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STANDARDS RESEARCH

Digital Transformation in the Canadian Built Asset Industry

Priorities for BIM Policy, Standardization, and Guidance

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Executive Summary

As with all economic sectors in Canada, the built asset industry, which is responsible for planning, designing, delivering, maintaining, and operating Canada's built environment, is undergoing a digital transformation. This is an opportunity for one of Canada's most important economic sectors to revolutionize the way it operates, allowing it to generate more value for Canadians by addressing current environmental, economic, and social crises. However, enacting this digital transformation and reaping its benefits poses significant challenges. The research conducted for this report developed a framework to identify and prioritize specific knowledge resources to address the challenges and support the Canadian built asset industry in its digital transformation.

The primary objective of this research was to develop a digital transformation framework to structure, articulate, and prioritize the standards, guidelines, and other resources (i.e., knowledge resources) needed to support building information modelling (BIM) adoption and implementation in Canada. Secondary objectives included validating current industry challenges, needs, and trends regarding BIM use in Canada; reviewing existing initiatives, resources, and tools from around the globe; discussing their adaptation or adoption; and where a specific need was uncovered, proposing avenues for development. To achieve these objectives, a three-pronged research methodology was selected. First, 24 domain experts from Canada, the United Kingdom (UK), the United States (US), and Australia were interviewed. Second, a survey was conducted to broaden the pool of respondents pertaining to specific questions regarding standardization and guidance for BIM in Canada. Finally, a broad review of available BIM resources was conducted, which identified over 500 noteworthy resources pertaining to BIM adoption and implementation for review. Data were analyzed through various qualitative and quantitative methods, including inductive coding using computer aided qualitative data analysis software and statistical analysis. This analysis informed the development of the framework and the list of knowledge resources that are presented in this report. Two workshops were also held to discuss and validate the findings.

The findings confirmed the overarching challenges that the Canadian built asset industry faces in initiating and sustaining its digital transformation, specifically around the adoption and implementation of BIM. These challenges lie primarily in three areas:

1. Lack of consistent demand by clients;
2. Lack of appropriate skills and competencies; and
3. Incompatibility of capabilities and workflows across built asset value chains.

These findings highlight the absence of a coherent operational framework for BIM adoption and implementation in Canada, the consequences of which are fragmentation and duplication of efforts and resources, as well as potential for the development of contradictory directions in this area. This could lead to wasted and missed opportunities, which could have significant economic, social, and environmental impacts. Indeed, while BIM use is increasingly delivering tangible benefits to stakeholders across Canada, these benefits are localized and asymmetric (e.g., they typically apply to a single organization or a subset of the supply chain). In essence, the absence of structure or an overarching strategy seriously hinders the progression and full potential of digital transformation in the Canadian built asset industry.

To overcome the challenges and broaden the scale and scope of economic, social, and environmental benefits, a Canadian position regarding policy and standards on BIM adoption and implementation must be developed. Such a position can and should rely on the significant work that has been done around the globe to standardize and develop guidance for government agencies and industry practitioners, namely the ISO 19650 series. Many of these resources could be adopted or adapted within Canada. However, while beneficial, these resources alone will not ensure the successful adoption and implementation of BIM in the Canadian built asset industry. They must be enacted and supported through targeted policy instruments, be they regulatory, economic, or other, and through clear implementation pathways with the objective of structuring and guiding how information is acquired, generated, exchanged, processed, managed, and consumed throughout the lifecycle of a built asset.

The research conducted for this report informed a proposal for a clear Canadian position on BIM adoption and implementation in the Canadian built asset industry through the development of an operational framework. Moreover, through this research, consensus emerged concerning the key role that standards and focused guidance must play in supporting the Canadian built asset industry to move ahead and be successful in its BIM adoption process. The findings discussed in this report identify and prioritize these standards and key resources and articulate them within the broader digital transformation framework, with a focus on the relationship between the different parts of the framework and how they are supported through these defined resources.

"Digital transformation, and its current expression through building information modelling (BIM) and digital twinning, implies a fundamental change in the industry's relationship to built asset data and information."

1 Introduction

There is growing international consensus on the need to transform how the built environment is planned, delivered, managed, and used in light of the significant challenges facing people around the globe. These challenges include the climate crisis, post-COVID-19 pandemic economic recovery, adequacy, sustainability and resiliency of infrastructure, housing crises, and skills and labour shortages. To overcome these challenges and help reap the environmental, social, and financial benefits for all actors, significant, concerted action by government, industry, and academic institutions is necessary to drive digital transformation in the built asset industry (i.e., the industry that plans, delivers, and maintains the built environment). In this report, digital transformation is defined as "the process that is used to restructure economies, institutions and society on a system level" [1, p. 1144]. Digital transformation, and its current expression through building information modelling (BIM) and digital twinning, implies a fundamental change in the industry's relationship to built asset data and information. Previous research has pointed to the significance of this transformation and its implications for the industry, which comprises individuals, organizations, project teams, government bodies, and sectors [2]. At its core, digital transformation of the built asset industry implies a complete rethink of how information flows across the value chain and throughout a built asset's lifecycle [3]. Over the past decades, there have been consistent, growing calls to develop strategies, reconfigure practices, workflows, and structures, and renew policy to support this transformation [4]. However, operationalizing the transformation, given the built asset industry's well known and well documented challenges, namely its willingness and ability to innovate, is a complex undertaking [5], [6].

Recognizing the need and growing interest for digital transformation in the Canadian built asset industry at all levels, the research conducted for this report identified and documented the need for specific resources, namely standards and guidelines, to support the digital transformation process through the adoption and implementation of BIM. In the past decade, there has been considerable work done internationally around guidance and standardization for BIM. Yet, while the benefits of these standards from an economic, societal, environmental, and safety perspective are well known [7], the areas of digital transformation, BIM implementation, and diffusion of complementary emerging processes and technologies still require significant work. Moreover, there is currently no common framework to identify and relate the different resources needed to facilitate and structure this transformation in Canada.

The primary objective of the research was to develop a digital transformation framework to structure the standards, guidelines, and other resources to support BIM adoption and implementation in Canada, and to articulate and prioritize these resources. Secondary objectives included validating current industry challenges, needs, and trends regarding BIM use in Canada; reviewing existing initiatives, resources, and tools from around the globe; discussing their adaptation or adoption; and where a specific need was uncovered, proposing avenues for development.

The results centre around three overarching challenges hindering the adoption and implementation of BIM in the Canadian built asset industry, as identified through interviews, workshops, and surveys:

1. Lack of consistent demand for BIM by clients;
2. Lack of appropriate skills and competencies to support BIM implementation; and
3. Incompatibility of capabilities and workflows across built asset supply and value chains.

In response to these challenges, three primary solutions were put forward:

1. Create and systematize demand for BIM along with digitalized project delivery and built asset management;
2. Upskill industry stakeholders across industry segments, building upon a core body of knowledge; and
3. Structure practice and harmonize capabilities across supply and value chains through standardization.

Underlying these challenges and solutions is the need for an operational framework for BIM adoption and implementation. This report proposes such a framework and uses it to position specific needs for knowledge resources to support BIM adoption and implementation. Forty-five knowledge resources are identified, described, and prioritized. This list of knowledge resources supporting BIM adoption and implementation can be used to mobilize key industry stakeholders and define an action plan to help the Canadian built asset industry in its digital transformation and ensure it reaps the benefits accrued through this significant endeavour.

2 Methods

The research project employed a mixed-method approach to data collection and analysis to develop a digital transformation framework that would serve to structure the standards, guidelines, and other knowledge resources needed to support BIM adoption and implementation in Canada. As presented below, the data collection and analysis as well as the validation process involved interviews, surveys, document analysis and workshops.

2.1 Interviews

Semi-structured interviews were conducted with 24 key stakeholders, including representatives from major national and international organizations, government officials involved in BIM across Canada, and industry representatives both within Canada and internationally. Interviewees included four respondents from the academic/institutional domain, two from the architectural domain, three from professional associations, two general contractors, three from the engineering domain, five representing public owners, two software vendors, and three from other domains, such as BIM consultants. Most interviewees were from Canada (20), specifically from British Columbia (2), Alberta (3), Ontario (11), Quebec (3), and New Brunswick (1). Two interviewees were based in the United States (US), one in the United Kingdom (UK), and one in Australia. Interviews covered the following topics:

- Current use of BIM within the organization
- Use of BIM and its evolution within their region and in Canada (or in their country)
- Obstacles and barriers to the use of BIM both within and outside their organization
- Use of resources to guide and enable use of BIM in projects
- Satisfaction with the quality and use of these resources
- Identification of needs and priorities for development

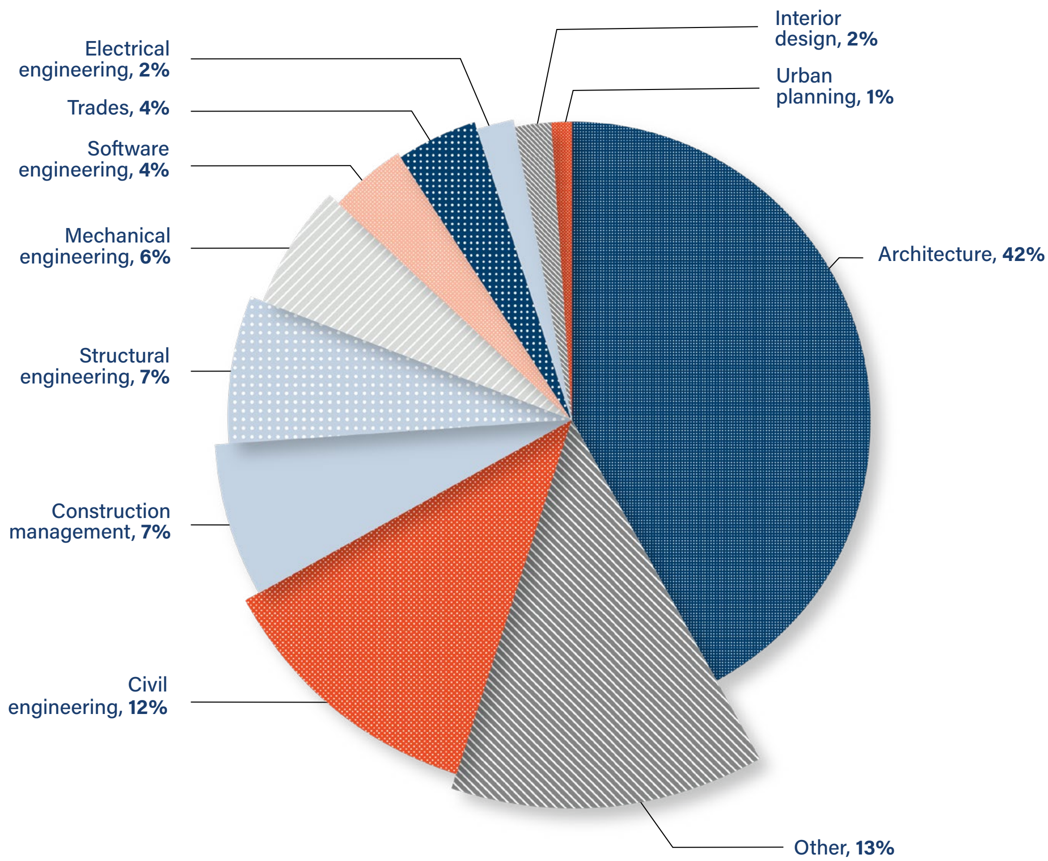
2.2 Survey

A survey was developed and distributed nationally in parallel to the interviews to reach a broader audience and to help with generalizing and prioritizing requirements and needs. The survey consisted of 48 questions divided into seven sections: Demographics and Organization Information, BIM Use, BIM Beliefs, Benefits and Barriers, Resources, Software, Education, and the Future of Construction Technology. The most relevant questions for this research pertained to BIM Resources and Barriers, and asked respondents to:

- Identify the barriers to BIM adoption that exist at the personal, organizational, and industry levels
- Identify their familiarity with various Canadian BIM resources
- Identify existing standards and guidelines that are in use at their organizations
- Discern their familiarity with the ISO 19650 series of standards[1] and their beliefs regarding its implementation in Canada
- Evaluate the importance of noteworthy BIM publications (NBPs) in Canada for the future development of BIM
- Identify the types of NBPs that would be useful in a Canadian context

A total of 171 responses were logged between November 2021 and January 2022. Figure 1 illustrates the distribution of survey responses by discipline. The outcomes of this stage provided the research team with a better understanding of the Canadian industry's priorities regarding BIM standards development and diffusion.

Figure 1: Distribution of survey respondents by discipline



1 The ISO 19650 series is based on and supersedes the BSI PAS 1192 series

2.3 Literature Review

A broad environment scan and literature review identified over 620 different resources pertaining to BIM standards and their development, adoption, implementation, and diffusion as NBPs. To accomplish this, the research team created a database of about 700 documents representing BIM resources from approximately 30 countries and various standards development organizations. Some documents were identified from existing lists, including the BIM Guides Wiki [8] and buildingSMART Spain's BIM Library [9]. Other documents were found through an internet search for BIM guides or through industry contacts. The database was not developed as an exhaustive list of BIM resources because there were too many to include them all. Instead, the focus was to capture BIM resources from a diverse range of landscapes, using the definition of NBPs developed by Succar and Kassem [10], which is presented in Appendix A.2. The research team also included some resources that were not classified as NBPs because they were hosted on websites, but were structured in such a way that they resembled a formal document. These resources were consolidated within the database and their scope, remit, relationship, and applicability were confirmed.

Once all the documents were in the database, each was reviewed and categorized based on criteria such as origin, author, language, year of publication, audience, and scope. In developing the database, each resource was counted individually. For example, a guide containing 13 parts that were published in 13 different documents was considered as 13 distinct documents. After categorizing the NBPs, a series of BIM ecosystems were developed for countries that had a combination of relevant and numerous NBPs, which typically indicates a high level of BIM maturity. Relevance was determined by the type and scope of the NBPs, while a greater number of NBPs suggested that an ecosystem had an established breadth of topics discussed, which is a sign of a developed BIM understanding. As this report focuses on standards and guidelines, the research team focused on NBPs of these types and associated types, including manuals, protocols, specifications, and requirements. Certain NBP types, such as reports and case studies, while valuable, were generally not included in the ecosystems as they usually offered an outside look at the ecosystem rather than being a part of the ecosystem itself. In terms of scope, certain documents with limited scope were excluded. For example, BIM requirements for universities were excluded as the reach only extends to the university itself. The outcomes of this stage provided the research team with a thorough understanding of the landscape of existing BIM-related standards and documents and their diffusion both nationally and internationally.

2.4 Workshops

Two workshops were held in which the findings were discussed and validated. The first workshop had 23 participants and was held in November 2021 to validate and prioritize the resources needed along with the framework and the knowledge resources. Participants were split into three groups, one for owners and two for industry stakeholders. Participants were asked to prioritize specific BIM resources in a 2x2 matrix according to importance and urgency. The elements placed in the matrix were then attributed a score based on their location. This score, while relative, helped prioritize the elements that are presented in Section 5. Finally, the elements were categorized using the proposed framework discussed in Section 4.1. The second workshop had 29 participants and was held in January 2022 to validate the proposed framework and the prioritized activities and deliverables.

3 Digital Transformation and BIM Adoption and Implementation in the Canadian Built Asset Industry: What Is It and Why Does It Matter?

3.1 Drivers of Change

Digital transformation in the built asset industry and its realization through BIM adoption and implementation must be driven by purpose. One such purpose is to act as a catalyst for industry reform. Calls for industry reform around the world, including those laid out in Latham's and Egan's reports in the UK [11], [12], [13], the Construction Industry Reform Strategy in Australia [14] or the Construction Industry Cost Effectiveness Project in the US [15], are examples of overarching strategies aimed at transforming industry that have targeted specific actions and highlighted opportunities for the industry to change. For Canada, the main takeaway from these studies is that efforts must be structured, directed, and sustained to enable the Canadian built asset industry to perform better and be more productive while improving the quality, sustainability, and performance of the Canadian built environment. Moreover, this transformation must provide benefits for industry stakeholders as well as Canadian citizens. The research conducted for this report identified, confirmed, and prioritized the following five drivers of change in the Canadian built asset industry:

1. The climate crisis and the growing push for significant climate action;
2. The economic crisis, including post-pandemic economic recovery;
3. The housing crisis;
4. Aging infrastructure; and
5. The growing labour and skills shortage.

These drivers can be mapped to the United Nations' Sustainable Development Goals (UN SDGs), which specifically target the built asset industry and environment [16], as has been done elsewhere (e.g., [15]). Table 1 describes these five key drivers for change, provides example targets, and maps each to the relevant UN SDGs.

Table 1: Key Drivers for Change in the Built Asset Industry

Driver	Description	Example target	UN SDGs
Addressing the climate crisis	There is global consensus on the impact of human activity on the climate and natural environment. The built asset industry, as a major consumer of resources and producer of waste and emissions, must undergo significant reform and transform its way of operating to ensure its impact is minimized.	Reduce emissions by 40 to 45 percent below 2005 levels by 2030 (Greening Government Strategy)	SDG 6, SDG 7, SDG 8, SDG 9, SDG 10, SDG 11, SDG 12, SDG 13, SDG 15
Ensuring post-pandemic economic recovery	Economies around the world have been hit hard by the COVID-19 pandemic. The built asset industry is notoriously ineffective and underperforms. The "productivity gap" between construction and other non-farm industrial sectors [18], [19] has prompted many discussion and calls for action. Solutions must be put forward to increase the industry's productivity and performance.	▪ Create 100,000 jobs each year (Investing in Canada Plan) ▪ Improve the construction industry's productivity	SDG 8, SDG 9, SDG 12
Addressing the housing crisis	Canada is facing an unprecedented housing crisis, which requires action to streamline the planning, authorization, and delivery of housing across the country.	▪ Create new housing supply ▪ Modernize existing housing (National Housing Strategy)	SDG 3, SDG 9, SDG 10, SDG 11
Addressing aging infrastructure	As highlighted in the Government of Canada's fixed asset review, a large percentage of Canada's infrastructure is approaching critical condition and end-of-life. Solutions must be found to facilitate the renewal of this existing infrastructure or the delivery of new, durable infrastructure.	▪ Improve the condition of existing infrastructure ▪ Deliver new infrastructure (Horizontal Fixed Asset Review)	SDG 6, SDG 7, SDG 9, SDG 11
Addressing the labour/ skills shortage	The construction industry is particularly sensitive to the aging workforce in Canada. Solutions must be put forward to (a) make the industry interesting to new generation of workers, (b) upskill the current workforce and enable it to embrace new ways of working, and (c) improve the safety of the construction industry by eliminating risky and unsafe working conditions through various means.	▪ Increase the industry's attractiveness ▪ Upskill a large portion of the existing workforce ▪ Improve the industry's safety	SDG 8, SDG 9

Note that each of the key drivers identified through this research have been or are currently being addressed through specific initiatives and programs set at various levels across Canada, as shown in Appendix D. Any digital transformation initiative or framework must serve and take these initiatives into account, where applicable. Digital transformation in the built asset industry can provide significant benefits that support the delivery of these initiatives and help realize their outcomes.

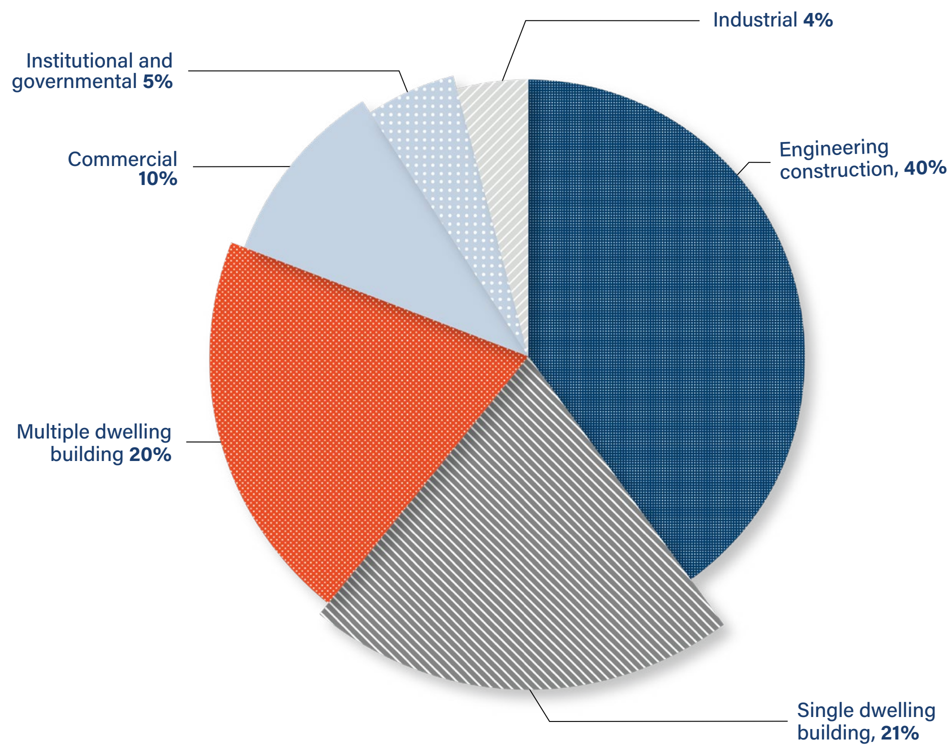
3.2 Context for Change: The Canadian Built Asset Industry

The Canadian built asset industry is one of the most important sectors in Canada, measured through its contribution to the country's economy and its impact on the environment and Canadian society. In 2020, the Canadian construction industry directly contributed $140.6B to Canada's economy, which represents 7.5% of the country's gross domestic product (GDP), distributed across residential, non-residential, engineering, and repair activities. In addition, the architectural, engineering, and related services domain contributed an additional $25.7B (1.7%) to the Canadian GDP. The construction industry contributes to the Canadian economy in many other ways, namely through consumption of manufactured products and complementary services. All in all, the Canadian built asset industry is responsible for about 12% of Canada's GDP [20].

All levels of government play a role in Canada's built asset industry, namely through regulation, demand, and mediation. Governments establish and enforce the environmental, technical, financial, and other regulatory constraints and conditions within which the built asset industry operates [21]. At the regional level, governments plan and dictate land use. Public institutions across the country at the different levels account for about 70% of capital expenditures in terms of ownership [22] and 26% in terms of funding source [23].

Figure 2 illustrates the distribution of the $295B spent in Canada's construction industry in 2019 across different sectors, including building and civil infrastructure. Forty percent of spending was in engineering construction and civil infrastructure [24], which was almost equal to spending in the residential

Figure 2: Distribution of spending in the Canadian construction industry in 2019 [24]



sector (both single and multiple dwellings). The remaining 19% was distributed across commercial, institutional, and industrial domains [25].

From an economic perspective, the Canadian built asset industry is known to have productivity issues. Figure 3 shows that labour productivity in the construction industry is considerably lower compared to all other business sector (excluding farms) and manufacturing industries. Moreover, labour productivity in the construction industry has stagnated over the past two decades compared to other sectors.

In parallel, the Canadian built asset industry's structure, namely that more than 90% of companies have less than 20 employees [158] , is a well documented characteristic that imposes certain constraints on how the industry operates and can be transformed.

The other measure of environmental impact is the amount of waste the built asset industry produces. Overall, it is estimated that as much as 30% of the total weight of building materials delivered to a building site is wasted [28]. A 2014 study characterized the total quantities of construction, renovation, and demolition (CRD) waste in Canada [29]. It is estimated that, out of a total of 24,780,000 tons of waste generated in Canada, 4,000,000 tons was generated in the construction industry. According to the study, 61% of the waste was generated in the residential sector and 39% was generated in the non-residential sector, and only 16% of all CRD waste in Canada is diverted from landfills [29].

From a societal perspective, the Canadian built asset industry plays a significant role. Beyond the importance of the built environment and its impact on the health, safety, and productivity of Canadian society, the industry is one of the top providers of jobs across the country. According to Statistics Canada, the Canadian built asset industry employs more than 1.1M people in various sectors [30]. However, the industry lags other industries in innovation, as evidenced by a lack of spending in research and development (R&D). While other sectors spend about 2% of their total revenue on R&D, companies in the construction industry spend between 0.3% and 0.8% of their total revenue on R&D [31]. This lack of spending can be attributed to the industry's structure low profit margins, payment delays, and lack of incentives to innovate, among other reasons.

Figure 3: Labour productivity in the construction industry vs. all industries, manufacturing, and business sector (excluding farms) [26]

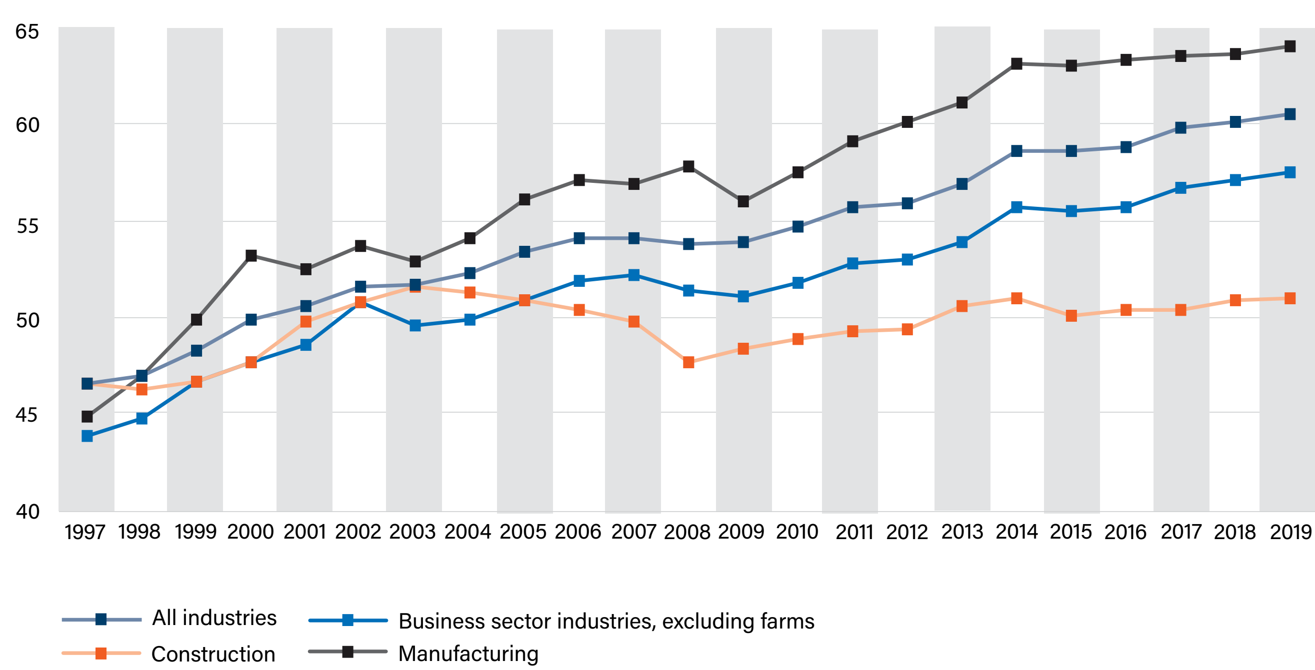
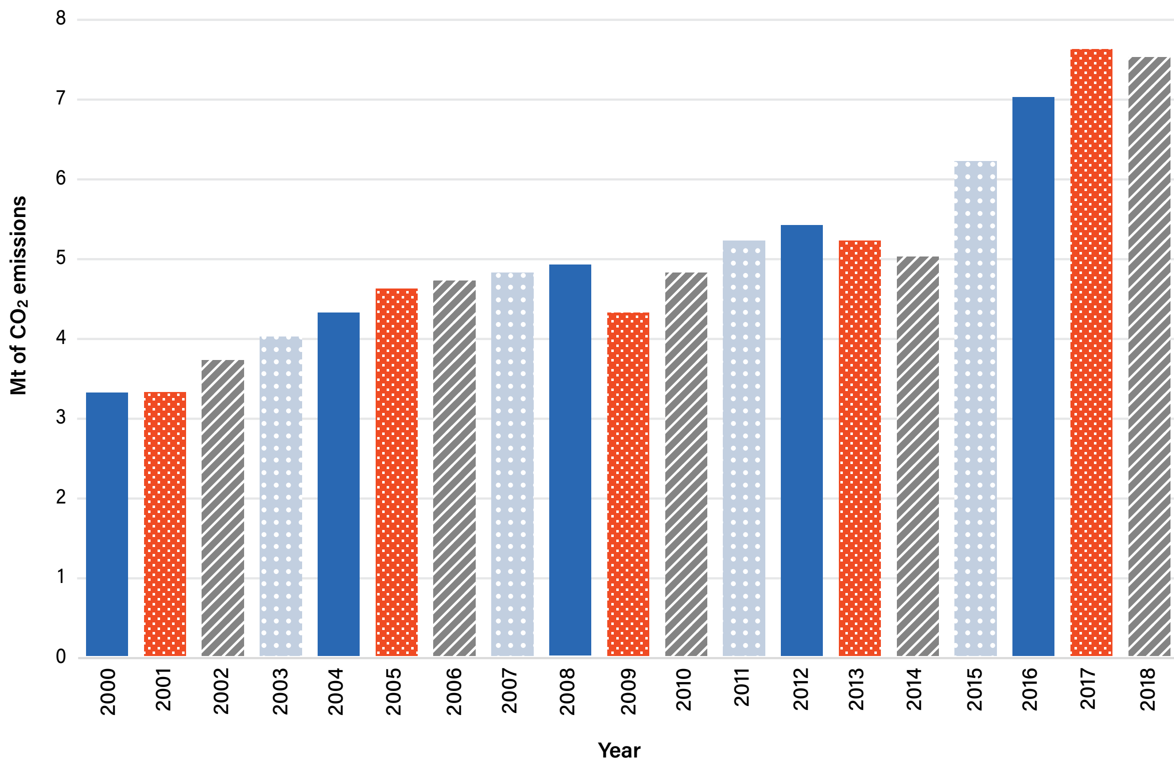


Figure 4: CO_2 emissions produced by the construction industry in Canada [27]



From an environmental perspective, the construction industry has a significant impact on Canada's natural environment. The first measure of this impact is the amount of greenhouse gas emissions produced by the built environment over its lifecycle. According to Natural Resources Canada, in 2018, the construction industry produced 7.5 metric tons (Mt) of CO_2 emissions (1.5% of total), residential buildings produced 65.9 Mt of CO_2 emissions (12.8% of total), and commercial/institutional buildings produced 49.0 Mt of CO_2 emissions (9.5% of total). Combined, the built asset industry produced 23.8% of total CO_2 emissions in Canada [27]. Furthermore, as illustrated in Figure 4, the amount of CO_2 emissions produced by the construction industry has grown consistently over the past two decades, more than doubling since 2000.

These three aspects — economy, environment, and society — form the crux of any transformation efforts within the built asset industry. Initiatives aimed at developing and formalizing knowledge should support improvements in one or all three of these areas.

3.3 Defining BIM Adoption and Implementation

The drivers discussed in Section 3.1 set the purpose for change: the why. The significant advances and innovations in technology, processes, and practices that have been developed in the built asset industry provide opportunities for transformation: the how. Correctly implemented, these innovations can help address the key drivers. While they come in many forms, innovations typically cover three areas:

- **Transforming what is built.** Innovations in how built assets are visualized and analyzed, and advances in requirements capture and engineering can help ensure that what is built is appropriate and meets the needs of clients and end users. Opportunities include optimization of existing assets through advanced analysis, and rethinking how assets are designed, what their functionalities are, and how to maximize their usage at the portfolio or regional level.

- **Transforming how it is built.** Advances in project planning, design, and delivery include integrated project teams and supply chains enabled through relational contracts, the application of lean design and construction techniques, and advanced project planning and analysis to streamline how built assets are delivered and to eliminate waste. Innovative materials, products, and equipment can also provide value to industry stakeholders.
- **Transforming how it is used and maintained.** Increased connectivity and advances in computing can help make real time analysis and predictions possible. Concepts such as high-performance buildings, focusing on user comfort, and adaptive reuse can ensure built assets are fit-for-use over their lifecycles. The use of digital twins and digital threads is becoming increasingly popular.

Specific innovations can be positioned across these three areas, with some spanning more than one. They can also be articulated across one or more "transformation dimensions," which include technology, organization, and process. Figure 5 provides examples of opportunities that can enable transformation across built asset lifecycles.

Digital transformation and BIM span and connect all three transformation dimensions. They can both enable and lead innovation, which means they can support most, if not all, of the innovations and opportunities identified in Figure 5. Digital transformation is predicated upon digitization and digitalization. For Rachinger et al. [1], digitization, which is the passage from analog to digital data sets, serves as "the framework" for digitalization, which is the "exploitation of digital opportunities." BIM is an example of digitization and is a cornerstone for digital transformation in the Canadian built asset industry [32].

The concept of BIM has existed since the 1970s to explain the digital modelling of building product data and information [31], [32], [33]. However, the term *building information modelling* first appeared in the 2002 white paper by Autodesk [36]. Since its coining, it has been defined in many ways. but the overarching

Figure 5: Opportunities enabling transformation across built asset lifecycles.

<table>
<tr><th></th><th>Transforming what is built</th><th>Transforming how it is built</th><th>Transforming how it is used and maintained</th></tr>
<tr><td rowspan="4">Organization</td><td colspan="3">Innovative business models</td></tr>
<tr><td colspan="3">Principles of circular economy</td></tr>
<tr><td colspan="3">Collaborative/relational procurement modes</td></tr>
<tr><td></td><td colspan="2">Integrated supply chains</td></tr>
<tr><td rowspan="4">Process</td><td colspan="3">Lean design and production strategies</td></tr>
<tr><td colspan="2">Off-site and modular construction</td><td></td></tr>
<tr><td>Generative design</td><td>Advanced project planning</td><td></td></tr>
<tr><td>Adaptive reuse</td><td>3D printing</td><td>Adaptive reuse</td></tr>
<tr><td rowspan="4">Technology</td><td>Predictive portfolio planning</td><td>Autonomous and remote equipment</td><td>IoT and built asset connectivity</td></tr>
<tr><td colspan="2">Advanced and innovative building materials and products</td><td>Digital Twins for operations</td></tr>
<tr><td></td><td colspan="2">Reality capture</td></tr>
<tr><td>High performance buildings</td><td>Industrialization and robotization</td><td>High performance buildings</td></tr>
</table>

concept has converged in a trilogy of definitions. The Canadian Practice Manual for BIM offers the first two definitions [37]:

- **Building Information Model:** An interoperable digital representation of physical and functional characteristics of a facility. It serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition (adapted from [38]).
- **Building Information Modelling:** A process focused on the development, use, and transfer of digital information models of a building project to improve the design, construction, and operation of a project or portfolio of facilities (adapted from [39]).

The third definition emerged with the ISO 19650 series of standards and the focus on information management, where BIM is defined as **Building Information Management**. Information management is defined as "the process of collecting, storing, managing and maintaining information in all its forms" [40].

Essentially, BIM is about built asset lifecycle information and its use to support decision-making by all involved stakeholders. As BIM adoption progresses and gains popularity in other sectors of the built environment, including civil infrastructures, the noun, *building,* is too restrictive in terms of application domain, whereas the verb, *building,* is too restrictive in terms of application across lifecycle phases. Consequently, in an effort to expand the scope, the term *better information management* has emerged. In parallel, and perhaps more pragmatically, the focus of the information model, the modelling, and the management process is on the built asset. Therefore, for the purpose of this report, BIM concerns all built assets, at all scales, and across all lifecycle phases.

3.4 BIM in Canada

3.4.1 Adoption and Implementation

It is challenging to paint a clear picture of the rate of BIM adoption and implementation across Canada. Evidence from past initiatives and from the findings of this research suggest that the use of BIM in Canada, as in other jurisdictions around the world, has grown significantly over the past decade. This growth has been variable across markets, domains, sectors, and asset lifecycle phases. As such, relatively high BIM maturity can typically be found in major urban centres across Canada. Higher maturity sectors and lifecycle phases include vertical infrastructure during the design and construction phases, whereas lower maturity areas include horizontal infrastructure, as well as operations and maintenance phases. Leading practice in BIM can be found among medium and large design firms and contractors and increasing maturity is being seen in subcontractors across the country. One interviewee from this study summed up the current situation in Canada:

> *In terms of where Canada is, now, we have pockets of impressive maturity, [...] but we don't have consistent maturity, and I don't even think we have a way to measure maturity [...] you see people who practice BIM across the table, and based on what they say, and what they talk about, and their ideas and their concepts, you kind of get a feel for whether or not they're on the same page. But aside from that, there's no real way to quantify our level of BIM in Canada.*
>
> (BIM Expert, Government Organization)

The rate of BIM adoption and implementation in Canada has been investigated through a series of studies over the past two decades [39], [40], [41], [42], [43], [44], [45], [46], [47], [48]. Due to inconsistency in findings and sample size, it is difficult to conduct cross-case analysis or uncover trends. Moreover, as recent reports from the University of Toronto acknowledge, samples may be biased due to the channels through which the surveys were distributed [40], [41], [42]. In other words, BIM adoption rates may have been reported as higher than they are, as many of the respondents operate in the BIM domain. Two surveys from Quebec with larger sample sizes showed lower BIM adoption rates [41], [50]. In both cases, the methodology cast a broad net within the Quebec construction industry, and therefore may be more representative. Despite the difficulty quantifying the actual adoption and implementation rates, by triangulating the different data sets and including the data collected and analyzed for this report, there is a clear trend in the increase of BIM adoption and implementation across Canada [39], [40], [41],[42], [43], [44], [45], [46], [47],[48].

"Evidence from past initiatives and from the findings of this research suggest that the use of BIM in Canada, as in other jurisdictions around the world, has grown significantly over the past decade."

3.4.1.1 Markets

According to the interviews, the rate of BIM adoption and implementation is higher in major urban centres across Canada than in small to mid-size urban and rural areas. This difference can be attributed to several factors, including more opportunity to implement BIM, from both a supply and demand perspective, and access to a broader pool of competent resources in major urban centres.

Looking at national, provincial, and regional markets, different government bodies have been working to develop and support BIM adoption within their organizations. At the federal level, both the Department of National Defence (DND) and Public Services and Procurement Canada (PSPC) have or are in the process of developing BIM requirements and including BIM as part of their project delivery and asset management strategies.

At the provincial level, Quebec and Alberta have been leading BIM adoption and implementation over the past decade through the agencies or departments responsible for delivering their vertical assets, particularly their office and institutional assets, namely the Société québécoise des infrastructures (SQI) and Alberta Infrastructure. For example, since April 2021, all projects over 50M$ managed by the SQI must be delivered using BIM. In April 2023, the threshold will be lowered to 5M$. Alberta Infrastructure publicly released their Digital Project Delivery requirements in 2018, which are being included in an increasing number of capital project contracts. British Columbia has stood up a committee to evaluate BIM adoption and implementation, and Ontario is considering implementing BIM on some of their capital projects. However, according to interviewees from both provinces, no formal strategies or requirements have been developed yet.

At the regional and municipal level, several municipalities across Canada have initiated a BIM implementation process or are actively using BIM on their capital projects, including the City of Calgary, Quebec City, and the City of Oakville, who have adopted BIM for different aims, such as e-permitting, design and construction, and asset management. In addition, many municipalities have expertise in geographic information systems (GIS), which they use to manage their linear infrastructures. Integration between BIM and GIS shows considerable promise but requires further work. Municipalities could significantly benefit from this type of integration, but they face considerable challenges in adopting and implementing BIM. For this reason, buildingSMART Canada has set up the Municipal Infrastructure Council to help structure BIM adoption and implementation in municipalities across Canada.

3.4.1.2 Domains

The rate of BIM adoption and implementation across domains is growing to include a larger portion of the supply chain. The architectural and engineering domains, as well as general contractors, have traditionally been the early adopters of BIM and continue to lead this process. However, an uptake in BIM adoption and implementation by owners, subcontractors, and manufacturers is also taking place.

> *I would say, architectural design is the most advanced from what I've seen. In terms of consultants, structural is almost always using some sort of BIM platform, as are electrical and mechanical consultants, somewhat civil and almost never in landscape. Interiors is now starting to kind of catch up a bit to the architectural practice, but still significantly further behind. And we are starting to see more subcontractors starting to get involved in BIM delivery. In fact, some of the more sophisticated subcontractors will actually deliver BIM shop drawings, which are always great and appreciated for enhanced coordination. But that's still pretty hit or miss within the industry, I'd say.*
>
> (BIM Expert, Design Firm)

BIM adoption by owners and public clients is growing, albeit inconsistently, across Canada. While this growth is positive, it introduces several issues regarding data exchanges, management, collaborative working, and more. Furthermore, as more owners look toward BIM, there is a risk that different types of standards, requirements, and protocols will be developed, which could create confusion in the industry.

3.4.1.3 Sectors

The rate of BIM adoption and implementation for larger vertical infrastructure (i.e., buildings) is relatively high, with respondents indicating that BIM use is now common on larger commercial, institutional, and multi-residential buildings. For larger, private developments, developers expect teams to use BIM to drive performance during the design and construction phases, but formal structure requirements are still lacking. However, there seems to be a shift taking place with these developers:

> *The things that we're seeing that's changing now with the rental market, and people were building purpose-built rentals. Now they care about not only just selling the property and exits, but they actually want to keep it for, you know, whatever, 15, 20 years. So now they care about Okay, what, let's maybe do this in BIM. Let's try to get an as-built BIM model, let's maybe use it for facility management, let's try to invest into the design and upfront costs. Because we are the ones that we're going to carry this building for the next 20 years.*
>
> (BIM Expert, Consulting Firm)

Single family residential, smaller multi-residential, and smaller commercial buildings have lower rates of BIM implementation, and the rate of BIM adoption and implementation for horizontal infrastructure (i.e., roads, bridges, tunnels, and other civil works) is also much lower and is inconsistent across the country. While major civil projects have been or are being delivered using BIM, its use is largely dependent on the team tasked with the project's delivery.

3.4.1.4 Asset Lifecycle Phases

The design and construction phases have traditionally been the ones where the rate of BIM adoption and implementation has been the most significant. As such, BIM uses have been formalized to support practices relating to the activities typically undertaken during these phases. There has been a noticeable increase in interest for BIM during the operations phase, which is seen by many as the phase during which BIM can provide the most benefits [51]. However, there are many questions regarding the implementation process and where BIM will provide the most value:

> *After the facility or the asset is built, what are we going to do with the model? This is where municipalities don't really know how they can use this. They have GIS systems, they know that if we can start to connect underground service locations with the GIS models, then there may be value there, but it's all theoretical at this point.*
>
> (BIM Expert, Engineering Firm)

In parallel, BIM adoption during the fabrication phase has also received significant attention due to the clear benefits of BIM in supporting design for manufacturing and assembly (DfMA) [52].

3.4.2 BIM Use

The growing rate of BIM adoption and implementation across markets, domains, sectors, and lifecycle phases mirrors the evolution of the use of BIM as capabilities are developed across the country. The notion of BIM use serves to frame and define specific processes, inputs, technologies, and deliverables to enable decision-making and support specific outcomes. For [53]: "A BIM Use can be defined as a method of applying Building

Information Modeling during a facility's lifecycle to achieve one or more specific objectives." According to the BIM Dictionary, BIM broadly supports several types of information uses, which are categorized as document uses, model uses, and data uses. Model uses are defined as: "The intended or expected Project Deliverables from generating, collaborating-on and linking Models to external databases. A Model Use represents the interactions between a User and a Modelling system to generate Model-based Deliverables. There are dozens of Models Uses including Clash Detection, Cost Estimation, and Space Management" [54]. The notion of BIM use or model use provides another level of analysis and structure when discussing BIM adoption and implementation. Indeed, BIM use can relate to the intensity of implementation within a given organization. Over the years, several strategies have been developed to classify, structure, and document BIM uses, such as the work by Penn State, through the BIM Dictionary, and by buildingSMART International.

In Canada, several core uses of BIM have been deployed over the years and have become common in specific sectors and domains. In particular, 3D coordination, clash detection, documentation, and visualization were consistently cited as the top BIM uses in a number of the studies mentioned above. For instance, the GRIDD-ÉTS survey conducted in 2015 identified creation of 2D documents, design support, visualization, multi-disciplinary, and clash detection as the top five uses of BIM [41]. The 2019 and 2020 annual BIM reports indicated that the top uses of BIM were coordination, collaboration, visualization, design, and clash detection [43], [44]. Similarly, action planning workshops with organizations that participated in the Quebec Construction 4.0 Initiative (IQC4.0) indicated that documentation, visualization, and clash detection were the most popular BIM uses [50]. It should be noted that the IQC4.0 used the classification of model uses developed by the BIM excellence initiative [55]. These three latter studies also identified advanced uses of BIM, including energy analysis, facility management, and code compliance checking. As BIM competencies and capabilities are developed, including tools and technologies, advanced BIM uses will likely grow in popularity and gain traction in the industry.

BIM Uses and nD Modelling

The concept of nD modelling with respect to BIM appeared around 2003. An nD model is an extension of a building information model incorporating all of the design information required at each stage of a facility's lifecycle [56], [57]. As early as 2000, the concepts of 3D and 4D modelling for the construction industry were discussed [58]. Over the past decades, nD modelling has been formalized to the point where 6D, 7D, 8D, 9D, and 10D modelling have been defined in various industry publications and mean various things to different people. Consequently, after 5D BIM, there is a lack of consensus on the definitions of these dimensions, and each dimension may include a number of model uses. Ultimately, the concept of dimensions is intended to offer a comprehensible way to categorize BIM uses, but the variability and lack of common definition can lead to confusion. Other categorizations have also been developed, such as the one proposed by the BIMexcellence initiative [55], which categorizes model uses according to domain and overarching intent.

3.5 Benefits of BIM Adoption and Implementation

The benefits of digital transformation and BIM implementation have been researched and discussed in previous studies. For example, a report by the Groupe BIM du Québec summarized the opportunities and benefits of BIM across the economic, environmental, and social domains, and at the industry level and within the built environment [32]. Table 2 illustrates some of the benefits identified in the literature.

In 2018, PricewaterhouseCoopers published a report on the BIM Level 2 Benefits Measurement Methodology (BMM), which they were commissioned to develop by Innovate UK [59]. The report presented results from applying the BMM framework to two projects, which indicated between **1.5% and 3.0% cost savings over the lifecycle of a built asset**, with the bulk of the savings accrued during the operations phase. In 2021, the Center for Digital Built Britain

Table 2: Benefits of BIM from the Literature

Economic benefits to the built asset industry	Environmental benefits to the built asset industry	Social benefits to the built asset industry
▪ 20 to 28% increase in productivity on site ▪ Improved competitiveness of the construction sector ▪ Increased capacity to export Canadian know-how ▪ Expansion of the digital service sector ▪ Step toward the single digital market	▪ Improved resource use ▪ Step toward the circular economy ▪ Increased resource efficiency of data infrastructure (reduced energy consumption)	▪ Safer jobs ▪ Better ability to attract people to the industry ▪ Increased data security ▪ Attraction of digital talent to construction
Economic benefits to the built environment	**Environmental benefits to the built environment**	**Social benefits to the built environment**
▪ 3% to 10% reduction in construction cost ▪ 7% to 19% decrease in the duration of the project (design and commissioning) ▪ 50% to 95% decrease in construction errors ▪ Reduction in maintenance and operation costs ▪ Between 66% and 98% reduction in intervention time during the operation phase ▪ Between 55% and 80% reduction in work time in the operation phase	▪ Reduction in waste on site ▪ Optimization of energy use during operation ▪ Possibility of a full life cycle analysis of the asset in operation	▪ Higher health and safety standards ▪ Improved public engagement and consultation ▪ Improved social benefits (improved patient care and students learning for instance)

Note: Adapted from Poirier et al., 2018 [30].

commissioned a report on the value of information management (through digital transformation and BIM) in the built asset industry [60]. The findings suggested that for every British pound invested in information management, the labour cost savings would be between 5.10 and 6.00 GBP and total cost savings would be between 6.90 and 7.40 GBP over time. The findings also suggested that every 1 GBP of productivity gained through information management could add an additional 3.70 GBP to the UK's annual GDP. Finally, these benefits could also contribute to wider social value through higher quality and more sustainable assets.

The promise of increased performance and wider societal benefits are driving BIM adoption and implementation across the globe. As shown above, the benefits of such a transformation are slowly being formalized and moving from anecdotal to quantifiable. Although there are challenges in documenting these benefits fully and unequivocally, the growing evidence provides a base to initiate and guide the BIM adoption and implementation process in Canada. However, while willingness and motivation are increasing, several significant challenges hinder this transformation process.

3.6 Challenges to BIM Adoption and Implementation

Since the 1980s, researchers have investigated barriers and challenges to digital transformation in the built asset industry. Issues such as fragmentation and poor collaboration [61], interoperability of information systems [62], lack of standardization [63], training and change management [64], and difficulty for small to medium sized enterprises (SMEs) to implement new technologies [65] were identified several decades ago and continue to act as barriers and pose challenges to innovation and digital transformation in the built asset industry.

Several studies have identified barriers that hinder BIM adoption and implementation. To summarize, the most important barriers can be classified into the following five categories:

1. Technological
2. Legal
3. Managerial
4. Fiscal
5. Human

Examples of these barriers include cost of investment, lack of industry standards and strategies, changes in workflows and inappropriate business models and organization, lack of client demand and managerial support, the fragmented nature of the architecture, engineering, and construction (AEC) industry, lack of subcontractors who can use BIM technology, the need to educate professionals about BIM, difficulties in measuring impacts of BIM, inadequate government policies, competing or lack of initiative and hesitance, lack of research on BIM implementation, and misunderstanding of BIM [64], [65], [66], [67], [68], [69].

Within Canada, the barriers and challenges to BIM adoption and implementation have been investigated and described through different studies and confirmed through this research project. Resistance to change, low rate of adoption by industry stakeholders, lack of knowledge and training, and learning curves have consistently been identified as significant challenges. Lack of client demand and lack of mandate have also been ranked as important challenges in previous Canadian BIM surveys [39], [40], [41], [42], [43], [44], [45], [46], [47], [48].

Many of these barriers point toward systemic and entrenched challenges within the industry, including the complex nature of the built asset industry, its fragmentation [72], lack of investment in research and development and innovation due to low profit margins [73], and a lack of change management [74]. In addition, significant and recurring barriers identified in past research point toward lack of knowledge and resources to adopt and implement BIM, including lack of education and training, lack of standards, non-conducive contractual environments, and maladapted practices. This was addressed by one interviewee, who stated:

> *I think [introducing advanced, standardized practices] would fundamentally change the way that BIM is used, if we didn't have to expend the energy on annotation and dimensioning so that it can be digested from a piece of paper, as opposed to the digital model, it would save a tremendous amount of time, and that time could either be realized as savings for the client, or it could be redirected into increased collaboration, increased design time, or improve the level of detail of the model.*
>
> (BIM Expert, Design Firm)

3.7 Challenge Areas to be Addressed

In the context of this research, the barriers and challenges to BIM adoption and implementation identified above were consistently mentioned throughout the interviews. The objective of the research was not to statistically quantify these barriers but to validate them and develop a response to them. As such, based on a categorization of past survey responses and an analysis of the data collected for this report, three main challenge areas were identified and are defined in Table 3. These challenges areas primarily relate to the operational aspects of BIM adoption and implementation. However, they also indirectly address corporate strategy and financial incentives (e.g., return on investment, operational costs, senior leadership support, etc.), highlighting a fourth challenge area that underlies the main three: the absence of a coherent operational framework for BIM adoption and implementation. This absence hinders the full potential of BIM adoption and implementation by introducing significant variability in its application and deployment. Increasingly, organizations are developing their own operational frameworks. While necessary to structure and support organization-wide BIM adoption, these ad hoc frameworks can lead to incompatible practices and workflows when working within project settings and across the different lifecycle phases of an asset. Therefore, these overarching challenges identified in the literature, validated through the interviews, and categorized above must be addressed through a structured response, which is discussed in Section 4.

Table 3: Challenge Areas for BIM Adoption and Implementation in Canada

Challenge area	Description
Lack of consistent demand by clients	Lack of client demand and lack of mandate for BIM consistently rank among the top barriers to BIM. This was echoed in the interviews with lack of consistent demand being a universal theme.
Lack of appropriate skills and competencies	Lack of in-house expertise, lack of knowledge and skills, lack of education and training, and lack of guidance have been identified as significant barriers for digital transformation and BIM adoption and implementation. Lack of technical, managerial, and operational know-how at all levels can seriously hinder the success of the transformation process and the realization of its benefits. The range and breadth of skills and competencies to be developed is considerable and requires a structured approach.
Incompatibility of capabilities and workflows across built asset value chains	Lack of collaboration and cooperation, inconsistency of workflows (BIM-based or hybrid), legal issues, inconsistent application, ad hoc standards, and interoperability issues (semantic, syntactic, process, and technical) hinder the full potential of BIM implementation.

4 Structuring BIM Adoption and Implementation in Canada: Responding to the Three Challenges Areas

Formulating a clear and consistent response to the challenges described in Table 3, that not only allows built asset industry stakeholders to fully realize the opportunities of BIM adoption and implementation but also addresses the key drivers of change is complex. Any response to address these challenges should facilitate this digital transformation and provide substantive improvements across industry segments. It should be proportionate, measured and targeted, and executed in a consistent manner, meaning that it must garner far-reaching support.

At their core, the three challenge areas stem from the absence of a coherent and broadly adopted Canadian body of knowledge (BoK) to support BIM and a framework to operationalize this knowledge. While work in this regard has been done in the past, both in Canada and internationally [75], [76], it does not account for recent standardization efforts and the scope of the proposed BoK targets specific BIM roles. A Canadian BIM-BoK should be broader in scope and more modular and scalable to be useful, which is the approach proposed below.

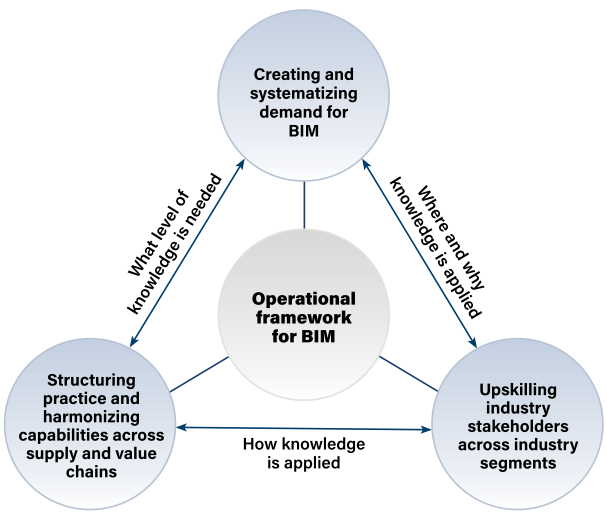
Responses to the challenge areas in Table 3 and their expected outcomes are shown in Table 4 and are described in detail in the following sections. Each response is first defined in relation to the challenge area that it addresses, and then specific Canadian needs and expectations are described. Next, past and current work relating to each response are outlined. Finally, gaps and the activities to address them are discussed. These responses are formulated to directly address the challenges and complexity of the task at hand: support the digital transformation of the Canadian built asset industry, through BIM adoption and implementation, to meet the broader economic, environmental, and social goals outlined in Section 3.1. While each of the responses requires sustained effort, there are meaningful synergies between all three, so they must be operationalized together to the greatest extent possible. This approach served as the foundation for the coherent operational framework for BIM adoption and implementation that is illustrated in Figure 6.

Many countries around the world have formulated strategies, developed programs, and implemented mandates to address these challenges and initiate and support the digital transformation of their respective built asset industries. In Asia, South Korea, China and Hong Kong, and Singapore have demonstrated leadership in this field. In Europe,

Table 4: Responses and Expected Outcomes to the Three BIM Challenge Areas

Challenge area	Response	Outcome
Lack of consistent demand by clients	Create and systematize demand for BIM along with digitalized project delivery and built asset management.	Consistent and harmonized demand across Canada at all levels of government and across all sectors.
Lack of appropriate skills and competencies	Upskill industry stakeholders across industry segments, building on a core body of knowledge (BoK).	A skilled and competent workforce with the capacity to fully implement and benefit from BIM and digital transformation.
Incompatibility of capabilities and workflows across built asset supply and value chains	Structure practice and harmonize capabilities across supply and value chains through standardization.	Highly capable supply and value chains that benefit from increased opportunities for integration of processes, workflows, and information flows.

Figure 6: Response to BIM adoption and implementation challenge areas



Finland, Norway, Denmark, Germany, France, and the UK have developed extensive frameworks and knowledge resources to support BIM adoption and implementation. In South America, Brazil, Chile, Argentina, and Peru have also developed initiatives to promote the use of BIM. Finally, both Australia and the US have a significant history of activity in this field. This research considered the various work undertaken around the world and how it could inform responses to the challenges identified in Table 4.

4.1 BIM Adoption and Implementation Frameworks

The challenges identified in Table 3 highlight the absence of a broadly adopted BoK and a coherent operational framework for BIM adoption and implementation in Canada. Formalizing such a framework is part of the overarching response to these challenges. BIM adoption and implementation, or "the set of activities undertaken by an organizational unit to prepare for, deploy or improve its BIM deliverables (products) and their related workflows (processes)" [54], have been the subject of significant research over the past decade. The research conducted for this report sought to better understand the different components and variables that affect this process at the industry, organizational, project, and individual levels.

Several frameworks have been developed to better frame, describe, and drive BIM adoption and implementation [67], [77], [78],[79]. These frameworks have many common characteristics, namely key dimensions and specific criteria or indicators that qualify this complex process. The dimensions found within these frameworks stem from work spanning multiple decades focusing on digital transformation, socio-technical systems, and organizational change management [80], [81], [82], [83], [84],[85]. These dimensions can be further distilled into knowledge parts and components, including:

- **Context:** The contextual dimension defines the environment in which BIM adoption and implementation takes place. It represents anything that is outside the organization and is concerned with issues such as norms, regulations, policies, markets, and cultures.
- **Organization:** The organization dimension relates to how teams and individuals are structured. It relates to contractual setups, hierarchical links created, and roles and responsibilities, including procurement and partnerships.
- **Process:** The process dimension underlies the practices, mechanisms, and actions that support BIM implementation. It is related to the generation of information and knowledge and its management and exchange between individuals within an organization, across a project network, and throughout a built asset's life cycle. Processes are supported through the people and practices, and include inputs and outputs, controls, and mechanisms.
- **Technology:** The technology dimension is related to the deployment of information and communication technologies and encompasses the tools, technologies, and platforms underlying BIM adoption and implementation.

A complementary perspective of BIM implementation is related to information and data management. The components identified in the context of this report align with the four key parts of information management, as defined in the ISO 19650 series: Information need and use, information requirements, information delivery planning, and information delivery. Accessibility of information and its architecture is also crucial. These terms are defined in Appendix A.1.

4.2 Creating and Systematizing Demand Through Policy

4.2.1 Why Is This Important?

Client demand is one of the main driving forces for BIM adoption and implementation [86], [87]. This was echoed in the data collected for this report. A lack of client demand and the absence of public mandates for BIM were consistently ranked amongst the top barriers to BIM adoption and implementation. The lack of demand by clients has several major consequences. First, industry is not incentivized to initiate or accelerate the transition, which results in the industry being slow to adopt BIM. Second, the lack of consistency of demand prompts rework and waste because requirements are not standardized to the greatest extent possible, which means that firms must adapt their deliverables to different types of demand. Lastly, interviewees consistently identified the fact that the asymmetry of BIM use, with more pronounced use during the design and construction phase, significantly hindered the full potential of BIM. This "drop-off" of BIM use at the subcontractor level and in later lifecycle stages negates the purported benefits of BIM.

Absence of demand is attributable to a lack of competencies on the part of owner organizations, which in turn hinders the progression of the Canadian built asset industry's BIM adoption, as highlighted by one of the interviewees:

> *And I think that's primarily the owner community just doesn't have the sophistication yet to ask for what they need. And many owners don't use digital tools for asset management, [...]. So, I think that's kind of a consideration as to why that hasn't been moving forward as fast as it might.*
>
> (Vice-President, General Contracting Firm)

4.2.2 Canadian Needs and Expectations in This Area

Client demand can be formalized and sustained through different channels and supported through different mechanisms. Primarily, client demand stems from information uses determined by built asset owners and operators to support their business operations throughout the lifecycle of their built assets. The built asset owner as client is the predominant view within the industry, but any downstream user or asset supplier can be considered a client, so increasing and systematizing demand also entails structuring and securing it throughout the supply chain. Client demand is formalized through information requirements as set out in the ISO 19650 series of standards.

Structuring and securing information uses and their supporting requirements, which essentially constitute the core of client demand, can be achieved by formulating clear and coherent policy and supporting instruments (regulatory, economic, or informative) to inform, promote, structure, and enable BIM adoption and implementation. These policy or instruments are primarily enacted through procurement routes, which constitute the models and strategies and the underlying contractual mechanisms that create the project setting, while binding the project participants together to deliver a service or a good. Using more integrated procurement models is seen as beneficial to promoting and supporting efficient and effective use of BIM [88].

The workshops conducted for this report prioritized several knowledge resources that support the formalization of information uses and requirements, including: level of X (LoX)/model progression specifications and level of information need, information security, information delivery specifications and manuals, and information deliverables to support specific model uses, formalized key decision points and acceptance criteria, and minimum required digital services.

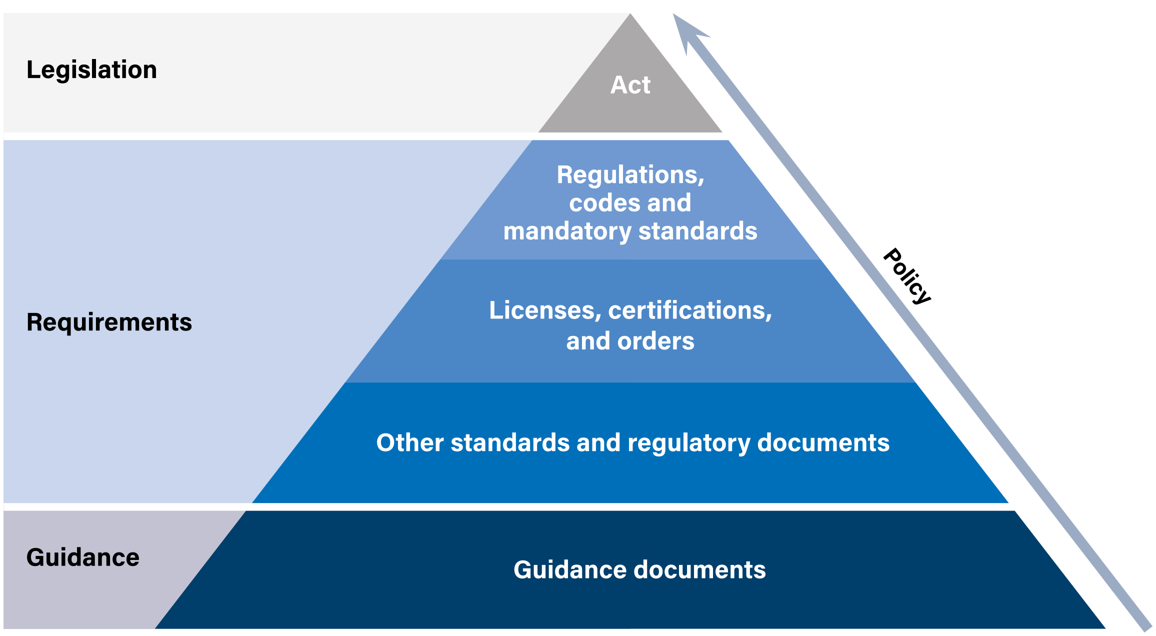
Two complementary themes regarding policy promoting BIM adoption and implementation emerged through this research. The first was the general importance of public bodies, at all levels, in structuring and promoting digital transformation and BIM adoption and implementation across the country. The second was the need for a clear BIM mandate from these public bodies. These themes are discussed in the following sections.

4.2.2.1 Government's Role and Influence on BIM Adoption and Implementation

Generally, governments will regulate what is built (e.g., through bylaws), how it is built (through building codes), and who builds it (through occupational training and labour laws). They will also set targets and strategies, through policy, that directly affect these areas. As discussed in Section 3.2, public bodies also account for the largest share of capital expenditures in the Canadian built asset industry, and are therefore the largest client group.

As illustrated in Figure 7, a jurisdiction's acts and laws (legislation) are enacted through regulations,

Figure 7: Relationship between legislation, requirements, and guidance



licences, codes, and standards (requirements), which are supported through guidelines (guidance). In Canada, the built asset industry is under provincial jurisdiction, meaning that laws, regulations, and codes affecting the industry are proposed, voted, enacted, and enforced at the provincial level. Examples include the BC Building Act, the Alberta Building Code Regulation, the Ontario Building Code Act, and the Quebec *Loi* sur les *bâtiments,* to name a few. These provincial acts mandate the use of building codes to set the minimum acceptable requirements for health, safety, accessibility, and protection for buildings. Some provinces use Canada's National Building Code (NBC), whereas others, including BC, Alberta, Ontario, and Quebec, publish their own codes which are based on the NBC but go beyond its minimum requirements. There are some exceptions for built assets on federally owned land. Authority and jurisdiction are sometimes given to municipalities to administer and enforce their province's building code, such as Vancouver, which has its own building code. Figure 8 illustrates the different regulations and codes, and their relationships within the Canadian built asset industry.

Municipalities may enforce bylaws that regulate specific characteristics of the built environment, including what can be built and what types of materials can be used. From a management perspective at the municipal level, some provinces have enacted specific legislation dictating requirements for the development of municipal asset management strategies and plans. For example, the Ontario Infrastructure for Jobs and Prosperity Act of 2015 included the Asset Management Planning for Municipal Infrastructure regulation, which requires that municipalities in Ontario prepare a strategic asset management policy and asset management plan. Failure to comply could lead to municipalities not receiving their share of the federal Gas Tax Fund [89].

Policy plays a key role in driving change in the built asset industry by establishing strategies and visions and setting the context for decision-making in terms of planning, delivering, and using the built environment. Policy can range in scope and focus from sustainability to procurement practices to prioritization of assets, and can be enacted through coercive or non-coercive means. There are policies concerning the built environment and built asset industry at all levels of government and across many agencies and departments, such as the federal government's Greening Government Strategy. Setting the right policies, in combination with other regulations, codes, standards, and guidelines, can create a context that is conducive for digital transformation and BIM adoption and implementation.

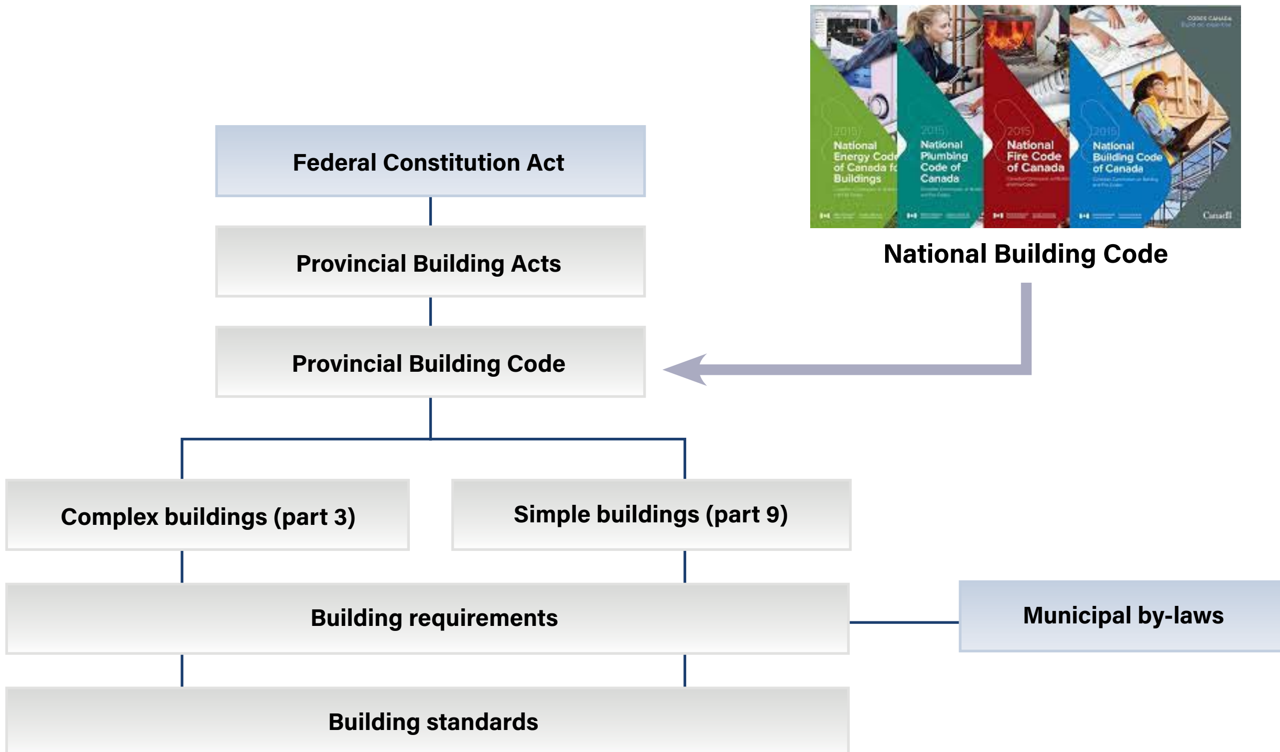
4.2.2.2 A Canadian Mandate for BIM

Governments have the capacity to regulate and enact policy supporting digital transformation and the adoption of BIM at different levels. As large client bodies, they also have the capacity to mandate BIM. While there has been a debate regarding the need for such a mandate in Canada, there is growing consensus that a BIM mandate is now necessary to support industry and to structure and leverage BIM-enabled practices to generate value for all built asset industry stakeholders. A majority (62%) of the respondents surveyed for this research either agreed or strongly agreed that BIM should be mandated and supported by the government, whereas 24% neither agreed nor disagreed. Less than 15% disagreed or strongly disagreed. Moreover, 69% of survey respondents indicated that the lack of governmental BIM mandates posed a significant barrier to their firm's digital transformation. This was echoed in the interviews:

> *And it was probably longer than five years ago. At that point, I thought, no, we would be able to manage this independently and we don't need a mandate. We don't need an authority to tell us how to deliver projects. That has changed mainly because of the success that I've seen abroad with other countries that have adopted a BIM mandate. The driving factors that help stimulate that and how rapid that has been.*
>
> (BIM Expert, Consultancy)

Defining and enacting a mandate is not a simple task. Similar to the US, the lack of a central government body in Canada makes enacting, coordinating, and enforcing a BIM mandate challenging. In the absence of this central body, a constellation of organizations

Figure 8: Regulations and codes in the Canadian built asset industry



and government bodies must coordinate and align their individual policies and practices to support such a mandate. A Canadian BIM mandate should point toward a common set of policies (including regulations, requirements, and codes) and a common implementation framework (standards, specifications, data architecture — see Section 4.4), and should rely on a common set of core skills and competencies (see Section 4.3). Given the regulatory context in Canada, a mandate, which would in fact be a multitude of mandates, would be enacted and enforced at the municipal, provincial, and federal levels. In this sense, the closest parallel are the National Model Codes [90]. Alternatively, the National Master Specification[91] could also serve as a precedent to inform and structure the adoption and implementation of BIM in Canada.

What is a mandate?

An official order to do something (Merriam-Webster dictionary)

What is a BIM mandate?

A BIM mandate could be defined as a requirement (or series of requirements) to deliver projects and manage built assets (or a portfolio of assets) in accordance with recognized standards to exchange and deliver information in a structured and consistent manner supported through BIM processes and technologies to achieve a set of specific objectives and outcomes.

Who can enact a BIM mandate?

Any owner, in relation to its portfolio of projects and assets.

4.2.3 Past and Current Work in This Area

Several jurisdictions around the world have made a significant effort to identify and formalize information uses and requirements, and to develop policy documents and procurement practices enabling BIM adoption and implementation. Examples include the UK's and the state of Victoria's (Australia) policies around digital transformation and BIM as well as the government of Quebec's BIM roadmap.

4.2.3.1 International Case Study: The UK and the BIM Level 2 Mandate

Much has been written about the UK's experience and the actions and initiatives leading up to the UK government's decision to mandate BIM (e.g., [92]). Originally developed in 2011, the UK's "BIM Level 2" mandate (which became BIM according to ISO 19650 series) is perhaps the most discussed example. It has now evolved into the UK's Information Management Mandate in the Transforming Infrastructure Performance: Roadmap to 2030, which was published by the Infrastructure and Projects Authority [17]. The initial mandate required all public projects to be delivered according to BIM Level 2 as of April 2016. Originally based on the PAS 1192 framework, the mandate evolved with the publication of ISO 19650 series of standards.

Supporters of the mandate indicate that it has had a significant impact in helping the UK's construction industry effectively transition to BIM. The fact that the mandate has been renewed through the Roadmap to 2030 document [17] is a clear indication that the UK government supports this path. Detractors, on the other hand, indicate that the mandate was poorly rolled out, which led to companies trying to achieve compliance through alternative paths, negating the original intent of the roadmap, which was to improve the performance of the industry [93].

Since the mandate was enacted, many resources have been developed to support the widespread adoption of the ISO 19650 series with the UK BIM Framework, under the direction of the UK BIM Alliance, acting as the central repository for most things BIM in the UK.

Table 5 illustrates the UK BIM Framework guidance that has been developed by the UK BIM Alliance.

Table 5: UK BIM Framework guidance [91]

ISO 19650 Guidance	Part 1	Concepts
	Part 2	Delivery Phase
	Part 3	Operational Phase
	Part 4	To be Confirmed
	Part 5	To be Confirmed
	Part A	The Information Management Function and Resources
	Part B	Open Data, buildingSMART and COBie
	Part C	Facilitating the CDE (workflow and technical solutions)
	Part D	Developing Information Requirements
	Part E	Tendering and Appointments
	Part F	Information Delivery Planning

4.2.3.2 International Case Study: Australia and Government Leadership at Different Levels

Australia has a similar context to Canada, with a federal government and state level governments that regulate construction. Around 2010, Australia took a leadership role and produced several documents supporting and structuring BIM adoption and implementation at the national level. However, due to political changes, the momentum had waned by 2012. This was echoed in an interview with an Australian representative:

> *Unfortunately, in Australia, there has been a lack of initiatives from the federal government. And it has sort of fallen more and more to the states to do something [it's now up to] the agencies that are dealing with building or infrastructure procurement, [to develop] these standards.*
>
> Standards Expert, Australia

At the state level, New South Wales and Victoria have been actively supporting and promoting digital transformation and BIM. For instance, Victoria developed the Victorian Digital Asset Strategy (VDAS) which "[...] sets out the vital process for safeguarding the digital systems that will allow [the State of Victoria] to monitor and improve the creation and management of infrastructure assets in Victoria." [94]. The VDAS builds upon and enables the Victorian Digital Asset Policy [95, p. 1]:

Victorian Digital Asset Policy

The digital asset policy (Policy) provides clear and consistent organizational and project requirements designed to optimize productivity and be appropriate and proportional to a project's value and risk context.

This Policy applies to all Victorian Government Departments, corporations, authorities, and other bodies under the *Financial Management Act 1994* (Vic.). The Policy is applicable to any asset investment proposal seeking budget funding and requiring the development of a business case, which is a mandatory requirement for capital investments with a Total Estimated Investment (TEI) of $10 million or more.

The VDAS is articulated around three parts, which are built on 10 appendices and several other resources. The three parts discuss strategic, organizational and application elements which comprise the VDAS. They are aimed at different audiences, including departments and C-level audiences, Asset, facility and portfolio managers and Project delivery teams. Other industry stakeholders have been active in Australia over the years to help structure and guide BIM adoption and implementation. From a standardization point of view, the National Building Specification (NATSPEC), "a national not-for-profit organisation, owned by Government and industry, whose objective is to improve the construction quality and productivity of the built environment through leadership of information" [96], has developed a portal containing resources for BIM, including the Open BIM Object Standard [97], the NATSPEC BIM Properties Generator [98], and the NATSPEC National BIM Guide [99].

4.2.3.3 Canadian Case Study: The Government of Quebec's BIM Roadmap

More recently, the Government of Quebec published its roadmap for BIM, *Feuille de route gouvernementale pour le BIM)* [100], which will be deployed over five fiscal years, from 2021-2022 to 2025-2026, and is broken into four components:

1. BIM deployment targets for each public owner involved in the roadmap.
2. Detailed BIM implementation targets of each of these public owners.
3. Streams and categories of actions supporting the implementation of BIM.
4. Annual activities within each stream and action category.

The roadmap contains the following six streams:

1. Piloting and coordination.
2. Stakeholder mobilization, engagement, and development of competencies.
3. Policies, contracts, and regulations.
4. Procedures, methods, and workflows.
5. Documentation and standardization.
6. Digital ecosystems.

Each stream presents three activity categories that articulate the different actions to support the roadmap, including standardization and upskilling activities. Working groups have been identified and mobilized to undertake certain activities (see Table 8).

The roadmap will be updated yearly and will grow in scope as more public owners get involved and commit to the provincial BIM implementation plan. Originally, six major public owners led the development of the roadmap, including the Ministry of Transport, the Quebec Infrastructure Society, the Quebec Housing Board, Hydro-Quebec, the City of Montreal, and Quebec City. Each public owner has identified and announced its progressive BIM implementation targets, which provides clarity around each public owner's intentions regarding digital project delivery (its BIM mandate of sorts). The scale, scope, breadth, and comprehensiveness of the Government of Quebec's roadmap makes it unique in North America.

4.2.4 What Is the Gap?

Creating and systematizing demand for BIM along with digitalized project delivery and built asset management can be achieved through policy, which leverages a clear set of information uses and requirements. These uses and requirements are delivered, to varying degrees, through various procurement routes. The primary gap in this regard is the lack of a policy framework for BIM and digital transformation in Canada that could help public bodies develop and align BIM mandates. As such, a Canadian BIM mandate would not be centrally enacted and enforced. Instead, it would likely be determined by different government bodies at different levels, similarly to the NBC. It could also be required by various clients, similarly to the use of the National Master Specification. A national code (or standard) for information modelling and management would set out the standards, specifications, and minimum requirements to be met and complied with, and would articulate the guidelines to be followed by industry practitioners as part of their obligations during project delivery. Government bodies could choose to implement or supplement the code as they see fit. A national code for information modelling and management would cover the key aspects of the BIM implementation framework discussed below and include the documents identified in this report. Given the proximity to the US and the current work taking place on the updated version of the NBIMS-US, *National BIM standard-United States* [101] (see Section 4.4.3.1), Canadian stakeholders may wish to align with this standard from an operational point of view. Table 6 summarizes the specific challenges, gaps, and required resources, and whether resources already exist to support the creation and systematization of demand for BIM.

Table 6: Challenges, Gaps, and Required and Existing Resources to Create and Systematize Demand for BIM

Challenge	Gaps	Required resources	Existing resources
Challenging contractual and procurement frameworks	Lack of understanding around procuring BIM-enabled projects and the necessary procurement framework required to support this.	Procurement guidelines	International
Inconsistent use of BIM	Lack of education and awareness on the principles guiding the development and identification of information uses and implementation. Lack of definitions on core requirements that specify consistent and repeatable information uses for general and domain-specific implementations.	Information uses	International
	Need to formalize capture, management, and exchange of information to enable use of digital tools and technologies to improve health and safety in relation to built asset throughout its lifecycle.	Information requirements and uses for health and safety	International
Lack of formal information exchange mechanisms	Lack of understanding around the concepts and principles guiding the acceptance of information by industry stakeholders. Once understood, information must be formalized and rigorously documented by stakeholders to ensure successful BIM implementation, which will help with automation of this process on a broad scale.	Information acceptance criteria	International

Challenge	Gaps	Required resources	Existing resources
Lack of general awareness on concepts and terminologies	Lack of a consistent framework to manage information across project and built asset lifecycles.	Information management principles	International
	Lack of in-depth investigations and documentation of what digital transformation entails and how it can benefit Canada to keep the industry abreast of the accelerating rate of technology growth.	General guidance on digital transformation in the Canadian built asset industry – trends and opportunities	None found
	Lack of understanding within industry and across different levels of government to ensure policy and regulation are in line with the strategy to enable digital transformation on a broad scale.	General guidance on digital transformation in the Canadian built asset industry – policy and regulatory development	None found
Lack of standard information management practices	Need to develop appropriate practices and methods to support information security when using BIM throughout the lifecycle of projects and assets.	Information security protocols and procedures	International
Unstructured or absence of information requirements	Need to communicate principles and concepts underlying delivery, and to explicitly define the appropriate amount of information required to suit a specific purpose when implementing BIM-enabled project delivery practices. Lack of such definitions can lead to waste or not adequately fulfilling client requirements.	Level of information need/level of X specifications and standards	International
	Lack of definition and communication about the concepts and principles, and the mechanisms to identify, capture, manage, deliver, and assess requirements for information across project and asset information lifecycles. Once concepts are established, core requirements for information exchange and delivery across project and asset information lifecycles need to be formalized.	Information requirements	International
	Lack of definition and communication about the concepts and principles, and the mechanisms to rigorously specify information requirements across project and asset information lifecycles. Once concepts are established, core specifications for information exchange and delivery across project and asset information lifecycles need to be formalized.	Information specifications	International

4.3 Upskilling Industry Stakeholders

4.3.1 Why Is This Important?

Creating and systematizing demand will put pressure on the industry to deliver structured digital information throughout the lifecycle of an asset. Industry must therefore possess the necessary competencies and skills to deliver on this demand. The systemic change required to operationalize BIM adoption and implementation and ensure that the benefits are realized involves structuring and harmonizing how business is conducted across the built asset lifecycle by various stakeholders [102] and configuring practices to allow for these new ways of working [103], which require new skills and competencies that are not readily available. Previous research and the research conducted for this report have identified lack of in-house expertise, lack of knowledge and skills, lack of education and training, and lack of guidance as significant barriers to BIM adoption and implementation. The lack of demand from clients and the industry's lack of appropriate competencies are root causes of the industry's inertia around BIM adoption and implementation, causing a disconnect between supply and demand. This disconnect can be addressed by providing a framework for upskilling industry stakeholders across all built asset industry segments that is based on a widely accepted BoK. An absence of initiatives and a BoK to support the upskilling of Canada's built asset industry could have dire consequences, as highlighted by one interviewee:

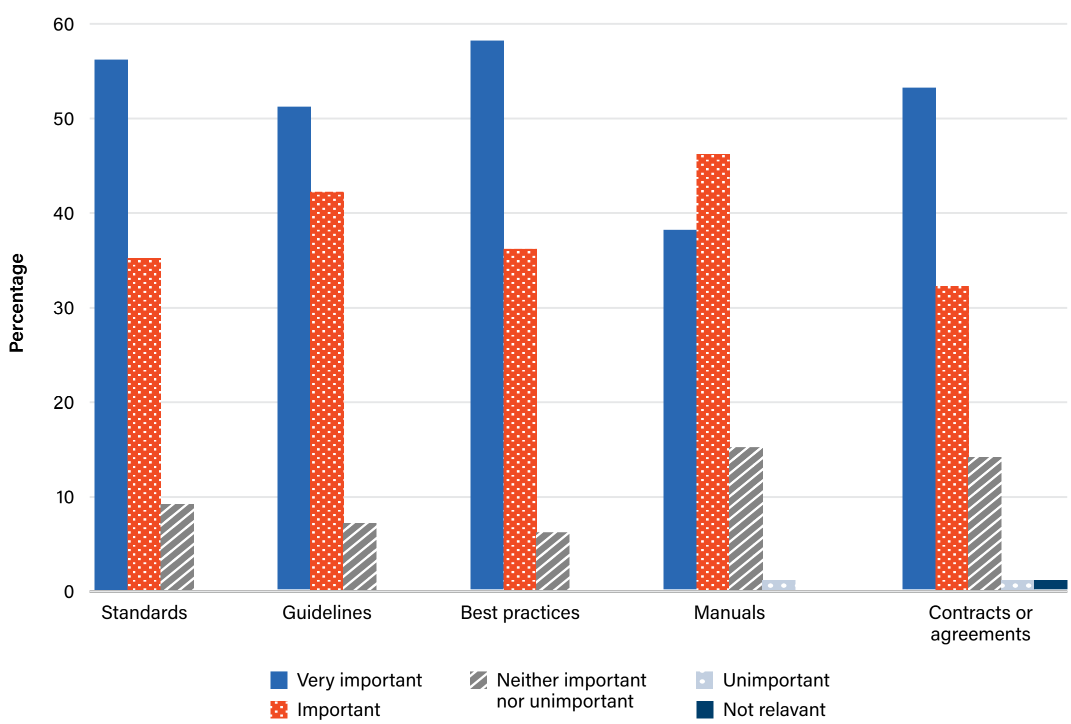
> *This is one of the things that I fear is that in Canada: there's still a significant chance that we don't advance quickly enough to seize the economic opportunity that's presented by BIM and information management between the US, the UK, our European trade agreements, any of these things, we won't be able to seize any of it, and will be left behind.*
>
> (BIM Expert, Government Organization)

4.3.2 Canadian Needs and Expectations in This Area

Through this research, consensus has emerged around the need for resources to inform, structure, and push BIM adoption and implementation (and digital transformation in a broad sense) within the Canadian built asset industry. For example, 81% of survey respondents indicated that there is a need for more resources to support the Canadian industry in its digital transformation. Looking at BIM adoption and implementation more specifically, there is consensus concerning the key role that standards and focused guidance must play to enable the Canadian built asset industry to move ahead and be successful in its digital transformation.

Figure 9 illustrates the importance placed on the development of specific knowledge resources, or NBPs, including standards, guidelines, best practices, manuals, and contracts or agreements. As shown, 91% of survey respondents indicated that BIM standards are either very important or important. Similarly, 93% indicated that BIM guidelines, 94% indicated that best practices, 84% indicated that manuals, and 85%

Figure 9: Importance of NBPs for the Canadian built asset industry

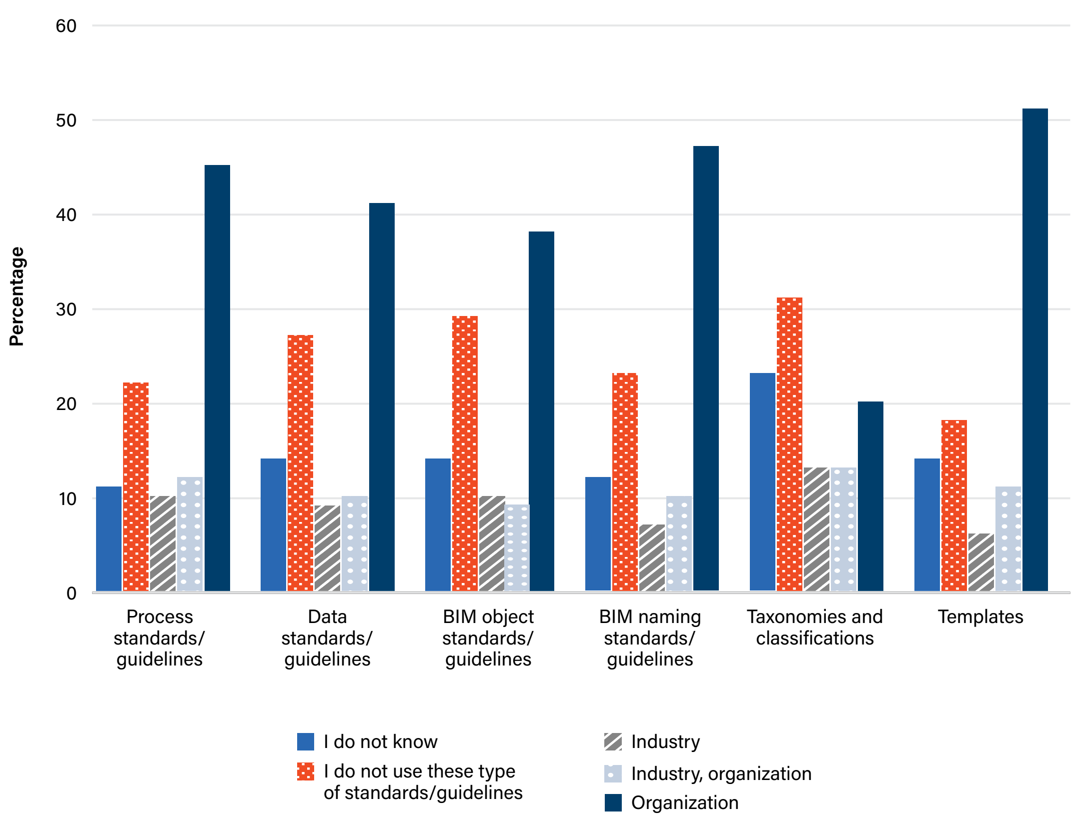


indicated that contracts or agreements are either very important or important. Looking at open BIM in the Canadian context, a majority of respondents (59%) indicated that there is a need for open BIM standards, whereas 39% responded that they did not know. Only 2% of respondents indicated that there was no need for open BIM standards. Of these NBPs, guidance, best practices, and manuals are the foundation for upskilling built asset industry stakeholders. Standards and contractual agreements constitute part of the BoK, and are addressed in Section 5.

Most of the NBPs and other resources that Canadian built asset industry stakeholders are currently using were developed at the organizational level. As shown in Figure 10, specific templates, BIM naming conventions and guidelines, data standards and guidelines, and BIM process standards and guidelines are developed for use within the organization in 40% to 50% of cases.

On the other hand, fewer than 10% of respondents indicated that these standards and guidelines were based on industry standards, and around 10% indicated that the resources were based either on industry or organizational precedents. Between 30% and 50% of respondents did not have any standards or guidelines pertaining to these knowledge areas. Interestingly, taxonomies and classifications were not used (or respondents did not know) in most cases. Where they were used, alignment with industry standards, while still low (around 25%), was the highest among all resources. As discussed in Section 4.4.1.1, the proliferation of organization specific standards and guidelines poses a risk to the effective and efficient implementation of BIM. There is a need to further promote and communicate existing resources and develop Canadian NBPs. One question this raises is whether to develop NBPs specific to Canada or to align with international resources. This is discussed below.

Figure 10: Development and use of BIM resources within Canadian organizations



Upskilling involves developing the people at the core of the BIM adoption and implementation process, who could be impacted, could lead, could resist, and so on, and therefore must be guided and supported throughout the transition. Upskilling also requires access to the appropriate platforms, which make up the overarching ecosystem of tools and technologies that support BIM use across supply chains and asset lifecycles.

These skills and competencies support the processes, tools, and practices that enable information delivery according to a specified plan that fulfill stakeholders' information requirements and support the use of information in decision-making throughout a built asset's lifecycle. They also ensure information accessibility, which includes the considerations and ecosystems supporting access to information throughout an asset's lifecycle.

The workshops conducted for this report prioritized several knowledge resources that assist in formalizing information delivery and accessibility, including common terminology and harmonization of concepts that are key to any guidance and education effort. Generalized guidelines around BIM use were also discussed. Regarding delivery and accessibility of information, common data environments and collaborative information systems, application programming interfaces (APIs), collaborative methods and procedures, quality assurance and control, and information exchange and review processes must be developed.

4.3.3 Past and Current Work in This Area

Resources and initiatives to train, educate, and guide industry stakeholders have been developed around the world and in Canada. Several governmental and non-governmental programs in Quebec and Ontario, which are discussed below, were developed to help industry develop their competencies and structure their practices. Moreover, a few NPBs were developed in Canada, most of which are aimed at structuring and enabling individuals to operate in these connected digital environments brought on by BIM. Questions around terminology are also being addressed in different ways through online resources.

4.3.3.1 Canadian Resources for BIM

Since 2011, a total of 42 Canadian NBPs have been published. For the purpose of this research, only NBPs that were publicly available on official websites were considered. As a result, almost half of the identified NBPs were published for a national audience. The provinces of Alberta and Quebec follow with the next largest number of NBPs. For Alberta, the majority of NBPs concern Alberta Infrastructure's Digital Project Delivery requirements, guidelines, and specifications, which are labelled as requirements, rules or policy types of NBPs [104]. In Quebec, several reports and guidelines have been published, with government organizations or advocacy groups being the most active in publishing NBPs. Generally, advocacy groups, such as local and national BIM organizations, published reports and learning modules, whereas government organizations published requirements, specifications, and protocols to support project delivery. Finally, most of the identified NBPs target either a general audience (no specific target) or built asset industry stakeholders. Unsurprisingly, the NBPs targeting a general audience are more general and informative in nature. Some examples include the annual national BIM reports [40], [41], [42]. The NBPs targeting industry stakeholders are more focused on enabling practice and include guidelines and protocols around BIM and information management, among others. A non-exhaustive list of Canadian NBPs is included in Table A.2.

Of the NBPs identified, 19 have a national perspective. Of these, 14 aim to inform and structure practices across domains. Table 7 describes the five remaining Canadian NBPs, with a national scope and general audience. As shown in Figure 11, even when these NBPs have been around for several years, awareness of them in the Canadian built asset industry remains relatively low, with 40% of survey respondents not being aware of any of these resources. Moreover, these NBPs have not been updated to reflect recent developments in the field. The challenges with these NBPs were highlighted by many of interviewees, not only in terms of updating and management, but also in terms of realizing their full potential:

> *[...] we can't scrape together enough attention or enough support to keep [these resources] consistently updated, consistently implemented, we can't connect them into how government is doing things, we can't connect them into how lower levels of the supply chain are doing things. And that's the weakness if we aren't all meeting together as sort of a strategic direction for standards development.*
>
> (BIM Expert, Public Owner)

Finally, several efforts are currently underway in Canada to develop specific resources for BIM, as shown in Table 8. These include whitepapers and reports, terminology, and classification efforts, as well as standards and templates to support specific requirements and practices.

Table 7: Canadian NBPs with a National Scope and General Audience

Title	Publisher	Year	Description
AEC (CAN) BIM Protocol [105]	CanBIM	2012 (V1) 2014 (V2)	Originally developed in the UK, the AEC (CAN) BIM protocol was adapted for Canada by CanBIM in 2012 and updated in 2014. "The document focuses primarily on encouraging adaptation of emergent standards for practical and efficient application of BIM in Canada, particularly at the design stages of a project." [105]
Benefits of BIM to Owners [106]	buildingSMART Canada (published initially under the Institute for BIM in Canada)	2013	Available in English and French, Benefits of BIM for Owners aims "to explore the use of BIM from an owners' perspective, identify the most common uses of BIM, and through a review of case studies and feedback from owners with experience with BIM, quantify the benefits they have realized through its use." [106]
BIM Project eXecution Plan (PxP) Toolkit [107]	buildingSMART Canada (published initially under the Institute for BIM in Canada)	2014	Available in three volumes or as a complete guide, both in English and French, the BIM PxP Toolkit includes: "documents designed to support the process of creating a BIM Project eXecution Plan and preparing for BIM projects. Each toolkit has been based around real world examples that have been compiled to create a composite illustrative project. Each volume has been repackaged to include all the supporting documents." [107]
BIM Contract Appendix [108]	buildingSMART Canada (published initially under the Institute for BIM in Canada)	2014	The BIM contract appendix is based on previously developed BIM contracts and designed to be appended to standard Canadian construction contracts, such as RAIC Document 6, ACEC 31, CCDC 2, and other standard form contracts already known to the Canadian construction industry. This contract appendix covers topics such as copyright, model element ownership and more.[108] It includes two parts: IBC 100-2014: BIM Contract Appendix and IBC 201-2014: LOD, Authorized Uses and Model Element Table. It is available both in English and French.
Canadian Practice Manual for BIM [37]	buildingSMART Canada	2016	The Canadian Practice Manual for BIM is available in three volumes or as a complete guide, both in English and French.

Figure 11: Percentage of respondents that are aware of Canadian BIM resources

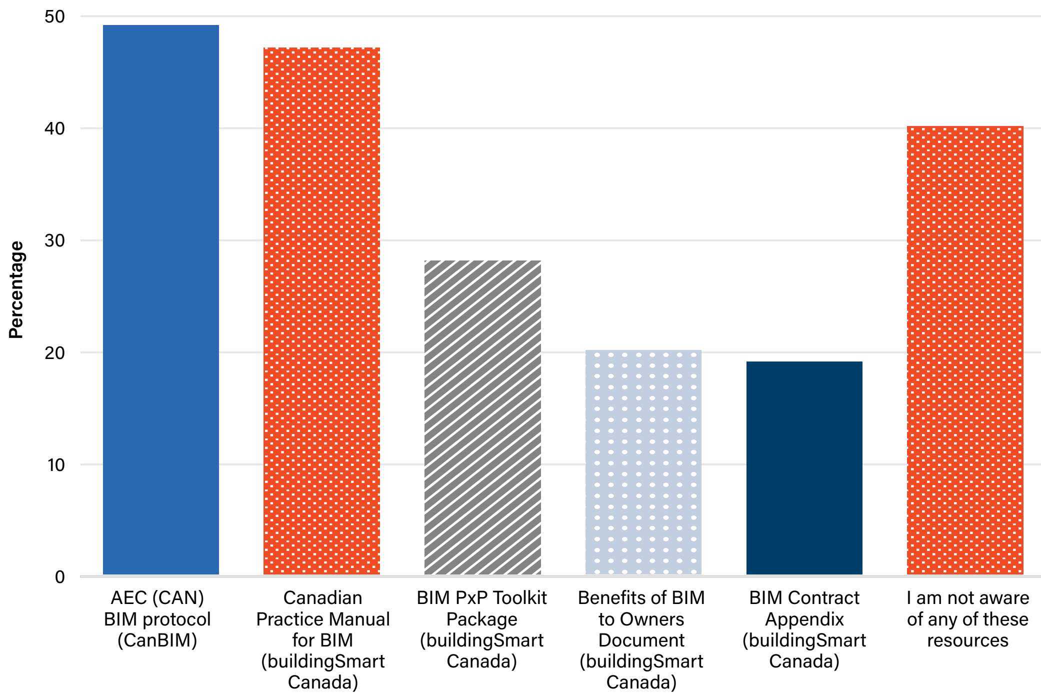


Table 8: Current National and Regional Initiatives for BIM Standardization and Guidance (as of March 2022 – available on respective organization's websites)

buildingSMART Canada
BIM for municipalities
Canadian Annex to ISO 19650-2
Canadian LoX Specification, Part 1 – Introduction
Contract appendix revision
CanBIM
BIM/VDC Career Benchmarking
Digitization and Data Glossary
Digitization Maturity Survey
Standards Repository
What Are the Needs of a VDC Team?
Groupe BIM du Québec
BIM Dictionary localization for the province of Quebec
BIM training and education inventory
Introduction to BIM for SMEs
Product data templates
Report on classifications and their use in Quebec

Notes: VDC: virtual design and construction; SMEs: small to medium sized enterprises.

4.3.3.2 International Case Study: Online Dictionaries

Several online resources have been developed to assist industry in the BIM adoption and implementation process. Two notable examples are described here. The first is BIMdictionary.com, "[...] a community effort to establish a reliable resource and a common understanding of frequently used terms across the Built Environment. The BIM Dictionary connects hundreds of terms to their vetted descriptions and translations and acts as a peer-reviewed reference to online guides and tools." [54] More than 810 terms relating to BIM and digital transformation in the built asset industry have been defined and have been, or are in the process of being, translated into 27 different languages. The second resource is the buildingSMART Data Dictionary (bSDD), "an online service that hosts classifications and their properties, allowed values, units, and translations. The bSDD allows linking between all the content inside the database. It provides a standardized workflow to guarantee data quality and information consistency." [109] Both of these resources are available and could potentially be adopted or adapted for the Canadian context.

4.3.3.3 Canadian Case Study: The One Ontario Coalition

In the Province of Ontario, over 30 organizations involved in the development approvals process have formed the One Ontario coalition. The coalition features representatives from a broad range of stakeholders, including building officials, planners, builders and developers, BIM groups, conservation groups, software providers, and individual municipalities. The coalition's goals are to streamline information exchange between stakeholders through the creation of an information exchange standard, develop a central review platform and reporting platform to easily track and review applications, and ultimately enable the use of BIM within the development approvals process to improve efficiency and reduce delays for industry, municipal governments, and other regulatory agencies. In January 2022, the Ontario government announced $45 million in funding for a new Streamline Development Approval Fund to aid Ontario's 39 largest municipalities in digitizing, streamlining, and accelerating their approvals processes, as well as an additional $8 million to aid large municipalities in finding potential additional savings and efficiencies through third party reviews [110].

Table 9: Intervention Areas to Support Digital Transformation in the Quebec Construction Industry

Stream	Initiative
1. Leadership and governance	1.1 Integrate governance poles to coordinate efforts to initiate and support the digital shift in Quebec. 1.2 Establish public bodies as exemplary owners of built assets. 1.3 Increase the demand for BIM by clients. 1.4 Develop and support a Quebec digital transition strategy for the construction industry with clear targets and sufficient concrete measures.
2. Engagement and guidance	2.1 Create a movement toward BIM to break through the inertia. 2.2 Create incentives for companies and institutions to make the shift. 2.3 Promote best practices in the delivery and maintenance of the built environment. 2.4 Expand the pool of projects by sector.
3. Collaboration and execution	3.1 Establish a policy, legal, and financial framework conducive to BIM deployment. 3.2 Develop standards to standardize work where it gains from standardization. 3.3 Frame the roles and responsibilities of project stakeholders and adapt them to new digital practices. 3.4 Define new collaborative approaches to project delivery and its life cycle.
4. Training and education	4.1 Orient curricula and teaching and training methods to emerging practices. 4.2 Support the development of training programs tailored to the diverse needs of the BIM field. 4.3 Ensure accessibility to quality education and training. 4.4 Support individual competency assessment.
5. Research and development	5.1 Encourage and increase partnerships between academia and industry. 5.2 Establish a Quebec centre dedicated to integrating new technologies in construction. 5.3 Develop a platform for sharing and centralizing knowledge and tools related to the digital shift. 5.4 Implement a benchmarking system for the industry to measure the benefits of BIM and promote the development of a culture of continuous improvement.

Notes: Adapted from Poirier et al., 2018 [32].

4.3.3.4 Canadian Case Study: The Government of Quebec's Construction 4.0 Initiative

In the province of Quebec, a report to identify key initiatives to enable BIM adoption and implementation was published in 2018. The report identified over 65 specific activities across 20 initiatives, articulated in five streams [32]. Table 9 lists the five streams and 20 initiatives that were identified to support digital transformation in the Quebec construction industry.

The report led to the creation of the Quebec Construction 4.0 Initiative[2] to help industry stakeholders plan and undertake BIM adoption and implementation. The five-year, $20M program, which aims to assist more than 1000 companies in Quebec, is supported by the Government of Quebec through the Ministry of Economy and Innovation and executed by *Groupe BIM du Québec* (GBQ) and *Institut de Gouvernance Numérique* (IGN). It is based on three core programs: (a) diagnosing and action planning, (b) guiding and training, and (c) piloting.

4.3.4 What Is the Gap?

As discussed throughout Section 4, upskilling industry stakeholders across industry segments can be achieved by developing a core BoK. The Canadian Practice Manual for BIM [37] is one valid resource that can act as a seed document, but it needs significant updating and expanding. Table 10 summarizes the specific challenges, gaps, and required resources, and whether resources already exist to support the upskilling of industry stakeholders across industry segments.

4.4 Standardizing Practices and Capabilities Across the Supply Chain

4.4.1 Why Is This Important?

While targeting supply and demand is key to breaking the built asset industry's inertia and building momentum, there is a need to provide a common structure for collaborative practice across built asset lifecycles by increasing competencies and harmonizing supply chain capabilities [111]. The lack of collaboration

Table 10: Challenges, Gaps, and Required and Existing Resources to Support Upskilling of Industry Stakeholders

Challenge	Gaps	Needed Resources	Existing Resources
Absence of specific technical skills	Lack of guidance and assistance concerning tools and technologies in the BIM technological ecosystems to ensure they are adequately implemented and used to achieve the desired results.	Guidance on tool use	International
Lack of general awareness on concepts and terminologies	Lack of common terminology and definitions, which are a critical success factor in the BIM adoption and implementation process.	Common Canadian dictionary	International
Unclear collaboration processes	Confusion and uncertainty around what constitutes a common data environment (CDE), how it should be implemented and deployed, the best practices in managing a CDE, etc.	Common data environments (CDEs)	International
	Tighter alignment of practices and workflows within project teams needs to be harmonized and facilitated to support collaborative production and management of information using BIM across a built asset's lifecycle.	Collaborative production of information	Canadian

2 https://www.constructionnumerique.ca/

and cooperation, inconsistency of workflows (BIM-based or hybrid), and interoperability issues (semantic, syntactic, process, and technical) hinder the full potential of BIM implementation. Moreover, legal issues, ad hoc standards, and a lack of common resources and operational frameworks introduce significant variability in the application and deployment of BIM. Increasingly, organizations are developing their own standards and internal guidelines, which are necessary to structure and support organization-wide BIM adoption, but can lead to incompatible practices and workflows when working within project settings. As the built asset industry relies more and more on digitalized processes and information and data flows, there is an increasing need to structure and standardize these flows [112]. This was echoed during the interviews:

> *I don't see any kind of standardization across the industry, how things are named how things are categorized is essentially how each organization has created their own BIM implementation plans and standards and library of resources. [...] So being able to have industry standardization around that would facilitate a lot smoother adoption as well.*
>
> (BIM Expert, Design Firm)

4.4.1.1 Importance of BIM Standards

According to France's PlanBIM 2022, the objective of standardization is to organize the dialogue between built asset industry stakeholders to: (a) improve the understanding of each other's roles and the impact of each other's actions on the work of the other actors, and (b) harmonize the rules and business practices to ensure an equivalent level of quality between professionals [113].

Hooper [114] highlighted the benefits and risks of BIM standardization, noting that contrary to the manufacturing or automotive industry, the construction industry is project-based, which makes it difficult to develop long-term feedback loops and consistently implement far-reaching management and technical standards. He also discussed the power imbalance within the industry, whereby large companies in the manufacturing and automotive domains own and control the supply chain, even large companies in the construction industry do not have the same level of influence over their supply chains. He pointed toward the need for centralized leadership to drive change and steer development of standards and common guidelines on a national scale.

Hooper also noted that there have been calls for caution in codifying and formalizing best practices because the construction industry is continually changing. He suggested that low adoption or misappropriation of standards could hinder or negate their effectiveness and cause more harm than good. However, the author concluded that the benefits of standardization far outweigh the risks (e.g., codifying obsolete practices) and observed that in the absence of a common set of industry standards, organizations are creating their own, leading to a "constellation of fragmented approaches" that could seriously impact the full potential and value of digital transformation and the BIM adoption and implementation process [114, p. 336]. This aligns with findings from other research that has identified a lack of standards as one of the main barriers to BIM [64], [65], [67], [68],[69], [106].

4.4.2 Canadian Needs and Expectations in This Area

BIM standards have typically related to either technical or process standards. According to volume one of the Canadian Practice Manual for BIM, "Technical standards are those developed through the software vendors and international bodies that describe how information is captured in one system or another. Process standards refer to documenting processes or protocols that describe how a particular business uses the technology during daily activities." [116, p. 27] With the publication of the ISO 19650 series, management standards are now also being developed. Canada has not yet developed a set of standards to guide and frame BIM-enabled project delivery, and asset and information management practices. It requires significant work to establish partnerships and harmonize capabilities within networks and between individuals within organizations that go beyond the boundaries set by a specific contractual mechanism. Collaboration is a core consideration of BIM that requires structuring and standards play an important

"Collaboration is a core consideration of BIM that requires structuring and standards play an important part in enabling this."

part in enabling this. Another core consideration concerns products and their data. In the context of this research, products refer to the materials, their assembly, and their digital counterparts, that comprise the built environment. As laid out in Stanford's Center for Integrated Facility Engineering (CIFE) POP (product, organization, and process) model, "The constructs related to Product refer to the physical and abstract concepts that describe the artifact itself, such as the columns and electrical system of a building." [80, p. 75]. According to this perspective, products have function and form and display behaviour.

The advent of the ISO 19650 series highlighted the need and possibility to standardize BIM-enabled project delivery and asset management processes in the built asset industry. While the popularity of the ISO 19650 series is growing around the world, the level of awareness about it in Canada remains low. For example, 35% of survey respondents were aware of the ISO 19650 series, whereas 65% were not. However, several government bodies across Canada, at the federal, provincial, and municipal levels are moving toward adopting and implementing the ISO 19650 series. Large public bodies, including PSPC and DND, are adopting the standard and slowly migrating their procurement and project delivery practices and adapting their policy frameworks to comply with the ISO 19650 series, so there is a need to structure and formalize Canadian resources pertaining to this standard, among other resources, as discussed below.

> *BIM level 2 And what is now ISO 19650 makes sense because it's a framework [...where...] the requirements are defined up front, they get issued to you, you have a pre contract BIM execution plan so that you can level the bids, so that you understand things, then you issue the BIM execution plan back afterwards to explain how you're responding, there's a Master Information Delivery plan, so everyone knows what is being delivered, when, etc.*
>
> (BIM Expert, Design Firm)

Information delivery planning, which underlies these components, is "one of the fundamental concepts of the ISO 19650 series" [117, p. 9], which lays out a progressive, yet structured, approach to plan the delivery of information. Another key aspect concerns information architecture, which "[...] is the structural design of shared information environments; the art and science of organizing and labelling websites, intranets, online communities, and software to support usability and findability; [...] Typically, it involves a model or concept of information that is used and applied to activities which require explicit details of complex information systems. These activities include library systems and database development" [118]. In this context, information architecture includes concepts relating to data schemas (i.e., Open BIM) and classifications.

The workshops conducted for this report prioritized several knowledge resources that help to formalize information delivery planning, including: federation strategies and the information container breakdown structures, responsibility matrices and task and master information delivery plans, BIM execution plans, risk registers, mobilization plans, and capability and capacity assessments. The workshops also prioritized resources concerning information architecture, including classifications and dictionaries, data templates, schemas, formats, and linked and integrated data such as BIM-GIS integration.

4.4.3 Past and Current Work in This Area

Many of the needs identified and prioritized through this research project could potentially be adopted or adapted from international sources for use within Canada. There is also considerable work underway in many of these knowledge areas, including the international standardization work for BIM happening within ISO, the European Committee for Standardization (CEN), and other international initiatives, such as the BIM excellence initiative (BIMe), as well as work happening locally within Canada. Any work undertaken within Canada should seek to align with and potentially support work happening internationally, while also supporting existing initiatives being undertaken in Canada. Current international initiatives for BIM standardization and guidance, as of the publication of this report, are listed in Appendix B. These provide a sense of the type of work undertaken internationally with which Canada could align.

Many of the components identified and prioritized through this research are considered within the ISO 19650 series, its parts, and its underlying guidance. In this sense, the UK BIM Framework may be the most significant resource to support implementation of ISO 19650 and should be considered for adaptation within Canada. Additionally, the VDAS, discussed in Section 4.3.3, and Hong Kong's Construction Industry Council (CIC) BIM Standards [119]–[122] rely heavily on the ISO 19650 series and have developed many useful resources and parts. Table 11 provides a list of such resources for the Hong Kong BIM standards.

There has also been a significant amount of work around classifications, a number of which are currently in use in Canada. However, several issues have been highlighted, namely that many of the classification systems in use were not updated or harmonized and therefore their full potential was hindered.

Considering the different characteristics of information architecture, open BIM principles have shown great value in successfully structuring data and enabling interoperability within the built asset industry. Specifically, technical BIM standards enabling data exchange and interoperability of information systems are comprised of three components that must be standardized to perform an information exchange between two or more information systems. This "standards triad" includes a standardized process (the information delivery manual, IDM), common terminology (the International Framework for Dictionaries, IFD), and a harmonized data schema to transport the data itself (the Industry Foundation Class, IFC). These three elements are at the core of open BIM. Two other standardized approaches that support the implementation of open BIM are the BIM collaboration format (BCF) and Model View Definitions (MVD). Many of the elements prioritized through this research have been or are currently in development by buildingSMART International, as shown in Appendix B. Any work undertaken in Canada would therefore have to align with work underway internationally in this regard, especially given the fact that the standards developed internationally are implemented within the various software tools used across Canada.

Finally, France and Norway have performed significant work on product data and object libraries, which includes product data templates and other standards and guidelines supporting product lifecycle information management. This work has led to the development of two ISO standards, ISO 23386 and ISO 23387, that frame the identification and management of object properties, data dictionaries, and product templates [123], [124].

Table 11: Hong Kong CIC BIM Standards

Content	BIM Standard – General	BIM EIR Template	Arch & Struct.	Underground Utilities	MEP	BIM Objects
Information Management [ISO 19650]	▪					
Organisational Information Requirements (OIR)	▪					
Asset Information Requirements (AIR)	▪					
Project Information Requirements (PIR)	▪					
Security Information Requirements (SIR)	▪					
Exchange Information Requirements (EIR)	▪	▪				
Level of Information Need	▪		▪	▪	▪	▪
Level of Graphics (LOD-G)	▪		▪	▪	▪	▪
Level of Information (LOD-I)	▪		▪	▪	▪	▪
Level of Documentation (DOC)	▪		▪	▪	▪	
Field Verification	▪		▪	▪	▪	
LOD Responsibility Matrix	▪		▪	▪	▪	
Asset Information Model (AIM)	▪					
BIM Execution Plan (BEP) Contents	▪	▪				
BIM Goals, Uses & Deliverables	▪	▪		▪		
Project Information Standards	▪					
Roles, Responsibilities and Authority	▪	▪				
BIM Team Resources, Competency and Training	▪	▪				
Software, Hardware, CDE and IT Infrastructure	▪	▪				
Quality Assurance – BIM Auditing	▪	▪				
Common Data Environment (CDE) [ISO 19650]	▪	▪				
Information Management Workflow	▪					
Contractual Documents	▪	▪				
Modelling Methodology and Requirements	▪					
openBIM	▪					
BIM Object Coding and Classification	▪					▪
Common Practice for Information Modelling			▪	▪	▪	

ISO 19650 series of standards

ISO 19650 series comprises of six parts:

- Part 1: Concepts and principles [125]
- Part 2: Delivery phase of the assets [126]
- Part 3: Operational phase of the assets [127]
- Part 4: Information exchange (under development)
- Part 5: Security-minded approach to information management [128]
- Part 6: Health and security (under development)

The standard "…sets out the recommended concepts and principles for business processes across the built environment sector in support of the management and production of information during the life cycle of built assets (referred to as 'information management') when using Building Information Modeling (BIM)." It is primarily intended for use by organizations and individuals involved in the procurement, design, construction, and/or commissioning of built assets; and those involved in delivering asset management activities, including operations and maintenance. In other words, the standard spans the entire lifecycle of an asset or a portfolio of assets (Parts 2 and 3). It also provides solutions to an increasingly important and highly relevant issue: data and information security (Part 5).

The main intent behind the standard is to provide a clear pathway for information management over an asset's lifecycle, supported through BIM that is based on consistent and specific terminology, concepts, and methods. This is especially useful for clients when procuring services and assets as it provides a baseline for their assessment and evaluation. It also provides a framework for project teams in the production and delivery of information using BIM across all asset lifecycle phases.

(adapted from [129])

4.4.3.1 International Case Study: The US and Grassroots Initiatives for BIM

Historically, the US has taken a hands-off, free market approach to BIM. Indeed, many in the US believe that a BIM mandate like the ones in the UK and in Victoria, Australia, is not possible or necessary. Pollock's 2017 article comparing the US and the UK approaches to BIM provided two reasons for this: decentralization and the culture of the US construction industry [130]. Regarding the first reason, as in Canada, the US does not have a central agency responsible for construction, which makes it difficult to align, develop, and enforce a key set of standards and practices in a consistent manner across the country.

The second reason, culture, is more subtle and complex. The article stated that many industry players in the US do not want a BIM mandate. The US industry's bottom-up approach is seen as more agile and suitable for the fast-paced rate of innovation underlying digital transformation and BIM adoption and implementation, rather than the "club-style academic exercise over BIM standards, mandates or requirements, where everyone tries to agree on one 'hypothetical' set of standards by which projects will happen." The people Pollock interviewed in the article pointed to a quasi-viral method of diffusion in contrast to the UK's top-down approach [130]. In this research, what emerged from the analysis of existing BIM standards and guidelines is that most universities in the US that have developed BIM requirements use the same set of documents, constituting a de facto standard for these academic institutions.

However, with the internalization of the original Level 2 framework through the ISO 19650 series, the debate surrounding the importance of a widespread and mandated set of standards appears to have evolved in the US. In fact, the upcoming version of NBIMS-US [101] may potentially be aligned with the ISO 19650 series. The hope is to provide a robust and consistent framework that public and private owners across the US can point to when specifying and implementing BIM on their projects:

> *We envision that [NBIMS-US V4] aligns with the ISO 19650 process, but we are not directly using that process to organize it. […] we will align the language for the most part, although not entirely like lead appointed party, appointed party, you know that other stuff, it's just people give us blank stares when we're talking about it, right. So, we're going to try to make it readily adoptable, using common language that our industry is familiar with.*
>
> (Academic Expert, United States)

One expert in standards development in the US indicated that they were focusing on making the next version of NBIMS-US "[...] a standard that can be implemented in a contract by an owner." To them, this is done by "[...] providing the layer down of how what's in the ISO 19650 framework gets implemented." This includes indications on how to request data to be provided, how to plan the execution of BIM on a project. Ultimately, the expectation is that "[...] once [the updated version of NBIMS-US] is released, and then bring the ISO 19650 framework into use in the US, we can address these challenges of helping the owners to get what they're looking for, and what they need on projects."

In terms of organizations, the national BIM Council has been established within the National Institute of Building Science (NIBS), which has historically led the development and coordination of BIM efforts in the US. Indeed, NIBS was originally the home of the buildingSMART alliance, which recently became the BIM Council, for reasons not relevant to this report. The BIM Council's mission is: "to lead the development and deployment of broadly adopted national information standards and best practices for the built environment, with a focus on significantly improving project delivery and operational processes." [131]

Many other organizations have displayed leadership in the US over the past two decades, namely the American Institute of Architects, the General Services Administration, the US Army Corps of Engineers, and the Association of General Contractors of America, who founded the BIMForum. These organizations have been supported by academic institutions to develop resources, namely Penn State's Computer Integrated Construction Research Group, Stanford's CIFE, and Georgia Tech's Digital Building Laboratory. Moreover, universities who are also large owners of building portfolios (e.g., Ohio State University), transportation authorities (e.g., MassPort), and large metropolitan areas (e.g., New York City and Los Angeles) have developed and implemented specific guidelines and requirements for BIM in their projects.

Regarding availability of specific resources for BIM in the US, a significant amount of NBPs have been developed over the years. Of these resources, three have garnered a lot of attention: the BIMForum Level of Development (LOD) Specification [132], Penn State's BIM Project Execution Planning guideline [133], and the NBIMS-US [101], [134], [135] . Table 12 shows the content of the NBIMS-US and its evolution across the four versions. Note that both the BIM Forum LOD Specification and Penn State's BIM Project Execution Planning guideline were included in version 3.

4.4.3.2 Canadian Case Study: Alberta Infrastructure's Digital Project Delivery Documents

The Alberta BIM Centre of Excellence (ACE) published one of the first reports on BIM in Canada. The BIM 'Best Practices' Project Report [82] offered an investigation into BIM best practices in the Canadian industry. Its intent was to better understand the potential benefits and challenges to BIM adoption in Canada. The authors summarized their findings across three dimensions, technology, organization and process. Many of the best practices listed are still relevant today.

In 2018, Alberta Infrastructure developed its Digital Project Delivery documents, which are listed in Table 13. These documents set out the requirements, templates, and checklists for service providers to use to deliver their projects for Alberta Infrastructure.

4.4.4 What Is the Gap?

The primary gap in structuring practice and harmonizing capabilities across supply and value chains is the lack of formal adoption of the ISO 19650 series in Canada and the development of standards and guidance to support its constituent parts. The development of NBIMS-US V4 should also be taken into consideration because the NBIMS-US has traditionally influenced the Canadian market, particularly in BIM execution planning. Table 14 summarizes the specific challenges, gaps, required resources and whether resources already exist to structure practice and harmonize capabilities across supply and value chains.

Table 12: Evolution of the Content in NBIMS-US Versions

Content	Version 1	Version 2	Version 3
Information Exchange Concepts	▪		
Data Models and Interoperability	▪		
Storing and Sharing Information	▪		
Information Exchange Content	▪		
Information Assurance	▪		
Capability Maturity Model	▪		
NBIM Standard Development Process	▪		
Terms and Definitions	▪	▪	▪
OmniClass	▪	▪	▪
Minimum BIM	▪	▪	▪
IFD Library/ buildingSMART Data Dictionary	▪	▪	▪
ISO 16739		▪	▪
W3C XML 1.0		▪	▪
Spatial Program Validation		▪	▪
Building Energy Analysis		▪	▪
Quantity Takeoff		▪	▪
BIM Project Execution Plan Content		▪	▪
MEP Spatial Coordination Requirements		▪	▪
Planning, Executing and Managing Handover		▪	▪
COBie		▪	▪
BIM Project Execution Planning Guide		▪	▪
BIM Collaboration Format			▪
LOD Specifications			▪
United States National CAD Standards			▪
Building Programming Information Exchange			▪
Electrical Information Exchange			▪
HVAC Information Exchange			▪
Water System Information Exchange			▪
BIM Planning Guide for Facility Owners			▪
Practical BIM Contract Requirements			▪
Uses of BIM			▪
BIM Requirements			

Table 13: Alberta Infrastructure Digital Project Delivery Documents for Owned and Supported Infrastructure

Resource	Revision date
Bid Document / Drawing Review Checklist [136]	February 2020
Asset Information Management, Consultant Requirements [137]	March 2018
Asset Information Management, Contractor Requirements [138]	March 2018
Asset Information Management, Execution Plan Template [140]	March 2018
Building Information Modelling, Consultant Requirements [104]	March 2018
Building Information Modeling, Design-Builder Requirements [139]	March 2018
Building Information Modelling, COBie Requirements [141]	March 2018
Building Information Modelling, Execution Plan Template [142]	March 2018
Alberta Infrastructure Standards for Consultant Deliverables for Building Projects [143]	March 2021
Project Manual (Specifications) Preparation Instructions for Alberta Infrastructure Building Construction Contracts [144]	February 2020

Table 14: Challenges, Gaps, and Required and Existing Resources to Structure Practice and Harmonize Capabilities Across Supply and Value Chains

Challenge	Gaps	Required resources	Existing Resources
Absence of widely adopted and harmonized information delivery workflows	Lack of formal mechanisms to align all relevant project stakeholders around the means and methods to deliver BIM projects according to a set of requirements.	BIM execution planning	Canadian
Contractual and procurement frameworks	Poorly adapted legal and contractual framework hindering the effective implementation of BIM in project settings. Need to address issues such as intellectual property, copyright, data ownership, etc.	BIM contract appendix (BIM protocol)	Canadian
		BIM legal and contractual framework	International
Difficulty in assessing supply chain capability	Lack of mechanisms to ensure the project team has the capacity and the necessary competencies to deliver projects using BIM and according to a set of clear requirements. Need to rigorously assess this competency and capacity.	Competency and capability assessment	International

Challenge	Gaps	Required resources	Existing Resources
Lack of consensus on data and information architectures	Lack of clarity around the concepts and use of classification systems within the Canadian built asset industry.	Classifications	Canadian
	Lack of awareness and understanding of the concepts, principles, and strategies to exchange data and information between project stakeholders and their information systems, including open API frameworks.	(open) API framework	International
	Need to introduce and communicate concepts relating to product data and the digital objects that contain it.	Product data framework	International
	Lack of consistent semantics and syntax within modelling tools and across information systems, which are required to ensure consistent and seamless flow of data and information.	Canadian data dictionary	None found
Lack of formal information exchange mechanisms	Need to formalize processes and mechanisms through which information is exchanged in digital means, including between BIM and GIS platforms, in a robust and repeatable manner to generate the benefits expected from BIM.	Information exchange (data framework)	International
		BIM-GIS information exchange requirements	International
	Adoption and uptake of open BIM in Canada has lagged due in part to the lack of information and guidance on open BIM, its principles, and applications.	Open BIM principles and applications	International
Lack of general awareness on concepts and terminologies	Need to develop the concepts supporting BIM-GIS integration to gain general acceptance within the industry.	BIM-GIS integration primer	International
Lack of standard information management practices	Need for a consistent framework to manage information across project and built asset lifecycles.	Information management framework	International

4.5 Summary

Three overarching challenges hindering the adoption and implementation of BIM in the Canadian built asset industry were identified through the interviews, workshops, and surveys conducted for this report:

1. Lack of consistent demand for BIM by clients;
2. Lack of appropriate skills and competencies to support BIM implementation; and
3. Incompatibility of capabilities and workflows across built asset supply and value chains.

In response, three primary solutions were put forward:

1. Create and systematize demand for BIM along with digitalized project delivery and built asset management;
2. Upskill industry stakeholders across industry segments, building upon a core body of knowledge; and
3. Structure practices and harmonize capabilities across supply and value chains through standardization.

Underlying these challenges and their solutions is the need for an operational framework for BIM adoption and implementation. In Section 5, a framework is proposed based on past research and drawing from the three solutions above. Each solution and its constituent parts articulate specific needs and identify gaps in the knowledge that are required to support BIM adoption and implementation. Table 15 provides an example of positioning knowledge areas defined through the interaction between the different components of the operational framework. Each cell could contain multiple resources, ranging from specific items to broad topics. Specific domains or sectors could be articulated on the z axis. Prioritization and development of these knowledge resources is discussed in Section 5.

Table 15: Example of Knowledge Resources Supporting the Development of Policy, Standardization, and Guidance for an Operational Framework for BIM

	Information use	Information requirements (IR)	Information delivery planning	Information delivery	Information architecture	Information accessibility
Policy	▪ Mandated information/ BIM uses	▪ Organizational and project information requirements (OIR, PIR)	▪ Mandated codes, standards, and specifications	▪ Mandated codes, standards, and specifications	▪ Open BIM mandate ▪ Standardized classifications	▪ Information security standards ▪ PIPEDA
Procurement	▪ Information use/BIM use specifications	▪ Exchange information requirements (EIR) ▪ Legal and contractual frameworks	▪ Competency and capacity assessment ▪ BIM execution planning (BEP)	▪ Quality assurance/ quality control process and gating ▪ Information acceptance	▪ Open BIM requirements and specifications	▪ CDE specifications ▪ Information security specifications
Partnerships	▪ Collaborative BIM/ information uses	▪ IRs for supply chain integration	▪ Inter-organizational standards	▪ Collaborative production of information methods	▪ Common terminology/ dictionary	▪ CDE implementation and management guidance
People	▪ Guidance and training on BIM and information uses	▪ Guidance on IRs and information specifications	▪ Information delivery plans	Certifications	▪ Open BIM guidance ▪ Common terminology/ dictionary	▪ Accessibility tools and management
Practice	▪ Information delivery manuals (IDM)	▪ IR guidance ▪ Level of information need	▪ BEP guidance	▪ Templates and guides ▪ Guidance on tools and processes	Classifications	▪ Risk registers
Products	▪ Object libraries	▪ Product data templates	▪ Product specifications	▪ Object libraries	▪ Data dictionaries ▪ Product data frameworks	▪ Object libraries
Platforms	▪ Model View Definitions (MVD)	▪ IR capture and management platforms	▪ Tool and technology specifications ▪ Mobilization plans	Tools for modelling, analysis, planning, etc.	▪ Open BIM data schemas ▪ (open) API frameworks	▪ CDE platforms ▪ GIS platforms

5 Priorities for Standardization and Guidance for BIM Adoption and Implementation in the Canadian Built Asset Industry

The outcome of this research project is the identification and prioritization of knowledge resources to support BIM adoption and implementation, with a focus on standardization and guidance. The ultimate goal is to provide a harmonized and broadly recognized foundation for the coherent adoption and implementation of BIM in the Canadian built asset industry. The core of the recommendations includes several activities and their deliverables, which are consolidated and categorized per the operational framework presented in Figure 6 and its dimensions, which are identified in Section 4.1. Table 16 provides the density of proposed activities and deliverables positioned within this operational framework.

Table 16: Density of Proposed Activities and Deliverables Positioned Within the Operational Framework

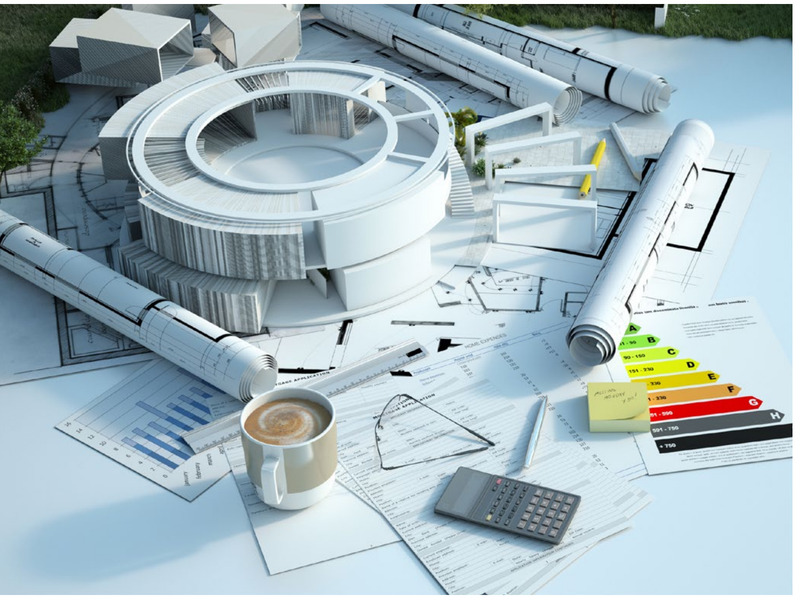
	General	Information use	Information requirements	Information delivery planning	Information delivery	Information architecture	Information accessibility	Total
Policy	1		2					**3**
Procurement			8	2	1			**11**
Partnerships					1			**1**
People	2			2				**4**
Practice	2	4	1	5	1	3		**16**
Products						3		**3**
Platforms						5	2	**7**
Total	**5**	**4**	**11**	**9**	**3**	**11**	**2**	**45**

Table 17 through Table 23 present the recommended standardization and guidance activity, deliverables, and responsibility. Each row identifies a knowledge resource to be developed in relationship to a gap identified in Section 4. The resources are described and the expected outcomes are defined. Responsibility for the deliverable is indicated by identifying the different stakeholders that should be involved in the activity. These generally include accredited standards development organizations (SDOs), governmental organizations, owner organizations, professional associations, industry professionals, and academic institutions. Core reference documents that should be considered are also identified. While there are several documents that could and should be considered for each activity, the ones listed are the key documents that were identified in the context of this research. Finally, the status of each knowledge resource (or their core reference) is provided, based on the following:

1. **Published internationally, to be adapted:** resources that have been published internationally that should be adapted for the Canadian context.
2. **In progress internationally, to be adapted:** resources that are in the process of being published internationally and should be adapted for the Canadian context once published.
3. **In progress:** documents that are currently being developed in Canada.
4. **To be undertaken:** documents that must be developed in Canada.

5.1 Operationalizing the Response

As shown in Table 17 through Table 23, the execution of activities and development of deliverables involves many stakeholders and requires concerted actions on many fronts. No timeline is given for these activities, but they are prioritized based on input received during the workshops. Priorities given range from 1 (highest priority) to 6 (lowest priority). A group of stakeholders recommended to undertake each activity. Except for the standardization activities, which must be led by accredited SDOs, there is no ownership attributed



"The ultimate goal is to provide a harmonized and broadly recognized foundation for the coherent adoption and implementation of BIM in the Canadian built asset industry."

to the activities. Therefore, each activity will require a committee and responsibility and sponsorship will need to be determined. In terms of sequencing, a general progression is proposed whereby foundational concepts and terminology for a given item must be established first, followed by core or general elements, and then domain-specific elements, as illustrated in Figure 12. This sequencing should follow a general evolution of capability within industry.

For the purposes of this report, although knowledge resources for specific domains were investigated, no domains are identified or prioritized in Table 17 through Table 23. This is primarily due to the lack of formal concept and terminologies as well as core or general elements pertaining to the prioritized items and deliverables. It is expected that domains will be identified and prioritized as the foundational items are delivered.

Figure 12: General sequencing of deliverables.

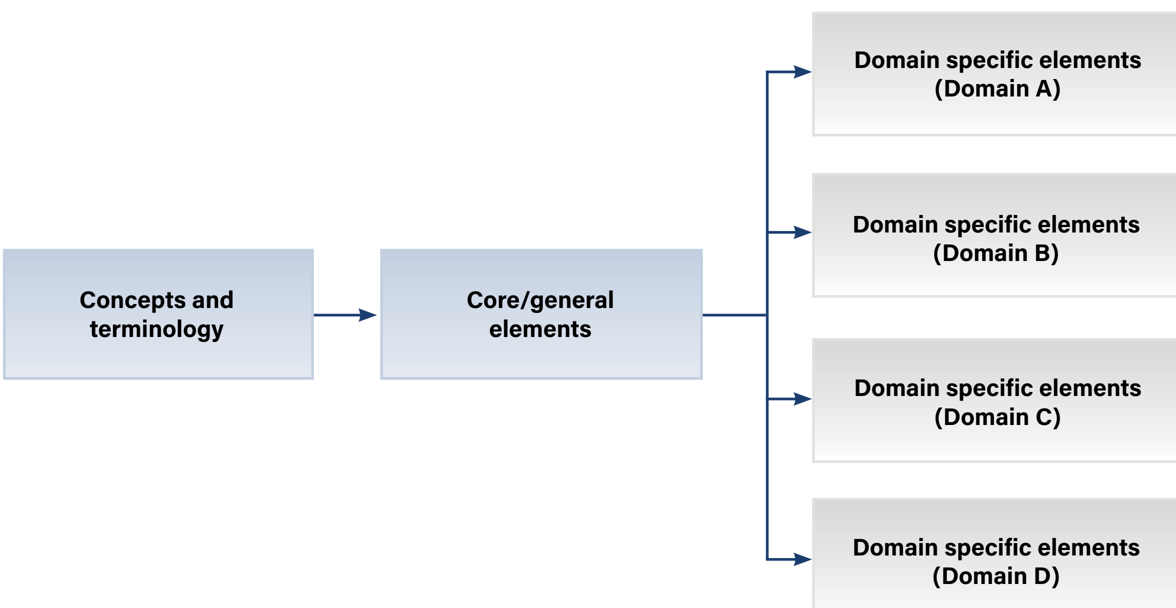


Table 17: General Items — Recommended Standardization and Guidance Activity, Deliverables, and Responsibility

Implementation dimension	Knowledge resource	Priority*	Required action for Canada	Deliverables	Responsibility	Core reference documents
Practice	Part 1: Concepts and principles	1	Published internationally, to be adapted	Adaptation of ISO 19650, Part 1: *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 1: Concepts and principles* for Canada.	Accredited SDO in collaboration with government and owner organizations, professional associations, and industry professionals	ISO 19650-1:2018, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 1: Concepts and principles*
People	General guidance on digital transformation in the Canadian built asset industry – trends and opportunities	1	To be undertaken	Development of a series of guides or white papers investigating and communicating trends and opportunities for digital transformation in the Canadian built asset industry. This can be supported through a continuous technology watch.	Collaboration of academic institutions, professional associations, and industry professionals	N/A
Practice	Guidance on tool use (miscellaneous)	1	To be undertaken	Development of a series of guidance documents to assist industry stakeholders in adoption and implementation of specific tools and technologies.	Collaboration of academic institutions, professional associations, and industry professionals	N/A
People	Common Canadian dictionary	1	In progress	Potential localization of the BIMdictionary.com, an online resource with over 800 definitions related to BIM and digital transformation. All of the terms have been translated to French. The next step is to develop the localization.	Collaboration of government and owner organizations, academic institutions, professional associations, and industry professionals	bimdictionary.com www.iso.org/obp/ui
Policy	General guidance on digital transformation in the Canadian built asset industry – policy and regulatory development	3	To be undertaken	Development of policy and regulatory frameworks and supporting documentation to facilitate and encourage digital transformation and innovation in the Canadian built asset industry.	Collaboration of government organizations, academic institutions, professional associations, and industry professionals	N/A

* (1-highest priority; 6-lowest priority)

Table 18: Information Uses — Recommended Standardization and Guidance Activity, Deliverables, and Responsibility

Implementation dimension	Knowledge resource	Priority*	Required action for Canada	Deliverables	Responsibility	Core reference documents
Practice	Information uses – Concepts and principles	1	In progress internationally, to be adapted	Development of a series of guidance documents to explain and popularize the concepts and principles of information uses in the built asset industry.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	NBIMS-US buildingSMART International – Use Case Management BIMe Initiative – Model Use Templates
Practice	Information uses – Core requirements	3	In progress internationally, to be adapted	Development of a series of documents outlining a set of core information requirements to be developed.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	NBIMS-US buildingSMART International – Use Case Management BIMe Initiative – Model Use Templates
Practice	Part 6 – Health and safety	4	In progress internationally, to be adapted	Adaptation of ISO 19650, Part 6: *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 6: Health and safety* for Canada once the standard is published.	Accredited SDO in collaboration with government and owner organizations, professional associations, and industry professionals	ISO/AWI 19650-6, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 6: Health and safety*
Practice	Information uses – Domain requirements	5	To be undertaken	Development of a series of documents outlining a set of domain-specific information uses to be developed.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	NBIMS-US buildingSMART International – Use Case Management BIMe Initiative – Model Use Templates

* (1-highest priority; 6-lowest priority)

Table 19: Information Requirements — Recommended Standardization and Guidance Activity, Deliverables, and Responsibility

Implementation dimension	Knowledge resource	Priority	Required action for Canada	Deliverables	Responsibility	Core reference documents
Policy	Part 5 – Security-minded approach to IM	1	Published internationally, to be adapted	Adaptation of ISO 19650, Part 5: *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 5: Security-minded approach to information management* for Canada.	Accredited SDO in collaboration with government and owner organizations, professional associations, and industry professionals	ISO 19650-5:2020, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 5: Security-minded approach to information management*
Practice	Level of information need/level of X – Concepts and principles	1	In progress	Development of a guidance documents to explain the concepts and principles of level of X/level of information need.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	buildingSMART Canada – Level of X Specification, Part 1: Concepts ISO/DIS 7817, *Building information modelling – Level of information need*
Policy	Level of information need – Standards	2	In progress internationally, to be adapted	Adaptation of ISO 7817, *Building information modelling – Level of information need* for Canada.	Accredited SDO in collaboration with government and owner organizations, professional associations, and industry professionals	ISO/DIS 7817, *Building information modelling – Level of information need*
Procurement	Information requirements – Concepts and principles	2	In progress internationally, to be adapted	Development of a series of guidance documents to assist industry stakeholders in understanding the concepts and principles of information requirements and their connection to other concepts.	Collaboration with academic institutions, professional associations, and industry professionals	NBIMS-US
Procurement	Information requirements – Core requirements	3	In progress internationally, to be adapted	Development of a series of documents outlining a set of core information requirements to be developed.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	NBIMS-US
Procurement	Information specifications – Concepts and principles	3	In progress internationally, to be adapted	Development of a series of guidance documents to assist industry stakeholders in understanding the concepts and principles of information specifications and their connection to other concepts.	Collaboration with academic institutions, professional associations, and industry professionals	buildingSMART International – Information Delivery Specification (IDS)
Procurement	Procurement guidelines	3	To be undertaken	Development of a guidance documents explaining the concepts and principles of procuring BIM-enabled projects.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	N/A
Procurement	Information acceptance – Domain specifications	4	To be undertaken	Development of a series of documents outlining a set of domain-specific information criteria and workflows.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	N/A
Procurement	Level of information need/level of X – Domain specifications	4	To be undertaken	Development of a series of documents outlining a set of domain-specific level of X/level of information need specifications.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	buildingSMART Canada – Level of X Specification, Part 1: Concepts ISO/DIS 7817, *Building information modelling – Level of information need – Concepts and principles*
Procurement	Information specifications – Core specifications	5	To be undertaken	Development of a series of documents outlining a set of core information specifications to be developed per domain and/or lifecycle phase.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	buildingSMART International – Information Delivery Specification (IDS)
Procurement	Information requirements – Domain requirements	6	To be undertaken	Development of a series of documents outlining a set of domain-specific information requirements to be developed.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	N/A

Table 20: Information Delivery Planning — Recommended Standardization and Guidance Activity, Deliverables, and Responsibility

Implementation dimension	Knowledge resource	Priority	Required action for Canada	Deliverables	Responsibility	Core reference documents
Practice	Part 2 – Delivery phase of the assets	1	Published internationally, to be adapted	Adaptation of ISO 19650, Part 2: *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 2: Delivery phase of the assets* for Canada.	Accredited SDO in collaboration with government and owner organizations, professional associations, and industry professionals	BIM excellence competency table
Practice	Part 3 – Operational phase of the assets	1	Published, to be adapted	Adaptation of ISO 19650, Part 3: *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 3: Operational phase of the assets* for Canada.	Accredited SDO in collaboration with government and owner organizations, professional associations, and industry professionals	Penn state BIM PxP Guidance
People	Competency and capability assessment – Concepts and principles	1	In progress	Development of general guidance explaining the concepts and principles of BIM capability and competency and how to assess it.	Collaboration with academic institutions, professional associations, and industry professionals	IBC BIM 100:2014 IBC BIM 201:2014
Practice	BIM execution planning – General	1	In progress internationally, to be adapted	Development of guidance and general templates for BIM execution planning.	Collaboration with government and owner organizations and industry professionals	N/A
Procurement	BIM contract appendix (BIM protocol)	1	In progress	Updating the IBC BIM 100 and 201 contract appendices to broaden their scope of application and developing other relevant guides and templates to suit.	Collaboration with government and owner organizations, professional associations, and legal professionals	buildingSMART professional certification CanBIM professional certification
Procurement	BIM legal and contractual framework – Guidelines	1	In progress	Development of guidance and general templates for BIM execution planning.	Collaboration with government and owner organizations, professional associations, and legal professionals	N/A
People	Competency and capability certification	3	In progress	Development of a robust set of certification criteria and the development of a certification program based on these criteria.	Collaboration with academic institutions, professional associations, and industry professionals	ISO/FDIS 19650-4, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 4: Information exchange*
Practice	BIM execution planning – Domain specific	3	To be undertaken	Development of guidance and domain-specific templates for BIM execution planning.	Collaboration with government and owner organizations and industry professionals	ISO 19650-5:2020, *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 5: Security-minded approach to information management*
Practice	Part 4 – Information exchange	4	In progress internationally, to be adapted	Adaptation of ISO 19650, Part 4: *Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Information management using building information modelling – Part 4: Information exchange* for Canada once the standard is published.	Accredited SDO in collaboration with government and owner organizations, professional associations, and industry professionals	buildingSMART Canada – Level of X Specification, Part 1: Concepts ISO/DIS 7817, *Building information modelling – Level of information need – Concepts and principles*

Table 21: Information Delivery — Recommended Standardization and Guidance Activity, Deliverables, and Responsibility

Implementation dimension	Knowledge resource	Priority	Required action for Canada	Deliverables	Responsibility	Core reference documents
Partnerships	Collaborative production of information – Concepts and principles	2	To be undertaken	Development of a series of guidance documents to assist industry stakeholders in understanding the concepts and principles guiding the collaborative production of information.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	N/A
Procurement	Information acceptance – Concepts and principles	2	To be undertaken	Development of a series of guidance documents to assist industry stakeholders in understanding the concepts and principles of information acceptance and their connection to other concepts.	Collaboration with academic institutions, professional associations, and industry professionals	N/A
Practice	Collaborative production of information – Specifications	6	To be undertaken	Development of a series of domain-specific guidance documents to assist industry stakeholders in implementing the concepts and principles guiding the collaborative production of information.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	N/A

Table 22: Information Architecture — Recommended Standardization and Guidance Activity, Deliverables, and Responsibility

Implementation dimension	Knowledge resource	Priority	Required action for Canada	Deliverables	Responsibility	Core reference documents
Platforms	Open BIM principles and applications – General	1	In progress internationally, to be adapted	Development of guidance documents explaining the principles and applications of open BIM in the Canadian context.	Collaboration with academic institutions, professional associations, and industry professionals	buildingSMART International – Resources on open BIM
Practice	Classifications – Guidance	1	In progress internationally, to be adapted	Development of guidance material on the development and use of classifications in the Canadian built asset industry. Work should align with ISO 12006, Building construction – *Organization of information about construction works – Part 2: Framework for classification.*	Collaboration with international organizations that manage current classification systems, industry associations, and industry professionals.	Omniclass Uniformat II Masterformat
Platforms	BIM-GIS integration – Primer	2	In progress internationally, to be adapted	Development of a series of guidance documents to assist industry stakeholders in understanding the concepts and principles of BIM and GIS integration.	Collaboration with academic institutions, professional associations, and industry professionals	ISO/TR 23262:2021, *GIS (geospatial) / BIM interoperability*
Practice	Information exchange (data framework) – General	2	In progress internationally, to be adapted	Development of a series of general guidance documents to assist industry stakeholders in understanding the concepts and principles of information exchanges and their connection to other concepts supported through the ISO 29481 series of standards. The intent is NOT to adapt the standard in Canada, but to explain its concepts and purpose as well as how it works.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	ISO 29481-1:2016, *Building information models – Information delivery manual – Part 1: Methodology and format* ISO/FDIS 29481-3, *Building information models – Information delivery manual – Part 3: Data schema and code*
Platforms	BIM-GIS information exchange requirements	2	In progress internationally, to be adapted	Development of guidelines pertaining to BIM-GIS integration and information exchanges.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	ISO/TR 23262:2021, *GIS (geospatial) / BIM interoperability*
Platforms	(open) API framework – General	3	In progress internationally, to be adapted	Development of a series of guidance documents to assist industry stakeholders in understanding the concepts and principles of the open API framework currently under development at buildingSMART International.	Collaboration with academic institutions and industry professionals	buildingSMART International – open API framework

Implementation dimension	Knowledge resource	Priority	Required action for Canada	Deliverables	Responsibility	Core reference documents
Platforms	Open BIM principles and applications – Domain specific	3	In progress internationally, to be adapted	Development of guidance documents explaining specific domain applications of open BIM in the Canadian context.	Collaboration with academic institutions, professional associations, and industry professionals	buildingSMART International – Resources on open BIM
Product	Product data framework – General	3	In progress internationally, to be adapted	Development of guidance document explaining the concepts and principles of product data and its management in BIM-enabled project delivery and asset lifecycle management.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	ISO 23387:2020, *Building information modelling (BIM) – Data templates for construction objects used in the life cycle of built assets – Concepts and principles*
Product	Canadian data dictionary (adaptation of buildingSMART Data Dictionary)	3	To be undertaken	Localization or creation of a Canadian data dictionary based on the buildingSMART Data Dictionary.	Collaboration with academic institutions and industry professionals	buildingSMART Data Dictionary ISO 23386:2020, *Building information modelling and other digital processes used in construction – Methodology to describe, author and maintain properties in interconnected data dictionaries*
Practice	Information exchange (data framework) – Domain specific	4	In progress internationally, to be adapted	Development of a series of documents outlining a set of domain-specific information exchange framework.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	ISO 29481-1:2016, *Building information models – Information delivery manual – Part 1: Methodology and format* ISO/FDIS 29481-3, *Building information models – Information delivery manual – Part 3: Data schema and code*
Product	Product data framework – Domain specific	5	In progress internationally, to be adapted	Development of domain-specific product data templates based on international best practices.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	ISO 23387:2020, *Building information modelling (BIM) – Data templates for construction objects used in the life cycle of built assets – Concepts and principles*

Table 23: Information Accessibility — Recommended Standardization and Guidance Activity, Deliverables, and Responsibility

Implementation dimension	Knowledge resource	Priority	Required action for Canada	Deliverables	Responsibility	Core reference documents
Platforms	Common data environments (CDEs) – Concepts and principles	1	In progress internationally, to be adapted	Development of general guidance explaining the concepts and principles of CDEs and their implementation in project settings.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	N/A
Platforms	Common data environments (CDEs) – Standardized practices	3	Published internationally, to be adapted	Development of standardized approaches to CDEs and their implementation in project settings.	Collaboration with government and owner organizations, academic institutions, professional associations, and industry professionals	DIN SPEC 91391, *Common data environments (CDE) for BIM projects – Function sets and open data exchange between platforms of different vendors*

6 Conclusion

A major transformation of the Canadian built asset industry is currently underway. New digital ways of working are enabling more effective and efficient design, delivery, management, and use of the built environment. However, there are significant challenges to overcome before the full benefits of this digital transformation can be reaped by one of the most important industries in Canada. To support and operationalize this new way of working through BIM adoption and implementation, substantial amounts of new knowledge must be formalized. Furthermore, this knowledge must be set in the right context to be effective: simply making it available will not ensure a successful digital transformation of the Canadian built asset industry. Instead, enactment and support through targeted policy instruments (regulatory, economic, or other) and clear implementation pathways with the objective of structuring and guiding how information is acquired, generated, exchanged, processed, managed, and consumed throughout the lifecycle of a built asset can play a key role in facilitation this transformation.

The research conducted for this report supported the development of an operational framework to structure this knowledge, expressed as standards, guidelines, and other resources required to support BIM adoption and implementation in Canada, and to articulate and prioritize these resources. A mixed-method approach was used to validate current industry challenges, needs, and trends regarding BIM use in Canada, review existing initiatives, resources, and tools from around the globe, discuss their adaptation or adoption, and propose avenues for development as needed.

The findings show the importance of all levels of government and their influence on the built asset industry, either through regulation or guidance. Therefore, any solution to support digital transformation and BIM should involve these different levels of government. The industry also has an important role to play and some industry stakeholders have already taken initiative to lead digital transformation and BIM adoption efforts without government influence. However, these stakeholders have also consistently expressed a desire for government to play a more active role in structuring and supporting this significant effort. Three specific challenges were identified through the interviews, workshops, and surveys:

1. Lack of consistent demand by clients;
2. Lack of appropriate skills and competencies; and
3. Incompatibility of capabilities and workflows across built asset value chains.

Underlying these three challenge areas is the absence of a coherent operational framework to support BIM adoption and implementation. Considering this dynamic, and in response to the three challenges, a framework was proposed based on three key components:

1. Create and systematize demand for BIM along with digitalized project delivery and built asset management;
2. Upskill industry stakeholders across industry segments, building upon a core body of knowledge; and
3. Structure practice and harmonize capabilities across supply and value chains through standardization.

Each a framework on their own, these components articulate the knowledge areas and resources required for BIM adoption and implementation in Canada's built asset industry. An in-depth analysis of the data yielded 45 distinct development activities, and their expected outcomes were presented and prioritized. These activities consider international resources and knowledge areas, namely the ISO 19650 series and open BIM principles and technologies. A list of specific knowledge resources was developed and presented to help prioritize and plan the allocation of effort and resources to achieve these deliverables. The list provides precise directions to reach a common outcome: the structured digital transformation of Canada's built asset industry.

6.1 Limitations

Several limitations were identified during this research project:

- **Representativeness of the interview sample:** While a conscious effort was made to interview experts from a diverse range of disciplines, organization types, sizes, and locations in Canada, the sample is missing representation from the Maritimes and the Prairies, and from smaller organizations.
- **Statistical significance of the survey sample:** While the 170 responses received in the survey allowed for an interesting sample, statistical significance was challenging to achieve because of the size of the built asset industry.
- **Interpretation:** As with any qualitative data analysis approach, conclusions are subject to interpretation by the researchers performing the analysis, and to their biases. While steps were taken to mitigate this, namely by developing and performing the data collection with a team of researchers and discussing results of the analysis, the results remain subjective.
- **Identification and prioritization of activities within the listed knowledge resources:** Identification and prioritization of activities and their outcomes were discussed and determined through the workshops. While the workshops were participatory and all feedback was considered, the sampling of experts present, while representing a breadth and depth of expertise from across Canada, was limited.
- **Detailing and prioritization of knowledge resources for specific domains:** As discussed above, no domains were identified or prioritized as there is a lack of formal concept and terminology as well as core/general elements pertaining to the prioritized items and deliverables. It is expected that domains will be identified and prioritized as the foundational items identified in this report are delivered.

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Appendix A – Glossary of Terms

A.1 General Terminology

Table A.1 Glossary of terms

Term	Definition	Source
BIM execution plan	A plan that explains how the information management aspects of the appointment will be carried out by the delivery team.	[125]
BIM mandate	A requirement (or series of requirements) to deliver projects and manage built assets (or a portfolio of assets) in accordance with recognized standards to exchange and deliver information in a structured and consistent manner supported through BIM processes and technologies to achieve a set of specific objectives.	
Body of knowledge (BoK)	A body of knowledge (BoK) is the complete set of concepts, terms and activities that make up a professional domain, as defined by the relevant learned society or professional association.	[145]
Building information management	Information management is "the process of collecting, storing, managing and maintaining information in all its forms."	[38]
Building information model	An interoperable digital representation of physical and functional characteristics of a facility. It serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its lifecycle; defined as existing from earliest conception to demolition.	adapted from [36]
Building information modelling	A process focused on the development, use, and transfer of digital information models of a building project to improve the design, construction, and operations of a project or portfolio of facilities.	adapted from [37]
Built asset industry	The industry that plans, delivers, and maintains the built environment.	
Built asset lifecycle	The phases involved in the planning, design, delivery, use, and refurbishment or demolition of a built asset.	
Built environment	The human-made surroundings that provide the setting for human activity, ranging in scale from buildings and parks or green space to neighborhoods and cities, which can include their supporting infrastructure, such as water supply or energy networks. The built environment is a material, spatial, and cultural product of human labour that combines physical elements and energy in forms for living, working, and playing.	[146]
Digital thread	Digital thread is the ability to dispose of product information from and to any phase of the product lifecycle, hence avoiding data loss or corruption (i.e., from human copying) and enabling extended features to be developed.	[147, p. 274]
Digital transformation	The process to restructure economies, institutions, and society on a system level.	[1, p. 1144]
Digital twin	A virtual representation of real-world entities and processes, synchronized at a specified frequency and fidelity. ▪ Digital twin systems transform business by accelerating holistic understanding, optimal decision-making, and effective action. ▪ Digital twins use real-time and historical data to represent the past and present and simulate predicted futures. ▪ Digital twins are motivated by outcomes, tailored to use cases, powered by integration, built on data, guided by domain knowledge, and implemented in IT/OT systems.	[148]
Digitization	The passage from analog to digital data sets, serves as the framework for digitalization.	[1, p. 1144]

Term	Definition	Source
Information accessibility	The considerations and ecosystems supporting access to information throughout an asset's lifecycle. According to Wikipedia, "Information access is the freedom or ability to identify, obtain and make use of database or information effectively. [...] Information access covers many issues including copyright, open source, privacy, and security."	[85]
Information architecture	"Information architecture (IA) is the structural design of shared information environments; the art and science of organizing and labelling websites, intranets, online communities, and software to support usability and findability; [...] Typically, it involves a model or concept of information that is used and applied to activities which require explicit details of complex information systems. These activities include library systems and database development." Information architecture in this context includes concepts relating to data schemas (i.e., Open BIM) and classifications.	[84]
Information delivery	The processes, tools, and practices enabling the delivery of information according to a specified plan to fulfill project stakeholders' information requirements and support the use of information to support decision making throughout a built asset's lifecycle.	
Information delivery manual	Documentation that captures the business process and provides detailed specifications of the information that a user fulfilling a particular role would need to provide at a particular point within a project.	[149]
Information delivery planning	"Information delivery planning is one of the fundamental concepts of the ISO 19650 series. There are three different ways in which delivery of information is planned in successive amounts of detail: ▪ The federation strategy and the information container breakdown structure ▪ The responsibility matrices ▪ The task and master information delivery plans."	[83, p. 9]
Information delivery specification	A computer interpretable document that defines the exchange requirements of model-based exchange. It defines how objects, classifications, properties, and even values and units need to be delivered and exchanged.	[150]
Information requirements	A "specification for what, when, how and for whom information is to be produced" (ISO 19650-1, Clause 3.3.2), which is generated primarily by the appointing party and then extended by the appointed party. There are complementary types of information requirements, including: organizational information requirements (OIR), asset information requirements (AIR), project information requirements (PIR), exchange information requirements (EIR), and security information requirements (ISO 19650-5) (bimdictionary.com).	[125]
Information use	Defines what information is needed to deliver a specific project outcome. Information uses include document uses, model uses, and data uses. Information use describes the purpose for which information is to be delivered.	[151]
Level of information need	Framework that defines the extent and granularity of information.	[125]
Level of X (LoX)	The emergence of the level of X (LoX) concept demonstrates the plurality of the concept associated with BIM model content. Among the different concepts found within LoX, there are: ▪ LoA: Level of Accuracy ▪ LoC: Level of Completeness ▪ LoC: Level of Coordination ▪ LoD: Level of Detail ▪ LoD: Level of Development ▪ LoI: Level of Information	[152]
nD modelling	An nD model is an extension of a building information model incorporating all the design information required at each stage of the life cycle of a building facility.	[57, p. 33]
Product data template	A product data template is a common data structure defining the properties (essential and non-essential product characteristics such as fire rating and colour) that describe any type of product in a way that can be traced to a credible source.	[153]

A.2 Noteworthy BIM Publications

Definition:

"Noteworthy BIM publications (NBP)s are publicly-available documents developed by various industry and academic entities; aimed at a wide audience; and intended to promote BIM understanding, regulate BIM implementation or mandate BIM requirements."[3]

Table A.2 Types of Noteworthy BIM Publications

Groupe	Type	Description
Guides	Best practice	Operational methods arising from experience; promoted as advantageous; replicable by other individuals, organizations, and teams.
	Case study	Summary and analysis (descriptive or explanatory) of projects and organizational efforts.
	Framework or model	Theoretical structures explaining or simplifying complex aspects of a domain by identifying meaningful concepts and their relationships.
	Guideline	Compilation of several BIM content types that provide guidance to individuals, teams or organizations.
	Learning module or material	All types of analogue and digital media (e.g., printed manuals or online videos) that deliver conceptual or practical insight for education, training, or professional development within industry or academia.
	Report	Compilation or summary of results from an assessment, calculation, or review process (e.g., BIM capability report or profitability statement).
	Strategy or vision	Articulation of vision, mission, and long-term goals.
	Taxonomy or classification	Classification covering roles, types, levels, elements, and other structured concepts.
Protocols	Metric or benchmark	Tools and criteria suitable for establishing levels of performance of systems, projects, individuals, teams, organizations, and other organizational units [1].
	Manual	Structured document that clarifies the steps needed to perform a measurable activity or deliver a measurable outcome (e.g., BIM Training Manual). Manuals typically focus on skill-intensive topics, while guides (a complementary label) typically focus on skill-intensive ones.
	Plan	Document describing activities to be performed, resources to be used, and milestones to be reached within a defined timeframe.
	Procedure or workflow	Structured information covering successive steps to fulfill an operational, rather than strategic, requirement. A documented procedure includes the small steps needed to deliver, if executed by a competent individual, a pre-defined and desired outcome. A workflow identifies the major steps to be performed and decision gates to pass through towards reaching a delivery milestone or fulfilling a project/organizational objective.
	Protocol or convention	Agreed or customary method of product/service development or delivery which are not by themselves contractually binding (e.g., keeping minutes of meetings, how to name files, and frequency of exchanging models)
	Specification or prescription	A set of criteria used to define or judge the quality of products (e.g., object dimensions or data richness) and services (e.g., timeliness). Specifications may or may not be a standard (a separate label).
	Standard or code	Detailed set of product/service descriptions (prescriptive or performance-based) acting as a reference to be measured against.
Mandates	Contract or agreement	Legally-binding document and its subparts, including contractual additions, amendments, and disclaimers.
	Program or schedule	Document associating one or more classification to time and/or location.
	Requirement, rule, or policy	Expectation or qualification mandated by clients, regulatory authorities, or similar parties.

3 https://www.bimframework.info/2014/07/noteworthy-bim-publications.html accessed November 15th, 2021

Appendix B – Current International Initiatives for BIM Standardization and Guidance (March 2022)

BIM excellence initiatives [154] include:

- BIM Dictionary
- Competency Benchmarking
- Integrated Information Project
- Macro Adoption
- Model Use Templates

European Committee for Standardization [155] initiatives include:

- Building Information Modelling – Level of information need – Part 3: Data Schema
- BIM in Infrastructure – Standardization need and recommendations
- Building Information Modelling – Information structure based on EN ISO 16739 1 to exchange data templates and data sheets for construction objects – Part 1: Data templates and configured construction objects
- Building Information Modelling – Information structure based on EN ISO 16739 1 to exchange data templates and data sheets for construction objects – Part 2: Configurable construction objects and requirements
- Building Information Modelling – Level of information need – Part 2: Guidance for application
- Building Information Modelling (BIM) – Data templates for construction objects used in the life cycle of built assets – Data templates based on European standards and technical specifications
- Building Information Modelling (BIM) – Semantic Modelling and Linking (SML)
- Common Data Environments (CDE) for BIM projects – Open data exchange between platforms of different vendors via an open CDE API
- Framework and Implementation of Common Data Environment Solutions, in accordance with EN ISO 19650
- Guidance on how to implement EN ISO 19650 Parts 1, 2, 3 and 5 in Europe
- Professions and competence related to the Building Information Management

International Organization for Standardization [156] initiatives include:

- Building construction – Organization of information about construction works – Part 3: Framework for object-oriented information (ISO/DIS 12006-3:2021)
- Building information modelling – Level of information need – Concepts and principles (ISO/DIS 7817)
- Building information models – Information delivery manual – Part 3: Data schema and code (ISO/DIS 29481-3:2021)
- Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) – Framework for specification of building information modelling (BIM) implementation (ISO 12911:2012)

Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 4: Information exchange

Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 6: Health and Safety

Current standardization initiatives at buildingSMART International [157] include:

Airport entities

BCF workflows

Building energy model IDM

Content and quality management

Documents API

Fire safety

FM handover equipment

FM openBIM

Foundations API

IFC 4.3, *Infra and rail extension deployment production*

IFC land and site development

IFC precast

IFC rail

IFC rebar

IFC tunnel

ifcJSON

Information delivery specification

Occupant movement analysis

openCDE

Product data templates

Properties API

Regulatory info requirements

Spatial zones

Steel construction

Structural requirements

Notes: BCF: BIM collaboration format; IDM: information delivery manual; API: application programming interface; FM: facility management; IFC: industry foundation classes; JSON: JavaScript Object Notation; CDE: common data environment.

Appendix C – Non-Exhaustive List of Canadian NBPs

Guide

Best practice

Building Information Modeling (BIM) 'Best Practices' Project Report

Guideline

Guide de Coordination 3D Basee sur des Maquettes BIM

Introduction à la Gestion des Actifs Facilitee par la Modélisation des Donnes du Batiment (BIM)

Learning module or material

BIM PxP Toolkit – Construction Phase – Volume 2

BIM PxP Toolkit – Design Development Phase – Volume 1

BIM PxP Toolkit – Handover and Maintenance Phase – Volume 3

BIM PxP Toolkits – Complete Guide

Manual

Canadian Practice Manual for BIM – Volume 1

Canadian Practice Manual for BIM – Volume 3

Report

1st Annual BIM Report – 2018

2nd Annual BIM Report – 2019

3rd Annual BIM Report – 2020

Adoption de la modélisation des données du bâtiment (Building Information Modelling – BIM) à l'échelle macro au Québec

Benefits of BIM for Owners

BIM Explained

BIM in Canada

Principes du déploiement de la modélisation des données du bâtiment (Building Information Modelling – BIM)

Rapport d'analyse des résultats des phases I et II des diagnostics numériques

Revue des outils d'évaluation de déploiement de la modélisation des données du bâtiment (Building Information Modelling – BIM) existants

Mandate

Contract or Agreement

IBC 100-2014: BIM Contract Appendix

IBC 201-2014: LOD, Authorized Uses and Model Element Table

Program or Schedule

Government roadmap for modelling of building data.pdf

Roadmap to Lifecycle Building Information Modeling in the Canadian AECOO Community

Requirement, Rule, or Policy

Digital Project Delivery Asset Information Management Consultant Requirements
Digital Project Delivery Asset Information Management Contractor Requirements
Digital Project Delivery Asset Information Management Design-Builder Requirements
Digital Project Delivery Building Information Modelling Consultant Requirements
Digital Project Delivery Building Information Modelling Design-Builder Requirements
Digital Project Delivery COBie Requirements

Protocol

Manual

Canadian Handbook of Practices for Architects 3rd Edition, Chapter 5.6
Canadian Practice Manual for BIM – Volume 2

Plan

Digital Project Delivery Asset Information Management Execution Plan Template
Digital Project Delivery Building Information Modelling Execution Plan Template
wBIMc BIM Execution Plan TEMPLATE

Procedure or workflow

Bid Document/Drawing Review Checklist

Protocol or Convention

AEC (CAN) BIM Protocol – V.1

Specification or Prescription

BIM Requirements Specification
Guide d'Application du BIM a la Societe Quebecoise des Infrastruture
Project Manual (Specifications) Preparation Instructions for Alberta Infrastructure Projects

Standard or code

CADD/BIM Standards Manual
PSPC National CADD Standard
Standards for Consultant Deliverables

Appendix D – Non-Exhaustive List of federal, Provincial, and Municipal Initiatives Addressing Key Drivers for Change in the Canadian Built Asset Industry

Table D.1 Example List of Federal, Provincial, and Municipal Initiatives driving Canadian Built Asset Industry Change

Driver	Addressing the climate crisis	Ensuring economic recovery	Addressing the housing crisis	Addressing aging infrastructure	Addressing the labour gap
FEDERAL					
	Greening Government Strategy	Investing in Canada Plan – Building a Better Canada	National Housing Strategy	Horizontal Fixed Asset Review	Labour and Skills Shortages in Canada: Addressing Current and Future Challenges Future Skills
PROVINCIAL					
British Columbia	Climate Targets + Accountability Report		Homes for BC - A 30-Point Plan for Housing Affordability in British Columbia		British Columbia Labour Market Outlook: 2019 Edition
Alberta		Selling Alberta to the World: An Investment and Growth Strategy	Alberta's Action Plan for the National Housing Strategy 2019-2022		Alberta 2030: Building Skills for Jobs
Saskatchewan	A Made-in-Saskatchewan Climate Change Strategy	Saskatchewan's Growth Plan - The Next Decade of Growth | 2020 - 2030	The Saskatchewan Housing Action Plan 2019-2022		
Manitoba	Made-in-Manitoba Climate and Green Plan	Protecting Manitobans, Advancing Manitoba	Manitoba Housing and Renewal Corporation Three-Year Action Plan		Manitoba's Strategy for Sustainable Employment and a Stronger Labour Market
Ontario	Made-In-Ontario Environment Plan	Supporting Ontario's Recovery and Competitiveness	More Homes, More Choice: Ontario's Housing Supply Action Plan	Rebuilding Ontario: an infrastructure plan for the people	The Future of Work in Ontario
Quebec	Plan pour une économie verte	Plan d'action pour le secteur de la construction		Plan Québécois des Infrastructures	National Workforce Strategy 2018-2023
New Brunswick	New Brunswick's Climate Change Action Plan	Economic Recovery and Growth Action Plan	New Brunswick Housing Strategy 2019-2029		New Brunswick's Labour Force and Skills Development Strategy 2013-2016
Prince Edward Island	PEI Climate Change Action Plan	The Premier's Council for Recover and Growth - Summary Report and Guiding Directions to move Prince Edward Island Forward	Housing Action Plan for Prince Edward Island		
Nova Scotia			Housing Nova Scotia 2019 - 2022 Action Plan		
Newfoundland and Labrador	NL Carbon Plan	The Big Reset - The Report of the Premier's Economic Recovery Team	3 Year Provincial Housing and Homelessness Action Plan	A Multi-Year Plan for Infrastructure Investments	Live Here, Work Here, Belong Here - A Workforce Development Action Plan for Newfoundland and Labrador, 2015 - 2020
Yukon	Our Clean Future: A Yukon strategy for climate change, energy, and a green economy	Economic Resilience Plan: Building Yukon's COVID-19 Economic Recovery	Ours to Build On - Housing Action Plan for Yukon 2015-2025		

Driver	Addressing the climate crisis	Ensuring economic recovery	Addressing the housing crisis	Addressing aging infrastructure	Addressing the labour gap
PROVINCIAL CONT'D					
Northwest Territories	2030 NWT Climate Change Strategic Framework - 2019-2023 Action Plan		NWT Housing Action Plan 2019-2022		
Nunavut	Climate Change Adaptation Planning: A Nunavut Toolkit				
MUNICIPAL					
Victoria	City of Victoria Climate Leadership Plan		The Victoria Housing Strategy 2016 - 2025		
Vancouver	Climate Emergency Action Plan		Housing Vancouver Strategy		
Calgary	City of Calgary - Climate Resilience Strategy Action Plans		Foundations for Home - the Corporate Affordable Housing Strategy		
Edmonton	Climate Resilient Edmonton: Adaption Strategy and Action Plan		Affordable Housing Strategy		
Regina	Renewable Regina		Housing Comprehensive Strategy		
Saskatoon	Climate Action Plan		Housing Business Plan 2013 - 2022		
Winnipeg	Winnipeg's Climate Action Plan		Housing Policy and Implementation Plan		
Ottawa	Climate Change Master Plan		10-Year Housing and Homelessness Plan 2020-2030		
Toronto	TransformTO Net Zero Strategy		Housing TO 2020 - 2030 Action Plan		
Hamilton	Taking Action on Climate Change in Hamilton – A Community Plan		Hamilton's Housing & Homelessness Action Plan		
London	Climate Emergency Action Plan		Housing Stability for All - The Housing Stability Action Plan for the City of London 2019-2024		
Montreal	Climate Plan 2020-2030				
Quebec City					
Halifax	HaliFACT - Action on Climate Together		Affordable Housing Work Plan		
St. John's			Affordable Housing Strategy 2019-2028		

CSA Group Research

In order to encourage the use of consensus-based standards solutions to promote safety and encourage innovation, CSA Group supports and conducts research in areas that address new or emerging industries, as well as topics and issues that impact a broad base of current and potential stakeholders. The output of our research programs will support the development of future standards solutions, provide interim guidance to industries on the development and adoption of new technologies, and help to demonstrate our on-going commitment to building a better, safer, more sustainable world.