIS Grade:

DEVELOPMENT & BASELINE			IMPACT EVALUATION			ALTERNATIVES/MITIGATION			COMMUNICATION OF RESULT			DECOMMISSIONING		
	Grade	Score		Grade	Score		Grade	Score		Grade	Score		Grade	Score
RA 1	F		**RA 2**	F		**RA 3**	F		**RA 4**	F		**RA 5**	F	
1.1 Dev't Description			**2.1 Impact Definition**			**3.1 Alternatives**			**4.1 Layout**			**5.1 Negatives**		
1.1	F		*2.1*	F		*3.1*	F		*4.1*	F		*5.1*	F	
1.1.1 Purpose/Objectives	F		2.1.1 Effects e.g. direct, indirect	F		3.1.1 Alt. site + adv./disadv.	F		4.1.1 Introductn/EIA aims	F		5.1.1 Contaminated receptors	F	
1.1.2 Design/size	F		2.1.2 Effect interactns-Man/Env.	F		3.1.2 Alt. process/design	F		4.1.2 Logical flow	F		5.1.2 Monitoring timeframe	F	
1.1.3 Physical presence	F		2.1.3 Impact from non-standard	F		3.1.3 Alternative reappraisal	F		4.1.3 Chap. Summary	F		5.1.3 Actions/Responsibility	F	
1.1.4 Production process	F		2.1.4 Deviation from baseline	F					4.1.4 Full references	F		5.1.4 Restoration strategy	F	
1.1.5 Raw Material Qty	F													
1.1.6 Tech. Operation	F													
1.1.7 Material balances	F													
1.2 Site Selection			**2.2 Impact Identification**			**3.2 Mitigation Measures**			**4.2 Presentation**			**5.2 Positives**		
1.2	F		*2.2*	F		*3.2*	F		*4.2*	F		*5.2*	F	
1.2.1 Land area takeup	F		2.2.1 Impact methodology	F		3.2.1 Measures, residual impts	F		4.2.1 Comprehensibility	F		5.2.1 Beneficial materials	F	
1.2.2 Landuse demarcation	F		2.2.2 Justification/rationale	F		3.2.2 Method description	F		4.2.2 Define tech. terms etc	F		5.2.2 Justification	F	
1.2.3 Duration of phases	F					3.2.3 Effectiveness, uncertainty	F		4.2.3 Integrated whole	F				
1.2.4 Workforce / phase	F													
1.2.5 Raw Mat.Transport	F													
1.2.6 Productn Zone	F													
1.2.7 Contruction details	F													
1.2.8 Site preparation	F													
1.3 Wastes			**2.3 Scoping**			**3.3 Mitigation Commitment**			**4.3 Emphasis**					
1.3	F		*2.3*	F		*3.3*	F		*4.3*	F				
1.3.1 Types/Qty & rate	F		2.3.1 Stakeholder participation	F		3.3.1 Commitment record	F		4.3.1 Proportionality	F				
1.3.2 Treatment disposal	F		2.3.2 Public opinion considered?	F		3.3.2 Monitoring arrangement	F		4.3.2 Neutrality	F				
1.3.3Methods,uncertainty	F		2.3.3 Investigate key impacts	F					4.3.3 Environ.'al Mgt. Plan	F				
			2.3.4 Challenges emanating	F										
1.4 Environment Description			**2.4 Impact Magnitude**						**4.4 Nontechnical Summary**					
1.4	F		*2.4*	F					*4.4*	F				
1.4.1 Affected environ	F		2.4.1 Data appropriateness	F					4.4.1 Non-tech. summary	F				
1.4.2 Description	F		2.4.2 Magnitude predictn method	F					4.4.2 Main issues covered	F				
1.4.3 Env. Laws	F		2.4.3 Measurability of predictn	F										
												Keys to grade interpretation in red:		
1.5 Baseline Condition			**2.5 Impact Significance**									Excellent	A	5
1.5	F		*2.5*	F								Very Good	B	4
1.5.1 Component	F		2.5.1 Significance	F								Good	C	3
1.5.2 Data source	F		2.5.2 Quality standard	F								Fair	D	2
1.5.3 Other baseline data	F		2.5.3 Justification	F								Poor	E	1
1.5.4 Unique areas	F											Very poor	F	0

NB: For details of assessment ratings, see Table 6. For keys to codes 1. RA, *1.1 RC*, and 1.1.1 RSC, pls see Table 4. NA - Not Applicable

Table 1: Summary details of published evaluation of EIA report/EIS quality (1991-2016) and review methods employed

No.	Author(s)	Country of Study	Period covered	No. of EIS examined	Method used/ adapted	Nature of Projects
1	Ahmed and Elturabi (2011)	Sudan	1999-2006	12	Checklist: Nadeem & Hameed 2008 Lee & Colley, EC 1994	River engineering, power, roads, oil exploration, agric.
2	Androulidakis and Karakassis (2006)	Greece	1993-2003	37	Non-obligatory but quality-related indicators	Various
3	Barker and Wood (1999)	UK, Germany, Spain, Belgium, Denmark, Greece, Ireland and Portugal	1990-1991; 1994-1996	112	Lee & Colley; EC (1994)	Dams, Waste, Roads, Extractive, Hotels
4	Canelas et al. (2005)	Portugal and Spain	1998-2003	46	EC 2001 (Lee & Colley used in earlier studies compared)	Transport, Waste, Ports, Dams, Electricity
5	Christophilopoulos (2001)	Greece	1979-2001	72	Lee & Colley	Diverse range (incl. energy & extractive ind.))
6	Dancey and Lee (1993)	Republic of Ireland	1988-1992	40	Lee & Colley	
7	Glasson et al. 1996 (HMSO)	UK	1988-1994	25 matched pairs (50)	IAU Criteria; EC Checklist; Lee & Colley; Matched pairs	Road, Waste, Windfarm, Opencast, Sewage, Extraction(sand/gravel)
8	Gray and Edwards-Jones (1999)	Scotland	1988-1996	~16 (20% of 81)	NI (Abstract only)	Forestry
9	Gray and Edward-Jones (2003)	UK	1988-1998	89	Lee & Colley	Forestry
10	Guilanpour and Sheate (1997)	Tanzania	1991-1995	18	IEA (1990)	Mining, Road, Hydropower etc.
11	Gwimbi and Godwell (2016)	Zimbabwe		22	Lee & Colley; and Mitchell's	Mining
12	Hirji and Ortolano (1991)	Kenya	1974-1988	4	TOR, 5-Dimentional factors	Water Resources
13	Ibrahim (1992)	Malaysia	NAD	NAD	Lee & Colley	NAD
14	IEMA (2004)	UK	2003-2004	4 docs.	Lee & Colley	Wind Farm
15	IEMA (2009)	UK	NA	NA	Lee & Colley	Planning, Waste etc.
16	Kabir et al. (2010)	Bangladesh	NI	30	Lee & Colley	Industry, Infrastructure, Energy and Water Sectors
17	Kabir and Momtaz (2014)	Bangladesh		40	Lee & Colley	Four major sectors
18	Lawrence (1997a)	Canada		10	Screening & Performance criteria	Mining, Hydro-Electric-Power, Waste, Landfill, Road
19	Lee and Brown (1992)	UK	1988-1991	NAD	Lee & Colley	
20	Lohani et al. (1997)	Continent of Asia	N/A	N/A	Triple 'A' test; TOR & Review Checklist	NI
21	McGrath and Bond (1997)	Cork, Eire	1988-1993	44	Lee & Colley	Diverse range (not including oil/gas)
22	McMahon (1996)	Northern Ireland, UK	1989-1995	10	Lee & Colley	Waste disposal/landfill
23	Modak and Biswas (1999)	NAD	NAD	NAD	General document review criteria, Lee & Colley; TOR	NAD
24	Morgan and Memon (1993) in Fuller (1999)	New Zealand	NAD	NAD	A 13-point criteria	NAD
25	Mwalyosi and Hughes (1998)	Tanzania	1981-1997	26	Lee & Colley; IEA (1990)	Mining, hydropower etc.
26	Nadeem and Hameed (2006)	Pakistan	NI	4	Modak & Biswas 1991	Industrial sector
27	Peterson (2010)	Estonia	2001-2005	50	EC 2001	17 in total inc mineral extraction & energy i.e. wind farm

No.	Author(s)	Country of Study	Period covered	No. of EIS examined	Method used/ adapted	Project Area(s)
28	Pinho et al. (2007)	Portugal	1990-2003	13	Lee & Colley; EC 2001	Hydropower
29	Ramjeawon and Beedassy (2004)	Mauritius	1993-2003	9	Hirji & Ortolano (1991), Wood (1994), Leu et al. (1996)	Tourism (Hotels & Beech)
30	Rout (1994)	India	NAD	NAD	Lee & Colley	NAD
31	Sadler (1996)	An international study on EIA effectiveness by CEAA & IAIA	NI	N/A	Triple 'A' test	NA
32	Samarakoon and Rowan (2008)	Sri Lanka	1981-2005	130	Common ecological review criteria	Diverse range (not incl. oil/gas)
33	Sandham, L., Hoffmann, A & Retief, F. (2008a)	South Africa	2004-2008	20	Lee & Colley	Mining
34	Sandham, L., Moloto, M. & Retief, F. (2008)	South Africa	1997-2006	4	Lee & Colley	Wetland
35	Sandham & Pretorius (2008)	South Africa	1997-2006	28	Lee & Colley	Telecoms, water/sewage, landuse & Elect./fuel
36	Sandham et al. 2010	South Africa	NI	6	Lee & Colley	Biological control/pest
37	Scholten (1995) in Fuller (1999)	NAD	NAD	NAD	An 8-point criteria	NAD
38	Shaw (2006)	Scotland	2005	1	Lee & Colley; EC 2001	Rail link
39	Simpson (2001)	UK	1995-1998	6	Lee & Colley	Local Authority Planning
40	The Netherlands EIA Commission Operational Criteria in Fuller (1999)	Netherlands	NA	NA	A 7-point criteria	NA
41	Tzoumis and Finegold (2000)	United States	1970-1997	19,236	USEPA (1984)	Forest, Road, Housing & Urban Dev. Etc.
42	Weston et al. (1997)	UK		10	IAU Criteria	Mineral extraction, Sewage, Reservoir, Wind-farms etc.
43	*Ahmad and Wood (2002)	Egypt, Turkey, Tunisia	NA	NA	Systemic & Foundation measure criteria	NA
44	*Doyle and Sadler, (1996)	Canada	NA	13	EAOGRAMS (Sadler 1996 p.47-48)	NA
45	*Leu, et al. (1996)	Taiwan	NA		Quality control mechanisms	NA
46	*Ross (1987)	Canada	NAD	NAD	NAD	NAD
47	*Wood and Bailey (1994)	Australia	NA	NA	System review criteria	All

*EA/EIA Systems rather than EA reports
CEAA – Canadian Environmental Assessment Agency;
EC – European Commission Review Checklist;
IEA – Institute of Environmental Assessment (most likely now IEMA); IAIA – International Association for Impact Assessment
NA – Not Applicable; NI – Not Indicated; NAD – No Access to Document yet. TOR – Terms of Reference
Triple 'A' test - Appropriateness (covering key issues and impacts); Adequacy (of impact Analysis); Actionability (for informed decision-making)

Table 2: List of oil and gas projects selected for EIS quality review in this study

No.	Project Type	Offshore/Onshore	EIS Submission Date
1	Oilfield development*	Offshore	1998
2	Oilfield development	Offshore	1998
3	Gas pipeline	Onshore	2001
4	Oil pipeline*	Onshore	2002
5	Oil facility and pipeline	Onshore	2002
6	Oil pipeline manifold	Onshore	2002
7	Gas pipeline	Onshore	2002
8	Seismic data acquisition	Onshore	2004
9	Gas project	Offshore/Onshore	2004
10	Liquefied natural gas project	Offshore/Onshore	2004
11	Gas pipeline & storage vessel	Onshore	2004
12	Gas gathering project	Onshore	2005
13	Gas project	Onshore	2006
14	Oil well drilling & pipeline*	Onshore	2006
15	Gas processing project	Onshore	2007
16	Gas pipeline project	Onshore	2007
17	Gas supply project	Offshore/Onshore	2007
18	Liquefied natural gas project	Offshore/Onshore	2008
19	Gas pipeline project	Onshore	2008

*EISs used for Pilot Study

Table 3: Characteristics of selected EIA report/EIS review criteria

No	EIS quality evaluation methods & Authors	Strength	Weakness
1	Lee & Colley (1990, 1992); Lee et al. (1999) EIA Centre, University of Manchester	1. Review results build-up from the lowest level to the top via an assessment pyramid (Fig. 1); e.g. review sub-categories, review categories, review areas and the overall quality assessment result. 2. It has been tested by many researchers (see Table 1) with relatively repeatable results in the 4 Review Areas 3. It has evolved through a number of versions and has 4 key Review Areas with about 52 review questions. 4. Comprehensive details and guides/advice for reviewers is available and accessible.	1. It exists in varied diluted versions adapted by different researchers. 2. It has the tendency to appear complex especially due to its hierarchical structure and adjoining collation sheet meant to record grade at each review stage. 3. The bottom-up approach could make scoring difficult sometimes when, for example, all the RSCs are well performed except for a major RSC.
2	European Commission (EC) 2001	1. It has seven (7) review sections with about 143 review questions as a prerequisite for quality judgment. 2. It is a model with a checklist and involves 'ticking the box' against a list of criteria to assess adequacy or otherwise. 3. Judgment is based on specific project extent in appraising the relevance of provided information. 4. It appears less complex especially without the presence of separately adjoining collation sheet, detailed instructions etc.	1. Susceptibility to *monotony due to longer list of questions. 2. It is similar to the Lee & Colley model 3. Scores at both review question and section levels may not necessarily be progressive unlike the hierarchical nature in Lee & Colley 4. The 143 review questions may take longer time to complete
3	IAU Oxford Brookes (HMSO 1996)	1. Combines Lee & Colley (1990, 1992); 1999 UK EIA Regulations and DoE checklist. It has 8 Review Areas. 2. Useful checklist for EIA preparation as well as EIA report review. 3. It has similar strengths as 1 and 2 above.	1. Some of the 92 review criteria may not all be relevant for one particular project; hence creates redundancy. This is also common to 1 and 2 above 2. Relatively new criteria and not yet widely used (see Table 1). Hence not many feedbacks on it in the literature 3. It may take longer time to accomplish

*This might be viewed as positive as it could ensure 'comprehensiveness' – it is however subject to value judgement.

NOTE: Lee and Colley (1990, 1992) and Lee et al. (1999) generally tend to be known as the Lee and Colley model. Hence, the Lee et al. (1999) model as referred in this article is synonymous with the Lee and Colley model.

Table 4: Short-listing of **Review Areas** - RA (e.g. **1**.), *Review Categories - RC* (e.g. *1.1*) and Review Sub-Categories - RSC (e.g. 1.1.1) used to assess each EIS. The full version can be found in Lee and Colley (1992) and Lee et al. (1999).

1. Description of Development and Baseline Environment *1.1 Description of the development* 1.1.1 Purpose(s) and objectives of development. 1.1.2 Design and size of development. 1.1.3 Indication of physical presence. 1.1.4 Nature of production processes & rate of production. 1.1.5 Nature/quantities of raw materials. 1.1.6 Technical operations: Well count, well-spacing, field life etc 1.1.7 Material balances, process technology, hazard potentials etc *1.2 Site description* 1.2.1 Land area taken-up on map and/or aerial photo/satellite imagery. 1.2.2 Land-use demarcation. 1.2.3 Duration of construction, operation & decommissioning phases. 1.2.4 Workforce volume during each phase, housing plans/ site access. 1.2.5 Transport mode for raw materials and products. 1.2.6 Production Zone(s): Depth; structure; oil/gas/water ratios etc. 1.2.7 Construction details: Methods & timing of construction, interruption etc. 1.2.8 Site preparation: land clearing/filling; excavation; river blocking etc. *1.3 Wastes and residuals* 1.3.1 Types and quantities, and their rates of production. 1.3.2 Waste treatment and routes of disposal. 1.3.3 Quantification methods; including uncertainty & confidence limits. *1.4 Environment description* 1.4.1 Affected environment indicated on map/aerial photo/satellite imagery. 1.4.2 Description of affected environment, including effects on nearby areas. 1.4.3 Existing environmental regulatory frameworks. *1.5 Baseline conditions(with and without the project)* 1.5.1 Important components of affected environments, methods/investigations 1.5.2 Existing data sources. 1.5.3 Other data collected to determine the baseline conditions. 1.5.4 Special/unique areas of scientific values and socio-cultural heritage	**2. Identification & Evaluation of Key Impacts** **(Site Preparation/Construction/Operation)** *2.1 Definition of impacts - predicted deviation from baseline.* 2.1.1 Description of project effects e.g. direct, indirect, cumulative etc. 2.1.2 Identifying effects on human-physical environment and their interactions. 2.1.3 Impacts from non-standard operating conditions, due to accidents. 2.1.4 Impacts described as the deviation from baseline conditions. *2.2 Identification of impacts and method used* 2.2.1 Impacts identification methodology. 2.2.2 Description of impact identification methods and rationale for their use. *2.3 Scoping* 2.3.1 Public participation by key stakeholders. 2.3.2 Evidence that the opinions/concerns of the public is considered. 2.3.3 In-depth investigation of key impacts. 2.3.4 Challenges emanating from scoping key impacts e.g. methods of river crossings. *2.4 Prediction of impact magnitude* 2.4.1 Description and sufficiency of data for estimating impact magnitude. 2.4.2 Describe impact magnitude prediction methodology. 2.4.3 Measurability of predicted impact magnitude; ranges & confidence limits. *2.5 Assessment of impact significance* 2.5.1 Impact significance on affected community, including residual impact. 2.5.2 National & international quality standards utilized in impact assessment. 2.5.3 Justification of standards, assumptions and value systems used.
3. Alternatives and Mitigation *3.1 Alternatives* 3.1.1 Alternative sites, including environmental advantages/disadvantages. 3.1.2 Alternative processes, designs/operating e.g. oil transport modes 3.1.3 Reappraisal of previous alternatives in difficult to mitigate impacts	*3.2 Scope and effectiveness of mitigation measures* 3.2.1 Description of mitigation measures. Justify residual impacts, if any. 3.2.2 Description of mitigation methods (MM) 3.2.3 Effectiveness of MM, including uncertainty and assumptions. *3.3 Commitment to mitigation*

4. Communication of Results *4.1 Layout* 4.1.1 Brief introductory description of the project and aims of the EIA 4.1.2 Logical arrangement of information, content table and index. 4.1.3 Chapter summaries, unless Chapters are very short. 4.1.4 Acknowledgment of external sources and full reference list. *4.2 Presentation* 4.2.1 Comprehensibility of information to non-specialists. 4.2.2 Technical terms, acronyms and initials should be defined. 4.2.3 Presentation as an integrated whole. *4.3 Emphasis* 4.3.1 Proportionate description of positive and negative impacts. 4.3.2 Statement should be unbiased 4.3.3 EMP including compliance with mitigation & emission standards *4.4 Non-technical summary* 4.4.1 Non-technical summary of main findings and conclusions. 4.4.2 Mitigation measures, residual impacts, data methods & confidence limits.	3.3.1 Record of proponent's commitment e.g. via EMP 3.3.2 Monitoring arrangements for conformity with predictions **5. Decommissioning/Closure/Abandonment** *5.1 Addressing the Negatives* 5.1.1 Method and processes of replacing contaminated receptors. 5.1.2 Chemical, biological or physical monitoring (Periodic). 5.1.3 Remediation plan with time elements, actions and responsibilities. 5.1.4 Explicit restoration strategy of entire project area. *5.2 Addressing the Positives* 5.2.1 In-situ beneficial materials e.g. rig-platforms as artificial reefs. 5.2.2 Justification for actions taken in 3.2.1 above

1. Review Areas (RA); *1.1 Review Categories (RC)*; 1.1.1 Review Sub-Categories (RSC). NB: the scorings/ratings as recorded in the result collation sheet (supplementary_folder_1) is based on how well each EIS has addressed the elements of RA, RC and RSC as detailed here in Table 4 above. This is akin to a typical assessment of exam scripts based on a standardised marking scheme.
Source: adapted from Lee and Colley (1992) and Lee et al. (1999).

Table 5: Summary of modifications to the Lee et al. (1999) review model as reflected in this article.

No.	REVIEW TOPICS AND OTHERS	KEY DIFFERENCES		MODIFICATIONS WITH REFERENCE TO TABLE 3
		Lee et al. (1999)	**As adapted in this article**	
1	Overall quality assessment and grading of review topics	A to F & NA	Lee et al. (1999) and HMSO (1996) assessment ratings and categories*	NA
2	Number of Review Areas (RA)	4	5	5.
3	Number of Review Categories (RC)	17	19	5.1 and 5.2
4	Number of Review Sub-Categories (RSC)	52	67	1.1.6, 1.1.7, 1.2.6-1.2.8, 1.4.3, 1.5.4; 2.3.4; 4.3.3; 5.1.1-5.1.4 and 5.2.1-5.2.2.
	Changes to score sheet and recording methods			
5	Type of assessment score sheet	Plain record sheet	Much enhanced score sheet with macros to automatically convert grades to numeric values (if need be)	See the differences in supplementary_folder_1.

*see Table 6.

NA – Not Applicable

Table 6: Grading / Scoring Criteria for the EIS quality review undertaken in this study

Symbols	Numeric Equivalents	Explanation
A	5	Excellent: relevant tasks **well performed**, no important tasks left incomplete.
B	4	Very Good: **generally satisfactory** and complete, only minor omissions and inadequacies.
C	3	Good: can be considered **just satisfactory** despite omissions and/or inadequacies.
D	2	Fair: parts are well attempted but must, as a whole, be considered **just unsatisfactory** because of omissions or inadequacies.
E	1	Poor: **not satisfactory**, significant omissions or inadequacies.
F	0	Very Poor: **very unsatisfactory**, important task(s) poorly done or not attempted.
NA	N/A	Not applicable: the review topic is not applicable/irrelevant in the context of this EIS.

Further Grading Criteria

A, B or C	Satisfactory
D, E or F	Unsatisfactory
A or B	Good
C or D	Borderline
E or F	Poor

Source: *after* Lee and Colley (1992); Lee et al. (1999); HMSO (1996)

Table 7: Matrix of Evaluation Results for Review Categories (RCs) and Review Areas (RAs) based on the 19 sampled EISs

	EIS Review Categories (RCs)	A	B	C	D	E	F	N/A	A-C %	D-F %	A-B %	C-D %	E-F %
Review Area 1	*1.1 Description of the development*	0	12	3	2	1	0	1	79	16	63	26	5
	1.2 Site description	0	5	3	8	3	0	0	42	58	26	58	16
	1.3 Wastes and residuals	0	2	5	4	8	0	0	37	63	11	47	42
	1.4 Environment description	3	11	4	1	0	0	0	95	5	74	26	0
	1.5 Baseline conditions	0	5	7	7	0	0	0	63	37	26	74	0
Review Area 2	*2.1 Definition of impacts as deviation from baseline*	0	1	4	13	1	0	0	26	74	5	89	5
	2.2 Identification of impacts	2	5	7	5	0	0	0	74	26	37	63	0
	2.3 Scoping	1	8	4	5	1	0	0	68	32	47	47	5
	2.4 Prediction of impact magnitude	0	2	5	8	4	0	0	37	63	11	68	21
	2.5 Assessment of impact significance	0	3	3	9	3	1	0	32	68	16	63	21
Review Area 3	*3.1 Alternatives*	5	8	5	1	0	0	0	95	5	68	32	0
	3.2 Scope and effectiveness of mitigation	0	3	4	9	3	0	0	37	63	16	68	16
	3.3 Commitment to mitigation	3	6	3	6	1	0	0	63	37	47	47	5
Review Area 4	*4.1 Layout*	0	11	8	0	0	0	0	100	0	58	42	0
	4.2 Presentation	1	16	2	0	0	0	0	100	0	89	11	0
	4.3 Emphasis	0	10	6	3	0	0	0	84	16	53	47	0
	4.4 Non-technical summary	0	15	2	1	0	0	1	89	5	79	16	0
Review Area 5	*5.1 Addressing the Negatives*	0	0	4	2	9	4	0	21	79	0	32	68
	5.2 Addressing the Positives	0	0	4	9	4	2	0	21	79	0	68	32
	Review Areas (RAs)												
	1. Description of Project & Baseline Environment	0	7	5	6	1	0	0	63	37	37	58	5
	2. Identification & Evaluation of Key Impacts (Site Preparation/Construction/Operation)	0	3	5	9	2	0	0	42	58	16	74	11
	3. Alternatives and Mitigation	0	6	5	6	2	0	0	58	42	32	58	11
	4. Communication of Results	0	14	4	1	0	0	0	95	5	74	26	0
	5. Decommissioning/Closure/Abandonment	0	0	4	3	9	3	0	21	79	0	37	63

Keys to grades:
A - Relevant tasks well performed, no important tasks left incomplete.
B - Generally satisfactory and complete, only minor omissions and inadequacies.
C - Can be considered just satisfactory despite omissions and/or inadequacies.
D - Parts are well attempted but must, as a whole, be considered just unsatisfactory because of omissions or inadequacies.
E - Not satisfactory, significant omissions or inadequacies.
F - Very unsatisfactory, important task(s) poorly done or not attempted.
A-C: Satisfactory; D-F: Unsatisfactory; A-B: Good; C-D: Borderline; E-F: Poor
Note: Grades A-C% and D-F% give a generic overview of EIS quality while grades A-B%, C-D% and E-F% are more specific.
See Table 6 for comprehensive translation of grades.

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<47% of the EISs were unsatisfactory; in particular, the key impact prediction and decommissioning areas need to be improved> 123

<We found no statistically significant evidence ($p<0.05$) of improvement in the quality of EISs over time> 103

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A

Test Statistics[a]

	Overall_EIS_Quality
Mann-Whitney U	28.500
Wilcoxon W	73.500
Z	-1.408
Asymp. Sig. (2-tailed)	.159
Exact Sig. [2*(1-tailed Sig.)]	.182[b]
Exact Sig. (2-tailed)	.164
Exact Sig. (1-tailed)	.094
Point Probability	.004

a. Grouping Variable: Years_of_EIS_submission
b. Not corrected for ties.

Surprisingly, both 1-tailed and 2-tailed tests' *p*-values suggest that there's no statistically significant evidence of an improvement in the overall EIS quality during the periods under consideration.

B

Test Statistics[a]

	The Five Review Areas				
	Baseline	Identify_Impacts	Mitigation	Communi_Resu	Decommission
Mann-Whitney U	35.000	26.500	20.000	40.500	40.000
Wilcoxon W	80.000	71.500	65.000	85.500	85.000
Z	-.859	-1.617	-2.149	-.477	-.435
Asymp. Sig. (2-tailed)	.390	.106	.032	.633	.663
Exact Sig. [2*(1-tailed Sig.)]	.447[b]	.133[b]	.043[b]	.720[b]	.720[b]
Exact Sig. (2-tailed)	.401	.119	.033	.851	.710
Exact Sig. (1-tailed)	.206	.067	.019	.444	.384
Point Probability	.034	.018	.011	.130	.097

a. Grouping Variable: Years_of_EIS_submission
b. Not corrected for ties.

Most surprisingly, the 1-tailed test at 95% confidence level suggests that only the 'Mitigation' Review Area (*p*-value = 0.019) has a statistically significant evidence of quality improvement in the latter years (2004-2008).

Fig. 4: **Hypotheses test results summaries for the experiment with 9 EISs for earlier years (1998-2004) vs 10 EISs for latter years (2004-2008).**
A: Testing overall EIS Quality improvement across the years. B: Testing EIS Quality improvement by Review Areas across the years.
NB: When the central breakpoint of the experiment was altered to have 10 EISs for earlier years (1998-2004) vs 9 EISs for latter years (2004-2008), the results in both A and B were no different. In fact, 1-tailed test at 95% confidence level for 'Mitigation' Review Area had *p*-value = 0.068