Emerging ICT-Based Methods in the Architecture, Engineering, and Construction Context

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INTRODUCTION

The profound impacts of globalisation within the AEC industry would lead a wide range of organisations towards adopting various technological innovations for improving performance and enhancing competitiveness (Azhar, Lukkad, & Ahmad, 2013). Such foresight was previously endorsed by Blayse and Manley (2004, p. 1) as they claimed that “the higher the levels of innovation in the construction industry, the greater the likelihood that it will increase its contribution to economic growth.” Nevertheless, the AEC industry has fallen behind other production-based industries in terms of adopting innovations and increasing the innovativeness level (Forsman et al., 2012; Hosseini, Chileshe, Zuo, & Baroudi, 2014). This calls for promoting adoption of Information and communication technology (ICT) methods in the field, for which the first step appears to be acquiring a deeper appreciation of the major aspects of ICT methods within the AEC industry.

In essence, adopting ICT methods has become imperative for AEC organisations due to the conditions rampant in today’s business environment such as globalisation, the fierce competition and the need to maintain high levels of productivity to survive (Toole, Hallowell, & Chinowsky, 2013). The foregoing challenges facing the AEC industry in recent years have led AEC organisations towards attempting to tackle the issues by harnessing the advantages offered by various ICT-based innovations (Budde, 2012). Likewise, due to a wide range of developments in the business environment (Akintoye, Goulding, & Zawdie, 2012), future of the AEC industry has become poised to gain enormous advantages of ICT by-products (Hoang, 2005). As such, ICT is regarded as the platform for many innovations within the AEC industry.

There is consensus within literature vis-à-vis the prominence and vital role of ICT innovations for the AEC context as some authors have described the deficiencies of the AEC industry in implementing ICT innovations as the major problem affecting the performance throughout the whole industry (Rezgui & Zarli, 2006). Even more, some researchers have postulated that the trend of adopting ICT within the AEC industry should not be an incremental change, but it must be a revolutionary movement towards ICT permeation in all elements of the industry (Brandon, Kocatürk, & Foundation, 2008). Such huge alterations within the industry take strong support from managerial levels, cooperation to make the necessary changes by all the involving practitioners in the industry and regulatory and financial incentives introduced by policy makers and authorities.

To this end, the first step towards the enhancement of ICT adoption in the AEC context includes generating the necessary motivation amongst practitioners for adopting ICT through highlighting the potential benefits (Sarshar & Isikdag, 2004). In response to such need, this article aims at introducing some advantageous ICT innovations and their unique capabilities in facilitating enhancing the performance within the AEC industry. Hence, the main objective of this article is gathering successful cases of ICT implementation from the fragmented structure of the AEC industry along with presenting their advantages.

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BACKGROUND

The driving forces pushing AEC sector towards adopting ICT have roots in various realities dominating the business environment. These include but not limited to the fierce competition between corporations to tap into global markets, the trend of globalisation and attempts to overcome the lifelong issues of AEC sector such as low performance through deploying technological innovations. In summary, the main reasons behind the interest of AEC practitioners to adopt ICT come from three main grounds:

1. The trend of globalisation.
2. Specific idiosyncrasies of the AEC context.
3. Proven advantages of ICT.

As illustrated in Figure 1, the benefits associated with implementing ICT in the AEC industry largely concern the capabilities of ICT in terms of facilitating achieving the main objectives of AEC projects. In this regard, enhancing collaboration level, facilitating accessibility and exchange of information and enhancing the effectiveness of communications has been acknowledged (Nitithamyong & Skibniewski, 2004). Besides, many studies have attested to the positive impacts of utilising ICT in the AEC industry on grounds of improving cost-effectiveness, scheduling and quality of products (Griffis, Hogan, & Li, 1995; Thomas, Macken, & Lee, 2001; Yang, 2004). In the same vein, ICT implementation has far-reaching positive impacts on all major aspects of AEC projects including time, cost, competitiveness enhancement and information exchange (Hosseini, Chileshe, Zuo, & Baroudi, 2012).

ICT methods are deemed a competitive tool for organisations in today’s market. Moreover, they are regarded as a catalyst for process improvement through deploying workflow tools and process modelling (Sarshar & Isikdag, 2004). As such, there is consensus regarding the positive effects of utilising ICT in AEC projects (Adriaanse, Voordijk, & Dewulf, 2010). However, the same literature postulates that the level the AEC industry has harnessed the advantages of ICT has still remained unacceptably low (Hjelt & Björk, 2006; Nitithamyong & Skibniewski, 2004). Such low level of ICT adoption stands in contrast with the fact that the necessary technology is already available and capable enough to fulfil the requirements pertinent to adoption and implementation of ICT in the AEC context as endorsed by Hosseini et al. (2012).

Against this backdrop, it is suggested frequently in many studies that the main barriers to adoption of ICT in AEC context have roots in the lack of awareness of practitioners about the benefits of adopting ICT in AEC projects, which has resulted in the lack of support from managers and primary decision makers. As a result, many research projects have been conducted to create and disseminate the relevant knowledge by the aim of enhancing the level of ICT adoption within the AEC industry as will be discussed briefly in the following section.

PROGRAMS TO ENHANCE ADOPTION OF ICT

Many organisations have attempted to develop a roadmap for the specific purpose of enhancing the level of adoption of ICT through creation of knowledge regarding the associated benefits. The programs as described in following are amongst some of the main AEC industry’s ICT development programs.

ROADCON funded by the European Commission under the IST program (Information Society Technologies) is geared towards developing a research and development roadmap for ICT within the AEC context. It largely encourages adopting ICT on grounds of effectively realising main industrial, and business opportunities and priorities (Rezgui & Zarli, 2006).

ELSEWISE as an EU funded research project is a user reference project directed at defining the information technology and product data technology requirements of the European large-scale engineering industry particularly in building, civil engineering, and construction fields (Sarshar & Isikdag, 2004).

Information Technology in Construction – Making IT Happen outlined the NSW Government (Australia) strategies to improve construction processes vis-à-vis ICT. This strategy aimed at improving the level of productivity, reducing cost and time of delivering buildings and facilities. This was pursued through defining a Research Agenda for AEC context as described by Sarshar and Isikdag (2004).

Think Lab is a cutting-edge facility established by the University of Salford for conducting research studies on ICT areas, including construction. It provides a
research forum for leading investigators globally. The topics mostly concern the future of developments in ICT in the AEC industry (Brandon et al., 2008).

The Australian Cooperative Research Centre (CRC) prepared the report “Construction 2020” to direct the Australian construction industry to overcome barriers and to promote initiatives concerning various aspects of ICT adoption (Hampson & Brandon, 2004).

As inferred from investigating the programs to promote ICT in the construction industry and as stated in (Rezgui, Boddy, Wetherill, & Cooper, 2011), the emphasis on ICT adoption has shifted from focusing on “data and object centric applications to high-level process driven semantic services” during the past 10 years. This could justify the lack of attention to programs to enhance ICT in years that are more recent. Even more, it is believed that ICT availability is not a major barrier to high levels of ICT adoption in the AEC context anymore (Hosseini et al., 2012). In fact, the primary obstacle has been spotted by Shelbourn, Bouchlaghem, Anumba, and Carrillo (2007), indicating that effective adoption of ICT could not be merely promoted through enhancing the use of information technology solutions. This is because any such program should target resolving the issues associated with the organisational and people aspects that are not directly solvable by means of pure enhancements of ICT related systems. There is a plethora of literature on the prominence of merging ICT into the AEC context activities. This is reflective of the consensus in AEC field in regards to the necessity of promoting the utilisation of ICT within the AEC industry. Nevertheless,
the effective dissemination of such knowledge within
the practitioners in the industry has yet to take place
in order to generate the sufficient motivation among
organisations to invest and make the essential changes.

EXAMPLES OF IMPLEMENTING ICT IN THE AEC CONTEXT

Virtual Prototyping (VP)

This concerns the exploitation of simulation process
for the test, evaluation and modification of prototypes
in a virtual design environment in order to obviate
the need for physical models. It covers all the processes of
test, evaluation, and amendment of design prototypes
starting from conceptual stages of design. In the con-
struction design phase, it will facilitate determining the
interactive outcomes of changes in designs, performing
tests during each phase of development, and identifying
risks (Brandon et al., 2008). Recently, a wide range of
VP techniques have emerged with different effective-
ness levels in respect to various stages of design (Sass
& Oxman, 2006).

Building Information Modelling (BIM)

The use of BIM has experienced a noticeable growth
within the construction industry over the last five years.
It is because, by employing BIM, AEC practitioners
ensure the improvement of the construction processes,
resulting in amending implications of construction
early in the initial stages of projects by allowing cor-
rection before even construction has begun. BIM is the
adoption of computer-generated modelling to simulate
the planning, design, construction and operation of
a facility. A building information model is a project
simulation consisting of the 3D models of the project’s
components with links to all required information
(Azhar, Khalfan, & Maqsood, 2012). Some studies
such as (Zuppa, Issa, & Suermann, 2009) have stated
that implementing BIM helps to avoid errors alongside
improving the productivity, scheduling, safety, cost
and quality of construction projects. BIM is a fast and
effective process by which information pertaining to
one project can be updated at any stage of project from
any department or unit (e.g. engineering department).
Accordingly, the entire project model will be updated
based on the changes on one aspect of the project.

Building Information Modelling is deemed a cata-
lyst of change for the AEC context. It is asserted that
BIM is capable of enhancing the performance within
the industry along with overcoming the problems stemmed from the fragmented structure dominating the
industry (Succar, 2009). As an emerging method within
the AEC context, BIM entails managing data flows
in different natures between different parties (Succar,
2009) manifesting a virtual working environment (Fox
& Hietanen, 2007; Howard & Björk, 2008). The use
of BIM is booming as according to Becerik-Gerber,
Gerber, and Ku (2011) around half of the leading
organisations in AEC sector have adopted BIM while
another twenty percent have planned to use it in the near
future. In this context, ICT should supply the platform
for BIM in the construction industry

Global Virtual Engineering Teams (GVETs)

One application envisaged for ICT innovations concerns
the novel structure for teams in which members of the
team might be located in different geographical areas.
This structure has become increasingly commonplace
in many organisations active within the AEC context
(Becerik-Gerber, Ku, & Jazizadeh, 2012; Peansupap,
2004). Thus, construction industry is witnessing the
emergence of Global Virtual Engineering Teams
(GVETs) regarded by experts as effective, efficient,
and creative service providers for construction or-
ganisations. There is a wide spread consensus over the
advantages of deploying GVETs in the AEC industry
(Hosseini et al., 2012). Accordingly, many teams active
in the AEC industry are becoming GEVTs gradually
(Iorio, Peschiera, Taylor, & Korpela, 2011).

Major envisaged gains out of utilising GVETs are
associated with their capabilities for crossing over geo-
graphical, organisational and temporal borders (Fuller,
Marett, & Twitchell, 2012), cost savings (Schweitzer
& Duxbury, 2010), timeliness of completion of tasks
(Gressgård, 2011) and higher qualities of products and
services (Gignac, 2004).

All the foregoing advantages of GVETs have
been confirmed by the studies in the AEC industry
on grounds of the high productivity of GVETs, their
abilities to deal with recent complicated construction
projects (Chen & Messner, 2010; Chinowsky & Rojas,
2003; Hosseini & Chileshe, 2013) and their capacity
for adding value for organisations out of processing
knowledge in a knowledge intensive industry such as construction (Vorakulpipat, Rezgui, & Hopfe, 2010). Moreover, Moore and Abadi (2005) described GVETs as a measure facilitating resolving the shortfalls of the AEC industry echoed in the work of Egan (1998) in terms of the fragmented structure of the industry as well as meeting the requirements of the today’s clients within the industry. In this spirit, the burgeoning growth in utilising GVETs in construction organisations and projects has underpinned the claims vis-à-vis the envisaged benefits of this team structure.

**Internet-Based Construction Project Management (ICPM)**

Nature of the AEC industry is highly fragmented while at the same time is in dire need of effective collaborations amongst numerous parties involving in a project. Delivering a construction project takes continuous exchange of information between clients, design firms and consultants, contractors, numerous subcontractors and many suppliers. In this context, a serious challenge confronting the AEC industry is that of maintaining the accuracy and timeliness of communications amongst construction project members. Currently, large amounts of data might be lost in the sense that crucial information is not retained for reuse and must be re-entered. Even more, it takes putting in much effort to ensure the employees working out of the project office have immediate access to the essential information to perform their tasks (Lee, Dossick, & Foley, 2013). This has been exacerbated by the location of delivering many construction projects in areas far from large cities and the great distance between members of projects’ teams (Hosseini et al., 2012).

Internet-based construction project management (ICPM) systems are regarded by many experts in the AEC industry as a remedial solution to enhance the quality of communications, increase efficiency, productivity and quality of products in construction projects. This method entails electronically linking the projects members alongside transferring and processing the project related data (i.e. creation, transmitting, and archiving) to and from dispersed project participants (i.e. clients, designers, architects, contractors, subcontractors, consultants, etc.) (Lee et al., 2013).

**SOLUTIONS AND RECOMMENDATIONS**

It could be construed that ICT and associated methods are still regarded as novel phenomena by a major part of practitioners in the AEC industry. On the other hand, Slaughter (1998) defined innovation for the AEC context as a nontrivial improvement in a system or procedure, which is deemed novel within the corresponding institution. As such, ICT methods could still be treated as innovations within the AEC context. Such viewpoint has been acknowledged within the relevant literature because some studies have referred to ICT as “ICT innovations” (Underwood & Khosrowshahi, 2012, p. 27).

Against this backdrop, a major part of the research studies have hitherto investigated ICT promotion within the AEC context in isolation from the influential organisational and human components and impacts (Ganah & Kamara, 2013).

Consequently, drawing upon innovation diffusion models (IDMs) as an established theory becomes relevant for the AEC investigators to clarify the aspects of adopting ICT in view of attitudes and perceptions of people towards ICT as an innovation. In this spirit, the diffusion of any innovation such as ICT is the process by which that method is communicated through particular channels among the members of a social system as the AEC industry and organisations (Rogers, 2010).

Given the central role of ICT for the future of the AEC industry, no effort should be spared in promoting the diffusion and adoption of ICT and measures in AEC organisations and projects. As a result, grounding the studies on ICT promotion in the AEC industry within the established body of knowledge pertinent to innovation diffusion theories and models would be a remedial solution to the low adoption of ICT in this industry.

**FUTURE RESEARCH DIRECTIONS**

Future researchers would contribute to the AEC industry body of knowledge by determining the drivers, barriers and practices associated with adoption of ICT methods (i.e. BIM, virtual teams and virtual prototyping) in AEC projects. This would enable the practitioners to enhance the positive factors and to eliminate those variables, which adversely affect ICT adoption within
the AEC industry. Such inquiries should be undertaken in different contexts, countries and economies due to the influential impacts of socioeconomic factors in adoption of such technological innovations. Otherwise, the results of the inquiries might be misleading and could not fit the main beneficiaries in the context at hand as pointed out by Alkalbani, Rezgui, Vorakulpipat, and Wilson (2013).

Moreover, further research studies should concentrate on ascertaining the most effective policies to lead AEC practitioners towards harnessing the benefits of adopting ICT methods in different levels of the AEC industry. To this end, future inquiries should present frameworks for facilitating managing change in construction organisations. A deep appreciation of the dynamics of change at the people/technology interaction is a prerequisite for the successful implementation of ICT methods in construction projects. This could be a fertile ground for future investigations.

Additionally, mapping the status of universities and the levels of skills and knowledge of graduates in regards to using ICT methods such as BIM should be considered as a subject for future inquiries. Such explorations should compare the pertinent requirements in the industry against the abilities of graduates and the content of university programs and accordingly spot the gaps and shortcomings in this area.

CONCLUSION

The AEC context has yet to harness the benefits of ICT methods effectively, due to cultural, organisational resistance coupled with the lack of knowledge in the industry. Hence, it becomes incumbent to practitioners and researchers to foster the culture of adopting ICT and promote adopting associated methods as described in previous sections. One remedial solution for this might be conducting research studies by academia to spot the true impediments towards uptake of ICT in AEC organisations and projects. In the same vein, procedures of merging ICT into AEC processes would be facilitated by incorporating the principles of established theories associated with innovation adoption in future inquiries on these topics. To this end, inquiries should consider building upon robust theoretical foundations such as principles of Innovation Diffusion Models (IDMs).

REFERENCES


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Category: Systems and Software Engineering


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ADDITIONAL READING


KEY TERMS AND DEFINITIONS

Architecture, Engineering, and Construction (AEC): those sectors of the construction industry that provide the services on the architectural design, engineering design and construction services.

Building Information Modelling (BIM): an ICT-based approach that entails integrating and maintaining a digital representation of all the information concerning a construction project during the whole lifecycle of the project in a data repository form.
Information Communication Technology: (ICT): any technology or product associated with storing, retrieving, manipulating, transmitting, or receiving information electronically in a digital nature.

Innovation: the profitable developments and implementation of novel ideas, procedures, products, and practices geared towards enhancing organisational performance.

Global Virtual Engineering Teams (GVETs): teams in which members might be scattered around the globe and have to coordinate their common tasks via ICT-based mediums.

ICT in the AEC Context: goods (such as office software suite and communication equipment), services and management (such as telecommunication including transmission and display) adopted to generate growth and improve productivity in the industry in the AEC context.