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INTEGRATION OF BIM AND CONSTRUCTION SUPPLY CHAIN THROUGH SUPPLY CHAIN MANAGEMENT; AN INFROMATION FLOW MODEL

A.P. Rathnasinghe[1*], M.K.C.S. Wijewickrama [1], U. Kulatunga[1], H.S. Jayasena [1]

[1]Department of Building Economics, University of Moratuwa, Moratuwa, 10400, Sri Lanka.
**Correspondence E-mail: akilapr1993@gmail.com, TP: +94765670054*

Abstract: Building Information Modelling (BIM) is a revolutionary stride of technology towards the orthodox construction and procedures in conventional Architecture Engineering and Construction (AEC) industry which is stressed for its delay on embracing new technologies. The strength of BIM has been disvalued on the eyes of many professionals as to think of BIM as just another 'software' which is in reality, a 'process' of attaining an outstanding collaboration among each and every stakeholder throughout a project's life cycle. Hence, the philosophy of Supply Chain Management (SCM) in a construction project can be achieved effectively with the BIM's promising of flexible and transparent interaction among Construction Supply Chain (CSC) contributors. However, the complexities in CSC of a conservative setup has been more composite with the intervention of BIM. Consequently, the BIM project stakeholders have been encountered with complications on the effective application of BIM on CSC while reaching the envisioned goals of BIM. Thus, the intention of this study is to develop a foreseeable information flow model related to construction supply chain of a BIM aided project. In order to attain the aim, an extensive literature synthesis was piloted to develop a conceptual informational flow model among CSC stakeholders of a BIM project. This contemporary research outlines that the CSC of a BIM project is much interactive and flexible with its collaborative effort of stakeholders in compared to the clashes among professionals in traditional setups. In practical context, the roles and duties of BIM project stakeholders identified in BIM standards, have been slightly differed due to practical complications in construction industry. Besides that, BIM standards have laid down charismatic arrangements on information flows among BIM project stakeholders, which is in reality, a complex and random setup. Hence, the research outcome has successfully answered the complications by laying down a guidance for any outsider to the BIM field as to recognise on what would be the contribution of each stakeholder throughout its BIM project's life cycle.

Keywords: *Building Information Modelling (BIM); PAS1192:2; Construction Supply Chain (CSC); BIM project stakeholders; Supply chain information flows.*

1. Introduction

The success of a construction project is usually due to its effective and efficient management of various knowledge areas. The areas identified are the major management knowledge areas in Organizational Management. Within the modern trends in global construction, Building Information Modelling (BIM) helps to substitute the customary procedures and implement innovation to the orthodox construction. BIM also acts as an 'Integrator' for all those aspects of management. Moreover, such quality of BIM would be more effective only with a clearly defined information flow among the project stakeholders. The development of a BIM model is based on coherent information feedings by said stakeholders. However, due to the vagueness in Construction Supply Chain (CSC), the defined information sharing, feeding or collection would be much difficult. This may result in reducing the productivity of BIM application too.

The paper comprehends the preliminary findings of the literature synthesis on how the information management among the BIM CSC stakeholders has been affected with the intervention of BIM standards as with special particulars to BIM Level 2 introduced by the United Kingdom (UK). Accordingly, the outcomes of the literature synthesis is illustrated in a mode of conceptual model as to express the information flows of BIM environment in a much structured manner.

21.Influence of BIM Towards The CSC

Construction projects establish the critical portion of all disciplines in projects focusing on their budget, multiplicity and cost (Rokooei, 2015). Moreover, Rokooei (2015) has highlighted the necessity of managing it, regardless of any financial scale of a construction project. Rokooei (2015) further extended the success criterion of construction project management into information management, where the successfulness could have been assured through aiding BIM.

Accordingly, modern Architecture Engineering and Construction (AEC) trade is multifaceted due to critical issues such as split nature in resources production, complexity in supply processes, constraints to construction and the outsized number of project stakeholders as of latest procurement pathways (Zavadskas, Turskis and Tamošaitiene, 2010). In view of that, the information supply chain concept is being used in investigating the contribution and dependence of stakeholders within project environment.

The concept of Supply Chain (SC) has been defined as "the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate customer" (Chirstopher, 2011, p.3). Consequently, Supply Chain Management (SCM) visions the entire supply chain as a process of production without been restricted to a single level, and expects to increase the transparency and logical alignment among the SC actors upon their interconnections which will not be limited on practical or commercial aspects (Cooper and Ellram, 1993). Besides, Mentzer et. al. (2001) further clarifies, SCM as a successful supervisory mechanism to manage the various flows of information and products within the project boundaries.

The implementation of BIM in the construction industry is appreciated by Robson, Boyd and Thurairajah (2014) as an expedition through the intelligence of building information up to the 'maturity' from the conventional 2D drawings at level 0, to the exclusively amalgamated 3D modelling in criterion of design, time and cost. However, Goh et al. (2014) underlined that BIM was conceived as a technological solution for problems related to the informational SC processes.

However, the traditional SCM intents at achieving naive and obvious interactions among the various stakeholders in SC, common profits and controlling the aforementioned project uncertainties (London, 2009). With the mandating of BIM in construction projects by the most of government authorities, the traditional SC of the construction projects was drastically changed due to the intervention of digital world to the orthodox construction and planning techniques. Accordingly, the British government has made a significant contribution towards introducing uniformed and consistent specification series, which is commonly practised in global context. Therefore, it is a worthy context to be investigated on how the information management among the stakeholders to be performed with this new technological interference of BIM as introduced by the British Standards on BIM implementation. This paper presents a literature synthesis aimed to identify a suitable information flow model for information management of a CSC of a construction project.

22. Research Method

This research seeks to address the research problem of "how the information management among BIM project stakeholders to be performed with the technological intervention of BIM in CSC" through a qualitative approach, as qualitative methods contribute to conduct in depth investigation on emerging concepts and is more appropriate, when the research has a trivial base of literature background. Accordingly, this research is mainly focussed on a thorough investigation of literature sources such as; BIM standards published by The British Standards Institution and other BIM related books, periodicals, and conference proceedings. Subsequently, the

outcomes have been illustrated in a mode of conceptual model which is totally based on BIM related literature.

23. Standard Practices of BIM and Their Effect on Traditional Construction Phenomena

As identified by Wickersham (2009), existing BIM-related standards provide a successful initiative to establish a collaborative BIM method. Further, McGraw Hill (2014) surveys suggested the high implementation of BIM should be effectively managed and controlled by introducing relevant standards depending on the project context.

However, mainly these BIM standards are paper-based standards (e.g. BS1192: 2007 and PAS 1192-1, 2 and 3), and IT related data exchange standards (e.g. COBie and IFC) (Smith, 2014). BIM implementation in the UK has improved gradually until the introduction of BIM policy by the UK government's BIM Task Group in May 2011 (HM Government, 2012). This transitional position has been called by the scholars as the BIM 'light bulb moment' for the UK construction (NBS, 2012). Henceforth, the UK is presently considered to be the most leading and influencing nation on global BIM resourcefulness (Saxon, 2013).

3.1 Publicly Available Specification (PAS) 1192-2:2013

This UK based specification is formed to manage the information with BIM which may arise during the supply stages of resources. Accordingly, it provides with a guideline to implement a BIM project and standard requisites on the Employer's Information Requirements (EIR) and the BIM Execution Plan (BEP) (Rock, 2018). Further, PAS 1192:2 describes the CDE upon its collaborative features to perform as an uniform stage for information distribution in between the task teams of different professional codes (Applecore Designs, 2016**).**

3.2 Significant Changes due to BIM Standards

Arayici, Egbu and Coates (2012) argued on BIM standards as it has made significant changes in predefined design instances regards of the documentation and management procedures of those design scenarios. Meanwhile, it is considered that those BIM values denote a mutual concern on utmost achieving of time, cost and quality triangle and employer's gratification (Takim, Harris and Nawawi, 2013). Lee (2008) highlights a different outlook on BIM as of reinventing the standard construction procedures, throughout a simulated environment which enables greater productivity, corporation and communication. Therefore, Takim et al. (2013) further appraised the implementation of BIM in AEC industry as a turnover point, which has improved the quality of life among stakeholders.

Even though, many authors suggest on achieving a greater efficiency through BIM implementation within the AEC industry, some have identified the limitations and issues in this scenario. Arayici et al, (2012) found out such limitation of BIM in the information congregation process where the final design proposal is solely based on the deliberation and user requirements which are poorly collected. As a remedy, Howard and Bjork (2007) highlighted on the importance of developing BIM standards which are compatible with industry's stakeholder requirements.

24. BIM Common Data Environment (CDE) and its Information Flows

The main pathway to achieve a well-organized data collection in a BIM-aided project is to have a CDE; a virtual platform managed by project team for assembling, handling and distributing digital information among themselves upon the requirement. Layout of a CDE is defined in the PAS 1192-2 specification which is the regulatory manual for public projects done in BIM Level 2. This guidance is based on the core principles of BS 1192: 2007.

As identified in PAS 1192:2, there are four main phases of a CDE. The first phase of CDE is 'Work in progress (WIP)' where data is currently in fabrication and has not yet been

checked and verified for use outside of the authoring team (Architectural, Engineering and Construction Council (AEC), 2018).

Once the WIP data has been checked, and approved by the particular stakeholder who does uploading and then those would be moved into the 'Shared' area. In this phase, other stakeholders may have in access and can use that information in the creation and development of their contributions. Under BIM Level 2, while the other stakeholders re-use the preliminary information, the ability to alter the information remains through its creator.

Once an individual WIP has been gone over the 'Shared' process, all other stakeholders of the BIM team may have already made their comments where the work has been matched and detected with any clashes with other personnel. Such piece of work will be suitable for publishing. 'Published' means the specific piece of information is the outcome to a particular client's information requirement. The outcomes of the Published or Issued area would deliver as 2D design format or Portable Document Format (PDF) drawings or data sheets, which would also be kept in the Published Area of the folder structure.

25. BIM Project Stakeholders

It is the common viewpoint that, BIM has established a rigid commitment based environment among the project members. Sebastian (2011), explained on the ideal status in BIM utilization can only be achieved through an effective collaborative environment consisted of multi-disciplinary professionals. Furthermore, Sebastian (2011) argued that this collaborative environment requires a clear administrative definitions on key roles rather than modifying them. Moreover, such environments will be successful through the rescheduled contractual relationships and re-engineered integration process.

a. Characteristics of BIM Project Stakeholders

Latest surveys revealed the necessity of engaging BIM skilled professionals for a successful BIM implementation (Allen Consulting Group, 2010). As mentioned by Olatunji (2011), experts with required professional skills can be gained with certain modifications and training to the conventional project professionals. Accordingly, the training of stakeholders should be compatible to comply with the specialized needs of BIM software.

Arayici et al. (2012), highlighted that BIM stakeholders should possess modern management skills with special concentration to external party support. Henceforward, research studies aim on an effective redevelopment of consultants within the BIM team who supports on completing milestones of the model.

As Ashcraft (2008) suggested, when producing a BIM model, the undivided commitment and care from the BIM project stakeholders is most important. The main aim of such collaborative environment should be to develop a comprehensive BIM model with less disputes among the project members. This point of view has been again discussed under BIM overlay to Royal Institute of British Architects (RIBA, 2012) as, expected job profiles and services to be performed by respective stakeholder within a BIM project.

b. Roles and Duties of BIM Project Stakeholders

Mostly, the arrangement of the BIM team and its members' copyrights will be settled by the end of project. However, on other hand, the expected usage of technologies and approaches may consider by the time of creating the model. Consequently, administration of BIM projects with such nature will be done by a panel of BIM experts consisted with BIM architects, BIM managers, model developers, and draftsmen (Olatunji, 2011). Even though, specific professional titles in BIM environment are still unexperienced to the conventional setup, the traditional professionals with BIM knowledge are still valuable as the substitutes to BIM job profiles.

As identified by Aranda-Mena et al. (2009), 'project manager' is one of critical BIM project team members which is be distinct with the BIM and technological interference Moreover, studies of Kassem et al. (2014), highlighted the role of 'BIM coordinator' as the main professional acts in behalf of the client with a professional liability and the job profile has been recognized by the BIM protocol as a central role in CDE.

CIC BIM protocol (2013) suggested that, lead designer and BIM coordinator should work in together as to embrace the contractual obligations related to the BIM model work distribution. Moreover, the protocol recommended on 'BIM manager' on regulating the administrative and procedural rules related to BIM model management as to preserve the collaborative nature and the duties attached with BIM concept. BIM overlay to RIBA (2012), introduced a number of professional profiles associated with the BIM project team as in Table 1 which are significantly different in compared to the traditional project team stakeholders.

Table 1: Identified duties of BIM Project Stakeholders

Job Title	Key duties within BIM environment
Main Designer/ Architect	Lead Architect is the person who ensures inter-relationships among various designs of task teams used in BIM environment. Moreover, lead designer is the main regulator on the accuracy of the information fed by the task team members to the shared model.
Client Representative	Briefly, a personality who represents the client at each phase of BIM project lifespan. Accordingly, the role is granted with limited decision making authority on project milestones, and power to assign minor project staff.
Technical Advisors	Technical advisors facilitate the construction professional staff and the client in understanding the technological aspects behind the BIM concept. Furthermore, the title holder is responsible with the upgrading of intelligent brief on the project plan.
Delivery Manager	Delivery managers are accommodated with the monitoring and supervising on the supply chain of the project whether the project is going along the intended progress of work. However, in practical context, the client's representative will replace with the role of delivery manager within the project team.

Source: Adapted from (BIM overlay to RIBA, 2012)

26. Information Flows in Construction Supply Chain Partnerships

A successful case study on communication amongst project and SC stakeholders with inspiration of BIM was conducted by Papadonikolaki, Verbraeck and Wamelink (2017). According to their outcomes, the communication among the SC stakeholders directs through the pre-defined channels as identified in their particular contract. The architect, the engineers and other identified main stakeholders would be continuously communicated over the contractor, where they have obliged to carbon copy on decision making through respective employment contracts.

Meanwhile, the supplier, who obliges with a 'chain contract' (SC framework agreement) to the contractor, may control a part of direct channels with subsidiary suppliers or engineers in behalf of contractor in ease of solving problems within an integrated environment. However, such communication is exclusively practiced among the engineers or suppliers correspondingly, where the consultants (architect, structural and mechanical) may not involve in. In contrast, the supplier vs consultant often communicates mostly on fiscal indecisions and build trust.

Further Papadonikolaki et al. (2017) recognised, the contractor's role towards the successful CSCM information establishment which would be impossible if it has been addressed from the monetary view instead of built trust. Moreover, lead designer holds a vital role in such information flows as he is the main outcome on explicating agreements on design and the material perspectives with the contractor.

27. Integration of BIM and Construction Supply Chain

As identified by Zavadskas et al. (2010), AEC industry is having a challenging SC because of split supply of resources, the building challenges and the increasing of project participants. Further, they suggested the deployment of BIM may neutralize such executive and bureaucratic impediments in the AEC SC.

Rezgui and Miles (2010) further commented on the use of inter-organisational IT, such as BIM to perform an effective CSCM. Therefore, they suggested the integration among BIM may cause an effective management of information flows of the SC, because BIM is a designed data model of building information (Eastman et al., 2011).

However, either the integration among those two concepts are vital to the effectiveness of the AEC industry, the organizational challenges due to this integration are not yet thoroughly reviewed by the scholars. In contemporary studies, BIM implementation and SCM integration are discussed only by means of theoretical aspects while not significantly involved in research process (Papadonikolaki et al., 2015). Accordingly, Flows of material, information, and the network of stakeholders are the main components to be considered in SCM.

a. BIM Integration with Information Flows and CSC Stakeholders

The definition on BIM by the National BIM Standard Project Committee, itself states BIM's relationship in assisting and controlling the information flows of a building (BuildingSMART, 2016). Accordingly, BIM provides with solutions for 3D modelling, interoperability and transparency in project decision making throughout the SC stakeholders. Furthermore, it provides an accessible podium for each project member to improve the harmonization among the stakeholders' decision making and feedback mechanisms while improving the traditional data management (Demian and Walters, 2014). However, while the impacts of the BIM models are still doubtful, Van Berlo (2012) recommends workarounds that provide reasonable BIM interoperability. Therefore, depending on above jurisdictions, it certifies BIM's effort on managing the information flows, a core feature of SCM.

28. Development of Flow Model for Construction Supply Chain's Information Flows

In developing the conceptual model as in Figure 1, it was profoundly concerned on the information management principles offered in PAS 1192:2 specifications, where it clearly represented out the relationships in between the documents and stakeholders in information management of a BIM project.

According to the readings, during the tender stage (Pre-contract stage), a forthcoming contractor to the project may develop a BIM Execution Plan (BEP) while validating their competence, and aptitude with evidences to fulfil Employer's Information Requirements (EIR). Accordingly, Pre-contract BEP makes the pathway to Project Implementation Plan (PIP) which is consisted of project goals for collaboration, information modelling and key project milestones and where they fit with the broader project programme.

However, when the most suitable contractor has been selected, he is required to develop a more comprehensive BEP while confirming SC's proficiencies. This is indicated in the conceptual model as the 'Post-contract BIM Execution Plan'. Furthermore, this Post-contact BEP arouses the need of 'Master Information Delivery Plan (MIDP)' which signifies on when and how the information is being produced. Meanwhile, it represents the responsible party's involvement in producing a piece of information and their probable use of standard protocols and procedures.

In general terms, BEP is the set of plans prepared by the respective suppliers of SC to signify on how the information modelling features of the BIM project are being sustained. Furthermore, BEP presents the solutions for the problems raised in EIR; the document consisted of standards,

procedures and information transmissions to be embraced by the respective contractor (supplier) as a part of continuing the project.

Furthermore, the final outcome as a MIDP is established on a compacted chain of individual Task Information Delivery Plans (TIDP), consisted of each team's tasks with layout, date and duties.

Accordingly, the combination of MIDP, BEP and the PIP, will form the BIM model based on the design and specification data provided by the lead architect and other task teams to the CDE. Henceforward, the traditional SC relationships among the contractor, suppliers and BIM task teams commence as illustrated in the bottom part of Figure 1.

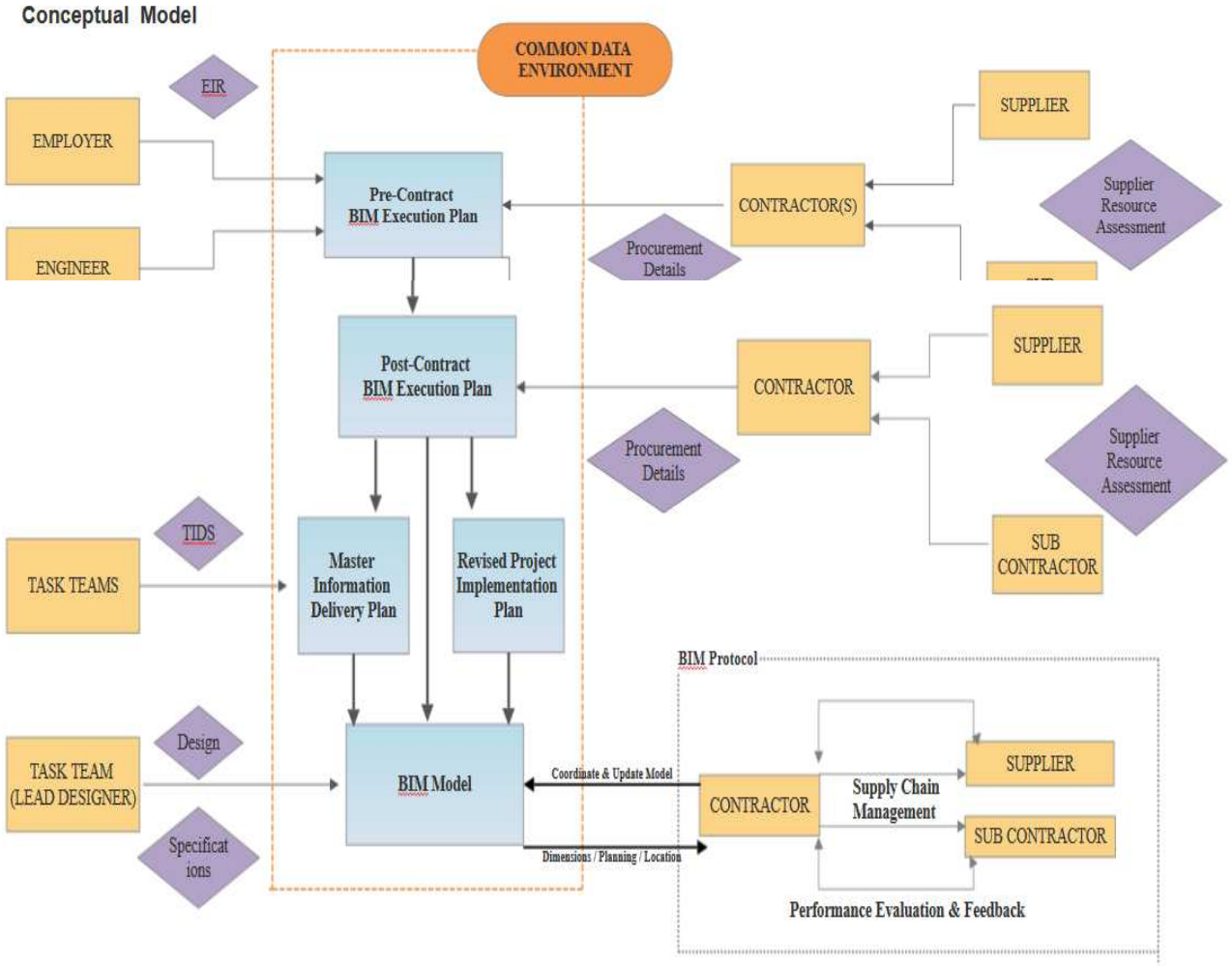

Figure 1 : Conceptual Information Flow Model

9. Conclusion

The comprehensive literature synthesis revealed the complexity of the CSC due to numerous dynamics and the intervention of BIM as an IT solution to the construction industry which is a later embracer on such contexts.

Furthermore, the paper discovered on the standard roles and duties of BIM project stakeholders and the composition of BIM project team as identified by the regulatory institutions. Accordingly, BIM related literature exposed on BIM specific job profiles such as; lead architect, client's representative, delivery manager and technical advisors.

Subsequently, as the BIM collaborative environment is technically called as the CDE, the literature proved that there are different flows among each and every stakeholder which makes it more complex to examine. Moreover, the standards had suggested technical stages of CDE and upon each stage standards had presented the flow of information from working stage to the published stage. Moreover, the works of scholars proved the effective management of

material and information flows can be ascertained through the integration of BIM with SC information flows.

Therefore, upon the outcomes on BIM project stakeholders of CSC and the information flows among them, a structure to the anticipated information flows for CSC of a BIM project was proposed as in Figure 1. Consequently, it was further developed with the assistance of researches in field of SC in BIM projects. As the model was totally based upon the literature outcomes, it was acknowledged as a conceptual model. In view of that, the model illustrated with main BIM project stakeholders and their anticipated information flows accordance with the informational outputs.

References

Allen Consulting Group (2010). *Productivity in the buildings network: assessing the impacts of building information models*. Built Environment Innovation and Industry Council. Sydney: Allen Consulting Group.

Applecore Designs. (2016). *The Eight Pillars of BIM Level 2 - Part One - Applecore Designs*. [online] Available at: https://www.applecoredesigns.co.uk/coreblog/pillars-bim-level2-part-one [Accessed 9 Nov. 2018].

Architectural, Engineering and Construction Council (UK). (2018). *AEC (UK) BIM Standard for Autodesk Revit*. [online] Available at: https://aecuk.files.wordpress.com/2010/06/aecukbimstandardforrevit-v1-0.pdf [Accessed 9 Nov. 2018].

Aranda-Mena, G., Crawford, J., Chevez, A. and Froese, T. (2009). Building information modelling demystified: does it make business sense to adopt BIM?. *International Journal of Managing Projects in Business*, 2(3), pp.419-434.

Arayici, Y., Egbu, C. and Coates, P. (2012). Building Information Modelling (BIM) implementation and remote construction projects: issues, challenges and critiques. *Journal of Information Technology in Construction (ITcon)*, [online] 17, pp.72-59. Available at: http://www.itcon.org/data/works/att/2012_5.content.03794.pdf [Accessed 9 Nov. 2018].

Ashcraft, H. (2008). Building Information Modelling: A Framework for Collaboration. *Construction Lawyer*, [online] 28(3). Available at: http://www.hansonbridgett.com/About-Hanson-Bridgett/press-and-news/~/media/Files/News/CL_HowardAshcraft_BIM.pdf [Accessed 9 Nov. 2018].

BuildingSMART. (2016). *Frequently asked questions about the national BIM standard-United States™*. [online] Available at: https://www.nationalbimstandard.org/faqs [Accessed 9 Nov. 2018].

Christopher, M. (2011). *Logistics and supply chain management*. London: Prentice Hall.

CIC BIM Protocol (2013). *CIC BIM Protocol*. London: Construction Industry Council.

Cooper, M. and Ellram, L. (1993). Characteristics of Supply Chain Management and the Implications for Purchasing and Logistics Strategy. *The International Journal of Logistics Management*, 4(2), pp.13-24.

Demian, P. and Walters, D. (2013). The advantages of information management through building information modelling. *Construction Management and Economics*, 32(12), pp.1153-1165.

Eastman, C., Teicholz, P., Sacks, R. and Kathleen, L. (2008). BIM Handbook: A guide to Building Information Modeling for owners, managers, designers, engineers and contractors. *Construction Economics and Building*, 12(3), pp.101-102.

Goh, K., Goh, H., Toh, S. and Peniel Ang, S. (2014). Enhancing communication in construction industry through BIM. In: *Proceedings of the 11th International Conference of Innovation and Management*. [online] pp.23-35. Available at: http://eprints.uthm.edu.my/6696/1/Enhancing_ Communication_in_ Construction_Industry_through_BIM.pdf [Accessed 9 Nov. 2018].

HM Government (2012). *Building Information Modelling, Industrial Strategy – Government and Industry in partnership*. London: Government Report.

Howard, R. and Bjork, B. (2008). Building information modelling – Experts' views on standardisation and industry deployment. *Advanced Engineering Informatics*, 22(2), pp.271-280.

Kassem, M., Iqbal, N., Kelly, G., Lockley, S. and Dawood, N. (2014). Building Information Modelling: Protocols for Collaborative Design Processes. *Journal of Information Technology in Construction (ITcon)*, [online] 19, pp.126-149. Available at: http://www.itcon.org/data/works/att/2014_7.content.00672.pdf [Accessed 9 Nov. 2018].

London, K. (2008). Industrial Organization Object-Oriented Project Model of the Facade Supply Chain Cluster. *Construction Supply Chain Management Handbook*, pp.13-1-13-46.

McGraw-Hill Construction (2010). *The business value of BIM in Europe*. Smart Market Report. [online] Bedford: McGraw-Hill Construction. Available at: http://images.autodesk.com/adsk/files/business_value_of_bim_in_europe_smr_final.pdf [Accessed 9 Nov. 2018].

Mentzer, J., De Witt, W., Keebler, J., Min, S., NIx, N., Smith, C. and Zacharia, Z. (2001). Defining Supply Chain Management. *Journal Of Business Logistics*, [online] 22(2). Available at: https://www.biblioteca.fundacionicbc.edu.ar/images/e/e4/Conexion_y_logistica_2.pdf [Accessed 9 Nov. 2018].

NBS (2012). *BIM Legal Roundtable Discussion*. [online] NBS Website. Available at: http://www.thenbs.com/roundtable/legal/bimLegalRoundtable_2012.asp [Accessed 9 Nov. 2018].

Olatunji, O. (2011). Modelling the costs of corporate implementation of building information modelling. *Journal of Financial Management of Property and Construction*, 16(3), pp.211-231.

Papadonikolaki, E., Vrijhoef, R. and Wamelink, H. (2015). Supply chain integration with BIM: a graph-based model. *Structural Survey*, 33(3), pp.257-277.

Rezgui, Y. and Miles, J. (2010). Exploring the Potential of SME Alliances in the Construction Sector. *Journal of Construction Engineering and Management*, 136(5), pp.558-567.

Robson, A., Boyd, D. and Thurairajah, N. (2014). UK Construction Supply Chain Attitudes to BIM. In: *50th ASC Annual International Conference Proceedings*. [online] Birmingham: Birmingham City University. Available at: http://ascpro.ascweb.org/chair/paper/CPRT224002014.pdf [Accessed 9 Nov. 2018].

Rock, S. (2018). *Construction: The eight pillars of Level 2 BIM*. [online] Herbert Smith Freehills - Real estate development notes. Available at: https://hsfnotes.com/realestatedevelopment/2016/05/04/the-eight-pillars-of-level-2-bim/ [Accessed 9 Nov. 2018].

Rokooei, S. (2015). Building Information Modeling in Project Management: Necessities, Challenges and Outcomes. *Procedia - Social and Behavioral Sciences*, 210, pp.87-95.

Royal Institute of British Architects [RIBA] (2012). *BIM Overlay to the RIBA Outline*. London: Author.

Saxon, R. (2013). *Growth through BIM*. London: Construction Industry Council.

Sebastian, R. (2011). Changing roles of the clients, architects and contractors through BIM. *Engineering, Construction and Architectural Management*, 18(2), pp.176-187.

Smith, P. (2014). BIM Implementation – Global Strategies. *Procedia Engineering*, 85, pp.482-492.

Takim, R., Harris, M. and Nawawi, A. (2013). Building Information Modelling (BIM): A new paradigm for quality of life within

Architectural, Engineering and Construction (AEC) industry. In: *Proceedings of AMER International Conference on Quality of Life*. Langkawi, Malaysia: Universiti Teknologi MARA (UiTM), pp.23-32.

Van Berlo, L. (2012). Collaborative engineering with IFC: new insights and technology. In: *Proceedings of 9th European Conference on Product and Process Modelling*. Iceland: Blackwell Publishers.

Wickersham, J. (2009). *Legal and Business Implications of Building Information Modelling (BIM) and Integrated Project Delivery (IPD)*. USA: Rocket Publishing Ltd.

Zavadskas, E., Turskis, Z. and Tamošaitienė, J. (2010). https://journals.vgtu.lt/index.php/JCEM/article/view/5898. *Journal of civil engineering and management*, 16(1), pp.33-46.