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EXPLORING THE KNOWLEDGE FUNCTION IN THE ADOPTION OF ICT IN SITE MANAGEMENT IN SOUTH AFRICA

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ABSTRACT

The study is centred about the adoption of ICT-based products in the site management process in South Africa. Selected constructs derived from innovation adoption, diffusion and technology transfer are used to examine aspects of ICT adoption in the South African site management scenario. Knowledge and awareness, and skills and utilisation of ICT are examined in association with adoption of ICT in site management. A purposive sample of literature on the aforementioned concepts, construction, site management and ICT adoption in construction is used to frame the study. Analysis of a recent practitioner survey using a mix of qualitative and quantitative data is applied to arrive at results which further the discussion on ICT adoption in local site management. Limitations of the research emanate mainly from the unknown size of the target population, a measure of purposiveness in the sampling for the study and the numerical strength of the final sample. With the use of a snowball effect, a response sample rate of approximately 80%, based on an effective sample population, was utilised for the research. However the survey was administered at a national level which ensured appreciable spread in terms of administration and demographics of respondents. Results point to considerable information related factors, which constitute hindrance to expedient adoption of ICT in the local site management. Such factors relate to the extent of awareness, skills and working knowledge of ICT in construction, especially site management. Results suggest the need for more awareness of potential in ICT, acquisition of ICT skills, and appreciable working knowledge of available ICT-based technologies which are relevant to site management. The results have implications for the diffusion of ICT in the local construction scenario, especially in the site management process. It also adds value by improving on the scarcity of relevant local information within this area of study.

Keywords: ICT, site management, adoption, technology transfer, awareness, ICT skills, ICT usage.

1. INTRODUCTION

The primary research interest here concerns the utilisation of information and communication technology (ICT) related products in construction, with special focus on the management of construction site processes in the South African context. The focus is on selected determinants of innovation adoption as applied to ICT in construction site management.

The construction industry is a complex set of loosely connected components, with individual degrees of autonomy, which still function together in project and site focused environments (Dubois and Gadde, 2002). The project environment accommodates participation by several parties with various functions and roles (Shirazi, Langford and Rowlinson, 1996). Such complexities of site management make appreciable planning indispensable (Kuprenas, 2003; Hendrickson, 2003). However despite good organisation, the construction project site remains a highly unpredictable environment (Forster, 1989). Increase in project complexity and volume of stakeholders, would expectedly stretch site management capacity (Ozumba and Shakantu, 2008a). In addition, practical management capacity issues based on human limitations plague the management of construction site processes (Ozumba and Shakantu, 2008b). The management of projects is therefore more critical under such circumstances. The effectiveness of managing vital issues, which affect overall construction progress and cost effectiveness, will depend heavily on site management capacity (Wikforss & Lofgren, 2007; Zhang, Ma and Cheng, 2001). Zhang et al., (2001), further state that the continuing increase in adoption of ICT-based technologies is partly due to the need for increased site management capacity.

Despite the need for improvement through adoption of new technologies, the construction industry is considered slow in this regard (Arayici, Aouad and Ahmed, 2005). Such aforementioned pressures on construction site management, and the attendant need for ICT adoption, would be particularly evident in emerging economies such as South Africa. As shown in Ofori (2000), the construction sectors in developing countries endure multiple stresses of globalisation, culture, and the need for more construction activities to increase physical development.

In the case of South Africa as an emerging economy, there is scarcity of studies exploring ICT in site management specifically. As such the current paper is intended as contribution to knowledge on ICT in construction site management in the South African context. Major concepts of discussion in the study are presented in addition to a review of related literature. The methodology, data analysis and results are then presented and discussed, leading to a concluding section.

2. MAJOR CONCEPTS IN THE STUDY

Adoption of ICT in site management centres about the concepts of technology transfer, innovation, and diffusion in the construction industry. Technology Transfer as defined in the Oxford dictionary embodies the concepts of innovation, diffusion and adoption; the acceptance and implementation of inventions, innovations, knowledge and techniques across different entities and situations (Oxford University Press, 2014). Elements of innovation include that it is aimed at creating purposeful social or economic change (Drucker, 1998). It involves the useful and profitable exploitation of an idea or concept (Ling, Hartman, Kumaraswamy and Dulaimi, 2007). Innovation also involves revolutionising with what exists currently (Lindley, 2003). Diffusion on the other hand is derived from knowledge areas in the classics and natural sciences.

It involves the property or act of dispersion; physical movement of substance from an area of high occurrence to an area of lower occurrence; or the dissemination of world view, way of life, skills and techniques from one society to another (Morales and Gilner, 2010). The widely held seminal definition for 'diffusion of innovations' states that it is a communication process through channels, by which an innovation is communicated to parties within a social system at both group and individual levels (Rogers in Rogers, Singhal and Quinlan, 2006; Rogers and Shoemaker, 1971). Though there are numerous definitions for each of the stated concepts, the following ideas are strongly suggested: adoption, useful exploitation, profitable exploitation, new applications, change, communication, and technology. Such keywords reflect some of the factors which have influenced the path of ICT in construction.

Theory on adoption of innovation connotes a decision process which results in the adopter choosing an idea above all others, in a given time frame and setting. Adoption is the third step in the innovation decision process, considering the five stage innovation decision process model by Rogers (2003). The major distinction between the meanings of adoption and diffusion is the scope. Adoption is focused on the individual adopter and his mental process backed by actions. Diffusion considers the social system and the process of spread of an innovation over time. Essentially adoption takes a micro perspective while diffusion takes a macro perspective. Thus adoption is contained in diffusion. It could be described as sub-processes within diffusion. Essentially it is individual adoptions over time which collectively constitutes diffusion. Similarly, diffusion could be described as the adoption process occurring across a population within a time frame (Straub, 2009). Adoption could be symbolic where the innovation has just an idea component, or action adoption, where a physical object component is involved (Rogers and Shoemaker, 1971). Within the body of theory for diffusion of innovations, there are some fundamental concepts which have emerged: bottom-up and top-down models; macro-level theories focusing on the institution, and micro-level theories focusing on the individual. Recent theories attributed to Evert Rogers include innovation decision process theory, individual innovativeness theory; rate of adoption theory; and perceived attributes theory (Carr, 1999).

From Rogers (2003) there is the knowledge function in operation within the innovation adoption process. The knowledge function is the main driver in the innovation decision process. Decisions made with regard to adoption, depend on prevailing information at the time and deductions made. Research has shown that the rate of awareness and knowledge of an innovation relates positively to the rate of adoption. Therefore knowledge is fundamental to the process of diffusion of innovations. Within this context there are three kinds of knowledge: awareness and knowledge that an innovation exists; knowledge about what an innovation requires for utilisation, area of application and how to use it; and knowledge about the guiding principles, on which the innovation is based. The first is essential in the beginning while the other two unfold. Research also shows that the rate of knowledge influences rate of adoption (Rogers and Shoemaker, 1971). Autant-Bernard, Guironnet and Massard (2010) also support the theory in stating that, adoption of any innovation depends primarily on three main factors; awareness, capacity to exploit the technology and perceived returns for adopting the technology. Though the third factor relates to cost in the first instance, other elements such as perceived benefits and risks, are information based. It is thus arguable that such elements would influence the perception and value placed on the technology by decision makers. Therefore in the context of construction, the knowledge function could be expected to have appreciable influence in the adoption of ICT across its many processes.

2.1 ICT Adoption in Construction

In the context of a construction project, innovation has been described as a new concept which could be adopted by a client, with the aim of deriving increased benefits through returns on that investment (Ling et al., 2007). It has also been inferred that innovation in a construction project environment could originate from any of the stakeholders regardless of position and status, and stage of the project. It is further described as a dynamic process which does not necessarily progress within strict definitions (Fryer, Egbu, Ellis and Gorse, 2004). Following the above mentioned authors' assertions, the challenging nature of site management as described elsewhere in the paper, would arguably facilitate innovativeness. Innovation as viewed here includes being creative with existing technology and adopting available innovations. Furthermore, since technology is appreciably utilised in site management, it is reasonable to expect substantial uptake of relevant technological innovations, including ICT.

The path of ICT usage in the field of construction, is traceable to the history of computing, which is more than a half a century old (Bedard and Rivard, 2003). Earlier research on the growth of ICT over time places built environment professionals in the mainstream of ICT development, in collaborations and self-initiated projects (Howard, 1998). The focus of development for ICT has moved between potential uses of computers, their capacity for enhancing natural human skills, presentation and visualisation, and applications. The shift in focus enabled practical uses through the development of existing knowledge and their application to areas of productivity. ICT in construction has since passed through various periods and levels of integration, namely: hardware, software, communications and the present data era (Howard, 1998; Haas & Saidi, 2005). It is therefore arguable that the development of ICT in construction has in part, been largely influenced by perceived needs and possibilities. As demonstrated in the next section, such needs have been expressed in industry circles, eliciting responses that have resulted in further development of ICT in construction.

2.2 The Need for ICT in Construction

Following the Latham and Egan reports in the UK, ICT is widely accepted as having a critical role in addressing some construction industry challenges. Furthermore the information age and globalisation have added to the needs for higher competitiveness at the organisational level (Yeomans, Bouchlaghem and El-Hamalawim, 2006). Existing research shows that by 2005, more than thirty-five years of ICT utilisation in the Architecture Engineering and Construction (AEC) sector had been recorded. The said period of ICT adoption has taken place with ground breaking results that have appreciably changed many processes (Haas & Saidi, 2005). The importance of such developments is highlighted by recent research on the need for process enhancement in the management aspect of construction activities, especially at the site stage (Patel, 2006). Such enhancement could be achieved through employment of ICT-based technologies (Ozumba and Shakantu, 2009a). The required enhancement would assist in addressing needs in areas such as H&S risk management (Chartered Institute of Building (CIOB), 2009a; Patel, 2006). In addition it would improve logistics and materials management (Ozumba and Shakantu, 2009b; Thomas, Riley and Messner, 2005); and security management (CIOB, 2009b; Strategic Forum for Construction, 2005). However the need for more efficient approaches to ICT implementation in construction has also been alluded to in the highlighting challenges to ICT in construction.

Ugwu & Kumaraswamy (2007) asserted the need for innovative approaches that are based on sound knowledge of the construction environment, its participants, and ICT sector developments.

2.3 Knowledge and Awareness, and Skills in the Adoption of ICT in Construction

Following the discussion in 2.2 above, it is arguable that the rate of adoption of ICT in construction for any locality would among other factors represent the following: availability of the technology; access to the technology; awareness of the technology and its potential on the part of users; necessary skills to engage with the technology; and some degree of working knowledge to enable productive utilisation of the technology. Williams, Bernold and Lu (2007) highlighted the influence of varying ICT literacy and depth of IT knowledge/awareness on decision makers across individual firms, with regard to ICT adoption. Michaloski and Paula (2010) on a study in Brazil noted that automation on job sites did not go beyond desktop applications. There was also considerable difficulty in using ICT in site management. Factors identified as challenges to more ICT adoption include complexity, difficulty in adapting ICT to company needs, and ignorance about available ICT. Following the theoretical framework in the paper, highlighted factors constitute knowledge and awareness, and skill related issues. Hewage, Ruwanpura and Jergas (2008) from a study in Canada reported a high degree of ICT adoption in site management work, whereby cell phones were used by managers across all levels; project coordinator, superintendent, supervisors and foremen. However final communication with workers was manually done as the workers were not encouraged to use ICT on site, based on perceived poor ICT skills. An initial Canadian study on the construction ICT market and companies serving the country's construction sector also revealed little emphasis on site management. Highlighted challenges include lack of technology acceptance, lack of awareness and lack of understanding. Here was also deficiency in knowledge of opportunities for exploiting potential in the technologies (Froese and Han, 2005). These findings support the theory, which links knowledge with adoption.

In the Swedish study by Samuelson (2007), the need for ICT skills was identified as a challenge. Another study on Swedish house building projects identified low levels of awareness of ICT availability and lack of requisite skills as challenges to adoption (Molnár, Andersson and Ekholm, 2007). Scarcity of requisite ICT skills was also identified in the Turkish study by Sashar and Isikdag (2004). Though awareness and intent to adopt ICT in site management was identified in this case, the necessary skills and skills levels were absent. As such the awareness and intent did not translate to action adoption. Ugwu and Kumaraswamy (2007) identified that perception of adopters with regards to possible benefits was important, with regard to enablers of new technology adoption in construction. Ease of understanding the technology, competence of the staff, and ICT capacity of staff were equally identified as key enablers. All factors mentioned here point to knowledge and awareness, existence of some degree of skills, and engagement with the technology in the form of attempts at utilisation. Therefore apart from other management and cost factors, lack of ICT utilisation in site management also indicates lack of the above mentioned key enablers. Similarly adequacy of such key enablers would reflect in commensurable adoption, especially when the focus is on decision makers at organisational, project and site levels.

In a Taiwanese study by Chien and Barthope (2010), results suggest that most of the available technologies were adopted for their basic uses, without any indications of application at site level.

Similarly in Malaysia, Gaith, Khalim and Ismail (2009) identified minimal use of technical software in site processes, despite the positive influence of investment in ICT on company performance. Kareem and Bakar (2011) reported considerable use of mobile technology, but however stated that some benefits of utilising ICT in site management were not realised in existing projects. Such findings are suggestive of knowledge and awareness, and skills issues. The Indonesian study by Memon, Majid and Mustaffar (2006) identified preference for manual systems as the core disposition of participants. Where there is little or no engagement with relevant technology regardless of its availability, it is arguable that knowledge and skill factors are minimal or non-existent. It is equally possible that regardless of awareness, there has not been any translation to skills and engagement with the specific technology in a unique area such as site management.

For example Pamulu and Bhuta (2004) in Malaysia identified appreciable integration of ICT at project level but no obvious occurrence at site management level. Ahuja and Yang and Shankar (2009) in India also identified that technologies such as teleconferencing and videoconferencing were available, but not exploited for the site. Oladapo (2006) in Nigeria identified that there was virtually no use of available technologies for the site management process, though the identified technologies have potential for site management. Oladapo (2007) in Nigeria found insignificant change in the ICT footprint of the AEC industry. Furthermore there was still no mention of ICT usage in site management, though contractors and engineers were included in the study. Following the theories of innovation diffusion and adoption set out in the paper, findings from review of literature suggest the presence of knowledge, awareness, skills and usage challenges to ICT adoption. Thus the relevance of aforementioned factors to ICT adoption in site management is further substantiated.

In a related context, Oyediran (2005) on AEC educators in Nigeria, identified a moderate level of awareness of available ICT and potential, and corresponding low levels of ICT facilities, average individual proficiency for basic ICT tools, and below average proficiency for industry specific ICT. Though this study is in a different, but related context, it further supports the theory linking knowledge and awareness, and skills and usage, to ICT adoption and diffusion.

Moreover Koekemoer and Smallwood (2007) on general contractors in South Africa, highlighted lack of awareness of latest technologies relevant to site management. Similarly general usage of ICT at operational management level was low. Ozumba and Shakantu (2012) reported an appreciable degree of familiarity with recent ICT-based products amongst South African site management practitioners, which did not translate to a corresponding degree of adoption in site management. There was low utilisation of ICT during the site or construction phase. Respondents' depths of utilisation of each product's features in site management were likewise low. Furthermore Ozumba and Shakantu (2013) suggested that knowledge related factors constitute some of the major challenges facing uptake of ICT in site management within the South African context.

Deductions from review of literature suggest that there is more engagement with a wider range of possibilities in the utility of ICT within advanced economies, than their emerging counterparts. Challenges such as lack of ICT awareness and skills are strongly highlighted in studies focused on developing countries. With regard to site management, there is appreciable lack of adoption of ICT in relation to the observed general occurrence of ICT in other aspects of construction. ICT adoption for office use and only for the basic utility is prevalent. Furthermore a contradictory lack of ICT up-take occurring alongside appreciable awareness and positive outlook for ICT seems to exist in some cases. In addition the choice of manual systems was highlighted in some cases.

With regard to South Africa, existing literature demonstrates that current opportunities for ICT integration seem to be accessible to the construction industry. Literature on ICT utilisation in site management however shows the same sub-optimality. While there seems to be considerable improvement in knowledge and awareness of ICT-based products and the required skills, there is a contradictory low observation of utilisation for each item of ICT. The contradiction places doubt on the claim of awareness of ICT potential for relevant areas of site management. It also points to a possible lack of adequate levels of skills and depth of usage which would enable exploitation of available technologies. While other factors such as cost and support could hinder ICT adoption, indications of awareness, skills and depth of utilisation should collectively influence ICT use in site management. This could be expected especially when the ICT has occurred in a construction project. It follows then that if there is occurrence of ICT in any aspect of a construction project, there would be a corresponding value of specific occurrence in site management functions; if other variables are in corresponding occurrence. It is substantiated in literature that if ICT occurs in a project, it suggests a degree of management support and cost coverage. Therefore in the presence of knowledge-based enabling factors, adoption in site management would most probably occur.

While some of the issues highlighted in the preceding discussion have been suggested in recent pilot studies in South Africa, there is still scarcity of information, with specificity to site management. The current paper therefore provides further insight to the state of ICT use in site management, in the South African context, exploring the knowledge-based constructs discussed thus far. Based on the preceding review of literature, the paper is focused on the following constructs: Awareness of ICT types, occurrence in terms of any form of usage in construction, usage in site management, necessary ICT skills, and working knowledge of relevant technology, as demonstrated by indication of depth of usage. The following section details the methodology used for data collection and analysis in the study.

3. RESEARCH METHODOLOGY

The paper is essentially purposed as an exploratory study, as highlighted in the introductory section. Further research was constituted into analysis of primary data from a national practitioner survey, performed as part of a multi-stage research project in South Africa. A combination of qualitative and quantitative data forms were collected for analysis. The sampling approach was generally purposive, as described in Leedy and Ormond (2010). Though survey could be time consuming and there could be poor and incomplete responses, many orders of questioning are addressed effectively through it (Saunders, Lewis and Thornhill, 2009). Survey follows a generally deductive process using a theory which is rigorously tested through the use of multiple questions. Surveys can assess many things including self-classifications; and knowledge (Neuman, 2007). Semi-structured questionnaires were used as the survey instruments. The design allowed for richness of data. The primary data was taken from a recent nation-wide survey of registered professional persons within management levels on construction sites, projects and companies, in South Africa. The time span was set between 2008 and 2011. The target population was the South African registration council for professionals in the construction project management and construction management professions. The survey instruments were administered electronically by email. The distribution of instruments was performed through the registrar's office of the relevant professional body in this case, due to information access restrictions.

However completed questionnaires were returned directly to the researchers by participants. Two versions of the research instruments were designed, whereby one version could be completed electronically and returned via email, and the other was in a downloadable PDF format. The later had to be downloaded, printed and completed manually before being digitised and returned to the researchers. Each prospective respondent received the two formats along with explanatory letter of introduction and informed consent form.

The sample population could not be determined with accuracy due to on-going registration process at the time of survey and lack of access to the register of relevant professionals. Therefore a snowball effect was utilised to derive an effective sample population of seventy two (72) from the returned questionnaires. Out of the effective sample population of 72, 14 responses were either incomplete or lacked adequate clarity and were discarded. A final sample of 58 respondents was used for analysis presented in the paper. Data was subsequently extracted from responses through content analysis of documents pertaining to each respondent.

3.1 Data presentation, analysis and findings

Respondents' general data included; general information about age, the value of projects involved in; experience in the spread of provinces they have worked in, projects, site work, and highest grade of project or firm involved in; location (Johannesburg – Gauteng Province or elsewhere); area of practice; and level of work in construction projects. The grading system of the Construction Industry Development Board (CIDB) was used. With regards to age, 31% were 56 years and above, 22% were (46 – 55) years, 33% were (36 - 45) years, 12% were (26 - 35) years, and 2% were (18 - 25) age range. On the spread of experience in site management within the 9 provinces of South Africa, 7% of respondents had worked in all 9 provinces between 2008 and 2011. A further 12% had worked in 4 provinces while the percentage of respondents with working experience in 2 and 3 provinces respectively share the same value of 17%. The highest value of 43% is by respondents with experience in only one province between 2008 and 2011. However those with experience in one province are spread across a number of provinces. From the survey response 55% of respondents are stationed in Johannesburg and the Gauteng province, while 45% of respondents are from other provinces. The grading of contractors by CIDB in South Africa is from 1 to 9, with 9 being the highest grade. An appreciable 72% of respondents have worked at the highest CIDB grade level of firm or project (9). Equal proportions of respondents (10%) have also worked at levels 7 and 8 respectively. Moreover an appreciable 64% of respondents have performed both project level and site management work.

3.1.1 Constructs and data description

Constructs used for the paper are: Awareness of ICT types, occurrence of usage in construction, usage in site management specifically, working knowledge as demonstrated by indications of the depth of usage, and necessary ICT skills for each technology by self-assessment. With regard to items of ICT for which questions were fielded, data on 27 items of relevant ICT from Ozumba and Shakantu (2012) were utilised. An additional 8 items of ICT identified during the study were also added to create the following categories of recent ICT-based products for which questions were answered in the survey:

Mobile hand-held devices: lap-tops, smart-phones/cell phones, Tablet PCs, digital pens, and digital assistants.
Geographic and surveillance devices: GPS, surveillance equipment, laser range finders or measurers, and digital surveying instruments.
Sensors and Scanners: alcohol breath testers, barcode scanners, biometric systems, circuit tracers, concrete scanners, and RFID/Auto-ID.
Hybrid technologies: machine control technology. Virtual Reality, Augmented Reality, Video Conferencing, Telepresence, 4D CAD, 5D CAD, nD modelling, BIM.
Wireless applications: Company Web portals, Electronic data management systems, Virtual Private Networks, Cloud computing, Wireless network WLAN / Wi-Fi, Wireless Internet, Site Intranet, Project Extranet.

Collectively, individual sub-groups under the aforementioned categories comprised 35 items of ICT, which are made up of hardware, software, applications, and services. Binary coding was used for the survey responses on the constructs examined here, where (1 = yes, 0 = no). Data on ICT skills and depth of utilisation of features in each ICT sub-group were based on self – assessments, which used ranking systems. In accordance with the purpose of the paper, there was need to detect any element or indication of skill or engagement with each technology. In so doing the research accounts for the most possible instances of knowledge, skill and usage, which would drive adoption to an appreciable extent as demonstrated in the review of literature. As such, for depth of utilisation of features in each ICT sub-group, respondents were asked to rate themselves on a Likert type scale of (1 – 10), where 1 = lowest and 10 = highest. This more elaborate scale accounts for any ambiguities, as each respondent that has engaged with any of the technologies in question is able to apply a rating. In addition the absence of any rating was accepted as an indication of 'non-engagement' with the technology, which was coded as (0). For the ICT skills variable, a three-point Likert type scale was used to also make it easier for respondents to rate themselves on an interval scale of 1, 2 and 3, where 1 = basic skills, 2 = intermediate skills, and 3 = advanced user. For the purpose of the paper, existence of necessary skills for utilisation of items within any ICT sub-group was the focus. As such any indication, regardless of the ranking, was recorded as 'yes' with a binary coding of (1). The same principle was applied to indications of depth of usage for each ICT.

Result of analysis performed on relevant constructs from the practitioner survey is presented in the sections following. Comparative analysis is utilised, whereby response values are considered as proportions of expected values which would occur if all responses were 'yes'. For the sake of analysis, total value of respondents answering yes is contrasted with the total ideal or expected value in order to derive a percentage. As stated earlier, the number of technologies for which practitioners were questioned was 35, while 58 responses were used for analysis. Therefore the total value of responses possible for all respondents indicating 'yes' for any variable would be:

Number of ICT sub-groups (35) multiplied by number of respondents (58) = total expected value for each variable. Mathematically the derivation is as follows: (58 x 35) = 2030.

In presenting results of the analysis, firstly a matrix and a chart are used to perform the comparisons.

Further exploration is done through chi-squared test, covariance and correlation analysis. Linear regression is finally performed in steps, to further explore emerging patterns and validate results of preceding steps in the analysis of the survey data.

3.1.2 Data analysis and results

Table 1: Comparison of response values with expected values for relevant constructs

Values	Aware	Use in construction	Use on site	ICT Utilisation	ICT Skills
Total	946	435	350	433	411
Average	27.0	12.4	10.0	12.4	11.7
Expected total value	2030	2030	2030	2030	2030
Percentage value	46.6%	21.4%	17.2%	21.3%	20.2%

Table 1 above presents aggregated values of responses for the stated variables. Expected values for parameters measured are stated in the third row. The first row 'Totals', represents aggregate proportions of respondents who indicated 'yes' to the relevant questions in each case. From the analysis, aggregate ICT awareness value is 946, which approximates to 46.6% of expected value. Response value for ICT usage in construction is 435 amounting to 21.4% of expected value. Similarly ICT usage in the SMP, on site is 350 amounting to 17.2% of the expected value. ICT utilisation was found to be 21.3% of expected value while ICT skills variable was assessed at 20.2%. Apart from awareness of ICT which is less than half of the expected value, all other variables have values less than 22% according to participants' responses. Moreover onsite IC use has the lowest value. Following comparisons in Table 1, a chart is used to further examine the variables in more detail, according to groups of ICT.

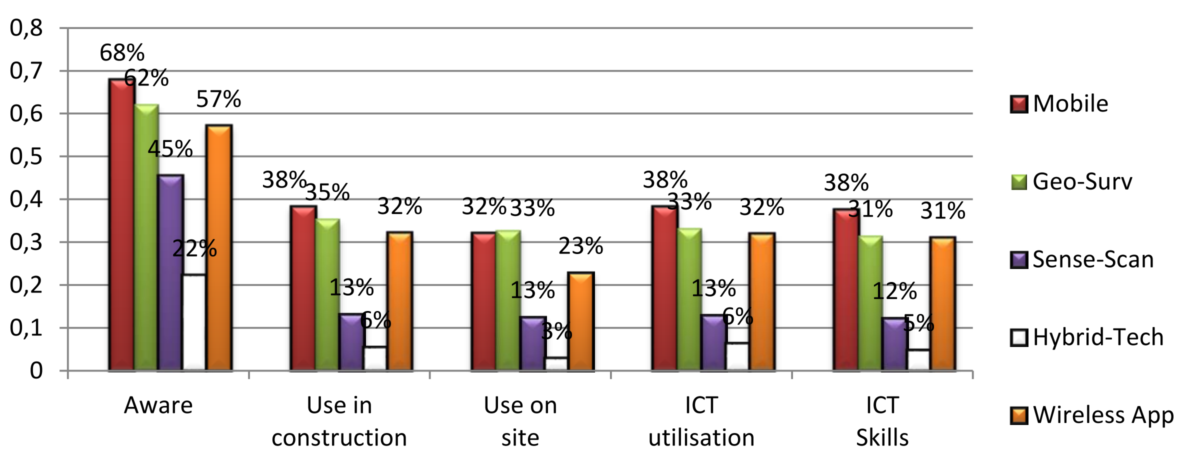

Figure 1: Comparative analysis of aggregate percentages of ICT categories – Stage 3 practitioner survey

Figure 1 presents comparative analysis of the aggregate values of all variables, grouped under the ICT categories investigated. Proportions of participants indicating 'yes' in each case are presented in order to explore the constructs according to ICT categories. The chart also assists visual assessment of possible patterns in their responses. Awareness ranks highest in aggregate value for all categories of ICT. Conversely usage of each corresponding ICT category in site management ranks the lowest. Mobile handheld devices rank highest across all variables except for usage in site management where it falls below geographic and surveillance equipment by a small margin of (1%). From the chart it would seem that general utilisation in construction is nearly the same as specific utilisation of the same ICT groups in site management. However on further scrutiny, only the use of sensors and scanners group of products is basically the same for general and site management specific utilisation. The other ICT groups have margins which range between (3%) and (11%). In addition, self-assessed depth of utilisation of ICT and skills seems to be closer to values for general use in construction, than values for site management specific use.

Next, the chi-squared test of goodness of fit is used to make statistical inferences comparing the observed and expected values, from the survey. The chi-square test statistic (X2) is calculated using the following formula which is programmed into MS Excel 2010, in line with (Remenyi, Onofrei and English, 2011):

X2 = ∑ (O - E)ˆ2 / E, where O is the observed value and E is the expected value.

The critical value (CV) is calculated, using the (0.05) probability and degrees of freedom (DF), as calculated from the number of entries (Count). The chi-square test statistic is compared with the CV. Large differences between the two demonstrate that the likelihood of probabilities of the outcomes being equal in any way is very low. The same applies when the chi-square test statistic is larger than the CV. Such a result would mean that the probability of the outcomes of the observed and expected values are not equally likely.

Table 2: Result of chi-square test of goodness fit comparing survey response with expected values for relevant constructs

	Awareness	Use in construction	Use on site	Depth of usage	skills
X^2	709.0	1359.5	1462.448276	1366.327586	1395.086
CV	48.60236737	48.60236737	48.60236737	48.60236737	48.60236737
Count	35	35	35	35	35
DF	34	34	34	34	34

Table 2 is highly indicative of the disparities between expected values and observations from survey response. For all variables analysed, the chi-squared statistic is grossly different from CV (critical value), implying that all variables measured, fall appreciably behind what would be ideal in this instance. The outcomes for all variables also follow the results presented in Table 1 closely. Awareness is relatively closest to the expected, among the variables analysed, though the margin is still appreciably wide. In addition, use in site management is farthest in terms of similarity with expected value.

In order to explore the preceding results of analysis further, correlation, covariance, and regression analysis is performed on the variables using Microsoft Excel 2010, following descriptions in (Remenyi et al., 2011; Berenson, Levine and Krehbiel, 2012). Tables 3 and 4 present results of covariance and correlation analyses respectively.

Table 3: Covariance matrix with focus on ICT usage in site management (Use on site)

Variables	Aware	General use in construction	Depth of usage	Skills
Use on site	140.1714286	141.2286	142.0857	138.9429
Corrected covariance for use on site	144.4190476	145.5082251	146.391342	143.1532468

In analysing the covariance, it is noted that values for the variable of interest, which is ‘ICT usage in site management’ (use on site), are corrected to sample covariance, since Microsoft Excel software calculates for population covariance. The corrected covariance values of use on site, with awareness, general use in construction, depth usage, and ICT skills, returned positive values. The result suggests positive relationship between ICT utilisation in site management and the other variables. Table 4 is used to compensate for the weaknesses of covariance table by using correlation analysis.

Table 4: Correlation matrix with focus on ICT usage in site management (Use on site)

Variables	Awareness	General use in construction	Depth of usage	skills
Use on site	0.87315559	0.973525	0.962894	0.968824

In Table 4 all correlation values are positive and very close to (1). The result further supports that usage of ICT in site management and each of the following variables; awareness, general use in construction, depth usage, and ICT skills, are strongly positively correlated. However out of the four variables correlated with ICT usage in site management, Awareness of ICT has the lowest correlation value of (0.87315559). The value for awareness is at least (0.1) points below the correlation values for other variables. While the value suggests a positive relationship, it does not prove that real values of entries for the participants are relatively the same. Considering the disparities in values for ‘Awareness’ and ‘Use on site’ in Table 1 and Fig. 1, regression analysis is used to further explore the strength of the relationships. Results of linear regression analyses are presented in Tables 5, 6 and 7. Additional regression analysis is performed in Table 8 to further validate outcomes of analyses presented in Tables 5, 6 and 7.

Table 5: Values of estimated regression line for variables (Criterion - ICT use in site management)

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-0.3281811	1.128637	-0.29078	0.773223	-2.63317	1.976803
Awareness	0.01746851	0.068496	0.255029	0.800441	-0.12242	0.157356
General use in construction	1.43995059	0.506108	2.845146	0.007925	0.40634	2.473561
Depth of usage	-0.775473	0.400682	-1.93538	0.062419	-1.59377	0.042829
ICT skills	0.13226863	0.500353	0.26435	0.793318	-0.88959	1.154127

In Table 5 the estimated regression line for the multiple regression analysis performed on the variables, using ICT use in site management as criterion is considered using estimated coefficients, standard error of coefficients, t-statistic and corresponding p-value, and the boundaries of the 95% confidence intervals. Of all independent variables regressed, only 'General use in construction' is statistically significant in explaining variation in ICT use in site management. The calculated t-statistic exceeds the critical values. The calculated p-value is less than the 5% significance level and closer to (0), showing a statistically significant relationship with use of ICT in site management. The estimated coefficient shows a positive relationship which means: the higher the general usage of each ICT-based item in construction, the higher its usage in site management. The coefficient value also indicates an approximate (1.44) points of increase in the use of each ICT in site management, for each (1) point increase in general usage of the same ICT in construction. Table 5 therefore suggests that awareness, skills and depth of usage are not strong predictors of ICT usage in site management, from the survey. Table 6 explores regression of the aforementioned three variables without General use of ICT in construction, in order to validate the lack of statistical significance.

Table 6: Values of estimated regression line for awareness, skills, and depth usage of ICT (Criterion - ICT use in site management)

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-0.65064	1.244818	-0.52268	0.604914	-3.18946	1.888184
Awareness	0.083676	0.071415	1.171683	0.250251	-0.06198	0.229327
Depth of usage	-0.35799	0.413317	-0.86614	0.393066	-1.20096	0.484974
ICT skills	1.091546	0.409823	2.663456	0.012158	0.255706	1.927386

Table 6 shows that awareness, depth of usage and ICT skills; do not have statistical significance as strong predictors of ICT usage in site management. Considering observed high values for awareness in Table 1 and Figure 1, further regression is performed with awareness and general usage in construction. In Table 1 and Figure 1, awareness was indicated highly while general usage in construction was ranked about the same values as usage in site management. However in the covariance, correlation and multiple regression analyses, the reverse was suggested.

Pairing the two as independent variables for use in site management would further validate preceding results of analyses. The stated regression is presented in Table 7.

Table 7: Values of estimated regression line for awareness and general use of ICT in construction (Criterion - ICT use in site management)

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	-0.1432483	1.157457	-0.12376	0.902278	-2.50091	2.214414
Awareness	0.01204431	0.066955	0.179887	0.858375	-0.12434	0.148427
General use in construction	0.78993051	0.074093	10.66141	4.62E-12	0.639009	0.940852

Table 7 further supports results of analyses in Tables 4, 5 and 6, concerning the strong positive relationship between general use in construction and use in site management as opposed to awareness. Apart from the estimated coefficient and calculated t statistic, the calculated p-value of general ICT usage in construction is exponentially statistically significant as a predictor. Furthermore, two-variable linear regression was performed individually for all predictors, with use in site management as outcome, and presented in Table 8. The estimated coefficients and p-values in the estimated regression line sections of individual regression reports are compared.

Table 8: Individual linear regression for awareness, ICT skills, depth of usage, and general occurrence in construction (Criterion - ICT use in site management)

	Awareness	ICT skills	Depth of usage	General use in construction
Coefficients	0.64989	0.807179	0.779691	0.80184001
P-value	7.87E-12	1.43E-21	2.42E-20	9.97E-23

From Table 8 all predictors have significant p-value when regressed individually. However general use of ICT in construction is the only predictor with the most appreciable combination of relatively high coefficient and the most significant p-value. Again the pattern is obvious here, that p-values for ICT skills and depth of usage do not correlate with the p-value for awareness. This result provides further support for preceding analyses in this section.

4. DISCUSSIONS

From the survey results, there is strong suggestion that occurrence of ICT in general usage within construction is the only significant influence on ICT usage in site management functions, within the South African context. Awareness, skills and working knowledge of ICT do not seem to have significant influence on ICT adoption in site management. This goes against initial deductions from definitions of technology transfer, and innovation adoption and diffusion (Rogers et al., 2006; Rogers and Shoemaker, 1971; Oxford University Press, 2014; Lindley, 2003; Morales and Gilner, 2010; Ling et al., 2007).

The emergent keywords as stated elsewhere in the paper connote knowledge, awareness, information, working knowledge, skills, and useful or profitable engagement with the innovation or technology. The highlighted factors are however not strong predictors for ICT adoption in site management from results of analysis. Adoption of ICT in site management is also very low as demonstrated by results of analysis in Table 1, Figure 1, and results of the Chi-squared test. Tables 3 and 4 also demonstrate that knowledge and awareness do not correlate with ICT skills, depth of usage, and adoption in site management. Results of the Chi-squared test in Table 2 also demonstrate lack of consistency between values returned for the constructs investigated. Michaloski and Paula (2010) identified considerable difficulty in using ICT in site management, in occurrence with factors of complexity and ignorance about available ICT. Hewage et al. (2008) also identified limited ICT integration in site management due to perceived low ICT skills of lower level personnel.

ICT adoption occurs easily and readily at project level, and for office uses on site. The same degree of adoption may not readily occur for the unique field usage needs of site management, regardless of availability of relevant technology. Chien and Barthope (2010) identified the existence of more inclination to ICT adoption for general office and basic uses, of which most project management applications have arguably become. In addition Gaith et al. (2009) confirmed the relatively low usage of more technical software in site processes. Similarly there is appreciable difference in the survey results for general use of ICT in construction, which is the strongest predictor in this case, and use of ICT in site management. Such differences suggest lack of knowledge related enablers as identified by Michaloski and Paula (2010).

Based on deductions from review of literature; it reasonable to expect that appreciable levels of awareness, skills, and depth of usage would result in a higher level of adoption, than values observed from the survey response. Results of analysis support, the argument that the observed degree of awareness, skills and usage do not result in further adoption in site management. Sashar and Isikdag (2004) identified that regardless of awareness and intent to adopt ICT in site management, lack of necessary skills and skills levels would hinder the progression of adoption. Ugwu and Kumaraswamy (2007) also identified that ease of understanding the technology, competence, and ICT capacity of staff were strong enabling factors for adoption. Considering that respondents are construction managers and construction project managers who play site management roles, they are decision makers within the project and site management process. It is therefore reasonable to expect more influence on adoption of ICT in site management from their roles. Since project and site level decisions would be made by such personnel, it is reasonable to expect that most ICT adopted in projects would be accounted for by site management usage. However from Ugwu and Kumaraswamy (2007) it could be extrapolated that the ICT knowledge and capacity of decision makers would strongly account for the disproportionate rate of adoption observed from the survey.

5. CONCLUSIONS AND RECOMMENDATIONS

The study presented in this paper investigated the use of ICT-based products in the specific area of construction site management, within the context of South Africa. The research purpose was approached through a systematic exploration of relevant concepts, review of existing literature, analysis of data and discussion of findings.

There were limitations of sampling purposiveness, numerical strength of survey participants and lack of direct access to sample population details and participants during the survey administration. Nevertheless the national level at which the survey was administered, ensured appreciable credibility and substantial grounds for extrapolating to a fairly general picture of the situation in the local context. Analysis of primary data led to deductions which strongly suggest sub-optimality in the adoption of ICT in site management within the local context. While results of the study mirror highlighted issues in the review of literature, there are strong indications that the knowledge function as set out in the theoretical framework is weak and incomplete. As such it constitutes appreciable hindrance to ICT adoption in the local context.

The major deduction from the study is that the extent of awareness, skills and working knowledge has not approached the adequacy level to increase adoption of ICT in site management appreciably. From various steps in the analysis, occurrence of ICT in construction generally was the strongest predictor as opposed to awareness, skills or depth of use. Following arguments presented in preceding sections, a high degree of awareness would expectedly generate a higher degree of skills and depth of usage, than what was observed. Therefore by controlling for other possible factors such as management support and cost, results suggest that awareness, skills and depth of engagement with individual ICT-based products is still relatively low. Thus recent ICT is available and accessible to the local industry, and there is some degree of awareness and skills. However these variables are not yet adequate to drive a corresponding rate of ICT adoption in site management.

Deductions stated thus far, support propositions in previous studies, which link limited exploitation of potential in ICT for improvement of site management in South Africa, to knowledge, skills and depth of usage. It has also been highlighted in previous scholarly preliminary findings about levels of awareness for items of ICT, not being accompanied by a corresponding degree of working knowledge, skills, and exploitation of the technology. Therefore, to a large extent, the current paper demonstrates that the knowledge function as described by other scholars is more of a process than an event. Knowledge and awareness must translate to adoption through the decision to engage with the technology, and the development of skills by application. The decision to engage with technology in construction is generally aligned to perceived needs, which is essentially a knowledge function. Needs must be perceived, existence and potential of technology must be known, and some connection must be drawn between the need and capacity built into the technology. While the described process does not necessarily demand a high degree of expertise, the mental engagement must occur for adoption to progress.

Regardless of the peculiarity of construction project contexts across the world, it is arguable that site management needs which could be efficiently addressed by exploiting ICT potential are fairly common. The difference would be the extent to which such needs have been identified as areas which ICT potential could be used to address. Another differential would emanate from the extent to which the industry in each context has awareness, knowledge, access and capacity to address perceived needs by exploiting potential in recent ICT. Capacity to exploit technology would among other factors require appreciable working knowledge and depth of utilisation of each product's features, and the necessary skills for application of such features. While capacity to exploit technology includes economic and financial elements as major factors, knowledge and information related factors constitute a major influence. Therefore regardless of financial capacity and management support, adoption of particular ICT may still not occur in a project.

In addition where adoption has occurred initially at project level, further adoption at the site stage may not occur, due to further requirements of working knowledge and skills.

In view of issues highlighted in the study and the limitations stated, there is need for further research into the predictive strength of other factors that could be considered under ICT adoption in site management, within the South African context. Such factors should include cost, management support and technology support. There is need to also investigate the relationship between availability of the ICT and the variables examined in the current paper. In addition to surveys, case study strategy should be employed in future studies. In conclusion, the study highlights possible areas of focus for the local industry in terms of increasing their exploitation of recent ICT for site management. The results point to possible areas, from where challenges to ICT adoption in the local context could emanate. In so doing the paper contributes to knowledge on issues relevant to ICT adoption in site management, with a focus on South Africa. Moreover discussion on findings and the synthesis presented, extend the value of the paper beyond the local context.

6. REFERENCES

Ahuja, V., Yang, J. and Shankar, R. (2009) "Study of ICT adoption for building project management in the Indian construction industry." Automation in Construction, 18(4), 415–423. Available from: http://0-www.sciencedirect.com.innopac.wits.ac.za/science/article/pii/S0926580508001611 [Accessed 17 March 2012].

Arayici, Y., Aouad, G. and Ahmed, V. (2005) "Requirements engineering for innovative integrated ICT systems for the construction industry." Construction Innovation, 5(3), 179–200. Available from: http://www.ingentaconnect.com/content/mib/ci/2005 [Accessed 20 April 2008].

Autant-Bernard, C., Guironnet, J. and Massard, N. (2010) The Determinants of Innovation Adoption. Groupe d'analyse et de théorie économique lyon - St Étienne, WP 1034, December. Available from: http://ssrn.com/abstract=1731550 [Accessed 9 July 2014].

Bedard, C. and Rivard, H. (2003) Two Decades of Research and Development in Building Design. In: Amor R. (Ed) Proceedings of CIB-W78 International Conference on Information Technology for Construction, 23rd – 25th April 2003, University of Auckland, New Zealand, 23-30.

Berenson, M. L., Levine, D. M. and Krehbiel, T. C. (2012) Basic business statistics, (12th edn). USA, Pearson Education Limited.

Carr, V. H. Jr. (1999) Technology adoption diffusion, Available from: http://tlc.nlm.nih.gov/resources/publications/sourcebook/adoption [Accessed 16 April 2011].

Chartered Institute of Building (CIOB) (2009a) "New Health and Safety Executive Strategy Launched." Contact. September/October (76), UK, CIOB.

Chartered Institute of Building (CIOB) (2009b) 'Industry Loses Millions every year Due to Theft, Vandalism and Health and Safety Neglect." Contact. September/October (76), UK, CIOB.

Chien, H. and Barthope, S. (2010) "The current state of Information and Communication Technology usage by small and medium Taiwanese construction companies." Journal of Information Technology in Construction, 15, 75-85. Available at: http://www.itcon.org/2010/5 [Accessed 21 March 2011].

Dubois, A. and Gadde, L. (2002) "The construction industry as a loosely coupled system: implications for productivity and innovation." Construction Management and Economics, 20(7), 621-631. Available at: http://dx.doi.org/10.1080/01446190210163543 [Accessed 6 December 2011].

Drucker, P. F. (1998) "The discipline of innovation." Harvard business Review, November-December, 3-8. Available from: http://wwwcbpa.louisville.edu/bruceint/drucker.pdf [Accessed 24 September 2011].

Forster, G. (1989) Construction site studies Production, administration and personnel. UK, Longman Group Limited.

Froese, T. M. and Han, Z. (2005) State of the construction information development industry in Canada, In: Scherer, R. J. and Katranuschkov, P. and Schapke, S. (Eds) Proceedings of CIB W78's 22nd International Conference on Information Technology in Construction June 2005, CIB, Dresden, Germany, 19-21. Available from: http://www.itc.scix.net/data/works/att/w78-2005-A10-2-Froese.pdf [Accessed 17 March 2012].

Fryer, B., Egbu, C., Ellis, R. and Gorse, C. (2004) The Practice of Construction Management. UK, Blackwell Publishing Ltd.

Gaith, F. H., Khalim, A. R. and Ismail A. (2009) "Use of Information Technology in construction firms; Malaysian construction industry." European Journal of Scientific Research, 28(3), 412-421. Available from: http://www.eurojournals.com/ejsr.htm [Accessed 15 March 2011].

Haas, C. and Saidi, K. (2005) Construction Automation in North America, In: Proceedings of International Symposium on Robotics and Automation in Construction ISARC 2005, 11-14 September, IEEE and Italian National Research Council, Faculty of Architecture Ferrara, Italy. Available at: http://www.nuovaquasco.it/isarc/program.htm [Accessed 10 June 2008].

Hendrickson, C. (2003) Project Management for Construction; Fundamental Concepts for Owners, Engineers, Architects and Builders, Carnegie Mellon University, Pittsburgh, USA. Available from: http://www.ce.cmu/pmbook [Accessed 7 February 2014].

Hewage, K. N., Ruwanpura, J. Y. and Jergas, G. F. (2008) "IT usage in Alberta's building construction project: Current status and challenges." Automation in Construction, 17(8), 940-947. Available from: http://www.sciencedirect.com/science/article/B6V20-4SFR7P3-1/2/b859ad71e9324c7515f2d9058d0222b9 [Accessed 9 December 2008].

Howard, R. (1998) Computing in construction; pioneers and the future, UK, Butterworth-Heinemann.

Kareem, H. I. A. and Bakar, A. H. A. (2011) "Identifying IT benefits for Malaysian construction companies", Journal of Information Technology in Construction ITCON, 16, 477-492. Available from: http://www.itcon.org/2011/28 [Accessed 15 March 2011].

Koekemoer, V. and Smallwood, J. (2007) Information Technology (IT) in the construction process, In: Proceedings of 23rd annual ARCOM Conference, Association of Researchers in Construction Management, Belfast, UK, 503-512.

Kuprenas, A. J. (2003) "Implementation of a matrix organization structure." International Journal of Project Management, 21(1), 51-62. Available from: http://www.elsevier.com/retrieve/pii/S0263786301000655 [Accessed 8 June 2008].

Ling, F. Y. Y., Hartman, A., Kumaraswamy, M. and Dulaimi, M. (2007) "Influences on Innovation Benefits during Implementation: Client's Perspective." Journal of Construction Engineering and Management, 133(4), 306-315. Available from: http://search.ebscohost.com/login.aspx?direct=trueanddb=aphandAN=24385509andsite=ehost-live [Accessed 7 January 2009].

Lindley, D. (2003) Innovation and Survival in the ICT Industry, INFORMATION AGE December 4, 20-22. Available at: http://www.infoage.idg.com.au/index.php?id=1559215138 [Accessed 24 April 2012].

Leedy, P.D. and Ormond, J.E. (2010) Practical Research, 9th Edition, New Jersey, USA, Pearson Education Inc.

Memon, Z. A., Majid, M. Z. A. and Mustaffar, M. (2006) Digitalizing construction monitoring (DCM): An overview of Malaysian construction industry and proposing prototype software, In: Proceedings of the 6th Asia-Pacific Structural Engineering and Construction Conference (APSEC 2006), 5 – 6 September, University of Technology Malaysia, Kuala Lumpur, Malaysia. D-15-D27. Available from: http://eprints.utm.my/400/1/ZubairAhmedMemon2006_DigitalizingConstructionMonitoring%28DCM%29Overview.pdf [Accessed 10 April 2011].

Michaloski, A. O. and Paula, A. (2010) "A survey of IT use by small and medium-sized construction companies in a city in Brazil." Electronic Journal of Information Technology in Construction, 15, 369-390. Available from: http://www.itcon.org/2010/28 [Accessed 15 March 2011].

Molnár, M., Andersson, R. and Ekholm, A. (2007) Benefits of ICT in the construction industry – Characterization of the present situation in the house-building processes, In: Proceedings of CIB-W78 – IT in Construction conference June 27-29, Maribor, Slovenia, 423-428.

Morales, F. and Gilner, L. (2010) The Sage's English Dictionary and Thesaurus, Sequence Publishing Co. Available from: http://www.sequencepublishing.com [Accessed 20 March 2010].

Neuman, W. L. (2007) Basics of Social Research, 2nd Edition, USA, Pearson Education Inc.

Ofori, G. (2000) Challenges of Construction Industries in Developing Countries: Lessons from various countries, In: Ngowi, A. B. and Segawa, J. (Eds) Proceedings of the 2nd International Conference of the CIB Task Group 29 (TG29) on Construction in Developing Countries 15-17 November, Printing and Publishing Company (PTY) Ltd., Botswana, 1-11.

Oladapo, A. A. (2006) "The Impact of ICT on professional practice in the Nigerian construction industry." The Electronic Journal on Information Systems in Developing Countries EJISDC, 24(2), 1-19. Available from: http://www.ejisdc.org/ojs2/index.php/ejisdc/article/viewFile/222/153 [Accessed 15 March 2011].

Oladapo, A. A. (2007) "An investigation in to the use of ICT in the Nigerian construction industry." The Electronic Journal on Information Technology in Construction ITCON, 12, 261-277. Available from: http://www.ejisdc.org/ojs2/index.php/ejisdc/article/viewFile/222/153 [Accessed 15 March 2011].

Oyediran, O. S. (2005) Awareness and Adoption of Information and Communication Technology (ICT) by Architectural, Engineering and Construction (AEC) Industry Educators in Nigeria, In: Scherer, R. J., Katranuschkov, P. and Schapke, S. (Eds) Proceedings of the CIB W78 22nd International Conference on Information Technology in Construction, 19-21 June, The Westin Bellevue, Dresden, Germany. Available from: http://itc.scix.net/data/works/att/w78-2005-A10-4-Oyediran.pdf [Accessed 9 July 2014].

Ozumba, A. O. U. and Shakantu, W. M. (2008a) Improving site management process through ICT, In: Verster, J. J. P. and Marx, H. J. (Eds) Proceedings, CIDB Postgraduate Conference 7 – 8 March, Bloemfontein, South Africa, 22-31. Available from: http://www.cib2007.com/papers/Proceedings%205th%20POST%20GRADUATE%20CONFERENCE.pdf [Accessed 24 July 2010].

Ozumba, A. O. U. and Shakantu, W. M. W. (2008b). Achieving Ubiquity in the Site Management Process through ICT, In: Proceedings of RICS COBRA 2008 Conference 4 – 5 September, Ireland, Royal Institute of Chartered Surveyors, UK. Available at: http://www.rics.org/NR/rdonlyres/98B9FD65-3A92-4EA0-894A-6F913D8BF98E/0/Ozumba.pdf [Accessed 10 March 2009].

Ozumba, A. O. U. and Shakantu, W. M. W. (2009a) Balancing Information and Communication Technology site support systems with available ICT skills, In: Proceedings of RICS COBRA 2009 Conference 10 – 11 September, Royal Institute of Chartered Surveyors, University of Cape Town, Cape Town, South Africa.

Ozumba, A. O. U. and Shakantu, W. M. W. (2009b) Information and Communication Technology – based application of just-in-time (JIT) to internal logistics on site, In: Proceedings of RICS COBRA 2009 Conference 10 – 11 September, Royal Institute of Chartered Surveyors, University of Cape Town, Cape Town, South Africa.

Ozumba, A. O. U. and Shakantu, W. M. W. (2012) ICT in site management process in South Africa, In: Proceedings, Royal Institute of Chartered Surveyors (RICS) COBRA 2012 Conference, 11-13 September, RICS, Las Vegas, USA. Available from: http://www.rics.org/sg/knowledge/research/conferencepapers/cobra-2012-ict-in-site-management-process-in-south-africa-/ [Accessed 3 April 2013].

Ozumba, A. O. U., & Shakantu, W. M. W. (2013) Investigating barriers to ICT adoption in site management: a pilot study in South Africa, In Proceedings, RICS COBRA 2013 Conference, 10 -12 September 2012. New Delhi, India: Royal Institute of Chartered Surveyors. http://www.rics.org/za/knowledge/research/conference-papers/cobra-2013---investigating-barriers-to-ict-adoption-in-site-management/ Accessed 19 February 2014.

Ozumba, A. O. U. and Shakantu, W. M. W. (2013) Investigating barriers to ICT adoption in site management: a pilot study in South Africa, In: Proceedings, Royal Institute of Chartered Surveyors (RICS) COBRA 2013 Conference, 10-12 September 2013, New Delhi, India. Available from: http://www.rics.org/za/knowledge/research/conference-papers/cobra-2013---investigating-barriers-to-ict-adoption-in-site-management/ [Accessed 19 February 2014].

Oxford University Press (2014) Oxford Dictionaries. Available from: http://www.oxforddictionaries.com/definition/american_english/technology-transfer [Accessed 7 February 2014].

Pamulu, M. S. and Bhuta, C. (2004) Managing IT in construction: the Indonesian experience, In: Proceedings of CIB World Building Congress, 2-7 May 2004, Toronto, Ontario Canada, International Council for Building, Netherlands. Available from: http://itc.scix.net/data/works/att/3a5d.content.03092.pdf [Accessed 14 March 2011].

Patel, K. (2006) Safety and health still neglected on building sites, Engineering news, 22 September, South Africa, Creamer Media. Available from: http://www.engineeringnews.co.za [Accessed 8 April 2008].

Remenyi, D., Onofrei, G. and English, J. (2011) An introduction to statistics using Microsoft Excel. (2nd edn). UK, Academic Publishing Ltd.

Rogers, E. M. (2003) Diffusion of innovations, (5th edn). New York, The Free Press.

Rogers, E. M. and Shoemaker, F. F. (1971). Communication of innovations. New York, The Free Press.

Rogers, E. M., Singhal, A. and Quinlan, M. M. (2006) Diffusion of innovations, An integrated approach to communication theory and research, A chapter In: Stacks D. and Salwen M. (Eds), New York, Routledge. Available from: http://utminers.utep.edu/asinghal/reports/emr-singhal-quinlan-june19-07-doi-word-file-stack-salwen%5B1%5D.pdf [Accessed 17 March 2012].

Samuelson, O. (2007) "The IT-Barometer – A decade's development of IT use in the Swedish construction sector." Electronic Journal of IT in Construction ITCON, 13, 1-19. Available from: http://www.itcon.org/2007/ [Accessed 21 March 2011].

Saunders, M., Lewis, P. and Thornhill, A. (2009) Research Methods for Business Students, (5th edn). England, Pearson Education Limited.

Sashar, M. and Isikdag, U. (2004) "A survey of ICT in the Turkish construction industry." Engineering, Construction and Architectural Management, 11(4), 238-247. Available from: http://www.emeraldinsight.com/0969-9988 [Accessed 15 March 2011].

Shirazi, B., Langford, D. A. and Rowlinson, S. M. (1996) "Organizational structures in the construction industry." Construction Management and Economics, 14(3), 199-212. Available from: http://dx.doi.org/10.1080/014461996373467 [Accessed 29 December 2011].

Strategic Forum for Construction (SFfc) (2005) Improving construction logistics, report of the Strategic Forum for Construction Logistics Group. Available from: http://www.strategicforum.org.uk/pdf/Logistics%20Report%20August%202005.pdf [Accessed 23 March 2008].

Straub, E. T. (2009) "Understanding technology adoption: Theory and future directions for informal learning." Review of Educational Research, 79(2), 625-649. Available from: http://rer.sagepub.com/content/79/2/625 [Accessed 25 April 2012].

Thomas, H. R., Riley, D. R. and Messner, J. I. (2005) "Fundamental Principles of Site Material Management." Journal of Construction Engineering and Management 131(7), 808-815. http://web.ebscohost.com/ehost/pdf?vid=3&hid=5&sid=cc2a1dbc-597c-423b-916c-0e393850f37a%40SRCSM2 [Accessed 20 May 2008].

Ugwu, O. O. and Kumaraswamy, M. M. (2007) "Critical success factors for Construction ICT projects – some empirical evidence and lessons for emerging economies." Electronic Journal of Information Technology in Construction Itcon, 12, 231-249. Available from: http://www.itcon.org/cgi-bin/works/Show?2007_16 [Accessed 24 January 2015].

Wilkfross, O. and Lofgren, A. (2007) "Rethinking Communications in Construction." Electronic Journal of Information Technology in Construction Itcon, 12, 337-345. Available from: http://www.itcon.org/data/works/att/2007 - 23. content.02309.pdf [Accessed 21 September 2007].

Williams, T., Bernold, L. and Lu, H. (2007) "Adoption Patterns of Advanced Information technologies in the Construction Industries of the United States and Korea." Journal of Construction Engineering and Management, 133(10), 780-790. Available from: http://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-9364%282007%29133%3A10%28780%29 [Accessed 24 January 2015].

Yeomans, S. G. and Bouchlaghem, N. M. and El-Hamalawi, A. (2006) An Evaluation of Current Collaborative Prototyping Practices within the AEC industry. Automation in Construction, 15(2), 139-149. Available from: http://www.sciencedirect.com/science/article/pii/S0926580505000592 [Accessed 24 January 2015].

Zhang, J.P., Ma, Z.Y. and Cheng, Pu. (2001) "4D visualization of construction site management." In: Proceedings Fifth International Conference on Information Visualisation, 25-27 July 2001, London, 382-387. Available from: http://dx.doi.org/10.1109/IV.2001.942086 [Accessed 24 January 2015].