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Sustaining Asset Integrity in the Trinidad and Tobago's Energy Sector: An Assessment

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Abstract: *This paper assesses what is needed to sustain the integrity of assets in Trinidad and Tobago's Energy Sector by identifying gaps in knowledge. The next step in continuing research outside the scope of this paper will be to conceptualise and propose a framework for an Asset Integrity Management System (AIMS). The approach used was to compare global and local AIMS to establish best practices and investigate the critical success factors required for a sustainable AIMS implementation. Next an analysis was done of global governmental regulations shaped by major accidents, and local safety regulations and the gap between AIMS research and practice identified. Finally, the findings of the National Facility Integrity Audit conducted in 2016 were explored. This research was limited to organisations in the local energy sector of Trinidad and Tobago. A large gap in knowledge was identified both in AIMS and associated governmental regulation. A robust AIMS will provide assurance to organisations that major accidents which are potentially business eliminating can be averted. It is also of paramount importance to the energy sector whose contribution to GDP was 42% in 2014, making that sector the major revenue provider to the government. The focus is how to communicate a standard and consistent message of a robust AIMS, and how to ensure that it is integrated into the existing business management system. Future research can focus on testing the proposed framework developed from the gaps identified with a larger sample of energy sector companies and use the findings to develop a national framework for AIMS for the energy sectors.*

Keywords: *Asset integrity management; critical success factors; governmental regulations; process safety indicators.*

1. Introduction

Codes and Standards provide common frameworks that ensure repeatability and consistency, thereby boosting competitiveness. Over the last fifteen (15) years we have observed that even though some companies have been able to implement very rigorous Asset Integrity Management Systems (AIMS): The majority across the Energy Sector have not. Without a proper AIMS, organisations expose themselves to major accidents that may result in significant asset loss; fatalities; or even environmental consequences as have happened in the Gulf of Mexico in 2010 with the Macondo disaster. That accident resulted in the organisation losing more than US$62 billion, 11 fatalities and disastrous environmental impact (NEBOSH, 2017).

The number of oil spills recently in the La Brea Area, Trinidad and Tobago, is a direct result of a failure to ensure the integrity of the assets in the Energy Sector. These events prompted a comprehensive audit commissioned by the Ministry of Energy and Energy Industries (MEEI) on 30 Energy Sector Companies across the Upstream, Midstream, and Downstream sectors (Lashley, 2017). The primary purpose of the audit was to establish the integrity of facilities in the T&T domestic energy sector. More than 75% of oil, gas and manufacturing facilities in T&T are 'ageing, or have been retrofitted to extend their economic lives. In recognition of their ageing energy infrastructure, the upstream companies embarked on a massive maintenance program following the 2010 Macondo accident to ensure that their facilities were up to international HSE standards. In the downstream sector, companies periodically conduct turnarounds to avoid unwanted accidents (Koch, et al., 2016).

An asset is defined as a physical item and related system that has a distinct and quantifiable business function in and potential or actual value to an organisation (IAM, 2004). Integrity in this study refers to Technical Integrity (TI), which is the state of being intact or the condition of being unified or complete (Murray, 2013). TI can also be described as the overall state of confidence in terms of functionality, operability and reliability (Rahim, et al., 2010). An AIMS assesses the ability of an asset to perform its required function safely, efficiently and effectively whilst protecting health, and the environment. It ensures that people, systems, processes and resources that deliver integrity are in place, in use and will perform when required over the whole lifecycle of the asset. The AIMS should address the quality at each stage of the asset life cycle, from the design of new facilities to maintenance management and decommissioning (ISO-55000, 2014).

Trinidad and Tobago has a very rich history in oil and gas which celebrated its centennial anniversary in 2008. This southern-most Caribbean twin-island nation has enjoyed a 144-year long association with the oil industry during which the world's major energy companies have, at one time or another, been attracted to the country (Guyadeen, 2010). While oil has declined over the last 31 years, Trinidad is now a gas driven economy with the natural gas production more than quintupling in the 21-year period from 1988 to 2008, increasing by 464.1% with the bulk beginning in 1999 (Renwick, 2010). The importance of the energy sector to the economy is evident as this sector's contribution to GDP stood at 42.0% in 2014, compared to 22.7% in 1988 (Guyadeen, 2010). Placide (2010) asserts that "people must be the drivers if we are to sustain a competitive world class energy sector with deeper, broader and more complex and environmentally responsible industries."

Improved fiscal terms by the government have changed the economics of new capital investment in upstream and many of the international oil companies (IOCs) are now very interested in future growth projects in the energy sector. In 2014, deep water production sharing contracts were awarded to several IOCs. Exploratory wells drilled in the deep-water acreage to date have confirmed the presence of a working hydrocarbons system. Deep and ultra-deep-water is yet to be fully explored and can represent vast potential. Jeffrey's (2015) states that "the country and particularly the local energy sector organisations will need to greatly streamline and optimise processes, if they are to capitalise in these exploration and production opportunities, particularly in the current challenging external environment". Following the major asset damage resulting in massive oil spill and environmental damage in 2013 and 2014, and the findings of the National Facility Integrity Audit (NFIA), indicated that a robust framework for Asset Integrity Management is lacking. Based on a literature review and analysis of existing practices, this paper identified gaps in knowledge and proposes a framework for Asset Integrity Management.

2. Critical Success Factors AIMS Implementation

This research was grounded in critical success factors (CSF) as identified in the literature review and the experience gathered in AIMS implementation during the period 2005 to 2018. The review of literature drew on research from the Texas City (Hopkins, 2010); Macondo (Hopkins, 2012); journal articles (Ratnayake and Markeset, 2011; Hought, et al., 2013); ALNG AIMS Implementation (2013); CCPS Vision 2020 (2014); T&T NFIA (Koch, et al., 2016), and the Shell Global AMS Implementation (2018).

The CSFs identified for AIMS implementation were:

- Disciplined adherence to standards; performance monitoring, control, assurance and management review.
- Appropriate organisation with effective planning and communications at all levels.
- AIM as part of an integrated management system that is embedded through significant employee engagement.
- Strong, committed and visible process safety leadership.
- Intentional process safety competency and capability development. The top five areas identified as the lowest industry averages from the NFIA are perfectly aligned with these CSF.

3. Government Regulations, Major Accidents and AIMS

Sovacool (2008) reviewed major energy industry accidents from 1907-2007. The main contributors to these accidents were a combination of technical complexity, tight coupling, speed and human fallibility. These have resulted in an increase in the number of accidents particularly in the natural gas, oil and nuclear sectors, as highlighted in Figure 1.

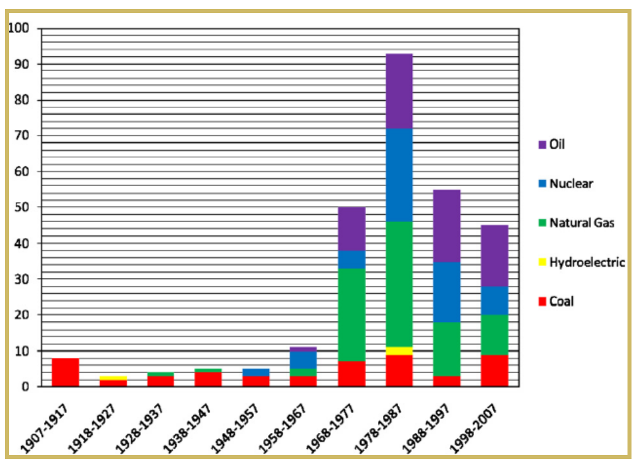

Figure 1. Energy accident frequency by decade and source
Source: Abstracted from Sovacool (2008)

This review examined the social and economic cost of major accidents. During this time 279 incidents were documented to be responsible for a loss of 41 Billion USD in property damage and 182,156 deaths. The majority of deaths, 176,134 were as a result of 3 major accidents. This is different from occupational safety which has shown a significant improvement over the years and highlights the need to prevent major accidents. It is important to remember that while natural resources bring with them great social and economic promise that provides financial growth and services for communities, the infrastructure currently in place to deliver these can surreptitiously breakdown and in rare circumstances destroy the very community it intends to serve.

This review of the social and economic cost of major accidents is important for three main reasons. Firstly, whilst dozens of indices to measure strengths and weaknesses of the energy sector have been crafted, there are no catalogued inventories of major energy accidents that look beyond individual technologies. Secondly, most studies have focused on the impact of externalities associated with energy production and seldom explore the energy accidents in detail and the cost that is inflicted on society and the economy. Thirdly, the frequency of major energy accidents depends greatly on how communities and countries manage their energy resources. Exploring where and when they occurred, drives us to start asking why and under what conditions. This review has shown that the death and destruction associated with large scale energy technologies are significant. Since it is systemic, it can be predicted to occur with certainty well into the future. Can better governance improve energy systems and prevent these failings of energy technology? We will analyse some of the Major Energy Industry Accidents that have shaped AIMS (CCPS, 2012). These are summarised in Table 1.

Lindoe, et al (2012) reviewed the governmental regulations of the UK, Norway and the US that were shaped by major accidents (Ekofisk Bravo Platform – 1977; Piper Alpha – 1988; Texas City – 2005 and Macondo – 2010), and compared the approaches taken in developing risk regulation regimes. Factors considered were the political-administrative and legal orientation, socio-cultural values, and industrial and labor relations. The empirical bases for this analysis were provided by multiple sources of information which included research

Table 1. Major accidents that have shapes AIMS

	Major accident	**AIMS Element**	**Gaps identified**
1	Flixborough (1974)	management of change and risk analysis	Hazard identification and management of change within the facility was poor, maintenance and operating procedures inadequate. Facility layout and control room design did not recognise the possibility of major disaster occurring.
2	Bopal (1984)	process safety barrier failures	Operating outside safe operating envelope, continuing operations with safeguards impaired. Critical safety systems not functioning properly.
3	Challenger (1986)	Leadership and culture	Well documented history of middle management repeated violation of safety rules, normalisation of risk and failure to communicate risk to top decision makers. Nonexistence of a strong safety culture and ineffective leadership.
4	Chernobyl (1986)	procedures	No secondary containment around reactor or the steam system, making the operations critically sensitive to procedures. The primary cause of the accident was the blatant disregard for formal operating procedures.
5	Piper Alpha (1988)	control of work	Inadequate management oversight and follow up on several outstanding issues
6	Brad Chemical Fire (1989)	audits	Previous audits had identified many of the process safety issues that contributed to the incident, but no actions had been taken to address these concerns. None of the workers were qualified to work with chemicals.
7	Castlefield – Batch Still Fire (1992)	process safety information	Lack of formal chemical data on the residue in the still. Materials not tested for hazardous properties. A management of change protocol should have been applied before any attempt was made to remove the unknown sludge.
8	Longford (1998)	training and competence	Hydrate problems and process upsets were frequently encountered but seldom reported or investigated. Hazard Analyses not conducted even though numerous changes were made. Inadequate competence in managing Cold Temperature Metal Embrittlement and process operations.
9	Tosco Refinery Fire (1999)	asset integrity	Pinhole leak on 6" Naphtha draw off line, entire line was severely corroded and had to be replaced. Change to processing scheme altered conditions within the line which was not monitored. Several serious errors made during the maintenance planning and field execution.
10	Colombia (2003)	learning from experience	Organisational contributors to the accident were normalisation of deviance; denial of vulnerability; lack of consistent, structured approaches identifying hazards and assessing risks; as with other major accidents like the Challenger (1986) and Apollo I (1967). "NASA organisational culture had as much to do with the accident as the foam". Conflict between production and safety goals.
11	Resin Plant Explosion (2003)	Physical warning signs	Management personnel were aware of the dust hazards; however, they initiated no action, and the problem was not corrected. Failure of the temperature controller and opening of the oven door to cool presented the opportunity of an ignition source for the dust cloud that was created by the maintenance activity.
12	Jilin, Benzene Plant Explosion (2005)	human factors, operating error	Incorrect execution of operating procedure during critical phase of operation. Corporate and facility management had not considered the possible consequence of major incidents resulting from failure to enforce process safety protocols - weak process safety leadership.

Table 2. Major Accidents and Phases of Regulatory Regimes

Time	Major accident	UK-regulations	Norwegian-regulations	US-regulations
1961 - 1970	Sea Gem (1965) Amoco Cadiz (1969)	Continental Shelf Act (1964)	Petroleum Act (1963)	Outer Continental Shelf Lands Act (1953)
1971 - 1980	Bravo (1977) Alexander Kielland (1980)	Mineral Working (Offshore Installation) Act (1971), Robens report (1972), HSWA (1974), Burgoyne Committee (1977)	Regulations relating to safe practices (1975 and 1976), Work Environment Act (1977)	
1981 - 1990	Piper Alpha (1988)	The Lord Cullen Report (1990)	Principles of internal control (1981), Petroleum Act (1985)	
1991 - 2000		Offshore Safety Act (1992)	Petroleum Act (1996)	
2011 - 2011	BP Macondo (2010)	Offshore Installation (Safety Case) Regulations (2005)	Revised regulations (2011)	Separation of leasing function and creation of BOEMRE agency, new prescriptive rules and SEMS rule (2010. 2011)

Source: Abstracted from Lindoe, et al. (2012)

Table 3. Characteristics of Control Components - 3 Regimes

Regime	Information gathering	Standard setting	Behaviors modification
USOCS	Legal requirement of loss time injury, oil and gas emission, but not yearly updating of safety performance data. Initiatives taken to improve voluntarily reporting	Laws and regulations with prescriptive detailed rules providing a multitude of legally enforceable requirements with industrial standards included.	Unannounced and announced inspections using detailed checklists of "Potential Incidents of Non-Compliance" (PINC). Hard policing and sanctions for non-compliance. Low involvement of workers and unions.
UKCS	Requirement to report injuries, diseases and dangerous occurrences. Yearly reports and statistics provided by HSE. The "Key program" provides important safety indicators	Goal and risk-based regulation with a detailed "Safety case" has to be qualified by independent and competent actor and approved by HSE	A flexible approach balancing enforcement with the industries choice of technology and systems to meet safety standards.
NCS	A monitoring program of safety performance based on tripartite effort has been developed since 2001. Gives priority for regulators enforcement strategy.	Coherent and integrated laws and regulations. Risk and performance based with use of legal standards with flexible interpretation and use of industrial standards.	Based on dialogue, trust based and soft instruments as enforcement strategy. Involvement of workforce, unions at national, industrial and company level.

Source: Abstracted from Lindoe, et al. (2012)

projects on the Norwegian and US approaches. The information was related to technological change, safety management and regulation, legal documentation from the countries, and key documents in the aftermath of the Macondo disaster. Table 2 summarises the interconnection and relations between major accidents and the development of the three regimes. Table 3 summarises some of the different characteristics of the US, the UK and Norwegian regimes.

Major accidents have led regulatory agencies in the UK and Norway to replace their prescriptive regulations with performance-based regulations. The US approach, however, has remained essentially unchanged with a prescriptive and technically detailed approach to their safety regulations. Following the Macondo accident in the Gulf of Mexico in 2010, the question of robust risk regulation for offshore oil and gas production facilities has had significant consideration in both the political and industrial agenda, not only in the US but in other oil and gas producing countries including Norway and the UK. The main US regulator was transformed into a successor agency, the Bureau of Ocean Energy Management, Regulation and Enforcement under the parentage of the Department of Interior. Several more stringent prescriptive rules on many aspects of deep-water drilling were imposed on existing MMS regulations based on the findings of the accident investigations and analysis. This replaced the initial moratorium that was placed on deep-water drilling through Presidential Order.

In T&T, the first HSE Regulations relevant to managing the risks around machinery, plants and hazardous process were the Factories Ordinance Chapter 30 No.2, 1950. This, however, proved to be inadequate and was replaced by the Occupational Safety and Health Act of 2004 (Ministry of the Attorney General, 2013). A significant gap still exists around asset integrity and process safety.

4. AIMS Practice and Research

Process safety indicators can provide insight into the safety of organisation processes, but a silver bullet has not yet been identified. It is also clear that indicators for occupational safety do not necessarily have a relationship with process safety. These indicators have been derived from both scientific literature (see Table 4)

Table 4. Process safety indicators from scientific literature

Process safety indicators	**Scientific literature references**
Alarms, failures, number per time period	Martorell et al. (1999), Hopkins (2009), Bandari and Azevedo (2013)
Exposure to dangerous substances/activities	Martorell et al. (1999), Sklet (2006), Kampen et al. (2013)
Process deviations, number	Sonnemans and K€orvers (2006), K€orvers and Sonnemans (2008), Hale (2009), Kongvik et al. (2010), Oien et al. (2011)
State of safety, unwanted	Grabowski (2007), Bandari and Azevedo (2013)
Incidents, number	K€orvers and Sonnemans (2008), Kampen et al. (2013)
Leakages, number, amount	Vinnem et al. (2006), K€orvers and Sonnemans (2008), Harms (2009)
Barriers quality	Bellamy (2009), Dryeborg (2009), Hale (2009), Reiman and Pietikainen (2012), Bandari and Azevedo (2013)
Fires, explosions, number, costs	Vinnem et. al (2006), Vinnem (2010), Bandari and Azevedo (2013)
Loss of containment, amount, number	Webb (2009), Bandari and Azevedo (2013)
Process design, failures, maintenance, quality control	Harms-Ringdahl (2009)
Tests, failures	Hopkins (2009)
Safety systems, frequency of activations	Kampen et al. (2013), Bandari and Azevedo (2013)
Inherent safe installations, numbers	Kampen et al. (2013)

Source: Abstracted from Swuste, et al. (2016)

Table 5. Process safety indicators in professional literature

Process safety indicators	**Professional literature references**
Alarms, failures, number per time period	OGP (2011), OGP (2008)
Exposure dangerous materials/activities	UK Oil and Gas Industry (2006)
State of safety, unwanted	OECD (2008a, b)
Incidents, number	CCPS (2011)
Leakages, number, amount	CCPS (2011), ANSI_API (2010), Cefic (2011)
Fires, explosions, number, costs	OGP (2011), HSE (2006), CCPS (2011), ANSI_API (2010), Cefic (2011)
Loss of containment, amount, number	OGP (2011), HSE (2006), CCPS (2011), ANSI_API (2010), Cefic (2011)
Process design, failures	UK Oil and Gas Industry (2006), OGP (2011), OGP (2008)
Maintenance, quality control, failures	OECD (2008 a, b), OGP (2011), OGP (2008), OECD (2008a,b)
Safety systems, frequency of activations	OGP (2011), ANSI_API (2010)
Inherent safe installations, numbers	OECD (2008a, b)
Process disturbances outside design envelope, numbers	EPSC (2012), ANSI_API (2010)
Safety systems, frequency of failure	HSE (2006), ANSI_API (2010)
Storage dangerous materials, amounts	OECD (2008a, b)

Source: Abstracted from Swuste, et al. (2016)

and professional literature (see Table 5) (Swuste, et al., 2016). Indicators are tools for safety monitoring of a system. Serious accidents are never the result of one assignable error or malfunction, but a pattern of events which have their roots in technology, the organisational and management domains. It is questionable whether such a pattern can be caught by one or a limited number of indicators. The definition of process safety indicators from both professional and scientific literature fits well together. The difference is that the professional literature focuses on improving and benchmarking while scientific literature focuses on effectiveness of barriers and safety levels.

Step change in safety of the UK Oil and Gas Industry has modified Shell's Hearts and Mind metaphor to specific leading indicators as shown in Figure 2. This H&M metaphor aspires to create a safety culture where the workforce is intrinsically motivated in HSE matters--people doing the right things naturally rather than forcing them to, resulting in lasting change. This concept of Watts Humphrey's original Capability Maturity Model with its five levels of initial, repeatable, defined, managed and optimising can further be developed to assess the effectiveness of AIMS (Paulk, 1996). Leading indicators in step change in safety are also represented by the process safety indicator pyramid (see Figure 3).

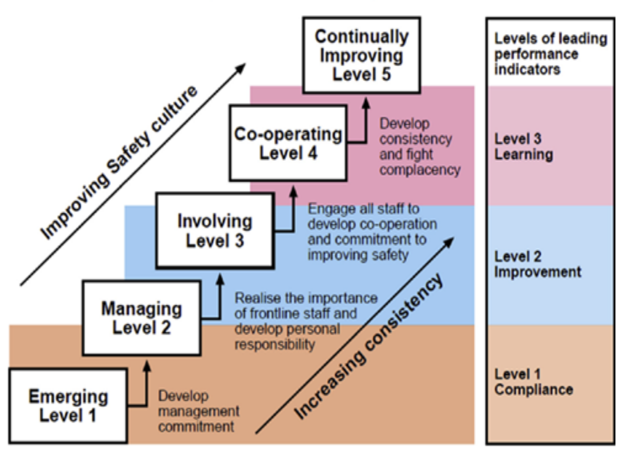

Figure 2. Safety culture maturity model
Source: Abstracted from Fleming (2001)

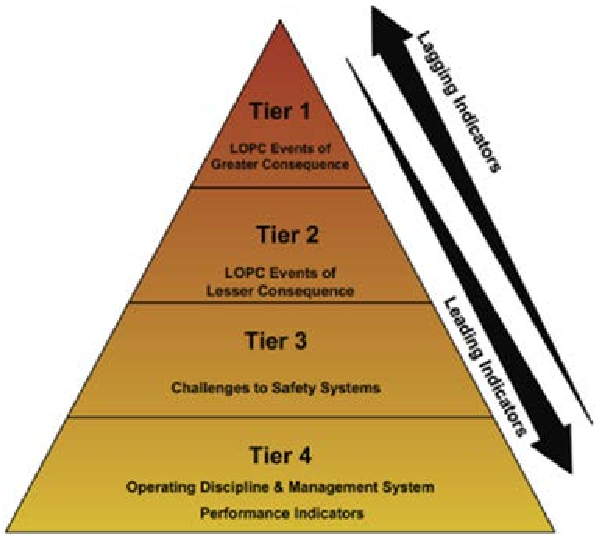

Figure 3. Process safety indicator pyramid
Source: Abstracted from ANSI/API (2010)

Whilst experienced operators can identify weak signals or deviations from their process and act upon them to prevent major accident scenarios, process safety indicators serve as an additional instrument. It shows changes in risk levels and their relationship with the effectiveness of safety management systems in place. It is premature to use process safety indicators as a predictor for future major accidents currently, as these have only been a topic in professional and scientific literature since 2008 (Knegtering and Pasman, 2013).

Risk analysis has been one sustainable approach used in AIM in practice and supported by numerous research studies (Shahriar, et al., 2012). Researchers and practitioners constantly keep looking for ways to improve how risk is managed, especially in industries where major accident hazards are a real likelihood to occur (Bigliani, 2013). Significant models have been developed to assess the health of asset integrity and risk exposure, particularly for pipelines and process piping systems. Statutory requirements demand that automated leak detection systems are installed for new and upgraded pipelines (Zhang, 1996). A major cause of pipeline failures leading to large leaks or even exposure is due to third parties either intentionally damaging the line to steal product or accidental damage by intrusion into the pipeline right of way (Nikles, 2009).

To detect and locate pipeline rupture immediately, the leakage detection method plays a key role (Yang, et al., 2011). Wireless sensor networks are also used to remotely monitor pipelines, natural gas leaks, corrosion, H2S, equipment condition, and real-time reservoir status (Akhondi, et al., 2010). Similar challenges are also possible in offshore subsea conditions and can be complicated by poor visibility (Jasper, 2012). Models for assessing corrosion risks were also developed. Corrosion pitting is recognised as the most severe type of corrosion because of the high rates at which pits can grow in pressure vessels and pipelines (Velázquez, et al., 2009). Fatigue stress initiation in pipelines has been attributed to corrosion defects which is exacerbated by cyclic loading (Ossai, et al., 2015); (Garber, et al., 2017).

Decision analysis frameworks have also been developed that incorporates structured expert judgement and analytic hierarchy process (Dawotola, et al., 2011); (Ratnayake, 2012). Risk based inspection models for pipelines (Dey, 2001), process plants, oil refineries (Bertolini, et al., 2009), as well as condition-based maintenance models for the oil and gas industry (Telford, et al., 2011) and other models have been developed with an aspiration to achieve sustainable AIMS (Ossai, et al., 2014). Corrosion can also significantly reduce the integrity of structures resulting in increased possibility of failure. To mitigate this risk a fuzzy logic-based model for predicting the rate of corrosion was also developed (Singh, 2009).

5. National Facility Integrity Audit

The audit protocol for the NFIA was derived from DNV GL's international safety rating system, 8th edition, and included the requirements of: OSHAS 18001 Health and Safety Standard; ISO 14001 Environmental Management System; ISO 9001 Quality Management Systems; ISO 55000 Standards for Asset Management; ISO 31000 Risk Management; OSHA 1910 Occupational Safety and Health Standards; and SEVESO II Directive -96/82/EC Directive on the COMAH approach. Table 6 gives the scoring methodology that was used.

The final report from the NFIA indicated that the average score of their AIMS was 1.89 (Koch, et al., 2016). Energy organisations globally and locally are expected to have a score between 3.0 and 3.5 or even better for mature assets. Such an efficient AIMS provide assurance that major accidents that are potentially business eliminating can be averted.

Table 6 Audit Scoring

Score	Stage	Stage Description
0	Learning	The activity/practice is absent or ad hoc and little awareness of the expectation is in place.
1	Developing	The activity/practice exists, although it may be incomplete and undocumented.
2	Implementing	The activity/practice is documented with implementation ongoing, but not fully mature.
3	Managing	The activity or practice is documented and effectively implemented.
4	Optimising	The activity or practice is effective and efficient. Visible continuous improvement culture/efforts are in place.

Figure 4 gives a comparative analysis of some of the core variables that is the focus of this study. The biggest gaps between the best in class and lowest performing sub-sector are in the areas of risk management; training and competence; leadership; and asset management (systems and processes). The best performing sub-sector is the IOC Downstream. Figure 5 gives the overall sector's performance on the systems audit and equipment audit. The best performance organisation in the Systems Audit scored 3.7 above the national average of 2.02 and is clearly at the optimising phase. The least performing organisation scored 0.19 and is at the learning phase. Similar trends were observed for the Equipment Audit.

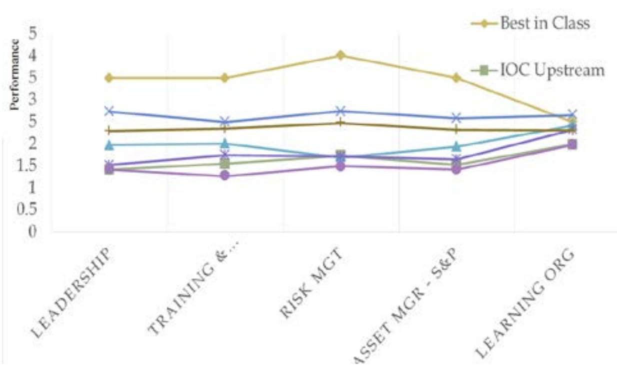

Figure 4: NFIA performance of the five worst overall performing AIMS elements across the Energy Sector.

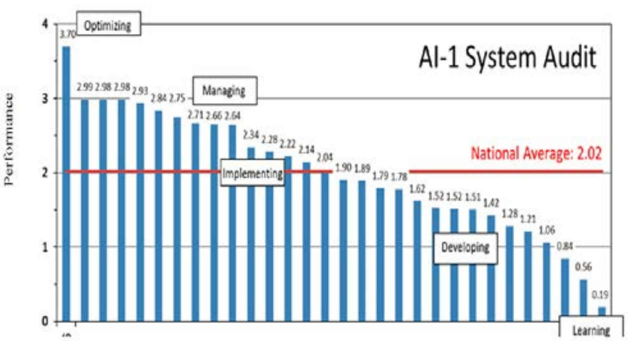

Figure 5: Performance of local energy sector organisations in the AIMS Audit
Source: Abstracted from Koch, et al. (2016)

The performance of the AIMS showed a wide variation across the industry, due to a lack of a common standard. The Equipment Audit showed a wide variation in the apparent management and condition of the assets across the industry. Joint Venture companies generally had the highest scores. There is a need for a common understanding and definition of Asset Integrity (AI) and AIMS. In many cases, company programs, analysis and trending of data are more developed and detailed for personal safety (HSE) than for AI. There is a lack of specific milestone targets and AIMS integration. Moreover, the industry is not effectively sharing best practices. Risk ranking and prioritisation policies for repair/replace decisions are almost nonexistent (Koch, et al., 2016)

Based on these findings the following questions arise: Why is there such a wide variation across the industry in the performance of AIMS? Why do joint venture owned companies generally have the highest scores? How would a common understanding and definition of AI and AIMS improve AIM implementation? Why are company programs for health, safety and environment (HSE) more developed than programs for Asset Integrity, and analysis and trending of HSE data more detailed than that of AI data? Why is the industry not effectively sharing best practices in AIMS? Some of these questions would provide a good basis for developing a national asset integrity management framework that can be sustainable if implemented successfully, effectively raising the competitiveness of energy sector organisations.

The findings of the NFIA have helped the Ministry of Energy and Energy Affairs shape the national vision for AIMS with the four aspirations (Lashley, 2017):

1) An enhanced standing for T&T as an active and competitive center for oil and gas exploration and production, and petrochemical industry development, committed to AIM on par with or exceeding other successful oil and gas producing countries, like the UK, USA and Norway.
2) Creating an environment where all operators effectively and consistently manage the risk of failure throughout the life cycle of any structure, plant, equipment, or system to prevent or limit the effect of a major asset integrity incident.
3) Total involvement and commitment of stakeholders at all levels, united in the belief that effective management of asset integrity is crucial to T&T maintaining and growing its position with respect to the oil and gas sector.
4) Realisation of a significant downward trend in the number and severity of AI-related incidents and ultimately achieving the shared vision of zero incidents.

6. Comparing Global and National AIMS

A comparison was made between the global and national AIMS that have been implemented in the energy sector to determine if it correlated with the findings of the NFIA. This finding stated that many local companies do not perform benchmarking of their asset integrity programs against industry peers or other high hazard industries. The organisations looked at were: National Energy Companies (The National Gas Company, Petrotrin); local joint venture companies (Atlantic LNG; Phoenix Park Gas Processers Ltd (PPGPL); local subsidiaries of international companies (e.g., bpTT, bgTT, STTL, PLNL, and PCS); International Energy Companies, BG, Chevron, Exxon Mobil, Shell, Woodside; global energy sector organisations (CCPS, DNV, and OGP).

The four strategic pillars used for the comparison were people, plant, process and performance. Under the people pillar the main themes were: 1) leadership, commitment and accountability; 2) organisation, competency and capability development; 3) third party resource management; and 4) external stakeholder management. The immediate gaps seen for the IOC sample were themes 3 and 4. The NFIA identified low industry averages in themes 1 (2.01) and 2 (2.01), in fact theme 4, was not even assessed. There is therefore a need to continue to study the requirements of the people pillar. Under the plant pillar the main themes were: 1) safe and secure operation; 2) asset integrity equipment care management; 3) license to operate; and 4) facility optimisation and value creation. A clear gap for the IOC sample was not obvious. However, the NFIA identified low industry averages in theme 2 (2.00). This element of the plant pillar should therefore be revisited.

Under the process pillar the main themes were: 1) hazard and effect identification and risk management; 2) management of change; 3) records and information management (Yeoh, et al., 2008); and 4) learning from events and knowledge management. No clear gaps were identified under this pillar for the IOC sample. However, the findings of the NFIA indicate a further need for research in themes 1, 3 and 4. Under the performance pillar the main themes were: 1) strategy, business and integrated activity planning; 2) performance measurement, monitoring and reporting; 3) compliance, assurance and management review; and 4) quality management and continuous improvement. It is immediately evident that there is a big gap in theme 1 not only for the IOC sample, but also for most of the other AIMS. To a lesser extent there is also a gap for theme 3. The findings of the NFIA also correlate with this, in fact the two lowest industry averages were themes 1 (1.83) and 2 (1.84). There's therefore a definite need to continue researching these two requirements of the performance pillar.

7. Discussions and Conclusions

It is well established that a robust asset integrity management system can prevent major accidents in the energy sector. Making these organisations more sustainable will increase the competitiveness of the local economy. However, the research identifies a large gap in knowledge of how to implement a robust AIMS. The main areas to focus on include how to communicate a standard and consistent message of what constitutes a robust AIMS, and how to ensure that it is integrated into the existing business management system. It is also important to distinguish between occupational and process safety and to ensure that the right type and level of key performance indicators (KPI) are measured to determine the health of the AIMS and process safety in the sector (Pasman and Rogers, 2014).

The research corroborates the major findings and gaps identified in the NFIA audit; the identified critical success factors in AIMS implementation (Yeoh, et al., 2008); the major recommendations from literature; and the aspiration and vision for AIM in the industry by global organisations. The five major recommendations identified in this study include:

1) The need for Energy Sector organisations to adopt a disciplined adherence to AIMS specific standards-performance monitoring; control; assurance; and management review.
2) Ensuring that the Energy Sector organisational structures are realigned to deliver the AIMS with effective planning and regular communications at all levels.
3.) Integration of the AIMS in the Energy Sector organisations as part of the overall business management system that is embedded through significant employee engagement.
4) Building and sustaining a strong, committed and visible process safety leadership in Energy Sector Organisations where executives are personally involved, managers and supervisors drive excellent execution every day, and all employees maintain a sense of vigilance and vulnerability.
5) Establishment of intentional process safety competency and capability development in Energy Sector Organisations, to ensure that all employees who impact process safety are fully capable of meeting the technical and behavioural requirements for their jobs.

Recommendations from the NFIA audit only covered a portion of the local energy sector. The next step of this research therefore is to conceptualise a framework for AIMS based on the gaps in knowledge identified and the professional and scientific literature reviewed. This framework will then be tested by collecting data through surveys and interviews of AIM practitioners and senior organisational leaders in the energy sector over a greater sample. The findings can then be used to develop a national framework for AIMS for the energy sector.

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