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IMPACT OF FRAGMENTATION ON VALUE GENERATION-TOWARDS A BIM-ENABLED LEAN FRAMEWORK

Donya Mehran [1], Erik Andrew Poirier [2], and Daniel Forgues [3]

ABSTRACT

Fragmentation in the construction sector has been identified as a main concern by several scholars over the years as it creates silos not only between the actors and stages across an asset's lifecycle but also across a portfolio of projects. Among other things, fragmentation has a negative impact on the flow of information between participating organizations, thereby affecting value generation. Despite the rising digitization of this sector, these challenges remain and even compound issues such as the effective management of information throughout the built asset's lifecycle. Research and development pertaining to the management of information and generation of value has mainly focused on separate phases of assets or the delivery stage. However, a gap in knowledge and theory for information management and requirements management throughout the use phase of the asset's lifecycle still remains. This paper highlights the consequences of fragmentation from an information management perspective and its impact on value generation across an asset's lifecycle.

KEYWORDS

Lean construction, value stream, benefits realization, BIM, Fragmentation.

INTRODUCTION

The Architectural, Engineering, Construction and Operations (AECO) industry has a highly fragmented structure despite the vast amount of information created, managed, and used across an asset's lifecycle (Fellows & Liu, 2012). This structural fragmentation, or separation between asset phases, is recognized as a major source of challenge within the construction sector. It negatively influences project performance, productivity, knowledge production, and innovative solutions and increases the complexity of the interaction of actors (Forgues et al., 2009).

The fragmentation (separation) between project phases and asset lifecycle management is well documented in the literature by many scholars (Koskela, 2000, Hoeber and Alsem, 2016; Forgues et al., 2009). However, the fragmentation (separation) between the Construction and Operation and Maintenance (O&M) phases across the asset lifecycle is, as of yet, poorly defined (Figure 1).

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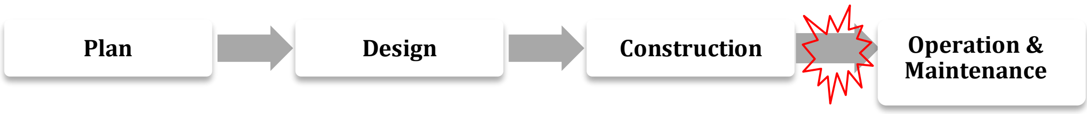

Figure 1: Fragmentation across asset lifecycle between project construction and O&M phase

The main cause of this fragmentation is the project management approach, in which the building asset lifecycle divide into independent phases, known often as planning, design, construction, and operation and maintenance (O&M). Also, fragmentation is observed in the relationships between multiple stakeholders, as they come from different disciplines and are involved in each phase but often have limited communication, interaction, and information exchanges among themselves. The management of information flow across an asset's lifecycle is known as asset lifecycle management (ALM) (Hoeber &Alsem, 2016). Information processing is a key part of ALM, but it is often error-prone and inefficient. For example, information may get lost over different phases as it is copied to other structures or stored without a consistent and predefined structure. Consequently, inadequate information management (IM) throughout an asset's lifecycle will lower the potential for value generation (Kagioglou et al., 2000).

Ensuring the value creation across an asset's lifecycle in the construction sector, while considering the involvement of many stakeholders with different backgrounds and objectives, requires having a common ground and mutual understanding of the "value concept" or "expected value" of construction projects (Zhang & El-Gohary, 2016; Drevland et al., 2018). This can be achieved only through effective collaboration and communication, which are efforts that depend on the willingness to compromise within the position or authority of different stakeholders (Khalife and Hamzeh, 2019). Of all the stakeholders involved across an asset's lifecycle, asset owner representatives, or asset managers, have the highest power of authority, which means they have a significantly influential role in value creation.

The critical role of asset managers stems from their financial involvement in the built asset's lifecycle, and their role shifts from the consumer of information during the design and construction phase to information management during operation and use. Thus, it is essential to leverage their benefits realization and ensure their investment can generate value that responds to their business needs. The asset owners are investors, but they also develop the requirements at the start of a project and expect other stakeholders (planners, designers, contractors) to deliver them. However, avoidable factors, such as lack of understanding of the asset owner's requirements and inaccurate information circulating among supply chain organizations, lead to value loss.

Several studies on productivity, efficiency and construction performance worldwide have led to technological advancements and the development of standards and guidelines that support their implementation (i.e., ISO19650). Many of these have been developed to enable seamless and continuous information exchange (IE) and information flow across the asset lifecycle to improve the AECO sector’s performance (Tzortzopoulos et al., 2020). While inefficient information management (IM) hinders the total potential value that could be gained, the solution is to apply available technologies, and IM is recognized as a strong catalyst for digital transformation in organizations (Succar & Poirier, 2020). As pointed out by KPMG (2021, P.14), *"Effective IM allows organizations to do more (output) with less effort (labour and materials inputs) – freeing up resources to either do more of the same or re-deploy those resources towards more productive activities."*

In response to this challenge, along with the demand for more complicated structures within the AECO sector's market (i.e., requirements for more efficient and effective information exchange with the use of technologies), new theories and approaches, such as Lean Construction (LC) and Building Information Modelling (BIM) have emerged within the AECO industry (Tzortzopoulos et al., 2020). The combination of Lean Construction and BIM application, a new view of information flow and value generation presents an opportunity to improve new and different information management within the construction domain. This paper aims to provide a deeper understanding of the impact of Fragmentation on the generation of value in the built asset industry and frame lifecycle information management as a potential avenue to reduce this impact.

A review of the papers published by the IGLC website indicated that fragmentation within the construction is not addressed in a broad range of topics. Thus, this research has several objectives. It aims to provide insight into the impact of fragmentation during the operational and use phases of an asset's lifecycle from the asset owner's perspective. It also aims to provide an overview of the importance of efficient information management across the lifecycle of assets, its relation to value generation, and the need for a framework for practitioners and scholars within the Lean Construction Community. Considering the authors are currently conducting further research on the same subject. The research questions are as follows: 1) How does fragmentation across the asset lifecycle hinder value creation from an information management (IM) perspective, and 2) what response is required to overcome these challenges, both from a pragmatic and hypothetical point of view? To answer these questions, the research presented in this paper consists of an in-depth literature review on the impact of various types of fragmentation on information management (IM) and their impact on value generation for asset organizations.

This paper draws attention to the consequences of fragmentation between the construction and operation phase on information flow and exchange across the asset lifecycle and justifies the need for a new framework to improve value generation. Thus, this paper highlights the value loss for construction professionals caused by inefficient information management due to existing fragmentation, both in theory and practice. It is worth noting that this research paper is a first step towards understanding the need for a new framework for the efficient management of information and explicit identification of value generation approaches and future research endeavours.

FRAGMENTATION ACROSS BUILT ASSET LIFECYCLES

Fragmentation within the construction sector is recognized as one of the significant challenges related to performance, delays, cost overruns, low satisfaction, etc., within the construction sector worldwide (Riazi et al., 2020). Godager et al. (2021) stated that the term "fragmentation" is the separation between project phases or working in silos, and the same definition is considered in this paper. The AECO sector is prone to three types of Fragmentation (Fergusson 1993) known as horizontal, vertical and longitudinal (Fergusson 1993; Poirier 2015). Figure 2 illustrates the three types of fragmentation in the construction industry: Horizontal fragmentation refers to the actors at a specific stage of a project, vertical fragmentation occurs between project stages, and longitudinal fragmentation occurs as project actors disband towards the project completion. As stated by Hall et al. (2014, P.3), *"Team members lose tacit knowledge about how to [….] This result in a learning disability and slows innovation diffusion."*

This paper will focus on a type of fragmentation part of vertical fragmentation situated between the construction and operation phases. Consequently, the information derived from the construction stage will not be useful for the operation stage and Facility Management (FM) team. The next section explains the role of technology to overcome or facilitate resolving the associated challenges.

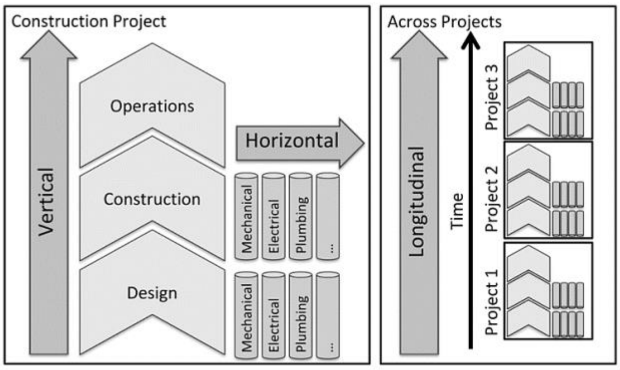

Figure 2: Three types of Fragmentation in the AEC industry (Figure 1 in Hall et al. 2014)

The impact of digitalization on fragmentation

Fragmentation hinders information flow and knowledge sharing among the project actors (Fellows & Liu, 2012), which results in information loss across the project stages (Teicholz, 2013). Among the 46 fragmentation issues within the construction sector identified in the study by Riazi et al. (2020), three are shown to be dominant (the first being the highest dominant and the third the lowest), as follows: 1) isolation of project professionals-geographically distributed at different locations, 2) the sequential nature of construction processes execution, and 3) confrontational culture between project parties.

To overcome challenges associated with fragmentation within the construction sector and improve information flow and management, Information Technology (IT) has come onto the construction industry scene by challenging the traditional ways of managing the re-evaluation of building asset lifecycle and creating integrated virtual temporary organizations (Betts 1999). Furthermore, many Information and Communication Technologies (ICT), such as BIM, Artificial Intelligence (AI), Augmented Reality (AR), Internet of Things (IoT), etc., have been adopted by the AECO sector to provide opportunities for efficient and effective information flow across all asset lifecycles. Whereas IM is often referred to as capture, re-use and sharing among stakeholders (Xu et al. 2014), Godager et al. (2021, p.42271) refer to IM as *"[...] [IM] is about ensuring that the right information is available when needed at the right destination at the right time to fulfil a specific purpose."*

One of the main challenges of fragmentation in the construction domain refers to further separation and disconnection between the on-site and off-site stakeholders. Despite technological advancements to facilitate information flow among stakeholders, regardless of their geographical location, and due to the willingness of stakeholders with various motivations in terms of conflict in economic incentives, unequal access to information and desire to spread the risk cause further separation challenges among stakeholders. As stated by Sacks et al. (2010b, p.56), *"The industry has failed to connect the "last mile" of information flow, between the office and the site, effectively."* Because construction projects are composed of many temporary stakeholders with different motives and have conflicts in economic incentives with various access levels to information, it is difficult to achieve smooth, continuous, and efficient information flow (Tzortzopoulos et al. 2020). Furthermore, Forgues et al. (2009) refer to socio-cognitive factors related to the behaviours of different stakeholders, which hinder collaborative working. It is difficult for stakeholders with various specialties and backgrounds to speak a common language in a project. Thus, the lack of common language among stakeholders is another challenge within the AECO sector because of its impact on communication and information flow (Jallow et al., 2014, p.506). Thus, as Forgues (2009, p.54) states, *"[...] technology proved to be sometimes more a nuisance than a benefit to collaborative work."*

Indeed, this next section will examine the challenge related to information interoperability issues caused by technological tools. For example, BIM is introduced into the construction domain to enhance information sharing, communication, and a set of interoperable technologies at the project level, but it does not address the issues of interoperability with and between asset management-related technologies (Poirier, 2015). Gallaher et al. (2002) state that inadequate interoperability and information exchange costs more than $9B during the O&M, compared to $2.6B during planning and design and $4B during construction. Asset owners and facility operators often store information received from the construction phase at handover and do not use it, and the FM tools are used without their being connected to the information received from previous stages (design and construction). But mostly, there are information interoperability issues between the various software platforms, or the FM team is unable to use information from previous stages properly (Godager et al. 2021).

Digital transformation strategies for the construction industry need to be integrated from the beginning (Godager et al., 2021). Their technological capabilities are not yet sufficiently advanced to overcome challenges associated with interoperability. This results in challenges and resistance to the efficient implementation of BIM during the O&M stage and the preference for manual and ad-hoc approaches among FM operators. As in the past, facility managers are not readily adopting new technologies for the O&M stage (Heaton et al., 2019): the BIM-enabled projects are not able to benefit from information stored during design and construction in the operation stage due to a lack of FM knowledge and their rare involvement from the beginning of the projects. Therefore, digital technologies and IT have entered the construction sector with the aim of improving the information flow among stakeholders to promote value creation. Hence, many organizations have invested in adopting and applying digitization across the asset lifecycle. However, information interoperability and the varying motives of stakeholders involved within the construction domain do not allow full potential value achievement of available technological improvements. This is mainly because digital advancements and transformation strategies require integration at their core (Godager et al., 2021). Thus, the next section provides further details about the consequences of fragmentation on value creation.

THE IMPACT OF FRAGMENTATION ON VALUE GENERATION

Value Concept - An Overview

First, it is essential that the meaning of the term "value" be clear, as various stakeholders are involved in the AECO industry, each with different backgrounds, objectives, and values (Khalife & Hamzeh, 2019; Drevland et al., 2018). There is a need to ensure that the value of all stakeholders involved is aligned with the asset owner organization's perspective on value. The term "value" also has several meanings in the literature, such as orals, standards, and rules, which reflect the behaviour of individuals and have an impact on the assessment of individuals within projects and services. Moreover, value is defined as benefits, or more specifically, it is defined as what you give and what you get, or cost minus benefits . Due to the importance of the concept of value within the AECO sector, there is an increasing demand to improve environmental, social, and economic value (Zhang & El-Gohary, 2016). According to the axiology-based value analysis study of Zhang & El-Gohary 2016), the National Research Council (NRC) addresses value understanding and assesses its influence on decision making as a "national imperative" (NRC, 2009). However, Drevland et al. (2018, p. 31) state, "*Value should be considered as something that fathoms more than the very narrow needs-based view that is common in much of the LC literature*." Thus, Drevland et al. (2018) define value as an evaluative judgement, where the judgment is based on the values and the evaluator's available knowledge. Similarly, Khalife and Hamzeh (2019) address the dynamic nature of value due to multi-disciplinary stakeholders within the construction sector. The dynamic nature of value is addressed in the conceptual framework developed by Khalife and Hamzeh (2019) (Figure 3). As construction projects are prone to change, any change in the scope, budget, organizations involved, and mode of operation would have an impact on other factors as all these factors are interrelated (Khalife & Hamzeh, 2019).

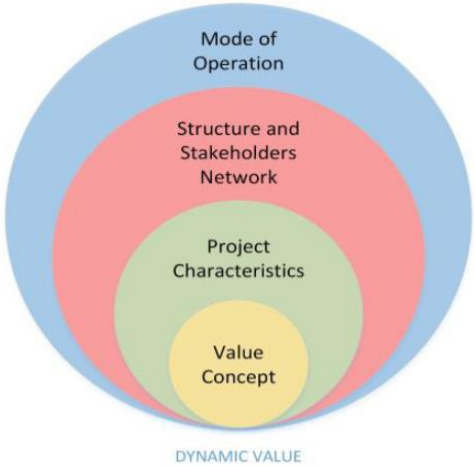

Figure 3: Integration of value-related aspects rendering value as dynamic (Figure 2 in Khalife & Hamzeh, 2019)

In this paper, the term "value generation" refers to the definition of both Lean Construction and BIM. On the one hand, according to Lean Construction pundits, value generation is the main goal of every project (Koskela 2000) as the client's business needs are linked to the client's business requirements within a project (Dave et al. l. 2013). To ensure value generation based on LC, Koskela (2000) identified five principles: 1) ensure all customer requirements are captured; 2) confirm all information required is progressively transformed to the next stage without disconnection in the information flow; 3) make sure all requirements of customers have guidance and direction to be followed; 4) ensure there is enough capability to deliver requirements; 5) certify the value is generated for the customer. On the other hand, from the perspective of business value and BIM, there are six categories: management, commercial, efficiency, industry user and technology, as defined by Munir et al. (2019). Table 1 shows in which dimensions BIM may have a positive impact and enable values to benefit at the organizational, end-user, and economic levels along with productivity, ecosystem, and functionality improvement.

Table 1. BIM Business value in Asset Management (Adapted from Munir et al. 2019)

No.	Value Category	Value benefits description according to value category
1	Management	Organizational– Enable value at strategic, tactical, and operational levels for organizations.
2	Commercial	Economic – Improve financial performance and profitability.
3	Efficiency	Productivity – enhance operations in AM.
4	Industry	Ecosystem – enable delivery of exclusive or collective functionalities and services.
5	User	End-User – Improve daily tasks for individuals.
6	Technology	Functionality – enable 3D visualization, real-time coordination, interactive real-time reporting, etc.

Impact of Fragmentation on value generation

Fragmentation, that is, the separation between project the construction and operation and use phases of construction assets, causes value loss as oftentimes, operators are not knowledgeable enough to use information derived from the construction phase for operations, so a lot of information is unusable by the operator's team. For asset owners, this has an impact on the achievement of total potential value and leads to value loss. On the one hand, asset owners are aware of technological innovations and are willing to invest in technologies to generate the "best possible value." On the other hand, due to interoperability and information exchange challenges along with a lack of operator knowledge on how to use information from the design and construction phases, the rate of return on investment (ROI) drops, causing value loss. However, set in their ways, facility managers are resisting the adoption of new technologies for the O&M stage (Heaton et al., 2019) and prefer manual and ad-hoc approaches. Hence, Information Flow and Information Quality, despite the existing trend in Information and Communication Technology (ICT) (Tzortzopoulos et al., 2020), are impacted, and this results in value loss.

Another challenge triggered by Fragmentation pertains to the asset owners' poor requirements management (RM), which causes value loss. The limited ability to identify and understand the asset owners' requirements, which refer to expectations, needs, wishes and objectives, and their coordination with other actors cause value loss. The challenges associated with the asset owners' requirements are stated by Jallow et al. (2014, p.506) as:

- Absence of a defined approach to managing and sharing asset owners' requirements
- Lack of storage and repository of asset owner's information requirements
- Insufficient coordination, sharing and control of required information
- Absence of a structured and standardized approach to change management
- Lack of interoperability and integration of change management systems with requirements management

The PAS1192-3 and ISO19650 address the information requirements (Munir et al., 2020) and present the relationship between precontract documents, which are Organizational Information Requirements (OIR), Asset Information Requirements (AIR), Employer Information Requirement (EIR), and post-contract documents of Project Information Model (PIM) and Asset Information Model (AIM). When the OIR is being developed, accordingly, the AIR is created, and as a result, the EIR is generated. Upon the contract award, the PIM contributes to AIM, and generally, the AIR document generation is from the bottom-up, meaning it is a technical document generated for the FM operators' use only. Most often, the financial, environmental, and reputational aspects of OIR are missed.

The lack of alignment of OIR with asset AIR to be used during the O&M stage causes value loss due to the absence of asset information AIR generation (Heaton et al., 2019). During the early stages of the project or many asset owners are not aware of what information is required for their operational stage for effective Asset Management (AM) purposes (Munir et al. 2019). The main reason for this is that asset owners usually get overloaded with information that is difficult or impossible to filter to ascertain the essential information needed to perform FM/AM tasks (Munir et al., 2019). Even with the availability of standards, such as BS1192, PAS1192-3:2014, and ISO19650 series, which recommend the development of OIR, the challenge still remains. Mostly, this is because there is a very limited application for AIR development in the industry. Also, most organizations set aside the development of the OIR, or if they do develop one, it contains technical information that is not usable and/or is challenging for the FM operators to use (Heaton et al., 2019). As stated by Heaton et al. (2019, p.14), *"Asset-related information that is not collected in alignment to the organizational requirements will restrict the performance of capital investment decisions, risk management and operational performance throughout the whole life of the asset portfolio [...])."* Thus, access to information– that is, having accessibility to the required information at the required time – causes the project many inefficiencies in terms of extra cost (Eastman et al., 2011).

PROPOSED SOLUTION DOMAIN - TOWARDS A BIM-ENABLED LEAN FRAMEWORK

The construction industry's performance and success factors are not limited to cost, time, quality, safety, and customer satisfaction. The success of the construction sector relies on meeting expectations of plan, design, construction, scope, budget, and asset owner satisfaction, which falls within the notion of value. The construction sector's asset management is changing through the application of BIM and Lean construction (LC). In a sense, enabled by technological advancements, BIM is a collaborative process that aims to optimize project delivery across a project's lifecycle. Similarly, Lean construction is a management philosophy aimed at creating value and eliminating non-value-added activities. Although both BIM and Lean construction originated from different domains, both approaches have made a positive and noteworthy impact on the AECO industry (Dave et al., 2013; Tzortzopoulos et al., 2020)

Several scholars have pointed out the beneficial application of both BIM and LC (Dave et al., 2013). As Tzortzopoulos et al. (2020, p.32) state, "*The links between BIM and Lean have attracted much interest since 2011."* Eastman et al. (2011, p.386) stated, "*The Lean construction and BIM are likely to progress hand-in-hand, because they are complementary in several important ways.*" Moreover, Eastman et al. (2011, p.298) stated, *"[...] there is a strong synergy between LC and BIM, even the use of BIM facilitates fulfilment of lean principles."* The use of an integrated LC and BIM workflow improves information flow across the asset lifecycle and benefits all organizations involved in the process. In other words, the workflow will be improved through the synergy of both BIM and LC. When acknowledging the impact of Fragmentation on the flow of information along with understanding the vital role of asset owners within the AECO sector, it is essential to address the management of requirements, information flow, accessibility, quality and alignment of the owner's requirements with the project deliverables across the asset lifecycle. Amongst all the stakeholders involved in the AECO sector, building asset owners play a vital role in the value generation of assets as they are at the forefront of procurement and operations of assets. To ensure the owner's project requirements (OPR) are addressed across the asset's lifecycle and ensure access to the correct information at the required time, a continuous exchange of information between the owner and all other actors is to be maintained in an electronic document, located on a cloud repository. Thus, the basis of a conceptual building performance evaluation (BPE) model as an innovative approach for the asset lifecycle is illustrated in Figure 4 by Preiser & Vischer (2005), which will be adopted as a foundation for project stages and feedback loops.

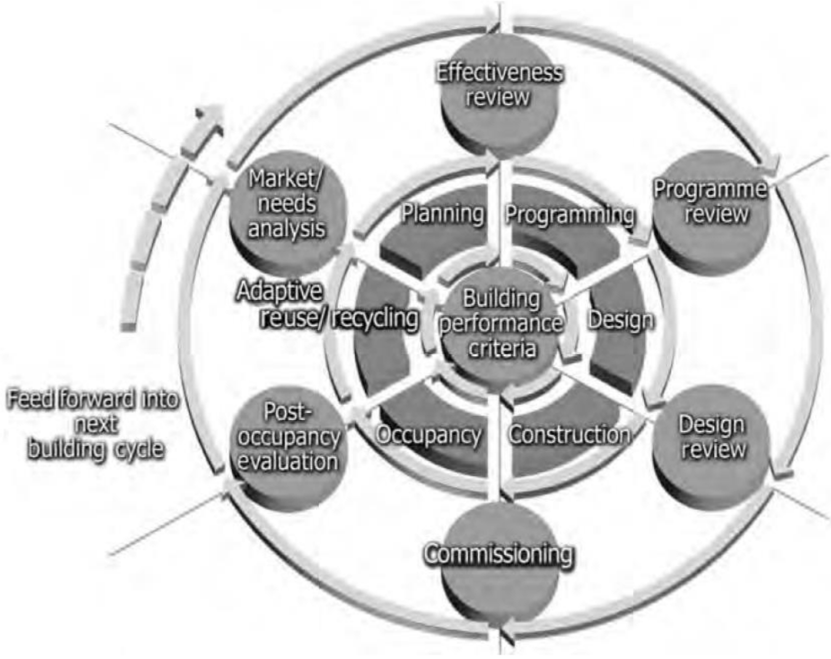

Figure 4: Building performance evaluation (BPE) process model. (Figure 2.1 Adapted from Preiser & Vischer, 2005)

Hence to overcome the challenges influenced by Fragmentation between the construction and operation phases of the asset's lifecycle and redefine the construction industry's business model regarding the management of information to maximize the generation of value, there is a need for a new framework. Thus, Table 2 presents a summary of the fragmentation challenges to be addressed and their relationship with their associated influence on information management and value generation, based on the two concepts of BIM and LC. As a canvas to develop a framework to help ensure efficient information management across all asset lifecycle, a feedback and evaluation loop at every step is needed, which requires an asset owner's (or asset owner representative's) evaluation and assessment.

This will also ensure that asset information requirements will be based on the FM team's requirements for operation and maintenance. Finally, to overcome the challenge of an information repository, a cloud-based CDE template will be devised to ensure efficient information exchange across organizations and preserve the rights of the asset owner in terms of security, data ownership and intellectual property (IP). There will be feedback and evaluation loops between each project phase to ensure all of the owner's requirements are communicated across all organizations involved.

Table 2. Summary of fragmentation issues and their influence on IM and Value

Criteria	IM Dimension			Value-based on LC and BIM						
				LC	BIM					
Points of consideration to overcome fragmentation challenges	Flow	Accessibility	Quality	Client Satisfaction	Management	Commercial	Efficiency	Industry	User	Technology
Ensure availability of information repository	×	×		×					×	×
Ensure development and update of Brief document at an early stage		×		×						
Facilitate RM through feedback and assessment loop at every milestone/phase	×		×	×	×		×		×	
Ensure development of OIR document at an early stage				×						
Ensure AIR development at an early stage aligned with the FM/AM team of operations	×	×	×	×	×		×	×	×	×
Consider 7 stages of asset lifecycle based on the PAS1192 document	×			×						
Address cloud-based common data environment	×	×	×	×	×				×	×
Ensure the FM/AM team's knowledge of using BIM models for operations purposes				×						
Ensure information security, IP, ownership		×	×	×	×	×			×	
Ensure collaboration among teams virtually	×	×	×	×	×		×	×	×	×
Ensure information interoperability between the platforms, if possible			×	×	×	×	×		×	×

CONCLUSION

This research focus on the fragmentation between the construction and operation phases of asset lifecycle and their effect on value generation from an information management perspective. A conceptual solution is subsequently proposed through application of both BIM and LC notions as a response to overcome the challenges caused by inefficient information management, mainly for asset owners. According to the literature, the integration of BIM and LC could enable the effective and efficient management of information across the asset's lifecycle and improve value generation. Value is referred to in seven categories, namely: asset owners' satisfaction, management, commercial, efficiency, industry, user, and technology. Future research and modes of evaluation and testing of the need for a framework in this paper are currently in progress by the authors at the conceptual level. Thus, the literature review presented in this paper will be used as a theoretical foundation to construct the basis of the consequences of Fragmentation on value generation. This will be further detailed using actual case studies from Canada. It is worth acknowledging the limitations of the present work, as this paper is at the theoretical level, and further research should be conducted for its practical application.

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