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KEY DIMENSIONS OF EFFORT FOR BUILDING INFORMATION MODELLING DATA CREATION

Faris Hyder Ali, Shamsulhadi Bandi
Faculty of Built Environment & Surveying,
University of Technology Malaysia, UTM, Johor, Malaysia

ABSTRACT

While major industries begun to embrace technologies to improve revenue and productivity, construction industry appeared to be lagging in many aspects of technology adoption. Despite the industry's straggle, there are several innovative work processes getting traction these days where Building Information Modelling (BIM) sits at the backbone of sector's digital strategy with the potentiality to produce voluminous data. Fortunately, the expected accumulation of huge BIM data can bring potential insights in various digital platform through proper exertion of effort especially through big data. Though the associations between BIM data and big data has been theoretically established, the effort exertion in the creation of BIM data is still in the oblivious state. Therefore, a study to relate the dimensions of effort and various BIM data is needed as a precursor for future research. The outcomes evidently depict a recognizable linkage among them in which intensity is the least related dimension while most of the BIM data related with demand.

Key words: Digital data, Building Information Modelling data, Dimensions of effort, Big Data.

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1. INTRODUCTION

Various industries are moving forward by adopting and innovating technology whilst construction is still left far behind. It has been proven by McKinsey Global Institute's 2015 industry digitization index that construction sector is among the least digitized industry [1]. This undeniable scenario is happening due to the unwillingness of the construction players to be digitized [2]. As delineated in KPMG report, more than 80% of players in the industry are hesitating to incorporate new technologies [3]. Hence, it depicts the rationale behind the fall back of construction industry.

Despite the slow digitization in the industry, the digital environment is still forming its place and refining albeit slowly, thus it is leading towards the formation of digital data through various platform. In the earlier days, computer aided design technology is the only construction related adoption in construction which replace the previous practice of designing through drawing boards [4]. However, recently, despite being the least digitized industry, few technologies like virtual reality, drone, Internet of Things, Building Information Modelling (BIM) software have been adopted in the industry where some of them are still at infancy stage [5]. These technological adoptions show the effort being exerted by key stakeholders in construction.

Amid these technological adoption, BIM software is playing a significant role in the industry where it is being recognized as among the most applied technologies [6]. This is due to fact that activities like collaboration, collision detection, forensic analysis, visualization and others were quite impossible before the BIM applications in the construction [7, 8]. In addition, BIM also being viewed as a backbone of new working method and digital strategy since the application is capable to connect and integrate with various kind of software [9]. Hence, it can be said that BIM applications is among the main contributor towards the improvement of construction activities and generation of utilizable digital data in the construction industry.

As it is expected that BIM applications could pave the way to leap the industry further, there is an essentiality to explore the level of effort that are being exerted in the creation of BIM data since the voluminous BIM data can bring potential insight especially through big data platform. However, there are lack of studies that emphasize the relationship of effort and BIM data creation which impede the possibility to carry out the research further. Thus, a study of these two domains is being conducted as a prerequisite for the main research. Thus, the aim of the paper is to establish the link between the dimensions of effort and BIM data. There are two objectives that need to be achieved: (1) to identify the relevant piece of literature that relates both dimensions of effort and BIM data, and (2) to identify the appropriate key dimension of effort to reflect the BIM data creation.

2. BIM AND BIG DATA

2.1 Data Creation in BIM Environment

Generally, data in the construction industry can be in three different forms which are structured, unstructured and semi-structured [10]. According to Soibelman, et al. [11], the structured data are commonly stored within databases and prescribed by set of rules, and on the other hand, there is no specific rules for unstructured data which comprises of various data. As for BIM software, the digital data that are being stored in its tool are largely structured [12, 13].

Currently, structured data are being formed in the BIM software which includes data such as types, quantities, price and brands of materials, dimensions data and other type of data [7, 14] where all these data will be useful to provide information to the construction players on how the real construction going to take place. Besides, after the completion of construction, BIM also can generate and provide repository of data and construction related information that can be utilized during the operation and maintenance stage [7, 15]. Hence, it depicts that BIM is continuously creating data throughout the lifecycle of buildings or infrastructure from planning stage until operation and maintenance stage as shown in the Figure 1.

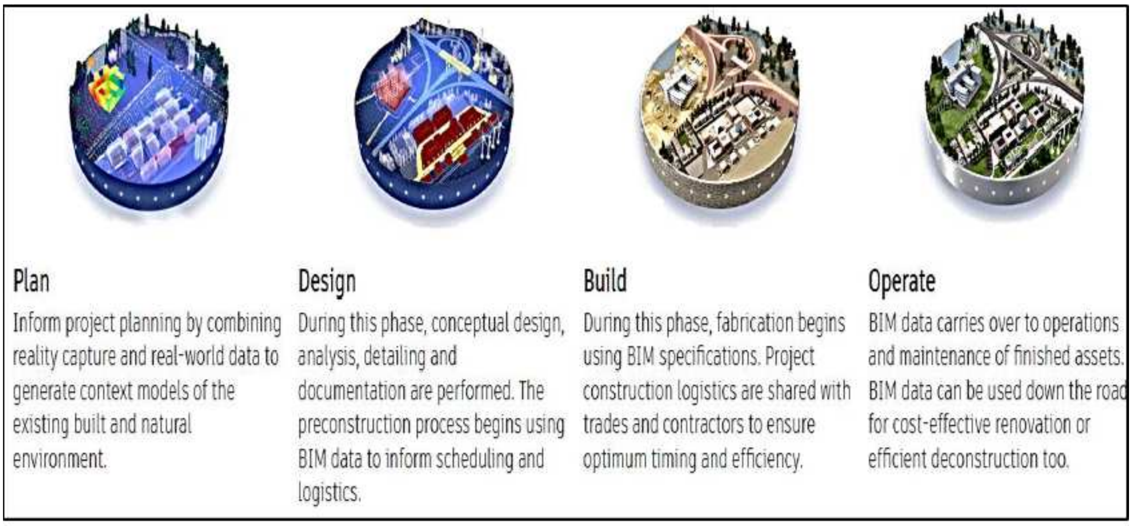

Figure 1 BIM Data Creation Throughout the Lifecycle [16]

Despite the humongous creation of BIM data throughout the lifecycle of building as in Figure 1., the insights derivation is only possible through the appropriate platform. It can get much more complex when the BIM data can be created exceptionally through the integration with Linked open Datasets or different applications within the construction industry [17, 18]. This situation will lead to the incapability of the conventional storing and processing tools which will require another platform to ensure the voluminous data can be managed and utilized [19, 20].

2.2 Prospect of Value in BIM Data

Currently, predictive and prescriptive analytics are capable to be carried out through various BIM software like Revit ,BIM 360, Cubicost and others where these tools can provide insights in terms of thermal and visual performance, cost prediction, energy consumption and so on [21-23]. This strongly exhibits that the BIM data can be analysed within its tool to provide valuable information to the players in the construction industry. However, this feasible golden opportunity through analytics is being underutilized and mostly being ignored by construction practitioners as it has been evinced that 70% of surveyed key stakeholders were not making use of analytics [3].

On top of that, the expected exponential creation of BIM data in the future will cause the obsoletion of the conventional analytics, though the derivation of value from BIM data is currently possible through the BIM software itself. As the current method is expected to become obsolete in the future, the construction industry will require to restructure the way of making use the digital data in BIM through innovation [24]. Therefore, the digital data can be leveraged to provide business value to the industry.

2.3 Big Data as a Medium for Value Creation

As analytics within the BIM software will become outdated due to the proliferation of BIM data in the future, it leads to the realization of big data in construction [21]. The big data concept existed for the last 3 decades, howbeit it is only being recognized lately in the sector [20]. Generally, big data technology has already being adopted and applied in many industries like manufacturing, entertainment, financial institutions and so on where they are actively using the technology due to its potentiality[25, 26]. However, construction is losing its potential since it is still at the inception stage of big data technological adoption [27].

Big data analytics can be considered as a savior for the unexploited digital data since it can resolve the underutilization issue within the construction [12]. In the context of BIM data creation, the huge accumulated BIM data can be utilized for the extraction of insights which can lead to the formation of new kind of business and services [28]. Besides, it is a reality that the big data analytics can bring betterment to the industry as manifested in various other industries in which they have achieved benefits in terms of cost and time savings, boost in productivity and increment in profits [27, 29].

Since the adoption of big data can bring positive impact towards the construction industry especially in terms of advanced analytics on BIM data [30]. Hence, there was a need to establish associations between BIM data and big data which have been theoretically mapped in the previous study. The outcomes indicated the connotations in between these two domains as depicted in Table 1.

Table 1. Mapping of BIM Data Types to Big Data Attributes [31]

Attributes of Big Data / BIM Data Types	Volume	Velocity	Variety	Veracity	Value	Visualization
Material	[32]		[21]	[4, 33-35]		[36]
Design	[20, 37]		[38]	[19, 39]	[20, 33, 38]	[4, 22, 38, 39]
Dimension				[34, 39]		[4, 39]
Cost			[21, 40]	[4, 22, 33, 35]		
Specification				[41, 42]		
Schedule				[43, 44]	[4]	[36, 44, 45]
Operation & Maintenance	[17, 20, 32, 46-57]	[17, 32, 47, 49, 50, 54, 58-61]	[21, 46, 48, 50, 52-54, 59, 62-66]	[19, 46, 53, 62, 65, 66]	[17, 47, 48, 52, 53, 63, 65]	[46, 51, 53, 58, 62, 63, 65]

Based on the Table 1, it delineates that every one of them, either BIM data types or big data attributes has at least an association between them and most of them has more than two. These outcomes reflect that there are hypothetical connotations among them which need to be confirmed in the real-world construction practice.

3. THEORIES UNDERPINNING EFFORT OF BIM DATA CREATION

Though the associations in between BIM data and big data have been theoretically established in the previous study, there is a need to explore the level of effort that being exerted in the BIM data creation. This is because the effort level has significant impact in the creation of BIM data [67] which will determine the fulfillment of big data attributes .

In general, effort can be defined as a “subjective intensification of mental and/or physical activity in the service of meeting some goal” [68]. There are various theories being related to effort such as Kahneman’s Theory, Theory of Achievement Motivation, Behavioural Change Theory and so on [69] where among them, the most relatable theory with the current study is Expectancy theory. Hence, the theory can be adopted to reflect the effort being imposed in BIM data creation towards big data progression. Before reflecting the effort of BIM data creation in the theory, the dimensions of effort have been extracted from several scholars which are important for the measurement of the effort. Table 2. shows the extraction of dimensions of effort.

Table 2. Extraction of Effort Dimensions

Author	Title	Content	Dimensions
Inzlicht, Shenhav & Olivola (2018) [68]	The effort paradox: Effort is Both Costly and Valued, Trends in Cognitive Sciences	Human & animals are applying more effort for better outcomes. Effort refers to intensity or amplitude of behaviour. Effort typically tracks demand where people work harder when the task is more difficult.	-Intensity -Demand -Task difficulty
Kahneman (1973) [70]	Attention and Effort, Prentice-Hall Series in Experimental Psychology	The terms "exert effort" and "invest capacity" will often be used as synonymous for "pay attention." When the supply of attention (effort) does not meet the demands, performance falters, or fails entirely. The indications are that effort is related to the dimension of accessibility. The amount of attention or effort exerted at any time depends primarily on the demands of current activities.	-Attention -Demand -Accessibility
Thomas (1983) [69]	Notes on Effort and Achievement Oriented Behaviour, Psychological Review	The relationships among average effort and, for example, level of task difficulty and efficiency of performance are being discussed within the theory. Effort would be positively correlated with task difficulty.	-Task difficulty

Based on the derived dimensions of effort, review was conducted to find out the key dimensions that have relation with the BIM related research as shown in Table 3. In addition, the BIM related research have been organized in the ascending order from 2007 until 2019 which have been randomly selected to link the key dimensions. Therefore, the Table 3 reflects the dimensions of effort that were being emphasized throughout those years.

Table 3. Studies on Dimensions of Effort

Author	Dimensions of effort				
	Intensity	Demand	Difficulty	Accessibility	Attention
Penttila (2007) [71]		✓			
Azhar et al. (2008) [72]				✓	✓
Mihindu & Arayici (2008) [73]			✓	✓	
Azhar (2011) [7]	✓	✓			✓
Thomassen (2011) [74]				✓	
Kubba (2012) [75]	✓				
Volk et al. (2014) [76]		✓			✓
Cao et al. (2015) [33]		✓	✓		
Lu et al. (2016) [35]		✓			
Olsen & Taylor (2017) [34]				✓	
Jeong (2018) [13]		✓	✓		
Bandi (2019)		✓			✓
Farghaly et al. (2019) [19]			✓		
Larsen (2019) [43]		✓		✓	
Matarneh et al. (2019) [62]		✓		✓	
Moreno et al. (2019) [6]				✓	✓
Olawumi & Chan (2019) [4]			✓	✓	

Table 3 depicts that four of the key dimensions have appeared and linked with at least in 5 numbers of articles where the highest is demand dimension which has been covered in 9 different articles. Meanwhile, the intensity dimension is the least emphasized and seems lacking in various studies. Hence, intensity will be selected as the key dimension that will be reflected as a part of the main research. As the least concerned dimension itself is achievable through the upcoming study, it is expected other dimensions also will be fulfilled in the effort of BIM data creation.

On the grounds that one of the key dimensions of effort has been selected, Figure 2 depicts on how the BIM data creation, intensity dimension and big data attributes can be reflected in the Kahneman's Expectancy Theory. Besides, Figure 2 also illustrates different BIM data types that are leading towards the fulfilment of big data attributes. Thus, the theoretical framework demonstrates the process that need be undergo by BIM data creation to become big BIM data.

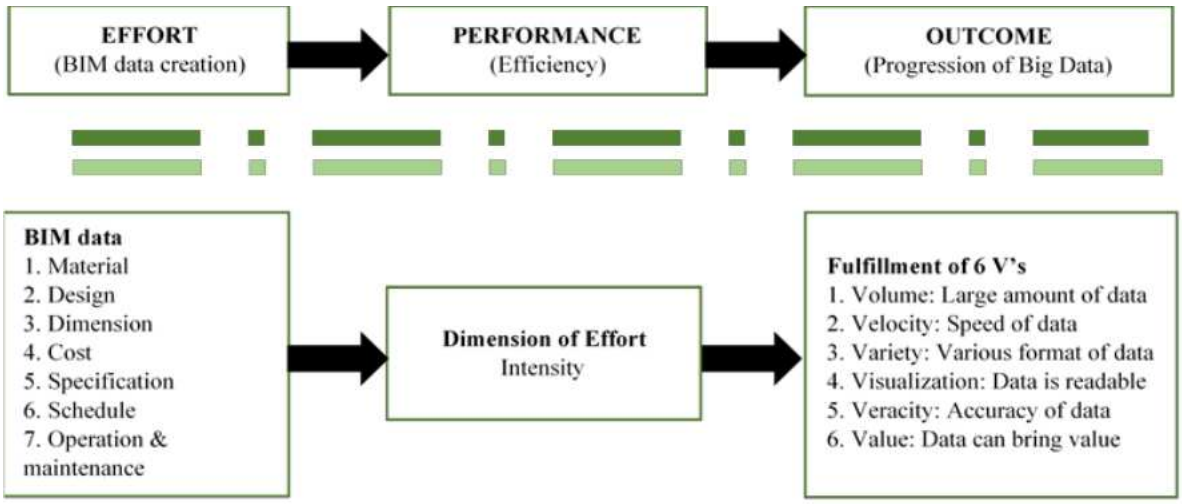

Figure 2 Theoretical Framework

4. CONCLUSIONS

The research is constrained by limited articles accessible through UTM database only. However, the study still managed to overcome the oblivious state by identifying the essential linkage between dimensions of effort and BIM data creation. The result of the current research is crucial to become the basis to conduct further the main research entitled effects of BIM data creation on big data progression in construction. Therefore, the research can verify whether the current effort exerted in BIM data creation will have an impact on big data progression or otherwise in the real-world practice.

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REFERENCES

[1] R. Agarwal, S. Chandrasekaran, and M. Sridhar, "Imagining construction's digital future," 2016.

[2] O. Wyman, "Digitilization of the construction industry," 2018.

[3] H. Busta, "KPMG report: Construction industry slow to adopt new technology," 2016.

[4] D. W. M. Chan, T. O. Olawumi, and A. M. L. Ho, "Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction: The case of Hong Kong," *Journal of Building Engineering,* vol. 25, p. 100764, 2019/09/01/ 2019.

[5] S. A. Ismail, S. Bandi, and Z. N. Maaz, "An Appraisal into the Potential Application of Big Data in the Construction Industry," *International Journal of Built Environment and Sustainability,* vol. 5, 2018.

[6] C. Moreno, S. Olbina, and R. R. Issa, "BIM Use by Architecture, Engineering, and Construction (AEC) Industry in Educational Facility Projects," *Advances in Civil Engineering,* vol. 2019, 2019.

[7] S. Azhar, "Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry," *Leadership and management in engineering,* vol. 11, pp. 241-252, 2011.

[8] S. Mordue, P. Swaddle, and D. Philp, *Building information modeling for dummies*: John Wiley & Sons, 2015.

[9] D. Kaufmann, X. Ruaux, and M. Jacob, "Digitalization of the Construction Industry: The Revolution is Underway," 2018.

[10] J. S. Hurwitz, "Big Data for Dummies," 2013.

[11] L. Soibelman, J. Wu, C. Caldas, I. Brilakis, and K.-Y. Lin, "Management and analysis of unstructured construction data types," *Advanced Engineering Informatics,* vol. 22, pp. 15-27, 2008.

[12] I. Motawa, "Spoken dialogue BIM systems – an application of big data in construction," *Facilities,* vol. 35, pp. 787-800, 2017.

[13] Y. Jeong, "A Study on the BIM Evaluation, Analytics, and Prediction (EAP) Framework and Platform in Linked Building Ontologies and Reasoners with Clouds," *Advances in Civil Engineering,* p. 14, 2018.

[14] S. Jansen, "The "I" In BIM: Which Information Should Be In Your BIM Model?," 2018.

[15] A. Mendelson, "BIM: Digital Data to Enhance Facility Management," 2019.

[16] Autodesk, "What is the Process of BIM," 2020.

[17] M. Arslan, Z. Riaz, and S. Munawar, "Building Information Modeling (BIM) Enabled Facilities Management Using Hadoop Architecture," in *2017 Portland International Conference on Management of Engineering and Technology (PICMET)*, 2017, pp. 1-7.

[18] W. Solihin and C. Eastman, "A simplified BIM model server on a big data platform," *CIB W78,* vol. 2016, 2015.

[19] K. Farghaly, "BIM-linked data integration for asset management," *Built Environment Project and Asset Management,* vol. 9, pp. 489-502, 2019.

[20] M. Bilal, L. O. Oyedele, J. Qadir, K. Munir, S. O. Ajayi, O. O. Akinade*, et al.*, "Big Data in the construction industry: A review of present status, opportunities, and future trends," *Advanced Engineering Informatics,* vol. 30, pp. 500-521, 2016/08/01/ 2016.

[21] C. Boton, G. Halin, S. Kubicki, and D. Forgues, "Challenges of Big Data in the Age of Building Information Modeling: A High-Level Conceptual Pipeline," Cham, 2015, pp. 48-56.

[22] S. Rokooei, "Building information modeling in project management: necessities, challenges and outcomes," *Procedia-Social and Behavioral Sciences,* vol. 210, pp. 87-95, 2015.

[23] Y. Lim, "BIM-based sustainable building design process and decision-making," in *2017 International Conference on Research and Innovation in Information Systems (ICRIIS)*, 2017, pp. 1-6.

[24] F. Correa, "Is BIM big enough to take advantage of big data analytics?," in *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction*, 2015, p. 1.

[25] L. X. Jingjing Li, Ling Tang, Shouyang Wang & Ling Li "Big data in tourism research: A literature review," *Tourism Management,* vol. 68, p. 23, 2018.

[26] A. Kumar, R. Shankar, and L. S. Thakur, "A big data driven sustainable manufacturing framework for condition-based maintenance prediction," *Journal of computational science,* vol. 27, pp. 428-439, 2018.

[27] M. G. Institute, "Big Data: The Next Frontier for Innovation, Competition and Productivity," 2011.

[28] K.-S. Schober, "Digitization of the Construction Industry " 2016.

[29] K. Ibrahim, H. Abanda, C. Vidalakis, and G. Wood, "Bim big data system architecture for asset management: a conceptual framework," in *Proceedings of the Joint Conference on Computing in Construction (JC3)*, 2017, pp. 289-296.

[30] Sarah, "How can big data analytics add value to BIM," 2018.

[31] F. H. Ali and S. Bandi, "Associations Between Building Information Modelling (BIM) Data and Big Data Attributes," *American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS),* vol. 76, pp. 1-11, 2021.

[32] Z. You and C. Wu, "A framework for data-driven informatization of the construction company," *Advanced Engineering Informatics,* vol. 39, pp. 269-277, 2019.

[33] D. Cao, G. Wang, H. Li, M. Skitmore, T. Huang, and W. Zhang, "Practices and effectiveness of building information modelling in construction projects in China," *Automation in Construction,* vol. 49, pp. 113-122, 2015.

[34] D. Olsen and J. M. Taylor, "Quantity take-off using building information modeling (BIM), and its limiting factors," *Procedia engineering,* vol. 196, pp. 1098-1105, 2017.

[35] Q. Lu, J. Won, and J. C. Cheng, "A financial decision making framework for construction projects based on 5D Building Information Modeling (BIM)," *International Journal of Project Management,* vol. 34, pp. 3-21, 2016.

[36] Y. Jiang and X. He, "Overview of applications of the sensor technologies for construction machinery," *IEEE Access,* 2020.

[37] M. Safa and L. Hill, "Necessity of big data analysis in construction management," *Strategic Direction,* 2019.

[38] Y.-W. Zhou, Z.-Z. Hu, J.-R. Lin, and J.-P. Zhang, "A review on 3D spatial data analytics for building information models," *Archives of Computational Methods in Engineering,* pp. 1-15, 2019.

[39] N. Xu, J. Zhao, F. Xie, Y. Wang, and X. Zhang, "Study on Construction Planning for Bridge Structure Based on BIM Technology," in *2020 International Conference on Intelligent Transportation, Big Data & Smart City (ICITBS)*, 2020, pp. 219-223.

[40] A. Pennanen, G. Ballard, and Y. Haahtela, "Target costing and designing to targets in construction," *Journal of Financial Management of Property and Construction,* 2011.

[41] K. Graham, L. Chow, and S. Fai, "Level of detail, information and accuracy in building information modelling of existing and heritage buildings," *Journal of Cultural Heritage Management and Sustainable Development,* 2018.

[42] L. Chen, P. Shi, Q. Tang, W. Liu, and Q. Wu, "Development and application of a specification-compliant highway tunnel facility management system based on BIM," *Tunnelling and Underground Space Technology,* vol. 97, p. 103262, 2020.

[43] Ø. Mejlænder-Larsen, "A three-step process for reporting progress in detail engineering using BIM, based on experiences from oil and gas projects," *Engineering, Construction and Architectural Management,* vol. 26, pp. 648-667, 2019.

[44] H. Guo, Y. Yu, and M. Skitmore, "Visualization technology-based construction safety management: A review," *Automation in Construction,* vol. 73, pp. 135-144, 2017.

[45] C. N. Rolfsen and C. Merschbrock, "Acceptance of construction scheduling visualizations: bar-charts, flowline-charts, or perhaps BIM?," *Procedia engineering,* vol. 164, pp. 558-566, 2016.

[46] Z. Aziz, "Leveraging BIM and Big Data to deliver well maintained highways," *Facilities,* vol. 35, pp. 818-832, 2017.

[47] H. M. Chen and K. C. Chang, "A Cloud-based System Framework for Storage and Analysis on Big Data of Massive BIMs," in *ISARC. Proceedings of the International Symposium on Automation and Robotics in Construction*, 2015, p. 1.

[48] Y. Peng, J.-R. Lin, J.-P. Zhang, and Z.-Z. Hu, "A hybrid data mining approach on BIM-based building operation and maintenance," *Building and Environment,* vol. 126, pp. 483-495, 2017.

[49] Z. Lv, X. Li, H. Lv, and W. Xiu, "BIM big data storage in WebVRGIS," *IEEE Transactions on Industrial Informatics,* vol. 16, pp. 2566-2573, 2019.

[50] M. Marzouk and M. Enaba, "Analyzing project data in BIM with descriptive analytics to improve project performance," *Built Environment Project and Asset Management,* vol. 9, pp. 476-488, 2019.

[51] M. Yalcinkaya and V. Singh, "VisualCOBie for facilities management: a BIM integrated, visual search and information management platform for COBie extension," *Facilities,* vol. 37, pp. 502-524, 2019.

[52] A. A. Aibinu, F. Koch, and S. T. Ng, "Data analytics and big data in construction project and asset management," *Built Environment Project and Asset Management,* 2019.

[53] M. Munir, A. Kiviniemi, S. Finnegan, and S. W. Jones, "BIM business value for asset owners through effective asset information management," *Facilities,* 2019.

[54] B. Golzarpoor, C. T. Haas, D. Rayside, S. Kang, and M. Weston, "Improving construction industry process interoperability with Industry Foundation Processes (IFP)," *Advanced Engineering Informatics,* vol. 38, pp. 555-568, 2018.

[55] F. Bianconi, M. Filippucci, and A. Buffi, "Automated design and modeling for mass-customized housing. A web-based design space catalog for timber structures," *Automation in construction,* vol. 103, pp. 13-25, 2019.

[56] T. Hong, J. Langevin, and K. Sun, "Building simulation: Ten challenges," in *Building Simulation*, 2018, pp. 871-898.

[57] D.-k. Jung, D. Lee, and S. Park, "Energy operation management for Smart city using 3D building energy information modeling," *International journal of precision engineering and manufacturing,* vol. 15, pp. 1717-1724, 2014.

[58] X. Liu, N. Xie, and J. Jia, "WebVis_BIM: real time web3D visualization of big BIM data," in *Proceedings of the 14th ACM SIGGRAPH International Conference on Virtual Reality Continuum and its Applications in Industry*, 2015, pp. 43-50.

[59] D. Pasini, S. M. Ventura, S. Rinaldi, P. Bellagente, A. Flammini, and A. L. C. Ciribini, "Exploiting Internet of Things and building information modeling framework for management of cognitive buildings," in *2016 IEEE International Smart Cities Conference (ISC2)*, 2016, pp. 1-6.

[60] R. Santos, A. A. Costa, J. D. Silvestre, and L. Pyl, "Informetric analysis and review of literature on the role of BIM in sustainable construction," *Automation in Construction,* vol. 103, pp. 221-234, 2019.

[61] A. Asadzadeh, M. Arashpour, H. Li, T. Ngo, A. Bab-Hadiashar, and A. Rashidi, "Sensor-based safety management," *Automation in Construction,* vol. 113, p. 103128, 2020.

[62] S. T. Matarneh, M. Danso-Amoako, S. Al-Bizri, M. Gaterell, and R. Matarneh, "Building information modeling for facilities management: A literature review and future research directions," *Journal of Building Engineering,* vol. 24, p. 100755, 2019/07/01/ 2019.

[63] J. K. W. Wong and J. Zhou, "Enhancing environmental sustainability over building life cycles through green BIM: A review," *Automation in Construction,* vol. 57, pp. 156-165, 2015.

[64] E. Halmetoja, "The conditions data model supporting building information models in facility management," *Facilities,* 2019.

[65] C. Wijekoon, A. Manewa, and A. D. Ross, "Enhancing the value of facilities information management (FIM) through BIM integration," *Engineering, Construction and Architectural Management,* 2018.

[66] K. P. Kim and K. S. Park, "Housing information modelling for BIM-embedded housing refurbishment," *Journal of Facilities Management,* 2018.

[67] J. McArthur, "A building information management (BIM) framework and supporting case study for existing building operations, maintenance and sustainability," *Procedia engineering,* vol. 118, pp. 1104-1111, 2015.

[68] M. Inzlicht, A. Shenhav, and C. Y. Olivola, "The effort paradox: Effort is both costly and valued," *Trends in cognitive sciences,* vol. 22, pp. 337-349, 2018.

[69] E. A. Thomas, "Notes on effort and achievement-oriented behavior," *Psychological Review,* vol. 90, p. 1, 1983.

[70] D. Kahneman, *Attention and effort* vol. 1063: Citeseer, 1973.

[71] H. Penttilä, "Early Architectural Design and BIM," Dordrecht, 2007, pp. 291-302.

[72] S. Azhar, A. Nadeem, J. Y. N. Mok, and B. H. Y. Leung, "Building Information Modeling (BIM): A New Paradigm for Visual Interactive Modeling and Simulation for Construction Projects " presented at the First International Conference on Construction in Developing Countries Pakistan, 2008.

[73] S. Mihindu and Y. Arayici, *Digital Construction through BIM Systems will Drive the Re-engineering of Construction Business Practices*, 2008.

[74] M. Thomassen, "BIM & Collaboration in the AEC Industry," *Construction Management, Master's (MSc) Thesis (Released 31 August 2011), p. 120,* 2011.

[75] S. Kubba, *Handbook of green building design and construction: LEED, BREEAM, and Green Globes*: Butterworth-Heinemann, 2012.

[76] R. Volk, J. Stengel, and F. Schultmann, "Building Information Modeling (BIM) for existing buildings — Literature review and future needs," *Automation in Construction,* vol. 38, pp. 109-127, 2014/03/01/ 2014.