Trends in BIM Research: Application in Nigeria AEC Industry

Akadiri Peter Oluwole[1], Omisakin Abimbola Juliana[2]

[1]*Assistant Professor, Architectural Engineering Department, University of Buraimi, Oman*
[2]*Consultant, Shelter Eades Design Group, Lagos, Nigeria*

Abstract -Building information modelling (BIM) has emerged in recent years as an innovative and intelligent 3D model-based technology transforming the way buildings and infrastructure are planned, designed, constructed and managed. The benefits that BIM offers to construction are limitless, but then, the adoption is not happening at the pace desired in some countries. In Nigeria, the BIM adoption has been much slower than anticipated in the architecture, engineering and construction (AEC) industry. This study provides an insight into BIM adoption in the Nigerian AEC industry by exploring the factors that affect its adoption, as seen by various participants in the AEC industry. Through an industry wide questionnaire survey, the result revealed that "lack of awareness", "lack of trained professionals to manage BIM innovation", and "cost of BIM software" were the top three factors identified by the respondents. Factor analysis aggregated the factors into six groups namely: "management", "financial", "psychological", "performance", "process", and "governmental". This will be used as part of an ongoing research project in developing a comprehensive BIM framework for practical implementation of the technology in Nigeria. The findings of this study provide useful information for the AEC community by advancing their understanding of the factors that affect the adoption of BIM technology and proffer solutions to its usage.

Key words- Application, AEC, Barriers, BIM, Factors, Nigeria

1. INTRODUCTION

Building Information Modeling (BIM) is a virtual digital information tool used by architectural, engineering and construction (AEC) industry, within a unified environment to visualize built facility and identify any potential issues within their lifecycle (Azhar *et al.,* 1986). It is a technology and a process to manage construction projects. It includes the application and keeps integrated digital representation of different information across different project stages (Eastman *et al.,* 2011). The potentials of BIM are enormous. Ku and Taiebat (2011) have found that the BIM technology has been welcomed by professionals in several countries and used to reduce cost, time, and enhance quality as well as environmental sustainability. Popov *et al.* (2010) suggest that BIM provides a platform that facilitates the creation and sharing of information relevant for design, construction and maintenance of buildings over their entire lifecycle. BIM is capable of supporting project integration into a collaborative process, to promote increase efficiency and reduce conflict in project delivery system (Grilo and Jardim-Goncalves, 2010). The completeness of the information enables better lifecycle management and sustainable building design (Azhar *et al.,* 2011). With the integrated information model, visualisation of construction process and design details is easier which facilitates analysis of alternative solutions (Popov et al. 2010) and identification of potential conflicts (Grilo and Jardim-Goncalves, 2010).

One of the main benefits of BIM is the accurate geometrical representation of the parts of a built asset in an integrated data environment (CRC, 2007). Furthermore, the BIM reduces the duration and cost of the project, improves maintenance management and increases the value of the building (Barlish and Sullivan, 2012). Tomek and Matejka (2014) pointed out that BIM has impact on both external and internal risks in construction industry. This is important according to what Rezakhani (2012) says that due to unique properties of construction operations, many risk factors are involved in construction project. BIM also improves communication between the different project parties (Hatem et al., 2012). On the other hand, the BIM as a new phenomenon seeks to renew the practices of the construction industry, so it is subject to several barriers facing its application despite its outstanding capabilities (Kekana *et al.,* 2014).

In Nigeria AEC industry, the adoption of BIM is considerably low. The industry is yet to fully embrace the adoption of BIM. In fact, the Nigerian building industry is notoriously conservative and slow to change, despite been faced with so many challenges. Her traditional procurement and building delivery methods have largely remained the same for decades. Building construction is undoubtedly a teamwork. It has been acknowledged worldwide that the process of building an edifice is the collaborative responsibility of various professionals/stakeholders and integration of the various phases/stages of a project to offer best quality products. The traditional building design is largely reliant upon two-dimensional drawings (plans, elevations, sections etc.). This denies having a virtual information model of the building project from the design team (Architect, Engineers, Builders, Surveyors, etc.); (where each professional adds discipline-specific data to the single shared model) to the main contractor and subcontractors and then on to the owner/operator. This scenario gives rise to loss of information that occurs when a new team takes ownership of the project. The present system of building process (traditional method) in Nigeria restricts communication to work in one direction only. BIM is a potent technology to enhance effective communication among other things if fully adopted. Although the use of BIM is starting to gain momentum among professionals in the Nigerian AEC sector, there are some specific factors preventing its widespread adoption according to Abubakar *et al.* (2014). Therefore, this study aims to identify the factors that affect the adoption of BIM in the Nigerian AEC industry.

2. THE CHALLENGES AND BARRIERS OF BIM USAGE

Although BIM is proving to be the answer to many constructions related problems, it has also been widely noted by authors such as Brewer et al. (2012) and Ashraf (2008) that BIM does not come without its challenges. The authors identified the increasing rate of introduction of new digital technology, increased global competition, greater client demands and higher costs, limited software knowledge as some of the challenges faced in BIM adoption. The fact that BIM is a new phenomenon that aims to change the way established construction industries have conducted their practices, makes it even harder to adopt and implement. Whyte (2011) research elucidates that BIM technology present a 'technological black box' with little visibility of the completeness of the design work represented in models and drawings. This makes it difficult in managing client's expectations.

Ashraf (2008) identified legal issues as factor that prevent full adoption and implementation of BIM technology. Ku and Taiebat (2011) identified issues such as lack of company investment in BIM, a reluctance to co-operate from other professionals, lack of collaborative working processes, lack of legal agreements and interoperability, which looks at the capability of BIM being used or operated reciprocally. Others include the comprehension levels of BIM amongst professionals, professionals' collaboration capabilities as well as software related.

In the white paper published by Autodesk (2004), three significant barriers were identified. They include transactional business process evolution, computability of digital design information and meaningful data interoperability. In Building Information Modelling innovation research of Shabanesfahani and Tabrizi (2012), a key barrier noted is in knowledge transfer of BIM innovation. Study made by Cory and Bozell (2001), identified practical issues such as such as software costs, utilization of new technologies, ability of the software to handle complex geometry, software learning curve, performance of software, level of detail needed and what the software can deliver, partition of the model among multiple users, integrate model from multiple sources, speed and working drawing extraction and maintenance, all of which affect the profitability of the company.

Civil Engineering Research Foundation (1996) in its research identified factors to BIM adoption in the building industry to include risk and liability, financial disincentives, high equipment cost, inadequate technology transfer, Inadequate basic and industrial research and development, adversarial relationships, poor leadership, inflexible building codes and standards and construction based initial costs. Researchers such as Inchachoto (2002) and Yoo *et al.* (2010) suggest the need for collaborative technological innovation as a solution to the barriers of BIM adoption discovered such as technical-risk, financial security, and psychological assurance.

These list of barriers is similar to the ones identified by Jones and Saad (2003) and Walcoff *et al.* (1983), in which they identified lack of mutual recognition of the need for innovation, insufficient technical capabilities and lack of skills, reluctance to change, inexperienced team members, lack of training, weak commitment and support by the administration , inadequate resources, deficiency in integration and collaboration, poor learning environment, lack of incentives and the difficulty in complying with the existing regulations and established standards.

3. RESEARCH METHODOLOGY

The study reviews extant literature on BIM technology, its barriers as well as the Nigeria AEC industry. A quantitative research method through structured questionnaire was employed for data collection and analysis. The sample frame consists of practicing professionals (architects, civil/structural engineers and building contractors) in registered AEC firms in Nigeria. Figure 1 illustrates the methodology for the research.

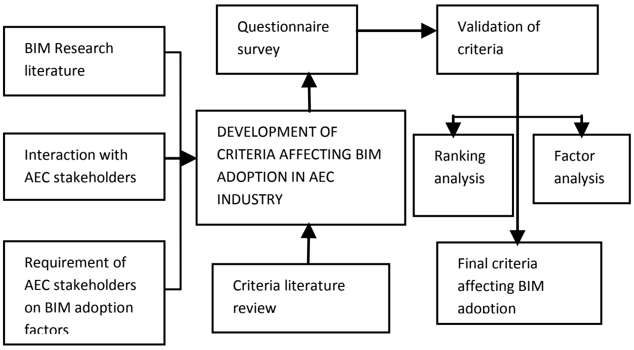

Fig.1: Research framework and methodology

3.1 Data Collection and sample

The survey first sought the background information of respondents and their organizations. Thereafter respondents were thus asked to rate the level of importance of the derived criteria based on a scale of 1-5, where 1 is "least important", 2 "fairly important", 3 "important", 4 "very important" and 5 "extremely important". The sample used in the survey was drawn from a database of around 3,000 AEC practices registered in Nigeria. A total of 490 questionnaires were mailed out to participants for completion, out of which 99 effective responses were received giving a response rate of 20.2 per cent.

3.2 Method of data analysis

Likert scale was used to rate the responses. In order to identify the relative importance of the criteria based on the survey data, ranking analysis was performed. Non-parametric statistics involving descriptive statistics analysis, relative index analysis and factor analysis were used to analyse the survey data. Relative index analysis was selected in this study to rank the criteria according to their relative importance. The following formula is used to determine the relative index (Chinyio *et al.* 1998; Olomolaiye *et al.* 1987; Akadiri, 2015):

$$RI = \sum w/A \times N \quad (1)$$

where w is the weighting as assigned by each respondent on a scale of one to five with one implying the least and five the highest. A is the highest weight (i.e. 5 in our case) and N is the total number of the sample. Following the work of Chen *et al.* (2010), five important levels are transformed from RI values: high (H) ($0.8 \le RI \le 1$), high-medium (H–M) ($0.6 \le RI < 0.8$), medium (M) ($0.4 \le RI < 0.6$), medium-low (M-L) ($0.2 \le RI < 0.4$) and low (L) ($0 \le RI < 0.2$). Knowing that the derived criteria are likely interrelated through an underlying structure of primary factors, and to obtain a concise list of criteria under these circumstances, factor analysis was used. After the primary factor analysis, Varimax rotation method was used to look for a linear combination of the original factors, such that the variance of the loadings is maximized. In all these, the Statistical Package for the Social Sciences (SPSS) and Microsoft Excel for Windows application software package were employed for data analysis.

3.2 Development of criteria affecting BIM adoption

In trying to develop a set of criteria, Foxon *et al.* (2002) proposed the consideration of two key factors. What use will be made of this set of criteria? To what extent can any set of criteria encompass the range of issues to be considered under the heading of "Building Information Modelling"? Based on the review of literature, combined with several researches in BIM and requirements of AEC stakeholders, 24 criteria were selected under three categories: laws and regulations; organizational; technological. A summary of the criteria is listed in Table1.

Table 1: Factors affecting BIM adoption

Source	Laws and Regulations	Organizational criteria	Technological criteria
Literature review, existing and focus of construction stakeholders	LR 1: Inflexible building codes LR 4: Submission of drawings is still hard copy LR 2: Submission of drawings doesn't use digital copy from digital innovations LR 3: High standard of digital modelling and procedure established by government for drawing submission.	O8: Poor leadership and organizational attitude towards digital innovation O7: Lack of empowerment and support to digital innovation O6: Lack of trained professionals to manage BIM innovation O4: Lack of awareness O1: Lack of client's demand O9: Cost of BIM software O11: Cost of training O2: Lack of assured return on investment O3: High equipment (computer) maintenance cost O5: Fear of work changes O10: Lack of psychological assurance	T7: Lack of training for technology T1: Lack of interest for the knowledge of digital technology, T6: Lack of adequate ICT infrastructure T5: Insufficient skills on the technology T4: Unavailability of new digital tools T3: Slow speed of computers in processing and drawing extraction T8: Poor power supply T9: Limited availability of digital tools to deliver digital innovation T2: Slow data processing of 3d models

4. DATA ANALYSIS AND DISCUSSION

4.1 Sample characteristics

Basic factual data were collected relating to the respondents personally as a professional designer/architect, civil/structural engineer, building contractor and his/her organization. Experience of respondents was highly impressive as 61.5 per cent have over 20 years' experience working in the building industry, 13.2 per cent has industry experience ranging between 11 and 20 years, while 25.3 per cent have at least ten years or less. As for the size of organization, 86.8 per cent work in small-to-medium size organizations, with a small proportion (13.2 per cent) working in large organizations with over 250 staff. The result also shows that 95 per cent of the survey participants have completed at least undergraduate degrees and 81 per cent have additional postgraduate qualifications. Summary of respondent's characteristics are shown in Table 2. From the above it can be concluded that respondents played important role in their organizations with good educational background and are very experienced. These characteristics make their view on the relevance of the criteria obtained through the survey important and their ratings dependable.

Table 2: Summary of respondent's demographic data

Variable	Number	Percentage (%)
Work experience		
<5 years	5	5.5
6-10 years	18	19.8
11-20 years	12	13.2
>20 years	56	61.5
Size of organization (by staff)		
<10 staff	44	48.4
11-50 staff	17	18.7
51-249 staff	18	19.8
250-500 staff	5	5.5
>500 staff	7	7.7
Age of organization (in years)		
<5 years	14	15.4
6-10 years	5	5.5
11-20 years	23	25.3
21-30 years	22	24.2
31-40 years	7	7.7
>40 years	20	22.0
Type of organization		
Architecture/design	35	38.4
Civil/structural engineers	32	35.2
Building Contractors	24	26.4
Area of project specialism		
Commercial	5	5.5
Residential	56	61.5
Institutional	29	31.9
Industrial	1	1.1

4.2 Criteria rating

Relative index analysis was used to rank the criteria according to their relative importance. Table 3 show the ranking results for each criteria category (e.g. technological) by using the relative index analysis in Equation (1). Based on these ranking results, 12 criteria were highlighted to have "high" importance levels in evaluating building material with an RI value between 0.808 and 0.898. These twelve criteria are " Lack of awareness (O4)", Lack of trained professionals (O6)", Cost of BIM software (O9)", Lack of clients demand (O1)", Lack of empowerment and support to digital innovation (O7)", Poor leadership and organization towards digital innovation (O8)", Unavailability of new digital tools (T4)", Slow speed of computers in processing and drawing extraction (T3)", Poor power supply (T8)", Limited availability of digital tools to deliver digital innovations (T9)", Inflexible building code (LR1)", Submission of drawings is still hard to copy (LR4)". "Lack of awareness" was ranked as the first priority in the organizational category with an RI value of 0.898, and it was also the highest among all criteria and was highlighted at "High" importance level.

A total of 12 criteria, consisting of 5 organizational criteria, 5 technological criteria, and 2 laws and regulations criteria, were recorded to have "High– Medium" importance levels. Although these 12 criteria were in the same importance level category, the laws and regulations criteria (average RI=0.695) were less important compared to the organizational criteria (average RI=0.774) and technological criteria (average RI=0.716). An interesting observation is that none of the criteria fall under the medium and other lower importance level. This clearly shows how important the criteria are to building professionals as factors affecting the adoption of BIM. All criteria were rated with "High" or "High–Medium" importance levels.

4.3 Factor analysis

Factor analysis was employed to analyze the structure of interrelationships among the criteria. Factor analysis was used to obtain a concise list of criteria. It is conducted through a two-stage process: factor extraction and factor rotation. Before the factor analysis, validity test for factors is conducted according to the method by Kaiser (1974). By Kaiser method, a value called eigenvalue under 1 is perceived as being inadequate and therefore unacceptable for factor analysis.

For the Technological criteria, the analysis results showed that the Kaiser –Meyer– Olkin (KMO) measure of sampling adequacy was 0.606, larger than 0.5, suggesting that the sample was acceptable for factor analysis. The Bartlett Test of Sphericity was 96.100 and the associated significance level was 0.000, indicating that the population correlation matrix was not an identity matrix. Both tests showed that the obtained data in technological category supported the use of factor analysis and these could be grouped into a smaller set of underlying factors. Using principal component analysis, the factor analysis extracted two latent factors with eigenvalues greater than 1.0 for the 9 technological criteria, explaining 53.7% of the variance. The rotated factor loading matrix based on the varimax rotation for the two latent factors is shown in Table 4.

The component matrix identifies the relationship between the observed variables and the latent factors. The relationships are referred to as factor loadings.

Table 3: Rank of criteria affecting BIM adoption

Variables	RI	Category Ranking	Overall ranking	Importance level
Organizational criteria				
O4: Lack of awareness	0.898	1	1	H
O6: Lack of trained professionals to manage BIM innovation	0.892	2	2	H
O9: Cost of BIM software	0.886	3	3	H
O1: Lack of client's demand	0.881	4	4	H
O7: Lack of empowerment and support to digital innovation	0.846	5	7	H
O8: Poor leadership and organization towards	0.820	6	10	H

digital innovation				
O11:Cost of training	0.723	7	19	M-H
O2: Lack of assured return on investment	0.717	8	20	M-H
O3: High equipment (computer) maintenance cost	0.692	9	21	M-H
O5: Fear of work changes	0.670	10	22	M-H
O10: Lack of psychological assurance	0.615	11	24	M-H
Technological criteria				
T7: Lack of training for technology	0.763	7	15	M-H
T1: Lack of interest for the knowledge of digital technology	0.793	5	13	M-H
T6: Lack of adequate ICT infrastructure	0.729	9	18	M-H
T5: Insufficient skills on BIM technology	0.749	8	17	M-H
T4: Unavailability of new digital tools	0.859	1	5	H
T3: Slow speed of computers in processing and drawing extraction	0.853	2	6	H
T8: Poor power supply	0.839	3	8	H
T9: Limited availability of digital tools to deliver digital innovations	0.825	4	9	H
T2: Slow data processing of 3D models	0.774	6	14	M-H
Laws and Regulations criteria				
LR1: Inflexible building code	0.810	1	11	H
LR4: Submission of drawings is still hard copy	0.808	2	12	H
LR2: Submission of drawings doesn't use digital copy from digital innovations	0.752	3	16	M-H
LR3: High standard of digital modelling and procedure established by government for drawing submission.	0.639	4	23	M-H

The higher the absolute value of the loading, the more the latent factor contributes to the observed variable. Small factor loadings with absolute values less than 0.5 were suppressed to help simplify Table 4. For further interpretation, the two latent factors under the technological category are given names as: *Factor 1: Process*; and *Factor 2: Performance*. Similar factor analyses were performed to identify the underlying structures for laws and regulations and organizational categories. For organizational category, both the KMO measure of sampling adequacy test [0.801] and Bartlett's sphericity (p=0.000) were significant, which indicated that factor analysis was also appropriate. Three factors under organizational category were extracted from the factor analysis, namely, *Factor 3: Management; Factor 4*: *Financial*; and *Factor 5: Psychological*. Along with rotated factor- loading matrix, the percentage of variance attributable to each factor and the cumulative variance values are shown in Table 5. From the table, it can be seen that the three factors accounted for 71.3% of the total variance of the eleven organizational criteria.

Table 4: Factor loadings for technological criteria after varimax rotation

Observed technological variable	Latent technological factors	
	Process	Performance
T8: Poor power supply	0.757	
T3: Slow speed of computers in processing and drawing extraction	0.693	
T9: Limited availability of digital tools to deliver digital innovations	0.576	
T2: Slow data processing of 3D models	0.573	
T6: Lack of adequate ICT infrastructure		0.830
T5: Insufficient skills on BIM technology		0.759
T1: Lack of interest for the knowledge of digital technology		0.579
T4: Unavailability of new digital tools		0.556
T7: Lack of training for technology		0.542
Eigenvalues	1.556	2.205
Percentage of variance (%)	22.234	31.502
Cumulative of variance (%)	22.234	53.736

Table 5: Factor loadings for organizational criteria after varimax rotation

Observed organizational variable	Latent organizational factors		
	Management	Financial	Psychological
O4: Lack of awareness	0.893		
O6: Lack of trained professionals to manage BIM innovation	0.882		
O1: Lack of client's demand	0.719		
O7: Lack of empowerment and support to digital innovation	0.586		
O8: Poor leadership and organization towards digital innovation	0.557		
O9: Cost of BIM software		0.824	
O11: Cost of training		0.773	
O2: Lack of assured return on investment		0.588	
O3: High equipment (computer) maintenance cost		0.546	
O5: Fear of work changes			0.812
O10: Lack of psychological assurance			0.871
Eigenvalues	5.505	1.216	1.116
Percentage of variance (%)	50.048	11.057	10.149
Cumulative of variance (%)	50.048	61.105	71.254

Observed laws and regulations variable	Latent laws and regulations factors
	Governmental
LR1: Inflexible building code	0.799
LR4: Submission of drawings is still hard copy	0.740
LR2: Submission of drawings doesn't use digital copy from digital innovations	0.712
LR3: High standard of digital modelling and procedure established by government for drawing submission.	0.658
Eigenvalues	3.016
Percentage of variance (%)	50.264

Table 6: Factor loadings for government regulations criteria after varimax rotation

In the laws and regulations category, the results for the factor analysis showed that the KMO measure was 0.804 and the Bartlett's test [p=0.000] was also significant, which indicated that the factor analysis was also appropriate in identifying the underlying structure of the technical category. The results of the analysis are presented in Table 6. Just one factor named *Factor 6: Governmental* was extracted, explaining 50.3% of the total variance of the six technical criteria.

Overall, six latent factors were extracted to present the underlying structure of the criteria that affect the adoption of BIM in the AEC industry. Three factors were under organizational category, two factors belong to technological category, and one factor for the laws and regulations category.

5. CONCLUSION AND FURTHER RESEARCH

This paper has described the development of a set of factors affecting the adoption of BIM technology in the AEC industry in Nigeria. A total of 24 criteria were identified through a thorough literature review and discussion with selected experts in the use of BIM technology. To obtain the perceived importance of the criteria, a questionnaire was distributed to a large sample of AEC professionals experienced in the use of BIM technology in Nigeria. Ranking analysis revealed that all criteria were highlighted at "High" or "High–Medium" levels in selecting building materials. Twelve criteria were highlighted at the "High" importance level, with lack of awareness, lack of trained professionals to manage BIM innovation and cost of BIM software the top three criteria of importance. Factor analysis of the data generated six latent factors. Two of these factors are under technological category: *performance and process;* three under organizational category: *management, financial and psychological;* and one under laws and regulations category: *governmental*. Since these factors are derived from the survey through expert opinion, they symbolize the factors that affect the adoption of BIM technology in Nigeria AEC industry. Consideration of these six factors will go a long way through vigorous campaigns, sensitization, and training of AEC professionals particularly on the use of BIM and its adoption in all construction projects. Further research is however recommended on improving clients' awareness and adoption of BIM. More so, simplified BIM training techniques and adoption framework are other areas for future research work.

REFERENCES

[1] Abubakar M., Ibrahim, Y.M., Kado, D., Bala, K. (2014). Contractor's perception of the factors affecting building information modelling (BIM) adoption in the Nigerian construction industry. Computing in Civil and Building Engineering, 167–178.

[2] Akadiri, P.O. (2015). Understanding barriers affecting the selection of sustainable materials in building projects. Journal of Building Engineering, 4, 86–93.

[3] Ashraf, H. W. (2008). "Implementing BIM: A report from the field on the issues and strategies", Proceedings of the 47th annual meeting of invited attorneys, Seattle, WA.

[4] Autodesk. (2004). Building Information Modelling in Practice [whitepaper]. Autodesk Building Industry Solutions. [Online] Available: http://images.autodesk.com/adsk/files/bim_in_practice pdf.

[5] Azhar, S., Carlton, W. A., Olsen, D., Ahmad, I. (2011). Building information modeling for sustainable design and LEED® rating analysis. Automation in Construction, 20, 217–224.

[6] Azhar, S., Khalfan, M, Maqsood, T. (2015). Building information modelling (BIM): Now and Beyond. Construction Economics and Building, 12, 15-28.

[7] Barlish, K., Sullivan, K. (2012). How to measure the benefits of BIM—A case study approach. Automation in construction, 24, 149-159.

[8] Brewer, G., Gajendran, T., Le Goff, R. (2012). Building Information Modelling (BIM): Australian Perspectives and Adoption Trends. Tasmanian Building and Construction Industry Training Board: Battery Point, Australia.

[9] Chen, Y., Okudan, G.E., Riley, D.R. (2010). Sustainable performance criteria for construction method selection in concrete buildings. Automation in Construction, 19, 235-244.

[10] Chinyio, E.A., Olomolaiye, P.O., Kometa, S.T., Harris, F.C. (1998). A needs-based methodology for classifying construction clients and selecting contractors. Construction Management and Economics, 16, 91-98.

[11] Civil Engineering Research Foundation, (1996). Needed: Lower Risks, More R&D. Architectural Record.

[12] Cory, C., Bozell, D. (2001). 3D Modeling for the Architectural Engineering and Construction Industry. International Conference Graphicon, Nizhny Novgorod, Russia.

[13] CRC for Construction Innovation, (2007). Adopting BIM for facilities management: Solutions for managing the Sydney Opera House. Cooperative Research Center for Construction Innovation, Brisbane, Australia.

[14] Eastman, C.M., Eastman, C., Teicholz, P., Sacks, R. (2011). BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors. 2nd ed. United States: John Wiley and Sons.

[15] Foxon, T. J., Mcilkenny, G., Gilmour, D., Oltean-dumbrava, C., Souter, N., Ashley, R., Butler, D., Pearson, P., Jowitt, P., Moir, J. (2002). Sustainability criteria for decision support in the UK water industry. Journal of Environmental Planning and Management, 45, 285–301.

[16] Grilo, A., Jardim-Goncalves, R. (2010). Value proposition on interoperability of BIM and collaborative working

environments. Automation in Construction, 19, 522–530.

[17] Hatem, W.A., Kwan, A., Miles, J. (2012). Comparing the effectiveness of face to face and computer mediated collaboration. Advanced Engineering Informatics, 26, 383-395.

[18] Inchachooto, S. (2002). Technological Innovation in Architecture: Effective Practices for Energy Efficient Implementation. PhD Thesis, Massachusetts Institute of Technology, USA.

[19] Jones, M., Saad, M. (2003). Managing innovation in construction. Thomas Telford, London, UK.

[20] Kaiser, H.F. (1974). An index of factorial simplicity. Psychometrika, 39, 31-36.

[21] Kekana, T.G., Aigbavboa, C.O., Thwala, W.D. (2014). Building information modelling (BIM): Barriers in adoption and implementation strategies in the South Africa construction industry. International Conference on Emerging Trends in Computer and Image Processing, Thailand.

[22] Ku, K., Taiebat, M. (2011). BIM Experiences and Expectations: The Constructor's Perspective. International Journal of Construction Education and Research, 7, 175-197.

[23] Olomolaiye, P.O., Wahab, K.A., Price, A.D.F. (1987). Problems Influencing Craftsmen's Productivity in Nigeria. Building and Environment, 22, 317-323.

[24] Popov, V., Juocevicius, V., Migilinskas, D., Ustinovichius, L., Mikalauskas, S. (2010). The use of a virtual building design and construction model for developing an effective project concept in 5D environment. Automation in Construction, 19, 357–367.

[25] Rezakhani, P. (2012). Fuzzy MCDM model for risk factor selection in construction projects. Engineering Journal, 16, 79-93.

[26] Shabanesfahani, A., Tabrizi, M.R. F. (2012). Barriers of Systemic Innovation to Increase Productivity of Engineering and Construction Industries of the World. IOSR Journal of Mechanical and Civil Engineering, 4, 43-50.

[27] Tomek, A., Matejka, P. (2014). "The impact of BIM on risk management as an argument for its implementation in a construction company", Procedia Engineering, 85: 501-509.

[28] Walcoff, C., Ouellette, R., Cheremisinoff, P. (1983). "Techniques for Managing Technological Innovation: Overcoming Process Barriers", Butterworth Publishers: Boston.

[29] Whyte, J. (2011). "Information Management and its Impact on Project Management", Oxford Handbook on the Management of Projects. P. Morris, J. Pinto and J. Soderlund, Oxford, Oxford University Press.

[30] Yoo, Y., Lyytinen, K., Boland, R., Berente, N., Gaskin, J., Schutz, D. (2010). "The Next Wave of Digital Innovation: Opportunities and Challenges", In: Research Workshop: Digital Challenges in Innovation Research, Institute of Business and Information Technology, Fox School of Business and Administration, Temple University.