CONSTRUCTION HEALTH AND SAFETY (H&S) PERFORMANCE: A CONCEPTUAL FRAMEWORK FOR ENHANCING INFORMATION AND COMMUNICATION TECHNOLOGY (ICT) IMPACTS

David Oloke[1], David Manase and Paul Olomolaiye

School of Engineering and Built Environment, University of Wolverhampton, Wulfruna Street, Wolverhampton, WV1 1SB, UK

The introduction of the Construction (Design and Management) – CDM Regulations of 1994 has significantly complimented efforts aimed at improving the health and safety performance of the industry. An Approved Code of Practice (ACoP) was developed to specifically outline responsibilities of duty holders under the five key stages of the construction process. Throughout the process, several procedures are outlined by the ACoP to ensure that all duty holders conform to the Regulations. These procedures have translated to the fact that huge volumes of paper work are usually associated with each stage of the construction process. Such a development continues to pose great challenges to an industry that is already overwhelmed by paper work. To overcome these challenges, however, several efforts have been made to provide ICT support for all stages of the process. Such efforts include those ICT tools that incorporate health and safety into construction critical path method (CPM) scheduling software and those that use navigable movies for hazard identification and safety improvement training; yet others attempt to provide solutions to hazard identification through hazard referencing. Other systems include the development of on-line health and safety file management systems; web-based pre-tender and construction stage health and safety plan development and knowledge-based system for designers. This study proposes to evaluate the current and potential impacts of ICT tools on construction H&S performance. A review of available ICT tools for health and safety management is performed and a pilot study of awareness, uptake and impacts of the tools is also envisaged. It is expected that the investigation will yield a framework for further enhancement of H&S ICT tool development, uptake and overall impacts on H&S performance.

Keywords: construction, framework, health and safety, ICT, performance

INTRODUCTION

According to the Health and Safety Executive (HSE), the UK construction industry is well behind schedule on its targets of achieving 40 per cent reductions in accidents by 2004-05 – as set at the 2001 Safety Summit (Construction News, 2005). So far, the industry has only managed to reduce major injuries by 15 per cent, while reducing fatalities and minor injuries by 25 percent (circa 2005). This result is despite several efforts made in terms of: the implementation of the CDM Regulations, the Approved Code of Practice and the development of the various Information Communication Technology (ICT) tools as aid for regulatory compliance at all stages of the construction process amongst other things.

The Construction (Design and Management) Regulations 1994 defines duty-holder responsibilities in respect of H&S management. For example, the designers' role in

[1] d.a.oloke@wlv.ac.uk

Oloke, D, Manase, D and Olomolaiye, P (2005) Construction health and safety (H&S) performance: a conceptual framework for enhancing information and communication technology (ICT) impacts. *In:* Khosrowshahi, F (Ed.), *21st Annual ARCOM Conference*, 7-9 September 2005, SOAS, University of London. Association of Researchers in Construction Management, Vol. 1, 465-74.

reducing health and safety risks during construction include avoiding hazards, combating risks and providing information. According to the HSE (2003), it was reported that despite some improvement in designers' understanding of health risks, safety risks and regulations, it was concluded that there is concern in the construction industry that there has been limited success in securing safer designs. The opportunities to design out hazards are not being exploited to the full. Indeed, it was also reported that designers are not always aware that they can help to reduce construction hazards by way of changing the design of structures. In particular:

- designers have limited experience and understanding of buildability;
- the differences in risk levels experienced by different trades and work methods is not well understood;
- the relationship of health and safety issues to lifetime costs is not well understood;
- risk assessment are often insufficient and;
- risk assessments are undertaken too late to bring about design changes, thereby the opportunity to consult with other members of the construction team at that point is often not taken.

These shortcomings in designers' comprehension of health and safety risks are compounded by the overwhelming amount of paperwork involved in compliance with the CDM regulations (HSE, 2000). Most importantly, these shortcomings arise despite the various well-researched and well-developed ICT tools, which aim to address problems associated with H&S management at various stages of construction.

AIM AND OBJECTIVES

It is against this background that this paper aims to evaluate the potential impacts of the current ICT tools on construction health and safety performance by addressing the following objectives:

- performing a review of the available ICT tools for health and safety management;
- conducting a review of utilisation of ICT tools in the construction industry;
- formulating a conceptual framework for further enhancement of health and safety ICT tools development, uptake and overall impacts on health and safety performance.

OVERVIEW OF THE CURRENT HEALTH AND SAFETY ICT TOOLS

The HSE (2001) set guidelines for the definitions of the goals, standards, and challenges for those with a duty of care to manage effectively their health and safety risks. The guidelines concern certain hazardous activities, which have been set with

codes of practice and guidance - giving solutions reflecting good practice in achieving compliance with the law. To enable the HSE be an effective regulator and to ensure that its policies and standards are technically sound and cost effective, high quality scientific and technological underpinning is essential.

In recent years, therefore, a number of innovative research projects are being carried out to demonstrate the application of various technologies within the construction industry. As a result of this, several health and safety systems using wide-ranging technologies have been developed. These include those incorporating health and safety into construction critical path method (CPM) scheduling software (Khartam, 1997). The aim of such a system was to introduce health and safety considerations as early as possible during the project within the construction schedule as it would allow advance planning to take place. Other studies such as Carter and Smith (2001), however, discussed the process of hazard referencing as a possible solution to the problem of hazard identification. This system has the capability of linking hazards to tasks so that a complete risk assessment can be produced automatically when a methodology is devised. Yet others such as Guillermo and Finchy (2003) involved the use of navigable movies to train users in hazard identification and safety improvement within the UK construction industry. Similarly, some studies had described a systematic way of considering and quantifying uncertainty in construction schedules (Mulholand and Christian, 1999).

Furthermore, a prototype knowledge based system was recently developed. This tool provides flexible access to relevant health and safety information, either as a standalone or interactively within a CAD tool (HSE, 2003). In addition, the system allows the designer to add new properties, which are relevant to health and safety, to building objects in their designs. This was as a result of a belief that the poor health and safety record in the construction industry could be improved by encouraging designers to give more consideration to health and safety issues during the design stage thereby upholding the principles of the CDM Regulations 1994.

Several other H&S ICT systems have been developed to date covering various aspects. These include: on-line health and safety file management systems; web-based pre-tender and construction stage health and safety plan development and knowledge-based system for designers. Currently, there are two main groups of ICT software products for construction H&S management in the UK (Anon., 2005a). The first group comprises those designed to assist construction professionals deal with generic health and safety issues, while the second group are those developed with the purpose of ensuring regulatory compliance (Anon., 2005a; Anon, 2005b; Anon., 2005c). However, the extent to which these tools and indeed other ICT tools have been utilised in the construction industry to realise the intended aims and objectives set at the commencement of the projects is not clear.

RESEARCH APPROACH

This study is being conducted under a 3-stage process. In the first stage, the research reviewed ICT tools with emphasis on impact issues in response of construction industry H&S performance. The second stage examined a review of ICT tools

utilisation in construction with a focus on historical issues surrounding uptake and impact of new technologies. The final stage involves the development of a proposed framework for improving construction H&S performance based on an innovative approach to improving uptake and impact of H&S ICT tools.

REVIEW OF IMPACT OF ICT TOOLS ON CONSTRUCTION INDUSTRY HEALTH AND SAFETY PERFORMANCE

During the past two decades, considerable research and industrial efforts have been devoted to implementing ICTs within the Architectural, Engineering and Construction (AEC) industry (Huang, 2003). The industry, however, seems to make slow progress towards capitalising on the opportunities IT offers, to gain competitive advantage and enhance performance. According to Stewart and Mohamed (2004), reasons for the slow uptake of IT include amongst others, the very nature of how the industry operates i.e. one-off projects, industry fragmentation, lack of client leadership, low level of technology awareness and training, the required up-front investment, on-going maintenance costs and resistance to change.

Furthermore, the HSE (2000) had stated that historically, the construction industry has been very fragmented in its use of computer software -this being a reflection of the fragmented nature of the industry itself. Numerous packages have been developed separately to address the requirements of the various disciplines involved in construction projects. Each package has evolved to suit its particular market with little regard for using the data at a later point in the project life cycle, and this has been particularly true for analysis and design packages. Problems identified as generally inhibiting innovation in general and health and safety ICT tool utilisation in particular are: poor rates of investment in research and development (R&D), fragmented supply chains, procurement systems, nature and quality of organisational resources and lack of coordination between academia and industry in research activities. The influences of these factors are the key issues that appear to be hindering ICT innovation and utilisation (ibid).

In addition to the above, the gap between the expectation and result of ICT tool utilisation has also been attributed to the fact that too many previous research projects and industrial-based ICT initiatives adopted a technology-driven approach (Huang, 2003). According to Huang (2003), there has not been enough effort given to understanding human behaviour, organizational culture, training and technology-process-culture combined issues, regarding adoption of the new ICT tools and systems. It is generally accepted that the successful adoption of ICT innovations is a key contributor to organisation success. However, relatively little research effort addresses the problem of getting new ICT innovations generally accepted and continually used in a specific AEC company. In the same vein, previous studies have also shown that technology push (i.e. technological solutions) is not sufficient to improve the efficiency and effectiveness of the working environments without clear consideration of the business processes and the human issues (ibid).

On the other hand, however, discussions between the HSE (2000) and ICT vendors confirmed that the utilisation of health and safety ICT tools is not regarded as an issue. As commercial organisations, vendors focused on the provision of solutions, which they can sell to their users. Justification for adopting computer systems stem from the ability to improve product design by better analysis, or to derive productivity benefits associated with faster working, removal of repetitive tasks, and elimination of errors. According to the vendors, health and safety ICT tools do not feature strongly with management or information packages. They are 'support systems' which even though may not directly contribute to revenue generation, they facilitate: the smooth management of the organisation, its stability and sustained business (Bhutto *et al*, 2004).

ENSURING ICT TOOLS UTILISATION IN CONSTRUCTION

According to Mitropoulos and Tatum (1999), advances in technology are widely regarded as major sources of improvement in the competitive position of firms and industries and are major factors for increased national economic growth and standards of living. In free market economies, technological diffusion is determined by managerial decisions at top levels of the firm. Thus, the evaluation and decision-making process regarding adoption of new technology is at the heart of the innovation process. However, the benefits from technological advances depend on the extent to which this technology is utilised. The successful implementation of new and innovative ICT in construction on the other hand requires the development of strategic implementation plans prior to ICT project commencement. Strategic implementation in construction organisations according to Stewart and Mohamed (2004) must tackle the main ICT management processes: setting strategic and technical direction for ICT applications, making decisions about funding, executing ICT business strategies, and reviewing performance of ICT investments over their lifecycle.

In addition, Mitropoulos and Tatum (1999) suggest that our understanding of how managers in construction organisations make decisions to adopt new technologies is very limited. Several important questions remain. How does the need for technological change emerge? How do managers select and justify new technologies? Is innovation driven by company goals, powerful internal or external organisational actors, or does it happen only when some organisational and environmental conditions simply allow it? And how do the managers deal with the uncertainties involved in the adoption of a new technology?

Therefore, according to Hampson and Brandon (2004) advanced approaches to concept development, design, and construction management using state of the art ICT tools should be standard fare in all industry education and training programs. An education strategy should identify exemplar projects, which can demonstrate commercial benefit and provide these for limited trial. The strategy would provide an action-learning environment where personnel and organisations can share experiences and learn from one another, and enhance the supply chain to encourage uptake and improved satisfaction of client need. Part of the strategy would involve diffusing the results of trials to industry through workshops, and distribution to media. Furthermore, a research and development strategy would be able to bridge the gap between general

technology push and construction industry pull to promote the development and uptake of ICT for construction. This strategy would also provide forward thinking for the industry so that investment can be made in an intelligent and united way, ensuring maximum benefit accrues to the industry as a whole.

DEVELOPING THE FRAMEWORK STRATEGY-THE INNOVATION JOURNEY

In order to understand the uptake of the H&S ICT research innovation and its impact, this study first reviewed the 'innovation journey' (Van de Ven *et al*, 1999). Figure 1 illustrates all the stages included in the innovation journey.

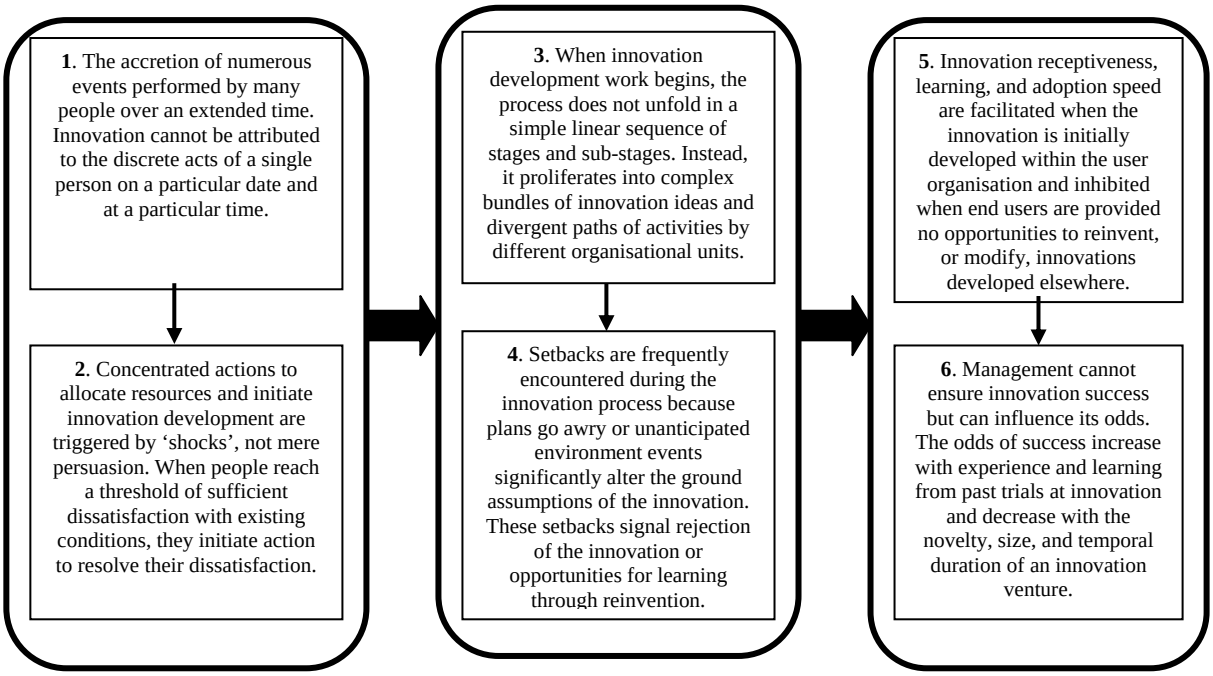

Figure 1: THE INNOVATION JOURNEY (Source: Van de Ven *et al*., 1999, pp10-11)

A close examination of Figure 1 shows that stages 5 and 6 of the innovation journey are primarily concerned with the adoption and enhancement of innovation. Furthermore, the study reviews the typology of literature on adoption and diffusion of innovation research such as is presented by Wolfe (1994); Roger (1995) and Osborne (1998) and illustrated in Figure 2.

As illustrated in the Figure 2, Wolfe (1994) argues that it is important to distinguish between three streams of innovation research (using a conceptual differentiation approach) while, Rogers (1995) had articulated a typology of diffusion research based on the aspect of the innovation process. Osborne (1998), however, deviates from an exclusive focus on technology innovation and proposes that while a distinction between product and process innovations can be helpful, in public services these are often inter-related. He therefore evolved a four-fold typology, which examines innovations in the developmental, expansionary, evolutionary and total forms (ibid).

Ultimately, each of these streams conceptualizes innovation and the diffusion process in different ways with each stream having its own insights and drawbacks. For this study, an initial analysis of the adoption of innovation literature is hereby undertaken

prior to conducting a synthesis of the factors underpinning the uptake and impact of construction H&S ICT tools on H&S performance.

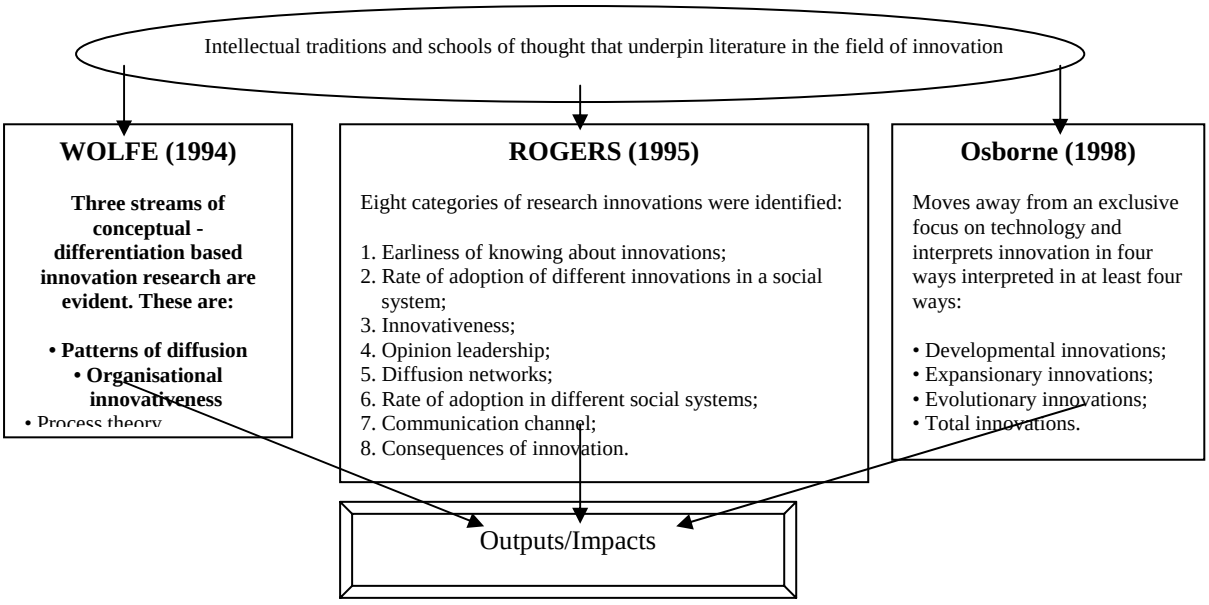

Figure 2: TYPOLOGY OF THE ADOPTION OF INNOVATION RESEARCH

Conceptual Framework for Improving H&S Performance

A conceptual framework for a methodology for a critical analysis of factors that affect the adoption of H&S ICT innovation is proposed. The framework pays particular attention to three key issues in three stages as illustrated in Figure 3.

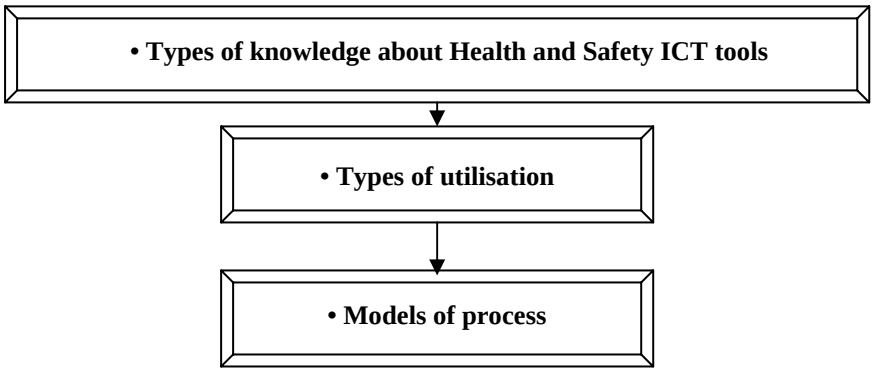

Figure 3: CONCEPTUAL FRAMEWORK DEVELOPMENT FLOWCHART

In developing this framework, knowledge about ways of practice (for example, process innovation), or knowledge embodied in specific technologies and products (product innovation) would be obtained using a quantitative survey. Questions asked, as part of this procedure covers issues such as:

- *What types of knowledge is the field concerned with?*
- *What forms of explicit knowledge are considered to be important and what attention, if any, is paid to the role of tacit knowledge in understanding knowledge transfer and utilisation?*

Three distinct types of knowledge will be addressed. These are:

'Awareness' knowledge – the awareness that an innovation exists, knowledge of its key properties, and understanding of how the innovation relates to current practices.

1. 'How-to' knowledge – the information necessary to use an innovation properly.
2. 'Principles' knowledge – information dealing with the functioning principles underlying how the innovation works.

All three types of knowledge are important in moving potential adopters from ignorance through awareness and on to adoption.

The 'types of utilisation' stage of the framework (Figure 3) will involve an in-depth look at H&S ICT innovation utilisation by addressing the following questions:

- *What forms of knowledge utilisation are envisaged?*
- *Are we concerned primarily with direct and instrumental use (for example, adoption of new technologies), or*
- *Are we also concerned with less obvious shifts in basic attitudes and values?*
- *How far is utilisation conceived in terms of replication as opposed to reinvention?*

Also, as illustrated in Figure 3, the final stage is the 'model of process'. This stage will seek to understand:

- *How the process of knowledge utilisation has been modelled by key authors within the field?*
- *What the key concepts employed are, and how have their interrelationships have been portrayed?*

The process of adoption could therefore be considered to revolve around four key elements: an idea or innovation, channels of communication to spread knowledge of the innovation, time during which diffusion takes place, and a social system of potential adopters in which this occurs (Rogers, 1995). Similarly, the study proposes to analyse how (within health and safety innovation research) the four generations of models identified by Williams and Gibson (1990) to characterise the technology transfer process, have been utilised. The four models include: the appropriability model - which emphasises the importance of quality research and competitive market pressures to promote the use of research findings; the dissemination model (where experts inform potential users of the new technology); the knowledge utilisation model (which stresses the importance of interpersonal communication between researchers and users and the role of organisational barriers and facilitators in promoting research use); and the communication and feedback model (which characterises technology transfer as an interactive process where individuals exchange ideas simultaneously and continuously).

CONCLUSION

This study commenced with a review of the available research on ICT tools for health and safety management in addition to a review of utilisation of ICT tools in the construction industry. Subsequently, the impact of ICT tools on the construction health and safety performance was evaluated in line with various established theories that underpin innovation adoption.

Evidently, several research/industry efforts have culminated into the development of ICT tools aimed at enhancing H&S performance. However, in order for the construction industry to enhance its effectiveness in securing better outcomes in health and safety, it requires a thorough technological advancement and management expertise that must be supported by well-resourced, creative and energetic research and innovation. An industry culture more embracing of research and innovation should therefore emerge. The need to ensure that construction health and safety innovation is poised to deliver clear and relevant research outcomes has been emphasised.

It is in this regard that a conceptual framework for the further enhancement of health and safety ICT tools development, uptake and overall impacts on health and safety performance is hereby formulated. The proposed framework puts forward a methodology that seeks to understand when and why innovations are adopted or rejected. Such output will provide an insight into the diffusion processes and also provide guidance on the enhancing the application and uptake of ICT H&S tools.

It is anticipated that the outcome of the study would invariably, improve the utilisation and impact of ICT tools in the construction industry and ultimately enhance the use and understanding of the CDM regulation and their accompanying Approved Code of Practice.

REFERENCES

Anon., (2005a), Safety Services Direct

http://www.safetyservicesdirect.com/index.asp?function=DISPLAYCAT&catid=13 (Accessed 20/02/05)

Anon., (2005b), Ergosystems WMB http://www.ergosystems.co.uk/ (Accessed

22/03/05)

Anon., (2005c), Ai Solutions Ltd.

http://www.aisolutions.co.uk/solutions/cdm-management/ (Accessed 22/03/05)

Bhutto K., Griffith A., Stephenson P., (2004), *Evaluation of Quality, Health and*

Safety and Environment Management Systems and their Implementation in Contracting Organisations, COBRA 2004, The International Construction Research Conference of the Royal Institution of Chartered Surveyors, Leeds Metropolitan University

Carter G. and Smith S. (2001), *It Tool For Construction Site Safety Management,* Cib

W78 Conference, Mpumalanga, South Africa

Construction News (2005), *Construction Way Behind Safety Targets*

Guillermo A. M, Finchy E. (2003), *Using Repertory Grids to Measure Changes in*

Risk-Taking Behaviour,. Journal of Construction Research, Vol. 4, No. 2 1, 14 World Scientific Publishing Company.

Hampson K, Brandon P., (2004) - *Construction 2020-A Vision for Australia's*

Property and Construction Industry, www.construction-innovation.info, Brisbane

Health and Safety Executive (2003), *The case for CDM: better safer design - Pilot*

study, Research Report 148

Health and Safety Executive (2001), *Science & Strategy – Innovation*, *www.hse.gov.uk*

Health and Safety Executive (2000), *Evaluation of Simulation Based Design Tools for the Construction Industries* – Final Report, Contract reference 4146/R72.062

Huang C. (2003), *The Development of a Triangular Technology Process Culture Model to Support Adoption and Integration of its Innovations*, ARCOM Doctoral Workshop Managing Innovation and Knowledge Management in the Construction Industry, The University of Reading, UK.

Khartam. N.A (1997), Integrating Safety And Health Performance Into Construction CPM-, *Journal of construction engineering and management* vol 123, no 2.

Mitropoulos P., and Tatum C. B., (1999), Technology Adoption Decisions In Construction Organizations, *Journal of Construction Engineering and Management*, Vol. 125, No.5

Mulholland B. and Christian. J (1999), Risk Assessment In Construction Schedules, *Journal of Construction Engineering and Management*, Vol. 125, No. 1,

Stewart R., Mohamed, S. (2004), *Barriers To Implementing Information Technology In Developing Countries*, www.construction-innovation.info, Brisbane

Van de Ven AH, Polley DE, Garud R and Venkatarum S (1999), *The Innovation Journey*. Oxford: Oxford University Press