The Construction Value Chain in a BIM Environment

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Abstract. This paper provides the findings of a research project aiming to understand the current level of industrial awareness, challenges and lessons learned during the application of the BIM (Building Information Modelling) across the construction value chain. A literature review was conducted to gather the state of the art and latest trends about BIM fundamentals, different elements in a BIM application, BIM dimensions and BIM maturity levels, as well as the associated standards. Furthermore, the BIM environment was investigated and information related to the construction value chain was gathered as the foundation to carry out a field study in which 29 organizations located in six countries were interviewed through face to face sessions with different actors involved in variety of roles across the construction value chain to enable an interdisciplinary and global understanding.

Keywords: Construction value chain · BIM environment · Full collaboration

1 Introduction

Several actors are involved in construction projects, such as architecture designers, structure designers, system designers, material providers, contractors, end users and more. Typically, each project member has a different vision of the final asset, as the organization is involved in a different stage of the project and uses a different software, making it difficult to have a common understanding and an integrated and complete overview and data model. Different kinds of issues, such as isolated work, differences between reality and the client's vision, delay in delivery, additional costs and more, might occur at any phase of the project lifecycle (Design and Engineering, Construction, Operation, Maintenance and Demolition) due to the lack of communication and collaboration between all these actors. Therefore, there is a need to have a single representation of the asset to help create one common and shared vision. Hence, the construction community gave rise to the concept of building information modelling [1, 4, 5, 12].

Building Information Modeling (BIM) might be misunderstood, referring to it as the software with which companies design their individual components up to the fully integrated construction asset. Nevertheless, BIM goes beyond a technology, it requires

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I. Moon et al. (Eds.): APMS 2018, IFIP AICT 536, pp. 255–262, 2018.
https://doi.org/10.1007/978-3-319-99707-0_32

a radical change in the mindset of how a construction project is carried out. One definition for BIM proposed by the World Economic Forum [17] is stated as follows: "BIM is a collaborative process in which all parties involved in a project use three-dimensional design applications, which can include additional information about assets' scheduling, cost, sustainability, operations and maintenance to ensure information is shared accurately and consistently, throughout total assets' lifecycles."

Adopting BIM requires an important change in the way the different actors involved in a construction project work together. Those actors represent the construction value chain. This paper presents a view of what the construction value chain could look like when collaborating in a BIM environment to help achieve benefits, such as cost and waste reduction impacting on faster projects delivery, risk reduction and more. The opportunity BIM is providing to the construction sector is the co-creation of one shared 3D-Model representing the physical and functional characteristics of an asset, including information that is frequently added, extracted, updated or modified, to provide a standardized information exchange. Therefore, BIM enables the integration of all the elements of the construction assets and therefore allows different actors to collaborate during the different stages of the construction project providing a way for an integrated team to make informed decisions. However, given that working approach is relatively new and has only recently become widely diffused, not all actors across the construction value chain have fully adopted BIM. Many clients still see BIM as merely a design tool and do not realize all its capabilities and advantages like, for example, in maintenance operations, where the data will be available and updated to schedule maintenance activities when required. BIM is one of the key drivers enabling the construction industry moving towards digitalization and the industry and government have started noticing its capabilities [1, 4, 5, 7, 8, 15].

This paper presents the summarized results of a BIM (Building Information Modelling) study that was conducted at Cranfield University, in collaboration with the Lean Analytics Association, and focuses on understanding the construction value chain within a BIM environment and on capturing the best practices in the industry as well as identifying the importance of its members.

Therefore, the research question to be answered by this study is as follows:

What is the current level of industrial awareness in the construction value chain about the application of BIM and which are the important enablers?

The research methodology is divided into the following four phases: Learn, Energize, Apply and Diffuse (LEAD). In the *Learn* phase, a literature review was conducted to obtain the state of the art of the current BIM fundamentals and BIM applications. In the *Energize* phase, a questionnaire was designed to help perform semi-structured interviews in a field study to capture current information from the industry. The data analysis of the field study in the *Apply* phase supported the understanding of the industrial perspective of BIM and its applications, and provided a general view of the construction value chain within a BIM environment. Finally, a final presentation, poster and this paper were developed as a part of the *Diffuse* phase.

2 BIM Fundamentals

A BIM model represents the physical and functional characteristics of an asset and consists of sub-models and BIM objects. Sub-models represent a model of one particular discipline, such as an architecture model, a structure model or a system model, and joining them together creates the actual BIM model. The National Building Specification points out that a BIM object represents the physical and functional characteristics of one component of the asset and contains geometric, technical, admin and functional information. Furthermore, a BIM application provides different elements, such as the modeling element, the technical element, the construction admin element, the simulation element and the business element. The modeling element includes the geometric modeling (2D and 3D) to visualize the shape of the buildings and their internal systems, such as the electrical system, the plumbing system etc., as well as the structure, system and clash analysis. Engineering data, such as material selection and specifications but also tolerances, are part of the technical element, whereas the construction admin element includes the bill of materials, the project plan, cost estimation, scheduling etc. The simulation of end-user operations, the management of the asset, environmental efficiency, sustainability, emergency and disaster events and the acoustic system are part of the simulation element, whereas the business element includes the feasibility study, contracts and legal management, return on investment, risk assessment etc. Different companies have managed to achieve different levels of implementation and integration of these elements, as well as different levels of collaboration. In a BIM environment, these are referred to as BIM maturity levels and dimensions [1, 5, 11].

As shown in Fig. 1, four maturity levels from 0 to 3 exist, where level 0 represents the lowest level of collaboration and is based on 2D and paper. It is very much a representation of the traditional manner in the construction sector and its disadvantages. Level 1 is an enhanced maturity level, where a 3D CAD model is developed and used to share the asset data but important technical and admin data is still missing. Level 2 is the start of real effective collaboration, where the BIM models consist of geometric, technical and admin data. Even though all actors use their own 3D CAD models, collaboration is achieved through sharing design information using a common file format. Typical dimensions for this level are 4D (time-related information and construction sequencing) and 5D (added cost aspect such as the purchasing, running and replacement cost). Level 2 has become compulsory as part of the government strategy in many countries such as the UK, the US, Singapore, etc. and several national and international standards have been developed. As visualized in Fig. 1, the UK has established four standards (BS1192, BS 7000, BS8541, PAS1192), required to complete work at level 2. However, the standards for level 0 and level 1 must also be met as fundamentals of level 2. In order to prove that companies work at level 2 and to obtain the trust of their clients and other actors of the value chain, certifications from formal standard bodies, such as BSI, are needed. However, at the moment, a BSI certification is not necessarily accepted by other countries, which puts the pressure on construction companies to have more certifications from different national standard bodies within the different countries they operate in. Therefore, creating international standards accepted by all actors in the construction value chain all over the world is the next necessary step. Level 3 is the top level and means full collaboration and full integration. There is only one shared model all parties across the construction value chain have access to in order to enable modification and improvement in real time. As visualized in Fig. 1, three new dimensions are associated with this top level. 6D is focused on the lifecycle management of the building and 7D is focused on sustainability. Finally, 8D represents accident preventions in which the UK government is very interested at the moment. Even though the UK government plans to reach level 3 by 2025, this is very optimistic from an industrial perspective [2, 3, 7–11, 14].

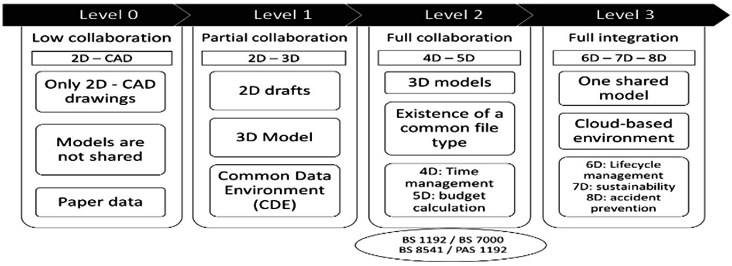

Fig. 1. BIM levels, dimension and required standards

Furthermore, in order to work properly in a BIM environment, every actor is required to use the same software to integrate the specific BIM elements for the work performed enabling the interoperability of data across the construction value chain. Currently, companies use more than one software to perform different types of work, such as concept design, architecture design, structure design and system design. This happens because designers are trained and have a lot of experience in a specific traditional software (non-BIM software) and feel uncomfortable working with any other kind of software even though its technical capability is higher than the traditional one's. This results in designers who do the same work twice, because the first design of the asset is done using traditional software and, subsequently, the whole asset is created a second time with a BIM software to add the technical and construction admin data and enable the actual collaboration. This results in additional time and increased cost which works against the expected benefits of using BIM. As of now, there is no single software available in the market capable of sufficiently covering every part of a project. This emphasizes the importance of efficient data exchange between the different BIM software applications. One of the findings was that the commercial software Revit, from Autodesk, is mainly used in the six countries within the scope of our research project: United Kingdom, Spain, Ireland, France, Saudi Arabia and Singapore and provides advantages in the structure and system design since it was developed by engineers. The second most used software is Archicad from Graphisoft which is preferred in architecture design since it was developed by architects and provides similar tools to traditional software. Another very important criterion for selecting a BIM software is its technical capability and the fact that this is the software used by the client. Using the same software across the construction value chain provides a lot of advantages as far as data compatibility is concerned, since open file formats such as IFC still cause a loss of data and, consequently, additional time and cost [1, 6, 15]. Figure 2 shows that from the sample of construction actors interviewed, 71.4% of the interviewees are using Revit and Fig. 3 the key challenges to implement.

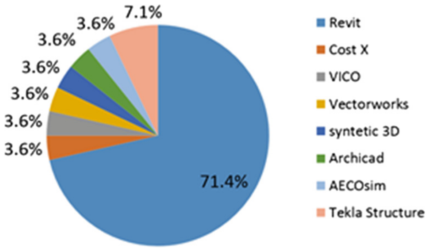

Fig. 2. BIM softwares used

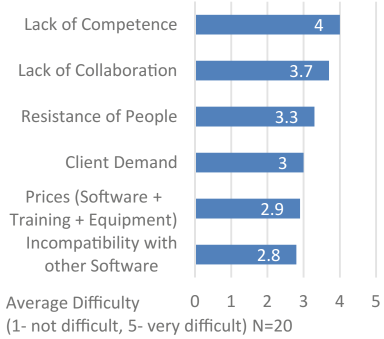

Fig. 3. Main BIM implementation challenges

3 The Construction Value Chain in a BIM Environment

Having understood the BIM environment, it appears that the focus lies on the end-to-end construction value chain, which integrates many different actors, each one providing value to the overall construction project. While the ideal construction value chain is perceived as linear with little complexity, the real construction value chain is a web of relationships and is, thus, complex and not linear. However, this work assumes a linear value chain including only the main phases: Design & Engineering, Construction, Operation, Maintenance & Renovation, and Demolition. These main phases have been identified through the literature review. A field study was conducted to understand the current industrial perspective of the construction value chain and to capture the current best practices and challenges in the industry.

A questionnaire was designed to help perform semi-structured interviews. In order to obtain sufficient amount of quantitative and qualitative information, interviews with diverse companies took place across six different countries around the world, including the United Kingdom, Ireland, France, Spain, Saudi Arabia and Singapore. These interviews involved actors from all disciplines across the construction value chain as well as directly related organizations, reaching the number of 29 companies: Architecture & Engineering (5), Construction (8), Consultancy (5), Materials & Elements Suppliers (4), Software, Standard and BIM Object providers (3) and Universities (4). Interviews were supported by a BIM expert from each organization. The respondents were BIM managers or designers in the case of architecture & engineering or construction companies, the person in charge of BIM applications when referring to materials & elements suppliers or software, standard and BIM object providers as well as professors and research fellows from architecture and engineering schools in the case of universities. This enabled the development of an interdisciplinary and global understanding of the construction value chain [13, 15, 16]. To gather quantitative information, the following question was asked:

Which of the following represents an important actor of the construction value chain in a BIM environment?

The result of the evaluation of the data collected for this question is visualized in Fig. 4, where the numbers represent the importance of ten given options corresponding to actors of the construction value chain in a BIM environment. The lowest relevance is represented by 1, the highest by 5. The graph demonstrates that the most important actor is the owner or investor, who is essential for the project to be launched. BIM enables a more efficient way to convince investors to start a project by providing more accurate information about cost and time at an early stage, as well as visualizing the final asset through augmented or virtual reality. Designers take the second place. At the moment, BIM is mainly used in the design phase as its true capabilities in terms of enabling full collaboration and the related benefits have not yet been recognized by all actors across the construction value chain. Even though BIM entails many benefits to improve maintenance, many owners still think BIM is merely a design tool. Maintenance might become more popular in the future when full collaboration and integration has been achieved and the mindset of each actor across the construction value chain has changed to see BIM not as a mere design tool but as an enabler of collaboration and integration. Suppliers are important for the construction value chain, but less important in a BIM environment. The reason for this is that the contractor determines the needed amount of goods and materials and sets the actual order. In terms of supplier selection, the contractor also has the final say and designers can only express their preferences. Finally, the demolition contractor has the lowest importance as an actor in the construction value chain in a BIM environment. That can be explained by the currently low number of companies in this field that are using BIM. However, this might also change in the future when BIM has reached its full maturity across the construction value chain. Figure 4 provides the findings showing which actors have a major role fostering a BIM collaborative environment.

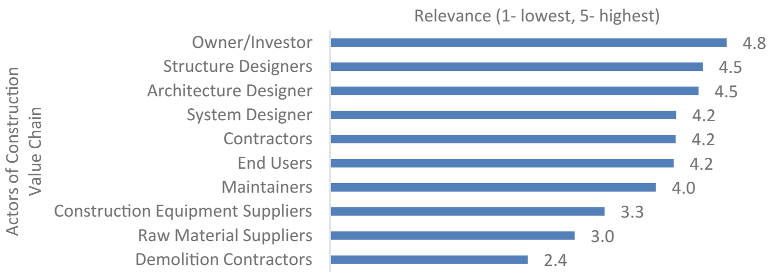

Fig. 4. Relevance of construction value chain actors fostering the BIM environment

The final construction value chain is visualized in Fig. 5. All actors have access to the BIM model as a single source of information, and each actor uses the model to finish their own work in the most efficient way. BIM can be used to design and analyze the asset, the structure (Finite Element Analysis) and the systems, such as the electrical system, the plumbing system, the climatic system, the acoustic system and the IT system (Mechanical and Electrical Analysis). Furthermore, the user experience should also be part of the design phase to provide an optimal solution. The main contractor but also subcontractors should use the same BIM model which provides everyone with the same information and enables off-site manufacturing, which also results in benefits such as time, cost, and risk reduction. The owner, operator and user of the building are provided with all asset information needed to use and manage it in the most efficient way.

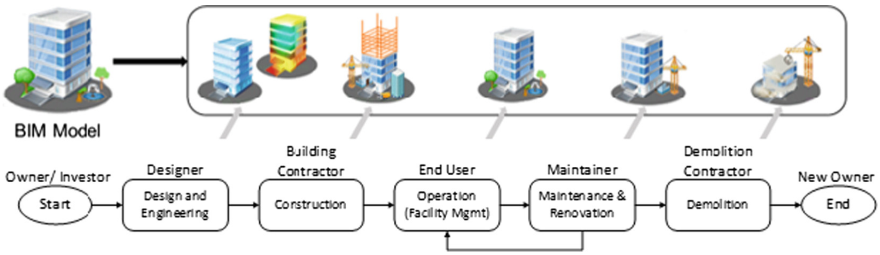

Fig. 5. Construction value chain in a BIM environment

Furthermore, BIM enables the creation of an accurate maintenance plan to prevent failures more efficiently and to eliminate them as fast as possible in case of any occurrence. However, as mentioned earlier, the different actors across the construction value chain have still not fully understood how to realize all benefits of BIM in terms of maintenance. Furthermore, even though BIM has not been fully implemented in the demolition industry yet, demolition contractors can use BIM to easily identify the best way an asset could be demolished. All these benefits are for the long term and are only achievable if BIM is fully adopted across the construction value chain and if the BIM applications are used properly to enable collaboration. Current challenges are the resistance to change, a lack of competence and expertise, incompatibility with other software and missing IT infrastructure [13, 15, 16].

4 Conclusion

The understanding of the reviewed literature related to the construction value chain and the captured industrial perspectives shown in Fig. 4 have led to the definition of the value chain in the BIM environment illustrated in Fig. 5. Therefore, gaining the real benefits of BIM by achieving full collaborations among the different construction actors is possible by understanding the construction value chain. This understanding should include the individual role and responsibilities as well as the value adding activities to the final definition and construction of the asset. Furthermore, this level of full collaboration has not yet been achieved, since not all actors in the value chain have successfully adopted BIM or realized and understood its capabilities. As many governments are pushing the industry towards full collaboration and integration, all actors across the construction value chain will have to improve their BIM adoption and consistently implement it at each project to achieve this level within the expected time frame.

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