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Adopting global virtual engineering teams in AEC Projects
A qualitative meta-analysis of innovation diffusion studies
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Abstract
Purpose – This study aims to present an integrated conceptual model in order to highlight the major aspects of diffusion of innovations in the architecture, engineering and construction (AEC) context. To this end, a critical review of literature is conducted, accompanied by synthesising the findings of previous studies. The driving force behind this study is stemmed from the fragmentation of literature on innovation diffusion, and paucity of research on diffusion of Global Virtual Engineering Teams (GVETs) as the platform form any technological innovations in relevant literature. Thus, the present study is intended to facilitate filling the gap in GVETs literature. That is, the proposed model will offer a foundation for academia for grounding studies on any innovation including GVETs in the literature on innovation diffusion in the AEC context.

Design/methodology/approach – This paper draws upon the qualitative meta-analysis approach encompassing a critical review of the relevant literature. To this end, the review builds upon studies found within 15 prestigious journals in AEC. The domain of this review was confined to areas described as “innovation”, “innovation diffusion” and “innovation adoption”, along with keywords used within a broad review of recently published GVETs literature. The rigour of review is augmented by incorporating 35 authoritative works from other disciplines published in 21 well-known journals in the manufacturing, business and management fields. Moreover, the study deploys the peer-debriefing approach through conducting unstructured interviews with five Australian scholars to verify a model presenting an aggregated summary of previous studies.

Findings – The key findings of the study include the following items: synthesising the fragmented studies on innovation diffusion in the AEC context. In doing so, a model capturing the major aspects affecting diffusion of an innovation in AEC projects is presented; providing a foundation to address the drawbacks of previous studies within the sphere of GVETs, based on the developed model.

Research limitations/implications – The developed model was only enhanced using a small sample size of academics, as such not empirically validated.

Originality/value – As possibly, the first literature review of innovation in the AEC context, this paper contributes to the sphere by sensitising the AEC body of knowledge on innovation diffusion as a concise conceptual model, albeit verified through the peer debriefing approach. This study will also further establish the research field in AEC on GVETs along with other methods reliant on virtual working such as building information modelling (BIM) through providing an expanded foundation for future inquiries and creation of knowledge.

Keywords - Innovation, Diffusion, Construction, AEC, Team working, Virtual team

Paper type - Conceptual paper
Introduction

Challenges facing architecture, engineering and construction (AEC) in recent years, such as globalisation, have led project managers towards attempting to tackle the issues by harnessing the advantages offered by various innovations (Budde, 2012). For example, because of a wide range of developments in the business environment (Akintoye et al., 2012), the future of AEC has become poised to gain enormous advantages of information communication technology (ICT) by-products (Hoang, 2005). Accordingly, AEC has witnessed an unprecedented interest in using web-based methods (Nitithamyong and Skibniewski, 2006; Wong and Zhang, 2013). A salient example is building information modelling (BIM), which is inherently built upon a virtual team-working environment (Fox and Hietanen, 2007; Howard and Björk, 2008). Hence, virtual teaming is the corner stone of many advantageous innovations in the AEC context; thus, failure in diffusion of virtual team-working into AEC projects will obstruct harnessing the benefits of all associated innovations, for example, BIM. In the case of BIM, separation between designers and drafters acts as a barrier to adoption of BIM in AEC projects (Tse et al., 2005). These issues could be resolved by promoting multidisciplinary cooperation between parties through effective information exchange using ICT (Becerik-Gerber et al., 2011), namely, through promoting virtual team-working (Figure 1).

Furthermore, there is a consensus in the AEC literature that global virtual engineering teams (GVETs) will be a central component of organisational structures in the near future (Chinowsky and Rojas, 2003) and the way AEC organisations will conduct their business (Nitithamyong and Skibniewski, 2011). As postulated by Becerik-Gerber et al. (2012, p. 234), “today’s construction projects require project teams that are geographically dispersed and working across multiple time zones and numerous organisational boundaries in a variety of cultures”. In addition, construction firms heavily rely on other organisations when it comes to acquiring information on innovations (Aouad et al., 2010). This means that implementing GVETs gives rise to higher levels of partnership and exchange of information between organisations, causing more innovativeness in each organisation (Gassmann, 2006). Hence, promoting GVETs in construction firms would beget higher levels of innovativeness in the industry, as implied by the authoritative work of Gann and Salter (2000).

Given the vital role of GVETs for the future of the AEC industry, no effort should be spared in promoting the diffusion of GVETs in AEC organisations and projects. Yet, in sharp contrast to the primacy of GVETs for AEC, there are very limited studies on GVETs in the sphere. Specifically, clarifying the procedure of GVETs’ diffusion into organisations in AEC is an overlooked area (Hosseini and Chileshe, 2013), eclipsed by issues of managing and implementing GVETs in AEC organisations.

From a broader perspective, AEC has lagged behind the manufacturing and aerospace industries in reaping the benefits of innovations (Toole et al., 2013). AEC projects have not reached a satisfactory level in the uptake of innovations (Davidson, 2013; Rundquist et al., 2013). This has given rise to research studies pertaining to the creation of knowledge on different aspects of diffusion of innovations in AEC (Panuwatwanich et al., 2009). Accordingly, some studies proposing models for diffusion of innovations in the AEC context have been conducted, for example, Slaughter (2000) and Widen and Hansson(2007). Nevertheless, the presented models have overlooked the influence of external factors and contextual settings (e.g. regulations) and mostly have focussed on analysing internal drivers (e.g. imitative behaviours) from a positivist perspective, as pointed out by Larsen (2011). Furthermore, major parts of the existing studies have not built their discussions on a
seminal innovation diffusion model (IDM) developed in other disciplines, as aptly postulated by Kale and Arditi (2010). This refers to a deficiency in the extant literature, as the robustness of any study is demonstrated by the strength of the links defined between the subject of the study and the broader established theories (Marshall and Rossman, 1995). Moreover, hitherto, the findings of research studies on diffusion of innovations in the AEC context have remained fragmented, and a wide range of aspects have been ignored, as explained by Ozorhon et al. (2014). This necessitates the integration of the existing literature, so that it “brings together different theoretical perspectives on innovation” (Aouad et al., 2010, p. 389).

Therefore, synthesising the existing literature to develop a model of innovation diffusion for the AEC context is one of the main objectives of this paper. The model will be built upon IDMs from an AEC perspective as well as other disciplines. Furthermore, as stated above, major aspects of diffusing GVETs in the AEC context have yet to be noticed and are in need of further investigation. This study will throw some light on diffusion of GVETs in the AEC context, drawing from the model developed for innovations diffusion in the AEC field as the second objective pursued in this study.

**Figure 1. The context to analyse GVETs**

**Delimiting the concepts and the context**

The generic terms and concepts with reference to the discussions presented in this paper are considered below. Corresponding construction-oriented definitions are presented in the narrative as appropriate.
Innovation

“An innovation is any idea, object, or practice that is perceived as new by members of the social system” (Mahajan and Peterson, 1985, p. 8).

Innovation diffusion

The literature on innovation considers two major processes vis-à-vis innovations: diffusion and implementation (Tornatzky et al., 1990). The interface between the former and latter terms is the decision to adopt the innovation due to the perceptions of decision-makers that their firm lags behind competitors in terms of performance (Winch, 1998). Thus, the diffusion of an innovation is considered the process by which that innovation “is communicated through certain channels over time among the members of a social system” (Rogers, 2010, p. 5). According to Wolfe (1994, p. 407), “the diffusion of an innovation refers to its spread through a population of potential adopters”.

It is noteworthy that streams of research on innovations could be classified in three main categories as the typology proposed by Wolfe (1994). This comprises investigating: diffusion of innovations, determinants of innovativeness of companies and implementation processes. This study will target the first typology, namely, the Diffusion of innovations in the AEC context as the overlooked stream of research in AEC studies.

Global virtual teams

Global virtual teams are those in which members are geographically dispersed and coordinate their work predominantly through ICT (e-mail, video-conferencing, etc.) in lieu of face-to-face meetings, as defined by Hertel et al. (2005) and Maznevski and Chudoba (2000). The context of discussions regarding GVETs and innovations in this study is confined within two different conditions. First, GVETs are the cornerstones and the foundations of all the operations for new paradigms such as BIM (Fox and Hietanen, 2007; Howard and Björk, 2008). In addition, as will be further clarified in the following, GVETs highly rely on ICT to the extent that they are regarded as spin-offs of ICT (Hosseini et al., 2012; Peansupap, 2004; Verburg et al., 2013). On the other hand, ICT is considered the platform of many innovations (Bhatt and Ved, 2013) and a recent phenomenon with, until now, lower than expected implementation levels within the construction context (Adriaanse et al., 2010; Samuelson and Björk, 2014). This level of novelty in AEC puts ICT within the domain of innovations. This assumption is underpinned by evidence from the literature referring to the concept as “ICT innovations” (Underwood and Khosrowshahi, 2012, p. 27). Hence, GVETs’ position with respect to innovations and ICT are described, as illustrated in Figure 1. Second, as per the definition presented for innovations, investigating any innovation needs a social system as a fundamental element. Defining the appropriate social system to investigate innovations in AEC has been a subject of interest in the literature (Aouad et al., 2010). According to Ozorhon et al. (2014, p. 256), “elements of innovation at the project level should be key to identifying the actual level of innovation in construction”.

This is denoted by Winch (1998, p. 273), postulating that “innovations in construction are, typically, not implemented within the firm itself, but on the projects upon which the firm is engaged”. Thus, in this study, projects of AEC firms are the context to frame the diffusion of innovations including GVETs, as illustrated in Figure 1. Nonetheless, as stated by Gann and Salter (2000), any study on innovation in project-based organisations involves the central resources within the firm also supporting the projects. This assumption has been
incorporated into Figure 1 by considering the domain of analysis outside the boundaries of projects covering some parts of an organisation. Furthermore, as pointed out by van Donk and Molloy (2008, p. 135), “all projects are organisations of one kind or another and therefore ought to be amenable to precisely the same kind of academic scrutiny as other types of organisation”. Hence, the findings of existing studies vis-a`-vis organisations are construed as applicable to the unit of analysis, namely, projects in this study. Besides, as pointed out by Frambach and Schillewaert (2002), adoption of any innovation in any organisation implies that adoption will occur within the organisation as well, namely, at the individual level. This assumption generalises the presented discussions to the individual level also.

*AEC and GVETs*

This study considers GVETs as an emerging ICT-oriented structure that is able to integrate and improve the efficiency of the AEC industry, as pointed out by Howard et al. (1989). Hereafter, the industries in the domain of the AEC context will be collectively referred to simply as “construction” in alignment with Froese (2010).

*Research methodology*

The methods and the procedure followed for conducting this study have been illustrated in Figure 2 and described as follows.

As illustrated in Figure 2, objectives of this study are followed by taking a qualitative meta-analysis approach, as described by Sandelowski and Barroso (2007). To this end, the qualitative findings of existing studies are synthesised into a conceptual model, which is an emerging approach of research within many disciplines (Major and Savin-Baden, 2011). The main reasons for deploying such an approach in this study are:

- The sphere is in need of a model incorporating the existing theories on innovation diffusion by synthesising the findings of previous studies, as implied by Aouad et al. (2010).
- GVET is an emerging topic within the construction context because of the challenges facing the foregoing industry within recent years (Becerik-Gerber et al., 2012; Chen and Messner, 2010; Moore and Abadi, 2005). Integrated literature reviews add great value to the body of knowledge of new topics by conceptualising and synthesising the existing information (Torraco, 2005).
- The strong interest in implementing GVETs in construction has been acknowledged in the literature; however, the research field has not kept pace with this trend (Chinowsky and Rojas, 2003). This falls within the cases in which developing conceptual models would advance the knowledge by systematising the inquiries (Rocco and Plakhotnik, 2009).
- Integrative literature review is regarded as an effective approach to conducting rigorous inquiries within academia. As evidence, one could refer to many seminal publications drawing upon integrative literature reviews as the sole method of research on GVETs (Hertel et al., 2005; Powell et al., 2004) and construction innovation (Sexton and Barrett, 2003; Slaughter, 1998).
It is necessary in qualitative meta-analysis to describe the procedure for conducting integrative literature reviews (Okoli and Schabram, 2010; Torraco, 2005). The method adopted in this study to review the literature in the construction industry on IDMs and GVETs was consistent with the three-stage method for conducting literature reviews in a construction context that was deployed in the recent work of Yi and Chan (2014) and Hong et al. (2012), as illustrated in Figure 3.

As illustrated in Figure 3, the first stage of the research encompassed a thorough desktop search considering the “title/abstract/keyword” fields. The keywords used were innovation, innovations, diffusion, innovation adoption and innovation implementation to identify the studies on innovation in construction literature. Researchers have used various labels to refer to virtual teams. Hence, the comprehensive list of keywords deployed by Hosseini and Chileshe (2013) was incorporated for searching publications concerning GVETs. Journals targeted included Construction Management and Economics; Journal of Management in Engineering; Engineering, Construction and Architectural Management; Automation in Construction; International Journal of Project Management; and Building Research and Information, according to Wing (1997). In addition, the relevant journals containing highly cited papers, including Building and Environment, Canadian Journal of Civil Engineering and Journal of Computing in Civil Engineering, were added to the search list in accordance to the list deployed by Yi and Chan (2014). As illustrated in Figure 3, two modifications were made to the abovementioned model, as introduced by Yi and Chan (2014) and Hong et al. (2012). The reason for modifying the former method was to define the protocol of the literature review to ensure that “all sources have been found and exhausted”, as pointed out by Okoli and Schabram (2010, p. 20). The details of the modifications are explained below and in Figure 3.

**Modification 1**

Five other journals were added to the review list, including Construction Innovation: Information, Process, Management, Architectural Engineering and Design Management; International Journal of Construction Management; International Journal of Construction Education and Research; and Australasian Journal of Construction Economics and Building. The additional journals were selected from the array of high-ranking construction management journals introduced by the list of Excellence in Research for Australia. Broadening the covered area of the literature by adding to the journals reviewed is justified by:

- The subjects targeted by this study fell within the specific area of interest of some of the journals not included in the lists in previous studies (Yi and Chan, 2014). Without extending the area to the journals added to the lists in previous studies, some papers directly relevant to the specific area of interest of the study would not be incorporated in the list. This would
lead to inadequate sampling of the review of the literature being one of the main threats to the validity of an integrated literature review, as postulated by Russell (2005).

- Covering the papers in journals other than those identified in previous studies is among the necessities for conducting rigorous literature reviews, as pointed out in the seminal work by Webster and Watson (2002).

Figure 3. The method deployed for searching the literature, as adapted from Hong et al. (2012)
Modification 2

Stage 3 (Figure 3) entailed identifying the publications citing the papers in List 1 (published from 2009-2013), resulting in List 2, according to the method proposed by Webster and Watson (2002), for the assurance of covering the existing publications. Hence, the outcome of the literature search was the collective list of publications in the two lists (Lists 1 and 2), as illustrated in Figure 3.

The literature review protocol for this study met the requirements of the methods confirmed in previous studies in the construction management field (Al-Sharif and Kaka, 2004; Hong et al., 2012; Ke et al., 2009; Tsai and Lydia Wen, 2005; Yi and Chan, 2014). This ensured the basic methodological robustness of literature review policy. However, the two modifications made in this paper broadened the area covered by the review of the literature to ensure the rigour of the literature review study, as per the guidelines prescribed by Okoli and Schabram (2010) and Webster and Watson (2002).

Construction researchers have passed over the literature in other disciplines to advance their discussions on innovations (Kale and Arditi, 2010). To address this matter, this study attempts to incorporate basic and seminal treatises from relevant industries, as captured in Table 1. Presentation of a broader review on studies from disciplines other than construction was beyond the scope of this study. Furthermore, it was not feasible within the space provided for one journal paper due to the large number of available treatises because, according to Crossan and Apaydin (2010), only a keyword search on a narrowed topic pertaining to innovation would return tens of thousands of papers.

As illustrated in Figure 2, the preliminary conceptual model was verified by deploying the peer-debriefing method. This method is derived from the qualitative approach for validating conceptual frameworks, titled face-validation. The basis of face-validation is of a qualitative nature (Landry et al., 1983), thus requires taking a qualitative approach, such as conducting interviews. The procedure termed as peer debriefing lends certain validity to the face-validation method (Creswell and Miller, 2000). This entails a review or debriefing of the results by someone who is familiar with the concept or the phenomenon of interest.

According to Lincoln and Guba (1985), implementing the peer-debriefing method results in improving the credibility of the results of qualitative studies, as is the case for this paper. Academic staff in construction, building and architecture disciplines with research interests and publications on innovations in Australia were identified through the websites of the universities and were invited via e-mails to participate in the study. Five scholars agreed to participate. As the model incorporated various constructs and needed prior thought, the model was sent to each interviewee by a letter of introduction before the time of the interview, as suggested by Crandall (1998). Five face-to-face interviews were conducted discussing different aspects of the developed conceptual model, which resulted in some minor modifications to the model. The robustness of the final model was triangulated by deploying the member checking method. This encompassed taking the final model, after amendments, back to the participants in the study (Figure 2) to confirm the credibility of the constructs of the final model, as described by Creswell and Miller (2000). As a result, the model as illustrated in Figure 4 is the outcome of synthesising the previous studies after being confirmed by deploying the peer-debriefing approach amongst academia in Australia.
Main features of innovations in the construction literature Slaughter (1998)

Regarded innovation as the actual usage of a non-trivial change in terms of an improvement in a system, procedure or product that is novel to the corresponding institution in accordance to the generic definition presented by Damanpour and Evan (1984). The former definition is widely accepted as the customised definition of innovation for the construction industry (Blayse and Manley, 2004; Egbu, 2004; Rigby et al., 2012). Nevertheless, other scholars have suggested that the definition of innovation should accommodate the benefits envisaged for implementing the innovation. As a salient example, innovation has been defined as:

[...] the act of introducing and using new ideas, technologies, products and/or processes aimed at solving problems, viewing things differently, improving efficiency and effectiveness, or enhancing standards of living ( Sexton and Barrett, 2003, p.3).

According to Kale and Arditi (2010), innovation refers to ideas, objects and practices that are regarded as novel by the elements of the institution adopting the innovation. Building upon the classification offered by Marquis (1988), Slaughter (1998, 2000) divided innovations in the construction industry into five categories based on the following definitions:

- **Incremental and radical innovations** are the two ends of the spectrum of innovations. Incremental innovations could be based on the current level of knowledge and experience in a project or a firm and are confined to small changes. Radical innovations stand in sharp contrast to incremental innovations, as they indicate a leap or breakthrough in science and technology culminating in changing the character and nature of an industry. In the case of radical innovations, the current system, commonplace interactions and linkages between the elements become unrelated and incompatible (Ozorhon et al., 2014).

- **Modular innovations** are those innovations, which change a concept significantly, while the links and interactions with other concepts remain almost unchanged. On the contrary, architectural innovations entail making huge changes in the links and connections with other systems. However, architectural ones leave the concept with small changes. System innovations refer to innovations made up of several independent innovations that should work interruptedly to enhance performance and fulfil multiple requirements.

From another approach, innovations could be divided into technological or administrative, which is the fundamental classification concerning studies of innovation according to
Damanpour (1987). Technological innovations bring change by introducing a change in the technology, which enables the employees, units and organisations to extend their capabilities (Schön, 1967). Administrative innovations concern the basic activities of an organisation and affect the managerial policies such as a new staff incentives system, as defined by Damanpour (1987). Firms should be well aware of the type of innovation they are dealing with, as the taxonomy of the innovation determines the prerequisites and the ramifications associated with adopting the innovation in any social system (Damanpour, 1987), including a project or organisation within the AEC context (Slaughter, 1998).

As shown in Table II, there are common fundamental attributes of an innovation in the construction context.

As illustrated in Table II and described in following sections, considering any technology or method as an innovation merely relies on its novelty to the context adopting it, regardless of the way others in the construction context treat it, as asserted by Panuwatwanich et al. (2009). Hence, a phenomenon could be commonplace in the realm of existing practices in many projects but still deemed an innovation in other projects (Gambatese and Hallowell, 2011; Manley and McFallan, 2006). This assumption has been underpinned by some methods deployed to define the typologies of innovation within the construction context literature, as described by Slaughter (1998). In this spirit, different categories of innovations are demarcated based on the nature and level of change and novelty they bring to the currently established systems (Harty, 2008).

As a result, any phenomenon complying with the attributes of innovations as illustrated in Table II, in terms of novelty, change and envisaged advantages would be supposed to be an innovation within the construction context.

**Figure 4. The conceptual IDM (applicable to GVETs) within the construction context**

![The conceptual IDM (applicable to GVETs) within the construction context](image)
<table>
<thead>
<tr>
<th>Nos</th>
<th>Attributes</th>
<th>Description</th>
<th>Scholarly support</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New to the institutions implementing the innovation</td>
<td>Any method or technology should be new to the organisations adopting it to be regarded as an innovation regardless of how the environment treats it</td>
<td>(Ganbatse and Hallowell, 2011) (Slaughter, 1998) (Toole et al., 2013) (Toole et al., 2013) (Dikmen et al., 2015) (Rigby et al., 2012) (Egba, 2004)</td>
</tr>
<tr>
<td>2</td>
<td>Imposing non-trivial change in the organisation</td>
<td>Using the innovation in the organisation takes making changes to many aspects of the organisation and drawing upon change management initiatives</td>
<td>(Slaughter, 1998) (Toole et al., 2013) (Peasgood and Walker, 2006) (Garn and Salier, 2000)</td>
</tr>
<tr>
<td>4</td>
<td>Add value to outcomes and end-products</td>
<td>Benefits of innovation transcend improving the performance of processes and include higher quality of products, which, in turn, leads to higher levels of clients' satisfaction</td>
<td>(Pries and Janssen, 1996) (Peasgood and Walker, 2006) (Toole et al., 2013) (Dikmen et al., 2015)</td>
</tr>
<tr>
<td>5</td>
<td>Alleviates the challenges facing construction context due to the</td>
<td>Many challenges face construction organisation in today’s business environment including globalisations, aged work force and change in clients' expectations, Innovations could be a remedy for most of them</td>
<td>(Ganbatse and Hallowell, 2011) (Blythe and Manley, 2004) (Ozerhan et al., 2014) (Panuwatwanchai et al., 2006) (Seades and Manse, 2003) (Egba, 2004)</td>
</tr>
</tbody>
</table>

(continued)
GVETs in the construction industry

Major gains from utilising GVETs concern their capabilities for crossing over geographical, organisational and temporal borders (Fuller et al., 2012), cost savings (Schweitzer and Duxbury, 2010), timeliness of completion of tasks (Gressgård, 2011) and higher qualities of products and services (Gignac, 2005). The foregoing advantages of GVETs have been
confirmed by studies in the construction industry on the grounds of their abilities to deal with very complicated construction projects (Chen and Messner, 2010; Chinowsky and Rojas 2003; Ramalingam et al., 2014) and their capacity for adding value to organisations out of knowledge in a knowledge-intensive industry such as construction (Vorakulpipat et al., 2010). Using GVETs would enhance the level of innovativeness of construction firms (Gann and Salter, 2000). As a result, because of the challenges of today’s business environment, adopting GVETs is becoming imperative for the construction industry (Becerik-Gerber et al., 2011).

Definitions of GVETs hitherto have mostly utilised the distinguishing attributes of GVETs in comparison to their collocated counterparts as the criteria to delineate this new structure of teamwork from the traditional ones (Cogliser et al., 2013). GVETs are considered as structures composed of:

[...] groups of geographically, organisationally and/or time dispersed intelligent workers with different skills and in different positions of the hierarchy heavily relied on ICTs to accomplish engineering tasks which for all are held accountable (Hosseini and Chileshe, 2013, p. 1103).

Major attributes of GVETs are shown in Table III.

As shown in Table III, GVETs are widely recognised as a novel system of team-working for construction organisations by previous studies. For example, Becerik-Gerber et al. (2012) postulated that the construction industry is still a beginner in adopting GVETs. GVETs have been described as an innovation in the construction context (Peansupap, 2004; Peansupap et al., 2006). Likewise, some research studies in the field have referred to GVETs as one of the spin-offs of ICT advancements (Moore and Abadi, 2005; Rezgui, 2007). These facts about GVETs seem to offer justifications for regarding this phenomenon as novel within the context. This brings GVEs into proper alignment with the conceptual definition of an innovation. The associated ramifications will be elaborated in the following.

The comparison between Tables II and III demonstrates the overall consistencies between the fundamental features of GVETs with distinguishing attributes of innovations. From this vantage point, theories and concepts developed for innovations in the construction industry literature would be equally applicable to GVETs as an innovation. A caution should be noted that defining the innovations classification applicable to GVETs depends on many factors, particularly the level of virtuality of the team that falls beyond the objectives of this study (Chudoba et al. (2005) and Kirkman et al. (2002) for extensive discussions on this matter). Generally, GVETs will be between the incremental and radical innovations based on the conditions of the context and the level of virtuality of the team in question. However, on the grounds of the other classification, GVETs fall within the domain of technological innovations. Therefore, using principles applying to technological innovations seems tenable for GVETs.

As illustrated in Figure 1, the relationships existing between GVETs and innovations in the construction industry seem readily recognisable; however, the relevant literature on GVETs has literally neglected this fact. The link existing between GVETs literature and the innovation body of knowledge is largely overlooked in the construction field. On the other hand, reviewing the available studies on GVETs from the construction industry revealed that inquiries conducted on GVETs have barely addressed the issues of diffusion of GVETs in projects and organisations. To the best of the authors’ knowledge, there is no study focussed on investigating major aspects of diffusion of GVETs in construction projects or
firms. Thus, utilising an IDM as the platform for conducting research studies on GVETs seems to offer the sphere valuable advantages, as explained in following.

Table III. Attributes delineating GVETs in the literature of the construction industry

<table>
<thead>
<tr>
<th>No.</th>
<th>Attributes</th>
<th>Scholarly support</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A new team working structure for construction organisations</td>
<td>(Ramalingam et al., 2014)</td>
</tr>
<tr>
<td>2</td>
<td>High dependency on ICT</td>
<td>(Hossain and Chileshe, 2013)</td>
</tr>
<tr>
<td>3</td>
<td>Imposing noticeable change in organisations’ processes</td>
<td>(Chen and Messner, 2010)</td>
</tr>
<tr>
<td>4</td>
<td>Considerable advantages in many aspects</td>
<td>(Vorakulpiset al., 2010)</td>
</tr>
<tr>
<td>5</td>
<td>Regarded as a remedy to challenges of construction industry in terms of globalisation and necessity of enhanced competitiveness</td>
<td>(Nayar and Taylor, 2009)</td>
</tr>
<tr>
<td>6</td>
<td>Prone to specific risks</td>
<td>(Zhang et al., 2008)</td>
</tr>
<tr>
<td>7</td>
<td>Immaturity of the literature</td>
<td>(Rossetti, 2007)</td>
</tr>
</tbody>
</table>

Note: *Attributes 1 through 6 are cited by the aggregated list of scholars as shown*

**Necessities of grounding GVETs’ diffusion in IDMs**

It is contended by the authors that grounding GVETs’ diffusion in the IDMs’ body of knowledge would contribute to the field. This is in accordance with the following arguments:

- Many aspects of GVETs including the areas concerning diffusion of GVETs and the process of migrating from traditional teams to GVETs have been neglected in the extant literature in the construction industry. The vast majority of existing studies have been devoted merely to issues regarding implementation of GVETs, e.g. Chen and Messner (2010) and Chinowsky and Rojas (2003). In short, considering the definitions for the major features of innovation as described (i.e. diffusion and implementation), it could be inferred that the research field has circumvented clarifying the diffusion process prior to investigating the implementation aspects. Nonetheless, as postulated by seminal innovation studies such as Slaughter (2000), a deep appreciation of the processes and the factors affecting the adoption of innovations are central to the success of implementing innovations. Acquiring an understanding of the major aspects of diffusion becomes even more important given that such features will also influence and shape the succeeding phases, that is, implementation of an innovation in construction organisations (Peansupap et al., 2006). Describing the processes by which an innovation is adopted in construction organisations falls within the realm of IDMs in the research field of the construction industry (Kale and Arditi, 2010) and other disciplines (Rogers, 2010; 1995). The increasing prominence of using GVETs in the construction context makes clarifying the diffusion features of GVETs even more urgent and relevant.

- As described above, the construction industry suffers from lack of knowledge on diffusion aspects of GVETs, in view of the fact that current body of knowledge is limited to few
research studies (Table III) that neglect the foregoing matters. Presumably, the field is in need of knowledge creation to bridge the gaps in the literature. However:

[...] knowledge is primarily created by building new theories, extending old theories and discarding either those theories or those specific elements in current theories that are not able to withstand the scrutiny of empirical research (Handfield and Melnyk, 1998, p.1).

In addition, modifications or extensions of theories should meet specific requirements to be a contribution (Whetten, 1989). Likewise, it should follow a scientific process for creating effective knowledge (Handfield and Melnyk, 1998; Meredith, 1993). In this regard, theories or frameworks act as the centrepiece and the director of future research studies (Shields and Tajalli, 2006). Thus, merging GVETs into a scientifically established body of knowledge, such as construction IDMs, would hasten the process of bridging the existing gaps of knowledge.

**GVETs’ diffusion in the construction industry**

**Innovation diffusion models**

As described by Kale and Arditi (2010), IDMs aim to clarify the procedure and to identify the factors, which lead to the adoption of innovations. Likewise, the IDMs aim to predict and explain the rates and patterns of adopting innovations in construction organisations. Few studies in the construction context, such as Kale and Arditi (2006), have developed IDMs by drawing upon the well-established frameworks such as the innovation diffusion theories, e.g. Rogers (1995), or prominent IDMs developed in other disciplines, such as the Bass model (Bass, 2004). However, neglecting theories of innovation by studies aiming at investigating any aspect of innovations seems irrational. Particularly, innovation diffusion theories and models have built upon the robust body of knowledge from sociology, psychology and communications to explain the trends in social systems (Kale and Arditi, 2005). Hence, neglecting them might result in overlooking many aspects of innovations in any field, including construction.

As stated by Kale and Arditi (2010) and Taylor and Levitt (2004), many studies on IDMs in the construction context (Peansupap et al., 2006; Widen and Hansson, 2007) have deployed robust empirical approaches. However, such studies for the most part have merely aimed at investigating the impacts of only one construct and have overlooked other potential influential constructs and pertaining variables. As an example, the study by Panuwatwanich et al. (2009) has established the great effects of the culture in the organisations on diffusion of innovations. However, investigation on other constructs and the factors within the constructs has been mentioned as the grounds for future investigations. Because of the abovementioned drawbacks alongside the fragmentation of the existing studies (Aouad et al. (2010)), an integrated approach seems necessary for clarifying the pattern of diffusion of innovations in the construction industry. This calls for synthesising the findings of the studies through a multidisciplinary approach.

Taking into account these arguments, the conceptual model presented in following Incorporates and aggregates the results of major relevant studies to describe the process leading to adopting any innovation (including GVETs). Thus, this approach will cover the gaps between different studies and will improve the comprehensiveness of the constructs used in preparation of the conceptual model, as pointed out by Whetten (1989).
The conceptual model for innovation diffusion
According to Whetten (1989), the first step in investigating a phenomenon should be defining the constructs that explain the phenomenon of interest. Building on the qualitative findings of previous studies on diffusion of innovations (i.e. the qualitative meta-analysis approach) and as the result of synthesising the models developed previously, a concise conceptual model has been developed, as illustrated in Figure 4. The model captures the primary constructs influencing the diffusion of any innovation including GVETs in the construction industry. Nevertheless, as per the objectives of this study, the model, as illustrated in Figure 4, could regard GVETs as the subject of interest.

The conceptual model, as illustrated in Figure 4, is largely based on the six-stage model for innovations developed by Slaughter (2000) and reaffirmed in the recent study by Murphy (2014), which conceptualised the lifecycle of innovation within the construction industry in six stages. The stages in the former study were defined as follows:

- identification;
- evaluation;
- commitment;
- preparation;
- use; and
- re-evaluation.

The same applies to GVETs as an innovation in the construction context. However, identification and evaluation stages, as described by Slaughter (2000), refer to the processes and activities for considering the pros and cons of innovations prior to making any decision about their adoption. This puts the aforementioned stages into alignment with the definition of diffusion of an innovation according to Rogers (2010) and Wolfe (1994). As illustrated in Figure 4, there is an interface demarcating the diffusion and implementation phases and the associated activities (Winch, 1998).

Project managers should evaluate the advantages and risks of adopting any innovation, such as GVETs, to justify any investment (Bhatt and Ved, 2013). They should deploy value management techniques considering all the available alternatives of an innovation to select the option with the best feasible value for money (Peansupap et al., 2006; Slaughter, 2000). The prominence of such evaluation is underpinned further by the cognitive model of technology adoption stating the prominence of viewpoints of practitioners regarding the perceived difficulty and the perceived benefits of adopting a technology (Au and Enderwick, 2000).

The effects of the outcomes of the activities fulfilled and the decisions made in this Stage transcend the initial stages of adopting GVETs and affects the whole performance of GVETs within their whole lifecycle in an organisation (Maynard et al., 2012). The findings of the study by Kam et al. (2013) endorsed such an insight by demonstrating that performance records of organisations in different stages of using virtual design and construction are correlated.

The adoption decision-making stage, as illustrated in Figure 4, is the outcome of the collective effects of the drivers pushing organisations towards deploying GVETs as an innovation in their projects. The driving forces in the construction industry pushing organisations towards using innovations mostly include the demands of stakeholders and clients (Na Lim, 2014), threats from globalisation and competitors (Becerik-Gerber et al., 2011), alongside necessity of fulfilling the strategies of organisations (Hosseini et al., 2012;
Toole et al., 2013; Liu et al., 2014). This is tenable, as the pressure to maintain the level of competition by adopting innovations could be enormous in highly competitive industries (Frambach and Schillewaert, 2002), such as the construction industry. In addition, alignment with organisational strategies gives rise to organisational support for adopting the innovation as the factor deemed essential to facilitate diffusion of an innovation (Frambach and Schillewaert, 2002). The effects of demands and needs are highlighted in the literature as well (Ozorhon et al., 2014). It is because any organisation should recognise the demands and the needs for an innovation even prior to any attempt to acquire information about the innovation (Larsen, 2011).

As illustrated in Figure 4, companies should consider their available resources and capabilities with regard to the requirements of adopting innovations as an important variable when considering adopting innovations in organisations (Hardie et al., 2013; Chan et al., 2014). Likewise, the results of the study by Gilligan and Kunz (2007) and Ozorhon et al. (2014) established that major barriers facing implementing virtual construction are associated with lack of resources in organisations, particularly lack of necessary skilled personnel. As stated in El-Ghandour and Al-Hussein (2004, p. 11), “describing and measuring the current state of a business process is useful in creating a new process”. This concept has been encapsulated into the phenomenon of perceived compatibility of the technology based on the cognitive model of technology adoption, as discussed by Au and Enderwick (2000). Even more, based on the theory of planned behaviour, the behaviour of professional individuals – such as project managers – towards any new technology is determined by their “perception of the availability of skills, resources, and opportunities necessary for using the technology”, as postulated by Chau and Hu (2001, p. 701).

As illustrated in Figure 4, consistent with the conceptual definition of diffusion put forward by Winch (1998) and acknowledged by Tatum (1989), “jumping on the bandwagon” could be a major driver for adopting innovations within construction organisations. In other words, organisations do not opt to adopt any innovation, including GVETs, merely because of the higher productivity levels or efficiency. The pressure might stem from the awareness about the sheer number of corporations using an innovation, which also applies to GVETs (Kale and Arditi, 2010). The pressure from the “bandwagon” effect occurs when non-adopters believe their project will end up experiencing below-average performance, while many competitors can increase their performance by adopting an innovation (Abrahamson and Rosenkopf, 1993) such as GVETs. In this spirit, the accumulated level of using an innovation in the market influences the decision in a project to adopt the innovation, as inferred from Frambach and Schillewaert (2002).

Furthermore, the regulatory environment affects the diffusion pattern of innovations in organisations (Blayse and Manley, 2004; Sergeeva and Radosavljevic, 2012). Even more, Aouad Et al. (2010) and Na Lim (2014) argued that innovation diffusion in the construction context depends on the policies enforced by the government. Hence, conditions enveloping diffusion of innovations become dissimilar in different countries (Liu et al., 2014). Nonetheless, the level of such impact is determined by the strength of the correlation between the type and nature of the innovation of interest with relevant regulations. For example, the adoption of environmental innovations in the construction context is strongly affected by the environmental regulations enforced (Hardie et al., 2013).

Idea generators and gatekeepers in Figure 4 represent the actors in the form of persons or units which catalyse the use of an innovation during the diffusion phase (Slaughter, 2000). Idea generators in general are those within the organisation who are able to develop
specific solutions for current challenges facing organisations (Aouad et al., 2010).

Gatekeepers, in turn, identify and discover new alternatives and take part in the process to evaluate them (Allen, 1984). They play vital roles in the diffusion of an innovation in the construction context (Slaughter, 2000; Skibniewski and Zavadskas, 2013). That is, promoting and generating an idea has been regarded as a prerequisite of any activity and procedure leading towards adoption and diffusion of an innovation in any context (Van de Ven, 1999), which is also applicable to construction (Rundquist et al., 2013). This fact underlines the strong effects of the aforementioned actors as well as the crucial role of disseminating knowledge of available good practices in facilitating adoption of any innovation, including GVETs, in construction projects, as implied by Verburget et al. (2013).

Innovation diffusion has been described as an “information-processing activity” (Frambach and Schillewaert, 2002). Slaughter (2000) and Liu et al. (2014) argued that the diffusion phase might be triggered merely after dissemination of knowledge about the innovations through the environment in the industry. Moreover, Kale and Arditi (2010) opined that innovation diffusion is under the influence of the environment because of the knowledge exchanged regarding the innovation between one organisation and the environment. In addition, Gambatese and Hallowell (2011) and Ding et al. (2014) enunciated that one of the main enablers of innovations in the construction industry is effective knowledge management. All the above discussions advocate for consideration of the great influences of knowledge management and the industry’s bank of knowledge over diffusion of innovations in the construction industry. Hence, as illustrated in Figure 4, the knowledge is processed through the knowledge management initiatives of the organisations and affects the diffusion process of implementing an innovation in the construction industry.

In essence, the knowledge acquired from the bank of knowledge in the industry about any innovation, such as GVETs, will be affected by the knowledge management initiatives in projects (Liu et al., 2014). This is the reason that knowledge management initiatives have been regarded as critical for the innovativeness of organisations in the construction context (Rundquist et al., 2013; Toole et al., 2013). The information generated in an organisation with regard to different aspects of diffusion and implementation of an innovation will be disseminated and added to the bank of knowledge in the industry, termed by Ozorhon et al. (2014) as “lessons”. The transfer of knowledge from organisations to the bank of knowledge mostly occurs at the final stages of implementing an innovation, during which the knowledge concerning different phases has become available (Maqsood et al., 2003).

As illustrated in Figure 4, change management practices will affect the diffusion of innovations in organisations, as pointed out by Bloch (2007) and Toole et al. (2013). It is because adopting innovations in organisations involves making a level of change to the Ordinary processes of organisations (Slaughter, 2000). Expressed another way, diffusion of innovations, such as GVETs, rely on change management initiatives in organisations to encourage people to opt for the innovation (Peansupap et al., 2006).

Organisational characteristics greatly affect the innovation diffusion process and its outcome (Frambach and Schillewaert, 2002; Bygballe and Ingemansson, 2014; Liu et al., 2014), as illustrated in Figure 4. The level of impact of some organisational characteristics is a matter of controversy, as some studies have described the effects of size as negligible (Damanpour, 1992), whereas some other authors have advocated for the great influence of size on the decision to adopt innovations (Frambach and Schillewaert, 2002). Nonetheless, it is established in the construction literature that the effectiveness of adopting and implementing innovations in organisations heavily rests on the climate prevailing within the
organisation (Dulaimi et al., 2005; Panuwatwanich et al., 2008). Even more so, as illustrated in Figure 4, the success of organisations in absorbing the relevant information from the bank of knowledge, and deploying the information in adopting and implementing innovations in organisations, primarily relies on the innovation-related culture dominant within the organisation (Hartmann, 2006; Sanz-Valle et al., 2011; Chan et al., 2014). Furthermore, the level of influence of knowledge management in every stage of implementing innovations in construction organisations is determined by the culture prevalent in the organisation (Panuwatwanich et al., 2009) and “internal attitudes” (Bygballe and Ingemansson, 2014). One such example could be the frequency and richness of sharing knowledge between members of a project, which facilitates the innovation diffusion process (Frambach and Schillewaert, 2002). This is consistent with the model, as illustrated in Figure 4, which shows that the relevant culture in the organisation acts as the medium between the outcome of the knowledge management practices and the drivers for using GVETs.

The status of research on GVETs as an innovation in the construction industry is illustrated in Figures 1 and 4. This draws upon three basic gap-spotting modes, namely, confusion, neglect and application, introduced by Sandberg and Alvesson (2011) to assess the state of research on GVETs. Confusion happens when knowledge on the matter is available, while the pertinent views are contradictory, puzzling and competing. If no reasonable research has been conducted on an issue or the existing knowledge has overlooked it, this could be defined as the neglect mode. When there is a need for extension of existing knowledge, it falls within the application gap-spotting mode. Authors are of the view that the diffusion stages of GVETs in organisations are neglected by the construction studies. This statement is underpinned by the agenda for research on GVETs recently developed by Hosseini and Chileshe (2013), which stressed the necessity for investigating the aspects associated with the diffusion of GVETs in organisations in the construction industry.

Finally, it is argued that the conceptual model developed in this study (Figure 4) could be regarded as the first model synthesising the findings of previous studies on innovation diffusion within the construction context from a multidisciplinary perspective. This could be regarded as a contribution offered by the present study to the construction context as according to Walker (1997, p.150) either “making a synthesise that has not been tried before” or “being cross-disciplinary” are bona fide reasons for recognising the contribution offered by a research study. In alignment with the criteria for contribution of theory-oriented studies, as explained by Holt et al. (2014), the present study adds value to the existing body of knowledge on GVETs in the construction context. This refers to providing an illuminative insight into major aspects of diffusion of GVETs in construction organisations through codification of the existing knowledge and presentation of generalised perspectives. Moreover, by locating research regarding GVETs within the context of IDMs in the construction industry, this study has contributed to the field by shedding some light into the complex system of the diffusion of innovations in construction field.

Conclusion
The analysis of the extant literature in the present study brought to light that body of knowledge on GVETs is not mature enough to offer a sound basis for unearthing major factors affecting adoption and innovation of GVETs in AEC project. In addition, the qualitative meta-analysis of previous studies conducted in this study revealed that
IDMs developed for the AEC context are disjointed and focus on different aspects of innovation diffusion. Furthermore, synthesising the findings of previous studies established that GVETs’ attributes align closely with definitions proposed for innovations in AEC field. Therefore, adoption/diffusions process of GVETs literally mirrors that of innovations in AEC projects.

To address the issue of fragmentation of existing IDMs, the study drew upon the qualitative meta-analysis approach, as illustrated in Figures 2 and 3, encompassing a critical review of relevant literature. The rationale and appropriateness for this approach was outlined within the research methodology of the study and supported by a number of studies such as Sandelowski and Barroso (2007), Aouad et al. (2010), Hertel et al. (2005) and Powell et al. (2004). This provided the foundation for an integrated conceptual model for innovation adoption/diffusions for the AEC context presented in this study. The findings derived from the qualitative meta-analysis approach and summarised in Tables I-III resulted in the development of the conceptual IDM (applicable to GVETs) within the construction context (Figure IV). This provides future studies with a sound basis for mapping out the processes and the factors affecting the adoption of GVETs in AEC projects from an all-inclusive perspective. On a practical level, the conceptual model presented can be translated into the basis for highlighting major aspects of the diffusion and adoption of GVETs in AEC organisations by underlining the constructs that favour shifting to GVETs in firms. This is because a supportive structure is necessary for facilitating diffusion of any innovation in the AEC context according to the seminal study of Winch (1998). GVETs are a subset of ICT-based innovations and a building block for implementing virtual construction (BIM) in AEC projects (Figure1). Research findings are considered general is able to such ICT-based innovations in the AEC industry. The sheer number of factors affecting innovation diffusion, particularly inclusion of behavioural-oriented factors in diffusion of innovations in AEC projects that came to light in this study necessitates treating the process of diffusion of innovations in construction project as a complex system. Moreover, as a complex system, the role of the nature and attributes of main decision-makers in the diffusion of innovations in AEC projects becomes particularly relevant as a topic for future inquiries.

Finally, a caveat should be noted that the robustness of the presented conceptual model was enhanced after being acknowledged by five experts in the field from academia. However, it could not be deemed validated because of the low number of respondents and single sector constraint. As a result, drawing upon a wide range of viewpoints including academia and industry practitioners for validating the developed conceptual model alongside designing the effective variables for evaluating the constructs introduced are necessary grounds for future inquiries.

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Further reading

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