Bridging the knowledge gaps to promote more environmentally sustainable buildings—It begins at the foundation

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Abstract

Toronto has recognized building structures as an integral tool for reducing its carbon footprint. Yet a paramount concern, however, is whether the building and construction industry is prepared and positioned to effectively design and communicate the importance of sustainable buildings. The decisions during the pre-design stage of new building developments are vital in affecting the project's overall sustainability. The plan for transitioning and promoting more environmentally sustainable buildings is hard to define; however, using design thinking, systems thinking, and strategic foresight, this report has clarified a pathway by focusing on knowledge management. This report concludes by offering three areas to strengthen knowledge building and management capabilities within the building and construction industry.

Land Acknowledgment

I acknowledge working near OCAD University, located in Toronto, Ontario, which recognizes the ancestral and traditional territories of the Mississaugas of the Credit, the Haudenosaunee, the Anishinaabe and the Huron-Wendat, who are the original owners and custodians of the land on which we stand and create. I recognize the enduring presence of all First Nations, Métis, and the Inuit peoples.

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Glossary of Terms

Absorptive capacity – the ability to identify new, external information, understand it, and then leverage it for innovation action and growth (Cohen & Levinthal, 1990).

Bounded rationality – is the idea that rationality is limited when individuals make decisions because of incomplete information, time constraints, and cognitive abilities (Boyce, 2021).

Climate Adaptation – Activities designed to reduce climate change's aftermath, or take advantage of new opportunities, are "climate change adaptation" (Oates, 2008). This term closely relates to that of resilience; they adjust and anticipate changes, disruptions, and external stresses (Cox et al., 2021., p.5)

Climate Change – refers to long-term shifts in temperatures and weather patterns, mainly attributed to the increased levels of carbon dioxide produced using fossil fuels.

Climate Mitigation - "climate change mitigation" refers to activities that aim to reduce greenhouse gas emissions. Climate change mitigation has overshadowed adaptation (Oxford Languages and United Nations).

Construction Management (CM) – includes the planning, scheduling, evaluation, and controlling of construction tasks or activities to accomplish specific objectives by effectively allocating and utilizing appropriate labour, material, and time resources in a manner that minimizes costs and maximizes customer/owner satisfaction (Patrick, n.d as cited in Jackson, 2020).

Coronavirus disease (COVID-19) – is an infectious disease caused by the SARS-CoV-2 virus (Colman, 2009).

Decarbonization - removes or reduces carbon dioxide (CO2) output into the atmosphere. Decarbonization requires switching to low-carbon energy sources (Vennix et al., n.d.).

Design thinking - is a method that focuses more on the general process of designing rather than just the artifacts of design (Archer, 1965; Jones, 1969, as cited in Ryan, 2014).

Emergent properties – are often described as unpredictable behaviours that come from the interaction between a system component and the environment (Johnson, 2006).

Embodied carbon – is the total energy consumed (carbon released) from direct and indirect processes associated with a product, such as material extraction, manufacturing, transportation, and demolition (Hawkins & Building Services Research and Information Association, 2011).

Human factors –"a discipline that discovers and applies information about human behaviour, abilities, limitations and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable and effective human use" (Chapanis,1985, as cited in Wenner, 2013).

Operational carbon – is a segment of carbon released from operational activities such as heating and lighting a building (Hawkins & Building Services Research and Information Association, 2011).

Sensemaking - is an action-oriented process of acquisition, reflection, and action (Kolko, n.d.).

Stakeholders - According to the Project Management Institute, "individuals and organizations whose interests are affected by the project's results and are actively engaged in the process" (2001).

Strategic Foresight – the ability "to produce and sustain a high quality, coherent and functional forward view and to use the insights arising in an organizationally useful way" (Slaughter, 1997, p. 1).

System Thinking – is a disciplined problem-solving approach involving activities like data analysis, identifying patterns of behaviour over time, and learning about the underlying structure that drives those patterns (Goodman, 2016).

Retrofitting – involves increasing energy efficiency in a building through activities such as replacing or improving lighting fixtures, ventilation systems, and heating/cooling systems (Natural Resources of Canada, 2018).

Disclaimer

This report represents a snapshot of the building and construction industry that is presently evolving. The primary researcher Carrie Emblem followed social-distance requirements by conducting virtual interviews. Carrie Emblem, an observer of the building and construction industry, developed the data analysis.

The Intended Audience

Personnel that will find this report valuable include senior management in development and construction with influential decision-making power, particularly those accountable for operating budgets, capital, and facility operation. Information also extends to professionals who design, build, and work in the architecture, engineering, and construction (AEC) industry and professors, property managers, and policymakers.

Positionality

Having grown up in Markham, Ontario, Carrie witnessed the development of “Downtown Markham” through continuous housing and commercial real estate development in the last 20 years. The once wide-open green fields slowly turned into new buildings and homes. The firm, in charge of the action plan, envisioned making this York Region hub a truly liveable and sustainable urban center.

When passing by the development, Carrie kept reflecting on the following questions.

- How can sustainability remain a high priority throughout the design process of urban development?
- How are these conversations structured, and who is involved?
- How can sustainable buildings and sustainable building management become more mainstream?

To widen my knowledge about buildings and sustainable design, Carrie virtually attended the 2021 Better Buildings Bootcamp and the Green Building Festival 2021 hosted by Sustainable Buildings Canada. These events featured live, interactive sessions facilitated by a group of leading academic experts and industry professionals.

“There are no passengers on Spaceship Earth. We are all [the] crew.”

Marshall McLuhan

Introduction

Context

The buildings we live, work, and play in significantly impact our economy and are central to our personal lives. Unfortunately, these buildings are highly vulnerable to the adverse effects of climate change, one of our time's defining global challenges in the real estate and construction sectors (Chopik et al., 2019). Due to climate variability, buildings have experienced poor effects on the exterior and interior surfaces. For instance, the building façade and extensive commercial damage to the service life of building foundations can result from increased precipitation (Natural Resources Canada, 2007 as cited in Boyle et al., 2013).

Factors influencing infrastructure's susceptibility to climate hazards include age, composition, and design.

Climate change is a significant threat to cities because their built infrastructure houses a dense population and high levels of economic activity (Bicknell et al. 2009; IEA 2008; Newman et al. 2009, as cited in Hallegatte &, Corfee-Morlot, 2010). Cities need to be protected, for they are not only important social, environmental, and cultural service centres but also responsible for a high proportion of the gross domestic product (GDP).

Ironically, buildings are not only susceptible to adverse effects of climate change; the construction, operations, maintenance, and eventual demolition of said structures are significant contributors to it. The United Nations Environment Program states that the building and construction sectors account for 36% of energy use globally and 39% of energy-related carbon dioxide emissions (Chopik et al., 2019). Canada's residential, commercial, and industrial building sectors produce 13% of the country's greenhouse gas emissions (Government of Canada, 2021). It is the third-largest source of greenhouse gas emissions after the energy and transportation sectors. According to the United Nations (2015, as cited in Dixon et al., 2018), by 2050, 66% of the global population will be living in urban areas.

Problem

Suppose a sustainable design building plan is neglected. We risk replicating future building stock with what already exists in Toronto, thus missing the opportunity to design better buildings for future weather patterns while reducing carbon emissions.

Toronto's municipal government – known as the City of Toronto hereafter – began the foundation of its ambitious climate change plan in 2007. Their main intentions were to minimize and prevent the effects of climate change and seek pockets of opportunity. On October 2nd, 2021, the Toronto City Council unanimously declared a climate emergency. They agreed to expedite activities for a more significant zero emissions reduction target of 2050 or sooner (Toronto, 2017). To expedite the process, the importance and implementation of such activities needs to be very well understood. A paramount concern is whether the building and construction sectors are prepared and positioned to design and communicate the importance of sustainable buildings in ongoing climate change. How do we ensure that the correct information is efficiently managed and circulated?

Scholars have defined knowledge management (KM) as "the process of creating a systematic approach to the retention, management, structure, and dissemination of knowledge throughout an organization in the interest of working faster, reusing best practices, and thus reducing costly rework from project to project" (Nonaka Takeuchi, 1995; Pasternack and Viscio, 1998; Pfeiffer and Sutton, 1999; Ruggles and Holtshouse, 1999, as cited in Dalkir, 2005).

Today, knowledge management theory and its application are significant due to business practices: globalization of business, leaner organizations, technological advances, and corporate amnesia (Dalkir, 2005). The phrase "corporate amnesia" refers to the fluidity of job positions and retention rates that challenges knowledge continuity.

As organizations become globalized, there is more pressure to optimize interconnections between culture, geography, and social interaction. Organizations that adopt a lean mindset strive to do more work with smaller, more capable operations systems. The powerful duality of urbanization and globalization lends itself to challenges of climate change and migration, immigration, and population growth. As stakeholders move from one project to another in the building and construction industry with different supply chains and partners, it is imperative to manage knowledge optimally

(Carrillo et al., 2000). Over the last few decades, it has been recognized in the building and construction industry that knowledge management can bring about the much-needed innovation and improved business performance the industry requires (Webb, 1998; Egbu et al., 1999).

Rationale

The rationale behind investigating this topic is supported by the fact that our existing building stock is estimated to double by 2060, with the construction of more than half of these buildings scheduled to happen in the next few decades (World Green Building Council, 2019). Therefore, the decisions regarding sustainable practices in the present and upcoming building design plans will have a considerable impact. Toronto, one of the fastest-growing cities in North America, will experience lots of construction. The city is expected to increase its population by 2.9 million reaching almost 10 million by 2046 (Ontario Ministry of Finance, 2021). According to Klepeis et al., North Americans spend 90% of their time indoors (2001), and the ongoing COVID-19 crisis further exemplifies the importance of a healthy work and living environment. This reflective and challenging time can be a catalyst to drive better architectural and sustainable innovations.

Primary Research Question

“How might we improve the knowledge management for environmentally sustainable design practices in the building sector in Toronto?”.

Objectives

This research aims to serve the following objectives
- Understand the current system
- Identify inefficiencies within the system
- Identify leverage points within the system
- Iterate solutions to improve the system

Scope

I selected the city of Toronto to investigate because it will benefit significantly from more sustainable buildings. This choice is due to its aging infrastructure, population, and property concentration, making the city vulnerable to climate change (Wieditz & Penney, 2006) and being one of the fastest- growing cities in North America, as mentioned above.

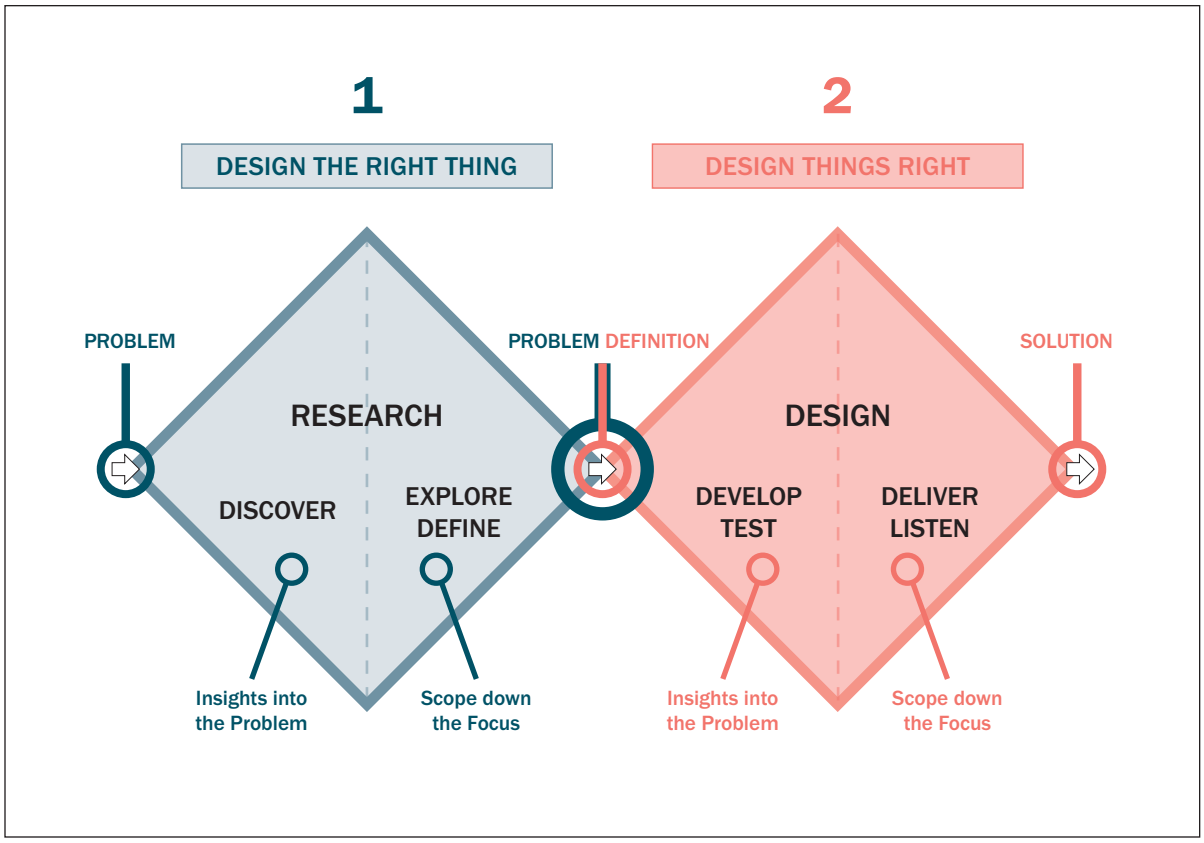
Building construction is a time-consuming process consisting of multiple divisions of labour across phases like pre-design, procurement, construction, and post-construction. This report focuses on the pre-design phase of construction, also known as the “pre-construction design” or “pre-con” stage since it is extremely influential in establishing the environmental sustainability performance of the building project. The pre-design stage sets up the direction of the entire project, focusing on eliminating risks regarding the building process, supply chain, inspection, and approval process.

In the past, the pre-design phase was merely preliminary work that did not hold much significance (Jackson, 2020). Today, it is a separate and highly influential discipline in the building process in providing services that support the decision-making of building owners, architects, designers, and engineers. During this phase, risk identification and mitigation discussions, cost information, schedule issues, design, and construction issues, building codes, and project feasibility occur (Jackson, 2020). Additionally, conversations regarding material and operations arise, and the city of Toronto determines whether the building’s general size, form, and function get approved.

This paper will produce three areas of exploration after completing a thorough analysis of the current reality of the building and construction industry, followed by collecting insights from interviewing and facilitating a futures exercise known as the “3 Horizons” with subject matter experts (SMEs) and my application of a human factors lens to the problem.

Project Methodology

I used design thinking, a method that focuses on the design process rather than just the outcomes of design (Archer, 1965; Jones, 1969, as cited in Ryan, 2014), to structure my thinking. I referred to the Double Diamond Design Thinking framework in Figure 1. This framework was popularized by the British Design Council in 2005 and modified from the 1996 divergence- convergence model created by Béla Heinrich Bánáthy (Möller, 2015).



Adapted from Digi-ark. (2020). [Image]. Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Double_diamond.png
Figure 1: Double Diamond of Design Thinking

Step 1: Discovering the System

The project started with primary research and a literature review. This step helped me develop a deeper understanding of the problem through exploration, identifying and challenging my assumptions, and questioning the implications of my discoveries.

Step 2: Framing the System

I chose environmental scanning to frame the system because it is one of the most effective data-input methods (Slaughter, 1997). To establish an environmental scanning foundation, I created a condensed timeline of the evolution of the building and construction industry (Appendix 1) and a STEEP (social, technological, economic, environmental, political) analysis. I determined the project's scope and primary research question with this information. This stage also included identifying the key stakeholders in the system.

Step 3: Listening to the System

I deliberately used a Knowledge vs. Power Grid (Figure 2) to reflect power dynamics between the relationships of the key stakeholders. I paired this grid with a stakeholder matrix to illustrate the priorities and needs of the stakeholders. After drawings key findings through analysis, I created a systems map that explores the elements and connections within the selected system (Acaroglu, 2017).

I sought ten subject matter experts varying in expertise in engineering, architecture, building science, sustainability, consulting, innovation, and urban planning. They participated in individual semi-structured interviews with ten open questions via video call. I incorporated strategic foresight (SF), which R.A Slaughter defines as the ability "to produce and sustain a high quality, coherent and functional forward view and to use the insights arising in an organizationally useful way" (1997, p. 1). I achieved this by guiding the interviewees through a future-thinking exercise called "The 3 Horizons".

Step 4: Understanding the System

I applied systems thinking at this stage by figuring out the cause-and-effect relationships within the system. Jamshid Gharagedaghi's work (2006) defines systems thinking as the art of handling an interdependent set of variables. His well-established methodology sees systems as more than the sum of their parts. In this section, I chose Braun's system archetypes and causal loop diagrams to define patterns and emergent qualities within the system nodes of the building and construction industry. It is vital to address the behaviour and relationships of the variables in the system, for they cannot exist without each other (Gharagedaghi, 2006). Steps 3 and 4 helped to address the questions of "what seems to be happening?", "what's really happening?", and "what might happen?".

Step 5: Challenges, Recommendations and Fostering the Transition

After exploring the current system, I entered the third section of the Double Diamond of Design Thinking, where I brainstormed challenges and recommendations through divergent thinking. I explored Donella Meadow's well-known leverage points and selected the most applicable ones that emerged from the building and construction industry. This ideation stage helped me to answer, "What might we need to do?" to improve the system. This further helped me to establish design criteria for prototypes.

This section also looks at the underlying human factors involved. Chapanis describes human factors as "a discipline that discovers and applies information about human behaviour, abilities, limitations, and other characteristics to the design of tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable, and effective human use" (1985, as cited in Wenner, 2013).

Finally, I arrived at the last part of the Double Diamond of Design Thinking. At this point, I applied convergent thinking by taking the insights from the ideation stage (the challenges and recommendations) and developed solution prototypes. I focused on the questions "what will we do?" and "how will we do it?" to implement prototypes successfully.

Step 6: Conclusion

The report reiterates the importance of implementing and promoting the value of environmental design strategies. These strategies can help reduce carbon emissions while enhancing resiliency for future weather-related events and future generations. Integrating the new prototypes needs to be practical and comprehensive, and the benefits must be transparent in the building and construction industry. The report concludes with further implications of this research.

Discovering the System

Literature Review

The urgency for sustainable buildings

In 2015, Canada was among 195 countries to sign the Paris agreement to fight against climate change. The building sector can be part of Canada's solution to reducing carbon emissions by using low carbon energy sources and mitigating energy inefficiencies. Compared to other countries, Canada and the United States use more energy per capita (Roseland et al., 2005). Focusing on the future of the built environment also creates opportunities that support public health goals such as improving occupational health.

Globally, greenhouse gas (GHG) emissions have risen to more than 40% over 25 years despite the numerous United Nations Climate Change Conferences over that same timeframe (Cole, 2020). The world energy consumption demand anticipates 150-230% growth by 2050 (World Resources Institute, 2002, as cited in Willard, 2005). This fact is fundamental as the building and construction industry consumes 50% of Canada's primary resources and is presently accountable for 35% to 40% of total national energy consumption (Nelms et al., 2005).

In the early 21st century, individual building owners believed that individual compounding efforts would save the planet, yet these random energy efficiency acts were insufficient. There was too much variance for effectiveness (Sharp, 2021). This information emphasizes that an integrated systemic design approach that merges toolsets of design thinking and systems thinking, is needed (Allen, n.d.). The benefits of this approach are a deeper context of the scope of the problem and the creation of more powerful and pragmatic outcomes (Bouganim, 2020). Compared to other industries, an integrated systemic design approach in the building and construction industry is more complex because of the number stakeholders and various stages of constructing a building. Nevertheless, the importance of a holistic approach should not be overlooked.

There are a variety of design techniques to make a building more environmentally sustainable. For example, the structure can have a better operating system to lower energy costs, thus leading to a better return on investment. The best practices in optimizing a building's energy performance extend its overall life cycle (Natural Resources Canada, 2015). Sustainable buildings can offer a superior indoor environment to improve the health and well-being of its occupants, such as efficient indoor air quality and sustainable materials. Methods involved in causing less environmental harm include stormwater management, prevention of waste production, and sensitivity to the surrounding environment (Akadiri, 2012). Retrofitting buildings by replacing older technologies with newer ones that have a lower impact on the health, environmental, and ecological factors is another benefit of sustainable design principles (Nelms et al., 2005).

Impact on physical infrastructure from climate change

The impacts of the future and current rate of climate change vary across Canada due to its large and diverse geography (Swanson et al., 2021). From forest fires to extreme heatwaves, there is a scientific consensus that the after-effects of climate change will increase in frequency and intensity. The timeline of preventing the earth's climate system from entering dangerous points of no return is slowly shrinking (Cole, 2020), and maintaining robust infrastructure systems is becoming increasingly difficult (Boyle et al., 2013). The structural damage buildings suffer from climate change, such as high winds, extreme precipitation, flash-freezing, and high temperatures, will likely affect the performance of such structures, thus making them uncomfortable and even deadly for occupants (Wieditz & Penney, 2006).

Real Estate, Energy, and Climate Change Expert Chris Chopik highlighted the significant impacts of property devaluation, high costs, and loss of regional economic productivity in Ontario. His study observed academic, scientific, meteorological, insurance data and expert interviews that reveal a lack of market awareness and response. His findings accentuate the need to narrow the gap between the increasing trend of climate risk impacts and the climate adaptation rate (Chopik, 2019).

The outcomes of extreme weather on buildings include economic losses, insurance claims, mental/social stress, and in some instances, death (Feltmate & Moudrak, 2021). The Government of

Canada and most Canadians are spending more on disaster relief programs and property insurance than ever before. In 2020, severe weather events cost Canadian taxpayers and insurers $2.4 Billion in insured damage (Government of Canada, 2021). Given the concentration of people, property, and aging infrastructure, Toronto is particularly vulnerable to severe weather incidents (Wieditz & Penney, 2006).

Slow progression towards sustainable buildings can result from multiple factors such as lack of coordination, challenges in incentives, and the absence of knowledge of renewable energy and its long-term benefits (Feige et al., 2011). If existing building practices do not change during the next decade, infrastructure failures linked to climate change could cost Canada $300 billion (Arsenault, 2019).

When nations experience financial crises or economic downturns, the building and construction sector has been critical in recovering economies (McGeorge & Zou, 2013). For instance, the specific investment component of infrastructure repairs from the 2009 American Recovery and Reinvestment Act (ARRA) in the United States led to decently paid jobs for thousands of Americans (Pollin & Garrett-Peltier, 2007). Toronto can use the building and construction sector as a part of the recovery plan from the Coronavirus (COVID-19) pandemic.

> “Covid-19 shows us that phenomenally rapid change is possible when humanity is united in common cause.”
>
> **Charles Eisenstein**

The COVID-19 pandemic: A wakeup call to city planning

The COVID-19 pandemic falls under the umbrella term VUCA meaning a Volatile, Uncertain, Complex, and Ambiguous world. This term describes the aftermath of the Cold War (Giles, 2018). Although this classification reflects lots of ambiguity, it also presents opportunities for new problem investigation and problem-solving techniques. The pandemic can be seen as an “unknown unknown,” as Madsbjerg and Rasmussen describe in their book The Moment of Clarity: using the human sciences to solve your most complex business problems, where present data and analytics often do not help (Madsbjerg & Rasmussen, 2014).

The COVID-19 pandemic highlighted immediate health and economic issues related to assessment processes in Toronto. This pandemic significantly affected how organizations and people function in a city by closing international borders, limiting social gatherings and interactions, and closing non-essential businesses (Moglia et al., 2021). It forced disciplines in the built environment to adapt without much warning at high costs.

The pandemic further highlighted wellness and sustainability in the built environment (Landreneau, n.d.). In addition, decision-making was complex as economic incentives often conflicted with citizens’ immediate health and safety. The pandemic also showcased the poor aftermath of miscommunication to the public in consistently practicing responsible societal behaviour (Cole, 2020).

This shows that when humans feel the immediate effects of the pandemic, there is a more rapid response when dealing with the consequences. If the mentality is that climate change is so far away, then there is less pressure to prioritize environmentally sustainable decisions. The point regarding miscommunication is significant as well. Poor public awareness of climate change leads to a lack of collective action and general support (Leach et al., 2021). The greater public needs comprehensive information to understand the urgency for sustainable buildings fully. Their actions can help drive market demand.

The COVID-19 pandemic has provided the opportunity to act on pathways to improve Canada’s

economic recovery (Canadian Construction Association, 2021). This post-pandemic world reveals a chance to re-examine ethical and design principles of urbanism, architecture, and adjacent disciplines to identify gaps in longstanding city planning. Addressing such gaps will allow future design strategies that promote sustainable, productive, and liveable cities (Alraouf, 2021).

The complexity of sustainability in business strategy and construction

Sustainability does not always resonate positively with business leaders; however, it is a much bigger problem when neglected. The skepticism associated with sustainability can result from a lack of sustainability expertise among board members, uncertain financial impact, and the view that boards should prioritize shareholder value through short-termism (Confino, 2015). The 1987 World Commission on the Environment and Development report was the first to coin "sustainable development." For this report, the primary definition for sustainable development will be "meeting the needs of the present without compromising the ability of future generations to meet theirs," as described by the World Commission on Environment and Development in 1987 (Kordi et al., 2021).

In the 1970s, local pollution, habitat issues, and national regulatory policy were core tenets of environmentalism. By the 1980s, there was a rise in awareness of global environmental problems (Carruthers, 2001). It was not until the 2010s that environmentalism became a key component within the sustainability dialogue across different technology and construction sectors. Although "sustainability" has appeared as a commonly used term in the last several decades, there is no consensus on a universal definition. Definitions for sustainability are likely in the hundreds (Vos, 2007). The absence of a universal definition highlights the difficulty of universally enforcing sustainable practices on a large-scale level. To add, the ever-growing body of knowledge regarding sustainable development and sustainability can be overwhelming (Hansen & Vanegas, 2006).

The multiple interpretations of the term sustainability have led to confusion resulting in a lack of collective action. At a minimum, the characteristics of the definitions often include the triple bottom line (TBL) framework, where companies address profit, social, and environmental concerns in an equal manner (Kenton, 2021). The term "sustainability" in this report focuses on the environmental aspect.

The building industry is an industry that has a high potential to make a valuable contribution to sustainable development (Akadiri et al., 2012). Sustainable development projects are achieved through intentionally designing, building, renovating, operating, and reusing in resource- efficient ways (Ortiz et al., 2010, as cited in Akadiri et al., 2012). There is an underlying consensus that the "status quo is no longer sustainable" (Hansen & Vanegas, 2006, p. 3).

According to a 2015 roundtable discussion with fifteen representatives of leading organizations across different sectors in Toronto, there are multiple reasons why businesses do not pursue business sustainability. Examples include difficulty in measuring metrics, lack of clarity from government regulations, factoring in whether sustainability consistently influences consumers purchasing decisions and communicating the company's reasonable steps towards sustainability without being perceived as greenwashing (Laughland & Bansal, 2011). Another prime example is the economic system that incentivizes profit/short-term thinking. It is for these reasons and the decentralized nature of the industry that designing a solution with a "one size fits all approach" is challenging.

Larry Fink, CEO of BlackRock, an American multinational investment management company, believes failing to invest in sustainable solutions will "catch up with [the] company and destroy shareholder value" (Holt, 2020). The adverse consequences of neglecting sustainability can lead to customer skepticism, losing talent to other companies, and not being seen as innovative. Seth Strongin, Associate and Vice-Chair at Arup engineering firm, believes businesses are incorrect by viewing the environment and the economy as an ultimatum (Nastu, 2020). Furthermore, senior decision-makers and strategists carry significant power when deciding whether sustainability is seen more as an opportunity than a threat to their business.

Framing the System

“The framing of a problem is often far more essential than its solution”

Albert Einstein

This section includes a STEEP analysis of the present building and construction industry and later identifies the system's stakeholders.

STEEP Analysis

The STEEP method, which looks at social, technological, environmental, economic, and political factors, was used to establish a holistic industry view. I chose it because it is simple to understand and examines the topic of environmentally sustainable design practices through various external considerations. After using this method, I developed a clear understanding of the current reality of the industry. The thorough investigation of the present reality is vital because it determines the precise context I'm investigating and the inefficiencies in the system, which provides a solid foundation for future investment in time and resources discussed later in the report.

Social factors

Today, companies in the building and construction sector face different kinds of pressure. When working on large and joint international projects, there can be differences in business and cultural objectives (Pampliega, 2013). There is also an increase in construction demands, thus leading to shorter turnaround times for projects (Avlijas, 2020). Risk management also changed. Managers must anticipate regulatory, strategic, and operational risks in addition to traditional silo-based financial and insurable hazards (KPMG, 2001, cited in McGeorge & Zou, 2013). This industry deals with globalization, e-commerce, build-own-operate transfer procurement, new organizational partnerships, and the increasing speed of business activities (McGeorge & Zou, 2013).

One of the fastest-growing policies within corporate management is environmental, social, and governance (ESG) (Bleasby, 2022). It is a group of measures covering a wide range of areas, such as the company's relationship with nature to how it deals with leadership. Focusing and revealing one's ESG can assist in establishing contracts, positive rapport with the greater community, and securing investors. According to Sahil Shoor, partner at Gowling WLG, disclosing ESGs is becoming normalized by institutional investors worldwide (Bleasby, 2022). Decisions linked to corporate social responsibility demonstrate good practice, which many organizations measure and issue in annual reports available to the public (Dixon et al., 2018).

The COVID-19 pandemic drastically changed worklife as many had to follow the work-from- home mandate. This period was difficult for the building and construction industry to follow. In construction, sequential interdependence is typical due to completing tasks in chronological order (Van der Vegt and Janssen in Yang et al., 2017). In contrast to other industries where working locations and workers are relatively static, the building and construction industry must coordinate workers to come at different periods to complete specific tasks (Navon etal., 2003, as cited in Yang et al., 2017). The mentioning of the work-from-home mandate reflects this industry's challenge as Toronto transitions to a post-pandemic economy.

Technological factors

The pandemic was also a digital stimulant of the decade, leading to digital adoption and transformation for many business sectors. It drove to increasing the need for updated technology, a centralized data repository, and online customer service. The increasingly data-driven economy has led to technical changes - smartphones and tablets, drones, cloud computing, artificial intelligence, and big data. Many computer programs are available for the countless tasks involved in construction, such as scheduling, estimating, quality control, information transfer, and building design (Jackson, 2020). There are also global positioning systems (GPS), building information modeling (BIM), and computer-aided earth-moving systems (Jackson, 2020).

The benefits of these technological advances include creating better efficiency and collaboration between the stakeholders by eliminating time delays in the workforce. Other benefits include lower costs, capturing and analyzing large amounts of data, and productivity (Jones, 2018).

Smart wearables have increased safety in the field by predicting and alerting workers of possible injury (Turner et al., 2021). Embedded intelligence in building materials, nanotechnology, micro- electromechanical systems, and metallic polymers will rise in popularity as the industry matures (Jackson, 2020). With accelerating technological

advancement, organizations must focus on improving and informing processes and decision-making in addition to the tools themselves (Crosby, 2020).

Although such technological advances exist in the construction industry, low digitalization and adoption of such innovations have been the norm even before the COVID-19 pandemic. This slow adaptation and implementation rate reflect the findings of a 2020 survey by KPMG and the Canadian Construction Association. Sixty percent of executives of the companies surveyed do not know which technologies will help them stay competitive (Israelson, 2021). James McKellar, Director of the Brookfield Centre in Real Estate and Infrastructure at York University's Schulich School of Business in Toronto, states, "Many companies resist change because the business model for construction does not lend itself to the easy adaptation of new technology" (Israelson, 2021). In addition, the reduced skill requirements upon entering the industry stall productivity with innovative and progressive changes (Turner et al., 2021). According to McKellar, the building and construction industry would require a massive overhaul to encourage the industry to embrace high tech quicker (Israelson, 2021).

Economic factors

The COVID-19 pandemic significantly impacted Ontario's construction industry in the short and long term. The building and construction sector employs over 1.4 million people in Canada and accounts for 7.5 percent of Canada's GDP, translating to $141 billion in the economy annually (Biorck et al., 2020). Microclimate impacts, labour shortages, building materials supply chain, and uncertain logistics have caused major operational disruptions (McManus, 2021). With the long-term lockdowns and shifts in investment patterns, economic activity is estimated to return to 2019 levels by 2023 (Biorck et al., 2020). The financial health of this sector will either be a make-or-break factor for the Sustainable Development Goals (Hartenberger, 2015).

Innovation in the building and construction sector is exciting but daunting for investors, especially in ambiguous times. Although there have been advances in innovation in the construction sector, often, many investment decisions lean towards the "tried and true approach," a commonly used approach that timelessly works (Government of Canada, 2018). This approach often means investing in ways in which buildings have always been built rather than investing in new sustainable design strategies and technologies. This approach reflects how we operate in a growth-based economy where profit-seeking is rewarded.

The socio-economic status within communities determines how quickly sustainable buildings will be developed. This factor is tied to access to skillsets, technology, and resource capacity to strengthen climate-resilient infrastructure systems (Swanson et al., 2021). The Pan-Canadian Framework on Clean Growth and Climate Change, developed by the Government of Canada, states that prices for constructing net-zero energy buildings have dropped by 40% within the last decade (Government of Canada, 2016).

Environmental factors

According to a 2019 report on Canada's Top Climate Change Risks commissioned by the Council of Canadian Academies, physical infrastructure is one of six major climate change risk areas that could lead to significant losses, damages, or disruptions over the next 20 years.

Although the temporary seasons and vast regional diversity Canada experiences make it difficult to foresee climate impacts on infrastructures (Boyle et al., 2013), there are generally agreed upon common trends. These include average summer temperatures rising by 2°C to 4°C over the next 50 years, expected higher sea levels, and increased precipitation. Greenhouse gases already emitted into the atmosphere will stay there for decades or centuries (Wieditz & Penney, 2006).

According to the Urban Land Institute, the environmental damage from events like flooding leads to sizable value loss, large-scale insurance payouts, and disruption to economic productivity (Chopik, 2019). In 2018, insured damage reached $1.9 billion from serious weather events across Canada. According to Craig Steward, Vice-president of Federal affairs from the Insurance Bureau of Canada, over the last decade, the average annual claims of property losses or damage to severe weather have more than quadrupled to $2 billion (Owen, 2021). The increase in

government-sponsored disaster relief programs, often overseen by the federal Disaster Financial Assistance Arrangements (DFAA) program, supports the escalation of climate change costs (Green Analytics, 2020).

Political factors

The Canadian government has recognized the vulnerability of its aging building stock and has invested heavily in it. Programs and funds in Canada are available, including the Disaster Mitigation Adaptation Fund, the Federal Gas Tax Fund, and the Smart Cities Challenge. The over $33-billion investment in Canada Infrastructure Program, which focuses on mutual agreements on funding and project delivery with the provinces and territories, has a COVID-19 Resilience stream (Canada, 2018). The Canadian government endowed the Federation of Canadian Municipal 550 million dollars with the Green Municipal Fund (GMF). The Canadian government is interested in sustainable buildings, yet investors can be hesitant, as mentioned in the economic section.

Summary Section of STEEP Analysis

TYPE OF FACTOR	KEY TAKEAWAYS
Social	• There is an increase in the number of opinions construction organizations must consider. • Organizations' response to obstacles such as the COVID-19 pandemic reflect their professional reputation.
Technological	• The COVID-19 pandemic has caused major operational disruption to Ontario's construction industry. • This results in multiple problems rather than one singular issue.
Economical	• The COVID-19 pandemic has caused major operational disruption to Ontario's construction industry. • This results in multiple problems rather than one singular issue.
Environmental	• Environmental factors are critical to pay close attention to justify the prioritization and urgency of sustainable design practice.
Political	• The development of programs and funding opportunities reflects the Canadian government's prioritization of sustainable buildings and retrofitting aging buildings. • There is a discrepancy between the Canadian government's stance versus many investors.

A condensed timeline of the evolution of the Building and Construction industry can be found in Appendix 1. This historical information further explanation on how the building and construction field arrived where it is today.

Stakeholders

A critical part of this design challenge is identifying the relationships between the key stakeholders and setting the boundaries within the system (Systemic Design Toolkit Guide, 2020). Building and construction work consists of teamwork as there are many divisions and sequencing of labour.

Project stakeholders do not always agree on goals, costs, or quality, which can result in conflict. As many stakeholders are involved, it is hard to provide a consistent level of communication and consultation in a project. The stakeholders' influence on project deliverables fluctuates (McGeorge and Zou, 2013). Although stakeholder identification and management insights have been previously acknowledged, integrating them is not as straightforward, especially in a profit-driven context – which I would place the building and construction industry (Jackson, 2003 cited in Achterkamp and Vos, 2007).

I categorized the stakeholders as either internal or external. Internal stakeholders are individuals and parties who contribute to the responsibilities and operational process of the organization. In contrast, external stakeholders are individuals and parties affected indirectly by business activities (Walker, 2020).

Internal Stakeholders

- **Construction workers and labourers** – tradespeople that undergo manual labour on construction sites.
- **Contractors** – responsible for labour hire and managing material delivery
- **Architects, designers, and engineers** – responsible for designing buildings and operating systems.
- **Developers/ Property owners** - responsible for developing land through construction and becoming landowners.

External Stakeholders

- **Tenants** – the users and renters of buildings.
- **Manufacturers and Suppliers** – create the materials needed to construct buildings and sell them to developers and contractors.
- **Investors** – provide funding for construction and retrofit projects with the expectations of returns on investments and return on equity.
- **Lenders** – often big banks, such as Canada Infrastructure Bank (CIB, provide construction and retrofitting loans.
- **Government (including regulators and policymakers)** – mandates codes as minimum standards for buildings and new development, develops climate targets and enforces policies to reduce GHG emissions.

Listening to the System

“The greatest danger in times of turbulence is not the turbulence; it is to act with yesterday’s logic.”

Peter Drucker

Knowledge and power

The building and construction sector is a global, omnichannel decentralized system with numerous stakeholders and moving parts, thus making it very convoluted with variances. The Knowledge vs. Power Grid (Figure 2) below reflects who of the internal and external stakeholders has the most influence and knowledge regarding sustainable building design.

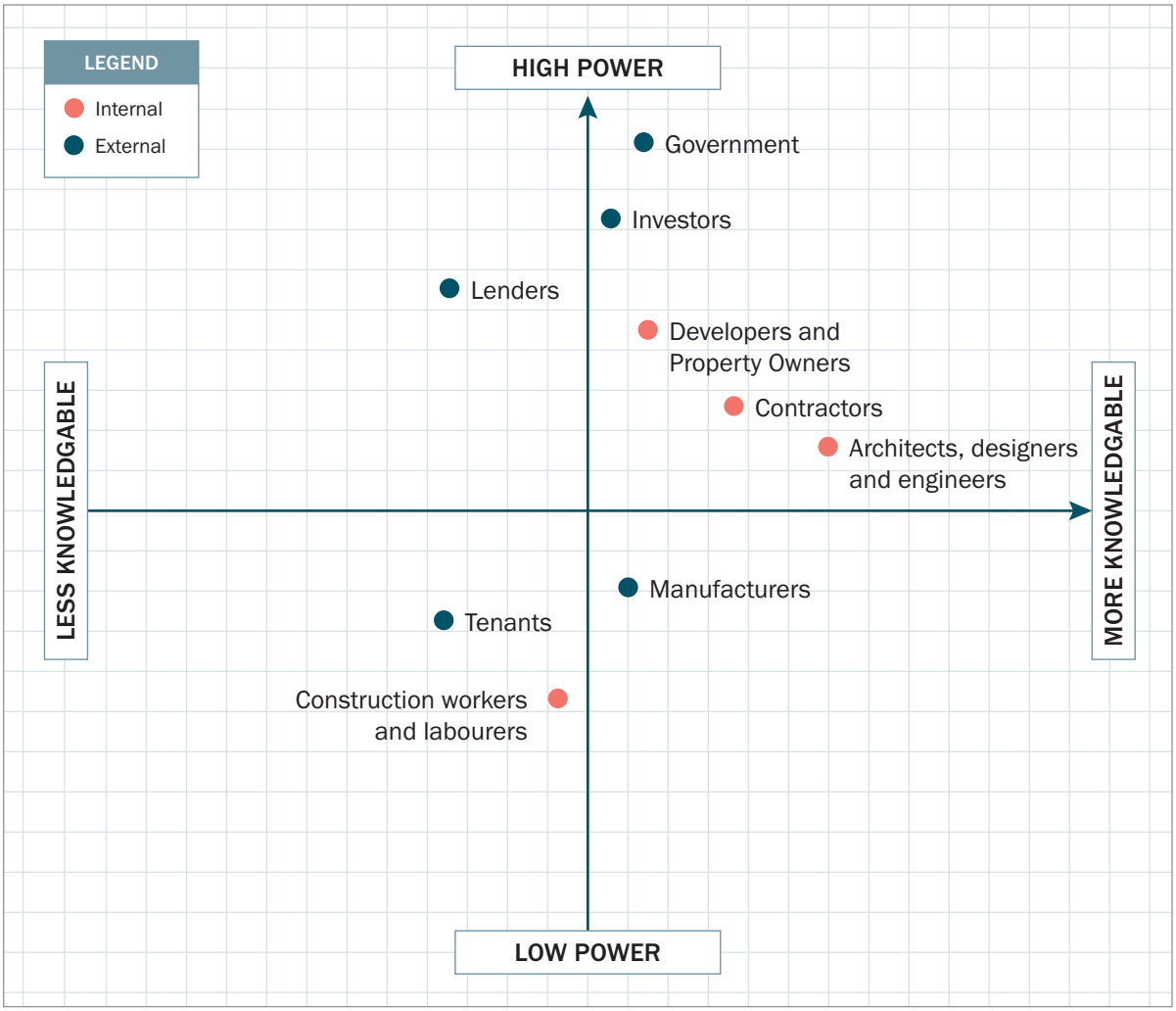


Figure 2: Knowledge and Power Grid

From the grid above, the government has the highest level of power. The government, including policymakers and regulators, are agents of change and have the resources needed, such as design, technology, and policy tools. They oversee funding and mandate sustainable policies that internal stakeholders must follow. Most of the external stakeholders, such as the investors and lenders, in charge of financial backing, hold more power than the internal stakeholders.

The architects, designers, and engineers are the most knowledgeable stakeholders, given their daily work, education, and industry experience. Developers and property owners are really at the heart of construction projects. Without their involvement, the projects would not exist. They are accountable for creating the budget for the project, determining the scope of work necessary to meet project requirements, identifying the needs and conditions, and establishing a funding plan for

the designers and contractors involved (Jackson, 2020).

In 2019, Canada Green Building Council stated that Ontario was losing billions in energy efficiency because of the lack of “low-carbon” trade skills (Rushowy). For this reason, I placed construction workers and labourers between the bottom two quadrants. In addition, construction workers and labourers often hold temporary contracts. They have little authority over the overall vision of the building. Whether sustainable design tactics are being implemented or not is often irrelevant to them. Examples of job titles that fall under this category include electricians, plumbers, welders, and dry wall specialists. Tenants usually do not bear any responsibility in the pre-design building stage and building execution unless that are also owners. For this reason, I placed tenants in the bottom left quadrant of the grid, holding little knowledge and power compared to the rest of the stakeholders.

Stakeholder Matrix

I used the design tool known as the Stakeholder’s matrix to compare all the stakeholders’ needs and wants. Readers can follow the different stakeholders from left to right horizontally across the top of the diagram. I arranged the stakeholders according to their influence and resources in a building project. Under each stakeholder is a column of needs they prioritize. I chose this tool because it represents the interconnectedness of the needs of the stakeholders within the industry.

The stakeholder matrix allowed me to consider and appropriately map out the fundamental needs of the stakeholders involved; otherwise, neglecting their needs can result in project failure (McGeorge & Zou, 2013). The nature of stakeholder management determines how obstacles and challenges are resolved (Pampliega, 2013). For successful implementation, construction professionals must be aware of and commit to the project’s goals (Liu, 1999, as cited in Leung et al., 2004). If the demands from the high-power stakeholders are not satisfied, specific needs from low-power stakeholders cannot be met. For instance, if developers and property owners do not secure adequate funding, then the architects, designers, and engineers cannot take on new contracts.

I placed the Canadian government at the very right because they have the most resources and leverage compared to the rest of the stakeholders. Conversely, the tenants of the buildings are placed on the very left because they have less agency, and their needs are ranked lower. Nonetheless, despite having lower priority needs than the government, tenants hold a lot of voting power when re-electing government officials. Topical issues such as housing affordability in Toronto and climate change affect voting decisions.

Stakeholders involved have different investment narratives and interests in construction projects. The hierarchy of needs is primarily related to capitalism, with terms such as profit maximization, return-on-equity, return-on-investment, and economic growth being the top needs for many stakeholders. Contractors know cost specifics and are best to assist building owners for investing in areas that will be beneficial and which areas to avoid (Jackson, 2020). Construction practitioners face the pressures of meeting construction owners’ assurance of long-term economic performance while simultaneously cutting costs (Akadiri et al., 2012).

Lenders such as Canada Infrastructure Bank (CIB), which reports to the Minister of Infrastructure, provide construction, and retrofit project loans. Lenders are often forward thinkers by evaluating decisions based on benefits to future Canadians. Investors usually want equity and partial ownership. Investors are more concerned about the building’s longevity, materials, and environmental output because they have greater risk involved. The danger, however, obviously varies from one investor to another and as previously mentioned, the ”tried and true approach” is often followed for investment decisions (Government of Canada, 2018). This tried-and-true approach can be a barrier to generating funding for environmentally sustainable buildings with innovative or experimental design tactics.

Without clear and articulated goals, the goal commitment can vary amongst the project stakeholders, especially if they are temporary participants such as construction workers and labourers. This

discrepancy and misalignment can lead to miscommunication and delay. If specific stakeholders do not have a long-term investment in the building, this can ultimately lower their concern about whether the building is sustainable or not. Also, when there is an increase in times of uncertainty and economic adversity, the goals of a project can significantly diversify. The prioritization of self-interest may overshadow project success (Walker, 1996; Leung et al., 2002 as cited in Leung et al., 2004).

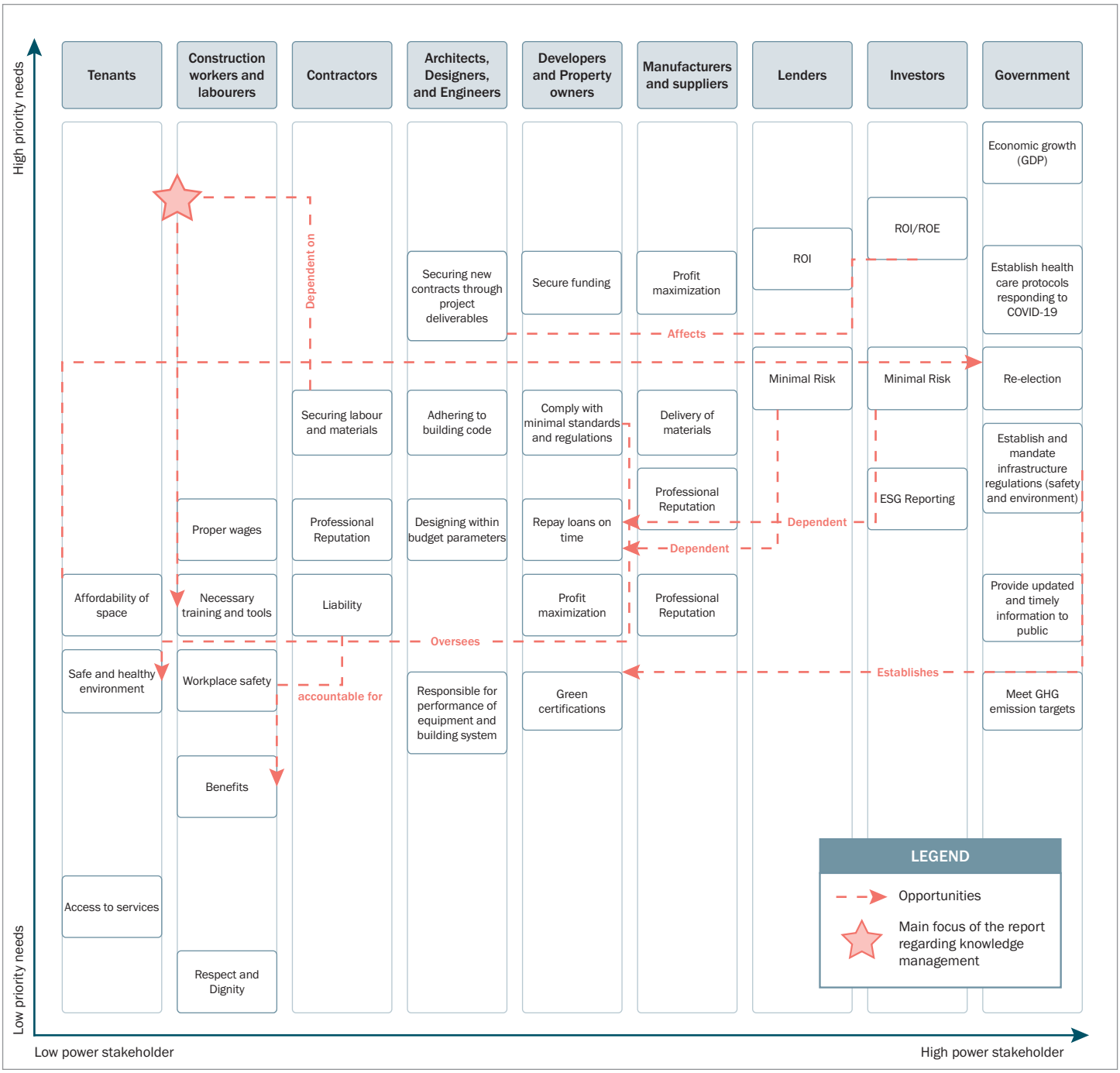


Figure 3: Stakeholder matrix

Systems Map

I placed the stakeholders in the systems map according to their involvement in the 6-step process of a building lifecycle. The stages include acquisition phase, pre-design phase, design phase, commissioning phase, operations and maintenance phase and the end-of-life phase. The systems map is intended to be read clockwise. I deliberately overlapped the circles of the phases to reflect the many iterations that occur.

In the pre-design stage, I incorporated various construction project delivery types which include at-risk construction management, design-build, design-bid-build, and intergrated project delivery. These options vary in work sequence, risk, timeline, and ownership. For instance, design build means that one entity is under contract for designing the project from start to finish. Whereas design-bid-build means the client hires independent designers and architects to develop building designs that reflects the developer's wants, that are then open for public bidding. This leads to separate contracts (Zurbrugg, 2019). I included the delivery types as they influence which entities are in the pre-design stage and their division of ownership. The selection of a construction project delivery type is based on the goals, objectives, and expectations of the client.

A systems map helps accentuate emergent properties. Emergent properties are unpredictable behaviours that come from the interaction between the components of an application and its environment (Johnson, 2005). By zooming out and looking at the industry at a macro level, emergent properties aid in identifying cause-and-effect relationships, which is crucial for system thinking (Fischer & Riechers, 2019). The map I created can be used as a general framework as the design process can vary depending on project complexity, size, and participants (Glavinich, 2008). This systems map's cyclical form demonstrates each design stage's interconnectedness and dependency within the traditional building life cycle.

One of the key takeaways is that the investment decisions that occur in the pre-design stage are far removed from the operations and maintenance phase. An empathetic design approach, displayed by taking in all perspectives before making decisions, can be lost in translation between the two phases. The predetermined design decisions should consider the overall impact on environmental and human health throughout the building life cycle. When life-cycle costs are not integrated into corporate decision-making processes, cost and price performance are often prioritized over energy-related operational costs (Natural Resources Canada, 2015). Reducing energy use from heating, cooling and operating buildings is the standard approach for reducing GHG emissions in Canada's building stock (Canada Green Building Council, 2019). Many processes stem from research, documentation, and knowledge distribution within the pre-design stage. It is hard to determine the effectiveness of coordination and collaboration during the processes found in the systems map. Although this report focuses on the pre-design stage in the construction project, which is indicated by the yellow star, it is vital to see how this stage connects to the entire building life cycle. The pre-design stage's decisions and activities set the groundwork for the whole building. The boundaries of the systems map show the accepted status quo of the industry and the industry's rules (McGeorge & Zou, 2013).

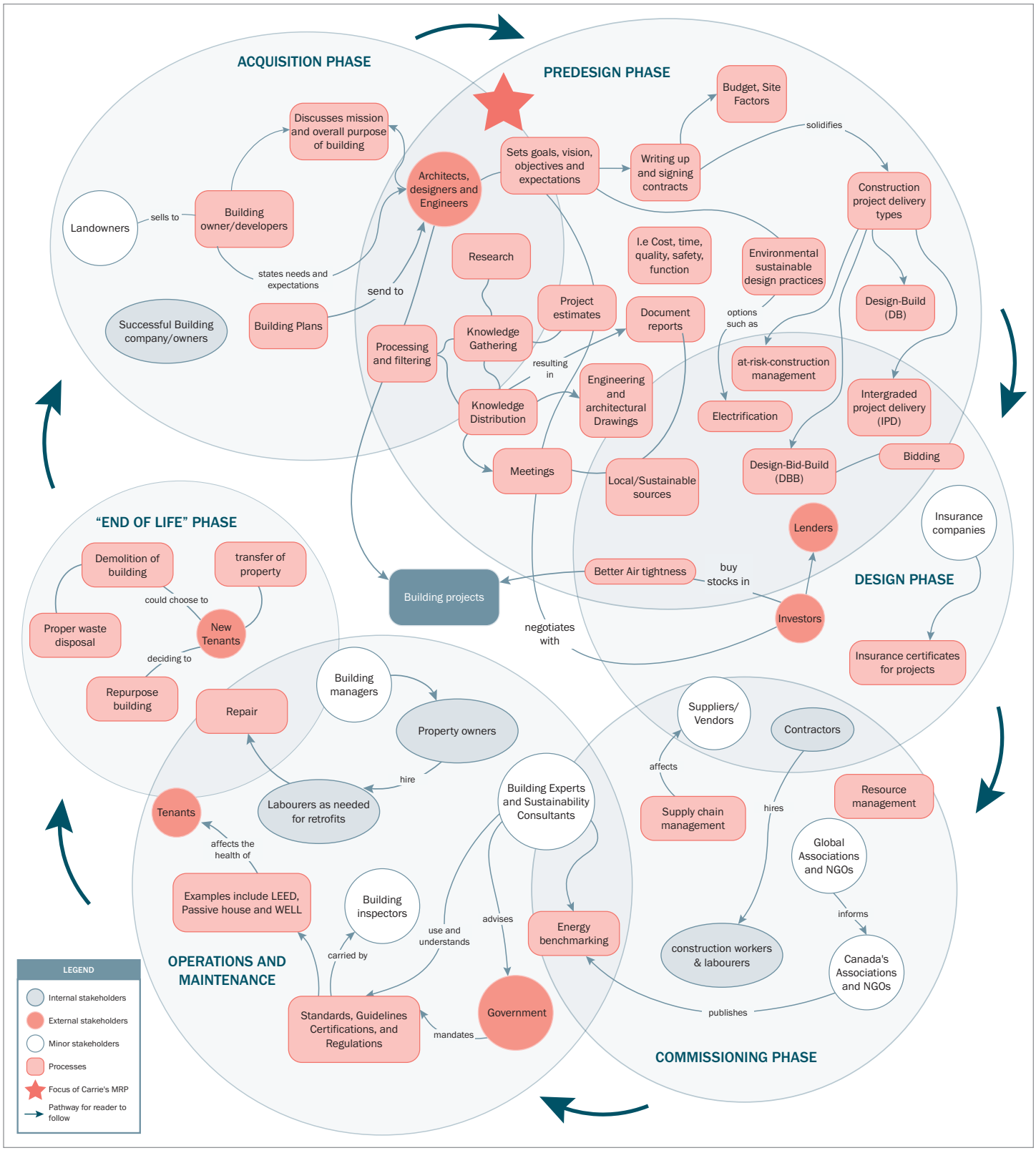


Figure 4. Systems map

“The only thing more dangerous than no progress is the illusion of progress,”

Brendan Leblanc

Subject matter interviews

This project raises questions and inquiries about various topics such as building science, energy efficiency, engineering, urban planning, and sustainability. As a result, I planned to recruit different subject matter experts. There was ten interviewees total, and all were given the choice to be accredited to this research or stay anonymous. Those who decided to remain anonymous were comfortable providing their job title. Due to the small number of subject matter experts interviewed, this report should be read as a snapshot of the entire industry, which is currently evolving.

The interview consisted of ten open questions and a futures exercise called "The 3 Horizons". The objective of the interview was for participants to answer the questions to the best of their abilities. I told the participants that there were no right or wrong answers. The discussion occurred individually via videophone call, with one exception of a telephone call. Each participant received an invitation request letter containing details, risks, and benefits of the research project. They also received an official consent form regarding permission for auto-recording and verifying voluntary consent.

The ten participants included

- Anjali Varma, Sustainable entrepreneur
- Chris Chopik, Senior Specialist, Policy Analysis, Canada Mortgage and Housing Corporation, Real Estate, Energy and Climate Change Expert, Sotheby's International Realty Canada, Associate Researcher, Intact Centre for Climate Adaptation, Associate Researcher, OCADU SLab (Strategic Innovation Lab)
- Dan Nicholson, Manager, Community Planning, City Planning Division
- Lee Hodgkinson, Head of Sustainability & Technical Services at Dream Unlimited, Mechanical engineer
- Larry Brydon, VP Business Development and Regulatory Affairs – Cricket Energy Holdings INC & Chair, Sustainable Buildings Canada
- Mercedes Byers, Principal at Pratus Group
- Sustainability consultant A
- Sustainability consultant B
- Senior mechanical engineer
- Director of Innovation in the building sector

I selected the following key questions from the semi-structured interviews. The primary data collected helped me as a researcher to spot the gaps in addressing "what seems to be happening?" and "what's really happening?". With the main research question guiding me, I was focused on how the experts collected and managed information, viewed the current and future state of the building and construction industry, and saw barriers to environmentally sustainable buildings.

1. Can you comment on your decision-making practices?

The majority of participants said their point of influence depends on the context, as many have taken the roles of facilitators, advocators, speakers, consultants, researchers, and planners.

Dan Nicholson mentioned decisions must be compliant to the Planning Act that was established in 1990. Three noted that the private sector is primarily interested in meeting market demand and prioritizing profitability. The Director of Innovation in the building sector mentioned that incentive is essential, especially when receiving buy-in approval.

A common theme presented was that decision-making is contingent on clients' expectations and what they are willing to agree to vary. As industry champions, the subject matter experts can identify the wants and needs of their clients and can come up with solutions. However, when hiring industry experts, clients sometimes do not know what they want. Anjali Varma summarizes current industry information for her clients to easily understand. Mercedes Byers mentioned that some clients only want to meet the bare minimum of their internal mandates, whereas others are interested in fostering a long-term sustainability plan.

Regarding decision-making, Lee Hodgkinson believes the building and construction industry is moving towards an Integrated Design Process (IDP) whereby one engages with many stakeholders very early in the development process – the pre-design and design phase of buildings. External stakeholders such as mechanical, electrical, structural engineers, and building

envelope specialists, landscaping experts, traffic and transportation experts, and geological experts, are paired with internal stakeholders to identify the vision of the building. IDP is a highly iterative process with diverse perspectives and expertise present. Through workshops, studies and consultations, stakeholders challenge each other and determine what works well and how best to apply that information to the project.

All industry champions make their decisions based on their expertise and input from other subject matter experts and clients. When clients are uncertain about what they want, the subject matter experts can educate them. This presents an opportunity to inform and communicate the value of sustainable design options.

2. How do you keep up to date with industry trends?

Eight of the 10 participants follow industry trends by reading newsletters and blogs, policy updates, collaborating with professionals, attending conferences and webinars, and advising and subscribing to industry organizations. The organizations commonly mentioned were Sustainable Buildings Canada, Canada Green Building Council (Greater Toronto Chapter), and Efficiency Canada. Programs such as WELL, a performance-based system for measuring and monitoring features that center on design practices that prioritize people's health and wellness (International WELL Building Institute, n.d.), and Leadership on Energy and Environmental Design (LEED) were also cited.

Three of the subject matter experts found that having the chance to meet and talk to people is extremely helpful in achieving a high-level understanding of the current and future reality of the construction and building industry. Asking many questions leads to more answers, which helps identify trends. As a city planner, Dan Nicholson collaborates with internal urban design experts and participates in internal workshops. Lee Hodgkinson expressed the importance of learning by doing, as it gives him and his team an opportunity to recheck an analysis, assumption, or decision. Chris Chopik gained valuable information about solar energy from first-hand experience with his home renovation and presenting at industry tradeshows.

With Sustainable Buildings Canada, Larry Brydon helps run a "Savings by Design" program through Enbridge. This program brings developers and a team of sustainability subject matter experts, including building envelope experts, lower-impact development experts, and civil engineers, to work on sustainable building programs. Through these exercises, Brydon gets access to the industry issues, which he described as the "sand under the saddle." He tries to match the research work with the industry sector's needs and uses his role to advocate or develop programs to execute that ambition.

Some interesting insights are as follows. Sustainable consultant A mentioned that they intentionally try not to live by their own bias and try to find counterpoints to find a balanced view. This conscious act counteracts confirmation bias where one seeks evidence verifying one's beliefs and ignoring evidence that might refute them (Colman, 2009). Practicing confirmation bias can lead to misinformation when influencing people and social structures. The senior mechanical engineer stressed the importance of client relationship building to hear what the clients are hearing. The conscious act opens the pathway to discovering how and where clients get their information.

3. Which trends will drastically shape the industry in the next decade?

I grouped the answers to this question into the following themes for clarification purposes.

a. Municipalities' getting ready for future climate crises

The Director of Innovation in the building sector stated that one could not mention climate change when thinking about the industry in the next decade. They noted that the ongoing COVID-19 pandemic provides a taste of what it is like to have one's world change radically without much warning. Climate change will likely result in people being unfortunately displayed or relocated in the coming years. When the impact of a disaster is felt at home, for example, in the massive floods in British Columbia

in 2021, there are more considerable efforts about what we will have to do to build our resilience to the changing climate. As the linkage between cities and buildings becomes stronger, Larry Brydon believes municipalities' will need to adopt climate emergencies and rebuilding standards unique to their own regional needs. He states that Toronto is heading towards a warmer climate like the U.S capital, Washington, D.C. Argo, and decentralized energy will likely be critical in the next decade – especially with the risk of power shortages from the changing environment.

b. Embodied carbon

Three participants stated that the building and construction industry has been paying attention to operational carbon for years but still needs to understand and address embodied carbon better. There is a lack of qualifications and results from projects that do these calculations today. Lee Hodgkinson and Mercedes Buyers both commented that the industry needs to prioritize understanding embodied carbon. Government agencies can use this information to update and mandate infrastructure regulations which assists the architects, designers, and engineers in practice. Strategies such as waterproofing, the term to reduce the greenhouse gases in a project, can grow in popularity (Canadian Construction Association, 2021).

c. Improvement in Data Accessibility

Lee Hodgkinson emphasized that sustainability experts constantly need current data to drive the best operations, but there is no standardized way to collect such data in the industry. Inadequate data can lead to poor working decisions and delay work progress. Two of the interviewees found working from home to be challenging in terms of data circulation. In addition, there can be cyber security data issues that hinder the distribution of information.

d. Decarbonization

Three interviewees believe decarbonization is possible but challenging to implement. The senior mechanical engineer stated that this movement of decarbonization could "fizzle out" because of the price of utility bills. This fizzling out will occur unless there is more efficient equipment and better price signals. Other experts believe that the Toronto Green Standard (TGS) is the cornerstone of accelerating decarbonization efforts in building design.

e. Health and Wellness

The COVID-19 pandemic, deemed airborne, helped increase the consideration of everyone's health, safety, and wellness – specifically with indoor environmental and air quality. This pandemic is now challenging the open-concept workspace. Poor employee mental health is a costly occupational health issue (Dreyer et al., 2018). Some building operators recognize the growing body of research and the positive impact of the role of design in achieving healthy buildings. Nonetheless, these principles are still in the early stages of building design.

Two interviewees mentioned that the idea of ecological catastrophe in Toronto is still far away from the general population thus resulting in a lack of urgency to act on it. Sustainability consultant A emphasized the importance of focusing on the health and wellness of the future occupants and everyone involved in the life cycle of the building, such as workers who are extracting the raw materials, transporting the materials, and manufacturing the materials. These principles can be achieved through sustainable and local materials, securing the building envelope, and using clean technology.

f. Building Codes

In the coming decade, seven interviewees mentioned the continuation of updates to existing building and retrofit codes and new energy modeling systems for higher performance of buildings. A significant building code, particularly related to new construction, is the Toronto Green Standard (TGS). It is driving those in the industry to choose more sustainable outcomes. Sustainability consultant A stated that TGS, is one of the most stringent codes worldwide as it constantly raises the bar for sustainability practices. For instance, TGS introduced absolute value into the building and construction industry, meaning it explicitly states what a building

of a specific size and shape needs to achieve energy-wise. The total value contrasts with the relative value, which compares a proposed establishment of a particular size with one already built. The problem with relative value is that it relies heavily on pre-existing buildings, which do not reflect the updated building science today and cannot withstand future weather patterns. Furthermore, raising awareness of absolute value will be a game-changer in the industry.

g. Carbon Tax Rebates

Sustainability Consultant B stated that the removal of the Cap-and-Trade regulation, grounded in the Environmental Bill of Rights, 1993 (the EBR), in June 2018 was one of the most significant barriers to advancing low-carbon emission efforts (Berlis, 2019). The Cap-and-Trade regulation charged extra for fuel organizations and houses produced in Ontario. The collective funding would go to a regulatory body to support actions like retrofits and social housing renewal.

The elected federal government then got involved and agreed to collect that money, but the government sent homeowners tax rebates instead of automatically funding low carbon projects. With a simple tax credit form, there was no guarantee that the funds would be used to reduce carbon emissions. Nonetheless, in 2019, the Canadian government introduced a price on carbon pollution and, as of early 2022, has organized Climate Action Incentive (CAI) payments to make carbon pollution more affordable for Canadian families (Department of Finance Canada, 2022). In Ontario, 90% of proceeds from carbon pollution pricing are returned to residents through CAI payments (Department of Finance Canada, 2022).

h. Building owners

There are different types of building owners. For instance, private owners aim for profit and often look for a 5-year payback. Larry Brydon stated that most commercial investors want a 10% return and are uninterested in a 15–20-year payback period. Institutional owners have different drivers, such as environment social governance (ESG) reporting. Nowadays there is an increase in building portfolio owners. In real estate, rather than looking at individual buildings, they want to focus on the portfolio level, which was the focus in the past. In this trend, there is more consideration for retrofits and low-carbon efforts. According to recent research from Canada Green Building Council (2019), driving down the cost of zero-carbon buildings for building owners is expected to occur as the price of carbon increases and building codes are modified.

i. Passive housing movement of planning

Two of the ten subject matter experts referred to the “missing middle.” This term refers to single-detached houses and apartment buildings that have been absent in our cities for the last 60 to 70 years (Evenson et al., 2018). Although this report focuses on commercial and institutional buildings, passive house design strategies align with this topic because they pay close attention to the potential investors and price signals. Passive housing will be possible with a robust funding methodology for a long-term time frame for life cycle cost measurements.

j. Electrification

Traditionally, heating and cooling are controlled by natural gas boilers feeding hot water loops in Toronto. The availability of electrification used to be scarce, yet it will likely gain popularity in the next decade. There seems to be a social commitment, especially in the corporate world, where people want to support low carbon options. However, Mercedes Buyers notes there is some hesitancy in going all electrical because the cost of carbon will have to increase.

4. How does your company address knowledge management?

Six interviewees stated that their participation in associations, webinars, and conferences is where they like to collect information. They feel empowered when they share that updated information with their colleagues. Chris Chopik mentioned the importance of relating functionality to the human experience by moving from complicated technical jargon to simple language. Two of the ten interviewees said that the vast amount of data could be challenging to

work with because of constant updates. Three participants acknowledged that they could dedicate more time optimizing data circulation and internal communications in their workplace. The work-from-home mandate resulting from the COVID-19 pandemic made knowledge management and data circulation particularly challenging.

5. What systemic interfaces do you believe stall environmental sustainability for commercial buildings in Toronto?

a. Lack of incentive

Four subject matter experts believe that unless a company aims to set itself apart, decarbonization methods and environmentally sustainable building strategies will not be pursued until required by law. Canada is a high-resource-driven economy with colossal energy and mining sectors. Many organizations do not want to spend the costs if they do not have to. Organizations want to be on an even level playing field, so many will not push beyond what is required. In the building and construction industry, it takes a long time to adopt new ways of doing things as there is less risk if trades keep doing what they know. The Director of Innovation mentioned they were hired as a sustainability strategist at one point. They found it an advocacy role because sustainability was not a significant consideration in the organization's programs. Whether the value of sustainable building design is communicated clearly to clients is critical for agreement and buy-in. According to Jackson, the average observer often thinks construction is inconsequential and insignificant (2020).

b. Lack of consistent information

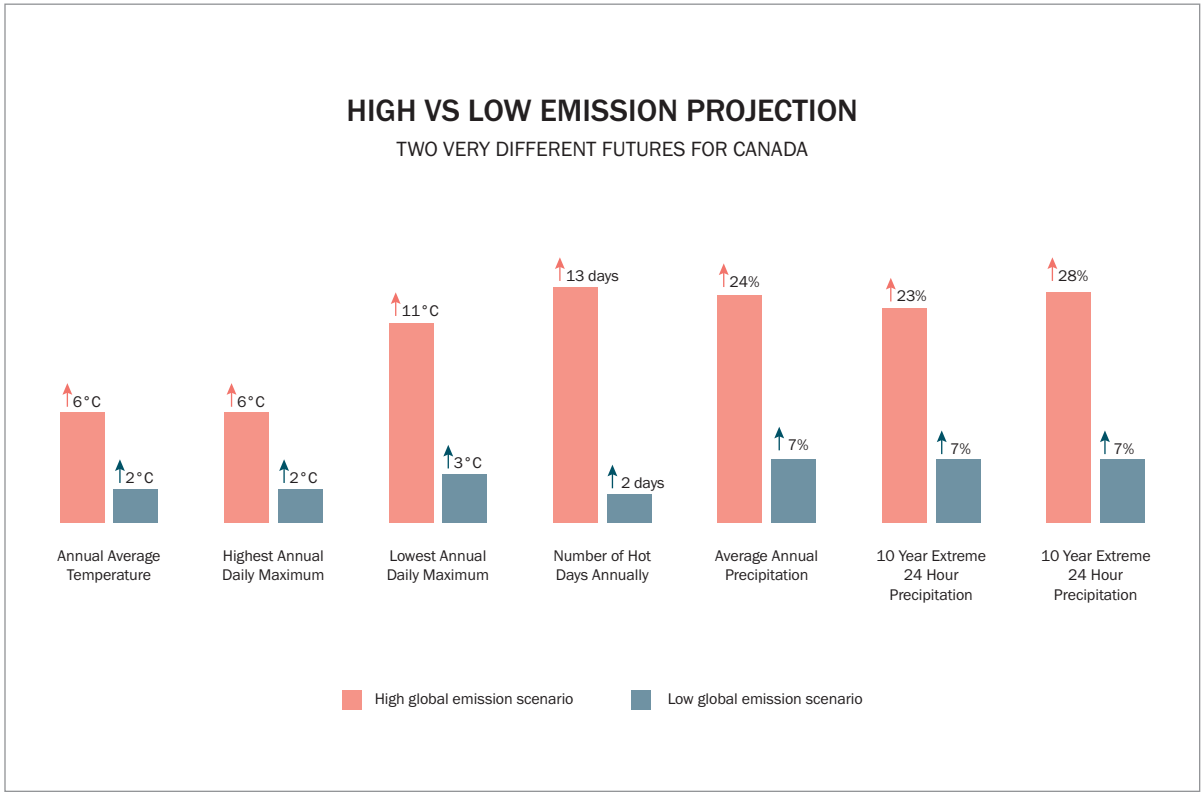
The sheer weight of decisions is overwhelming. As Mercedes Buyers states, "sustainability can mean many things" (2022). Stakeholders in the industry are bombarded with certification programs, green standards, and rating systems (Jackson, 2020). The senior mechanical engineer mentioned that establishing a solid client relationship helps determine their point of view and understand where the client receives their information. This information is invaluable in the project. The measures in clarifying concepts, however, can be time-consuming. It is difficult to pinpoint how and where building owners get their input without spending the time and effort on productive client engagement.

c. Nature of the industry

The building and construction industry is highly fragmented, complex, and primarily self- employed. It is often the slowest to attract talent and is considered one of the most argumentative industries. When construction teams complete a project and then separate to work elsewhere, it makes knowledge sharing difficult. Limited knowledge sharing leads to heavy reliance on sub-contracting, low levels of research and development, and a lack of sector integration within the supply chain, a weakness in the industry (HM Government, 2015b as cited in Dixon et al., 2018).

d. Nature of the climate change

Building-related decisions based on historical weather data have resulted in assets not designed for future climate impacts, let alone the extreme weather events we are experiencing today (Canada, 2018). The predicted heatwaves, shifts in sea levels, sea ice coverage, wind speed, glacial retreat, precipitation levels, and permafrost will affect Canada's climate drastically (Bush & Lemmen, 2019, as cited in Swanson, 2021). Figure 4 illustrates the projected changes in Canada's changing environment and presents two scenarios regarding the anticipated temperature changes.



Adapted from Government of Canada. (2019). Canada's Changing Climate Projected Changes this century. [Infographic]. https:// building.ca/ this-is-a-wake-up-call-swift-action-needed-on-rising-seas-experts-say/

Figure 5. Canada's Projected Climate Changes

e. Split incentives

According to Harvard researchers cited by Chopik (2019), future investors will demand properties in municipalities that prioritize successful infrastructure investments in resilience. According to the Institute of Sustainable Finance's Mobilization for a Canadian Low-Carbon Economy report, there is a common trend of investing in the lowest discount cost projects. This mentality is supported by the common occurrence of low-cost projects in Request for Proposals (RFPs). Due to market volatility, long-term investments are scarce (Dixon et al., 2018). Nonetheless, the decision of asset developers and real estate investment trusts (REITs) to invest in low-cost projects can be counter-productive if it restricts higher-cost but higher long- term potential projects (Canadian Construction Association, 2021). Developers overshadow the value of long-term resilience by choosing bidders based on the lowest cost (Canadian Construction Association, 2021). These decisions create resistance to deploying more sustainable materials and operating systems in the industry—a massive barrier to environmentally sustainable buildings.

f. Education and Training

Toronto is experiencing a trade shortage as more than 1 in 5 workers in the industry will retire in the coming decade (Engineered Design Insider, n.d.). According to a 2019 Toronto Star article, over the next 15 years, there will be approximately 150,000 job openings in the industry (Rushowy). This shortage directly impacts the quality and timing of construction projects

(Jackson, 2020). Sustainability consultant A believes there is a lack of attraction for diverse young thinkers, especially for marginalized groups like BIPOC. As mentioned, the Ontario government is desperate for trade workers, losing billions of dollars in energy efficiency because of the lack of "low-carbon" trade skills (Rushowy).

g. Old paradigms

Neoliberalism supports buying and selling, promotes a hierarchy of winners and losers, and defines citizens as consumers. This ideology punishes inefficiency and rewards merit (Monbiot, 2016).

Having a neoliberal mindset can be a hindrance to sustainable development. Inter-generational and distributional equity is a central principle of sustainable development, yet neoliberalism favours deregulation and austerity policies (Carruthers, 2001). Larry Byron highlights the notion that a trade degree is sometimes seen as somehow-sub-standard degree compared to other post-secondary education degrees. This mindset can deter young people from entering the trades.

Reflection on Interview Data

The array of insights about the reality and future of the building and construction industry reflects the complexity of the research question, "How might we improve the knowledge management for environmentally sustainable design practices in the building sector in Toronto?". Not only was the complexity of the problem emphasized, but the combination of overlapping themes from the diverse insights signaled the importance of speaking with different subject matter experts. The categories that I found most significant included the lack of consistent information and the importance of establishing a solid client relationship, health and wellness, and education and training.

Sustainability consultant B used the metaphor of a giant phonebook to reflect the vast amount of information, particularly the regulations and policies in the industry. If the information is not straightforward and easily digestible than clients can refer to default design decisions that follow the "tried and true approach". Design professionals can see and influence where clients receive their information. Health and wellness within the industry does not fully resonate with the public until the effects are dire and immediate. The ongoing COVID-19 pandemic presents an opportunity to communicate and design strategies to connect building science to human and environmental health.

About half of the interviewees believe post-secondary institutions need to place more emphasis on learning the technical skills with the new technology and innovative design techniques emerging from the industry. These technologies and design techniques can help curb greenhouse gases and assist in making buildings more sustainable. In addition, young professionals need to be able to navigate conversations especially when there might be disagreements or resistance from higher, more experienced workers. New and sustainable ways of designing and completing work can only be implemented properly if there is alignment of goals and information among the work team.

3 Horizons Exercise

After completing the interview questions, I led all ten interviewees through the three horizons exercise. The three horizons exercise is a simple, intuitive way to encourage a conversation about the challenges in the present, our aspirations for the future, and the kinds of innovation we might need to address simultaneously (International Futures Forum). The interview questions helped segue into the exercise because the participants had to visualize the reality and desired future of the industry. The full explanation of how I conducted strategic foresight method can be found in Appendix 2.

I used this specific exercise to explore the following objectives

- The future shape of the building and construction industry
- How the construction industry will need to adapt to address changes to the future environment
- What the response of industry professionals should be to these challenges and opportunities

I created Figure 5 based on each interviewee's insights drawn from the 3 Horizons exercise. I developed a fictional persona for the readers of the report to follow named Roberta Wells, a reliable

construction worker in her mid-20s. I wanted to personify specific conditions for the readers throughout all three horizons. In design thinking, the human element of personas in the defined stage helps designers with the ideation phase of a design challenge (Dam & Siang, 2022). I chose to develop horizons 1 and 3 as scenarios because improving organizational leaders' decision-making capabilities is a deliberate outcome of scenario planning (Schwartz, 1991, as cited in Chermack, 2004).

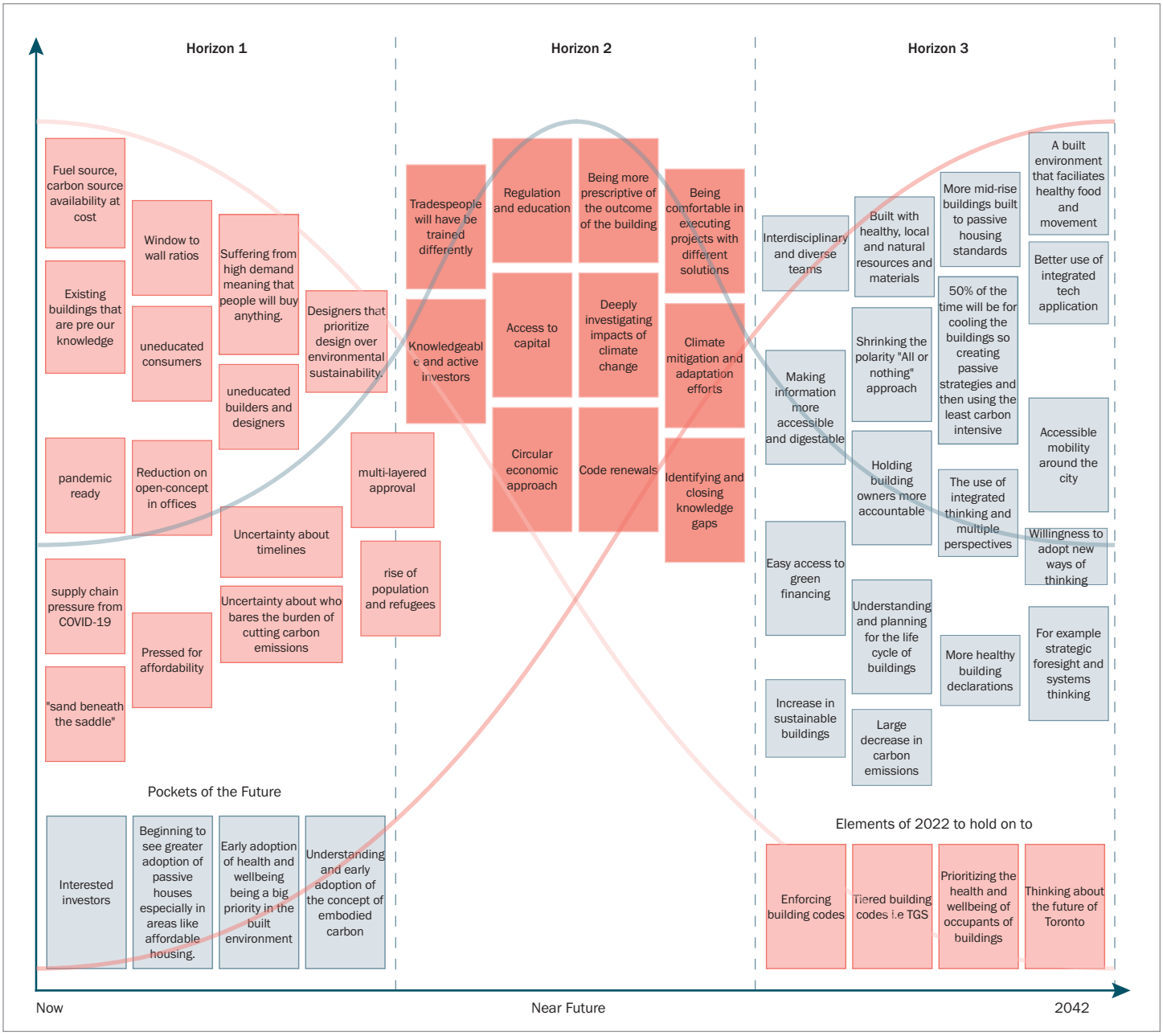


Figure 6. 3 Horizons Exercise.

Horizon 1 – Present Reality 2022

In the present day of 2022, Roberta heads over to the construction site of an up-and-coming office building, where she notices fewer workers than she expected. She is really noticing the lack of tradespeople in her industry. In the evenings, Roberta enjoys home renovation television shows, yet she dislikes the popular notion of sending all discarded waste heads right to the dumpster. This lack of repurposing and recycling the material troubles Roberta as she seeks to enhance sustainability in her field. She understands that the long-term benefits from sustainability investments can be challenging to sell to clients, but she is eager to try.

Today, Roberta has learned that Ontario is amid building code renewal - changing how to develop and use codes. There is a set of national model codes in the code-making system. Canadian provinces can adapt, change, or dismiss them. There are nuances in certain regions. There will be timelines and attached are penalties. Roberta's father, also in the building and construction industry, has explained to her the industry's tension and advocates for sustainability. One group says Ontario is being pressed for affordability and increased building performance. At the same time, the other side acknowledges the cost pressures, uncertainty in timelines, multi-layered approval processes, and suspended chain pressure. Roberta's father suggests she keeps up with current policy changes in the industry.

There are massive juridical pressures, and there is a sizeable affordable housing problem concerning supply and demand. The development community is aware of these pressures and understands improvement is desperately needed yet navigating the road to get there is unclear. The industry cannot quickly bring the collection to the market to meet the demand. The government cannot overlook the importance of sustainable buildings in combining climate change, natural disasters, refugee crises, and the expected population growth.

Yet not all hope is lost, as Roberta sees the pockets of opportunity within today's building and construction industry. These include youth activists, like Greta Thunberg, willing to speak up about climate change, using carbon reduction design methods and government-funded low-carbon emission programs. There is also a greater adoption of passive houses, especially in affordable housing— understanding and early adoption of embodied carbon and recognizing health and well-being in the building.

Horizon 3 – Desired Future 2042

Roberta admires the work she has put into the built environment of Toronto as she strolls around Yonge Street. She enters one of the offices she helped build on her right, where the door has the updated LEED and WELL Building standards. This signage is widespread around the city. Roberta walks around the comfortable ambiance of the ergonomic foyer and spots the numerous vents tied to the well-circulated air ventilation system that took weeks to finalize.

This building, like most, have been equipped with intelligent technology and artificial intelligence ever since the cost of sensors plummeted. These building details are lessons emphasized by the COVID-19 pandemic that occurred decades earlier.

Throughout her career she has worked with numerous and diverse professionals. Her father, a senior project construction manager, mentioned that he has noticed a lot more representation from marginalized groups in comparison to when he started his career. He mentions that having more diverse perspectives has led to more meaningful and better work. This work has been instrumental to where Toronto is today.

Roberta is glad that implementing sustainable design, such as prioritizing the least carbon-intensive methods, has become mainstream though she remembers the pathway to get there was not easy. This prioritization has leveled the playing field in the industry. This popularization results from a whole-of society approach involving regional, national, and international policies; energy management, community engagement, and the integration of Indigenous knowledge and rights (Cox et al., 2021).

In 2042, many professionals and non-professionals have a more significant concern about the carbon footprint buildings have, particularly when it comes to embodied carbon. Embodied carbon relates to carbon emissions during the entire lifecycle of a building from the materials extracted to the

transportation of said materials to building of the structure to the eventual demolition. Professionals and non-professionals understand what it is and the long-term impacts it has. For instance, there is a sense of local value creation by supporting local enterprises, and Canadian brands oppose to the transportation of good to Toronto. Buildings are made with restorative local natural materials built to passive house standards with shared community space linking neighbours and communities.

It is a future-oriented city, with better anticipation regarding the surrounding weather and the safety and health of tomorrow's citizens. A place with better performance housing and infrastructure outcomes for its citizens.

Horizon 2 – The Steps on how to get to Desired Future 2042 from Present Reality 2022

"We cannot solve our problems with the same thinking we used to create them."

Albert Einstein

Roberta knows she cannot do it alone to achieve the desired future state. There is no replacement for commitment. Stakeholders within the industry should know how they can make an impact to support a sustainable building design. Factors that will assist in the shift towards more sustainable buildings include addressing the knowledge gap, circulate green financing and creating changes of coalition and communities of practice. Best design practices and ideas for more sustainable cities should be shared and supported. Other steps Roberta believes in is promoting an integrated system design approach. An integrated, holistic approach where knowledgeable subject matter experts with diverse backgrounds come together, learn, and re-evaluate can lead to faster, more consistent results. Access to funding is likely to go hand in hand with this, so the roles of asset and portfolio managers and investors will be deeply impacted going forward.

By 2040, urbanization in the Americas will grow from 80% to 90% (IBI, 2018). With this prediction on the horizon, preparation for making buildings multi-functional rather than just being seen as a single use of living is imperative. This also requires a shift towards life-centered design rather than simply human-centered design. Life-centered design focuses more on long-term environmental impacts and the health of all living creatures whereas human-centered design focuses more on the health of humanity (Are Your Human-Centered Design Practices Hurting the Environment?, 2019). Roberta sees that sustainable infrastructure will require lots of regulation, education, and participation from all stakeholders within the industry. Today, new buildings are supposed to be audited via building inspectors, yet it is not always a guarantee. Furthermore, enhanced oversight is needed to ensure sustainable goals and investments are achieved.

Regarding education, Roberta has heard mixed views about whether young workers are well equipped for entering the building and construction industry. Some believe that the school training of young workers receives a more innovative idea of the industry than the current reality. Therefore, there can be a discrepancy between current operations and the idealistic industry the students have prepared for.

A main concern is integrating the knowledge new graduate students have in an industry that does not adopt change very well. Drivers perpetuating sustainable buildings include seeking innovative solutions and respecting nature (Farrelly, 2018, as cited in Dixon et al., 2018).

Benefits of 3 Horizons

This exercise is useful when paired with day-to-day decisions regarding the direction of a business, especially when guiding policy, devising strategy, and exploring new markets. It helps companies prepare for the “big picture,” thus avoiding narrow-mindedness. Short-term, conventional empiricist thinking often overshadows strategic foresight (Slaughter, 1997). The 3 Horizons also allows experts to be more reflective while they visualize their opinions of the industry’s present and future state. The next section explores the building and construction industry through system archetypes, a prominent tool used in systems thinking.

Understanding the System

System Archetypes

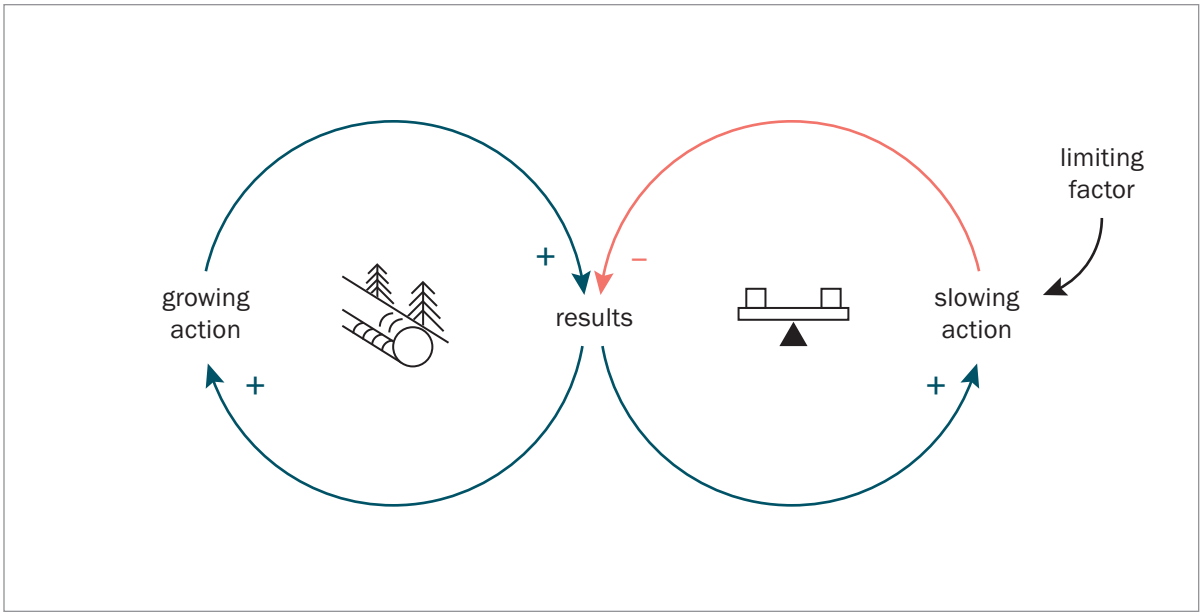
The building and construction industry is an active and open system. This means this industry interacts with other industries and its surrounding environment. From a macro perspective, this industry relates to various sectors such as lumber, steel, furniture, and concrete (Jackson, 2020). Characteristics of an open system include self-organizing, exchanging information with its environment, and increasing complexity over time (Ryan and Hamilton, 2012). Common behaviour patterns within organizations are classified as System Archetypes (Braun, 2002).

Benefits of System archetypes

I used system archetypes, a component of systems thinking, to showcase the critical insights from my primary and secondary research. I paired the system archetypes with causal loop diagrams (CLDs) which visually depict variables and their interactive nature over time (Williams & Hummelbrunner, 2011). The benefit of causal loop diagrams is that they distill complex information into explicit patterns. This improves accessibility for wider audiences. Applying system archetypes to the building and construction industry helped me identify corrective action-specific leverage points. The benefit of identifying System Archetypes is to ensure decision-makers are aware of underlying system behaviour and deeply consider the time factor in their decision-making processes. Because these archetypes are generic, decision-makers must dig deep into the context to identify specific variables causing such archetypes. Below I selected three archetypes that apply to the building and construction industry.

Limits to growth (also referred to as Limits to Success)

The “Limits to Growth” archetype reflects Toronto’s finite spaces for buildings. Continuing to build how Toronto has always built is a wasted opportunity. As mentioned, Toronto’s existing building stock is to double by 2060, with more than half of these buildings scheduled to happen in the next few decades (World Green Building Council, 2019). Toronto will increase its population by 2.9 million, reaching almost 10 million by 2046 (Ontario Ministry of Finance, 2021). The sense of urgency needs to be met with long-term rather than short-term, conventional empiricist thinking.



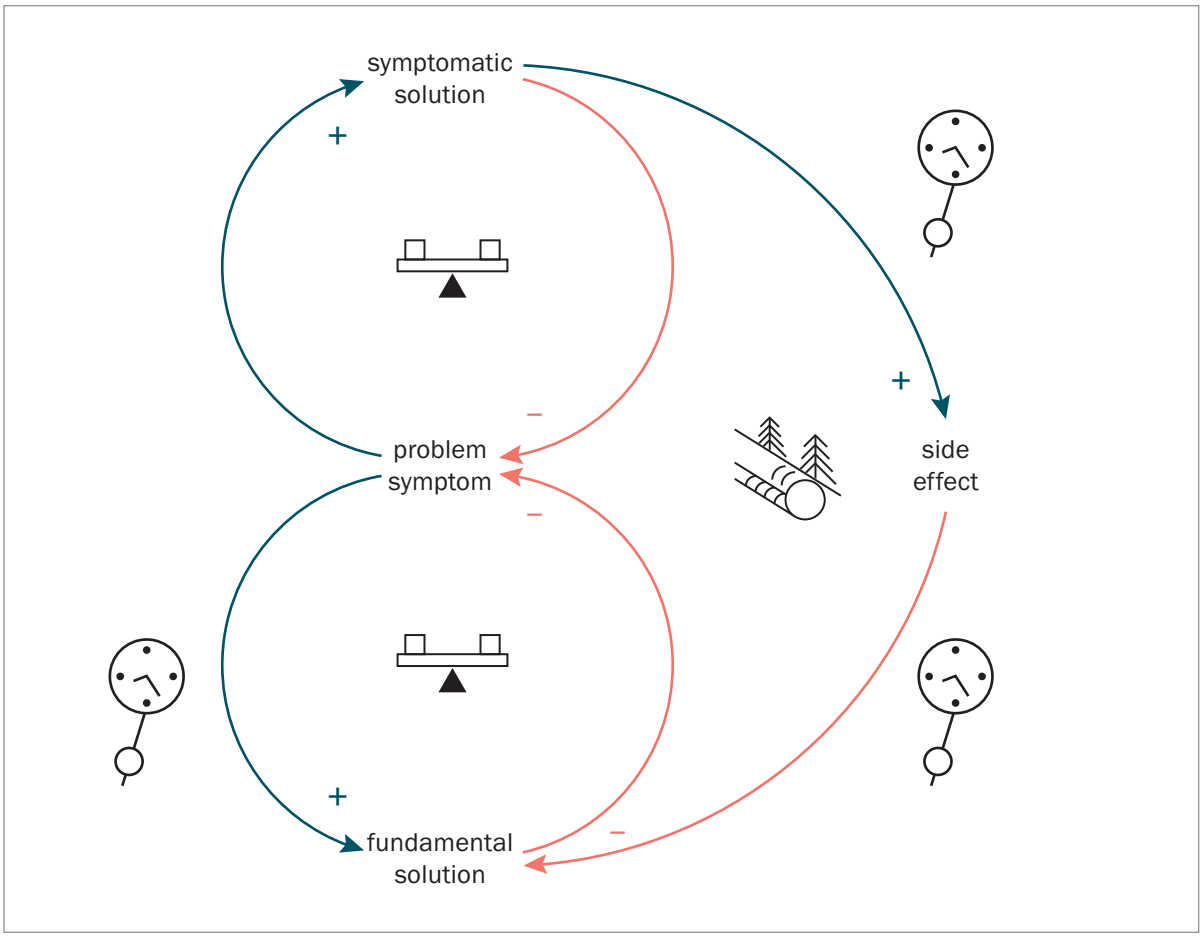
Adapted from Braun, W. (2002). System Archetypes. https://www.albany.edu/faculty/gpr/PAD724/724WebArticles/sys_archetypes.pdf

Figure 7: Limits to Growth archetype

Neglecting climate risks to buildings and the construction industry would be incredibly costly. According to the Intergovernmental Panel on Climate Change (IPCC), the global cost of associated damages is estimated to be $54 and $69 trillion – impacting Canadian homes, economy, and health (Canadian Construction Association, 2021). The escalation from roughly $5 billion per year in 2020 could be between $21 billion and $43 billion per year by the 2050s (Canadian Construction Association, 2021). Developing and retrofitting future-oriented and sustainable buildings can increase community resilience, reduce disaster-related risks, protect natural resources, and enhance livability (Canadian Construction Association, 2021).

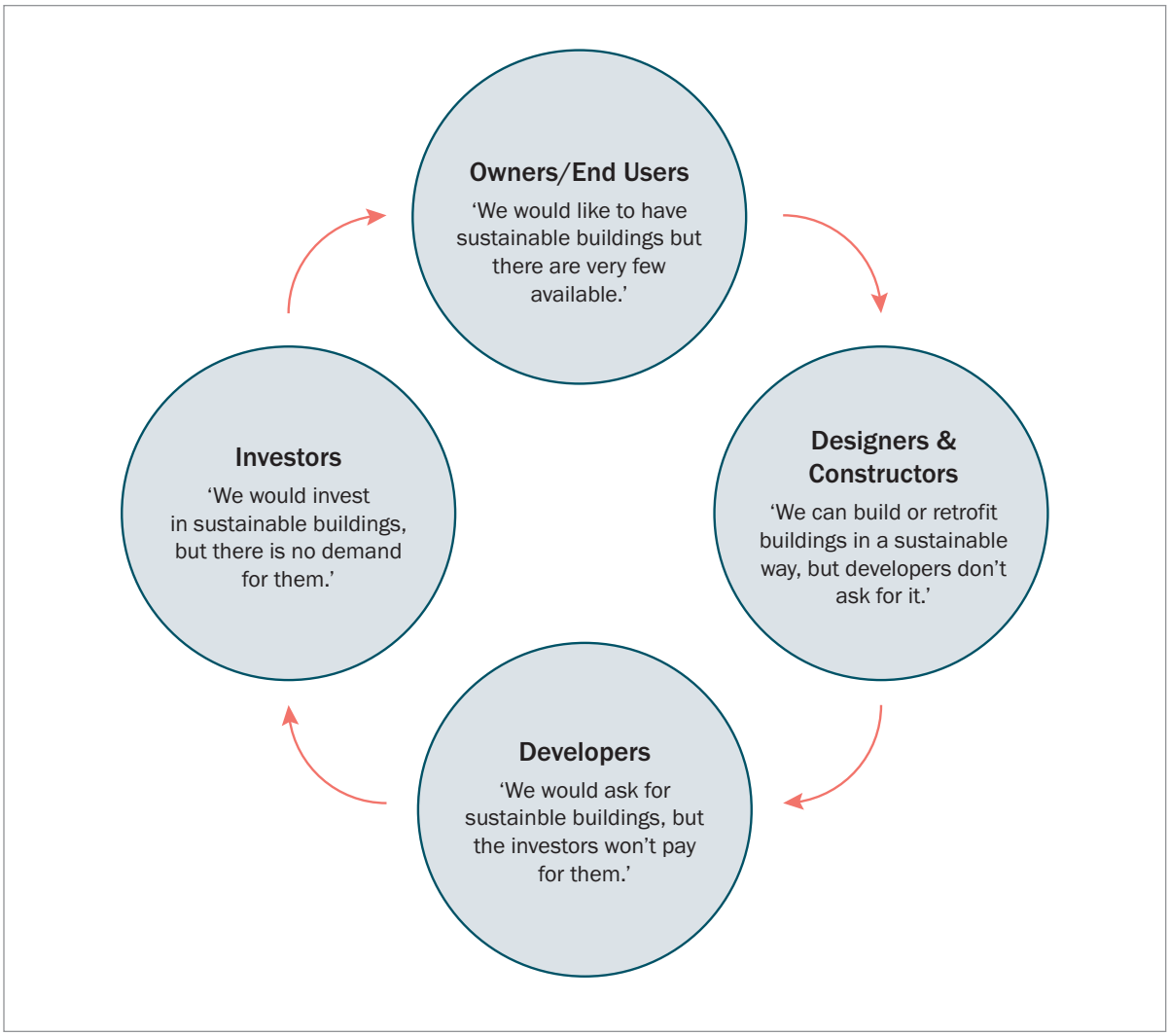
Shifting the burden to the Intervenor

This archetype exists when a short-term solution is repeatedly used, rather than a long-term sustainable strategy, to yield immediate results. However, as this solution is continuously used, the more long-term fundamental solutions are used less and less (Braun, 2002). Over time, the long-term solution becomes obsolete, and there is more dependence on the short-term solution. The industry's Vicious Cycle of Blame (Figure 9) further supports Shifting the burden to the Intervenor archetype.



Adapted from Braun, W. (2002). System Archetypes. https://www.albany.edu/faculty/gpr/PAD724/724WebArticles/sys_archetypes.pdf

Figure 8. Shifting the burden to the Intervenor archetype



Adapted from Cadman, 2000, as cited in Hartenberger, U., & Lorenz, D. 2008, June. Breaking the Vicious Circle of Blame – Making the Business Case for Sustainable Buildings. Findings in Built and Rural Environments. https://www.researchgate.net/publication/263782010_Breaking_the_ Vicious_Circle_of_Blame_-_Making_the_ Business_Case_for_Sustainable_Buildings

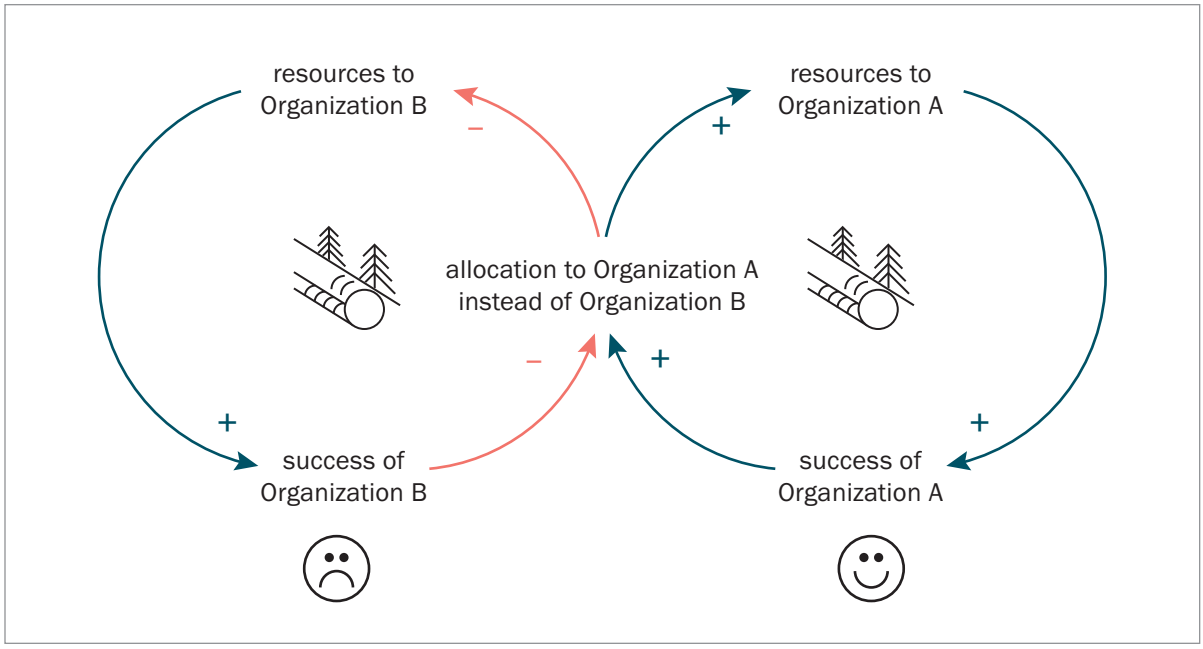
Figure 9. Vicious Cycle of Blame

With so many stakeholders involved in the lifecycle of a building - investors, occupants, labourers, etc., there is ample opportunity to place responsibility on another stakeholder, which is often referred to as the "Vicious Cycle of Blame" (Cadman, 2000, cited in Hartenberger & Lorenz 2008). As mentioned previously, the ambiguous term of sustainability can overwhelm industry professionals. Environmental performance relates to various matters, including pollution, management, energy, water, waste, materials, transport, site ecology, and health (Dixon et al., 2018). Skepticism associated with sustainability can result from lack of sustainability expertise among board members, uncertain financial impact, and the view that boards should prioritize shareholder value through short-termism (Confino, 2015). Therefore, there is a strong tendency to rely on decisions based on what has worked in the past (deMonsabert et al., 2003, as cited in Nelms et al., 2005).

When someone is "to blame," there can be dire consequences to one's professional reputation as, Loosemore (2009) argues that we live in an

increasingly paranoid society. This paranoia and unprecedented scrutiny of management practices often result from white-collar corporate scandals. To mitigate the blame game, Edmondson and Brown (2020) suggest having a sophisticated approach to failure's contexts, such as proper documentation of learnings from failure. This information can be stored and circulated in organizations to ensure these lessons are addressed. This further supports the importance of knowledge management within the building and construction industry.

Success to the Successful



Adapted from Braun, W. (2002). System Archetypes. https://www.albany.edu/faculty/gpr/PAD724/724WebArticles/sys_archetypes.pdf

Figure 10. Success to the Successful archetype

The best quote that really reflects "The Success to the Successful" is "Money goes where money knows" by Anjali Varma. Varma alludes to the fact that often investments support building efforts and strategies that have worked in the past rather than new, innovative strategies. This statement relates to the hardship of designating where funding is received to generate prosperity. Without these professionals like Varma, making more sustainable decision decreases, and past choices, which may not be the most environmentally sustainable option, are made. As mentioned earlier, when funding for new construction is available, the socio-economic status influences where funding is distributed and how quickly buildings will be developed. This factor is tied to access to skillsets, technology, and resource capacity to strengthen climate-resilient infrastructure systems (Swanson et al., 2021).

I created a separate systems section because, as previously mentioned, it is a significant component of the integrated systemic design approach in combination with design thinking. Systems thinking is a unique method of investigating methodic behaviour (Derrick, 2019). The patterns of behaviour observed in the building and construction industry were Limits to Growth, Shifting the burden to the Intervenor, and Success to the Successful. The next step is understanding the conditions that create, balance, and reinforce such behaviour of these system archetypes.

Challenges, Recommendations and Fostering the Transition

“In the past, changing the self and the world were regarded as separate endeavours and viewed in either-or-terms. That is no longer the case.”

Joanna Macy

By practicing systems thinking and referring to the systems map in Figure 3, I recognized multiple challenges such as fixed mindsets, standards, guidelines and policies, and the network of information flows. The challenges I identified in the building and construction industry have helped me recognize leverage points for intervention which I will discuss below.

Leverage points, popularized by Donella Meadows, one of the world's leading researchers on human-environment systems, are places within a complex system where a small force of one element can cause a ripple effect and lead to more extensive changes (Meadows, 1999). MIT professor Jay Forrester, cited by Meadows, states that often people know where the leverage points are, yet they are unwilling to intervene. Adopting a leverage points perspective means one can bring about transformative change when one focuses on points to intervene (Fischer & Riechers, 2019). Transformative change refers to completing tasks differently rather than reducing or increasing what is already being done (Chan, 2019). This is concept ties to the importance of looking at knowledge sharing and circulation.

History shows that relying on only one strategy can lead to high costs (Rosenberg, 2014). Therefore, I created multiple recommendations to improve knowledge circulation within the building and construction industry. I am applying a "human factors" lens to the recommendations. This was a deliberate choice because I found this topic deeply embedded in individual and organizational thinking and decision-making. As a researcher, I find this perspective instrumental in understanding why organizations and professionals operate the way they do and why there could be resistance to change.

The table below highlights the challenges identified through my primary and secondary research, recommendations to follow and the steps in fostering the transition for implementation.

CHALLENGES	RECOMMENDATIONS	FOSTERING THE TRANSITION
Fixed mindsets	• Increase in absorptive capacity through training and knowledge sharing. • Diverse viewpoints and process evaluations	• Knowledge Spreaders
Standards and policies	• Explicit policies and green financing	• Circulating Green Financing and standards
The network of information flows	• Review of organizational learning and knowledge management • Popularizing value engineering • Increasing "floodgates"	• Change Coalitions and Communities of Practice (CoPs)

I established the following design criteria based on primary and secondary research collected.

Design Criteria for Solutions

- Comprehensive
- Accessible
- Measurable

The solutions must be comprehensive, so they are implemented easily by any organization. Accessibility closely aligns with measurability. For instance, precise quantities of greenhouse gas emissions from a particular material will help inform supply chain management decisions, leading to long-term financial savings. This information allows organizations to formally establish their sustainability department – a practice widespread across all economic sectors.

Leverage points within the building and construction industry

1. Fixed mindsets

I found the concept of orthodoxies very much aligned with for this specific leverage point. Orthodoxies are deeply held beliefs that usually become company standards that are often unquestioned or unrecognized (Evans et al., n.d.) Organizations and employees can rely on these standards – ultimately leading to work efficiency. Unfortunately, adverse effects of "how things are done around here" can lead to resistance to change and blind spots for an organization (Evans et al., n.d.) One central belief within the building and construction industry is that perpetuating sustainable development requires immediately switching to electrification and stopping all-natural gas and fossil fuel production. Although this is an end goal, there needs to be a transition period from fossil fuels to low-carbon sources rather than shocking the pre-existing system with this "all or nothing" mindset. In addition, ambiguity makes it much more problematic when it is unclear whether savings will mitigate upfront costs of climate-resilient material and design in the medium to long-term (Canadian Construction Association, 2021).

This factor leads organizations to fall back on short-term thinking, neglecting long-term impacts on environmental and human health. This leads to bounded rationality which occurs when organizational thinking exclusively focuses on "here," "now," and "us" often overlooking the future and external entities. It limits the scope of the investigation and often deters the merit of being open-minded to opportunities elsewhere. Different problem-solving strategies diverge from past work tactics and can face resistance. Often many people find it unsettling when reevaluating their expertise, purpose, and certainty (Williams & Hummelbrunner, 2011) yet it is critical that organizations get out of their own way to be innovative (Walters, 2011).

Making difficult trade-offs to make meaningful progress comes with the territory within the building and construction industry. The effectiveness of such progress is conditional to numerous factors such as timeline, project complexity, and level of risk. Personal perceptions of risk habitually diverge from the objective assessments by subject matter experts. Their behaviour reflects these perceptions (Berry, 2004, as cited in Loosemore, 2009). Loosemore argues that a multi-dimensional approach that identifies and considers social, political, psychological, and cultural decision-making factors is valuable, especially in high-risk situations (2009). Without such a method, blind spots and missed opportunities occur.

Recommendations

A crucial component of innovation capabilities is how well organizations can exploit external knowledge (Cohen & Levinthal, 1990). The recommendations for this challenge are expanding one's absorptive capacity and seeking and empowering diverse viewpoints. Absorptive capacity is generated when firms routinely invest in R&D, technical training, and knowledge sharing throughout the organization. If organizations do not expand their pre-existing knowledge base, they will face challenges because this knowledge base is limited. Organizations should prioritize knowledge documentation, especially when projects are completed, and employees leave the company. Finished projects should review methods used, what worked well and

didn't, and critical learnings that will help with future projects.

Firms that resist acknowledging and have a negative attitude towards innovative ideas from the external environment experience what is known as the not-invented-here (NIH) syndrome (Cohen & Levinthal, 1990). Furthermore, ignoring external expertise and knowledge can make companies less adaptable and lead to missed opportunities. As mentioned above, reevaluating expertise, purpose, and certainty can be unsettling to many within an organization, yet I believe the benefit significantly outweighs the discomfort. Organizations should have designated positions such as process designers and design strategists to assist and achieve desired outcomes through workshops and design research.

Fostering the Transition: Knowledge Spreaders

As mentioned earlier, knowledge management theory and its application are significant due to changes in modern business practices, such as the increased rate of globalization and technological advances (Dalkir, 2005). As shown in Figure 1: Knowledge vs. Power Grid, most internal stakeholders are the most knowledgeable about environmentally sustainable building design tactics. This means that they act as critical change agents in circulating that knowledge.

Closing the knowledge gap helps promote the knowledge economy, a system that capitalizes on applied research and scientific discoveries (Hayes, 2021). Factors that promote the knowledge economy include skilled labour and education, robust communication networks, and institutional systems that incentivize innovation (Hayes, 2021). The intangible assets of intellectual organizations and workers' knowledge have significant value. Roles such as process designers and design strategists can think about reflective questions such as "Is the correct information available at the most appropriate level of a situation" (Williams and Hummelbrunner, 2011). These efforts to streamline sustainable design techniques and increase accountability can help break down the Vicious Cycle of blame (Figure 8).

Coordinating the various project interactions and activities in a construction project is daunting. Often smaller organizations that do not have contract administration (CA) software only rely on traditional paper forms, spreadsheets, and logbooks - quite inadequate in comparison (Jackson, 2020). The CA software helps organize, track, process, and share project information while following security guidelines. Every knowledge gap is an opportunity—applicants where tech-savvy can add additional value to the construction management process.

Construction work often works in silos, yet there are opportunities to focus more on collaboration and diverse thinking during the early stage of design. Opportunities such as using integrated design process (IDP), mentioned by Lee Hodgkinson, and value engineering. Value engineering is a valuable tool to use in the pre-construction stages of building. It occurs when subject matter experts come together to discuss several aspects of the project, such as cost, quality, functionality, sustainability, and aesthetics, to enhance the objectives of the building owner (Jackson, 2020). It is challenging to determine the cost, price, and value without value engineering, especially regarding location and aesthetics. As shown in Appendix 4, using the method of value engineering during the pre-construction phase is extremely rewarding. When there is restructuring in roles and positions, crucial knowledge may be difficult to emulate because helpful employees can take this information, made up of skills, networking contacts, specific functional expertise, and experience, when they leave (Massingham, 2008). Valuable knowledge increases an organization's overall human capital.

Becoming a subject matter expert is not going to happen by accident. It is indisputable that nowadays, innovations are stimulated and created through deliberate combinations of external knowledge and the knowledge resources of a company (Agata, S. & Andrzej, L., 2015). How organizations obtain knowledge, consider it, and utilize it directly impacts their business decisions. Narrow-minded or unitary thinking can lead to stagnation, inhibition of investment, and shortening timelines (McGeorge & Zou, 2013). Unable to invest because one does not

know what to look out for and what to invest in. This limited view can result in closer attention to numerical measures of success, ultimately reducing quality.

2. Standards and policies

Standards and policies can be a challenge because not only is there vast amount of them, but because they can be difficult to understand especially for clients. If the information is not straightforward and easily digestible than clients can refer to default design decisions that follow the "tried and true approach". There is a strong argument that knowledge is now the organization's most valuable resource in today's day and age. A combination of communication, consultation, and involvement in decision-making is critical in eliminating blind spots (Loosemore, 2009). Loosemore argues that comprehensive language must be used rather than "exerting dominance disguised by indecipherable jargon" to achieve thorough decision-making when communicating with stakeholders (2009).

Recommendation

The recommendation for this challenge is enforcing clearer sustainable building standards and more green financing. The reasoning behind such standards and financing needs to be explicitly communicated. As eight sub-subject experts mentioned, building environmental assessment methods allow for clarity in measuring building performance. This opportunity requires a change in the mindset regarding the goals of the building and construction system. As William Braun famously states, "If we do not plan for limits, we plan for failure" (2002). If we are to build, we need to build optimally and sustainably. The depletion of the earth's natural resources – like water and energy - is required in every building process step. Sustainable design strategies will assist in diminishing waste, reducing non-renewable resources, and designing a healthier Toronto.

Fostering the Transition: Circulating Green Financing and Standards

The financial health of this sector will either be a make-or-break factor for the Sustainable Development Goals (Hartenberger, 2015). The Canadian government has made great strides toward a low-carbon economy, especially with the formation of the Sustainable Finance Action Council in the fall of 2020. This entity is responsible for identifying which investments should be classified as sustainable by acting as the liaison between the government and the financial sector (Hamilton et al., 2021). With more green financing available, this can help drive incentive for clients to pursue sustainable design building techniques. Johnathan Hackett, the head of the sustainable financial group at Bank of Montreal, says the rise of sustainability-linked loans can result from actionable banking regulation. Capital distribution assists clients' sustainability goals–ultimately supporting the journey toward a low-carbon economy (Duarte, 2021). For actionable banking regulation to flourish, data regarding carbon emissions must first be recognized and widely understood.

Recipients of sustainability-linked loans and green loans should avoid greenwashing and sustainability washing – terms that depict situations where a project had explicit sustainable goals, but claims were not delivered (Hamilton et al., 2021). These false accusations undermine the investors' confidence and the integrity of the organization responsible for the project. The attitude and values determine the application process. It should be on the city level, yet because of the diversity of Toronto, some areas will be prioritized over others – (relating to capacity, resources, and skill). As I review the stakeholders involved in the industry, the investors, lenders, and the Canadian government hold significant power in implementing this recommendation, identifying sustainable materials, and applying a circular economic approach. Many empirical studies show a strong correlation between substantial environmental certification of buildings and measurable financial rewards (Dixon et al., 2018).

One of interviewees compared the vast amount of information, particularly the regulations and policies in the industry, to a giant phonebook. This is a wakeup call for government officials and sustainability building experts to communicate concise building guideline and jargon for professionals and non-professionals

to understand. On this topic, organizations in the building and construction sector should their workforce understands and recognize the terminology and common concepts involved in sustainable design.

3. The network of the information flows

The nature of learning breaks down into data, information, and knowledge. The changeover of data to information is contextual, whereas the transfer of information to knowledge is based on sensemaking (Williams and Hummelbrunner, 2011). Sensemaking is an action-oriented process of acquisition, reflection, and action (Kolko, n.d.). It is a process people automatically go through when trying to understand their experiences with the surrounding environment. Therefore, it is incorrect to assume that data equals knowledge because it takes different forms and shapes (Williams and Hummelbrunner, 2011). The unique point of view that everyone grows up with is known as the "frame." This frame is biased and difficult to change as it is shaped by accumulating an individual's thoughts and life experiences (Kolko, n.d.).

With the nature of the numerous divisions of labour, stakeholders, and projects on the go, managing information and data effectively is necessary for the building and construction industry to operate correctly. Neil Hutchison, widely known as the father of building science in Canada, points out in his 1973 lecture that [There is a critical relationship between knowledge and predictability. During the early design decisions, there [is] always a requirement for as much relevant or related knowledge as possible] (Bomberg, 2012). I bring attention to Hutchison's statement because it further supports the importance of knowing as much information as possible in the pre-design phase. This statement also supports that the most in-demand skills are not just about staying ahead of the technological curve. Skills related to "leadership, teamwork, communication, productivity, and wellness are critical to every employee's performance" (2022 Workplace Learning Trends Report, 2022). Failure to capture and transfer knowledge leads to wasted activity and poor project performance. Tacit knowledge made of organizational memory, learning contribution, and personal ability (tied to the person rather than the position) is overlooked by organizations. Organizations that often focus more on deliverables like organizational reports and charts (Massingham, 2008).

Recommendation

The recommendation includes reviewing organizational learning and knowledge management, popularizing value engineering and increasing "floodgates" As mentioned earlier in the report, organizations nowadays, including those in the building and construction industry, are susceptible to "corporate amnesia." Corporate amnesia can result from turnover rates, information overload, and improper knowledge distribution (Schneider, 2016). Toronto is currently dealing with a discrepancy as the rate of labour is not sufficient to counter the large rate of retirees. As more of the workforce in the building and construction industry retires, their knowledge and experience leave with them if not appropriately documented and shared. Without regulatory guidance to the industry, there can be too much-antiquated data.

The recommendation includes introducing more floodgates within the building and construction industry. A floodgate is someone who uses their knowledge to make others more independent and better, thus benefiting the organization. In contrast, a gatekeeper of knowledge is someone whose unique talent makes others in the organization very reliant on them (Ahearn, 2019). Floodgates provide training on the "why" and will patiently teach others their embodied knowledge. Benefits include increasing the likelihood of reciprocity and creating an abundance mentality. Language action theory developed by Fernando Flores is a specific way of communication that accelerates project results (Jackson, 2020). Flores mentioned an initial culture focused on "holding people accountable" to a culture of "being accountable." Reliable promising reduces rework, defects, and waste (Jackson, 2020). The use of data and evidence to support long-term infrastructure needs and priorities, providing long-term clarity for industry and the supply chain, is a crucial component. The importance of language for

communicating with stakeholders cannot be understated as research shows respect for all perspectives involved; it needs to be built on a mutual foundation.

Fostering the Transition: Change Coalitions and Communities of practice (CoPs)

This systemic problem deserves a systemic solution, a commitment to multiple diverse perspectives (William & Hummelbrunner). Poor public awareness of climate change leads to a lack of collective action and general support (Leach et al., 2021). There needs to be a broad recognition that the current state of construction buildings is not sustainable and needs to be changed. Creating change coalitions and communities of practice will be steps towards knowledge circulation. A change coalition is an assembly of individuals within an organization who act as social leaders of change initiatives towards a common goal that differs in expertise and perspective (Carpen, 2021). Communities of practice are groups of people with similar knowledge and passion for a common purpose (Wenger & Snyder, 2000).

Change coalitions and communities of practice assist in establishing public awareness, civic engagement, knowledge exchange, and creating momentum for a social movement. With immense knowledge of historical and national systems, Indigenous peoples must be involved in the planning and enacting climate solutions. The likelihood of sustainable plans being approved increases when more community stakeholders and councils are involved, seeing how sustainable building and construction reflects a wide range of community interests (Whitelaw, 2016).

Dixon et al. (2018) state that discussions need to occur outside board rooms and design studios, but rather among and with communities themselves, particularly in the pre-design stage of buildings. New perspectives from a multidisciplinary approach must be prioritized to achieve a sustainable future (Dixon et al., 2018). This is particularly important because of the numerous environmental sustainability decisions buildings can endure, such as upgraded ventilation systems, waste management, and material type. Open critique and refinement are welcomed because knowledge is never static but rather iterated. Reflectiveness is the most significant element of success in planning practice (Faludi, 1978, as cited in Olesen, 2018).

Alignment across all orders of the government is necessary to accelerate sustainable infrastructure. The building and construction industry must be viewed as a tool for economic and environmental reactivation in building a post-COVID-19 economy (Canadian Construction Association, 2021). For successful implementation of these strategies, there needs to be engagement across the industry on multiple levels.

Conclusion

“Unless you consciously include, you will unconsciously exclude”

Stephen Frost

Infrastructure is the backbone of communities and is highly impactful on how citizens work, live, and play. Physical infrastructure is a primary climate change risk area that will likely cause severe damages, losses, and disruptions in Canada in the coming decades (Council of Canadian Academies, 2019). Despite being one of the largest industries and contributors to the global economy, the building and construction industry is slow to innovate. Different design strategies, especially those related to new technology, can be seen as more expensive and riskier in construction, so it is met with resistance by professionals in the industry. This fact, coupled with the slow legislative change, makes the industry stagnant.

Developing and redeveloping future-oriented and sustainable buildings can increase community resilience, reduce disaster-related risks, protect natural resources, and enhance livability (Canadian Construction Association, 2021). Implementing and promoting the value of environmental design strategies can help reduce carbon emissions while enhancing resiliency for future weather-related events. When organizations focus on variables that can be controlled, such as knowledge and risk management, this can ease ambiguity and aid in day-to-day operational strategies. Within the building and construction industry, the pre-design stage of buildings is where decisions regarding environmental design strategies have the highest impact. This crucial period of planning, conceptualizing, researching, and designing is key to promoting and constructing more environmentally sustainable buildings for future generations. Such a transition requires adopting a perspective that prioritizes “prosperity” rather than simply “development” (Moore, 2015, as cited in Dixon et al., 2018).

The frameworks of decision thinking, systems thinking, and strategic foresight helped to support investigating the primary research question, “How might we improve the knowledge management for environmentally sustainable design practices in the building sector in Toronto?”. As my primary and secondary research has shown, the building and construction industry is slow to adopt the latest innovative technologies and moving away from traditional work tactics. Without coordination, proper communication, and collaboration, a project will be slow to complete and not be able to benefit from the most updated technological advances (Jackson, 2020). To incentivize buy-in and support, the monetary and environmental value must be demonstrated is a clear manner and validated. The integration of innovation and new techniques need to be practical, comprehensive and the benefits must be transparent. As the Director of Innovation stated, our memories are short until the next disaster. This lack of urgency and forgetfulness affects momentum towards reflection and improvement.

Further Implications

The most general definition of a sustainable community is one designed to promote and maintain sustainable living (Dixon et al., 2018). Building stock and building design are prominent components of sustainable communities, yet they are intrinsically linked to other factors. Factors such as public mobility, energy and other real estate should work in tandem in addressing sustainable living while reducing greenhouse emissions. These environments must also be resilient enough to address displaced people resulting from emergency natural disasters or social upheaval. Therefore, the learning about emergency management is an actionable step to further develop this research.

Within this report there has been multiple references towards holistic and interdisciplinary approach to problem solving. To achieve such as process, there needs to be a closer review at the voices that are brought into these conversations. This review further associates with issues of diversity, equity, and inclusion in the pre-design planning stage. This foundation of planning will assist to move not only Toronto, but other places towards more sustainable and resilient living areas faster.

“Climate change is the single biggest thing that humans have ever done on this planet. The one thing that needs to be bigger is our movement to stop it.”

Bill McKibben

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Appendix

Appendix 1: Condensed Timeline of the Evolution of the Building and Construction Industry

The 1910s	• Establishment of Canadian Standards Association CSA Group
	• Canada's federal health department was created when Toronto closed from the deadly Spanish Flu.
The 1940s	• After WW2, there was a strong desire for new infrastructure. New building techniques and building codes and standards were established.
The 1980s	• The UN Sendai Framework for Disaster Risk Reduction and its call to "Build Back Better."
The 1990s	• The Environmental Protection Act 1990 Canada Urban institute was established in 1990. • BREEAM (Building Research Establishment Environmental Assessment Method) is established in 1990. • The Building Code Act of 1992 • BEEs (Building for Environmental and Economic Sustainability) launched in 1997. It allows designers, builders, product manufacturers, and consumers to select cost- effective, environmentally preferable building products based on consensus standards.
The 2000s	• Professions within the industry is dictated mainly by pen and paper on job sites. In the late 2000s, the age of connectivity began to form (real time-data and wifi). Toronto's Climate Change, Clean Air and Sustainable Energy Action Plan 2007 Climate Change Adaptation Strategy 2008
The 2010s	• In 2011, the National Round Table on Environment and Economy (NRTEE) stated that the economic impact will span between $21 billion and $43 billion by 2050. Preparing for Extreme Weather Events 2013 • Preparing for a Changing Climate 2014 New Building Canada Fund (NBCF) 2014 TransformTo 2015 • Pan-Canadian Framework on Clean Growth and Climate Change 2016 Paris Agreement 2016 • Canada Infrastructure Bank was created in 2017 Disaster Mitigation and Adaptation Fund (DMAF) 2018 • Mass production of tablets helped to innovate and automate field operations. This eventually led to (BIM), virtual design and construction (VDC), drone technology, laser scanning, GPS tracking, robotics, modular construction, and IoT, to name some significant players (Crosby, 2020) • Current technological advancements in the industry include building Building Information Modelling (BIM) and Geographic Information systems (GIS). innovative smart urban management applications and BIM for automated code compliance (Shahi, 2018, p. ii.) • Lately, the industry has been striving toward solutions for expediting and streamlining the manual and labour-intensive construction permitting processes. Efforts include using a centralized document management platform to replace the paper-based permitting system (Fiatech, 2008 as cited in Shahi, 2018, p.1)

	• Complex processing practices, policies, and regulations have been imposed, causing delays, and construction software providers have noticed. Project management tools like Procore, PlanGrid, and Fieldwire have emerged to meet demand as teams ditch paper and rely more on apps to tackle issues on site.
The 2020s	• On March 11th, the Coronavirus (2020) is declared a pandemic. Work from home mandate except for essential workers. • The Government of Canada made a good start when it launched on September 28th Disaster Mitigation and Adaptation Fund. • Canada's first-ever National Infrastructure Assessment. • Over the last decade, Canada has made tremendous progress in climate adaptation, from research to public engagement and actions toward climate change reduction (Green Analytics Corp, 2020)
	• Version 4 of the Toronto Green Standard (TGS) was approved by Council on July 15th, 2022. • Beginning May 1st, 2022, all new development applications must comply with Version 4

Appendix 2: Interview Questions and 3 Horizons Exercise

Background

Question 1: Tell me a bit about your background and why you chose to work in this industry?

Question 2: Tell me about your current role and decision-making (prompts include, do you have processes, are they mainly group decisions)?

Question 3: How do you stay up to date with the latest trends in the industry? Can you give me a sense of what those trends are?

Question 4: Which trends do you believe will drastically shape the industry in the next decade?

Question 5: What current trends do you believe the industry is addressing well? (Why or why not?)

Question 6: How does your company address decarbonization methods?

Question 7: How do you measure success concerning environmental sustainability?

Question 8: What barriers do you believe stall environmental sustainability in the building sector in Toronto?

Question 9: Do you believe the education system provides labourers with the right skills for entering this industry?

Thank you, now we will do a quick Futures exercise called the 3 Horizons Exercise.

The 3 Horizons framework is used to visualize something over time and is broken down into three segments, one for each of the three horizons.

1. The first horizon involves mapping the current state of the system you are exploring.
2. The third horizon is the preferred future (2042)
3. In the transitional stage, the second horizon is the intermediate steps that will help you get from the current state (H1) to the desired future state (H3).

To get started we are going to start at H1 by identifying the challenges with today's system. If you're having trouble coming up with ideas, some questions to keep in mind are:

- What do I already know about this topic? What's happening now?

This horizon is your ideal vision of the future. Here, you're going to ask **How could tomorrow's system be ...** vibrant, thriving, and resilient?

Next, ask, **"What evidence of the future want we can be seen today?"** What pockets of the future already exist in the present?

This is where you add examples of change already in practice.

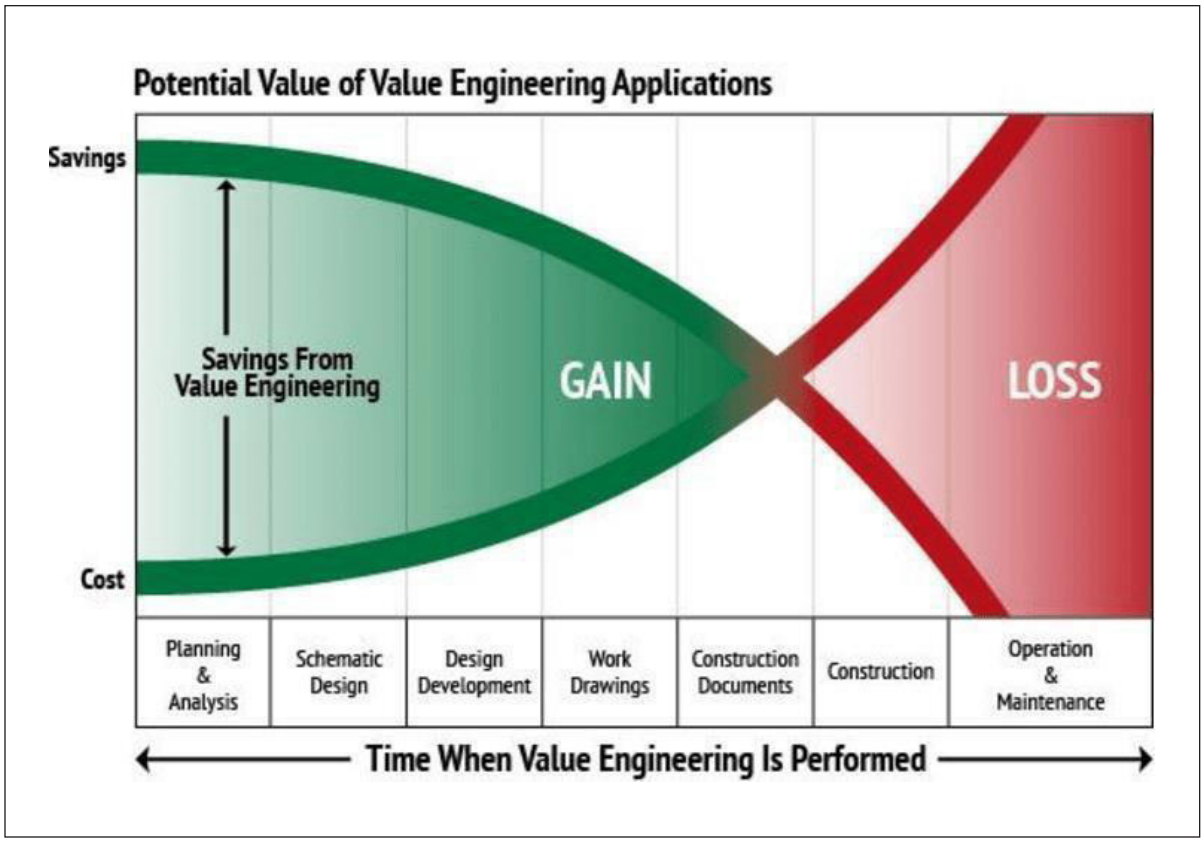
We can move to H2, where you'll map pathways to change. We've already mapped out where we are and want to be. In H2, we ask, "**How can we get there?** Emerging practices we want to foster and grow from the present through the second horizon go under the blue line.

Now, we can go back to H3 and ask, **"What elements of the present (H1) and transition (H2) do we want to keep in the future?"**

Closing

Question 10: Is there anything else you would like me to know, or do you have any final thoughts on this topic?

Appendix 3: Potential Value of Value Engineering Applications



Dashti Latif, S. (2020). *Potential savings from value engineering application.* [Graph]. Research Gate. https://www.researchgate.net/publication/345849713_Implementation_of_Value_Engineering_in_Optimizing_Project_Cost_for_Sustainable_Energy_Infrastructure_Asset_Development/figures?lo=1&utm_source=google&utm_medium=organic