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Investigation of stakeholders' awareness and adoption of Inherently Safer Design (ISD) principles in South African utility industry projects

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ABSTRACT

The paper examines the level of awareness of stakeholders in adopting Inherently Safer Design (ISD) principles in the Project Life Cycle Management (PLCM) of South African Energy utility projects. It seeks to understand whether stakeholders in the latter stages of the Project Life Cycle are competent to make design change decisions on these projects. ISD principles are essentially useful for reducing risks and as such, safety experts have acknowledged it as an excellent approach in the design process. However, there are no known efforts to date that attempt to integrate ISD concepts into PLCM. This paper seeks to fill this gap. This study, through the review of extant literature establishes that ISD principles can be used in project procurement, and adopts a quantitative survey approach in obtaining information from stakeholders in the South African utility industry. Findings reveal that the principles of inherent safety are permeating into the management of South African utility projects but the level of awareness and its adoption are below optimal levels. It also emerged that there is a divergent awareness of ISD strategies amongst PLCM stakeholders and that the design engineers are better informed about the ISD approach of eliminating risks and hazards in the industrial systems studied than other stakeholders. The findings also indicate that the level of awareness of stakeholders of ISD principles is greater within earlier project phases. Based on these findings, the paper concludes that the hazards witnessed within the project execution and finalization phases could be as a result of the low levels of awareness, divergent views and lower use of ISD strategies by PLCM stakeholders. It is suggested that the level of awareness of the principles, concepts, basics and benefits of integrating ISD into PLCM be raised amongst stakeholders functioning within utility industry project procurement in South Africa and that design changes be limited to the earlier phases of utility project procurement.

1. Introduction

The concept and principles of Inherently Safer Design are (ISD) as old as nature itself, except that the principle was not identified with the name; rather, it was acknowledged as a good design and a method of eliminating hazards and minimizing risks (Hendershot, 2011; Kletz & Amyotte, 2010). Inherently Safer Design, according to Hendershot (2011), is an attitude for addressing safety issues in the design and operation of facilities that use or process hazardous chemicals. However, in spite of the obvious potential advantages of ISD with respect to cost savings, as well as safety, health and the environment (SHE) (Heikkila, 1999), it is rarely applied in utility companies, especially in the African context. The essence of the principle is to minimize hazards or eliminate risks in the design process. More importantly, the early design stage, which affords a review process, offers the greatest advantage to integrate and incorporate ISD principles, helping to reduce hazards and eliminate risk as well as to improve cost savings.

It is common knowledge that inherent safety in design is mainly about eliminating or reducing risks and improving health and safety in the process at the every opportunity as early as possible in the planning and design stages of a Project Life Cycle (PLC) (Amyotte, Pegg, & Khan, 2009; Kletz, 1984). The PLC can be described as a logical sequence of activities required to achieve the goals or objectives of a project irrespective of its scope or complex nature. Hence, ISD can be adopted to offer vigorous and reliable risk management throughout the PLC by making the process easier and more cost effective through the exclusion of the need for expensive

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safety systems and procedures (Hendershot, 2011). This supports the earlier assertion of Mansfield and Hawksley (1998), who contend that if the process is made easier, simpler, smaller or less hazardous in nature, it can be cheaper to build, operate and maintain and, in the long run, that it can enhance business performance and meet the desired safety requirements.

Presently, there are few specific obligations and regulations in the utility industry in South Africa in regard to health and safety issues in design and construction as well as the awareness that designers can have a positive influence on safety through their design. Inherent-safety concepts acknowledge that process hazards should be identified as early as possible, starting from the process development and design stages (Kletz, 1984). Hackitt (2013) asserts that ISD is a principle which can be used during certain "windows of opportunity" in the life of any project or facility. Hence, consideration for safety throughout the entire project life cycle in the context of ISD will make a positive difference and further facilitate the most efficient usage of the principle in obtaining safety in construction as well as other risk mitigation methods and strategies (Hendershot, 2011). However, from project management or construction perspectives, the principle of inherent safety in design is a key issue in the Construction Design and Management Regulations. Central in the objectives of these regulations is the safety consideration of people engaged in projects beyond the construction phase, and to incorporate into the design the means for utilizing, operating, maintaining and ultimate demolition of the facility more safely (Hackitt, 2013). This paper thus examines the knowledge and level of awareness among stakeholders in the South African utility industry of the use of ISD in identifying and eliminating hazards, assessing and mitigating inherent risks in the various PLC phases to enhance personal safety of operatives involved in the construction process.

2. General background

When an idea begins to be pursued as a project, there is a process life cycle or various stages that the project must go through until construction is complete or until the launch of a product and beyond. The delivery process consists of various phases of the Project Life Cycle Model such as the (i) Review Opportunity phase, (ii) Pre-project Planning phase, (iii) Concept phase, (iv) Definition phase, (v) Execution phase, (vi) Finalization phase, and (vii) the Benefit Realization phase (Cooper, 2001; Eskom, 2010). Cooper (2001) regards the Project Life Cycle Management (PLCM) or stage gate model as one of the fundamental processes for strategic solutions and decisions. PLCM is a project management methodology that has several phases and stage gates that can be made adaptable to the size of an organization as well as to technical and business practices (Nicholas & Steyn, 2008).

Nicholas and Steyn (2008) elaborate that projects vary with regard to their complexity, resource needs, risks, and uncertainty. According to Gupta and Edwards (2002), the public has a poor image of the process industry because of its larger number of hazards. They posit that the increasing use of Inherently Safer Design (ISD) will reduce these hazards and improve the public image of the process industry. The application of Inherently Safer (IS) principles and philosophy to every stage in the process life cycle has been established as capable of reducing risks and as being economically appealing for process plant procurement (Rusli, Shariff, & Khan, 2013). The Center for Chemical Process Safety (2009) defines ISD as an iterative process that allows safety to be built into a process or product but not added on. ISD considers options such as eliminating hazards, reducing hazards, substitutions with less hazardous material, using less hazardous process conditions, and designing a process to reduce the potential for, or consequences of, human error, equipment failure, or intentional harm. ISD implies that the safety aspects of a system have been addressed at the design stage (Gupta & Edwards, 2002).

The concept of ISD was developed by Kletz (1991) using the following elements: substitution, minimization or intensification, moderation or attenuation, simplification, limitation of hazardous effects, avoiding knock-on effects, making incorrect assembly impossible, making statuses clear, tolerance, ease of control, and administrative controls/procedures. These ISD elements were classified by Kletz into four risk management strategies with an aim of minimizing risk: (i) Inherent (safety 'built in', not 'added on'), (ii) Active (control, prevent, or mitigate the consequences of incidents), (iii) Passive (minimize hazards using process or equipment design features), and (iv) Procedural (safety standards, rules or procedures) strategies. Gupta (2000) identified three strategies (i.e., Active, Passive and Procedural) as categories that can be related to current practices or operations (e.g., control, prevent, and mitigate), while an 'Inherent' strategy implies that they are present in the system as permanent and inseparable.

2.1. Motivation for the research

Evidence from the extant literature indicates that nuclear power plants are a high safety risk environment if there is no systematic ISD framework in place because they are more susceptible to hazardous events or scenarios (Edwards & Bowen, 2005). These events or scenarios have undesirable consequences on the project life cycle and system safety integrity levels, which lead to accidents, production loss, property damage and loss of life (Reuters, 2013). Moore (1999) established that in the power generation and nuclear industries, there is a lack of documented methods for integrating ISD concerns into safety management processes. Furthermore, Moore (1999) and Cooper (2001) established that there is a lack of safety experience and knowledge apparent amongst many of the stakeholders who are to apply these principles, tools and techniques in the early phase, or Project Front End Loading, and in the latter stages of PLCM. In addition, studies have also demonstrated that project initiators, project managers, project engineers, design engineers and senior managers are not aware of systematized methodologies, do not apply process hazard analysis to project designs and fail to include inherent safety into PLCM (Gupta & Edwards, 2002; Hassim & Hanafi, 2012; Moore, 1999). This is aligned with the findings of Heikkila (1999) and Khan and Amyotte (2005), which indicated that stakeholders are not aware of the applications and limitations of ISD tools within PLCM. These findings, according to Moore (1999), increase the risk levels and, according to Gupta and Edwards (2002), indicate that ISD has a lot of ground to cover to achieve its due prominence in design and analysis. This paper therefore investigates the level of awareness and adoption of ISD strategies among South African energy utility industry stakeholders using a project management approach.

3. The need to implement inherent safety in the project life cycle

It has been estimated that the world's energy consumption will increase by 56 percent (US Energy Information Administration, 2013). To meet this growing demand, there is a need for the construction of new power and process plants. In South Africa, electricity demand is increasing, and industry requires the replacement of existing power stations that are aging to meet the estimated 20,000 MW demand over the next 15 years (Inglesi & Pouris, 2010). The extension or replacement of existing plants and new construction depict a need for structures, techniques and infrastructure that support the management of risks, safety, costs and regulatory compliance for plant projects (IBM, 2014).

As a result, utility companies that require the replacement or extension of existing plants as well as the construction of new power plants may encounter numerous unusual problems such as the management of a highly complex project, unrelated procedures, changing stakeholders, highly controlled industry environments, unexpected delays and increased costs (IBM, 2014; McKenna, Wilczynski, & VerderSchee, 2006). According to Hurme and Rahman (2005), plant design processes undergo a series of phases of the life cycle irrespective of their complexity such as research and development, design, construction, operation, modification, and finally, decommissioning. This study views both the design and construction of supporting infrastructure as a project that requires a sequential process to achieve the overall objectives of the project. Because the main objectives of adopting ISD are to develop a process that is safe, economically viable and environmentally harmless (Hurme & Rahman, 2005), energy companies that have insight into the required information and actions at each phase of the project life cycle can efficiently mitigate risks, eliminate hazards before they occur and enjoy the important benefits of cost savings by bridging the gap between the design, construction and operation phases (IBM, 2014). Therefore, this study acknowledges that the adoption of ISD throughout the project life cycle will provide the best opportunities for implementing inherent safety in design to enhance personal safety.

4. Overview of Project Life Cycle Management, ISD principles and knowledge among stakeholders of ISD principles

The manner and approach of managing a project have changed over time, and many organizations in this new era have learned how to manage their projects and reduce risks in a better way with less paper work by utilizing different approaches such as ISD (Labuschagne & Brent, 2005; Rusli et al., 2013). However, Kerzner (2001) asserts that one of the approaches in project management involves having a better knowledge of the project life cycle phases and adopting suitable risk management methods. According to Patel and Morris (1999), the life cycle is the only thing that distinctively distinguishes projects from non-projects, and it is the series of phases through which the project will progress. Allen (cited in Wideman, 2004) considers the project life cycle in terms of time dimensions and thus views the principle as ‘Major Management Phases’ of nearly any type of project and recognizes that project management functions and their applications often change as the project progresses through the different phases of its life cycle. Bonnal, Gourc, and Lacoste (2002) posit that a variety of project life cycle approaches have been identified in the extant literature, including quality-oriented, control-oriented and risk-oriented models, some of which are company-specific project life cycles, in addition to a fractal approach to the project life cycle.

The number of phases identified, including the terms adopted in describing the phases in each of these approaches, varies, and because of complexity and diversity of the nature of industrial organizations and projects, a consensus cannot be reached on describing the life cycle phases of a project (Kerzner, 2001). According to Wideman (2004), this incongruence in the classification of project life cycle phases is partially due to some researchers considering a project as a process, whereas others view it as a product. However, a requirement for effective Project Life Cycle Management is an unambiguous understanding of the different life cycles involved in a project and their interactions. This will permit all the project roles and responsibilities as well as the project planning, estimating, scheduling, monitoring, and control methods and tools to be appropriately related to the overall Project Life Cycle Management process (Archibald, 2003).

4.1. Alignment of project management process areas with ISD principles

The PLCM phases are classified into the seven phases shown in Fig. 1, which is modified from earlier studies by Hurme and Rahman (2005). In the first of these phases, which includes the review opportunity, pre-planning and concept phases, the ISD strategy “Inherent” is applicable, and there are a large number of opportunities to apply the ISD principle to “minimize” or reduce hazards by using safer materials and operating conditions, to minimize inventory, and to design a simpler and friendlier plant (Palaniappan, Srinivasan, & Tan, 2004). At the concept/preliminary design phase, the process flow diagram is developed to completely minimize (intensify) risks (first ISD principle) (Hurme & Rahman, 2005), and the process flow sheet, process instrumentation diagram (PID), and the equipment specifications are developed (Heikkila, 1999; Hurme & Rahman, 2005). For example, Kidam and Hurme (2012a) have established that poor layout designs and unsuitable materials are responsible for piping failures.

The ensuing phase wherein the solution to the project problems or opportunities identified earlier are further developed so that all the necessary steps are taken to achieve the project's objective is called the definition phase. The most effective tool that is used at the pre-planning phase toward the definition phase is the Work Breakdown Structure (WBS), which is a part of project management planning when a new project has been initiated (PMI, 2008). Westland (2006) acknowledges that this is the phase in which all project stakeholders should be identified and at which time a plan for communicating and describing the information and techniques required by the stakeholders for the effective delivery of projects should be established. Furthermore, according to Archibald (2003), this phase involves the feasibility study, project development, demonstration, design prototype, the quantification. It also includes the provisioning of quality management and assurance and the establishment of control measures along with an acceptance plan to clearly define the client's requirement (Westland, 2006). At this definition phase, the ISD strategy “Inherent” can be applied with the ISD principle “minimization”, which involves the replacement of hazardous tasks or activities with less hazardous ones.

During the execution phase, the planned project is implemented, and the identified tasks are performed. Archibald (2003) argues that the execution phase consists of the actual implementation of the plan, production, the adequate deployment of resources, design/construction/commissioning, installation and testing. During the project execution phase, stakeholders are to execute tasks and ensure that progress is being documented and reported through intermittent stakeholder meetings. One of the most important hazard assessment tools that DowellIII (1998) and Heikkila (1999) recognized as useful at the execution phase during the detail design is the HAZard Operability Analysis (HAZOP). HAZOP is a technique used for identifying safety management failures and safety cultural factors that cause these failures (Blanquart, Astruc, Baufreton, & Boulange, 2012; DowellIII, 1998). At the Execution phase, fewer opportunities to apply ISD principles exist, and the applicable ISD principle is “moderate”, which involves attenuation, detail changes, operating parameters and passive safety design approaches. An example of this includes reducing failures through appropriate analysis, protection equipment and the use of correct instrumentation to control the process (Heikkila, 1999; Kidam & Hurme, 2012b). According to Hassim and Hanafi (2012), moderation means using less hazardous conditions or less hazardous forms of a material.

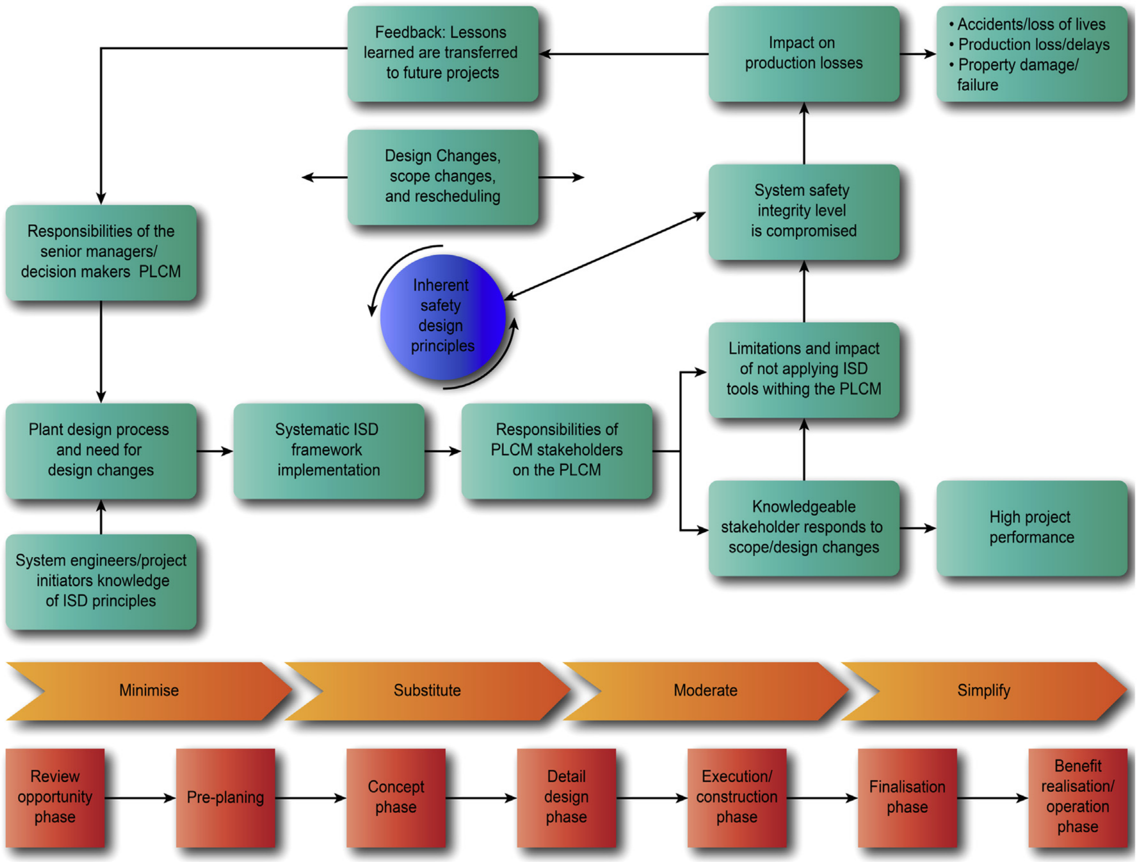

Fig. 1. Conceptual framework of the study.

At the final and closure or closeout phases, the emphasis is on handing over the final project to the owner. This includes releasing all the project documents to the client with the subsequent termination of supplier contracts and the handing over of project resources and the communication of the completion of the project to all stakeholders. The final part of this stage is the post-project review, which identifies what went wrong and what was done well so that lessons learned can be transferred to future projects to avoid committing the same mistakes in future projects (Archibald, 2003; Westland, 2006). Similarly, after the execution phase, all the risk management strategies (Inherent, Active, Passive and Procedural) are applicable during commissioning and plant operation, while the ISD principle "simplify" can be adopted to permit added-on safety: better design and passive controls rather than active controls. During the plant operation phase, a number of design changes emerge, whereby some changes are initiated during the incident investigation process. Gupta and Edwards (2002) established that simplification entails revising/clarifying ambiguous operating instructions to reduce incorrect actions.

4.2. Knowledge among stakeholders of ISD principles

Considering that there are different types of projects based on their complexity, Edwards and Bowen (2005) discussed the need for all PLCM stakeholders to have sufficient risk awareness and project risk management competencies, especially when making decisions. Edwards and Bowen (2005) and Nicholas and Steyn (2008) provide examples of complex projects such as mega projects in the nuclear, aerospace, power station, and railway industries that require substantial capital budgets, where most financial decisions involve public, legal, government, and other stakeholders. It is in this environment that appropriate and effective project risk management, communication and investment appraisal tools need to be used to facilitate effective decision making (Dasgupta & Pearce, 1974; Edwards & Bowen, 2005; World Nuclear Association (WNA), 2012).

Each project has a core project team of stakeholders that includes the project initiator, the project manager, project engineers, design engineers, and senior managers (PMI, 2008). The participation of project stakeholders is vital within PLCM to ensure that ISD principles are adequately applied. Nicholas and Steyn (2008) state that with diverse organizational structures, project initiators or system engineers are mostly expected to perform project management duties during the project concept phase. Therefore, these stakeholders and senior managers are expected to have full knowledge of risk management tools (Cooperation in Reactor Design Evaluation and Licensing (CORDEL), 2012).

According to Kessides (2012) and WNA (2012), the practices or rules at a nuclear power station differ from fossil fuel and other power generation stations in regard to safety design principles. Rules in the nuclear industry are particularly strict in a manner such that design engineers are the ones that are mainly responsible for safety design processes (CORDEL, 2012; WNA, 2014). Design engineers ensure that safety scenarios are compiled for each safety-related project or modification as well as being in charge of reviewing all designs to ensure that National Nuclear Regulator (NNR) requirements are met (CORDEL, 2012). The concern is that this occurs later in PLCM at the definition phase. Furthermore, the design engineer might have no control over design and scope changes that project managers, system or production engineers, project initiators and clients bring about at later stages of PLCM (Cooper, 2001; Eskom, 2010). These changes are approved by senior managers who are unaware of the ISD principles, which are applicable at the early stages of PLCM (Cooper, 2001). The common concern that arises is that PLCM stakeholders are not aware of the application and limitations of ISD tools within PLCM (Heikkila, 1999; Khan & Amyotte, 2005).

4.3. Responsibilities of project stakeholders and senior managers in PLCM

Nicholas and Steyn (2008) determined that little is known in regard to the scope of the project, especially within a diverse organizational structure. Project initiators or system engineers are primarily expected to perform project management duties during the project concept phase. For example, it was found from the Bhopal plant accident that ignorance over the importance of design change requirements was due to delays in senior managers' decision-making processes (Edwards, 2005). These design change requirements are implemented either as a result of previous operating experience or accidents or from identified opportunities. The WNA (2008) reports that nuclear projects are unique and capital intensive and have longer project timelines. Project stakeholders need to ensure that the project scope and design or technology are understood in utility projects to reduce rework/scope changes or redesigns and prevent accidents from occurring because, according to Nicholas and Steyn (2008), utility/nuclear projects are complex.

Leveson (2011) raises the issue that new technology must be simpler because the complexity in safety engineering systems is mostly encouraged through design changes as a solution to a problem, which can end up as an 'accidental complexity'. Accidental complexity results from a suboptimal approach chosen to solve problems (Holt, 2004). This may occur during a developmental process that is considered unnecessary to a problem's resolution. In addition, Hopkins (2011) argues that decision making within PLCM is taken as non-operational decisions that impact safety because it involves planning, design and investment decisions. Hopkins (2011) reckons that to reduce accidents in hazardous industries, the controversial issues of converting risk management into rule compliance are vital. This means that senior managers or any decision-making stakeholder should have full knowledge of the purpose and function of the risk management/ISD framework.

Edwards, Hardcastle, and Bowen (2005) has determined that there is a need for a risk management tool that will support project management stakeholder's effective management of complex projects by incorporating the nature, type and intensity of the complexities and risks associated with their projects. Throughout the PLCM process, there are numerous stage gates or decision points that projects are subjected to, whereby the uncertainty/risk and complexity increase proportionally with the PCLM process (Hopkins, 2011; Nicholas & Steyn, 2008). Within each stage gate, senior managers may further increase risks during the decision-making process if they do not possess adequate knowledge of ISD principles and project complexity, risk, and uncertainty (Edwards et al., 2005; Heikkila, 1999).

Project stakeholders and senior managers should be aware of various ISD tools and techniques available for use within PLCM. For example, Leveson (2011) developed the System-theoretic Accident Model and Processes (STAMP) framework, which addresses accidents that arise from different types of complexities. Leveson (2011) regarded the STAMP framework as a new accident model that addresses the chain-of-events model, which forms the basis of most safety and reliability engineering analyses that project initiators/system and design engineers use during project design phases (e.g., events and fault tree analyses, probabilistic analyses, failure mode and effect analyses). In addition, SSC ISD tools are designed for redundancy, overdesign, and SIL/safety margins (Leveson, 2011; WNA, 2012). Heikkila (1999) suggests that relative ranking and process hazard analysis (PHA) are suitable tools for the review opportunity and concept phase. PHA is used for any SIS (Safety Instrumentation System) process to determine the mechanical integrity of the process equipment, process control, and other protective equipment that are insufficient in mitigating potential hazards (Summers, 1998).

5. Conceptual framework of the study

Fig. 1 shows the framework used to describe the concepts of the study.

In Fig. 1, the study acknowledges that the utility plant design process and the need for design changes are indirectly responsible for personal safety issues (such as accidents) and production losses. Fig. 1 shows that within PLCM, major decisions in regard to opportunities for applying or installing inherent safety features are made at the project initiation phase but are more appropriate at the conceptual design phase (following Heikkila, 1999; Hurme & Rahman, 2005). At the initiation phase (i.e., during the basic engineering design), opportunities for applying ISD principles increase while project information is less available. In contrast, as the project proceeds through the detail design/definition and execution phases, these opportunities diminish (Heikkila, 1999; Hurme & Rahman, 2005). According to Nicholas and Steyn (2008), one of the limitations of applying ISD principles at the concept or preliminary design phases is that little is known about the scope.

In addition, plant modifications as design changes are mostly initiated with the intention of reducing process hazards, while in contrast; it is these modifications that are inherently unsafe. Kletz (1991) and Heikkila (1999) note that these design changes are not initiated to eliminate hazards if the add-on safety systems are incorporated late in the design phases. For successful design changes, system engineers or project initiators are expected to have full knowledge of ISD principles to sustain the Structure Systems and Component (SSC) Safety Integrity Levels (SIL) and maintain uninterrupted electricity production in power generating plants (CORDEL, 2012). In addition, most of the safety-related projects are initiated to ensure that the SILs of the plant are not compromised (Kessides, 2012). However, project stakeholders (i.e., senior managers) that are decision makers might be aware of this risk but may still delay their decisions pending approval based on the project schedule or design during project development. In contrast, the aforementioned risk overwhelms the project manager, thereby causing delays of project implementation (Cooper, 2001; WNA, 2012). In addition, these senior managers might not be aware of and may not apply ISD tools that will address the risks identified in utility projects if design changes are initiated.

Therefore, this study examines the level of awareness of the use of ISD principles during the project life cycle phases, what stakeholder is the most aware of ISD principles and if there are any significant differences in the awareness of ISD principles amongst PLCM stakeholders.

6. Research methods

This study adopted a quantitative survey approach to obtain information from stakeholders in the South African utility industry. However, studies analogous to this current study have been carried out by Gupta and Edwards (2002), who used a survey approach to elicit information from industrialists, academics and regulators in

11 countries on inherent safety. Similarly, Hassim and Hanafi (2012) conducted a survey study at the national level to investigate the level of knowledge and adoption of the inherent occupational health (IOH) concept in Malaysia. This study, through the review of extant literature (Heikkila, 1999; Hurme & Rahman, 2005), establishes that ISD principles can be used in project procurement. This study adopts an empirical investigation approach using a structured questionnaire administered to PLCM stakeholders (e.g., system engineers, design engineers, project and programmer managers, and senior managers) working on on-going construction projects in the utility and nuclear industries in South Africa. This quantitative questionnaire investigates their perceptions regarding the integration of the ISD concept into PLCM to identify and reduce inherent risks in the management of construction delivery processes.

In addition, a pilot survey, which assisted in identifying potential stakeholders that can answer the prepared questionnaire, was conducted by industry experts. The population of the study was drawn from the South African utility and nuclear power generation industries. To gain a deep understanding of the stakeholders' level of awareness and to determine the level of usage of ISD strategies across project life cycles, questionnaire variables identified from the review of extant literature were expressed on a 3-point Likert scale. The respondents were asked to rank their level of awareness of the inherent risk strategies on a 3-point sliding scale, where 3 represents "highly aware and used it", 2 represents "somehow aware but never used it", and 1 represents "Not aware". This provides an opportunity to measure the awareness level of the stakeholders in using the inherent risk management principle in Project Life Cycle Management. The designed survey questionnaires were then administered electronically to obtain an understanding or extent of awareness of ISD principles amongst a sample size of 500 PLCM stakeholders identified using a snowball and convenience sampling technique. At the end of the survey period, a total of 127 responses were obtained, of which 81 were valid for analysis.

The elicited quantitative data from the stakeholders were analyzed using descriptive and non-parametric statistics. Percentile and frequency indexes were used to measure the responses of the PLCM stakeholders on the level of awareness in using the inherent risk management strategies in the project life cycle. The Frequency Index (FI) was measured using the formula used in Spillane, Oyedele, and von Meding (2012):

$$\mathrm{FI} = \left\{ \sum (f)/NF \right\},$$

where f is the frequency weighting, from 1 to 3, assigned by the respondent in the questionnaire; F represents the highest rating possible for each of the ISD strategies, which is 3; and N is the total number of respondents with valid data in each of the cases. To further explore the inconsistencies that may likely exist within the data set with respect to the different groups, the Kruskal–Wallis nonparametric analysis of variance was used. The Kruskal–Wallis nonparametric analysis of variance is a statistical test used when comparing more than two independent groups and when variables being measured do not meet the underlying normality assumptions of ANOVA. The Kruskal–Wallis H test is an analog or equivalent of one-way ANOVA and an extension of the Mann–Whitney U test that allows groups to be compared. The Kruskal–Wallis analysis is used in this paper because the measurement variables are not normally distributed and because of the need to understand if levels of ISD strategy awareness differed based on the perception of the stakeholders involved in the execution of projects in both the utility and nuclear industries.

7. Results and discussion

7.1. Results

The study sought to determine the level of stakeholder awareness of the risk management strategies used in PLCM. Table 1 shows the results of the descriptive statistics and Frequency Index (FI) for the level of awareness of stakeholders of the risk management strategies used in PLCM. Table 1 clearly indicates that the design engineers are relatively more aware of the risk management strategies used in PLCM compared to the other stakeholders (project initiators/system engineers, project managers, program managers and senior managers/decision makers) and that the highest level of unawareness can be found within the project initiator cohort.

The overall average scores suggest that the Procedural risk management strategy is relatively better known and used more often amongst the PLCM stakeholders studied compared to the other strategies, while the Inherent risk management strategy was the least known. The overall average scores presented in Table 1 reveal that only 23% of PLCM stakeholders are aware of the Inherent (safety "built in", not "added on") risk management strategy applied within PLCM, while 77% of the surveyed PLCM stakeholders are somehow aware or not aware of the Inherent risk management strategy applied within PLCM. The average FI is 59% for the response of using the Inherent risk management strategy. Furthermore, approximately 32% of the PLCM stakeholders are aware of and use the Active risk management strategy, which provides the opportunity to control, prevent or mitigate consequences of incidents in the project life cycle, while approximately 78% of PLCM stakeholders are somehow aware and never used risk management tools or are not aware of it (average FI = 63%). In addition, 27.8% of the PLCM stakeholders are aware of and employ the Passive risk management strategy within PLCM to minimize hazards in the process or phases of projects, while approximately 72.2% are either not aware or somehow aware and have never used it (average FI = 61%). A number of PLCM stakeholders (approximately 32%) are aware of and have used the Procedural risk management strategy, which involves safety standards, rules and procedures, while 68% are not aware of or have never used it (average FI = 64%).

The results suggest that PLCM stakeholders working on South African utility projects have a generally poor awareness of risk management strategies, which poses the problem that PLCM stakeholders might not know which risk management strategy should be applied at which phase of PLCM, leading to SSC risk and project risk not being properly identified. According to Gupta and Edwards (2002), ISD concepts are applied throughout PLCM. However, ISD concepts are applied only if people with knowledge of ISD are involved.

The output in Table 2 contains the rank sum (Wilcoxon scores) and the mean rank for each group of stakeholders for which homogeneity is being tested. Table 2 shows that overall, the design engineers were more aware of ISD strategies than project managers, project engineers and systems engineers in that order. There was a significant difference between the stakeholders' awareness level in the use of the inherent strategies, as indicated in Table 3. This is shown by the Kruskal–Wallis test statistics, where the chi-squared distributed (H) = 12.897059, the chi-squared approximation (the p-value) = 0.01, and where there are four degrees of freedom (d.f.). The analysis presented in Tables 2 and 3, using the Kruskal Wallis test, explores if there is a significant difference in the perceptions of the different categories of respondents used in the survey. The p-value ($p = 0.01$) indicates that there is a significant difference in the perceptions of the respondents at a 99% confidence level.

Table 1
Descriptive statistics showing the level of stakeholders' awareness of risk management strategies.

Process safety management strategies	3	2	1	FI (%)	3	2	1	FI (%)
	Project initiator/System engineer				Project manager			
Inherent	4 (14.8%)	8 (29.63%)	15 (55.56%)	53	8 (44.44%)	0 (0%)	10 (55.56%)	63
Active	6 (22.22%)	6 (22.22%)	15 (55.56%)	56	8 (44.44%)	3 (16.67%)	7 (38.89%)	69
Passive	4 (14.8%)	8 (29.63%)	15 (55.56%)	53	8 (44.44%)	2 (11.11%)	8 (44.44%)	67
Procedural	7 (24.14%)	11 (37.93%)	11 (37.93%)	62	10 (55.56%)	1 (5.56%)	7 (38.89%)	72
Process Safety management strategies	**Project engineer**				**Design engineer**			
Inherent	1 (33.33%)	1 (33.33%)	1 (33.33%)	67	2 (33.33%)	2 (33.33%)	2 (33.33%)	67
Active	1 (33.33%)	1 (33.33%)	1 (33.33%)	67	3 (50.00%)	2 (33.33%)	1 (16.67%)	78
Passive	1 (33.33%)	1 (33.33%)	1 (33.33%)	67	3 (50.00%)	1 (16.67%)	2 (33.33%)	72
Procedural	1 (33.33%)	1 (33.33%)	1 (33.33%)	67	4 (66.67%)	0 (0%)	2 (33.33%)	78
Process Safety management strategies	**Others**				**Overall average scores**			
Inherent	3 (18.75%)	13 (54.17%)	8 (33.33%)	60	18 (23.1%)	24 (30.8%)	36 (46.1%)	59
Active	7 (29.17%)	8 (33.33%)	9 (37.5%)	64	25 (32.1%)	20 (25.6%)	33 (42.3%)	63
Passive	6 (24%)	9 (36%)	10 (40%)	61	22 (27.8%)	21 (26.6%)	36 (45.6%)	61
Procedural	10 (40%)	8 (32%)	7 (28%)	71	23 (31.9%)	21 (29.2%)	28 (38.9%)	64

Scores assigned: 3 = highly aware and used it; 2 = Somehow aware and never used it; and 1 = not aware.
Others: Program managers and senior managers/decision makers in South African utility projects.

Table 4 shows the level of awareness of the process of adopting ISD as a risk management strategy within PLCM. The mean values range from 1.7 (Inherent – safety “built in”, not “added on”) to 2.1 (Procedural – safety standards, rules or procedures), with standard deviations, which measure the spread of the responses, ranging from 0.80 to 0.87, respectively. The variance values are greater than zero, which shows that all the variable values are not identical. Based on the skewness and kurtosis, the data are approximately distributed in a multivariate normal distribution, and this is shown by the values, which are between −1.0 and +1.0 (Hair, Black, Babin, & Anderson, 2010).

The study sought to determine the level of awareness among stakeholders regarding the ISD principles used during the project life cycle. Table 5 provides a summary of the results obtained for the level of awareness of the use of ISD principles during Project Life Cycle Management (PLCM) phases. The results show that a higher percentage of the respondents view the minimization ISD principle as being relevant to the concept phase and substitute, moderate and simplify as the ISD principle that is adopted at the definition phase in PLCM. In addition, there are some respondents who are of the view that the minimize and substitute principles of ISD can be used at the execution and finalization phases, while there are others who believe that ISD principles should be used throughout PLCM.

These answers indicate a lack of knowledge of the appropriate ISD principle to use at a particular phase of PLCM within the cohort of PLCM stakeholders surveyed. At the definition phase wherein it is expedient to use substitution (use a safer material instead of a hazardous one), the respondents do not have a clear answer regarding the ISD principle that should be used. Similarly, in the execution phase, the moderate ISD principle, which involves using less hazardous conditions or less hazardous forms of materials, should be applied to reduce project failures. However, empirical evidence shows that PLCM stakeholders are not aware of this because their responses are fairly equally distributed amongst the three ISD principles of Substitute, Moderate and Simplify. Another incongruity that emerged is that the respondents placed less emphasis on moderation in the execution phase and simplification in the finalization phase. The results therefore suggest a lack of understanding of ISD principles and risk management strategies among PLCM stakeholders in South African utility industry projects.

7.2. Discussion

This study explores the level of awareness of project stakeholders of the application of ISD principles through PLCM in utility industry projects. The findings from the study indicate that the principles of inherent safety are permeating into the industrial systems studied mainly because the application of ISD principles to the management of entire project life cycle does not appear to be a completely new concept among the stakeholders surveyed, but the level of awareness and its adoption are below optimal levels considering the results showing that a minority of respondents have used or are aware of its adoption. The findings also show that project managers, though engineers or training, are better informed about the ISD approach of eliminating risks and hazards more so than project and system engineers, while the design engineers are the most aware. This is contrary to the results of Evans and Chaffin (1986), who surveyed 40 engineers/designers and 60 staff engineers in the manufacturing industry and determined that ergonomic principles that contribute to comfort, efficiency and safety were more likely to be given attention by plant engineers compared to higher engineers in the organization's divisions. However, the results also resonate the findings of Gupta and Edwards (2002) and Hassim and Hanafi (2012), who conducted surveys globally and in the context of Malaysia, respectively. They determined that the levels of awareness of ISD and IOH adoption were less than ideal amongst industrialists due to the lack of knowledge on the indices developed for ISD.

Moreover, the stakeholders place less emphasis on Inherent safety and Passive strategies. This result is consistent with Mansfield and Poulter (1996), who determined that those strategies could fail because “add on” approaches can be maintenance intensive and capable of adding to costs, while other strategies can generate enhanced safety, require lower initial capital and lower operating costs. The research identifies minimization as the key principle of inherent safety used during the concept stage, which Mansfield and Poulter (1996) determined to be highly pertinent to the economics of plant installation and argued that a methodical use of the approach can lead to further improvements in safety and cost reduction. The project definition stage of the life cycle supports the inventory or reduction principle of Inherent Safety (IS) as the best approach, and this is aligned with the assertion of Westland (2006), who contends that at the planning phase (definition), the most important objective will be to reduce the probability of risks or hazards occurring or to reduce its impact on projects. However, the moderate and simplify principles of ISD are identified as relevant to the execution and finalization stages, respectively. Adequate knowledge of this is essential as reiterated by Edwards and Bowen (2005), and it is imperative for all the PLCM stakeholders to have sufficient risk awareness and project

Table 2
Kruskal Wallis test rank table.

Stakeholders	Rank sum	Mean rank
SE	12	3
PM	51	12.75
PE	46	11.5
DE	68	17
OTHERS	33	8.25

Key: SE = System engineer; PM = Project manager; PE = Project engineer; DE = Design engineer.

Table 3
Kruskal Wallis test statistics.

Test statistics		
Kruskal–Wallis' statistic	12.897059	
X^2 statistic	12.897059	
DF	4	
p	0.0117899	(chi-sqr approximation, corrected for ties)

risk management knowledge, especially when making decisions. This was also supported by Edwards et al. (2005), who argued that there is a need for risk management/ISD tools that will support project management stakeholders to effectively manage complex projects and understand the nature, type and intensity of the complexities and risks associated with the projects. The CORDEL, 2012 also posited that PLCM stakeholders and managers should have sufficient and requisite experience and be fully equipped with adequate knowledge on how to determine project risk and its prioritization to prevent accidents and economic loss. This result is also the position of previous researchers who argue that PLCM stakeholders are required to be fully aware of inherent risks and decisions to ensure safety at project sites (Cooper, 2001; Nicholas & Steyn, 2008).

Another major finding of the study is that the level of awareness of stakeholders of ISD principles is greater within earlier project phases (concept and definition) and lesser during the latter stages (execution and finalization). This pattern of use of ISD principles may also be responsible for the spate of accidents and fatalities witnessed during the execution phase of utility projects in South Africa (Reuters, 2013). However, some of the stakeholders recognize the principle, but the divergence in their opinions indicates that some of them do not have a clear understanding of the ISD approach and its meaning. This is because there is an obvious significant difference, as shown by the Kruskal–Wallis test, in the perception of the stakeholders as to what ISD and IS represent and how it could be used to minimize risks or hazards. Some of the stakeholders, such as design engineers, appear to be familiar with or come in contact with the terms, but few of them apply the principle in whole or in part in their work.

8. Conclusion

This research evaluates the degree to which the principle and concept of ISD and IS are being practiced and adopted within PLCM by the stakeholders in the utility industry. The study determined that, to a certain extent, the awareness of ISD principles subsists but at the lowest levels in all respects at the earlier project phases, and a divergent awareness of ISD strategies was found to exist amongst PLCM stakeholders. The difference in awareness amongst PLCM stakeholders implies that while safety strategies are being applied by design engineers to a greater degree at the project initiation and concept phases, systems engineers and project managers perform project tasks and include project design changes with little or no knowledge of ISD principles, resulting in accidents and a loss of lives during the project execution stages. This study therefore concludes that the hazards and fatalities witnessed within the execution and finalization phases of utility industry projects could be a result of the low level of awareness, divergent views and lower use of ISD strategies by stakeholders during the execution and final phases of utility projects. It is therefore noted that there is a need to increase the level of awareness of the principles of ISD and IS among stakeholders in the industry. This will provide windows of opportunity for inventory reduction, for the simplification of plant management and to make conspicuous the need to apply other strategies of the ISD approach. Therefore, the research suggests that the level of awareness of the principles, concepts, basics and benefits of integrating ISD into PLCM be raised amongst stakeholders functioning within the utility industry in South Africa. The industry stands to benefit when awareness is promoted and when the application of ISD principles is encouraged. This could reduce costs by preventing risks and hazards. In addition, it is recommended that design changes be limited at the latter phases of utility project procurement because PLCM stakeholders at these latter stages do not have knowledge of ISD principles that could be applied and are therefore not competent in regard to making decisions that will prevent risks or hazards.

Table 4
Level of awareness of the process of risk management strategies used within PLCM.

	Mean	Standard deviation	Sample variance	Kurtosis	Skewness	FI
Inherent (safety "built in", not "added on")	1.71	0.80	0.64	−1.20	0.57	0.58
Active (control, prevent, or mitigate the consequences of incidents)	1.85	0.86	0.74	−1.59	0.30	0.62
Passive (minimize hazards using process or equipment design features)	1.75	0.82	0.67	−1.33	0.50	0.59
Procedural (safety standards, rules or procedures)	2.10	0.87	0.75	−1.65	−0.20	0.70

Table 5
Level of awareness of the ISD principles used during Project Life Cycle Management (PLCM) phases.

ISD principles	Concept phase	Definition phase	Execution phase	Finalization phase	Throughout PLCM
Minimize (intensify: major changes, e.g., material, process)	43 (53.09%)	15 (18.52%)	12 (14.82%)	2 (2.47%)	9 (11.11%)
Substitute (use a safer material instead of a hazardous one)	23 (28.40%)	31 (38.27%)	17 (20.99%)	2 (2.47%)	8 (9.87%)
Moderate (attenuate: appropriate analysis, passive safety design, protection equipment and use of correct instrumentation to control the process)	26 (32.10%)	28 (34.56%)	17 (20.99%)	3 (3.70%)	7 (8.64%)
Simplify (add-on safety: better design, passive controls rather than active)	22 (27.16%)	27 (33.33%)	14 (17.28%)	9 (11.11%)	9 (11.11%)

Gray shade = Project phase in which the ISD principle is mostly used.

References

Amyotte, P. R., Pegg, M. J., & Khan, F. I. (2009). Application of inherent safety principles to dust explosion prevention and mitigation. *Process Safety and Environmental Protection, 87*, 35–39.

Archibald, R. D. (2003). *Managing high-technology programs and projects* (3rd ed.). NY: Wiley.

Blanquart, J.-P., Astruc, J.-M., Baufreton, P., & Boulange, J.-L. (2012). *Criticality categories across safety standards in different domains*. ERTS2012_Paper-Criticality-CG2E-Blanquart-et-al_V4. (pp. 1–10)

Bonnal, P., Gourc, D., & Lacoste, G. (2002). The life cycle of technical projects. *Project Management Journal, 33*(1), 12–19.

Center for Chemical Process Safety (CCPS). (2009). *Inherently safer chemical processes: A life cycle approach* (2nd ed.). Hoboken, NJ: John Wiley & Sons.

Cooper, R. (May–June 1991). Stage-gate systems: a new tool for managing new products. *Business Horizons*, 44–53.

Cooperation in Reactor Design Evaluation and Licensing CORDEL-WNA. (2012). *Design change management in regulation of nuclear fleet*. A Report by the World Nuclear Association's Working Group on Cooperation in Reactor Design Evaluation and Licensing (pp. 1–22).

Dasgupta, A., & Pearce, D. (1974). *Cost benefit analysis: Theory and practice*. Great Britain: The Macmillian Press LTD. ISBN: 333 11395 0.

Dowell, A. M., III (1998). Layer of protection analysis for determining safety integrity level. *ISA Transactions, 37*(3), 155–165.

Edwards, D. (2005). Export inherent safety not risk. *Journal of Loss Prevention in the Process Industries, 18*, 254–260.

Edwards, P. J., & Bowen, P. A. (2005). *Risk management in project organisation*. Australia: Butterworth Heinemann.

Edwards, P. J., Hardcastle, C., & Bowen, P. A. (2005). Mapping risk and complexity for construction projects. In *Becon2005: 1st International Conference on Built Environment Complexity. 11–14 September 2005*. University of Liverpool: Centre for Complexity Research.

Eskom. (2010). *Eskom standard project life cycle model (PLCM) policy: 32-1155*. South Africa: Eskom.

Evans, S., & Chaffin, D. (1986). Computerized biomechanical models in manual work design. In *Proceedings of the Human Factors and Ergonomics Society, 30th Annual Meeting* (Vol. 30, pp. 96–100). SAGE Publications. No. 1.

Gupta, J. (2000). A course on inherently safer design. *Journal of Loss Prevention in the Process Industries, 13*, 63–66.

Gupta, J. P., & Edwards, D. W. (2002). Inherently safer design – present and future. *Transactions of IChemE, 80*, 115–125.

Hackitt, J. (2013). *ICE (Institution of Civil Engineers) and costain health and safety lecture 2013Process safety – Do they mean us?*. Available from http://www.hse.gov.uk/aboutus/speeches/transcripts/hackitt191113.htm Accessed 31.07.14.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). *Multivariate data analysis: A global perspective* (7th ed.). Upper Saddle River, N.J.; London: Pearson Education.

Hassim, M. H., & Hanafi, N. H. (2012). Current status and future direction of inherently healthier design in Malaysia. *Energy Procedia, 14*, 1939–1944.

Heikkila, A. M. (1999). *Inherent safety in process plant design: an index -based approach*. Libella Painopalvelu Oy: Technical Research Centre of Finland ESPOO, VTT Publication 384.

Hendershot, D. C. (2011). Inherently safer design: an overview of key elements. *Professional Safety*, 48–55. Available at www.asse.org.

Holt, J. (2004). *UML for systems engineering: Watching the wheels* (p. 8). IET, ISBN 978-0-86341-354-4.

Hopkins, A. (2011). Risk-management and rule-compliance: decision-making in hazardous industries. *Safety Science, 49*, 110–120.

Hurme, M., & Rahman, M. (2005). Implementing inherent safety throughout process lifecycle. *Journal of Loss Prevention in the Process Industries, 18*, 238–244.

IBM Corporation. (2014). *Plant lifecycle information management: Managing project risk and regulatory compliance for CAPEX build projects, design through decommission*. http://public.dhe.ibm.com/common/ssi/ecm/en/lbe12345usen/LBE12345USEN.PDF Accessed 15.05.14.

Inglesi, R., & Pouris, A. (2010). Forecasting electricity demand in South Africa: a critique of Eskom's projections. *South African Journal of Science, 106*(1/2), 50–53. http://dx.doi.org/10.4102/sajs.v106i1/2.16. Art. #16, 4 pages.

Kerzner, H. (2001). *Project management: A systems approach to planning, scheduling and controlling*. New York: Wiley.

Kessides, I. N. (June 2012). *The future of the nuclear industry reconsidered: Risks, uncertainties, and continued potential*. Policy Research Working Paper: 6112 (pp. 1–70).

Khan, F. I., & Amyotte, P. R. (2005). I2SI: a comprehensive quantitative tool for inherent safety and cost evaluation. *Journal of Loss Prevention in the Process Industries, 18*, 310–326.

Kidam, K., & Hurme, M. (201218 February). Design as a contributor to chemical process accidents. *Journal of Loss Prevention in the Process Industries, 12*, 655–666.

Kidam, K., & Hurme, M. (201216 May). Origin of equipment design and operation errors. *Journal of Loss Prevention in the Process Industries*, 1–13.

Kletz, T. A. (1984). *Cheaper, safer plants, or wealth and safety at work*. Rugby: Institution of Chemical Engineers.

Kletz, T. A. (1991). *Plant design for safety: A user-friendly approach*. NY: Hemisphere Publishing Corporation.

Kletz, T. A., & Amyotte, P. (2010). *Process plants: A handbook for inherently safer design* (2nd ed.). Boca Raton, FL: CRC Press.

Labuschagne, C., & Brent, A. C. (2005). Sustainable project life cycle management: the need to integrate life cycles in the manufacturing sector. *International Journal of Project Management, 23*, 159–168.

Leveson, N. G. (2011). Complexity and safety: chapter 2. In *Complex systems design & amp; management* (pp. 27–39). Massachusetts Institute of Technology: Aeronautics and Astronautics.

Mansfield, D., & Hawksley, J. (1998). Improved business performance through inherent safety, health and environmental design and operation: a report of a London conference. *Journal of Cleaner Production, 6*, 147–150.

Mansfield, D., & Poulter, L. (1996). *Improving inherent safety*. HSE Books. Prepared by AETA Technology Plc and Loughbough Consultant for Health and Safety Executives.

McKenna, M. G., Wilczynski, H., & VerderSchee, D. (2006). *Capital project execution in the oil and gas industry*. http://www.boozallen.com/media/file/Capital_Project_Execution.pdf Accessed 15.06.14.

Moore, D. A. (1999). Incorporating inherently safer design practices into process Hazard analysis. In *Proceedings Process Safety Symposium, Mary Kay O'Connor Process Safety Center, 26–27 October*. College Station, TX, USA: Texas A&M University.

Nicholas, J., & Steyn, H. (2008). *Project management for business, engineering, and technology, principles and practice* (3rd ed.). Amsterdam: Butterworth-Heinemann.

Palaniappan, C., Srinivasan, R., & Tan, R. (2004). Selection of inherently safer process routes: a case study. *Chemical Engineering and Processing: Process/Intensification, 43*(5), 641–647.

Patel, M. B., & Morris, P. G. W. (1999). *Guide to the project management body of knowledge, centre for research in the management of projects* (p. 52). UK: University of Manchester.

Project Management Institute (PMI). (2008). *A guide to the project management body of knowledge guide (PMBOK)* (4th ed.). Newtown Square, Pennsylvania: Project Management Institute.

Reuters. (2013). *Eskom says 6 workers die in accident at construction site*. Retrieved on 11/11/2013 from http://news.yahoo.com/africas-eskom-says-6-workers-die-accident-construction-140427163.html.

Rusli, R., Shariff, A. M., & Khan, F. I. (2013). Evaluating hazard conflicts using inherently safer design concept. *Safety Science, 53*, 61–72.

Spillane, J. P., Oyedele, L. O., & von Meding, J. (2012). Confined site construction an empirical analysis of factors impacting health and safety management. *Journal of Engineering, Design and Technology, 10*(3), 397–420.

Summers, A. E. (1998). Techniques for assigning a target safety integrity level. *ISA Transactions*, 95–104.

US Energy Information Administration. (2013). *International energy outlook (IEO)*. http://www.eia.gov/forecasts/ieo/ Accessed 15.05.14.

Westland, J. (2006). *The project management lifecycle*. Kogan Page Limited.

Wideman, R. M. (2004). *The role of the project life cycle (life span) in project management: A literature review* (pp. 1–22). Vancouver: AEW Services.

World Nuclear Association (WNA). (2008). *Structuring nuclear projects for success: An analytical framework*. London: World Nuclear Association.

World Nuclear Association (WNA). (2012). *Design change management in regulation of nuclear fleet*. London: CORDEL Group.

World Nuclear Association (WNA). (2014). *Safety of nuclear power reactors*. Available on http://www.world-nuclear.org/info/Safety-and-Security/Safety-of-Plants/Safety-of-Nuclear-Power-Reactors/ Accessed 16.05.14.