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ACCEPTANCE OF BUILDING INFORMATION MODELLING: A SURVEY OF PROFESSIONALS IN THE CONSTRUCTION INDUSTRY IN GHANA

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SUMMARY*: Building Information Modelling (BIM) can contribute significantly to the successful implementation of construction projects. This paper tests the level of acceptance of BIM in the construction industry in Ghana using the Technology Acceptance Model (TAM). TAM postulates that the level of success of an information system can be determined by user acceptance of the system, measured by factors including: perceived usefulness (PU), perceived ease of use (PEOU), attitudes towards using (ATU) and behavioural intentions to use (BUI) the system. Based on the TAM constructs, hypotheses were developed, questionnaire designed, and a survey was conducted among professionals within the construction industry. 200 questionnaires were distributed, with 125 responses obtained and analysed. Professionals' behavioural intention to use BIM was determined by their attitude towards using BIM and perceived usefulness of BIM. Generally, the study has revealed that there is high level of acceptance of BIM among respondents. The findings enrich the understanding of user acceptance of BIM in the Ghanaian construction industry. If the factors identified are considered, it will successfully lead to significant acceptance and subsequent adoption of BIM in the Ghanaian construction industry. There is the need to create awareness on the importance and use of BIM among professionals in the Ghanaian construction industry, through workshops and seminars. It would also help if attention were to be paid to the technology in the curricular of academic institutions offering construction related programmes. Clients should be encouraged to demand for BIM in their projects.*

KEYWORDS: *BIM, TAM, Construction Industry, Ghana.*

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1. INTRODUCTION

The construction sector is one of the most information-dependent industries. The project chain may involve a large number of stakeholders, with often repetitive activities and accumulation of paperwork. These participants require timely access to accurate information (Murray et al, 2001). Normally, several documents such as drawings, specifications, bills of quantities and schedules are exchanged manually. Face to face communication is also prevalent (Hore and West, 2004). Ineffective communication and management are considered the major contributing factors to poor project delivery (Building SMART, 2010).

The importance of BIM in addressing information challenges within the construction industry cannot be overemphasised (Jung and Lee, 2015, Botchway, 2016). As construction becomes complex and sophisticated, the need for BIM will be more apparent (Abubakar et al, 2014). Ayirebi-Dansoh et al (2010), addressing the need to adopt BIM in the Ghanaian construction industry, note that construction activities are progressively becoming technical with high quality standards and specification rising from the advancement of new information system and growing competition throughout the industry. They stressed on the need for intensive education and training, sustainability and innovation, as well as the practical use of BIM. However, stakeholders are sometimes unwilling to accept new technologies (Bradley, 2008). Martínez-Caro et al (2013) note that when a new technology is presented to users, several factors determine its acceptance.

Technology Acceptance Model (TAM), an adaptation of the Theory of Reasoned Action (TRA), originally developed by Davis (1989), is a theory that determines user acceptance of an information technology. Davis (1989) proposes that the intention of users to accept any technology is influenced directly by attitude towards using (ATU), Perceived usefulness (PU) and perceived ease of use (PEOU). TAM has been applied extensively in explaining the adoption of information systems (Averweg, 2005, Enegbuma et al, 2014, Xu et al, 2014, Son et al, 2014, Mathews et al, 2014, Batarseh and Kamardeen, 2017). Mathews et al, (2014) note that TAM concentrates on adoption of technology by individuals. Batarseh and Kamardeen (2017) also establish that the purpose of TAM is to explain individuals’ acceptance of new technologies and their related behaviours. Revisions to TAM led to TAM2 and then TAM3. TAM2 extends TAM by integrating constructs such as social influence processes: subjective norm, voluntariness, and image and cognitive instrumental processes: job relevance, output quality, result demonstrability (Samaradiwakara and Gunawardena, 2014). TAM3 combines TAM2 and the model of the determinants of Perceived Ease of Use (PEOU). To improve PEOU, TAM3 includes the external variables of Computer Self-efficacy, Perceptions of External Control, Computer Anxiety, Computer Playfulness, Perceived Enjoyment and Objective Usability (Chen et al, 2016).

Many recent studies on technology acceptance (e.g. Diatmika et al, 2016, Pipada and Xu, 2016, Lundberg, 2017, Lai, 2017, Shih et al, 2017, Mugo et al, 2017) tend to adopt the original TAM. Lai (2017), comparing TAM, TAM2, TAM3 and other models, note that the original TAM is easy to apply across different research settings. Mugo et al (2017) also, adopting the original TAM, argue that it has a stronger theoretical basis and enjoys sufficient empirical support. With regards to BIM, Lee et al, (2013) employed the original TAM and incorporated external variables; technology quality, organizational competency, personal competency and behaviour control, in proposing what they referred to as BIM Acceptance Model (BAM). However, Chung and Chin (2015) adopted TAM in investigating the intentions of construction managers in using BIM. Merschbrock and Nordahl-Rolfsen (2016) also employed TAM in examining the acceptance and usage of BIM by reinforcement workers.

There is very little research on BIM in the construction industry in Ghana. To the best of our knowledge, no research has been undertaken in Ghana applying TAM to BIM. This study contributes in this regard. We adopt the original TAM based on the argument offered by Mugo et al (2017) that it has a stronger theoretical basis and enjoys sufficient empirical support.

The aim is to explore the relationship between the usage of BIM and TAM construct. The objective is to examine the awareness and usage of BIM in the construction industry in Ghana and examine the acceptance of BIM using TAM.

2. LITERATURE REVIEW AND HYPOTHESIS DEVELOPMENT

2.1 Building Information Modelling

BIM is the act of making an electronic model of a facility for the reason of imagining, analysis of conflict, checking of code criteria, engineering analysis, cost engineering, as-built product, planning and other reasons (Kreider and Messner, 2013). It is described as offering a better way by which outcomes of a project can be predicted, enhance communication among team members throughout the entire project life-cycle, lessen rework, manage risk, and better the operation and routine maintenance of a facility (Sanchez et al, 2014). Blackwell (2015) considers BIM as a collaborative way of working, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining construction facilities. InfoComm (2009) notes that the purpose of BIM is to make the design information explicit, so that the design intent and program can be immediately understood and evaluated.

According to InfoComm (2009), BIM can reduce the need for re-gathering or re-formatting information. This should result in an increase in the speed and accuracy of transmitted information, reduction of costs associated with a lack of interoperability, automation of checking and analysis, and unprecedented support of operation and maintenance activities. The building owner can utilize the data within the model during the occupation of the building. Harvesting the information in that database can help everyone be more efficient and also create new opportunities for revenue expansion. The BIM system requires a model manager who acts as a link between the system and the participants of the project. The manager does not participate in decision making concerning engineering solutions or design, or the organizational processes, but rather focuses on the fruitful and co-operative use by all stakeholders (Sebastian, 2011).

BIM makes it possible to quickly create sections and elevations of a room without the need for the architect to provide sketches. The synchronized and collaborative nature of BIM allows for earlier conflict identification among members of the design team and hence its management. BIM improves coordination among team members by making design changes, and all consequences of those changes, evident and available to all users of the model and to all parametric model elements. Design team members stay in sync with one another’s progress.

BIM offers numerous benefits (Azhar et al, 2008, Eastman et al, 2011). Azhar et al, (2008) explains that the model increases profitability, accelerates and promote collaboration among project teams, reduces costs, provides improved time organisation and develops client/customer associations. Hergunsel (2011) adds that BIM ensures effective management and dissemination of information. Technical benefits include three-dimensional (3D) coordination, prefabrication, cost estimation, and as-built model (Yan and Demian, 2008). Throughout the bidding stage, the project manager can offer renderings, walkthroughs, and sequencing of the model to better show the BIM concept in 3D. Also, virtual replicas like laboratories can be given to the owner and the designer. The virtual replicas aid to connect and work together among the project members (Hergunsel, 2011). If the architect is only providing 2D drawings, then the construction manager should convert the 2D drawings to 3D intelligent models (Hergunsel, 2011). If mechanical, electrical, plumbing (MEP) contractors and steel fabricators are involved, they need to coordinate their work. Just after the model is produced, 3D coordination can begin to make sure that any same space interference (hard clash) or clearance clash (soft clash) disagreements are resolved (Wang et al, 2016). Prefabrication needs field and design accuracy. Building information models shall give this level of accuracy by including the specifications, sequence, finishes, and the 3D visual for each component (Eastman et al, 2011). BIM can be used to construct prefabricated walls, rooms and houses with roughed MEP components. Final MEP connections can be made once the prefabricated components are assembled onsite. BIM can be removed to an excel file or a cost database. The cost estimator is required to examine the material constituents and ways they are installed (Sattineni and Bradford, 2011). The cost estimator might need additional breakdown of the component for more precise pricing if the value for any particular activity is not captured in the database (Forgues et al, 2012). A record Building Information Model can be provided by construction managers to the owner at the end a project (Teicholz, 2013). Also, each object property in the model can comprise links to submittals, operations and maintenance, and warranty information. Record model can be used to manage security and safety information such as emergency lighting, emergency power, egress, fire extinguishers, fire alarm, smoke detector and sprinkler systems (Liu, 2010).

2.2 Technology Acceptance Model (TAM).

TAM explains how users respond to the introduction of a new technology. It helps predict their acceptance and assists the modification and improvement of the system. Lee et al (2013) notes that TAM aims to explain the determinants of computer acceptance that can explain the behaviour of users across a wider range of end-user computing technologies and user populations, while at the same time being both parsimonious and theoretically justified. In the original model, Davis (1989) indicates that TAM measures, predicts and explains technology use. He explains that the level of success of an information system can be determined by user acceptance of the system, measured by factors including: perceived usefulness (PU), perceived ease of use (PEOU), attitudes towards using (ATU) and behavioural intentions to use (BIU) the system. If a system is easy to use, then it will be perceived as useful. Usefulness is explained as "the capability of an information system to be profitably used". A user's perceptions about the system's usefulness and ease of use result in a behavioural intention to use (or not to use) the system (Davis et al, 1989). Davis (1989, pp. 320) defined PU as: "the degree to which individuals believe that the usage of a particular information system will improve their performance on the job ". Attitude towards using a technology is the assessment of the desirability of employing a specific information system by a user. It partly mediates the effect of perceived ease of use of the technology and its perceived usefulness on behavioural intention to use (Davis, 1989, Suki and Ramayah, 2010). PEOU is defined as the extent to which a user believes that the usage of an information system will be free of efforts. BIU is a degree to which a person will accept the technology (Davis, 1989). BIU defines the actual use of a given information system and therefore determines technology acceptance. Behavioural intention to use is a measure of the chances that a person will employ the technology. Davis et al (1989) suggests that the usage of a technology is chiefly determined by behavioural intention to use the technology. Behavioural intention to use a technology is sequentially determined by perceived usefulness of the technology and attitude towards using the technology.

As depicted in Figure 1, the model states that ATU and PU together influence BIU. BIU is also indirectly affected by PEOU. ATU is directly influenced by both PU and PEOU, while PU is directly influenced by PEOU. In addition, TAM posits that PU and PEOU are affected by external variables. As a result, PU and PEOU mediate the effect of external variables on user's attitude (ATU) and Behavioural Intention to use, and therefore the actual system use.

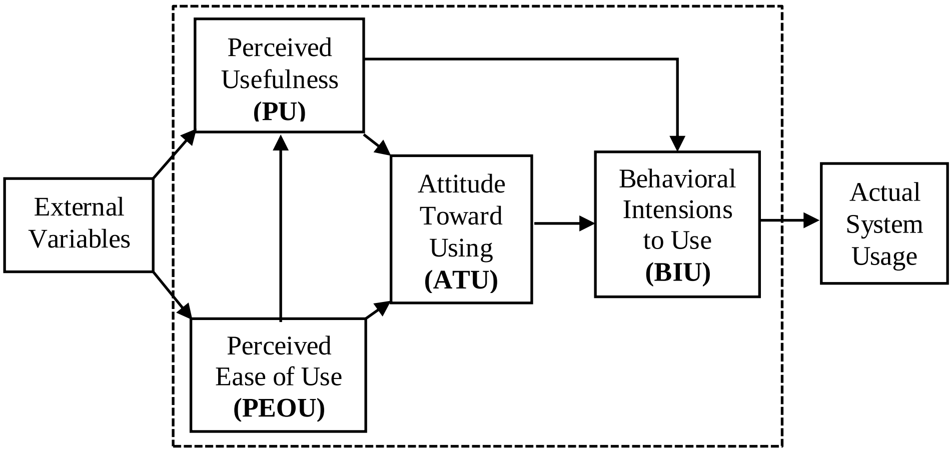

Figure 1: Technology Acceptance Model (Davis et al, 1989)

2.2.1 Hypotheses.

From the discussion, the following relationship between the TAM constructs were proposed:

a) Attitude toward using and perceived usefulness positively affect Behavioural intention to use (Davis, 1989, Wong and Teo, 2009, Šumak et al, 2011).

b) Perceived ease of use and perceived usefulness and positively affect Attitude toward using; (Davis,1989, Wong and Teo, 2009, Šumak et al, 2011)

c) Perceived ease of use positively affects Perceived usefulness (Davis,1989, Wong and Teo, 2009, Šumak et al, 2011)

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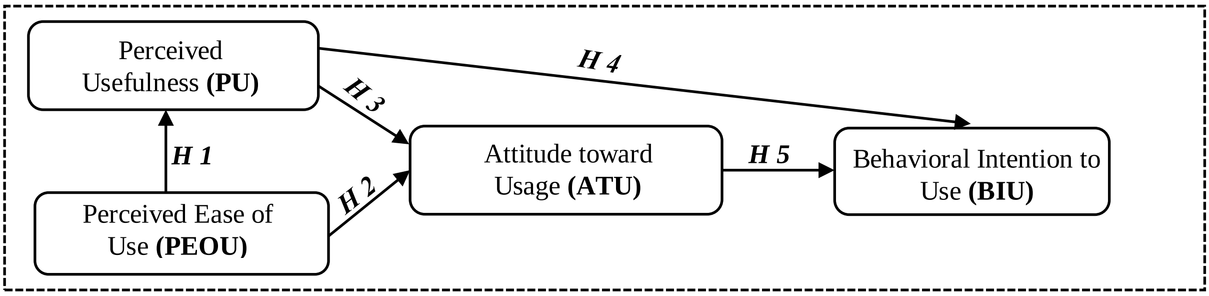

Figure 2: Proposed Hypotheses (Based on Davis, 1989)

2.2.2 Perceived Ease of Use (PEOU) of BIM.

PEOU is the degree to which stakeholders and professionals of the Ghanaian construction industry believe that the usage of BIM is stress-free than other systems or the traditional way of doing things. All other things being equal, an information system is more likely to be accepted by users if it is perceived to be easier to use than another. When users perceive that the system will be easy to use and can assist them to work successfully, they will develop a desire to use the information system (Marwan et al, 2014, pp. 23). The following was accordingly hypothesized that:

H1) Perceived ease of use of BIM positively affects perceived usefulness of BIM.

H2) Perceived ease of use of BIM positively affects attitudes towards using BIM.

2.2.3 Perceived Usefulness (PU) of BIM.

The perceived usefulness is the degree to which stakeholders perceive that accepting BIM would improve their activities. Several studies have discovered that PU successfully justified the behavioural intention to use (BIU) an information technology system (Davis and Venkatesh 2004, Teo and Noyes, 2011, Sentosa and Mat, 2012). We therefore hypothesized that:

H3) Perceived usefulness of BIM positively affects attitudes towards using BIM.

H4) Perceived usefulness of BIM positively affects behavioural intention to use BIM.

2.2.4 Attitude towards use (ATU).

Attitude towards use of BIM is hypothesized to influence behavioural intention to use BIM. However, it is explained as the degree to which a person's attitude is positively or negatively inclined towards the usage of BIM. Accordingly, we hypothesized that:

H5) Attitude towards using BIM positively affects Behavioural Intention to Use BIM.

3. METHODOLOGY

Purposive sampling technique was adopted to select project managers, architects, quantity surveyors and engineers working in various construction and consultancy firms within the Accra and Kumasi metropolis of the Greater Accra and Ashanti regions respectively. Kumasi and Accra were chosen for this study because it is established that almost all the "big" construction and consultancy firms are located in these two major cities (Ofori-Kuragu et al, 2016). These firms are most likely to have first-hand experience with BIM technologies. Firms well known to the authors were selected based on the size and nature of projects they undertake, their financial capacity and their experience with the usage of BIM. These firms further suggested other firms of the same calibre and questionnaires were given out in person to project managers, architects, quantity surveyors and engineers working there to answer. The questionnaires solicited background information on of respondents. 23 items were used in collecting data in relation to the various constructs of TAM. Ten questions were adapted from the perceived usefulness scales established by Davis (1989), Davis et al (1989), Ajzen and Fishbein (1975). The ten questions include how BIM improves the quality of project delivery; increases productivity and performance; enhances efficiency and effectiveness on the job; and increase profitability. Six questions (scales) were adapted from the perceived ease of use scales established by Davis (1989), Davis et al (1989), Ajzen and Fishbein (1975). The questions concern ease of learning to operate BIM; skilfulness; mistakes in using; confusion and frustration; understanding. Three questions (scales) were also adapted from the attitude towards use questions (scales) established by Davis (1989), Davis et al (1989), Ajzen and Fishbein (1975). Four questions (scales) were adapted from the behavioural intensions to use questions (scales) established by Davis (1989), Davis et al (1989), Ajzen and Fishbein (1975). Below is a representation of the survey questionnaire.

Table 1: Survey Questions

Constructs	Questions
Perceived Usefulness (PU)	
PU1	I think using BIM improves quality of project delivery.
PU2	I think using BIM increases productivity and work performance.
PU3	I think using BIM enhances efficiency and effectiveness on the job.
PU4	I think using BIM raises our chances to increase our profits.
PU5	I think that the advantages of using the BIM outweighs the disadvantages.
PU6	I think using BIM provides help us make better decisions.
PU7	BIM system enables me to accomplish tasks more quickly
PU8	Using BIM makes it easier to do my job.
PU9	BIM gives me greater control over my work
PU10	Overall, I find BIM useful in my job
Perceived Ease of Use (PEOU)	
PEOU1	I think learning to operate BIM is easy for me.
PEOU2	It is easy to use BIM to perform tasks on site.
PEOU3	I rarely make errors when using BIM
PEOU4	I rarely become confused or frustrated when using BIM
PEOU5	BIM is clear and understandable
PEOU6	Overall, I find it easy to use BIM.
Attitude towards Use (A)	
A1	I think that using BIM is a good idea.
A2	I think it is worthwhile to use BIM.
A3	Overall, I like the idea of using BIM.
Behavioral Intension to Use (BIU)	
BIU1	It is probable that I will use or continue using the BIM.
BIU2	I intend to begin using the BIM.
BIU3	I will frequently use BIM in the future
BIU4	I will recommend others to use the BIM.

An excerpt of the questionnaire is provided in appendix 1. Out of the 200 questionnaires distributed, 125 valid responses (represent 62.5%) were recorded and used for the analysis. The reliability test was conducted to measure internal validity and the consistency of items used for each construct. Correlation analysis and multiple regression analysis were used to analyse the TAM construct.

4. DATA ANALYSIS AND DISCUSSION

4.1 Validity and Reliability of TAM Variables

Cronbach Alpha was performed to test the reliability, validity and consistency of the constructs used. The results indicated a high level of reliability, ranging from 0.75 to 0.81, with an agreeable value of 0.75 for Perceived ease of use. Cronbach's alpha reliability values are all well above 0.70, and therefore the survey is regarded as highly reliable (Nunnally, 1967).

Table 2: Validity and reliability of TAM Variables

Constructs	N	Cronbach's Alpha(α)
Perceived Usefulness (PU)	10	0.821
Perceived Ease of Use (PEOU)	6	0.748
Attitude towards Use (ATU)	3	0.813
Behavioural Intension to Use (BIU)	4	0.818

4.2 Descriptive Statistics

Table 3 indicates that the respondents showed a positive attitude towards BIM on all the four variables: perceived usefulness of BIM (M= 1.97, SD= 0.50), perceived ease of use of BIM (M=2.43, SD= 0.61), attitude towards using BIM (M= 1.73, SD= 0.61) and behavioural intention to use BIM (M= 1.88, SD= 0.71).

Table 3:Descriptive statistics of the measurement scales

Constructs	N	Mean	Standard Deviation
Perceived Usefulness (PU)	10	1.97	0.50
Perceived Ease of Use (PEOU)	6	2.43	0.61
Attitude towards Use (ATU)	3	1.73	0.61
Behavioural Intension to Use (BIU)	4	1.88	0.71

4.3 Correlation Analysis.

As mentioned in Wong and Hiew (2005), r- value between 0.10 and 0.29 is regarded as not strong, between 0.30 and 0.49 is moderate and between 0.50 and 1.0 is regarded as strong. Then again, Field (2005) added that to avoid multi-collinearity, correlation coefficient should not be further than 0.8. From table 4, the largest correlation coefficient value (r- value) is 0.573 of which 0.8 is higher than. As a result, there is no multi-collinearity problem in this research.

Table 4: Correlation Matrix (Pearson Correlations)

		PU	PEOU	ATU	BIU
PU	r- value	1			
	p-value				
	N	125			
PEOU	r- value	.332**	1		
	p-value	.000			
	N	125	125		
A	r- value	.498**	.315**	1	
	p-value	.000	.000		
	N	125	125	125	
BIU	r- value	.442**	.216*	.573**	1
	p-value	.000	.015	.000	
	N	125	125	125	125

****. Correlation is significant at the 0.01 level (2-tailed).** ***. Correlation is significant at the 0.05 level (2-tailed).**

4.4 Hypotheses testing

Correlation analysis of all five hypotheses are presented indicating the r -values and p- values. A lesser p-value (≤ 0.05) specifies a strong indication of contradiction to the null hypothesis. Large p-value (> 0.05) means the evidence against the null hypothesis is weak, as a result the null hypothesis will be accepted (Greenland et al, 2016). The r -value (correlation coefficient) range from -1.0 to +1.0. How closer an r- value is to +1 or -1, signifies how stronger the relationship between the two variables are. An r- value closer to Zero (0) shows that there is a very weak or no correlation between the variables. A positive correlation coefficient signifies that as a variable increase, the other also increases and vice versa. However, a negative correlation coefficient signifies that as a variable gets larger, the other variable reduces and vice versa (inverse correlation) (Taylor, 1990).

4.4.1 H1. Perceived ease of use of BIM positively affects perceived usefulness of BIM.

Table 5 presents r- value of 0.332 and p-value of 0.00 which is highly significant. There is also a significant positive correlation between the perceived ease of use of BIM and perceived usefulness of BIM. As a result, H1 is supported.

Table 5: Pearson Correlation (H1)

Factors		**Perceived usefulness (PU)**
Perceived ease of use (PEOU)	r- value	.332**
	p-value	0.00
	N	125
****. Correlation is significant at the 0.01 level (2-tailed).**	***. Correlation is significant at the 0.05 level (2-tailed).**	

4.4.2 H_2. Perceived ease of use of BIM positively affects attitudes towards using BIM.

From table 6, the p-value is highly significant and there is also a positive relationship between the perceived ease of use of BIM and attitude towards usage of BIM. For that reason, H2 is supported.

Table 6: Pearson Correlation (H2)

Factors		**Attitude towards usage (ATU)**
Perceived ease of use (PEOU)	r- value	.315**
	p-value	0.00
	N	125
****. Correlation is significant at the 0.01 level (2-tailed).**	***. Correlation is significant at the 0.05 level (2-tailed).**	

4.4.3 H_3. Perceived usefulness positively affects attitudes towards using BIM.

From table 7, the p-value is highly significant and there is also a positive relationship concerning perceived usefulness of BIM and attitude towards usage of BIM. The correlation between perceived usefulness of BIM and attitudes towards using BIM suggests a stronger relationship than the correlation between perceived ease of use of BIM and attitudes towards using BIM. H_3 is as a result supported.

Table 7: Pearson Correlation (H3)

Factors		Attitude towards usage (ATU)
Perceived usefulness (PU)	r- value	.498**
	p-value	.000
	N	125
**. Correlation is significant at the 0.01 level (2-tailed).	*. Correlation is significant at the 0.05 level (2-tailed).	

4.4.4 H_4. Perceived usefulness positively affects intention to use BIM.

From table 8, p-value (0.00) is highly significant. Again, there exist a positive correlation between behavioural intention to use BIM and perceived usefulness of BIM. Thus, H_4 is supported.

Table 8: Pearson Correlation (H4)

Factors		Behavioural intention to use (BIU)
Perceived usefulness (PU)	r- value	.442**
	p-value	.000
	N	125
****. Correlation is significant at the 0.01 level (2-tailed).**		***. Correlation is significant at the 0.05 level (2-tailed).**

4.4.5 H_5. Attitude towards using BIM positively affects behavioural intention to use BIM.

From table 9, p- value is considered highly significant. There is also significant positive relationship between the attitude towards the usage of BIM and behavioural intention to use BIM. Statistically, H_5 is supported.

Table 9: Pearson Correlation (H5)

Factors		Behavioural intention to use (BIU)
Attitude towards usage (ATU)	r- value	.573**
	p-value	.000
	N	125
**. Correlation is significant at the 0.01 level (2-tailed).		*. Correlation is significant at the 0.05 level (2-tailed).

Table 10: Summary of Analysis.

Hypotheses	Statement	Result
H1	Perceived ease of use of BIM positively affects perceived usefulness of BIM.	Supported
H2	Perceived ease of use of BIM positively affects attitudes towards using BIM.	Supported
H3	Perceived usefulness of BIM positively affects attitudes towards using BIM.	Supported
H4	Perceived usefulness of BIM positively affects intention to use BIM.	Supported
H5	Attitude towards BIM use positively affects intention to use BIM.	Supported

4.5 Multiple Regression Analysis

The mean score of the multi-items for a construct were calculated and the scores obtained were used to conduct the regression analysis. Multiple regression is computed using the below formula: -

$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \ldots\ldots + \beta_k x_k + \varepsilon$

Where: -

	y	the value on the dependent variable.
	β_0	the value of y if all $X_s = 0$, the y intercept.
	X	the independent variables
	$\beta_{1 \ldots k}$	the coefficient ascribed to the independent variables during the regression.
	ε	the standard error.

In testing the hypotheses of TAM in the acceptance of BIM, the enter method of multiple regression analysis was used. The following hypotheses were constructed.

Table 11: Results for Hypotheses Testing

Hypotheses	Statement	DV*	IV*
H1	Perceived Usefulness of BIM is dependent on Perceived ease of Use of BIM	PU	PEOU
H2	Attitude towards the usage of BIM is dependent on Perceived ease of Use of BIM	ATU	PEOU
H3	Attitude towards the usage of BIM is dependent on Perceived Usefulness of BIM	ATU	PU
H4	Behavioural intention to use BIM is dependent on Perceived Usefulness of BIM	BIU	PU
H5	Behavioural intention to use BIM is dependent on Attitude towards the usage of BIM	BIU	ATU
DV*. Dependent Variable	IV*. Independent Variable		

4.5.1 Hypothesis 1 (Model 1)

The first Hypothesis states that perceived ease of use of BIM would have positive influences on perceived usefulness of BIM. The test was done by regressing perceived ease of use of BIM on perceived usefulness of BIM.

The multiple regression model for hypothesis 1 can also be illustrated in the equation (multiple linear regression) below: -

Perceived Usefulness of BIM = Constant + β_1 Perceived ease of use of BIM (H1) + ε

The regression model proposed in Table 12 shows an adjusted R^2 value of .103, which indicates that 10.3% of the variance in the Perceived Usefulness of BIM was explained by the multiple regression model. 10.3 % of the observed variability in perceived usefulness of BIM was explained by perceived ease of use as the independent variable (R^2= 0.110, Adjusted R^2= 0.103). Accordingly, perceived ease of use of BIM explains the variation in Perceived Usefulness of BIM in a positive way.

Table 12: Summary of Model (H1)

Model	R	R Square (R^2)	Adjusted R Square	Std. Error of the Estimate
1	0.332[b]	.110	**.103**	.47714

a. Dependent Variable: Perceived Usefulness b. Predictors: (Constant), Perceived Ease of Use

Table 13 explain the outcomes of this Analysis of Variance. The results of the value of F (the ratio of the two mean squares) is 15.20 (F = 15.20, P<0.001). Also, the level of significance observed was lesser than 0.001. As a result, perceived ease of use of BIM as an independent variable influences the dependent variable which is Perceived Usefulness of BIM by professionals.

Table 13:Summary of ANOVAa results (H1)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.461	1	3.461	15.200	.000[b]
	Residual	28.002	123	.228		
	Total	31.463	124			

a. Dependent Variable: Perceived Usefulness b. Predictors: (Constant), Perceived Ease of Use

The t-statistic and its observed level of significance were used in testing the null hypothesis for the variables that the partial regression coefficient for the population is equivalent to zero. The outcomes are presented in table 14

Table 14: Results for Regression Coefficients a.(H1)

Model		Unstandardized Coefficients		Standardized Coefficients	T- value	Sig.	Collinearity Statistics	
		β	Std. Error	Beta			Tolerance	*VIF
1	(Constant)	1.309	.176		7.442	.000		
	Perceived Ease of Use	.274	.070	.332	3.899	.000	1.000	1.000

a. Dependent Variable: Perceived Usefulness b. Predictors: (Constant), Perceived Ease of Use. * Variance Inflation Factor (VIF)

From the outcomes in table 14, the null hypotheses that the coefficient for perceived ease of use of BIM (B= 0.332, t= 7.442, p <0.001) is equal to zero can safely be rejected. From table 14, multicollinearity amongst the independent variables is very minimal. The tolerance value and the variance inflation factor (VIF) are both 1.00 signifying that the outcomes are reliable. The value of tolerance under 0.2 indicates that the variable is correlating with other independent variables and as a result should not be included. Again, the beta weights mean that the perceived ease of use of BIM (B= 0.332) is reasonably strong in explaining perceived usefulness of BIM by professionals.

In summary, the influence of Perceived ease of use of BIM (β= 0.274) on Perceived Usefulness has a significant level of 0.00. R^2 is 0.110, these results indicated that 11.00% of variance on Perceived Usefulness of BIM can be explained by perceived ease of use. With reference to the previous analysis, this hypothesis is accepted.

4.5.2 Hypotheses 2 and 3 (Model 2)

The second and third Hypotheses suggested that the perceived usefulness of BIM and the perceived ease of use of BIM would have significant positive influences on the attitude toward using BIM respectively. Multiple regression was performed for Hypotheses 2 and 3 by regressing perceived ease of use of BIM (H2) and perceived usefulness of BIM (H3) on attitude toward using BIM. This model can also be illustrated in an equation (multiple linear regression) below: -

Attitude toward using of BIM = Constant + β_1 Perceived ease of use of BIM (H2) + β_2 Perceived Usefulness of BIM (H2) + ε

In examining the hypotheses above, the computed variables for perceived ease of use of BIM and perceived usefulness of BIM were put into a single block. In Tables 15-17, the model proposed indicates that whole model had a value of 0.262 for adjusted R^2. This can be explained that 26.2% of the variance in the attitude toward using of BIM was explained by the multiple regression model. In addition, 26.2% of the variability observed in the attitude toward using BIM is explained by the two independent variables (perceived ease of use of BIM and perceived usefulness of BIM, R^2= 0.273, Adjusted R^2= 0.262). Accordingly, perceived ease of use of BIM and perceived usefulness of BIM explains in a positive way the variation in attitude toward using BIM.

Table 15: Summary for the Model (H2, H3)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.523[b]	.273	**.262**	.52389

a. Dependent Variable: Attitude towards use. b. Predictors: (Constant), Perceived Usefulness, Perceived Ease of Use

In Table 16, the results of this Analysis of Variance are illustrated. The table indicated that the value of F (the ratio of the two mean squares) was 22.957 (F = 22.957, P<0.001). The level of significance observed was lesser than 0.001. This indicates that the two independent variables have influence on attitude toward the usage of BIM by professionals in the Ghanaian construction industry.

Table 16: Summary of ANOVAa results (H2, H3)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	12.602	2	6.301	22.957	.000b
	Residual	33.484	122	.274		
	Total	46.085	124			

a. Dependent Variable: Attitude towards use. b. Predictors: (Constant), Perceived Usefulness, Perceived Ease of Use

The t-statistic and its corresponding level of significance observed in table 17 were used in testing the null hypothesis for the variables that the partial regression coefficient for the population is equivalent to zero.

Table 17:Results of Regression Coefficients a (H2, H3)

Model		Unstandardized Coefficients		Standardized Coefficients	T- value	Sig.	Collinearity Statistics	
		β	Std. Error	Beta			Tolerance	*VIF
1	(Constant)	.263	.232		1.129	.261		
	Perceived Ease of Use	.169	.082	.169	2.060	.041	0.890	1.124
	Perceived Usefulness	.535	.099	.442	5.407	.000	0.890	1.124

a. Dependent Variable: Attitude towards use b. Predictors: (Constant), Perceived Ease of Use, Perceived Usefulness.
* Variance Inflation Factor (VIF)

In table 17, the null hypotheses that the coefficients for perceived ease of use of BIM (B= 0.169, t= 2.060, $p<0.05$) and perceived Usefulness of BIM (B= 0.442, t= 5.407, $p<0.001$) are equivalent to zero can safely be rejected. Again, tolerance was 0.890 and its corresponding variance inflation factor (VIF) was 1.124 for both independent variables. This indicates that multicollinearity amongst the independent variables was very minimal. For that reason, the results are very reliable. From the results, the beta weights showed that the perceived usefulness of BIM (B= 0.442) is reasonably stronger as compared to perceived ease of use of BIM (B= 0.169) in explaining the attitude towards use of BIM by professionals and stakeholders in the Ghanaian construction industry.

From the model, the regression analysis indicated that attitude towards use of BIM was significantly explained by the perceived ease of use of BIM (β= 0.169) and the perceived usefulness of BIM (β= 0.535). R^2 being 0.273, the two variables (PEOU and PU) explains 27.3% of variance of attitude towards usage of BIM by professionals and stakeholders in the Ghanaian construction industry. From the previous analysis, Hypotheses 2 and 3 are both accepted.

4.5.3 Hypotheses 4 and 5 (Model 3)

The fourth and fifth Hypotheses indicated that attitude toward the usage of BIM and perceived usefulness of BIM would have significant positive influences on behavioural intention to use BIM, respectively. The hypotheses in model 3 were tested by regressing both attitude toward the usage of BIM (H4) and perceived usefulness of BIM (H5) on behavioural intentions to use BIM. The can be illustrated in an equation (multiple linear regression) below:

Behavioural intention to use BIM = Constant + β_1 attitude toward the usage of BIM (H4) + β_2 Perceived Usefulness (H5) + ε

In Table 18 the model proposed indicates that the whole model had a value of 0.350 for adjusted R^2. This can be explained that 35.0% of the variance in the attitude toward using of BIM was explained by the multiple regression model. It can also be said that, 35.0% of the observed variability in the attitude toward using of BIM is explained by all the two independent variables (attitude towards use and perceived usefulness, R^2= 0.361, Adjusted R^2= 0.350). Therefore, attitude towards use and perceived usefulness explains in a positive way the variation in attitude toward using of BIM.

Table 18: Summary for the Model (H4, H5)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.601b	.361	**.350**	.57331

a. Dependent Variable: Behavioural Intention to Use b. Predictors: (Constant), Perceived Usefulness, Attitude towards use

Table 19 indicates that the value of F (the ratio of the two mean squares) was 34.418 (F = 34.418, P<0.001). The significance level observed was less than 0.001. As a result, the two independent variables have influence on Behavioural Intention to Use by professionals in the Ghanaian construction industry.

Table 19: Summary of ANOVAa results (H4, H5)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	22.625	2	11.312	34.418	.000b
	Residual	40.099	122	.329		
	Total	62.724	124			

a. Dependent Variable: Behavioural Intention to Use b. Predictors: (Constant), Perceived Usefulness, Attitude towards use

The t-statistic and its corresponding level of significance observed in table 20 were used in testing the null hypothesis for the variables that the partial regression coefficient for the population is equivalent to zero.

Table 20: Results of Regression Coefficientsa (H4, H5)

Model		Unstandardized Coefficients		Standardized Coefficients	T-value	Sig.	Collinearity Statistics	
		β	**Std. Error**	**Beta**			**Tolerance**	***VIF**
1	(Constant)	.356	.215		1.659	.100		
	Attitude towards use	.547	.097	.469	5.614	.000	.752	1.330
	Perceived Usefulness	.295	.118	.209	2.501	.014	0.752	1.330

a. Dependent Variable: Behavioural Intention to Use b. Predictors: (Constant), Perceived Usefulness, Attitude towards use.

In table 20, the null hypotheses that the coefficients for perceived attitude toward usage of BIM (B = 0.469, t = 5.614, p <0.001), perceived usefulness (B = 0.209, t = 2.501, p <0.05) are equivalent to zero can be rejected. Tolerance was 0.752 and its corresponding variance inflation factor (VIF) was 1.330 for both independent variables. This indicates that multicollinearity amongst the independent variables was very minimal. For that reason, the results are very reliable. From the results, the beta weights showed that the attitude towards usage of BIM (B= 0.469) is reasonably stronger as compared to perceived usefulness (B= 0.209) in explaining the attitude towards use of BIM by professionals in the Ghanaian construction industry.

From this model, the multiple regression analysis indicated that Behavioural Intention to Use BIM was significantly explained by the attitude towards usage of BIM (β= 0.547) and Perceived usefulness (β= 0.295). R^2 being 0.361, the two variables (PU and ATU) explains 36.1% of variance of Behavioural Intention to Use BIM by professionals and stakeholders in the Ghanaian construction industry. From the previous analysis, Hypotheses 4 and 5 are both accepted.

Table 21: Summary of Results from the Hypotheses

Hypotheses	Statement	Results
H1	Perceived usefulness of BIM is dependent on Perceived ease of use of BIM	Accepted
H2	Attitude towards the usage of BIM is dependent on Perceived ease of Use of BIM	Accepted
H3	Attitude towards the usage of BIM is dependent on Perceived Usefulness of BIM	Accepted
H4	Behavioural intention to use BIM dependent on Perceived Usefulness of BIM	Accepted
H5	Behavioural intention to use BIM dependent on Attitude towards the usage of BIM	Accepted

5. CONCLUSION AND RECOMMENDATION

Based on the examination of TAM in the adoption of BIM, it can be concluded that the constructs used were valid and consistent with the original TAM model by Davis (1989) and other related studies including Davis et al (1989), Gefen and Straub (2000), Legris et al (2003). All hypotheses were confirmed. Respondents showed a positive attitude towards the usage of BIM, and had an intention to use BIM. When professionals' perception of ease of use of BIM increase, their perceived usefulness increased. When they found BIM easy to use, they established a positive attitude towards its usage. Similarly, when they observed that BIM was useful, their attitude towards the use of BIM increased. Furthermore, their behavioural intention to use BIM increased significantly when both their perceived usefulness and attitude toward its usage increased. For professionals of the Ghanaian construction industry to consider BIM useful, they must recognize it to be user friendly. When they consider it to be useful, they would develop a positive attitude towards its usage and have an intention to use BIM.

In summary, this research has explored the relationship between perceived ease of use, usefulness, attitude towards usage and behavioural intention of professionals to use BIM in the Ghanaian construction industry. Professionals' behavioural intention to use BIM was determined by their attitude towards using BIM and perceived usefulness of BIM. Generally, the findings in the study enrich the understanding of user acceptance of BIM in the Ghanaian construction industry. If the factors identified are considered, it will successfully lead to significant acceptance and subsequent adoption of BIM in the Ghanaian construction industry. Professionals of the Ghanaian construction industry need to be educated on BIM. Further research can be conducted to further examine the acceptance BIM from a larger perspective by extending TAM to include other belief constructs.

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7. APPENDIX A

Based on your experience, and using this scale from 1 to 5 in the table below, indicate by a ticking your opinion regarding the following statements .					
	1	2	3	4	5
	I strongly agree	I agree	Indecisive	I disagree	I strongly disagree

ITEMS						
Perceived Usefulness (PU)		***1***	***2***	***3***	***4***	***5***
PU1	I think using BIM improves quality of project delivery					
PU2	I think using BIM increases productivity and work performance					
PU3	I think using BIM enhances efficiency and effectiveness on the job					
PU4	I think using BIM raises our chances to increase our profits					
PU5	I think that the advantages of using the BIM outweighs the disadvantages					
PU6	I think using BIM provides help us make better decisions					
PU7	BIM system enables me to accomplish tasks more quickly					
PU8	Using BIM makes it easier to do my job.					
PU9	BIM gives me greater control over my work					
PU10	Overall, I find BIM useful in my job					
Perceived Ease of Use (PEOU)		***1***	***2***	***3***	***4***	***5***
PEOU1	I think learning to operate BIM is easy for me					
PEOU2	It is easy to use BIM to perform tasks on site					
PEOU3	I rarely make errors when using BIM					
PEOU4	I rarely become confused or frustrated when using BIM					
PEOU5	BIM is clear and understandable					
PEOU6	Overall, I find it easy to use BIM.					
Attitude (A)		***1***	***2***	***3***	***4***	***5***
A1	I think that using BIM is a good idea					
A2	I think it is worthwhile to use BIM.					
A3	Overall, I like the idea of using BIM.					
Behavioural intentions to use (BIU)		***1***	***2***	***3***	***4***	***5***
BIU1	It is probable that I will use or continue using the BIM					
BIU2	I intend to begin using the BIM					
BIU3	I will frequently use BIM in the future					
BIU4	I will recommend others to use the BIM					