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Review

A review of the offshore oil and gas safety indices

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ABSTRACT

Derivation of a performance index demonstrating integrated safety achievement of offshore oil and gas platforms has not been subject to extensive study. The indices proposed and adopted thus far are related to inherent safety and chemicals used in processes, with focus placed on the conceptual and design stages. Safety of offshore installations is a combination of asset integrity and personal safety, driven by organizational culture. Asset integrity covers process safety, structural integrity as well as aspects of safety climate dealing with personnel management such as training and competence. Indicators for various aspects of platform safety have been separately proposed in multiple studies. It would be significant to develop a composite index linking the major aspects of safety including the cultural and climatic factors to provide a more representative picture of platforms' safety performance. This also facilitates performance benchmarking and continual improvement of safety management on the platforms. The adoption of leading indicators is crucial to drive and monitor inputs into the safety system. For the index to ultimately be meaningful, effective and easily understood, the underlying indicators should be specific, measurable, achievable, relevant, timely, evaluated and reviewed.

1. The definition of index

An index is fundamentally a means to present a measure of interest numerically using relevant indicators. The measure of interest can be performance, productivity, risk-level or sentiment. (Färe et al., 2004). Indices have been used for a myriad of subjects, for instance, to compare sustainability of cities (Mori and Yamashita, 2015), stock performance (WSJ Market Data Group, 2017), health and safety performance (Tang et al., 2017), air diffusion performance (Liu et al., 2017), environmental performance (Hsu and Zomer, 2016) and myocardial performance (Olson et al., 2016), to name a few.

With emergence of diverse indices measuring different subjects, many have argued whether the numbers presented by the indices carry much weight and significance (Jacobs et al., 2004; Saisana et al., 2005; Saltelli, 2007). A good index presents information efficiently, succinctly and meaningfully, thus enabling the audience to quickly get the necessary message for decision-making (Khan and Amyotte, 2004). An index is closely tied to the criteria or indicators constituting the index. In certain instances, an index only has one indicator such as the lodging index whose sole indicator is the average revenue per room-night (Wassenaar and Stafford, 1991). In other instances, an index is based upon multiple indicators, for example the DOSE index, which assesses the risk of chronic obstructive pulmonary disease, uses four criteria, i.e. dyspnea, airflow obstruction, smoking status and exacerbation frequency. These indices are also known as composite indices (Jones et al., 2009).

As indices are as good as the indicators adopted, the indicators are usually selected to fulfil the SMART criteria. SMART stands for specific, measurable, achievable, relevant and timely. Indicators should be specific in the domains measured or represented, measurable by permitting presentation of quantitative data, achievable in the sense that the data needed can be obtained via day-to-day operations, relevant where the indicators are realistic and related to the underlying aspects of interest, and timely to permit tracking of trends and quick response to deviations (Jacobs et al., 2004). The SMART criteria have been expanded to SMARTER with E symbolizing evaluated and R symbolizing reviewed. The additional criteria imply that index development and use should be a dynamic process with the underlying indicators constantly evaluated and reviewed for their 'SMARTness' (Yemm, 2013).

Indicators have been popular in the field of safety especially in sectors with high risks. The reason is the need to capture data which reflects safety performance and allows preventive and corrective actions to be initiated (Øien et al, 2011). In safety, the most common indicators are fatality rates, injury rates as well as frequency of fire and explosion. These indicators paint an immediate picture of how a sector is performing in terms of safety (Vinnem, 2010; Reiman and Pietikäinen, 2012). Ironically, while the industry endeavors to uphold safety by preventing fatalities and injuries as far as reasonably

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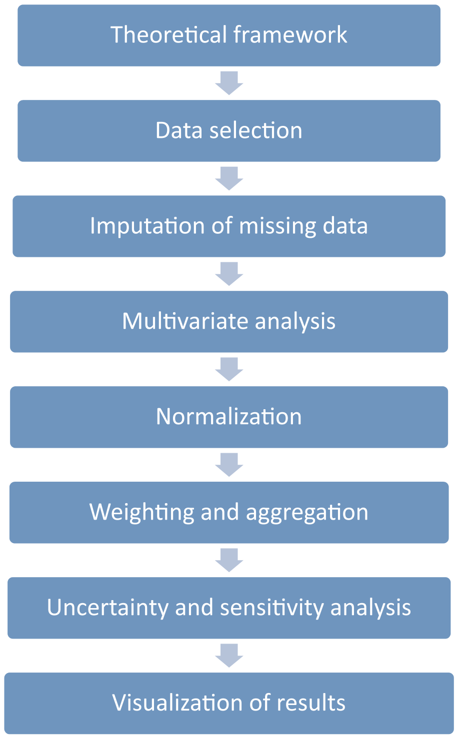

Fig. 1. Composite index development process.
adapted from Nardo et al., 2005

practicable, these indicators are only made possible with the occurrences of incidents causing injuries and fatalities. Often, these indicators are called the lagging or reactive indicators due to the nature of information they present which comprises the safety outcomes (Vinnem, 2010). These indicators create an immediate sense of alertness and prompt actions to be taken to improve safety but they do not monitor the effectiveness and adequacy of actions taken. This leads to the rise of leading indicators for safety which drive or monitor the effort and inputs into a safety system (Lauder, 2012).

Ideally, for safety, a composite index, if developed, should include both lagging and leading indicators with the SMART or SMARTER features to provide effective representation of a system's state of safety. Having said that, it is worthwhile to look at how a composite index is developed.

2. Method of index development

Development of a composite index generally follows the sequence shown in Fig. 1.

Theoretical framework involves determining the area or phenomenon to which an index applies, the domains or sub-domains governing the phenomenon, and the methods for development of the index (Nardo et al., 2005). Once the phenomenon prompting an index is determined, data selection follows during which indicators for measurement are selected based on SMART, i.e. specific, measurable, achievable, relevant and timely (Jacobs et al., 2004). Often, the indicators selected may require different presentation of existing data or collection of new data which could be expensive and impractical. Imputation of missing data accounts for such situations whereby the missing or expensive data are substituted with comparable ones (Royston, 2004). Multivariate analysis aims to establish the weights of and statistical correlations between the indicators. It enables clusters of inter-related indicators to be identified. This stage also examines internal consistency of indicators to minimize outliers. Common multivariate analysis comprises principal components analysis, Cronbach alpha and cluster analysis (Hair et al., 2006).

As indicators may require multi-dimensional data in diverse forms with different units, converting the data into a comparable form is crucial. This is achieved via normalization. The simplest method of normalization is ranking where performance over time is presented as relative positions or ranks (Nardo et al., 2005). Information and Communications Technology Index was normalized via ranking (Fagerberg, 2001). Safety scores in the oil and gas sector are often normalized by means of qualitative categorical scale. A typical example of qualitative categorical scale is the traffic light system with red indicating non-compliance or major failure, amber representing partial compliance or isolated failure, and green representing compliance (HSE, 2008).

Though indicators of an index are, in many instances, assumed to have equal weights, in reality they are not. Assigning unique weights to indicators enables more important indicators to have greater influence on an index (Munda and Nardo, 2005). Weights can originate from survey of the indicators conducted among subject experts or the public, as well as statistically via principal component analysis based on existing data (Nardo et al., 2005). Having assigned weights to indicators, performance of the indicators needs to be brought together for index generation via aggregation. Selection of aggregation methods depends on the tolerance for compensability among indicators. Linear and geometric aggregations permit compensability while multi-criteria approach deters compensability. Non-compensability prevails in aggregation of indicators with highly dissimilar dimensions for instance sustainability indices combining the triple bottom lines where it is arguable whether increased economic performance can compensate for higher pollution (Munda and Nardo, 2005).

After an index is developed, it should be tested for sensitivity and uncertainty as a means of continuous improvement. Uncertainty permeates all stages of index development and prompts a constant review of the indicators, methods of normalization, weighting and aggregation as well as quality of data collected (Saisana et al., 2005). Sensitivity analysis not only tests the robustness of an index via alteration of variables one at a time to examine their effects on the index, it also probes how uncertainties affect the index. Finally, a robust index has to be communicated in a meaningful way to the stakeholders, to serve its purpose. Visualization of the findings is worth a careful thought. Often, well-designed graph can convey the message more succinctly than numbers merely (Saltelli, 2007).

3. Safety of the offshore oil and gas sector

Conventionally the oil and gas sector has been regarded as a high-risk sector, particularly the offshore sector where workers face not only process hazards associated with the exploration, storage and processing of hydrocarbons on platforms but other forms of hazards related to the harsh working environment and transportation (Broni-Bediako and Amorin, 2010). It is generally agreed that there are two overarching domains governing the offshore safety, i.e. personal safety and process safety (Swuste et al., 2016). Personal safety deals with matters related to chemical and noise exposure, ergonomics, exposure to mechanical and electrical hazards to name a few, resulting in injuries and fatalities of workers (Mearns et al., 2003; Mearns and Hope, 2005). Process safety, however, concerns major hazards of the oil and gas installations particularly major spills, fire and explosion leading not only to injuries and fatalities, but property and environmental damage (Knegtering and Pasman, 2009; Swuste et al., 2016). The consequences of a process safety event are usually, more severe than those of a personal safety event, potentially involving multiple injuries and fatalities (Knegtering and Pasman, 2009).

In many instances, the term 'process safety' is used interchangeably with 'asset integrity'. Asset integrity aims to monitor whether an asset can perform to its desired function to safeguard safety, health and environment (HSE, 2008; Lauder, 2012), and comprises three main areas, i.e. structural, operational and technical (Frens and Berg, 2014). Asset