

Ontology of the Communication Performance Prospects of Building Information Modelling Adoption among Project Teams in Construction Project Delivery

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Abstract: The need for improved communication performance among project teams has significantly underlined the increased adoption of many computer-based tools and information communication technology (ICT) in project delivery in the construction industry. Though the literature has espoused the key benefits of Building Information Modelling (BIM), relatively less attention has been paid to the communication performance influence of BIM to profession-specific tasks and wider industry adoption. The primary aim of this study is to assess the communication performance prospects of BIM adoption among project teams in construction project delivery. Using deductive research design, a structured questionnaire survey was conducted on 52 experienced construction industry practitioners in the use of BIM tools in project delivery. The results indicated a significant influence of BIM adoption to accuracy, understanding, timeliness and improvement in the dissemination of shared project related information among project teams. However, contrary to opinion espoused in literature, there was no significant impact on overcoming underloading, overloading and gatekeeping issues in communicated information among the team. The findings provide empirical support into the perceived communication benefits of BIM adoption and thus this knowledge can be an overriding impetus to extensive adoption of BIM tools across all the project life cycle to enhance communication in the construction industry.

Keywords: Building Information Modelling, BIM tools, Communication performance, Project team communication, Construction project delivery

INTRODUCTION

Enhanced communication through prompt, reliable access and sharing of project-related information is vaguely reported in literature among the copious benefits of the use of information communication technology (ICT) in project delivery (Eastman et al., 2008; Becerik-Gerber, Gerber and Ku, 2011; Becerik-Gerber and Kensek, 2010). Additional communication-related benefits of the use of ICT is said to include process efficiencies, enhanced coordination and collaboration in construction project delivery (Levitt, 2007; Becerik-Gerber, Gerber and Ku, 2011). However,

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the construction project delivery process is said to form complex communication networks among team participants and environment coupled with organisational fragmentations and virtuality making communication ineffectiveness a persistent feature (Davies and Harty, 2013; Bryde, Broquetas and Volm, 2013; Chi, Kang and Wang, 2013). The adoption of Building Information Modelling (BIM) in the construction process is perceived to be extensive in the global construction industry but regionally it can be said to be varied. The widest spread use of BIM in the communication context is said to be at the design stage (Sacks et al., 2010; Eastman et al., 2010). This assertion is theoretically underpinned by the fact that BIM tools aid multiple dimensional visualisations that are perceived as potential effective communication benefits. This dimension of the benefit of BIM usage is cursorily asserted to aid understanding, access and timeliness in the sharing of project related information for task function and decisions (Bryde, Broquetas and Volm, 2013; Sacks et al., 2010; Eastman et al., 2010). However, the empirical knowledge and understanding of this perceived communication performance of BIM are lacking any theoretical and practical rigour.

In recent times, most construction projects delivery has adopted one or more project related information sharing technology aimed at enhancing communication performance from a plethora of several available tools (El-Saboni, Aouad and Sabouni, 2009; Ahuja, Yang and Shankar, 2009a; Davies, McMeel and Wilkinson, 2017). However, it has been contended that the mere adoption of any technological tool towards project communication does not automatically stimulate success. Rather the adoption decision of ICT communication tools must consciously be based on the understanding of the communication effectiveness potential of the tool as well as its contextual limitations in its usage (Yang, Ahuja and Shankar, 2007; El-Saboni, Aouad and Sabouni, 2009; Bräthen and Moum, 2016). This is because the knowledge and understanding of the communication potential of ICT tools have a strong significance and catalyses decisions on ICT adoptions to ensure effective communication protocols in project delivery.

A plethora of literature have espoused an increase in BIM adoption and its potential to enhancing communication for many developing countries such as Ghana, Nigeria, South Africa, Rwanda and others (Addy, Adinyira and Ayarkwa, 2018; Abubakar et al., 2014), yet there remains a continuous admission of ineffective communication in construction project delivery still being persistent (see Bernstein and Pittman, 2005; Eastman et al., 2008; Liu et al., 2013). Armah (2015) suggested that BIM adoption in the Ghanaian construction industry (GCI) has the potential to improving communication, information management and protocols in project delivery. However, this assertion is yet to be subjected to and theoretical and practical rigour. Hence, the primary objective of this study is to explore the communication performance potential of BIM as a communication protocol tool in construction project delivery in the GCI. The findings from this study are thus considered very important for engendering effective construction project management protocols and underpin decisions on BIM adoption in project delivery especially in Ghana and other developing countries with similar structural, social, technical and professional characteristics such as Ghana, Nigeria and South Africa. This knowledge will further contribute to the discourse of the communication performance benefits of ICT in construction project communication during project delivery to mitigate the social dilemma induced by project complexities, isolation and fragmentation of the project delivery process (Gu and London, 2010; Leiner et al., 2009; Chi, Kang and Wang, 2013; Eastman et al., 2010).

LITERATURE REVIEW

Construction Project Communication and ICT Adoption

The construction industry and project delivery process are said to be highly data and information-dependent and thus the adversarial, fragmented nature, non-collaborative and widely dispersed nature of participants makes effective communication of project related information almost impossible without the use of ICT. However, literature reflects an incessant report of the available technology not being utilised to their full potential especially in the communication and management of construction-related information (Ahuja, Yang and Shankar, 2009a; 2010; Smith and Tardiff, 2009). Ahuja, Yang and Shankar (2009b) revealed that construction project teams and organisations share information that is needed for managing internal operations, making decisions and policy directions and managing the tasks and actions in the construction project delivery process. In the light of this, ICT is required to integrate, bring agility and induce effective action in the information system and the communication for all of these in an effective manner (Yang, Ahuja and Shankar, 2007; Ahuja, Yang and Shankar, 2009b; 2010; Dawood, Akinsola and Hobbs, 2002; Smith and Tardiff, 2009).

In the construction industry, the adoption of ICT has notably been premised on enhancing integration of the various project phases leading to improvements in performance (Addy, Adinyira and Ayarkwa, 2018; Wong and Zhang, 2013; Wang and Love, 2012; Dawood and Sikka, 2008; Alshawi and Ingirige, 2002). Against this, integration approaches on construction project delivery and in the industry have primarily been pinned on technical and managerial strategies (Yang, Ahuja and Shankar, 2007; El-Saboni, Aouad and Sabouni, 2009; Alshawi, 2007; Alshawi and Faraj, 2002; Dawood and Sikka, 2008; Wong and Zhang, 2013; Craig and Sommerville, 2006). In enhancing technical integration, the focus has been to project information through computer-aided application in workplace technology (Alshawi and Faraj, 2002; Wang and Chong, 2015; Yang, Ahuja and Shankar, 2007). However, in managerial integration, there has been the adoption of the Internet, intranet related computer-supported collaborative work (CSCW) which are sometimes web-based to manage information communication among the project stakeholders and participants to enhanced collaborative work management (Davies, McMeel and Wilkinson, 2017; Dawood and Sikka, 2008; Alshawi and Ingirige, 2002; Goulding, Pour-Rahimian and Wang, 2014). As the growth of adoption of communication technology in the construction industry is increasing, their efficient use is anticipated to be made to effect an impact on traditional processes and develop more efficient collaborative workflows (Davies, McMeel and Wilkinson, 2017; Wang and Love, 2012; Ahuja, Yang and Shankar, 2009a; 2010; Howard and Björk, 2008; Campbell, 2007; Pena-Mora and Tanaka, 2002). On the contrary, it has been contended that the mere adoption of these ICT tools with their related intents does not guarantee results. Rather the clear understanding of the effectiveness of the ICT tools in the sharing of the related information, as well as careful consideration of human-related (e.g culture) issues and their strategic adoption, can potentially engender success (Davies, McMeel and Wilkinson, 2017; Wang and Love, 2012; El-Saboni, Aouad and Sabouni, 2009; Yang, Ahuja and Shankar, 2007; Weippert, Kajewski and Tilley, 2003).

Traditional Approaches of Construction Communication and BIM Adoption

From extant literature, it can be noted that the adopted dominant traditional means of construction communication have included the sharing of paper-based contract documents, bill of quantities, 2D drawings, etc. (Mead, 1999; Campbell, 2007; Howard and Björk, 2008; Wang and Love, 2012). A critique of recent happenings and developments in the industry suggests a departure from this traditional paper-based approach to the use of electronic-based means of communication using computer-aided technology (Ahuja, Yang and Shankar, 2009a; El-Saboni, Aouad and Sabouni, 2009; Otter, 2005). Additionally, it can be asserted that this shift from paper-based communication to electronic-based communication has also changed the construction culture with people adopting different ways of communication (Leiner et al., 2009; Rimmington, Dickens and Pasquire, 2015). This has led to the rapid development of various IT tools and means over the last decade through various technological innovations for the creation, transfer and storage of project-related information (Wang and Love, 2012; Wong and Zhang, 2013; Davies, McMeel and Wilkinson, 2017). The adoption of ICT platforms as a communication performance tool in construction communication has evolved from the use of simple Intranet, Internet, groupware in hosting and sharing information and now including the hosting of information from the widely touted BIM (Mead, 1999; El-Saboni, Aouad and Sabouni, 2009; Ahuja, Yang and Shankar, 2010; Adriaanse, Voordijk and Dewulf, 2010).

Leiner et al. (2009) and Rimmington, Dickens and Pasquire (2015) intimated that the use of Internet has revolutionised the computer and communications in an unprecedented way providing a means of information distribution, communication, collaboration and individual interactions via computers devoid of location in various forms. According to Sacks et al. (2010) and Merschbrock and Nordahl-Rolfen (2016), sharing information in paper format still dominate construction work and thus there are notable shortcomings of using traditional drawings to explore building information in current construction practice. In this regard, shortcomings such as poor portability and improper handling of the drawings, poor display of related information, as well as problems related to browsing and readability are well-acknowledged (Yeh, Tsai and Kang, 2012; van Berlo and Natrop, 2015). According to Hwang, Zhao and Ng (2013) and Howard and Björk (2008), BIM has been put forward as an ICT tool to respond to the challenge of improper information flow among participating parties, thereby dominating the most adopted means of sharing project related information in construction project delivery. The adoption of BIM is considered a panacea for curtailing most of the significant information sharing challenges which will consequently lead to effective coordination and reduction in reworks as well as scope changes in construction projects through enhanced communication (Hwang, Zhao and Ng, 2013; Howard and Björk, 2008; Bräthen and Moum, 2016). From the extensive studies focusing on the adoption of ICT technologies towards improving communication, coordination and managerial effectiveness in the architectural, engineering and construction (AEC) industry in the last two decades, it can be contended that BIM has received the most rapidly growing attention in the global industry due to its ability to offer a digital representation of the physical and functional characteristics of a building facility as well as a shared knowledge resource for information contributing to a strong and formidable basis of decision making during the project life cycle/phases (Yang, Ahuja and Shankar, 2007; Skibniewski and Zavadskas, 2013; Irizarry, Karan and Jalaei, 2013; Ding et al., 2015;

Rogers, Heap-Yih and Preece, 2015; Nitithamyong and Skibniewski, 2011; Wong and Zhang, 2013; Bråthen and Moum, 2016).

The BIM and Its Communication Performance Usages

From existing literature, it can be said that BIM has been defined in various forms (see Jensen and Jóhannesson, 2013; Gu and London, 2010; Arayici et al., 2011; Arayici, Egbu and Coates, 2012; Eadie et al., 2013; Eastman et al., 2008; 2010). However, in the context of information sharing, this study adopts the definition by Eastman et al. (2010) as "a tool, processes and technologies that are facilitated by digital, machine-readable documentation about a building project and facility, its performance, its planning, its construction and later its operation". Campbell (2007) suggested that BIM is a comprehensive information management tool based on the simulation of design and construction rather than merely a three-dimensional (3D) graphic representation of design intent. According to Bråthen and Moum (2016), the most widespread use of BIM today is in the design phase and pre-construction planning. However, in the last decade, the use of BIM in construction project delivery has been explored beyond its traditional design phase and pre-construction planning to embrace on-site activities, project coordination and information update and sharing across other phases of the project life cycle (Merschbrock and Nordahl-Rolfen, 2016; Wang and Chong, 2015; Sacks et al., 2010; Ahuja, Yang and Shankar, 2010).

Against this background, Sacks et al. (2010) reiterate that BIM is used in sharing and enabling 3D and four-dimensional (4D) visualisation of the building product and this allows for effectively communicating design intent. It is also acknowledged that BIM usage allows for rapid generation of alternative design, building performance prediction, automatically monitoring the integrity of model and reports, providing a communication platform and promoting collaboration between design and construction professions (Sacks et al., 2010; Rogers, Heap-Yih and Preece, 2015; Ding et al., 2015; Campbell, 2007; Ahuja, Yang and Shankar, 2010; Otter, 2005). From this, it can be said that the communication potential of BIM usage is in no doubt essential, and enormous. However, rigorous empirical evidence of its communication performance will seemingly be a very important impetus to legitimising certain decisions, actions and skills in the use and adoption of BIM in construction project communication. Lee and Rojas (2013) and Ahuja, Yang and Shankar (2010) have also revealed that visual representation is an additional attribute of ICT mediated information sharing that enhances the performance of shared information among project teams in construction project delivery by aiding accurate interpretation of the shared data and information.

BIM Adoption in the Ghanaian Context

The GCI in the past half a decade has recognised BIM as an integrated tool that has potential to improve process, management and integrated delivery (Addy, Adinyira and Ayarkwa, 2018; Armah, 2015). In the past few years, BIM tools such as Autodesk suite and Bentley suite have become common tools for architectural, structural, cost estimating mechanical and electrical components of projects (Armah, 2015). In respect of asset and facilities management, there are not recognised evidence of BIM usage. It is thus noted that BIM usage in the GCI is fragmented, unregulated,

uncoordinated and integrated especially at the pre-contract stage (Addy, Adinyira and Ayarkwa, 2018; Armah, 2015).

Overall, it can be said that the use of BIM in the GCI can be described as infancy with no clear policy guidelines and regulations. Despite this obvious observation, it is well acknowledged that BIM adoption has seen a significant surge especially among project teams in the managing project information, sharing and assess from the design phase to closure. However, it is more significant at the construction stage (Addy, Adinyira and Ayarkwa, 2018; Armah, 2015). Armah (2015) and Addy, Adinyira and Ayarkwa (2018) asserted that BIM adoption in the industry in the case of Ghana is motivated by improved performance expectancy. However, the issue of behaviour, social and price value of BIM tools have often affected the decision to adopt on some projects. Generally, there is a high perception that the use of BIM improves information management, integration and access among project teams in the GCI. However, there is yet to be any studies focusing on BIM related communication and information sharing in the GCI context.

Communication Performance Measurement

The construction industry is information-intensive and all teams involved in a given construction project need to communicate with one another effectively to satisfy the project requirements. Also, a continuous assessment of the performance of project team communication in construction project delivery is considered a precursor to identifying evaluating and legitimising concepts, process, approach, tools and skills that can engender enhanced effective communication (Xie et al., 2010; Liu, 2009; Marshall-Ponting and Aouad, 2005; Dawood, Akinsola and Hobbs, 2002; Xie, 2002; Xie, Thorpe and Baldwin, 2000; Thomas, Tucker and Kelly, 1998). Thomas, Tucker and Kelly (1998) intimated that the development of a means of measuring and evaluating communication performance is a necessary step towards improving project communications. However, varying concepts, approaches and definitions have been given and applied to communication performance. The performance of communication has often been described by how well the aims and functions of communication are met (Liu, 2009; Thomas, Tucker and Kelly, 1998; Mead, 1999; Dawood, Akinsola and Hobbs, 2002; Xie, Thorpe and Baldwin, 2000).

In the context of assessing the performance of communication, some studies attribute information timeliness, accuracy and completeness as predominant criteria for the measurement (see Dainty, Moore and Murray, 2006; Thomas, Tucker and Kelly, 1998; Xie, Thorpe and Baldwin, 2000; Dawood, Akinsola and Hobbs, 2002; Liu, 2009; Xie et al., 2010). Sonnenwald (1996) and Shen (1992) evaluated issues related to construction project related information sharing as ascribed information underload, information overload, timely delivery of information, a clear understanding of the shared information, easy and unobstructed access to information as the tenets of the effectiveness of the communication performance outcome. The Construction Industry Institute (CII) (1997) evaluated communication performance effectiveness on construction projects by using six critical communication variables, namely accuracy, timeliness, procedure, barriers, understanding and completeness of the shared project information. This approach by CII (1997) has been described as an important and significant milestone in measuring communication performance towards the improvement of project team communication in construction project delivery (Thomas, Tucker and Kelly, 1998; Xie, Thorpe and Baldwin, 2000; Liu, 2009; Xie et al., 2010; Kwofie, Adinyira and Fugar, 2016). This was further expanded to

consider issues such as gatekeeping and distortions of the information in some studies (Thomas, Tucker and Kelly, 1998; Liu, 2009; Xie et al., 2010). This has extensively been used in assessing communication problems in construction project delivery.

Drawing from several studies on communication performance measurement in the construction project environment, it could be said that, the CII (1997) has the dominant approach to communication performance assessment in construction project delivery. The emergence and acceptance of the CII (1997) indicator approaches are underpinned by the fact that the model considers the social and behavioural attribute of communication which is a common feature of the global construction project environment. Against this background, the measure of the communication performance in this article has been perceived as the quality of the communication composition and flow among the project team due to the adoption of BIM tools in the project delivery. Hence, the communication performance outcome consequent from the adoption of BIM tools on construction projects can be conceptualised effectiveness of the accuracy, timeliness, understanding, access, completeness and coherency of the shared information.

By drawing on the practical and theoretical perspective of the construction project environment and the traditional construction industry in Ghana, the communication performance indicators (see CII, 1997) conceptualised and operationalised as indicated in Table 1.

Table 1. Explanation of the Communication Performance Measurement Variables

Indicators	Explanatory Variables
Accuracies	<ol style="list-style-type: none"> 1. Receiving non-conflicting information from team participants. 2. Consistency in communicated information leading to effective coordination among the project team. 3. Conciseness in communicated information among the project team.
Timeliness	Timely delivery of needed communicated information.
Distortions	<ol style="list-style-type: none"> 1. Coherency in the meaning of communicated information. 2. Consistency in the content of communicated information. 3. Enhanced clarity in communicated information resulting in uniform interpretations.
Barriers	<ol style="list-style-type: none"> 1. Easy access to communicated and shared information from channels. 2. Efficient dissemination of information among project team in channels.
Underloading	Receiving less information than expected from team participants for tasks.
Overloading	Receiving more information than necessary for the tasks than expected.
Understanding	Understanding communicated information.
Gatekeeping	<ol style="list-style-type: none"> 1. Withholding of part of the information by the one who controls communication. 2. Withholding of whole of the information by the one who controls communication.
Procedure	<ol style="list-style-type: none"> 1. Efficient disseminating protocols relating information sharing among teams. 2. Clearly defined roles and responsibilities among members of the team.

Sources: CII (1997), Thomas, Tucker and Kelly (1998), Xie, Thorpe and Baldwin (2000), Xie (2002), Liu (2009), Xie et al. (2010) and Kwofie, Adinyira and Fugar (2016)

STUDY METHODOLOGY

Assessing the influence or impact of factors and other attributes on communication performance outcome is said to lie in the objective and deductive research design domain entailing quantitative explanation of the causal relationship, significance testing and directionality among various variables (see Kwofie, Adinyira and Fugar, 2016; Liu, 2009; Xie et al., 2010; Xie, 2002; Dawood, Akinsola and Hobbs, 2002; Xie, Thorpe and Baldwin, 2000; Thomas, Tucker and Kelly, 1998; Sonnenwald, 1996). A quantitative research design using a structured questionnaire was therefore adopted to collect the primary data assessing the contribution of the use of BIM to the communication performance among project teams in construction project delivery. To ensure valid and reliable data to evaluate the contribution of BIM adoption to the communication performance among project teams in construction project delivery, project team participants who are involved in the management and delivery of projects at the construction stage were deemed as the potential source of data required given that they use BIM tools and are thus considered to have an understanding and experience in using BIM to share project related information. The construction project team participants such as project managers, architects, quantity surveyors, construction managers, engineers, clients, main contractors, subcontractors and suppliers are noted to be involved in the construction stage communication; sharing of information as well as using the adopted communication approach and tools (see Kwofie, Adinyira and Fugar, 2016; Xie et al., 2010; Liu, 2009; Uher and Loosemore, 2004; Dawood and Sikka, 2008; Dawood, Akinsola and Hobbs, 2002).

Thus, the project team participants were deemed as suitable with experience in the use of BIM in sharing project related information and were therefore targeted in a questionnaire survey to elicit their experience on the contribution of BIM adoption to communication performance in construction project delivery. The suitability of using a questionnaire in this study was largely due to the objective and deductive requirements in communication performance assessment expressed in previous studies (see Kwofie, Adinyira and Fugar, 2016; Xie et al., 2010; Liu, 2009; Dawood and Sikka, 2008; Xie, 2002; Xie, Thorpe and Baldwin, 2000; Thomas, Tucker and Kelly, 1998; Sonnenwald, 1996). The questionnaire for the data collection was developed using the communication performance indicators adopted in Table 1. The questionnaire was designed to measure the communication performance in the project team participants have been involved in by indicating the frequency of the effectiveness in those communication performance indicators as a result of the BIM tool adopted on the projects at the construction stage. The measurement was done using the conventional five-point Likert scale similar to previous construction communication performance measures (see Kwofie, Adinyira and Fugar, 2016; Xie et al., 2010; Liu, 2009).

In ensuring reliable data to validly evaluate the extent of the potential influence of BIM adoption on communication performance, it was important to draw on the experience of construction professionals who have been involved in BIM adopted projects in the industry. Given the lack of an organised database of BIM base construction projects in the GCI, the adoption of snowball sampling to select construction projects and construction team participants that have used and delivered projects using BIM was most appropriate. The project team participants who have used and delivered project adopting BIM tools on various projects were invited to indicate the extent to which the use of BIM tools influenced the level of

communication performance in their project communication based on a five-point Likert rating scale interpreted as "Very Significant" = 5, "Significant" = 4, "Moderately Significant" = 3, "Not Significant" = 2 and "Not Very Significant" = 1. The questionnaires were distributed using both electronic forms (58) and administered personally to participants in their located offices (28). A total of 86 questionnaires were distributed with a yield of 52 responses in the survey within four weeks through a snowballing sampling due to lack of data across all the built environment professionals on the use of BIM in the GCI. The questionnaire also assessed the background of the respondents in respect of their professional roles as well as their experience in the use of BIM tools in their communication on construction projects. These attributes according to Hallowell and Gambatase (2009) are important in ensuring the validity and credibility of the responses and thus offer credence to the research findings. The data collection focused on the experiences in the adoption of BIM at the construction stage in construction project delivery. This is partly due to the fact that, practically, the significant use of BIM in integrated and coordinated communication and information management in the construction industry in Ghana is at the construction phase. Although in the other phases such as inception, design and procurement, there is enough evidence of BIM usage, it is fragmented, uncoordinated and unintegrated. Mean scores were used to aggregate the responses given on the variables in respect to the influence of BIM adoption on the communication performance in their project delivery. To aid conformity in the interpretations of the aggregated means with the scale of the assessment of the influence of BIM usage to communication performance, the mean ratings were approximated to the nearest point on the five-point assessment scale used.

Gisev, Bell and Chen (2013) emphasised that assessment of the extent of agreement in the responses among a cluster of varying respondents on a given variable in any quantitative assessment is critical to offer credence and confidence in the interpretation of the mean scores on each variable. Against this, a single item inter-rater agreement index (rWG) for significant agreement among the responses were estimated through simulations based on a uniform null distribution using a sample size (i.e. group size) of 52 and a number of response items of five (i.e. the five-point Likert scale) based on 95% confidence interval estimates (after Gisev, Bell and Chen, 2013). The choice of the rWG was mainly due to its traditional and extensive usage in testing significant agreement among the raters/respondents in statistical measures (see Field, 2009; Cohen, Doveh and Nahum-Shani, 2009; Takim, Akintoye and Kelly, 2004; James, Demaree and Wolf, 1984). The process used in the rWG follows after James, Demaree and Wolf (1984), Cohen, Doveh and Nahum-Shani (2009) and Manu et al. (2014). This was through estimation by running simulations based on a uniform null distribution using a sample size (i.e. group size) of 52 and a number of response items of five (i.e. the five-point Likert scale) on 95% confidence interval.

DATA ANALYSIS, FINDINGS AND DISCUSSIONS

Profile of the Background of Respondents

Out of the total 86 questionnaires distributed via electronic mail and administered personally to participants in their located offices, 52 were received at the end of the four weeks representing a 60% response rate. This is above the minimum

recommended 20% to 30% response rate recommended for the questionnaire survey (Takim, Akintoye and Kelly, 2004). The banded breakdown of the professional roles in project teams and years of experience in BIM usage is presented in Table 2. Assessment of research instrument reliability is useful in offering credence and acceptance of findings, conclusions and generalisations drawn (Field, 2009). In this study, Cronbach's alpha used in assessing the reliability of the research instrument used. This follows similar approaches by Kwofie, Adinyira and Fugar (2017), Ahadzie, Proverbs and Sarkodie-Poku (2014) and Takim, Akintoye and Kelly (2004). The Cronbach's alpha yielded 0.869 which was above the recommended minimum of 0.700, suggesting that the instrument used was good and more likely to yield reliability results.

Table 2. Profile of the Professional Background and Experience of Respondents

Professional Role	Frequency
Project manager	8 (15%)
Architect	10 (19%)
Quantity surveyor	16 (31%)
Civil/Structural/Mechanical engineer	4 (8%)
Construction managers	6 (11%)
Main contractors	4 (8%)
Subcontractors	2 (4%)
Suppliers	2 (4%)
Total	52 (100%)
Experience in the Use of BIM	Frequency
1 to 5 years	36 (69%)
6 to 10 years	14 (27%)
11 to 15 years	2 (4%)
16 years and above	0 (0%)
Total	52 (100%)
BIM Software Used	Frequency
Autodesk Revit Suite	24 (46%)
Bentley Suite packages (structural, cost, electrical, etc.)	28 (54%)
Total	52 (100%)

Field Data

From Table 2, it can be deduced that almost all the key professional members that form the project teams are represented (project managers, architects, quantity surveyors, engineers, construction managers, main contractors, subcontractors and suppliers). This result indicates that the notable professionals in the project team are adequately represented and thus the results are likely to reflect balanced opinions

and experiences in the use of BIM in construction project delivery. Additionally, the experience of the respondents as presented in Table 2 further suggests that about 69% of the respondents had a maximum of five years of experience whereas about 31% have had over five years of experience in the use of BIM in construction project delivery in the GCI. The mean working experience of the respondents in the use of BIM was estimated to be approximately two years. With this, it could be suggested that the respondents are deemed to have some form of experience in the use of BIM in construction project delivery and thus, their responses could be interpreted as valid, credible and more likely to reflect the practical reality in BIM communication performance in the GCI. Also, the Revit Suite and Bentley Suite were identified as the main BIM tools being used by the project teams in their project delivery. The Autodesk Revit Suite was mostly used for the designers whereas the structural, costing were done with Bentley setup.

MAIN ANALYSIS AND FINDINGS

The Extent of Influence of BIM Adoption on Project Team Communication Performance

The summary of the aggregated mean scores and the level of agreement among the responses using the rWG are presented in Table 3. From Table 3, it could be said that the rWG indices for all the variables had a minimum score of 0.61 and a maximum score of 0.82. According to Gisev, Bell and Chen (2013) and Cohen, Doveh and Eick (2001), a measure of inter-rater agreement is interpreted: < 0 as "Poor Agreement", 0.0 to 0.20 as "Slight Agreement", 0.21 to 0.40 as "Fair Agreement", 0.41 to 0.60 as "Moderate Agreement", 0.61 to 0.80 as "Substantial Agreement" and 0.81 to 1.00 as "Almost Perfect Agreement". From this, it could be said that a minimum score of 0.61 suggests a substantial agreement whereas a maximum score of 0.82 is an indication of almost perfect agreement. Hence, the overall on the results indicate significant consensus amongst the respondents with regards to the interpretation of the assessment on the variables. This is an indication that the aggregated mean ratings of the influence of BIM adoption on communication performance can be considered as being a realistic representation of the respondents' practical judgement based on their experience.

Field (2009) suggested that the standard mean error in any statistical measures is an indication of how representative a sample is likely to be to the population thus enhancing the generalisation that can be accorded the statistical results. In this regard, a large standard mean error is an indication of significant variability between the sample and population means whereas a small value suggests an accurate reflection of the population (Field, 2009; Motulsky, 2005). From Table 3, it can be deduced without any contradiction that, standard mean errors associated with all the mean scores were relatively close to zero (< 0.1) (Field, 2009; Motulsky, 2005). This suggests that the sample chosen gives an accurate reflection of the population and thus, the results and findings is a practical reflection of the reality thus giving credence to the results, interpretations and generalisation of the findings in this study.

By rounding off the mean scores in Table 3 to the nearest point (i.e. to conform to the five-point Likert scale), it could be deduced that the overall assessment of BIM adoption show "Very Significant" (5.0) and "Significant" (4.0) influence on communication performance in construction project delivery thus implying that the

use of BIM tools generally has a potentially significant impact on construction project team communication performance.

The summary of results in Table 3 further shows that the use of BIM tools in construction project delivery induces very significant impact on the accuracy of communication performance in respect of "receiving non-conflicting information from team participants".

Table 3. Extent of Influence of BIM Adoption on Project Team Communication Performance

Indicators	Explanatory Variables	Mean	Standard Mean Error (SME)	rWG	Overall Influence
Accuracies	Receiving non-conflicting information from team participants	4.52	0.070	0.78	Very significant
	Consistency in communicated information leading to effective coordination among the project team	3.75	0.093	0.67	Significant
	Conciseness in communicated information among the project team	3.75	0.077	0.75	Significant
Timeliness	Timely delivery of needed communicated information	4.17	0.094	0.69	Significant
Distortions	Coherency in the meaning of communicated information	2.23	0.089	0.61	Not significant
	Consistency in the content of communicated information	4.04	0.074	0.73	Significant
	Enhanced clarity in communicated information resulting in uniform interpretations	3.75	0.062	0.71	Significant
Barriers	Easy access to communicated and shared information from channels	4.37	0.073	0.70	Significant

(continued on next page)

Table 3. (continued)

Indicators	Explanatory Variables	Mean	Standard Mean Error (SME)	rWG	Overall Influence
	Efficient dissemination of information among project team in channels	4.10	0.082	0.68	Significant
Underloading	Receiving less information than expected from team participants for tasks	1.28	0.074	0.73	Not very significant
Overloading	Receiving more information than necessary for the tasks than expected	1.19	0.089	0.62	Not very significant
Understanding	Understanding communicated information	4.29	0.088	0.68	Significant
Gatekeeping	Withholding of part of the information by the one who controls communication	2.17	0.081	0.70	Not significant
	Withholding of whole of the information by the one who controls communication	2.08	0.089	0.62	Not significant
Procedure	Efficient disseminating protocols relating information sharing among teams	4.06	0.049	0.82	Significant
	Clearly defined roles and responsibilities among members of the team	2.38	0.075	0.76	Not significant

Notes: rWG indices are based on a uniform null distribution simulation runs using the conventional 95% confidence interval for group size of 52 and five response options (five-point Likert scale).

Likewise, the impact on "consistency in communicated information leading to effective coordination among project team", "conciseness in communicated information among the project team", "consistency in the content of communicated information", "enhanced clarity in communicated information resulting in uniform interpretations", "timely delivery of needed communicated information", "easy access to communicated and shared information from channels", "efficient dissemination of information among project team in channels", "understanding communicated information" and "efficient disseminating protocols relating information sharing among teams" were deemed to have a significant influence on the use of BIM in project communication effectiveness. However, it is interesting to

note that, whilst there is a consensus on the need to overcome the communication challenges related to "coherency in the meaning of communicated information" ensure completeness in construction communication through eliminating underloading and overloading of shared information as well as enhancing "clear defined roles and responsibilities among members of the team" to overcome role conflict, the influence of BIM adoption in the delivery of construction projects was deemed as being very insignificant.

DISCUSSION OF FINDINGS

Accuracy of BIM Adopted Communication

The findings seem to suggest that the adoption of BIM tools in project delivery significantly enhances the accuracy in the communication performance among the project team by ensuring conciseness and consistencies in the shared information. Evidence from this study further affirms that the incidence of receiving conflicting information among the project participants can be overcome by the adoption of BIM tools. These findings seem to be consistent with Lee and Rojas (2013) and Ahuja, Yang and Shankar (2010) who revealed ICT mediated information sharing and management enhanced by visual representations of data help streamline communication and improve project efficiency through accurate interpretation and use of the information. However, Liu (2009), Sacks et al. (2010) and Rogers, Heap-Yih and Preece (2015) revealed that management and documentation of project related information as well as the medium for sharing such information often impact on the accuracy which is often inherent from the incidence of various organisations and project participants using different types of software applications in accessing information. It can thus be argued that the feature of BIM tools allowing for access to shared information through the same medium, tools or techniques thus enhance standardised and accurate interpretations over other forms of ICT tools used in construction communication.

Timeliness in BIM Communication

Prompt and fast access to accurate and reliable information shared among project participant has continuously been deemed as critical to achieving success and performance in project delivery (Otter and Emmitt, 2007; Xie, Thorpe and Baldwin, 2000). Liu (2009) revealed that timeliness in the communication of project related information is indicated by the frequency of delivery as well as updating changes in design, schedule and other key documents for prompt decisions and action. In this regard, it is said that timeliness in communication among construction project teams can be enhanced using computer tools for data processing and information management through ICT. However, Ahuja, Yang and Shankar (2010) and Otter (2005) intimated that not all ICT tools can aid timeliness in construction communication but rather a strategic adoption of ICT that allows all the supply chain members prompt access and update irrespective of location. Here in this study, the findings reveal that contribution of BIM tools to timeliness in the shared project-related information among the project team was significant. The plausible explanation is indicated by Merschbrock and Nordahl-Rolfen (2016), Wang and

Chong (2015) and Sacks et al. (2010). BIM tools allow for a quick update to project information that is instantly available to all protocols across all project life cycle/ phases. In the light of this, it can be affirmed that the use of BIM tools in construction communication can significantly contribute to alleviating the untimeliness in communication that has been well acknowledged in the industry (see Thomas, Tucker and Kelly, 1998; Mead, 1999; Xie, Thorpe and Baldwin, 2000).

Overcoming Barriers in Communication When BIM is Used

Otter (2005) revealed that, exploring the use of new ICT tools in construction communication was highly underpinned by the primary recognition that, ICT tools might solve important barriers in team communication in construction project delivery. The problem of barriers leading to difficulty in access to communicated information or inaccessibility due to poor presentation has remained a notable communication problem in the industry (Xie, Thorpe and Baldwin, 2000; Liu, 2009). Here in this study, the results revealed that the contribution to enhancing "easy access to communicated and shared information from channels" and "efficient dissemination of information among project team in channels" as criteria to accessing barriers to information access was significant. This suggests that the use of BIM tools in construction communication enhances access to the communicated information. This finding seems to be consistent and in agreement with Ahuja, Yang and Shankar (2010), Wang and Love (2012) and Otter (2005) that the web-based properties of most ICT tools in information management and sharing in construction communication greatly improves access to information and thus eliminates the challenges associated with the virtuality of project teams in the global construction industry.

Avoiding Distortions in BIM Mediated Communication

Consistency, clarity and coherency in shared project information during communication among the project team in construction project delivery is among the critical factors in ensuring right decisions and use of information for tasks and actions (Xie et al., 2010; Liu, 2009; Xie, Thorpe and Baldwin, 2000; Dawood and Sikka, 2008; Dawood, Akinsola and Hobbs, 2002). These attributes of communicated information minimise all forms of distortions that are likely to affect the meaning of the information. According to Liu (2009), in a typical construction project environment, information distortion often occurs through conflicting interpretation, change in meaning and lack of clarity and consistency. The results of the study as presented in Table 3 reveal that the adoption of BIM tools significantly influences the consistency and clarity of communication among the project team whereas, in respect of coherency, the impact was adjudged to be not significant to Merschbrock and Nordahl-Rolfen (2016), Hwang, Zhao and Ng (2013) and Nitiithamyong and Skibniewski (2011) contended that the 3D and 4D visual presentation of drawings and other specialist aspects of project information in BIM environment account for ensuring clarity, coherency and consistency of information which are benefits that are far and above the notable shortcomings other ICT tools used in construction information management, sharing and communication. However, the results reveal a contrary situation in the case of enhancing coherency in the information in BIM adopted communication among the team.

Understanding Communicated Information in BIM Environment

Collective or mutual understanding of communicated project information is another important indicator of effective communication performance in construction project delivery as suggested by Thomas, Tucker and Kelly (1998), Dawood, Akinsola and Hobbs (2002) and Xie et al. (2010). As described by Arayici et al. (2011), Bråthen and Moum (2016) and Wang and Chong (2015), BIM remains the most comprehensive information management tool through enhancing understanding of shared information leading to the accurate and coherent interpretation of shared information thus underlining its widespread usage in the industry today. Indeed, the findings in Table 3 seem to affirm this fact, indicating that BIM adoption significantly contributes to understanding project information communicated. Xie, Thorpe and Baldwin (2000) acknowledged that information misunderstanding remains a notable communication challenge among construction project teams and thus an effective information management system enhanced by ICT could aid in curtailing the incidence in project delivery. This should offer an empirical impetus to further advance the adoption of BIM tools as information management and communication platform to engender improvement in the understanding of shared project information among project teams in construction project delivery.

Enhancing Communication Protocols (Procedure)

Using the accepted procedure in communication has remained the panacea in overcoming role conflicts and enhancing dissemination of project-related information in communication protocols (Ahuja, Yang and Shankar, 2010; Otter, 2005; Shen, 1992). Ahuja, Yang and Shankar (2010) intimated that the strategic adoption of ICT requires that all the supply chain members follow the accepted methods, defined procedures and the communication protocols in a controlled and coordinated manner. This enhances information control, monitoring and effectiveness of feedback to the rest of the project team throughout the project life cycle through better-defined roles and clear protocols. Additionally, Ahuja, Yang and Shankar (2010) further intimated that the use of using computer tools for effective data processing and information management through ICT can bring about the clear definition of roles on projects and information dissemination as assess to the information is by roles and responsibilities on the projects. However, in this study, the empirical results have given evidence that the use of BIM tools has a significant impact on efficient disseminating protocols relating information sharing among teams whereas in the case of "clearly defined roles and responsibilities among members of the team" the influence is adjudged to be not significant. From this, it can be argued that even though there are enough suggestions that, the use of BIM tools have high prospects of improving relationships in collaborative working and reducing role conflicts through clear definition (see Rimmington, Dickens and Pasquire, 2015; Eadie et al., 2013; Eastman et al., 2008), the evidence from the study seems to suggest otherwise.

Ensuring Completeness and Reducing Gatekeeping Impact in BIM Communication

Liu (2009) and Thomas, Tucker and Kelly (1998) defined completeness of communication as a situation where the information communicated is not less than

(underload) or more than (overload) what is expected. Information gatekeeping, on the other hand, refers to the act of withholding information by the person who controls the communication in a medium (gatekeeper) (Xie et al., 2010; Thomas, Tucker and Kelly, 1998; Mead, 1999). Liu (2009) and Xie et al. (2010) accounted that, information underload and overload, as well as deliberate holding back of needed information by the gatekeeper, is a common problem in the Chinese and Hong Kong construction industry. However, the revelation by Mead (1999) that the use of ICT tools such as groupware, Intranet and Internet in construction communication has a high propensity to ameliorating issues of completeness of the information and gatekeeping. Against this background, the emergence of a lack of significant influence on improving the completeness of information communicated and overcoming gatekeeping with the use of BIM tools among the project team is surprising. These results offer a practical understanding of stakeholders thinking of finding solutions to information completeness and gatekeeping issues related to project team communication by relying on ICT tools to rethink.

CONCLUSIONS AND IMPLICATIONS OF FINDINGS

From existing literature, there is the general perception and assertion that BIM is a communication tool that significantly improves communication performance among project teams in construction delivery (see Ahuja, Yang and Shankar, 2010; Jensen and Jóhannesson, 2013; Gu and London, 2010; Bråthen and Moum, 2016). However, there is a lack of studies giving empirical accentuation to this assertion by ascertaining the taxonomy of communication performance inherent from BIM tools. This article has sought to fill this knowledge gap by examining the profile of the influence BIM adoption could have on the communication performance among the project team in construction project delivery. This study has drawn on the experiences of the project teams in the GCI in the use of BIM tools and identified their inherent contribution to the communication performance among those project teams. Through this study, some inherent communication performance attributes on BIM adopted communication in construction project environment seem to concur with some noted outcomes in general literature while others could be seen as an eye-opener.

The results in this study show that the adoption of BIM in project team communication and information management induces significant contribution to the accuracy of communication, improves understanding of the shared information and enhances the timeliness of the communicated information among the project team. However, in the case of ensuring completeness of communication, removing gatekeeping challenges and giving clarity to roles, the impact of BIM was seen to be insignificant. The evidence from this study affirms the fact that the adoption of BIM tools in construction project environment has significant potential in improving communication performance among construction project teams. From extant literature, the existence of the acknowledged communication ineffectiveness in construction project environment inherent from the fragmentation of the supply chain, behavioural and cultural complexities as well as role-related challenges are real and this should allow stakeholders to adopt BIM as an information management systems that can significantly improve the communication performance outcome in project delivery.

It has become obvious and widely accepted that, in the last decade, the use of BIM in construction project delivery has been explored beyond its traditional design phase and pre-construction planning to embrace on-site activities, project coordination, information update and sharing across other phases of the project life cycle (Merschbrock and Nordahl-Rolfen, 2016; Wang and Chong, 2015; Sacks et al., 2010; Ahuja, Yang and Shankar, 2010). Hence, the overall communication performance insights given in this study and the high level of agreement in the response should give credence to the findings which should motivate an increase in the use of BIM as well as offering practical and theoretical implications in the construction industry. The findings indicate that the adoption of BIM tools has a significant contribution to communication performance among the project team. Hence, to overcome the numerous communication-related problems of inaccuracies, misunderstanding, untimeliness and barriers to communication in the construction industry (see Liu et al., 2013; Liu, 2009; Xie et al., 2010; Dawood, Akinsola and Hobbs, 2002, Xie et al., 2000), practitioners develop their skills and knowledge in BIM applications to engender its ease of adoption in the industry. The understanding of profession-specific tasks communication performance, generalisation to various project typologies as well as delivery context and behavioural dimensions were not assessed in this study and they are noted as an apparent limitation. Hence, further studies are required to explore these dimensions of the communication performance impact of BIM tools in construction project delivery.

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