Digital Transformation in Asset Management – A Case of BIM Adoption in New Zealand Local government

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Abstract –

Digital technologies are taking place in all spheres of the society and affecting every business sector including the construction industry. As a key player of the industry, local government in New Zealand invests in numerous digitalised Asset Management Information Systems (AMIS) in order to efficiently and effectively manage its infrastructure assets that are critical to the local economy and social wellbeing. However, the silo nature of the organisational operations and proprietary constraints of AMIS have created challenges to the system's interoperability and asset information sharing. Recognised as a key driver behind digital transformation in the industry, BIM has the potential to provide a holistic solution to system integration and fundamentally change the current asset management practices. Based on a tree-pillared framework observed in the existing studies, where the three key aspects, i.e., business models, operational processes, and end-user experience are used as a development roadmap, this study creates a BIM-based digital platform, namely the Asset Management Common Data Environment (AMCDE) model that can integrate multiple systems to improve AM process interoperability and data sharing. Using a case study of a BIM implementation project carried out by a local government in New Zealand, this study demonstrates the development and validation of the AMCDE model. The novel BIM use presented in the study contributes empirical evidence in addressing the sector's siloed manner of business operations, as well as sets the foundation for future studies in local government's digital transformation such as developing the true asset Digital Twins.

Keywords – Asset Management Information System; BIM; Digital Transformation; Common Data Environment; Local Government

1 Introduction

The advent of digital technology has dramatically changed routines and practices in most areas of human activities. Digital technologies bring about "disruption" in the marketplaces where businesses operate [1]. To enable business agility and changing the way people work in order to optimise business performance to stay competitive, companies have undertaken transformation through adopting digital technologies that provide the game-changing opportunities and reduce existential threats to business [2]. Subsequently, digital transformation is generally taking place in all spheres of the society and affecting every business sector [3]. These transformations have had an impact to enable major business improvements by enhancing customer experience, streamlining operations or creating new business models [4, 5].

While technological innovation and disruption is nothing new, it is widely accepted that the increasingly pervasive nature of technology disruptions and the pace of change will create significant opportunities for countries like New Zealand to achieve a productive, sustainable, and inclusive economy [6]. Consequently, as one of the country's largest infrastructure asset owners and the biggest client of the construction industry, New Zealand local government plays a key role in transforming the traditional business models into digitalised forms. Asset managers are increasingly turning to 'digital' to help deal with the complexity and multi-disciplinary nature of the infrastructure asset management. In particular, the local government sector invests in numerous computerised Asset Management Information Systems (AMIS) such as Computer Aided Maintenance Management (CAMM), in order to support their infrastructure asset operations and management decision-making. However, the segmental nature of the organisational operations and proprietary constraints of AMIS have resulted in multiple information systems being sourced and operated in different locations across the whole organisation in a silo fashion [7].

In recent years, the emergence of Building Information Modelling (BIM) has made dramatic changes in the design, construction, and operation processes of buildings and other physical assets [8]. BIM has been envisaged uses in each stage of an asset's lifecycle management [9, 10]. The diffusion of BIM technology has transformed the construction industry towards more digitalised operation environment; therefore, it is not a question of "if", but rather "when" and "how" to adopt and implement BIM in asset management practices. Despite the urgency that practitioners and researchers present to the industry on taking the digital transformation journey through BIM adoption, however the adoption rate is low where BIM use in asset management practices is absent from both the industry practices and research with few studies showing the "how". Apart from the various barriers and obstacles such as cultural, organisational, and lack of real cases [11], the missing of a strategic transformation roadmap also contributes to the slow transformation pace.

In past years, various studies have contributed to the theoretical and practical knowledge base in the domain of digital transformation. For example, Fitzgerald, et al. [5], Westerman, et al. [12] argue that digital transformation is more than just a technological shift [4]. Instead, the transformation affects every aspect of an organization, from the business models, operational processes, to the user experience. The transformation building blocks or the "three pillars" as described by [12], are identified as the vital motivational factors for digital transformation [8], thus providing a strategic roadmap for those organisations that plan to take the transformation journey. On the other hand, the existing studies have largely focused on the enterprises or businesses where customer satisfaction, market demand, and business competitiveness are identified as the key drives for technologies adoption, while studies of digital transformation in none profit driven organisations such as the local governments are limited and the research in asset management is even rarer. In addition, although the digital transformation has entailed a wide range form of technologies including, Cloud, Internet-of-Things (IoT), Blockchain (BC), Artificial Intelligence (AI), and Machine Learning (ML), which constitute a bulk of what is being adopted by organisations as part of their innovation effort, yet technologies with specialties such as AMIS and BIM lack for research in the realisation of transformation projects, thus requiring particular attention.

By examining the existing studies and applying the established theories and concepts, this study intends to explore the opportunity for BIM use in asset management and discuss how digitally transform the current management models and process to improve AMIS interoperability and data sharing. Using the three-pillar transformation concept, this study aims to 1) develop a planning model built on a digital platform as the single information source; 2) create a BIM-enabled asset management common data environment (AMCDE) to integrate the existing planning process and AMIS, and 3) to develop an end-user friendly interface within the AMCDE to support information access, analysis, and decision-making. The development process and research findings are validated through a case study of a BIM implementation project undertaken by a New Zealand local council. In addition to providing a much-needed real project case, which is limited and incomplete in the current BIM/AM studies, this research contributes to the industry's digital transformation in particular the adoption of BIM by integrating multiple systems that are commonly implemented independently and operated in a silo fashion, thus creating a new business model by digitalising and integrating the existing asset management processes and multiple AMIS deployed across the organisation. The AMCDE model is fully scalable to further include a wider range of digital technologies, such as CAMM, BMS, and IoT applications, that can be used to develop a true asset Digital Twin operation environment, thus helping the organisation achieve the full scope of digital transformation.

2 Background

Local governments and other public entities worldwide play an important role in taking stewardship and custodianship responsibilities of public infrastructure assets that are fundamental to the local economy [7]. Their responsibilities have also been reinforced further to promote the local communities' well-being beyond the economic aspect by satisfying social, environmental and cultural requirements. Collectively, local governments in New Zealand owned $123.4 billion worth of the built assets and had an annual operating expenditure of $10.3 billion in 2018 alone [13]. Among those assets, the public building and community facility assets accounted for 9% of the total capital expenditure. The public buildings and community facilities, defined as the "social infrastructure", form part of the ecosystem of the overall construction industry, which constituted 13% of the global GDP [14], is ranked the largest industry in the world. Consequently, adopting a systematic and structured approach helps asset owners manage these public assets more efficiently and effectively.

In the past 20 years, the concept and best practices of asset management have been widely adopted in the local government sector in New Zealand and other developed countries. In particular, long-term lifecycle planning has been recognised as one the key asset management principles to support a resilient and sustainable built environment. Furthermore, with the long-term uncertainties, asset lifecycle planning becomes increasingly complex and sophisticated. Thus it requires the right asset information and tools to enable asset managers to make the right decisions, at the right times, and for the right reasons [15]. Subsequently, local governments are obligated to adopt and implement digital technologies such as a AMIS to support decision making [7].

2.1 Asset Management Information Systems (AMIS)

An AMIS is a computer-based system which is designed to assist the user for the asset management function [16]. It is a combination of process, data, software, and hardware applied to provide the essential outputs for effective asset management [15]. Most asset intensive organisations such as the local government that own or operate buildings or facilities in long term have a significant existing portfolio, thus it requires some forms of AMIS to manage the FM/AM information. The purpose of implementing an AMIS is to enable asset managers to "plan, monitor, and control" all maintenance that impact on staff and financial resources and the lifecycle performance of the fixed assets. These AMIS serve asset owners with different functions such as asset registers, Computer Aided Maintenance Management (CAMM), Geographical Information Systems (GIS) and asset lifecycle planning [17]. The AMIS are also specialised in different types of assets, such as roading, water supplies, and public buildings. Given the speciality of AMIS, asset owner is relying heavily on different and incompatible systems to various management activities, ranging from operations, maintenance and repairs, space management, to asset valuations and long-term strategic planning etc, [18]. In addition, the fast-growing asset data in both the quantity and variety terms have resulted in multiple information systems being sourced and operated in different locations across the whole organisation in a silo fashion [7].

The diversity in software tools, which are proprietary in nature, has not only created the interoperability and collaboration issues, but also presented challenges to the end-users that have to face multiple systems with various level of technical knowledge and skills required. Although using a consolidated enterprise management system based on the existing business model to integrate the financial, customer service, and asset management functions into a single interface have been adopted by some, the integrated system is not yet widely adopted simply because of the cost and complexity to operate and maintain the system [19]. Therefore, there is a great desire to create a unified business model based on a centralised information platform that can bring disparate information and systems together to enable asset managers and end-users to coherently manage their assets.

2.2 Building Information Modelling (BIM)

In recent years, BIM has become more and more used in the construction industry. BIM is described as a coordinated set of processes [20], supported by technology that add value through the sharing of structured information for buildings and infrastructure assets. In a more thorough description, Sacks, et al. [21] claim that: *"BIM supports support design through its phases, allowing better analysis and control than manual processes. When completed, these computer-generated models contain precise geometry and data needed to support the construction, fabrication, and procurement activities through which the building is realized."* As a shared knowledge resource for information, BIM forms a basis for decisions in each stage of the facility's lifecycle [9], ranging from the phases of design, construction, to operation, and maintenance [10]. Benefited from the enhanced system interoperability and asset lifecycle synchronous collaboration, the adoption of BIM has resulted in various management improvements, from cost and time savings, reduced errors and omissions, reduced rework, to maintained repeat business and enhanced construction productivity [22]. Unlike most of the specialised AMIS, BIM's capabilities of object 3D modelling, open access to information, data visualization, and multidisciplinary integration [23], enhance the interoperability of different systems and collaboration among the stakeholders, thus streamlining operational processes and management activities at the strategic, tactical and operational levels [24].

Nevertheless, despite BIM's immense technical advantages and potential benefits, the use of BIM worldwide still falls considerably short of its capabilities, and the rate of BIM adoption is much lower than expected [25], in particular in the operation stage where BIM is still perceived by many as merely a design assistance tool, rather than a lifecycle management system [26]. Overall, the current practices in asset management have not fully embraced BIM technology. Further observations from the authors indicate that an asset planning process integrated with BIM has not yet been developed, nor the related literature been published. While various barriers such as cultural and organisational and lack of real cases reasons for BIM adoption have been extensively studied, however, developing a road map to guide how BIM can be adopted is missing from the practices and BIM studies.

2.3 Digital Transformation and the Three Pillars

Digital technology has become central to how the business operates, thus leading to organizations to effectively re-think and possibly re-invent their business models in order to remain competitive [27]. Defined as a process that aims to improve an entity by triggering significant changes to its properties through the integration of information, computing, communication, and connectivity technologies [3], the term of Digital Transformation refers to a broad concept affecting a wide knowledge domain concerning politics, business, and social issues [28]. Various studies expose that digital transformation affects every aspect of an organization. For example, [5, 12] summarise that digital technology can expect to improve business performance in at least three areas, namely, better customer experiences and engagement, streamlined operations, and new lines of business or business models. In addition to these three key areas, [4] also emphasise digital capability as the fourth element, of which the capability of Information Technology (IT) enables managers to adapt their business strategy to the digital reality, by integrating new technologies in their business models and operation processes. While studying digital transformation in the public sector, [29] acknowledge a set of five factors, namely, strategy, leadership, workforce skills, digital culture, and user focus that shape the path to digital transformation from an organisational perspective. Digital transformation's success thus depends on operational process and management changes, not only by doing something completely new, but also by taking advantage of digitising the existing operations and processes, i.e. to turn existing products or services into digital variants, and thus offer advantages over tangible product and services [30].

By examining the existing studies, it can conclude that, although the current trend of research is largely focusing on the enterprises or businesses where customer satisfaction, market demand, and business competitiveness are identified as the key drives for technologies adoption, it does however set a roadmap to guide digital transformation not only for businesses that are market and profit-driven, but also for non-profit organisations such as local governments, by emphasising session, followed by the case study that demonstrates and validates the findings of the AMCDE framework. the three key elements described as building blocks or "pillars" of transformation [12], they are: business models, operational processes, and experiences of users that can be either external customers or the employees who make the business operate and have first-hand insights on where processes need to improve [31]. The Three Pillars provide a theoretical framework to support organisations to shape their transformation strategies.

3 Research Methodology

In this paper, we investigate local governments as the public client responsible for managing large public property portfolio and community facilities and examine how they use the "three pillars" as the organisation's digital transformation roadmap for their BIM adoption. This research applies a qualitative method with a mixed approach to include literature review, workshop, and case study methods.

The research data was collected through author's observations and a project stakeholder workshop during a BIM implementation project carried out in the case study as described in Section 4. The first author of this research had observed the overall implementation process, as well as reviewed the relevant documentation including the case owner's asset management policies, procedures, database, and the organisation's BIM implementation strategies and plans that help authors foster the conceptual framework of AMCDE. The first author also participated in the workshop designed for understanding the owner's current asset management practices, establishing project information requirements, and obtaining feedbacks of the proposed AMCDE during the workshop, where discussions and outcomes were noted. The participants of the workshop included the owner appointed project manager, a BIM manager from the consultancy firm, and the owner's facility management staff as the potential user group.

Using the "three pillars" as the transformation development reference, this research describes Pillar One to represent the AMCDE framework, a new business model in asset management decision making. Then the process of developing the AMCDE shows the integrated BIM and AMIS as Pillar Two. And last, Pillar Three is a machine/user interface created using a novel BIM-GIS interoperability solution that enhances user's experience with 3D visualisation and easy data access portals. Each of the three pillars is described in Figure 1 to 3, followed by the case study that demonstrates and validates the findings of the AMCDE.

3.1 Pillar One – Business Model

Pillar One of the transformations is to develop the business model built on a digital platform as the single information source. Figure 1 illustrates a conceptual model of AMCDE, which enables various building asset management functions to be performed through an integrated platform. The AMCDE determines and describes asset data flows and the relationship between building hierarchy, BIM, AMIS, and asset management decision-making framework throughout the in-use stage of an asset lifecycle planning system. The conceptual framework will enable the geometric models and asset database to be mapped to the CDE, of which the data then are fed to AMIS such as Computer Added Facility (Maintenance) Management (CAFM & CAMM) systems, Building Management Systems (BMS), or other Application Programming Interface (APIs) etc., for analysing, processing, and optimizing to support an

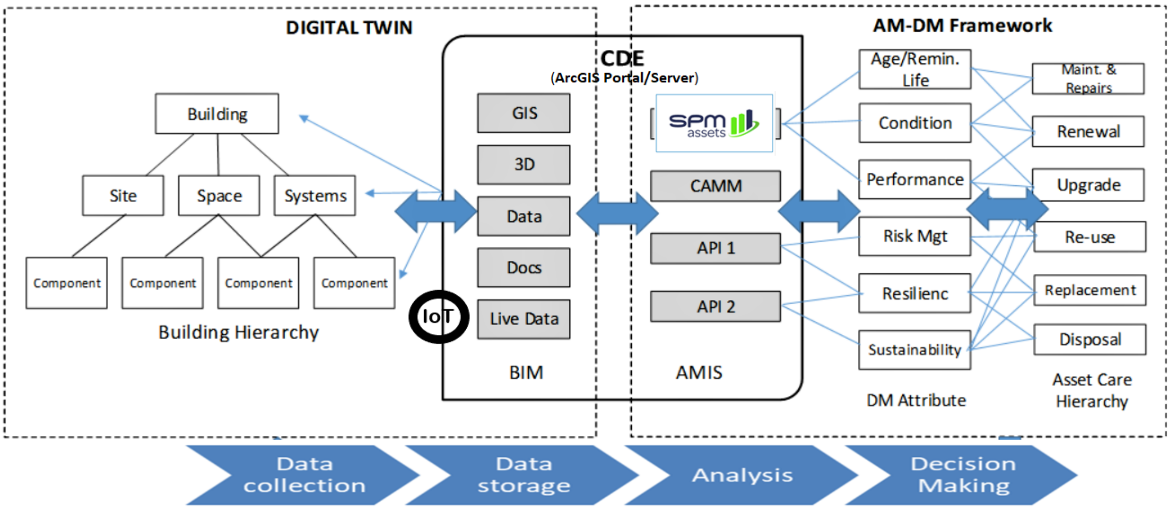

Figure 1. Pillar One. AMCDE and Asset Management Decision-Making Framework

evidence-based decision-making for asset care interventions.

The outputs defined in the proposed decision-making process (AM-DM) provide the various options for management's consideration based on the asset lifecycle interventions with a selection of various construction activities, such as maintenance and repairs, like-for-like renewals, upgrades, replacement, and even the disposals as described in the list of asset care hierarchies.

3.2 Pillar Two – Operational Process

Pillar Two of the transformations involves the creation process of a BIM-enabled AMCDE to integrate the existing planning process and multiple AMIS. The core process is to develop the CDE that consists of five steps, namely, planning, data collection, modelling, CDE and interface development, and project peer review. The breakdown steps including data flows are illustrated in Figure 2.

The BIM implementation project provides the organisation with the opportunity to create a formalised process that supported the changes induced by the introduction of BIM. In particular a BIM-based asset planning process is created through the following steps: 1) as-built data capture can be conducted by utilising a combination of point cloud scanning, photogrammetry mapping, and site surveying; 2) 3D geometry models is produced using BIM authoring tool such as Autodesk Revit from the data extracted in the capturing process; 3) while the non-geometry data, including building element metadata such as age, cost, condition, capacity, and criticality, etc., are captured in a separate database aligned to the classification defined by standard formats such as those defined in NAMS property manual [17]; 4) a single sourced data system acting as the central data

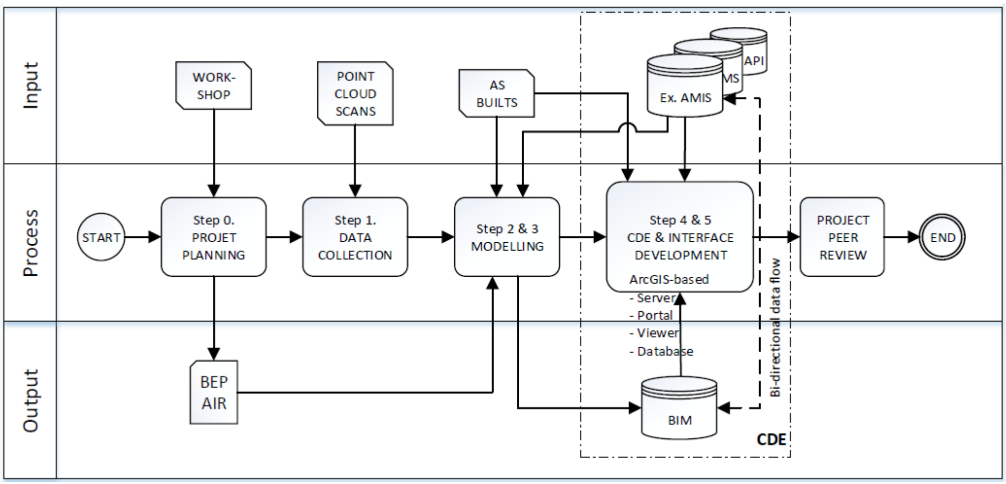

Figure 2. Pillar Two - Integrated AMCDE development process

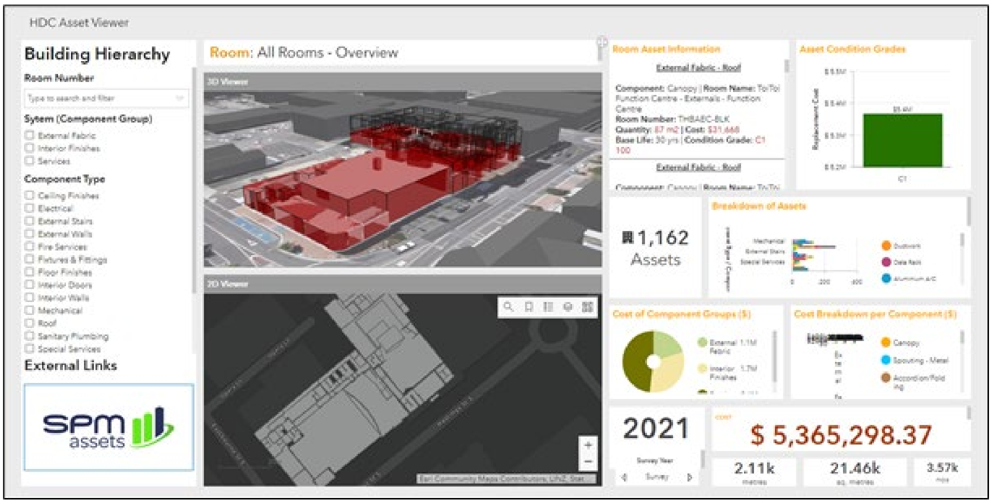

Figure 3. Pillar Three - ArcGIS User Webviewer/Interface

repository is created and hosted in a model and data integrated platform such as GIS-based interface; and 5) asset information dashboards were established to provide management insight into the building data, such as physical condition, space usage and surface areas etc. It is worth noting that while step 4) and 5) can be one-off and unique to this project, step 1) to 3) is repetitive and applicable to the future assets for digitalisation.

3.3 Pillar Three – End-user Experience

Pillar Three of the transformations represent the ultimate goal of this project, which is to develop a user-friendly interface within the AMCDE to support information access, analysis and reporting, as shown in Figure 3. The BIM model created from the previous steps is integrated with the existing AMIS, along with asset data, photographs, GIS data, O&M manuals, and other as-built documentations, using a selected database and portal. In this study, ArcGIS Pro of Esri is adopted as the CDE architecture to store, retrieve, analyse, and visually represent asset data and information. The ArcGIS-BIM integration enables a standards-based Extract-Load-Translate (ELT) to extract the geometry and data from the BIM models and translate into 3D and location enabled GIS data, via data common denominators. For example, using MSSQL as a back-end repository for data storage and management to enable different asset data formats to be integrated with Esri GIS data. ArcGIS' Rest API allows the integration of various data to remain in-sync across multiple platforms and the specific AMIS.

4 Case Study

The building chosen for the case study is a historical opera house complex (aka Toitoi Arts & Events Centre) built in Hastings, New Zealand. Figure 4 illustrates a sample floor plan and the interior image of the theatre. The Toitoi building was constructed in 1915 and has had numerous renovations and modifications over its life. With a combination of new and old building blocks, the complex has a total floor area of 5,000m² that comprising of theatre, exhibition, office, and amenity facility spaces. The project was driven by the owner's decision to adopt

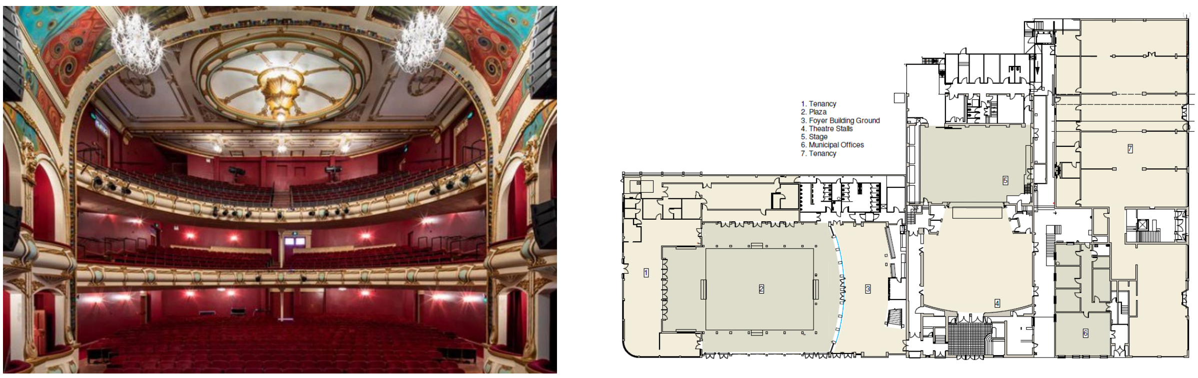

Figure 4. Toitoi Arts & Events Centre (Source: Hastings District Council)

a BIM-based planning platform to support the integration of the existing AMIS. The scope of BIM implementation in this project includes the process of data collection, modelling and the creation of an easy-to-use interface that can bring asset information, including static data such as drawings, documents, asset data, as well as geospatial information on a single digital platform AMCDE, as shown in the above Figure 1 to Figure 3.

5 Discussion and Conclusions

Digital transformation can effectively enhance the performance of organisational management and business operations in various aspects such as better customer experiences and engagement, streamlined operations, and new lines of business or business models. Digital technologies such as BIM as illustrated in this study help asset owners improve their management practices in numerous perspectives, ranging from automating data collection, enhancing analysis, to optimising asset performance. The study demonstrates an efficient method of using BIM to improve system interoperability and information sharing by populating multiple AMIS, where asset data can be stored and exchanged on a centralised digital platform, i.e., the AMCDE model, to provide the insight of asset management from a single source of information normally stored in multiple systems and locations. In addition, the development of a user-friendly interface supported by the AMCDE, of which the enhanced end-user experience helps remove obstacles in accessing asset data across the whole organisation and shared by different stakeholders in a remote manner, is particularly useful in the situation such as Covid-19 pandemic, where working remotely has become the new norm. The case study demonstrates that digital technologies not only enhance the efficiency of the operational process for data collection, but also improve data accuracy and reduces human errors that are commonly occurring in a manual process. Overall, local governments in New Zealand will benefit from adopting digital technologies including BIM to improve their asset management efficiency through time and cost savings, a more collaborative operation environment, and visualised information analysis and reporting.

It is noteworthy to mention that, the existing studies have largely focused on the enterprises or businesses where customer satisfaction, market demand, and business competitiveness are identified as the key drives for technologies adoption. Using these drives to guide the organisations such as the local government, which are non-profit driven business and whose operation objective is more towards improving management efficiency, is up to debate. Furthermore, unlike the private sector, the local government has its own unique operation processes, management models, and digital technologies (e.g., AMIS), thus using the existing transformation theories as the roadmap without adaption presents challenges due to the lack of studies, theories, and empirical evidence.

While BIM research and practice is currently intensifying in project-oriented design and construction activities, there is still an untapped potential to view BIM as a catalyst to develop new business models from a service innovation perspective. Hence, this study focuses on the BIM use in asset management planning in a built environment. In addition to contributing a much-needed real project case, this study takes a holistic transformation approach to the challenge of integrating multiple systems that are commonly implemented independently and operated in a silo fashion. The novel business model based on AMCDE platform that is developed for integrating the existing asset management process and the multiple AMIS deployed across the organisation, has the potential to further include a wider range digital technology, such as CAMM, BMS, and IoT applications, in order to form true asset Digital Twins and further advance organisations towards a full digital transformation.

Nonetheless, this research is limited by several factors. Firstly, BIM is such a disruptive technology as previously mentioned, its adoption and implementation requires changes in workflow, practices, and most of all, human habits and ways of working that form the key pieces of an organisation's culture, which requires further research. Secondly, asset management is a complex process. To digitally transform the management practice requires a balance of people, processes, and technology, where the three-pillar theory only address the latter two elements. The people factor deserves a deep investigation and certainly warrants a fresh new chapter and requires further research. And finally, the research uses a single case study to provide a way of concept validation, which has its limitation. Future studies using multiple real cases, reviews, and other validation methods need to be explored and examined.

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