STAKEHOLDERS' AWARENESS OF INHERENT SAFETY DESIGN STRATEGIES WITHIN PROJECT LIFE CYCLE MODEL

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Abstract

The application of Inherent Safety Design (ISD) principles to every stage in a process lifecycle has been established as capable of reducing risk and economically appealing for process plant. Nevertheless, several options available are distinct at different phases of project lifecycle. This study examines the need for methodical risk management approach and the level of awareness in adopting ISD strategies among South African energy utility industry project stakeholders' using the Project Life Cycle Model (PLCM) approach. The study adopts a quantitative research approach using a structured questionnaire among a focus group to investigate their perceptions regarding the integration of the ISD concept with risk review techniques in order to identify inherent risk management principles used by project initiators. A total of 500 questionnaires were administered to the identified stakeholders and 127 responses were obtained, of which 81 were valid for analysis. This amounts to a response rate of 16.2%. The data was analysed using descriptive and non-parametric statistics. The research reveals poor awareness or knowledge regarding the ISD strategies among the stakeholders, and evidence of an increase in scope changes and production losses when appropriate ISD strategies and techniques are not used on the project. It was concluded that design engineers, more than other stakeholders, have to apply ISD strategies at every stage in the construction lifecycle of a process plant.

Keywords*: Inherent Safety Design, Project Life Cycle Model, Risk, South Africa and Utility Industry.*

INTRODUCTION

The Center for Chemical Process Safety (2009) defines Inherent Safety Design (ISD) or Technology as an iterative process that allows safety to be built into a process or product, but not added on. It considers options such as eliminating a hazard, reducing a hazard, substituting a 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. The concept of ISD was developed by Kletz (1991) with the following elements: substitution; minimisation or intensification; moderation or attenuation; simplification; limitation of hazardous effects; avoiding knock-on effects; making incorrect assembly impossible; make status clear; tolerance; ease of control; and administrative controls /procedures. ISD elements were classified by Kletz (1991) into four strategies with the aim of minimising risk: (i) Inherent (safety 'built in', not 'added on'); (ii) Active (control, prevent, or mitigate the consequences of incidents); (iii) Passive (minimise hazard using process or equipment design features) and (iv) Procedural (safety standards, rules or procedures) (Gupta, 2000). Three strategies (i.e. Active, Passive and Procedural) are categories to be related to current practice or operation (e.g. control, prevent, and mitigate), while 'Inherent' strategy implies that they are present in the system as permanent and are inseparable (Gupta, 2000). In order to minimise probability for design errors, Gupta (2000) suggests that through the application of inherent strategies, none to minimal periodic testing, maintenance intervention and replacement will be required. Procedural safety design strategy includes prevention or minimising of incident impact through: safe operating procedures and operator training; administrative safety checks; management of change, and planned emergency response (INSET, 2001).

Project Life Cycle Model (PLCM) is the project management methodology that has several phases and stage gates that can be made adaptable to the size of the organisation, technical and business practices (Nicholas and Steyn, 2008). Cooper (2001) regards PLCM or stage gate model as one of the fundamental processes for strategic solutions and decisions, whereby Senior Managers would use the stage gate tools effectively for new project initiation, modifications, and for better management of an innovation process. Nicholas and Steyn (2008) elaborate that projects vary with regards to their complexity, resource needs, technology, cost, strategic value, risk, and uncertainty. Therefore, Cooper (2011), and Nicholas and Steyn (2008) acknowledge the need to cater for different projects by considering that organisations should manage projects through different project management methodologies or approaches and culture from project to programme to portfolio management, and the application of relevant PLCM. The design process consists of various phases of the Project Life Cycle Model as follows: (i) Review Opportunity phase, (ii) Pre-Project Planning phase, (iii) Concept phase, (iv) Definition phase, (v) Execution phase, (vi) Finalisation phase and (vii) Benefit Realisation phase (PLCM) (Cooper, 2001 and Eskom, 2011). When an idea is initiated to be pursued as a project, there is a process life cycle or various stages that the project has to be subjected to until construction or the launch of a product and beyond. Therefore, this study investigates the level of awareness of ISD strategies among South African energy utility industry stakeholders' using project management methodology approach and also establishes a need for systematic risk management approach on utility projects.

The rationale for the research

The operating experience indicates that nuclear power plants are a high safety risk environment, due to the lack of a systematic Inherent Safety Design framework as they are more susceptible to hazardous events or scenarios. 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. Thus, in power generation and nuclear industries, poor awareness on Inherent Safety Design (ISD) strategies, principles, tools and techniques in the early phase or project Front End Loading by project initiators, project managers, project engineers, design engineers and Senior Managers as project life cycle model stakeholders within the PLCM increases the risk levels.

LITERATURE REVIEW

Level of Awareness Expected of Stakeholders on ISD Principles

Considering that there are different types of projects due to their complexity, Edwards and Bowen (2005) emphasise 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 nuclear, aerospace, power stations, and railways on which risk awareness is required. On the other hand, complex projects require substantial capital budget and most financial decisions involve public, legal, government, and other stakeholders. In this environment, appropriate and effective project risk management, communication and investment appraisal tools need to be used for effective decision making (Dasgupta and Pearce, 1974; Edwards and Bowen, 2005; World Nuclear Association, 2012).

Each project has a core project team of stakeholders such as project initiator, project manager, project engineers, design engineers and senior managers (PMBOK, 2008). The participation of a project stakeholder is vital within the PLCM to ensure that ISD principles are adequately applied. Nicholas and Steyn (2008) state that with diverse organisational structures, project initiators or system engineers are mostly expected to perform project management duties during the project concept phase. Therefore, these stakeholders are expected to have full knowledge of risk management tools (Cooperation in Reactor Design Evaluation and Licensing (CORDEL), 2012). Projects throughout the PLCM are often subjected to design, scope changes, early close-outs or redesigning by initiating a new modification/project and cancellation. (Nicholas and Steyn, 2008). This means that stakeholders presiding over the technical or investment committee are expected to be experienced and authorised personnel for the relevant approvals within PLCM phases and stage gates (Cooper, 2001). The same applies to programme and project managers; these PLCM stakeholders and Senior Managers should have sufficient experience and full knowledge on the basis of determining project risk prioritization to prevent accidents and economic loss (CORDEL, 2012).

The practice or rule at a nuclear power station differs from the fossil and other power generation stations as regards safety design principles (Kessides, 2012 and WNA, 2012). Nuclear industry rules are particularly strict in a manner that design engineers are the ones that are mainly responsible for safety design processes (CORDEL, 2012; WNA, 2012). Design engineers ensure that safety cases are compiled for each safety related project or modification as well as reviewing all designs to ensure that National Nuclear Regulator (NNR) requirements are met (CORDEL, 2012). The concern is that this happens later in the PLCM at the detail design phases, while at the Front End Loading (FEL), system engineers and project managers leave everything to the design engineer. Meanwhile, at the latter project phases, opportunities of stakeholder influence and scope changes are reduced and cost of changes become increasingly expensive (Nicholas and Steyn, 2008; PMI, 2008). The design engineer may have no control over design and scope changes that project managers, system or production engineers, project initiators and clients bring about at latter stages of the 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 the PLCM (Cooper, 2001). In order to avoid these hazards and consequences, there are different tools used during different stages of the project life cycle. The common concern that arises is that PLCM stakeholders are not aware of the application and limitations of ISD tools within the project life cycle (Heikikila, 1999; Khan and Amyotte, 2005).

Responsibilities of Project Stakeholders and Senior Managers on PLCM

Nicholas and Steyn (2008) discover that little is known regarding the scope of the project, especially within a diverse organisational structure. Project initiators or system engineers are primarily expected to perform project management duties during the project concept phase. Lessons learnt from the Bhopal plant accident due to ignorance over the importance of design change requirements was due to delays in Senior Managers' decision making processes (Edwards, 2005). Considering plant design change requirements in the nuclear power plant, normal project duration takes longer when compared to fossil power plants (Edwards, 2005; Hopkins, 2011). Design change requirements occur either as a result of previous operating experience of accidents that occurred or from identified opportunities.

WNA (2008) reports that nuclear projects are unique and capital intensive, with longer project duration. During operation, they have low fuel costs and other lower operational costs, whereas they uphold high safety standards. On the other hand, Nicholas and Steyn (2008) state that nuclear projects are amongst complex projects (e.g. aerospace) as regards the three dimensions of complexity (i.e. time, cost, and technical performance) as they are regarded as expensive along with high complexity and uncertainty. What this means is that stakeholders need to perform extra work to ensure that the project scope and design or technology is understood. The primary purpose of this is to reduce rework /scope changes or redesigning, prevent accidents from occurring, which will in turn sustain safety integrity levels of the Structure, Systems and Components (SSC). This means that, more time and focus on resources is required at the project development phases (Nicholas and Steyn 2008). Studies discover that the application of ISD principles benefits inherently safer designs that are cost effective, enhance profits, lower capital and operational costs, avoid costly hazard controls and reduce uncertainty (Edward, 2005; WNA, 2008; Khan and Amyotte, 2005).

Leveson (2011) posits that the new technology must be simpler, as complexity in the safety engineering system is mostly brought about through design changes as a solution to the problem which can end up as an 'accidental complexity'. In addition, Hopkins (2011) argues that decision making within the PLCM is taken as non-operational decisions that impact on safety, as it involves planning, design and investment decisions. Hopkins (2011) reckons that in order to reduce accidents in hazardous industries, controversial issues of converting risk management into rule-compliance is 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. Hillson (2011) contends that there are three zones that people pass through when faced with change as indicated through the Patterson-Connor Commitment Curve in Fig. 1. This means that PLCM stakeholders or senior managers during the new project or project change approval processes are subjected to cultural and political ethics during the decision making process as every project brings about design change. The Patterson-Connor Commitment Curve emphasises the means to increase the level of senior management support as positive perception during project development phases and the need to ensure that PLCM stakeholders are aware of the change from the onset. This is done to prevent delays in decision making due to lack of understanding that in turn leads to misunderstanding and negative perception (Hillson, 2011).

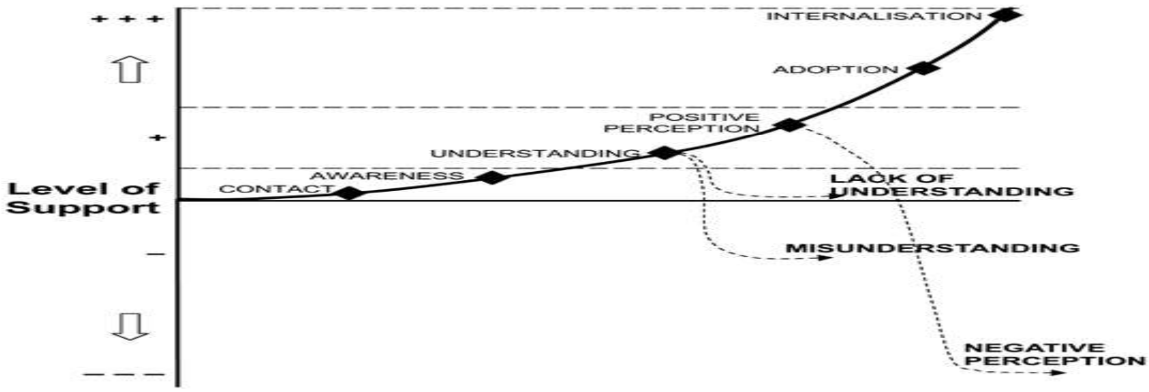

Figure 1: Patterson-Connor Commitment Curve indicating change level of support (Source: www.pmtoday.co.uk)

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

Leveson (2011) emphasises that during the design of the complex SSC, the unnecessary complexity should not be added to the design and safety requirements. This should be analysed at project development phases to ensure that standards of ISD approaches are applied. Researchers have over the decades established ISD tools and techniques. Leveson (2011) developed the System-Theoretic Accident Model and Processes (STAMP) framework that addresses the accident arising from different types of complexity. Leveson (2011) regarded the STAMP as the new accident model that addresses the chain-of-events model that form the basis of most safety and reliability engineering analysis that the project initiators/system and design engineers utilised during project design phases (e.g. events and fault tree analysis, probabilistic analysis, failure modes and effects analysis). In addition, SSC/ISD tools cater for redundancy, overdesign, Safety Integrity Levels/safety margins (Leveson, 2011; WNA, 2012).

RESEARCH METHODS

The study adopts a quantitative research approach using a structured questionnaire amongst a focus group to investigate their perceptions regarding the integration of ISD concept with risk review techniques in order to identify ISD principles used by project initiators. The population of the study was based on selected project stakeholders within South African utility and nuclear power generation industries to assess the awareness of ISD principles and examine existing ISD strategies, principles, tools and techniques used by these cohort of respondents within the PLCM. The study focuses on quantitative data obtained through a questionnaire survey. To have an understanding of the stakeholders' level of awareness and level of use of ISD strategies across the project life cycle, questionnaire variables identified from the review of extant literature were measured on a 3-point likert scale. The respondents were asked to rank their level of awareness of the inherent risk strategies on the 3-point scale, where 3 represents "highly aware and used it", 2 represents "somehow aware but never used it", and 1- Not aware. This provides the opportunity of measuring the awareness level of the stakeholders in using the inherent risk management models in project life cycle management. The questionnaires were then administered to gather an understanding or extent of awareness of ISD principles amongst PLCM stakeholders (e.g. system engineers, design engineers, project and programme managers, senior managers, etc.) working on projects within the utility and nuclear industries. A total of 500 questionnaires were administered to the identified stakeholders and 127 responses were obtained, of which 81 were valid for analysis.

The elicited quantitative data from the stakeholders were analysed using descriptive and nonparametric statistics. Percentile and frequency indexes were used to measure the response of the PLCM stakeholders on the level of awareness in using the ISD strategies in the project life cycle. The Frequency Index (FI) was measured using the formula used in Spillane *et al.* (2012):

$$FI = \{\sum(f)/NF\} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{equation 1}$$

In Equation 1, f is the frequency weighting assigned by the respondent in the questionnaire from 1 to 3. F represents the highest ratings possible for each of the ISD strategies which is 3, while N is the total number of the 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, Kruskal-Wallis nonparametric analysis of variance was used. Kruskal-Wallis nonparametric analysis of variance is one of the most commonly used statistical test when comparing more than two independent groups, it is used when variables being measured do not meet the underlying normality assumptions of an ANOVA. Kruskal-Wallis H test is an analogue or equivalent of a one-way ANOVA and an extension of the Mann-Whitney U test that allows groups to be compared. Kruskal-Wallis is used in this study because the measurement variables are not normally distributed and also because of the need to understand whether the level of ISD strategies awareness differed within the cohort of stakeholders involved in the execution of projects in both utility and nuclear industries.

RESULTS AND DISCUSSION OF FINDINGS

Table 1 shows the results of descriptive statistics and the frequency index for the level of awareness of stakeholders of ISD tools in the PLCM. The Table shows that 22.22% of PLCM stakeholders are aware of the inherent strategy (safety "built in" not "added on") risk management tools applied within the PLCM, while 78% of the PLCM stakeholders are somehow aware or not aware of the ISD strategy applied within the PLCM. The mean FI is 55.2% for response using inherent strategy. About 30.86% of the PLCM stakeholders are aware and use active inherent safety design strategy which provides the opportunity to control, prevent or mitigate consequences of incidents in project life cycle, while approximately 70% of PLCM stakeholders are somehow aware or never used the ISD tools (mean FI= 67%). 27.16% of the PLCM stakeholders are aware and employed passive inherent safety design strategy within the PLCM to minimise hazard in the process or phases of projects while approximately 73% are either not aware or never used it (mean FI= 64%). Appreciable number of PLCM stakeholders (approximately 40%) are aware of procedural strategy, that is the safety standard, rules and procedure while 60% are unaware or yet to use it (mean FI = 70%). The results imply that PLCM stakeholders have poor awareness of risk management tools, which poses a problem that PLCM stakeholders may not know which ISD Tools and techniques to be applied at which phase of the PLCM, leading to SSC risk and project risk not being identified properly. Edwards and Bowen (2005) reiterate the fact that it is essential for all the PLCM stakeholders to have sufficient risk awareness and project risk management abilities, especially when making decisions. This assertion was also supported by Edwards *et al.* (2005) who argued that there is a need for the risk management/ISD tool 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 projects. CORDEL Group (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, 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 risk and decision to ensure safety on project sites (Nicholas and Steyn, 2008; Cooper, 2001).

Tables 2 contains the rank sum (Wilcoxon scores) and the mean rank in each group of the stakeholders for which homogeneity is being tested. There was a significant statistical difference between the stakeholders' awareness level in the use of the inherent strategies, as indicated in Table 3. This is shown by Kruskal-Wallis test statistics, where the Chi-square is the H-statistics of the Kruskal-Wallis, which is approximately Chi-square distributed (H) = 12.897059, the chi-square approximation, is the p-value = 0.01 for Degree of Freedom=4.

Table 1: Descriptive statistics showing level of stakeholders awareness of ISD strategies

Inherent safer design strategies	Scores		assigned				
	3		2		1		FI%
	N	%	N	%	N	%	
Project initiator/system engineer							
Inherent (safety "Built in" not "Added on")	4	14.8	8	29.63	15	55.56	53
Active (control, prevent or mitigate the consequences of incidents)	6	22.22	6	22.22	15	55.56	56
Passive (minimise hazard using process or equipment design features)	4	14.87	8	29.63	15	55.56	53
Procedural (safety standards, rules or procedures)	7	24.14	11	37.93	11	37.93	62
Project manager							
Inherent (safety "Built in" not "Added on")	8	44.44	0	0	10	55.56	63
Active (control, prevent or mitigate the consequences of incidents)	8	44.44	3	16.67	7	38.89	69
Passive (minimise hazard using process or equipment design features)	8	44.44	2	11.11	8	44.44	67
Procedural (safety standards, rules or procedures)	10	55.56	1	5.56	7	38.89	72
Project engineer							
Inherent (safety "Built in" not "Added on")	1	33.33	1	33.33	1	33.33	67
Active (control, prevent or mitigate the consequences of incidents)	1	33.33	1	33.33	1	33.33	67
Passive (minimise hazard using process or equipment design features)	1	33.33	1	33.33	1	33.33	67
Procedural (safety standards, rules or procedures)	1	33.33	1	33.33	1	33.33	67
Design engineer							
Inherent (safety "Built in" not "Added on")	2	33.33	2	33.33	2	33.33	67
Active (control, prevent or mitigate the consequences of incidents)	3	50.00	2	33.33	1	16.67	78
Passive (minimise hazard using process or equipment design features)	3	50.00	1	16.67	2	33.33	72
Procedural (safety standards, rules or procedures)	4	66.67	0	0	2	33.33	78
Others							
Inherent (safety "Built in" not "Added on")	3	18.75	13	54.17	8	33.33	60
Active (control, prevent or mitigate the consequences of incidents)	7	29.17	8	33.33	9	37.50	64

Passive (minimise hazard using process or equipment design features)	6	24.00	9	36.00	10	40.00	61
Procedural (safety standards, rules or procedures)	10	40.00	8	32.00	7	28.00	71

Table 2: Kruskal Wallis Test Rank Table

Stakeholder	Rank sum	Mean rank
System engineer	12	3
Project manager	51	12.75
Project engineer	46	11.5
Design enfgineer	68	17
Others	33	8.25

Table 3 Kruskal-Wallis Test Statistics

Test statistics	Result
Kruskal-Wallis	12.897059
X^2	12.897059
DF	4
p	0.012

Discussion of results

The rationale of this study is to explore the level of awareness of the stakeholders in the application of ISD principles through the PLCM in the utility industry in order to reduce hazard and risk to life, properties and loss of economic resources. A better understanding of this will bridge the gap that gives rise to threats and risks from project start to finish, and this will bring together all the stakeholders to jointly solve the problems and challenges that may likely be experienced throughout the project life cycle. The findings from the study indicate that the principles of inherent safety is about permeating into the system of the industry studied. This is because the application of ISD principles to the management of the entire project life cycle appears not to be a completely new concept among the stakeholders surveyed, but the level of awareness and its adoption is below optimal level considering the fact that less than half of the respondents have used or are aware of its adoption.

The findings also show that project managers though engineers by training are better informed about the ISD approach to eliminating risks and hazard more than project engineers, this is contrary to the result of Evans and Chaffin (1986), who explored 40 engineers/designers and 60 staff engineers in the manufacturing industry and found that ergonomic principles that contributes to comfort, efficiency and safety were more likely to be given attention by plant engineers than by higher engineers in the organisation's divisions. Moreover, the stakeholders place less emphasis on Inherent safety "built in", not "added on" and Passive strategy to minimise hazard using process or equipment design features. This result is consistent with Mansfield and Poulter (1996), who found that those strategies do fail. Moreover, "add on" approaches can be maintenance intensive and capable of adding to the cost while other strategies can generate enhanced safety, low initial capital and operating cost (Mansfield and Poulter, 1996). Adequate knowledge of this is essential as reiterated by Edwards and Bowen (2005) that it is imperative for all the PLCM stakeholders to have sufficient risk awareness and project risk management, especially when making decisions. This was also supported by Edwards et al. (2005) who argued that there is a need for the risk management/ISD tool that will support project management stakeholder's to effectively manage complex projects and understand their nature, type and intensity of the complexities and risks associated with the projects. CORDEL Group (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, 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 risk and decision to ensure safety on project sites (Cooper, 2001; Nicholas and Steyn, 2008).

However, some of the stakeholders recognise the principle but the divergence in their opinion indicates that a significant number 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 of statistics in the perception of the stakeholders as to what ISD and IS represent and how it could be used to minimise risks or hazard. Some of the stakeholders such as design engineers appear to be familiar or come in contact with the terms, but only few of them apply the principle or part of it in their work. Therefore, 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 opportunities for inventory reduction, simplification of plant management and make conspicuous the need to apply other strategies of the ISD approach.

CONCLUSION

This research was conducted to evaluate the degree/extent to which the principle and concept of ISD and IS are being practiced and adopted within the PLCM by project stakeholders in the South African utility industry. The study found that to a certain extent, awareness about ISD principles subsist but at the lowest level. This finding suggests that changes and decisions taken in the latter phases of the project life cycle will be effected by project stakeholders who have little knowledge of ISD tools or requirements. Managing or handling of risks or hazards at an early stage can be most cost efficient way of reducing risk and improve project safety performance as the cardinal principles of ISD encompasses cost reduction however, changing the project design during latter phases might negate this. Therefore, the paper recommends that the level of awareness and knowledge should be improved amongst stakeholders functioning within the utility industry in South Africa. These should include knowledge about the principles, concepts, basics and benefits of integrating ISD into PLCM. It will be of immense benefit to the utility industry when knowledge is improved and the application of the ISD principles are encouraged. It will also bring about cost savings and risk/hazard prevention.

REFERENCES

Center for Chemical Process Safety (2009). Inherent Safer Chemical Process- A life cycle approach. 2nd ed., American Institute of Chemical Engineers, New York.

Cooper, R. (2001). Stage-Gate Systems: A New Tool for Managing New Products. *Business Horizons*, May-June 1991, 44-53.

Cooperation in Reactor Design Evaluation and Licensing CORDE-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*, 1-22.

Dasgupta, A., & Pearce, D. (1974). *Cost Benefit Analysis:Theory and Practice.* Great Britian: The Macmillian Press LTD. ISBN: 333 11395 0.

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. *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, Proceedings of the Human Factors Society, 30th Annual Meeting, pp. 734-737.

Gupta, J. (2000). A course on Inherently Safer Design. *Journal of Loss Prevention in the Process Industries, 13*, 63-66.

Heikikila, A. M. (1999). *Inherent Safety in Process Plant Design: An Index -Based Approach.* Libella Palnopavelu Oy: Technical Research Centre of Finland ESPOO, VTT Publication 384.

Hillson, D. (2011, January/February 2011.). Change is Risky. *The Risk Doctor. The Project Manager today. www. pmtoday.co.uk*, January/February 2011.

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.

INSET. (2001). The INSET TOOLKIT: Inherent SHE Evaluation Tool. *The INSIDE Project Team Partners: AEA Technology, Volumes 1 and 2 - The Full Toolkit*, November 2001, 1-481

Kessides, I. N. (2012). The Future of the Nuclear Industry Reconsidered: Risks, Uncertainties, and Continued Potential. *Policy Research Working Paper: 6112*, June 2012, 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. (2012). Design as a Contributor to Chemical Process Accidents. *Journal of Loss Prevention in the Process Industries, 12*, 18 February 2012, 655-666.

Kidam, K., & Hurme, M. (2012). Origin of Equipment Design and Operation Errors. *Journal of Loss Prevention in the Process Industries*, 16 May 2012, 1-13.

Kletz, T. A. (1999). The Origins and Histrory of Loss Prevention. *Trans IChemE, 77*, May 1999, 109-116

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

Nicholas, J., & Steyn, H. (2008). *Project Management for Business, Engineering, and Technology, Principles and Practice,3rd Edition.* Amsterdam: Butterworth-Heinemann.

Project Management Institute, (2008). *A Guide to the Project Management Body of Knowledge guide (PMBOK)*, 4th Ed. Project Management Institute, Newtown Square, Pennsylvania.

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.

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