

Model for Creating Cloud-BIM Environment in AEC Firms: A Grounded Theory Approach

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Abstract This paper focuses on Cloud-BIM services and develops a model for creating Cloud-BIM environment in AEC firms using a Grounded Theory approach. The paper describes a Cloud-BIM environment as an environment within an organization that serves as a workspace for accessing cloud-BIM services. Cloud-BIM is also described in this paper as the integration of BIM application services with cloud computing deployment models. Based on the definitions of Cloud-BIM, Cloud-BIM environment, and Cloud-BIM services, this paper develops a model of Cloud-BIM environment by adopting a five-step form, specifically representing the organizational processes when creating a workspace for accessing cloud-BIM services in AEC firms. The five stages include the selection of the appropriate Cloud-BIM deployment method, selection of the appropriate Cloud-BIM services, selection of the appropriate Cloud-BIM service provider, creation of online accounts with the selected Cloud-BIM service provider, and set-up a dashboard of online accounts. The model contributes to Cloud-BIM research by increasing understanding of Cloud-BIM, Cloud-BIM environment, and Cloud-BIM services. The practical benefit of the model is that it creates awareness and knowledge of Cloud-BIM for the professionals and top management of AEC firms; and also provide information on entrepreneurial opportunities made available by Cloud-BIM.

Keywords: *Cloud-BIM, Cloud-BIM environment, Cloud-BIM services, BIM, Cloud-computing*

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1. Introduction

A Cloud Building Information Modelling (Cloud-BIM) environment is an environment within an organization that serves as a workspace for accessing cloud-BIM services [1]. The term cloud refers to the use of internet connection for computing tasks, communication, and obtaining services provided by a remote internet host [2]. Cloud-BIM, on the other hand, refers to the various BIM application services that are available over the internet using internet-based hardware (infrastructure) and internet-based software technologies (platform) [3]. Cloud-BIM is believed to meet the need for a central repository platform; need for an open interoperability (inter-application communication) for different BIM tools and technologies; need for an efficient and effective information exchange and sharing; need to save time spent on installation, maintenance, and updating of BIM software technologies; need to reduce the cost of BIM adoption; and need to process and interchange voluminous data in large-scale construction projects [3]. Similarly, [4] maintained that cloud-BIM will encourage small and medium Architectural Engineering and Construction (AEC) firms to utilize BIM on their

projects; will help bridge BIM education; will eliminate the creation of multiple copies of data during information exchange and sharing; will help meet the need for on-demand access to project information; and will help meet the need for real-time collaboration.

Several theoretical and conceptual models have been developed for the implementation of cloud-BIM in the AEC industry. For example, [5] developed a model for cloud-BIM integrated LEED automation, [6] developed a cloud-BIM collaborative design model for construction projects, [7] proposed a social cloud-BIM model for object-based lifecycle information exchange, and [8] proposed a cloud-BIM interoperation model. However, the understanding of the process of creating a cloud-BIM environment and the model for creating a cloud-BIM environment in AEC firms remains relatively unexplored [4]. Thus, this study investigates the process of creating a cloud-BIM environment and develops a model for creating a cloud-BIM environment in AEC firms.

The paper is organized as follows: Section II presents the research method for the study. Section III contains theoretical grounding for the proposed model with regards to methods of cloud-BIM, cloud-BIM services, and cloud-BIM services providers. Application, future work, and some concluding remarks are given in Section VI.

2. Method

Grounded Theory is a general methodology for developing and validating conceptual models because of its usefulness in providing a thorough theoretical explanation for a well-integrated set of concepts [9]. This study adopted the five-stage process of Grounded Theory outlined by [10] to develop and validate the model for creating a cloud-BIM environment that was proposed in this paper. The five-stage Grounded Theory process for developing and validating models are as follows:

- defining the selection criteria for the dataset,
- searching and selection process,
- dimensions identification (open coding),
- category development (axial coding),
- and meta-synthesis (selective coding).

The selection criteria for research articles to be included in the dataset for this study were as follow (i) the research articles must be published in refereed journals, conference proceedings and other scholarly publications (ii) the research articles must be within the domain of cloud-BIM, cloud-BIM services, and cloud-BIM services providers (iii) the research articles must contain relevant texts on the topic of the study (iv) the research articles must be written in English Language.

For the searching and selection of articles to form the dataset for the study, a comprehensive literature search was conducted using the Scopus, SCI and Google Scholar. The search terms included cloud-BIM methods, cloud-BIM deployment models, cloud computing in construction, cloud-BIM services, and cloud-BIM services providers. Titles, abstracts, and keywords of the articles were used as the selection method for the articles. A total of 30 articles (16 cloud-BIM methods related articles, 7 cloud-BIM services related articles, 7 cloud-BIM services providers' related articles) were identified and included in the dataset (see Figure 1).

Searching and selection stage was immediately followed by the Identification of dimensions (open coding) for each of the search terms. Four dimensions were identified for cloud-BIM methods and the number of research articles supporting the four dimensions identified for cloud-BIM methods is presented in Figure 2. The three dimensions and the number of research articles for cloud-BIM services are presented in Figure 3. Finally, a meta-synthesis of the dataset was conducted to develop and validate the model.

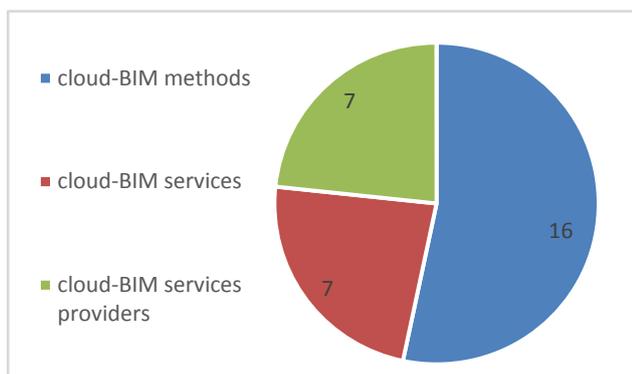


Figure 1. Number of research articles by dimensions of the cloud-BIM environment

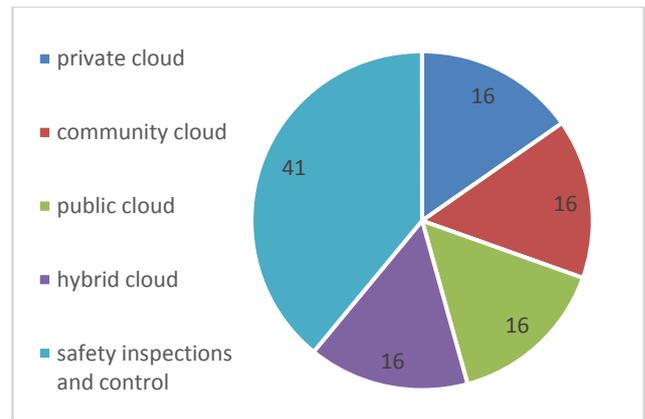


Figure 2. Number of research articles by cloud-BIM methods

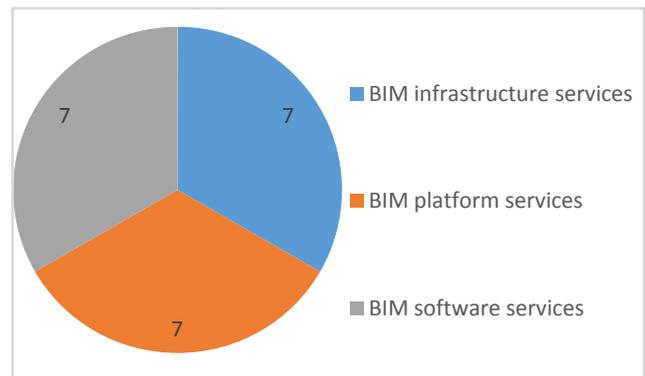


Figure 3. Number of research articles by cloud-BIM services

3. Theoretical Grounding

3.1. Cloud-BIM and Methods of Deploying Cloud-BIM

Cloud-BIM is an integration of BIM application services with cloud computing deployment models. According to [11], cloud computing provides an effective means of mitigating challenges of the cost of BIM adoption, data storage, and data exchange in BIM. As noted by [12], cloud computing makes use of virtualization technology to develop virtual versions of ICT resources such as hardware, software, file storage, and networks and makes them available through the cloud (internet).

The deployment methods for cloud computing in BIM include private cloud, community cloud, public cloud, and hybrid cloud [5,13]. Private cloud is a deployment model for BIM application services that allow single organization access [13,14]. Private cloud is built and managed by individual organizations and serve as a storage platform which affords a corresponding service to AEC firm or a construction project with integrated resources [15]. Private cloud is like intranet as it is set up within an organization's internal data center or workshop space. In terms of benefits, security and maintenance are easier to manage in Private cloud.

[11] noted that a private cloud must have at least 3-major components: service components, monitoring, and management component, and a security component. The service component provides access to the firms, the monitoring, and management component is required to

ensure the reliability of each layer in the cloud, and it allows the service provider to monitor and to initiate activities of each layer contained in-service components. The security component is required to ensure the privacy, recovery, integrity, and security of user data and transactions [16]. Private cloud is operated solely within a single organization and managed by the organization or a third party regardless of the location where it is set up.

The difference between private and public cloud is that in public cloud, the service provider has the full ownership of the public cloud with its own policy, value, profit, costing, and charging model [17]. Also, the public cloud allows users access to the cloud via interfaces using web browsers. Users only need to pay for the time duration they use the service. However, the public cloud is less secured because it is prone to malicious attacks [18].

A community cloud is a type of cloud computing deployment in BIM where many organizations jointly construct and share a cloud infrastructure, requirements, and policies [18].

A hybrid cloud combines public and private cloud services or private and community cloud by linking a private cloud to one or more external cloud services. It allows the organization to access the public cloud for intensive computing resources while controlling data and applications in the private cloud [18]. Hybrid cloud is mostly adopted where organizations want to optimize their resources and to increase their core competencies [17].

3.2. Cloud-BIM Services and Cloud-BIM Services Providers

There are three categories of cloud-BIM services. These include BIM infrastructure services, BIM platform services, and BIM software services. BIM infrastructure refers to the hardware that is required for the use of BIM platforms and software applications. There are cloud-BIM services providers who provide BIM infrastructure for AEC firms to make use of on the internet. Examples of such cloud-BIM services providers are Amazon's EC2, GoGrid's cloud servers, Joyent, BIMX, RackSpace, OpenStack, ProjectWise Navigator, i-Model, Autodesk Collaborative Project Management, Onuma System, RevitServer, CaddForce, BIM9, Migenius' Reality Server, ProjectWise Interaction Server, AssetWise, Graphisoft BIM Server, EDMmodel Server, Dropbox, Amazon Cloud Drive, Backblaze, Crashplan, Box, Google Drive, and BIMServer [13,19]. As reported by [20], BIM infrastructure services include an operating system, storage, network resources, servers, storage systems, routers, firewalls, load balancer, internet connectivity, service-level agreements, domain name service, and dynamic host configuration protocol.

BIM platform services is a combination of BIM infrastructure and BIM application services being offered by cloud-BIM services providers such as Google App Engine, Force.com, 800 APP, Microsoft's Azure, Amazon web services, CarbonBuzz, CADer, Accelo, Google Cloud Platform, AEC Cloud, AppEngine, Heroku, Eucalyptus, Microsoft Visual Basic, Apple, and GAE. BIM applications include data storage (database), interoperability, data sharing and exchange, clash detection, coordination and collaboration, programming, BIM management, knowledge management,

model authoring, fabrication detailing, site data management, programming languages, and application programming interfaces [6,21].

BIM software services refer to the BIM software technologies provided by cloud-BIM services providers. This form of cloud-BIM service is also referred to as virtualization of BIM software because it allows users to make use of BIM software technologies that were installed in the cloud by the cloud-BIM software providers. The use of BIM software services eliminates the need to install and run software applications on the user's computer system and it also gives network-based access to software applications. Examples of BIM software services providers are Autodesk360, Caddforce, BIM9, Onuma System, VMware, Citrix, Webex, 4Projects, and Trimble Connect [15,21,22].

4. Model Development

The model for creating Cloud-BIM environment in AEC firms as presented in this paper was conceptualized as a procedure-based model with 5-steps. As presented in Figure 4, the model for creating Cloud-BIM environment in AEC firms provides information and guidance for AEC professionals and BIM managers towards the creation of Cloud-BIM environment.

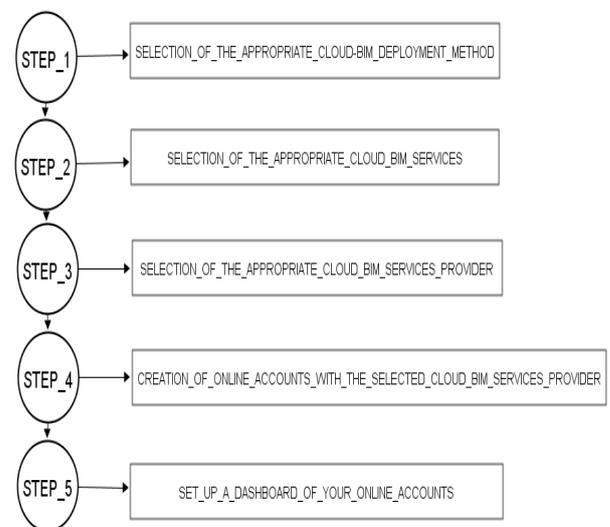


Figure 4. Model for creating Cloud-BIM environment in AEC firms

4.1. Selection of the Appropriate Cloud-BIM Deployment Method

As discussed in Section 3.0, there are four methods of deploying Cloud-BIM. Figure 5 presents a summary of the Cloud-BIM deployment method. The starting point for the model for creating Cloud-BIM environment in AEC firms is the selection of the appropriate Cloud-BIM deployment method. However, there are factors to be considered in order to ensure the appropriateness of the Cloud-BIM deployment method to be adopted in AEC firms. First, the operating cost of the methods must be considered. The essence of Cloud-BIM is to reduce the cost of BIM adoption, hence the Cloud-BIM deployment method that will support this objective would seem the appropriate one.

Second, the extent of openness and multi-party involvement (information sharing boundaries) that is required is another important factor to be considered in the selection of Cloud-BIM deployment method. As discussed in Section 3.0, each of the Cloud-BIM deployment methods has specific information sharing boundaries. For example, private Cloud-BIM is limited to in-house collaboration and will not be appropriate for small firms that lack the capacity to develop all discipline-specific information models in-house. Third, the security risks of the methods should be considered before deciding on the appropriate method that suits the risk management strategy of the firm. Lastly, data integrity and privacy required should also be given due consideration when selecting the appropriate Cloud-BIM deployment method.

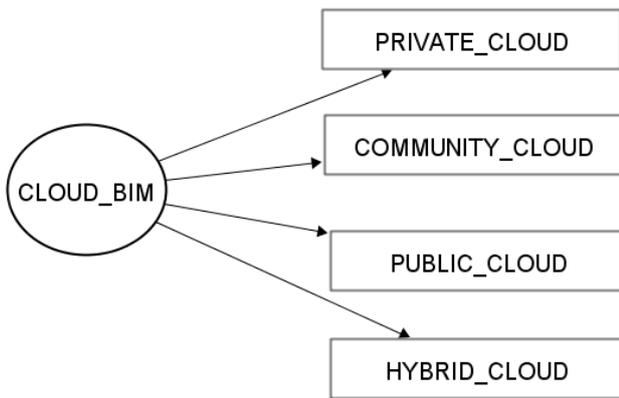


Figure 5. Cloud-BIM deployment methods

4.2. Selection of the Appropriate Cloud-BIM Services

Following the discussion in Section 3.0 and Figure 6, an AEC firm that wants to adopt Cloud-BIM has 3-types of Cloud-BIM services to select from. The appropriateness of Cloud-BIM services depends on the size of the firm, the vision of the firm, and most importantly, the services being rendered to clients by the firm. The area of specialty or operation of a firm may be used to decide on the appropriate Cloud-BIM services required by the firm. Another method of selecting Cloud-BIM services is to out-source services that are outside the area of specialty of the firm to a Cloud-BIM services provider. This also depends on the procurement system of projects that the firm is participating on. For example, an architectural firm executing a Design and Build project may out-source services such as structural analysis and design, cost analysis and estimation, and project and site management as Cloud-BIM services.

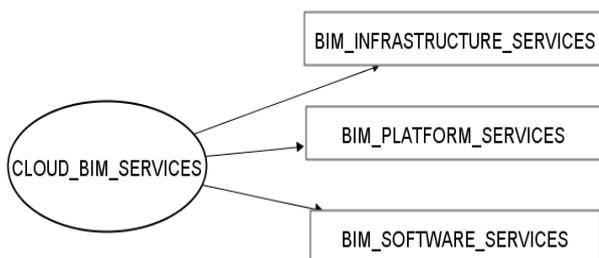


Figure 6. Cloud-BIM services

4.3. Selection of the Appropriate Cloud-BIM Service Provider

Following the selection of the appropriate Cloud-BIM services, the next step is to select the appropriate Cloud-BIM service provider. Table 1 shows the various Cloud-BIM services with examples of their Cloud-BIM service providers. The ability of the Cloud-BIM service provider to tailor available resources to meet specific requirements of the firm, the reliability and capability of Cloud-BIM service provider, the liability of Cloud-BIM provider in circumstances of data loss or insolvency, and location transparency are some of the considerable factors for the selection of the appropriate Cloud-BIM service providers.

Table 1. Examples of Cloud-BIM service and Cloud-BIM service providers

BIM services	Cloud-BIM service providers
Building performance and energy analysis	Generative Components, Bentley Connect, Carbon Buzz, Autodesk Cloud, Vasan Energy Analysis, Sefaira Architecture
Cost analysis and estimation	Cost OS Estimating 4, Cubit, MudShark, Global, ProContractor, B2W Estimate, Sage Estimating, Estimator360, ProEst, WinEst, EasyEstPro, PlanSwift, Clear Estimate, Estimate Master, e-SPECS
Project and site management/4D scheduling	Autodesk Buzzsaw, Autodesk ConstructWare, Prolog, Threshold CM, Builder Trend, Co-Construct, Synchro 4D, Sage 100 Contractor, Sage 300 Construction and Real Estate, Sage 300 Trade Specialty, Builder MT, Field Connect, Google Docs, Tick, Toggl, Harvest, GSuite, Xero, Workflow Max
Collaboration and communication	4Projects, Union Square, Skype, Dropbox, Webex, Online Construction Project Extracts, SharePoint, FieldConnect, Microsoft One Drive, Google Drive, iCloud Drive, Huddle, Evernote, Google Hangout, Yahoo mail, Gmail, Hotmail, Basecamp, Intermedia, Prezi, Slideshare
Architectural design software	Autodesk BIM 360, Autodesk Cloud, Rendercore, Vectorworks Cloud, Pictometry Connect, ArchiCAD 16, Sunglass, Autodesk 360 Rendering, Shaderlight Cloud Rendering, Felix, Sefaira Architecture
Structural analysis and design	Autodesk's Flow Design, SkyCiv Structural 3D, Structural Analysis for Revit®, CloudCalc, IDEA StatiCa
Facilities management	Bluebee®Cloud, FM: BIM, QuickFMS, iTouchVision, Cloud-based Computational Maintenance System, FMX, FSI, eSSETS, 360Workplace, VFA facility
Information exchange and integration	BIMX, Intermedia, Trimble Connect, Unifi, G Team, Autodesk 360, HP e-Print and Share, Oce' Mobile WebTools, Sculpteo, 3D Model-to-Print

4.4. Creation of Online Accounts with the Selected Cloud-BIM Service Provider

The next step is to open online accounts with the selected Cloud-BIM service provider. The account serves as a form of registration and documentation of the firm's details on the Cloud-BIM service provider's website. The account usually consists of different layers of access points. For example, the common layers in private Cloud-BIM accounts are presented in Figure 7. User Interface Layer provides various access points to account holders in accessing the private Cloud-BIM services. Business Layer is required to regulate resources supply and demand using

economy and service level agreement. System Layer is required for daily operation of the account for BIM application services. Resource Interface Layer provides interfaces and plug-ins to various virtual versions of ICT services made available by the Cloud-BIM service provider.

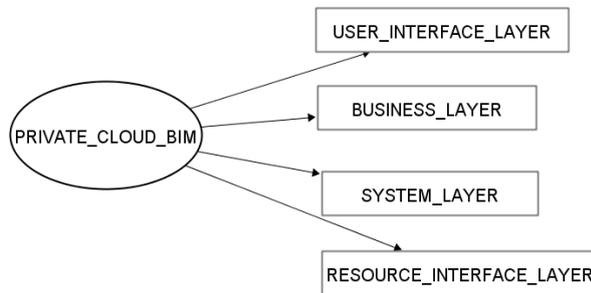


Figure 7. Layers in private Cloud-BIM

4.5. Set-up a Dashboard of Online Accounts

As a way of managing the online accounts with the selected Cloud-BIM service provider, a dashboard must be set-up on a dedicated computer at the workspace (Cloud-BIM environment) located in the firm. Alternatively, the Cloud-BIM service provider's website may be bookmarked on the computer browser at the workspace.

5. Implications for Practice and Future Research

The rate of BIM adoption of BIM by the AEC firms will be enhanced by the availability of a model for creating Cloud-BIM environment in AEC firms. Apart from the awareness and knowledge of Cloud-BIM that will be created by the model for the professionals and top management of AEC firms; the model will also provide information on entrepreneurial opportunities made available by Cloud-BIM. However critical research questions still exist on the reliability, cost, and security of Cloud-BIM services. Another important implication of the adoption of Cloud-BIM is the competence of Cloud-BIM service providers. More importantly is the need for a case study of Cloud-BIM adoption.

6. Conclusion

A model for creating Cloud-BIM environment in AEC firms is developed in this paper. The model is a procedure-based model with 5-steps of selection of the appropriate Cloud-BIM deployment method, selection of the appropriate Cloud-BIM services, selection of the appropriate Cloud-BIM service provider, creation of online accounts with the selected Cloud-BIM service provider, and set-up a dashboard of online accounts. It is observed in the paper that there are four methods of deploying Cloud-BIM and that the first and the most important step in creating Cloud-BIM environment in

AEC firms is the selection of the appropriate Cloud-BIM deployment method.

Three types of Cloud-BIM services (BIM infrastructure services, BIM platform services, and BIM software services) were identified in this paper. The selection of the appropriate Cloud-BIM services depends on the size of the firm, the vision of the firm, and the services being rendered to clients by the firm. Two methods were identified for selecting Cloud-BIM services, namely, the area of specialty of the AEC and out-sourcing of services that are outside the area of specialty of the firm to a Cloud-BIM services provider. Furthermore, the paper identified the various Cloud-BIM services together with examples of the Cloud-BIM service providers. The considerable factors for the selection of the appropriate Cloud-BIM service providers are the ability of the Cloud-BIM service provider to tailor available resources to meet specific requirements of the firm, the reliability and capability of Cloud-BIM service provider, the liability of Cloud-BIM provider in circumstances of data loss or insolvency, and location transparency. Finally, the paper discussed the importance of creating online accounts with the selected Cloud-BIM service provider and setting-up a dashboard of the online accounts.

This research was conducted to stimulate further discussion and creation of Cloud-BIM environment in AEC firms. This research has therefore provided a model for creating Cloud-BIM environment in AEC firms and has also raised some questions for further research on the reliability, cost, security of Cloud-BIM services, and competence of Cloud-BIM service providers. However, the scope of this study did not include the evaluation of the relationships in the model.

References

- [1] Olugboyege, O. Framework for Creating a Building Information Modelling Environment in Architectural, Engineering and Construction Firms and Projects. *PM World Journal*, 6(6), 1-10, 2017.
- [2] Chen, W., Da Silva, R.F., Deelman, E. and Fahringer, T. Dynamic and fault-tolerant clustering for scientific workflows *IEEE Trans. Cloud Comput.*, 4 (1), 49-62, 2016.
- [3] Redmond, M. D., F. Forcella, and N. N. Barger. Declines in pinyon pine cone production associated with regional warming. *Ecosphere*, 3(12): 120-130, 2012.
- [4] Matthews, B.B., Dos Santos, G., Crosby, M.A., Emmert, D.B., St Pierre, S.E., Gramates, L.S., Zhou, P., Schroeder, A.J., Falls, K., Strelets, V., Russo, S.M., Gelbart, W.M., FlyBase Consortium, Gene Model Annotations for *Drosophila melanogaster*: Impact of High-Throughput Data. *G3 (Bethesda)* 5(8), 1721-1736, 2015.
- [5] Wu, W. and Issa, R.R.A. Leveraging cloud-BIM for leed automation. *Journal of Information Technology in Construction*, 17(1), 367-384, 2012.
- [6] Chen, S.M., Griffs, F.H., Chen, P.H. and Chang, L.M. A framework for an automated and integrated project scheduling and management system. *Automated Construction*, 35(1), 89-110, 2013.
- [7] Das, M., Cheng, J.C., and Kumar, S.S. BIMCloud: a distributed cloud-based social bim framework for project collaboration. International conference on computing in Civil and Building Engineering, Orlando, Florida, 2014. American Society of Civil Engineers, Reston, VA, USA, 41-48, 2014.
- [8] Afsari K., Eastman C., Castro D. JavaScript Object Notation (JSON) data serialization for IFC schema in web-based BIM data exchange. *Automation in Construction*. 77(1). 24-51, 2017.

- [9] Corbin, J., & Strauss, A. Grounded theory research: Procedures, canons, and evaluative criteria. *Qualitative Sociology*, 13(1), 3-21, 1990.
- [10] Wolfswinkel, J. F., Furtmueller, E, and Wilderom, C.P.M. Using Grounded Theory as a Method for Rigorously Reviewing Literature. *European Journal of Information Systems* 22(1), 1-11, 2011.
- [11] Mahamadu, A., Mahdjoubi, L., and Booth, C. Challenges to digital collaborative exchange for sustainable project delivery through building information modeling technologies. In Zubir, S. S. and Brebbia, C. A. (Eds) "Proceedings of 8th International Conference on Urban Regeneration and Sustainability", Putrajaya, Malaysia, 2013, pp. 547-557, 2013.
- [12] Bhardwaj, Sushil, Leena Jain, and Sandeep Jain. "Cloud computing: A study of infrastructure as a service (IAAS)." *International Journal of engineering and information Technology* 2, no. 1 (2010): 60-63.
- [13] Wong J., Wang X., Li H., Chan G. and Li H. (2014). A Review of Cloud-Based BIM Technology in the Construction Sector. *Journal of Information Technology in Construction*, 19, Special Issue: BIM cloud-based Technology in the AEC Sector: Present Status and Future Trends, 19(1), 281-291, 2014.
- [14] Liu Y, et al. Mechanistic perspectives of calorie restriction on vascular homeostasis. *Sci China Life Sci*, 57(8), 742-754, 2014.
- [15] Goyal, P., Mikkilineni, R. and Ganti, M. "FCAPS in the business services fabric management", Proc. of 18th IEEE Intl. workshop on Enabling Technologies, 2009.
- [16] Doelitzscher, F., Sulistio, A., Reich, C., Kuijs, H., & Wolf, D. Private cloud for collaboration and e-Learning services: from IaaS to SaaS. *Computing*, 91(1), 23-42, 2011.
- [17] Dillon, M.E., Wang, G. and Huey, R.B. Global metabolic impacts of recent climate warming. *Nature*, 467(7316), 704-707, 2010.
- [18] Jadeja Y. and Modi K. Cloud Computing - Concepts, Architecture, and Challenges. *Proceedings of the International Conference on Computing Electronics and Electrical Technologies*, Nagercoil, India, 2012.
- [19] Chong JJ, Yang X, Don CW, Minami E, Liu YW, Weyers JJ, Murry, C.E. Human embryonic-stem-cell-derived cardiomyocytes regenerate non-human primate hearts. *Nature*. 2014. [PMC free article] [PubMed] [CrossRef], 2014.
- [20] Goyal, V. Role of SOA & Cloud Computing in IT Industry. *International Journal of Engineering Research & Technology*, 1 (6). pp. 1-5, 2012.
- [21] Amarnath, C.B., Anil, S. and Maheswari, J.U. Cloud Computing to Enhance Collaboration, Coordination, and Communication in the Construction Industry. *Conference proceedings of IEE, World Congress on Information and Communication Technologies*, 11, 1235-1240, 2011.
- [22] Isikdag, U. Emerging technologies for BIM 2.0. *Construction Innovation*, 11(3), 252-258, 2011.



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