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Digital transformation in the construction industry: Applying a Knowledge Management System lens

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Abstract

Over the past decade stakeholders in the Australian construction industry have made limited progress with digital transformation of their sector. To identify the gaps in the industry's approach to data and information management a conceptual Knowledge Management System (KMS) theoretical Framework was developed and applied. The Framework focused on five processes, including the project definition, design, build and commission, handover and closeout, and operations and maintenance, that are foundational for the lifecycle of a building project's knowledge system.

Participatory research was the methodology applied. Using case study data, five KM processes were aligned with the people, process, technology, and content elements of knowledge projects. Overarching Culture and Governance dimensions were added to the Framework. This original investigation describes the knowledge system strengths and weaknesses in two major, local construction projects. The findings can be used to seek improvements to data management and information systems to underpin digital transformation.

Keywords: digital transformation, participatory research, construction

1. Introduction

The digital age presents numerous opportunities for the construction sector to optimize access to a wide array of knowledge sources, such as regulations, standards, policies, building codes, case studies, technical guides, along with geospatial data and information. The use of building information modelling (BIM), new data sources and analytical processes are being implemented throughout the industry. Even so, knowledge in the construction industry has a poor reputation for being inaccessible, unstandardized and fragmented (Construction Knowledge Task Group, 2022).

In 2020, the Victorian Digital Asset Strategy (VDAS) was published (Victoria State Government, 2020) setting out the processes for safeguarding digital systems that enable monitoring and improvements in the creation and management of infrastructure assets within Victoria, Australia. This was followed by a Digital Asset Policy, which provides information management requirements to improve the planning, design, and delivery of Victorian infrastructure projects (Victoria State Government, 2021). The VDAS and the Digital Asset Policy are based on the international standard, ISO 19650 which details the approach to naming convention information consistency and information management processes across project lifecycle stages (International Organization for Standardization, 2018). The Digital Asset Policy applies to capital investments of AUD$10 million or more (Victoria State Government, 2021). Over recent years construction businesses in Victoria have been struggling with digital transformation of their industry. In comparison with other industry groups, the Australian construction industry, despite significant investment, is less digitized than the manufacturing, mining and utilities industry (McKinsey Global Institute, 2017).

Participatory research was undertaken over a one-year period during 2022-2023. The researchers were

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engaged to investigate the challenges and implications of adopting sustainable data assets amongst stakeholders in digital build projects. The main objective of this paper is to demonstrate the Knowledge Management System (KMS) Framework's analytical power as a tool to compare and evaluate the strengths and weaknesses of five Knowledge Management (KM) process stages, drawn from two major construction projects. The five KM process stages underpinning construction projects are Definition, Design, Build and Commission, Handover and Closeout, and Operations and Maintenance. The Framework, including the theoretical background, the procedure to tabulate the data for the evaluation and the findings are reported.

2. Theoretical background

The motivation behind the development of a KMS Framework was to identify and map the industry's approach to data, information and knowledge practice in the context of multi-party construction projects, aligned with the perspectives of key stakeholders, such as the project owner, the appointed party, delivery team members and community stakeholders. A KMS Framework is a conceptual representation of combined KM practices, comprising methods to support learning and organizational processes of KM development, and KM tools, such as IT-based systems supporting the practices (Centobelli et al., 2019). Defining KM has been controversial based on the differing approaches and context (Intezari et al., 2021). For this research, KM is defined as getting the right knowledge to the right user at the right time, and using this knowledge to improve organizational and/or individual performance (American Productivity & Quality Center, 2023; Jennex et al., 2009). KM is doing what is needed to get the most out of knowledge resources (Becerra-Fernandez & Sabherwal, 2015).

The proposed KMS Framework takes a holistic socio-technical approach in order to identify the strengths and weaknesses of an information system to serve the objective of knowledge management for all of the stakeholders. The KMS Framework provides a way to help diagnose issues and guide improvements in the coordination of *people, process, technology* and *content* elements in KM (Standards Australia, 2005). Poor coordination of these elements results in a costly disconnect in the pipeline that delivers the information at the point of need for decision making (Kruesi et al., 2020). This research proposes that a KMS approach also provides a theoretical framework for developing, designing and evaluating designs for knowledge systems (Kruesi et al., 2020).

A system is a collection of processes, elements or components that are organized for a common purpose (*Definition of system*, 2023). KM is concerned with the discovery of tacit and explicit knowledge from data and information or from the synthesis of prior knowledge (Becerra-Fernandez & Sabherwal, 2015, p. 59).

The KMS Framework is a means to help manage Knowledge Management (KM) processes throughout the entire asset production life cycle (Kruesi et al., 2020). The Framework differs from other tools because it provides a means to undertake an assessment based on KM processes and the interplay with the *people*, *process*, *technology* and *content* elements, whereas other frameworks and tools focus on technology developments (You & Feng, 2020) and building models (Hossain et al., 2020).

The KMS Framework's overarching principles which exist within the wider construction industry environment include Governance and Culture. It was determined that Governance (Kruesi et al., 2020; Ruhlandt, 2018) and Culture (Boamah et al., 2022) are important overarching principles for an effective KM system in the construction industry. Governance is represented by controls and mechanisms by which organizations and their people are held to account (Governance Institute of Australia, 2023). The key to the establishment and success of future smart cities is to have an effective Governance system (Ruhlandt, 2018).

Culture is the other overarching principle in the theoretical KMS model. Culture is reflected in an industry's shared basic assumptions, beliefs, and values (Schein, 2010) and is an area where improvement for the Australian construction workforce is underway (Australian Broadband Advisory Council, 2022; Construction Industry Culture Taskforce, 2021). A positive and effective organizational culture has been found to be an enabler of KM (Boamah et al., 2022). A process-centric approach to embedding a digital culture, is a means to shape the implementation of digital technologies among members in construction organizations (Olanipekun & Sutrisna, 2021). In the application of the Framework for this research it was evident that Governance and Culture principles do not exist within each process and element, but operate within the wider environment. Effective Governance and Culture are required for the KMS elements and processes to crystalize, perform and flow through their lifecycle. A diagram of the theoretical KMS model for the construction industry is in Figure 1.

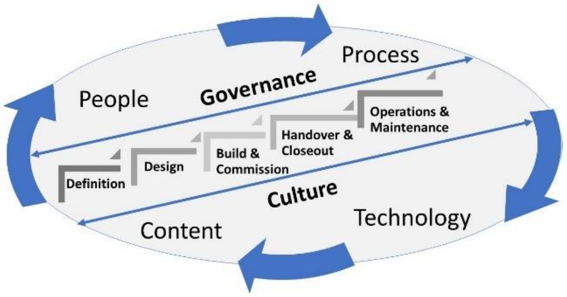

Figure 1 Theoretical KMS model for the construction industry

3. Methodology

3.1 Research design

Participatory research was undertaken in collaboration with key staff responsible for the construction projects. The research data collection techniques comprised semi-structured interviews using a pre-determined set of open questions. The University's Human Research Ethics Committee approved the study and the associated documentation. Two case study examples investigated the data, information and knowledge systems underpinning the construction of a major university engineering and technology building for teaching and research, and a primary school building. To explore and illustrate the power of the conceptual KMS Framework for analyzing the strengths and weaknesses of knowledge systems, it was tested on two case studies in the construction industry. A profile of the case study construction projects evaluated is shown in Table 1.

Table 1. Construction Project Case Studies

	Project One	**Project Two**
Type	University building (for engineering and technology research and teaching)	Primary school building
Location	Suburban Victoria, Australia	Regional Victoria, Australia
Year Completed	2020	2021
Budget	AUD$176 million	AUD$1.9 million
Area	23,000 sqm	490 sqm

Qualitative methods of investigation are regarded as suitable for analyzing complex environments (Barrett & Sutrisna, 2009) and are suited for research in the construction industry (Hastie et al., 2017).

The KMS Framework was identified as a means to achieve a coordinated approach and break down the silos that form over many decades within construction projects. The Framework is a means to make vital connections that are required to achieve a productive KM cycle throughout all the stages of a construction project. It was found that identifying the relationships and linkages between elements in the Framework provides a lens to expose redundant historical organizational boundaries that occur. Within the elements of *people*, *process*, *technology* and *content* that occur with the data, information and knowledge practice within each project, depend on achieving a fine balance within a project's Definition, Design, Build and Commission, Handover and Closeout through to Operations and Maintenance processes that underpin the knowledge lifecycle.

3.2 Interviews

Twelve interviews were undertaken for Projects One and Project Two, including nine interviews for Project One and three interviews for Project Two. For Project One the interviewees from the construction company comprised three senior project managers, one technology in property manager, three engineers (two were digital engineers) and two academic users of the building. For Project Two the first interview was with the construction company's head of design, and the following two interviews were with both the head of design and the virtual design construction manager. The initial questions provided a profile of the respondent, such as current position, years of experience in the field and size of projects worked on. Further questions focused on the use of connected data and information management for the project case study. The questions were designed to explore the implications and challenges of adopting sustainable data assets amongst stakeholders in digital build projects. A total of ten questions were asked if they were relevant to the interviewee. The interviewer explored themes, concepts and responses to questions, reflecting the semi-structured nature of the interviews. Each interview lasted approximately one hour and was undertaken using a video conferencing system. All interviewees received the questions prior to the interviews, along with explanatory documentation. Consent to share the interview findings was provided by all interviewees. The conceptual KMS Framework was not discussed with interviewees.

The open-source tool, Taguette, was used for qualitative thematic data analysis of each interview transcript. The interviews took place during November 2022 until June 2023.

3.3 Procedure

A KMS Framework evaluation template was set up using MS Excel for the assessment of each project. The information management requirements as detailed in the VDAS were noted in the relevant column. Following collection of the data by application of the procedure described below, the findings were synthesized into a combined evaluation document. A four-step procedure was applied with each of the two case studies evaluated.

Step 1. Plan

An Excel template was used to tabulate the data for the evaluation. The template comprises a worksheet with a column for each of the five KM processes: Project Definition, Design, Build and Commission, Handover and Closeout, and Operations and Maintenance. Listed as column headings, and aligned with the elements*: people, process, technology* and *content* that are listed in the first column as row headings. Each of the processes and the elements have been defined to achieve a consistent approach (see Table 2: Definitions of the elements, adapted from the Australian Standard on Knowledge Management (Standards Australia, 2005)). Definitions of each of the five KM processes are based on an associated *people, process, technology*, and *content* element and form the basis of the findings synthesized in the two project evaluations. In the Findings section Table 4. includes the descriptions of the five KM stages (processes) with associated *people, process, technology* and *content* element. An example of a definition for the KM process, Build and Commission, associated with the *people* element is represented by explicit knowledge in the form of digital assets and/or the metadata for the objects that describe the physical objects. The project stages (processes) identified underpin construction knowledge and intellectual property and are adaptations based on the VDAS lifecycle of an asset (Victoria State Government, 2020). The definitions are a permanent feature of the template.

Table 2. Adapted from Standards Australia (2005)

Element	Definition
People	The ‘who’ such as digital engineers, asset managers, project sponsors, data custodians, architects, consultants, internal and external stakeholders.
Process	The ‘how’ and includes standards, regulations, technical guides, plans, checklists, codes, taxonomies, policies, procedures and other explicit sources.
Technology	The ‘tools’ such as software, hardware, storage, digital systems, platforms, databases and other expert systems.
Content	The ‘what’ such as research data, metadata, database records, graphics, maps, visualizations, reports and other digital objects.

Step 2. Thematic analysis

Thematic analysis to identify the findings from the interview data was based on an established methodological procedure (Braun & Clarke, 2006).

Step 3. Document

This step involved mapping the data into an Excel worksheet template (described in Step 1.) for each case study. Table 3. provides an example from an Excel template of the KM processes: Design, and Build and aligned with the *content* element taken from the evaluation of Project One.

Step 4. Reflect

Step 4 involved reflection on the process of grading the data in each cell, and then evaluating and reporting on the results. The overarching principles of *Governance* and *Culture* identified during the evaluation are indicated in the cells of the Framework by a code, i.e., Governance=**G** and Culture=**C**.

Table 3. Example taken from an Excel template of the *content* element aligned with KM processes: Design, Build and Commission.

Project One	Stage: Design	Stage: Build and Commission
Content The 'what' such as research data, metadata, database records, graphics, maps, visualizations, reports and other digital objects.	Exchange Information Requirements (EIR) – detailed of the BIM process. Project Information Model (PIM) that reflects the physical construction in line with the EIR Establishment of the Digital Engineering Execution Plan (DEEP) **G, C**	PIM finalised. Review undertaken of the Master Information Delivery Plan (MIDP), the Exchange. Information models are verified and approved as defined in the Exchange Information Requirements (EIR)/Digital Engineering Execution Plan (DEEP). Needs of the physical asset reflected in the digital asset. **G, C**

4. Findings

As introduced in the Methodology, the elements of *people*, *process*, *technology* and *content* that occur with the data, information and knowledge practice, work most effectively together when a fine balance is achieved with the project's processes: including Definition, Design, Build and Commission, Handover and Closeout through to Operations and Maintenance. When working together in balance the elements and processes underpin the knowledge lifecycle. In the findings each of the five stages for the *people*, *process*, *technology* and *content* elements are described and a summary of interview data in relation to them is provided.

4.1 *People* element

Descriptions of the five Stages from the Framework to achieve balance of the *people* element are provided in Table 4.

For Project One, for the *people* element, it was found that new roles, such as environmentally sustainable design and social procurement are of most relevance to the Design Stage, in addition to building information modeling manager, digital engineer and data champion which are roles relevant to Stages 1-4. Greater understanding of the roles of subcontractors was viewed as important for Stages 2-3.

Managing architect and designer input, as they continue to tinker with digital models, was viewed as important in the Design Stage. Human effort to edit data to a high standard remains essential, for example "the amount of work and the human input that goes into the 3D model is vast, and we had a 3D modeler, who was engaged very early and I would have thought he would have been working 18 hours a day for 4 months, just in the models… Was it smooth? No. Was it beneficial? Yes." (Senior Construction Manager). The tacit knowledge and skills of *people* are recognised as critical and are relied upon by team members for optimising technology for example, to develop construction models that are precise and accurate; This occurs in the Definition and Design stages in particular.

In Stages 2 and 3, it was raised that substantial commercial and financial penalties linked to failure to deliver on a project stifle innovation and technology transformation. Such penalties are a disincentive for best practice KM.

For Project Two, Inhouse design expertise and embedded knowledge were highlighted as key to the Design Stage of the Project. Involving *people* in estimating for manufacturing is required at the project's Design Stage. "We're coming from a space where people are siloed, the lessons learned have become siloed. We can stop that from happening from earlier engagement with those working in manufacturing construction and estimating sooner." (Virtual Design Construction Manager).

Having contractors involved as early as possible in the project (in particular from the Design Stage through to Build and Commission) was viewed as essential to achieving efficient outcomes such as improved data and information management, for both Projects. In addition, the frustration from the lack of senior management support to lead the digital transformation required was raised by interview respondents.

4.2 *Process* element

Descriptions of the five Stages from the Framework to achieve balance of the *process* element are provided in Table 4.

Based on being "more efficient with the upfront *process* at the Definition Stage, the design *processes* are quicker" according to a Senior Construction Manager. In regards to *process* the application of

Table 4. KM stages (processes) with associated *people, process, technology* and *content* element descriptions

Stages	**1. Definition**	**2. Design**	**3. Build & Commission**	**4. Handover & Closeout**	**5. Operations & Maintenance**
People	Knowledge at the definition stage entails the development of new tacit or explicit knowledge from data and information or from the synthesis of prior knowledge.	Original design assumes knowledge that characterises the innovation that did not exist beforehand. Design entails creation of a model to meet the needs of the project owner.	Represented by explicit knowledge in the form of digital assets and/or the metadata for the objects that describe the physical objects.	Key parties undertaken integration of Project Information Model (PIM) into Asset Information Model (AIM). The appointed party transfer Common Data Environment (if available) to the owner's system.	Staff take responsibility for operating and maintaining the building's information systems (platforms, databases and repositories) for management and ongoing development of the facility.
Process	*Processes* are governed by the rules, regulations and guidelines established by government and professional bodies.	*Processes* are influenced by government and professional bodies that issue the codes, regulations and laws.	*Processes* are found in standards, policies, checklists, related frameworks and codes.	Adherence to audit and assurance *processes*, such as Asset Information Requirements (AIR)/Exchange Information Requirements (EIR) and the Building Code Australia (BCA) requirements.	*Processes* are based on government requirements, organizational standards, policies and practices.
Technology	*Technology* systems that underpin the definition of a construction project.	*Technology* includes access to BIM databases and relevant data sets.	*Technology* systems provide the format of digital asset records.	*Technology* tools include BIM, Computer Aided Design (CAD), Geographic Information Systems (GIS) and other digital engineering systems.	*Technology* systems, such a computerized maintenance management system is used for ongoing operations, maintenance and installed in buildings for future research, teaching and learning opportunities.
Content	*Content* is required that underpins the construction project e.g. data standards.	*Content* is in the form of contracts, Common Data Environment, drawings, models, Uniclass 2015 for asset classification.	*Content* comprises explicit knowledge in the form of digital models, objects or the metadata for the object.	*Content* includes lessons learnt during the project, feedback from the appointed party, handover of PIM including project data and schedules.	*Content*, including digital asset metadata, needs to be stored in a standard way, that can be efficiently migrated to future systems.

standards to achieve compliance with laws and regulations is applied to all five Stages.

"Each supply chain has their own internal *processes* that we don't have access to." (Digital Engineer), related to Stages 2-3 and a reflection of the fragmented workflow experienced by team members.

Legislative requirements of government and standards, such as ISO 19650, require the right *people* to apply the *processes*. According to a Project Lead Digital Engineer, "the Government enforces rules and many of us don't understand why they are important. Articulating 'why' is the missing piece."

Aligned with Stage 3, offsite production *processes* to speed up construction were applied in Project One and resulted in improved safety, less waste and improved communication.

For Stages 4 and 5, audit and assurance *processes* were set in place for Operations and Maintenance to develop further. This was evident from the successful certification of Passive House status that was implemented and awarded.

For Project Two, the Design Stage, the *process* of sharing information without a Common Data Environment takes "a huge amount of time" (Construction Company, Head of Design and Innovation). There was the appearance of being weighed down by an abundance of *processes*. The Virtual Design and Construction Manager, expressed that "we lack an understanding role of information management." Even so, it was conveyed by the Construction company's Head of Design and the Virtual Design and Construction Manager that standards are used as a guide when setting up systems. To support the Design, Build and Commission Stages a kit of BIM families was accessed to draw and build upon existing knowledge.

Team integration has been achieved across the steel and design departments for Project Two, Stage 2. *Processes* to standardized the documentation for advanced steel, from the modeling exercise, sped up work that would have previously taken days down to eight minutes.

4.3 *Technology* element

Descriptions of the five Stages from the Framework to achieve balance of the *technology* element are provided in Table 4.

In relation to all of the Project Stages the stakeholders are challenged by "a sea of different technology systems that are not connected" (Digital Engineer). The *technology* does not always have the functionality required to achieve the digital asset management requirements set in the standards.

The *technology* using BIM has enabled visualization of the build prior to being on the site. Using the 3D *technology* makes it possible to build with confidence.

To speed up project reporting an inhouse data warehouse *technology* system ingested data from numerous sources to generate reports was used by the Construction team for Stages 2-4.

The *technology* allowed Passive House certification for Stages 4-5.

Sensors were installed throughout the building to enable a living building infrastructure, for the teaching, learning and research stakeholder communities to optimize; this involved *technology*, *process* and *people* aspects throughout Stages 1-5.

Limited *technology* software licensing inhibits efficiencies for Stages 2-3 as team members cannot always access building models. For the Design Stage improved workflow occurs when access, if possible, and the production team (*people)* can provide instant feedback to the design team. Numerous commercial *technology* systems that are costly and require a high level of expertise were used for the project.

4.4 *Content* element

Descriptions of the five Stages from the Framework to achieve balance of the *content* element are provided in Table 4.

Diminished data integrity was reported from transferring data around multiple *technology* systems using application programming interfaces during the Project Stages. For example, "when you take data out of one system and put it in another you lose the connections between the revisions and the versions. It is difficult to do what the ISO is trying to achieve. Difficult to apply in practice." (Construction Company, Digital Engineer)

During Stages 2-3 a level of confidence is gained from working in 3D and knowing the building would look aesthetically good and that the design would work.

For Stage 3-4 the model and a vast amount of data was used to commission the site. Significant challenges were resolved from troubleshooting using the data derived from the BIM in conjunction with the Building Management System to achieve the required heating and cooling (which provides automated control of the energy in the building for the passive house).

Work was commenced to share a Common Data Environment with consultants. For Stage 2 the geometry for the design work is automatically generated. Building clashes are identified and reduced from increased visibility of building materials using an integrated system. It was not possible to generate reliable metrics because of system limitations. Diminished data integrity from moving data in and out of systems, "Data integrity is lost as various functions in the business value different things, resulting in diminished integrity from a holistic perspective that would be addressed by the introduction of Common Data Environment integration across business functions" (Construction Company, Head of Innovation and Design). Lack of connected data to manage digital assets was reported, "Whilst we certainly aspire for a more connected and collaborative data environment, that is not the current reality.

Without a Common Data Environment and rollout in the organization we will be hard pressed to quantify accurately any likely improvements" (Construction Company, Head of Innovation and Design).

5. Discussion, future research and limitations

Developing and applying a KMS Framework provided a powerful lens to identify the existing strengths and weaknesses of construction industry knowledge management practices, based on two major construction projects.

People issues are significant throughout all Stages of a building project. In particular for Project One, the vital importance of the team, the dependence on effective collaboration with a range of stakeholders and the reliance on individual's expertise to achieve the precision and accuracy necessary for a complex build was evident from the Definition through to Handover and Closeout Stages. For both Project One and Two, a lack of senior management backing to invest in digital transformation existed as a significant *people* challenge. In addition, another common challenge, raised by participants from each Project, is the unclear definitions of digital build, uncertainty about what the transformation should achieve, and the failure of digital tools to mesh with business *processes*.

Further industry baseline metrics to demonstrate the benefits of digital build need to be established for modular and offsite construction. Even so, the Project One case study found passive house certification and some of the BIM data to support the benefits of a Common Data Environment. Research has also identified numerous benefits from using BIM in areas such as quality assurance, buildability (Sompolgrunk et al., 2022) and safety (Zhang et al., 2015).

The inherent nature of a 'project' that has timelines and strict contractual obligations, aligned with Design, Build and Commission through to Handover and Closeout Stages, can inhibit the innovation *process*. Whilst participants indicated their standards, regulations and contractual compliance *processes* were in place for each Project, detailed understanding of the VDAS was not evident. The VDAS guidelines for managing data and information assets (*process*) is overwhelming for many in the industry. It was found that the work environment has a lack of connected data, differing workflows and time lags with federated data. The approach to managing (*content*) data and information is fragmented because data is stored in disconnected data sets.

In regards to Operations and Maintenance Stage for Project One, the 'data as part of the space' was a community benefit aligned with the *people* element, that resulted from the construction project. The sensors installed in the commissioned building for Project One has resulted in a living building, which opens up significant teaching, learning and research opportunities for the users of the building including academics, students and their collaborators from wide ranging disciplines (Burbridge, 2017).

Current *technology* does not always have functionality to achieve ISO 19650 information management requirements. New systems have significant costs, that are often out of reach for Tier 3 and Small and Medium Enterprises (SMEs) (the majority of traders in the construction sector). *Technology* was found to be relevant to all KM stages though efficient interconnectedness in relation to systems and *people* is a major area for improvement.

The Australian construction industry is largely comprised of SMEs (Australian Broadband Advisory Council, 2022; Hong et al., 2019). To facilitate digital transformation of SMEs governing bodies need to lead the implementation and strengthen collaborative partnerships amongst stakeholders. The VDAS is an aspirational blueprint and an essential part of the overarching Governance principles essential to the digital transformation of the construction industry in Victoria, Australia. A less complex version of the VDAS that can be part of the new skills training options for the construction industry by the Government is recommended.

Future research synthesizing the latest findings on Culture in the construction industry and related fields, aligned with the KMS Framework to identify further synergies is also recommended.

To help achieve advancements in data quality, future research should take a deeper dive into the *people* element associated with data quality, aligned with *content, process* and *technology* throughout all of the KM stages in construction. Further research on the *people* element will help to break down the silos in multi-stakeholder environments.

A limitation of this research is only a small number of the Project stakeholders were available for interview. It is recommended that focus group sessions with representatives from each Project stakeholder group be conducted to develop prototype data and information approaches and prioritize the steps required to advance digital transformation for the industry. Following this a more detailed stakeholder analysis can be reported using the KMS Framework and a graphical version of the Framework published to illustrate the gaps for addressing in the future.

6. Conclusion

This research makes a unique theoretical contribution to the field of KM by demonstrating the interplay of elements and processes to further develop, refine and sustain data, information and knowledge practice throughout the knowledge lifecycle. The practical benefit of this work includes a future pathway of required actions for the construction industry that can be taken to improve their management of data and information to result in an effective and sustainable KMS for all stakeholders.

Extensive research was undertaken to document and analyze the data, information and knowledge practice of two major construction projects. The definitions of the project's five Stages as KM processes, that were aligned with their associated *people, process, technology,* and *content* elements form the basis of the findings synthesized in the two case evaluations reported. The findings from the case study evaluations support the proposition that the KMS Framework is an effective theoretical lens for analyzing and evaluating complex stakeholder practices to achieve a coordinated approach and continue to move data and information out of silos and flow continuously throughout the KM stages of construction projects.

The KMS framework differs from existing evaluation and assessment frameworks as it is focused on the construction project knowledge life cycle. In particular, the Handover to Operations and Maintenance Stage must be further strengthened in the future from improved system workflow and management of digital assets. It is recommended that the five KM processes: Definition, Design, Build and Commission, Handover and Closeout, and Operations and Maintenance be included in future industry platform designs. Putting the KMS Framework to further use and enhancing its design through application is strongly recommended for future research.

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