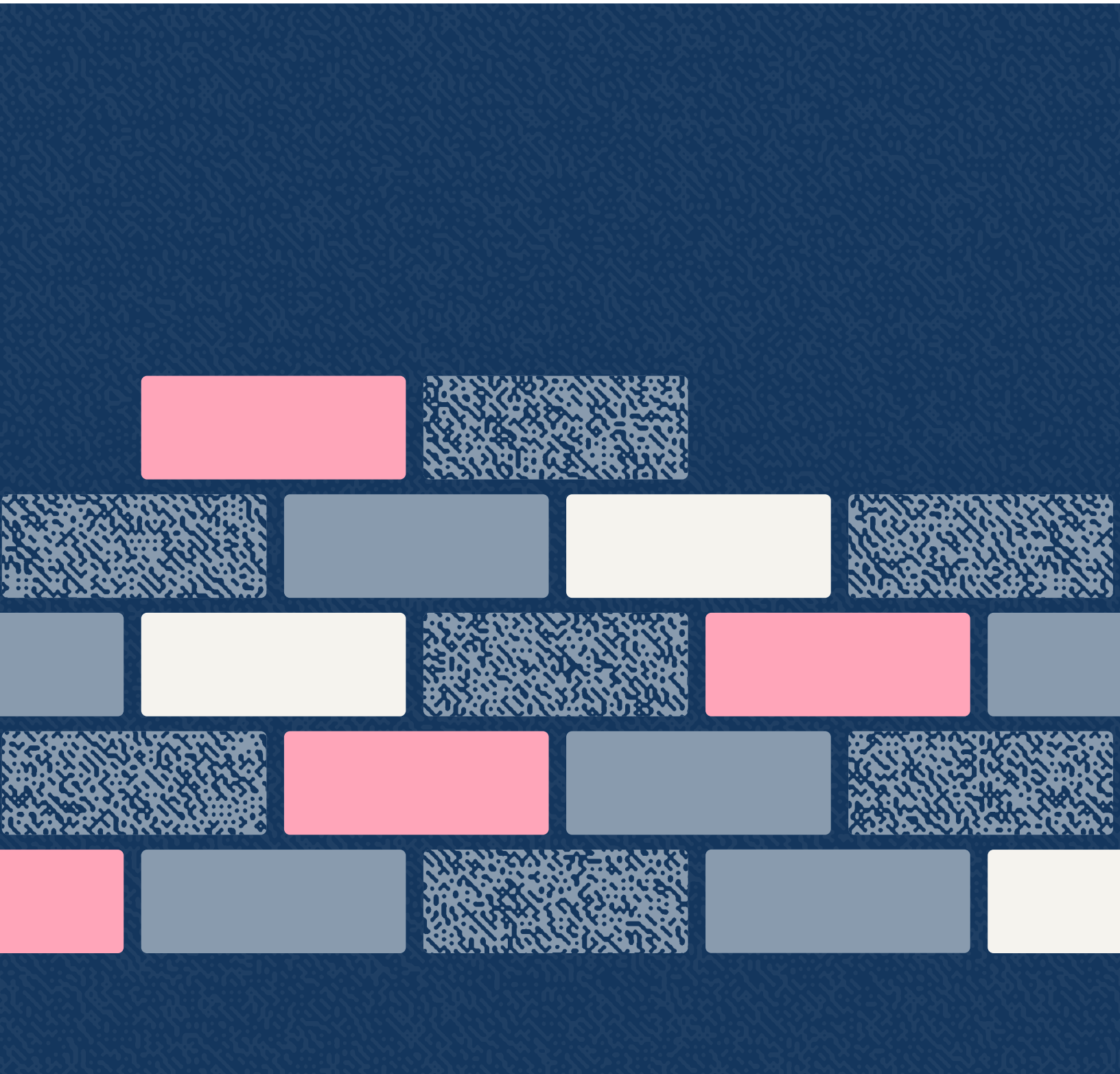
Laying Foundations

TECHNOLOGICAL MATURITY IN CANADA'S CONSTRUCTION SECTOR

brookfield institute
for innovation + entrepreneurship

MARCH 2022

JOSHUA ZACHARIAH
DR. THOMAS GOLDSMITH



Authors

JOSHUA ZACHARIAH

Joshua is an Economist at the Brookfield Institute for Innovation + Entrepreneurship. His main research interests include understanding how the gains from the innovation economy can be broadly shared across social classes and minority groups. He is also interested in social networks in entrepreneurship, access to credit among disadvantaged groups and alternative business models. Joshua holds a Masters in Economics from the University of British Columbia and a Bachelor of Arts in Economics at the University of Guelph.

DR. THOMAS GOLDSMITH

Dr. Thomas Goldsmith is the Director, Innovation Policy for Mitacs, a national, not-for-profit research and training organization dedicated to advancing collaborations between industry, academia and government in Canada, and to fostering international research networks between Canadian universities and the world. Tom previously led his own innovation-focused consultancy, helping organizations understand public policy, and create coalitions and partnerships to help build an inclusive innovation economy in Canada. He has worked in a number of policy teams in Canada in the UK, including serving as Policy Director, Innovation and Technology for the Toronto Region Board of Trade, leading the digital trade policy workstream for techUK, the UK's largest technology business association, and was as a policy adviser for the Royal Society, the UK's national academy of sciences. Tom holds a Ph.D. in History from the University of East Anglia.

Ryerson University

brookfield institute
for innovation + entrepreneurship

The Brookfield Institute for Innovation + Entrepreneurship (BII+E) is an independent and nonpartisan policy institute, housed within Ryerson University. We work to transform bold ideas into real-world solutions designed to help Canada navigate the complex forces and astounding possibilities of the innovation economy. We envision a future that is prosperous, resilient, and equitable.

For more information, visit brookfieldinstitute.ca

20 Dundas St. W, Suite 921,
Toronto, ON M5G 2C2

/BrookfieldIIE

@BrookfieldIIE

The Brookfield Institute for Innovation + Entrepreneurship

Acknowledgements

BROOKFIELD INSTITUTE FOR INNOVATION + ENTREPRENEURSHIP TEAM

Erin Ellis, Manager, Strategic Partnerships

Nina Rafeek, Marketing + Communications Specialist

With special thanks to graphic designer Lindsay Smail, copyeditor Suzanne Bowness, and UBIQUS for their translation services.

Thank you to the following for reviewing this report and providing invaluable feedback.

Markku Allison, Vice President, Strategy + Innovation, Chandos Construction

Mikele Brack, President + Founder, Urban Living Futures Inc.

Raly Chakarova, Executive Director, BOLT Charitable Foundation

Thank you to the project's interviewees for offering their expertise. We are grateful for the valuable discussions on technology adoption and for their strategic advice on this paper.

Laying Foundations: Technological Maturity in Canada's Construction Sector is funded by the Government of Canada's Future Skills Centre.

Table of Contents

Foreword from the Future Skills Centre

NEW TECHNOLOGIES IN the workplace are becoming ever more commonplace across industries and sectors of Canada's economy. Organizations are incorporating digital technologies that can lead to new and improved approaches to day-to-day operations, productivity measurement, and even how they train their employees.

While the Canadian construction industry, specifically, has made efforts to expand their digital capabilities and increase technological integrations over the last few decades, it lags behind other major industries in its overall adoption of and cultural attitudes towards new technology in the workplace. For example, building information modeling (BIM) technology, which provides architects with 3D renditions of their building designs, has proven to be a breakthrough in construction that has increased efficiency. Yet, challenges persist preventing greater technological maturity to keep up with emerging trends in the future of work. This could be due to a myriad of reasons including an organization's leadership structure undervaluing the benefits of innovation or being risk-averse to change because of fears of running costs or timelines over budget.

This report, "Laying foundations: Technological maturity in Canada's construction sector", examines the critical issues impacting Canada's construction trade and technological development.

Led by the team at Brookfield Institute for Innovation and Entrepreneurship, and supported by the Future Skills Centre (FSC), this report draws upon interview responses and surveys from fourteen industry leaders, and aims to improve the understanding of the factors contributing to the low uptick of technological innovation in the construction sector. Furthermore, this report points to policy solutions that may help address current barriers and boost technology adoption.

At FSC, we are dedicated to helping Canadians gain the skills they need to thrive in a changing labour market. We are constantly looking ahead, gaining and sharing insights into the world of work of today and the future. Based on these insights, and with our partners, we test and measure innovative approaches to skills development and training to learn what works.

Please join us as we reflect on the evidence and next steps needed to support the Canadian construction sector succeed and adapt to change in the years to come.

TRICIA WILLIAMS, Director,
Research, Evaluation and Knowledge Mobilization,
Future Skills Centre

Interviewees

FOR THIS REPORT, we interviewed fourteen individuals from eleven different firms that we classified into three categories.

DEVELOPERS AND CONTRACTORS

Markku Allison and Vincent Plourd from Chandos Construction

Markku has over 35 years of experience both as an award-winning designer and as a thought-leader on design and construction industry transformation issues. His background as a practice owner and industry subject-matter expert with strong relationships across disciplines and organizations uniquely positions him to assist in shaping responsive strategies to drive change in business and culture today. In his current role, Markku heads up Chandos Construction's innovation initiatives.

Markku is a past president of the Integrated Project Delivery Alliance (www.ipda.ca) in Canada, which published "Integrated Project Delivery: An Action Guide for Leaders" (Markku was a co-author) as well as several influential IPD research studies, and provides IPD training for industry. Markku also held positions at the American Institute of Architects, where he was instrumental in developing the AIA's "Integrated Project Delivery: A Guide," in 2007.

Vincent possesses over 15 years of experience in the Building Information Modelling (BIM) field. He passionately provides support to project teams and paves the way for digital adoption in the construction industry in his role as Chandos Construction's Director, VDC. Since joining Chandos in 2016, Vincent has led the national VDC Team and has been instrumental in implementing the BIM process on most of the company's projects while pushing the limits of what BIM can do for a general contractor.

Chandos Construction is a B Corp certified, purpose-driven national technical builder in Canada, with focuses on IPD, net zero, and social procurement. Chandos employs over 500 field and office staff working from offices in Vancouver, Calgary, Edmonton, Red Deer, Kelowna, and Toronto. Proud to be 100 percent employee-owned, Chandos is the largest B-Corp certified contractor in North America.

Neil Vohrah and Kate Murray from TAS

As Chief Operating Officer, Neil is accountable for the execution and delivery of projects within TAS's portfolio, which covers planning and design, development, construction, and revenue generation. Neil also ensures that impact objectives are met on each project, while maintaining the required return for investors and partners.

As director of Impact, Kate is responsible for leading and coordinating #TeamTAS in its collaborative efforts to advance and achieve the objectives set out in its Impact Framework. These include work on the Breakeven Goals as a Future-Fit pioneer, and advancing efforts on affordability, equity, climate change, and building social capital.

TAS is an unconventional impact company that promotes connected neighbourhoods and caring, committed communities. TAS has a total of six million square feet of residential and commercial space in their active development pipeline and portfolio.

Graeme Armster from Tridel

Graeme Armster is the director of Innovation and Sustainability at Tridel and leads the team in developing and implementing new products and processes across the company's portfolio.

Tridel is a multi-unit residential building developer supporting a sustainable future for Toronto. Tridel has more than 85 years of home-building experience in the city, with 87,000 homes built. Tridel is a 12-time recipient of the Building Industry and Land Development's Green Builder of the Year

award. Tridel also has over 15-million square feet of LEED® Silver, Gold or Platinum certified and candidate buildings. Tridel's homes are built with a commitment to sustainable building practices. Tridel continues to lead the industry in innovation, technology, and design.

DIGITAL TECHNOLOGY PROVIDERS

Daniel Gottfried from Highrise AI
Daniel Gottfried is a Next-GENeration technology founder with a passion to lead high-performance teams. He has experience growing early-stage emerging technology companies in augmented reality/virtual reality, crowdfunding, payment and mobile, both in the U.S. and Canada. Daniel is a co-founder of Highrise AI.

Highrise AI is a software company centralizing autonomous interactions between Internet of Things (IoT) devices and cross-departmental business functions. Highrise AI software acts as a unified broker between siloed technologies, coordinating pre-defined interactions between them.

Julie Scarcella from EcoSpex Inc.
Julie has over three decades of experience in the green building industry, including building science, technical consulting, and project management, both in Canada and internationally. She is a proven leader in providing environmental, social, and economic solutions, and a key contributor to some of Canada's advanced innovative initiatives. Julie is passionate about knowledge in sustainability that drives new innovative ideas to market and is currently working on her B Corp certification. Julie is the co-founder of EcoSpex Inc.

EcoSpex is a collaborative, online, business-to-business, software as a service (SAAS) platform that delivers access to trusted, verified low-carbon, climate, water and clean-tech technologies to architects, engineers, contractors, and sustainability professionals. It is the first online SAAS platform that gives those in the commercial building sector the ability to access, share, store, and compare verified climate, water, low carbon and clean-tech technologies. EcoSpex uses automation to reduce the time in finding technologies by up to 90 percent, significantly reducing costs.

Kasia Borowska from DAISY AI
Kasia Borowska is a director at DAISY AI. She is also the co-founder and managing director at Brainpool AI, a worldwide network of 500 artificial intelligence experts. With degrees in mathematics and cognitive science, as well as corporate experience, Kasia understands how important it is to connect the two worlds.

DAISY (Design AI SYstems) is the first fully automated timber design software powered by artificial intelligence. DAISY is able to find the optimal residential floor design automatically in under 10 minutes by applying genetic programming, leading to higher efficiency, reduced construction costs, and less timber waste.

Kathleen Kewley from Esri
Kathleen Kewley is the director for AEC global business development at Esri. Kathleen has over 20 years of professional experience working with executive leadership in global engineering, architecture, consulting, and construction firms. With a unique combination of industry and GIS skills, Kathleen leads a team that supports the Architecture, Electronics and Construction (AEC) industry's digital transformation and leverages GIS to unlock the business value of the digital twins of natural and built environments.

Esri is the global market leader in GIS software, location intelligence, and mapping technology. With its pioneering commitment to geospatial information technology, Esri engineers the most innovative solutions for digital transformation, the Internet of Things, and advanced analytics.

PHYSICAL TECHNOLOGY PROVIDERS

Bolis Ibrahim from Argentum Electronics
Bolis Ibrahim has an electrical engineering and project management background in the electronics manufacturing and electrical contracting industries. Bolis is passionate about

the rise of intelligent buildings that use direct current (DC) power distribution, advanced sensors, and intelligent automation to drastically reduce energy consumption. He is the co-founder and CEO of Argentum Electronics Inc.

Argentum aims to reduce energy consumption on LED lighting and HVAC systems by up to 40 percent through a mix of patented high-efficiency DC power distribution systems and self-optimizing building automation algorithms. Argentum deploys a mix of high and low voltage DC transmission systems, wireless sensor networks, and digital twin software to lower project capital costs and system operating costs.

Emelie Reis from Mitrex
Emelie is a member of the business development team at Mitrex where she delivers communications strategies to create company awareness on a global scale. She is a young professional who is passionate about sustainable energy and combating climate change.

Mitrex is a developer and manufacturer of integrated solar technology, such as solar cladding, windows, railings, and more. Mitrex products meet the construction and design needs of builders, architects, engineers, and developers by making multi-purpose, aesthetically pleasing building-integrated photovoltaics (BIPV) that extend a structure's energy-generating potential down to the vertical walls.

Monty Chong-Walden from Calmura Natural Walls
Monty Chong-Walden has been in sustainability and has introduced novel products to the building industry for over 25 years. Under his leadership, Calmura Natural Walls became a regional winner in the 2021 Cleantech Open. The company also achieved a Deep Tech Pioneer recognition by Hello Tomorrow and has received over $350,000 in funding and support for innovation. Monty Chong-Walden is the CEO and co-founder of Calmura Natural Walls.

Calmura Natural Walls is a Canadian social venture and has developed a patented monolithic bio-composite (aka adobe, cob or hempcrete) wall system that provides healthy, durable and comprehensively protective shells to homes and buildings. The wall system protects from fire, pests, mold and thermal variations, giving visionary homeowners a fully comfortable and safe home for generations.

Natalie Giglio and Ryan Bourns from Carbon Upcycling Technologies
With a Bachelor of Commerce degree from the University of Guelph and a second degree in Sustainable Energy Development from the University of Calgary, Ryan has the skills and awareness to help shape both the near and long term development strategy at Carbon Upcycling Technologies. Today, Ryan's primary focus is evaluating project opportunities, which involves direct client-facing work and coordination of the material evaluation program.

With a Bachelor of Commerce degree from the University of Calgary, Natalie adds much-needed capacity to the business development and strategy efforts within the team. Today, Natalie is responsible for the company's safety program, operation logistics, content creation, and business development outreach and support.

Carbon Upcycling Technologies is a world-leading carbon utilization company that has developed a patented technology that can use low-purity CO_2 and low-reactivity feedstocks to create high-performance, low-carbon cement replacements. Carbon Upcycling has tested and verified over 40 feedstocks from around the world, and continuously demonstrates strength and durability improvements of concrete by upwards of 20 percent—ultimately resulting in concrete that has a 30 percent lower carbon footprint. Carbon Upcycling is based in Calgary, Alberta and will be expanding across North America and Europe in 2022.

Executive Summary

WHETHER CANADA'S ECONOMY can thrive in a post-pandemic world will largely be a reflection of the health and competitiveness of its largest business sectors. The construction industry stands out as a huge contributor to GDP, but also a sector that is particularly slow to adopt and use new technologies, which impedes productivity. The competitiveness of Canada's construction sector is central to a large number of challenges such as housing affordability, infrastructure build-out, and climate resiliency.

The competitiveness of Canada's construction sector is central to a large number of challenges such as housing affordability, infrastructure build-out, and climate resiliency.

In *Picking up Speed*, the Brookfield Institute's recent report on digital maturity across firms in Canada, we analyzed data from the Canadian Survey on Business Conditions (CSBC) which identified some critical sectors that stand out as laggards in technology adoption, with the construction sector among them. For example, seven percent of businesses in construction had adopted software or databases for purposes other than telework or online sales. This is a fraction of the adoption rate when compared to front-runners such as wholesale trade, professional and technical services, and informational and cultural industries, which had adopted new software and databases at 24,19, and 15 percent of firms respectively. Similarly, only three percent of construction businesses said they had automated certain tasks, compared to finance and insurance at 13 percent, agriculture and forestry at 12 percent, and information and cultural industries at 11 percent.

Low technical maturity is having a detrimental effect on both labour and capital productivity in comparison to the overall economy, which is hurting international competitiveness. Between 2015 and 2019, labour productivity in the construction sector dropped 2.2 percent below the economy standard to 11.2 percent, while capital productivity hovered between 0.7 percent and 3.9 percent below the standard throughout the period.

In an effort to understand low technological maturity in the construction sector and point to policy solutions that might address it, this report draws upon interview responses from fourteen experts from the sector as well as companies that innovate specifically for the sector.

THE LAY OF THE LAND: Characteristics of the Construction Industry that Impact Technology Adoption

Risk is central to the structural challenges that the construction industry faces when trying to increase its technological maturity, which comes from three main sources:

1. Physical Mishap

From structural collapse that endangers lives, to smaller, but still costly, problems like lost materials, breakages, and other mistakes that require redoing work, these risks create an aversion to implementing new technologies.

2. Long timelines

Large commercial and residential projects take years to complete, and innovation, whether process or technological, begins with trying something new, monitoring the effect, learning lessons, and modifying. Long timelines that are due to these complexities, directly contribute to the significant costs of projects, and, in turn, to the difficulty in increasing technological maturity at a firm level.

3. A highly competitive environment

Fierce competition and thin profit margins contribute to a lack of coordination and information-sharing across the industry.

Such a large number of competing firms also contributes to some firms isolating themselves to preserve their competitive advantages.

BREAKING GROUND: Factors Contributing to Technological Maturity

While technological maturity in the construction industry is low, responses from our sample of interviewees reveal there is at least a keen awareness of this situation, with steps being taken to address it. Of the construction companies that were interviewed, all were in the process of improving their technological maturity, and some have advanced quite far. Below are some of the steps taken by the firms that are successful in moving forward.

1. Careful planning

Moving forward in that technological maturity journey requires careful planning, being cognizant of what is actually needed, and being flexible. A technology roadmap moves forward by nurturing innovation skills and instincts in individual teams building their own “guiding inspirations” about how they would like their work to integrate with technology, and what solutions they need.

2. Forward thinking leadership and flexible culture

Simply adopting a new technology is a necessary but not sufficient condition for reaching technological maturity. A culture that enables the successful integration and deployment of technology is equally essential. Research from BDC that explored the concept of digital maturity identified five key factors that are necessary to foster a technologically mature culture:

- A strong digital strategy and vision
- Support from leaders
- Appropriate planning
- An environment that rewards risk taking and collaboration
- A focus on training and continuous learning[1]

Not only are these features necessary for technological maturity, but in the construction industry they are also necessary for overcoming the risks described above to adopt in the first place. The construction firms that are successful in adopting new technologies are those that have the necessary culture and leadership.

3. Industry-wide solutions

While new technologies often create risk, they also lower it. For example, better sensors can detect water damage, quickly lowering the risk of that particular physical mishap. This is increasingly recognized by the industry in general, and especially insurance firms, a few of which have built technology review panels and discussion forums to work on the problem. A major hurdle is the competitive nature of the construction industry and the siloing of information. One solution being pursued is a strategy called integrated project delivery (IPD), where instead of keeping stakeholders siloed there is a single agreement to design and deliver projects together.

BUILDING TO NEW HEIGHTS: What More Can Be Done to Boost Technology Adoption

While this report has not presented a comprehensive examination of the different levers that could be deployed to increase technological maturity in Canada's construction sector, there are nevertheless a few key actions that have been identified by our interviewees as next steps towards this goal:

1. Draw on international best practice

In the effort to build policy that addresses digital maturity in construction, a good first step for policymakers may be to look internationally. A notable example is the Centre for Digital Built Britain in the United Kingdom. In partnership with the government, the Centre educates the industry on how the construction and infrastructure sectors could use a digital approach to better design, build, operate, and integrate the built environment.[2] Building Research Establishment (BRE), also in the UK, is designed to inspire and showcase the latest in technologies to support age-in-place, sustainable materials, and low-carbon technologies, enabling the industry and government to fast track to a net-zero economy.

2. Better utilize government procurement and regulation to encourage technological maturity

A greater willingness by governments to create new partnerships with the industry, while taking on some burden of risk alongside firms, was also a cornerstone of interviewee suggestions.

There are a number of ways that governments can encourage innovation and technological maturation. These include:

- integrating technologies into government-funded projects
- creating test-beds where experimental products can be tested

- enabling more flexible regulations that are more responsive to emerging technologies

- Implementing purpose into adoption: technology adoption and integration is risky in construction, but it is worthwhile for governments to take on that risk instead of firms if it fulfills important policy goals

3. Encourage youth uptake of skilled trades and building science programs

Governments should focus on continuing to encourage more young people to join building sciences and skilled trades programs. Investing in building science and skilled trades would not only elevate the number of qualified people in the field, but it would also make the industry younger, and therefore perhaps more technologically-aware and willing to take risks. Clearer pathways need to be created for young people to enter these careers in order to show them that they are attractive options.[3]

Curricula should also be reassessed in order to integrate more innovative and sustainable practices. This not only has the potential to attract more young people, but would ensure that workers in the future have the skills to reach sustainability goals.

4. Build structures to share information

Implement "pre-competitive collaboration", a process whereby a group of competing companies comes together to develop a solution for a problem that they all share, and from which none of them would gain a competitive advantage.[4]

To address the reality of limited resources faced by smaller companies, larger organizations with a vested interest in the technological maturity of the industry—such as regulatory agencies or insurance firms—should be tasked with setting up such platforms.

Introduction

IT IS WELL UNDERSTOOD that the construction industry is particularly slow to adopt and use new technologies. Literature reviews,[5] academic research,[6] and other surveys have clearly demonstrated this problem. While there has been significantly less research focused on Canada specifically, there is survey evidence for low digital maturity in both the Canadian Survey on Business Conditions (CSBC) and a recent survey by KPMG in partnership with the Canadian Construction Association. In Q1 of 2021 the CSBC found that only seven percent of businesses in construction had adopted software or databases for purposes other than telework or online sales, compared to front runners such as wholesale trade, professional and technical services, and informational and cultural industries, at 24, 19, and 15 percent respectively. Similarly, only three percent of construction businesses said they had automated certain tasks, compared to finance and insurance at 13 percent, agriculture and forestry at 12 percent and information and cultural industries at 11 percent.[7] The KPMG study found similar results, with most construction companies rating their digital capabilities poorly, and most respondents reporting that their adoption of other technologies, such as additive manufacturing or robotics, were merely experimental or not leveraged at all.[8]

This low technological maturity has important implications for the Canadian economy, as the construction sector plays a truly outsized role. It is central to a large number of challenges such as housing affordability, infrastructure investment, and climate resiliency, and it is a major employer, employing 1.37 million people in 2020, down from 1.47 million in 2019.[9] But, despite its importance, the construction sector has been a consistent laggard in both labour and capital productivity in comparison to the overall economy. Between 2015 and 2019, labour productivity went from 2.2 percentage points (pp) below the economy standard to 11.2 pp, while capital productivity fluctuated between 0.7 pp and 3.9 pp below the standard throughout the period. Except for a sharp bump during the COVID-19 pandemic, labour productivity in construction has consistently been below 2012 levels. Low labour productivity and capital productivity imply that inputs are not being used efficiently and one of the primary reasons for that is an ineffective use of available technologies.

In an effort to understand low technological maturity in the construction industry and to point to policy solutions that might address it, this report draws on interview responses from fourteen individuals who are in the industry and/or in companies that innovate specifically for the industry. While this report does not seek to provide a definitive description of this problem,

it instead offers a necessary documentation of firm-level qualitative perspectives. Those perspectives are the basis for recommendations that both industry and government policymakers should consider, in order to improve technological maturity in the sector.

This report focuses on answering three questions:

- Why has technology adoption been slower in the construction industry?
- What technology investments have firms made, and what made them successful?
- What could firms or governments do in the future to improve technology maturity?

These questions are tackled in the following structure:

In **The Lay of the Land**, we describe how the construction industry faces particular challenges in growing technological maturity, driven by the high-risk nature of the industry.

In **Breaking Ground**, we then discuss how, despite these challenges, progress is being made, and highlight some of the features of companies at the higher end of technological maturity. Such features include careful planning, more flexible work culture, leadership that is willing to take risks, and coordination between different players.

Finally, in **Building to New Heights**, we point out some possible tools and approaches that might improve the situation.

What do we mean by "technological maturity" in the construction industry?
We define technological maturity as comprising:

1. Technological intensity—the level of technology adoption and use across both internal and customer-facing operations and processes
2. Technological culture—whether there exists the skills, leadership, and governance to successfully integrate technologies.

It is important to note that the adoption of technology alone is a necessary but not sufficient requirement for technological maturity, as the culture must exist for its effective and continued use.[10]

Our definition of technology is drawn from Samad M.E. Sepasgozar and Steven Davis's 2018 investigation into the technology adoption process in construction:

"Construction technology embraces systems, tools, equipment and any combination of resources used in the process of construction from design to demolition"[11]

While this is perhaps a broad definition, it acknowledges the differences in adoption challenges for different types of technology. Namely, we break technology into two sections: physical and digital.

Digital technologies encompass any systems, tools, or equipment where the main technology involved is software. In construction, such software could include backend and client-focused softwares, project management such as CAD or Building Information Modelling, and onsite management tools.

Physical technology is any technology that is primarily a physical addition to a project and could include materials, machinery, tools, and electronics.

The Lay of the Land: Characteristics of the Construction Industry that Impact Technology Adoption

WHEN IT COMES to the structural challenges that the construction industry faces when trying to increase its technological maturity, it is all about risk. In the construction industry, risk comes from three main sources:

1. **Physical mishap:** When things go wrong in construction, they can go *very* wrong. Companies, clients, and insurers often take a risk-averse approach as a default.

2. **Long timelines:** Long project timelines with high costs mean that the trial-and-error of technological innovation and adoption is seen as a superfluous cost rather than a necessity.

3. **Contractual environment:** Fierce competition, thin profit margins and high liability create a contractual environment that leads to a lack of coordination and information sharing across the industry.

These interrelated challenges each have profound implications on construction firms and influence the freedom-of-action that decision makers experience in their recommendations pertaining to the adoption of digital technologies.

When it comes to the structural challenges that the construction industry faces when trying to increase its technological maturity, it is all about risk.

PHYSICAL MISHAP

A key characteristic of the construction sector relates to the substantial physical risks involved. There is a risk of everything from a structural collapse that endangers lives to smaller, but still costly, problems like lost materials, breakage and other mistakes that require redoing work. Even smaller problems can expose companies to costly and protracted litigation.

Such high stakes, and the liabilities involved, narrow the space for increasing a firm's technological maturity. Bolis Ibrahim, CEO of Argentum Electronics, described how "no one wants anything to go wrong because the potential for damages and lawsuits is very high, and the liability is very high, so there are a lot of risks in tech adoption."[12]

This source of risk not only affects construction firms making adoption decisions, but the technology creators themselves, especially physical innovators where a faulty piece of equipment or material can yield disastrous outcomes. As a result, innovative materials that are used in projects are often tested to extremes, a process that can take years. Natalie Giglio, an operations and development associate, and Ryan Bourns, the business development and strategy lead of Carbon Upcycling Technologies, a company that makes environmentally-friendly concrete, described how despite going through two years of durability testing and receiving sign-off from third-party engineers, clients have still asked for "10 years of field experience for literally the lowest-risk projects, like sidewalks." They noted that they can face a "chicken- and-egg situation" to prove their technology is safe and works to specification.[13] This means that the timelines and costs of getting a technology out are much higher in the construction industry.

To a lesser degree, the same problem is true of digital innovations. It is particularly the case with digital technologies that have a monitoring or calculation and design function, though digital innovations do have the potential "on the health and safety side to improve documentation", said Graeme Armster, director of innovation and sustainability at Tridel, one of Canada's most prolific developers.[14]

Given the stakes involved when things go wrong, "there's a huge aversion to risk" in the industry, as Monty Chong-Walden, CEO of Calmura Natural Walls summarized.[15] For companies, there has to be a very clear return on investment to justify the direct and indirect costs associated with adopting new technologies.

The impacts of risk aversion on overall technological maturity are compounded by the ways in which construction companies seek to manage risks. As KPMG found, "many construction firms have had little incentive to invest in technology, with current procurement practices placing much of the project risk and associated costs on the shoulders of contractors".[16] This was supported by interviewees. Daniel Gottfried, CEO of Highrise AI, pointed out how "a lot of the bigger companies are able to really de-risk themselves between the construction company, the management firms, [and] the actual developers themselves" with firms "throwing the risks on someone else."[17]

"The potential for damages and lawsuits is very high, and the liability is very high, so there are a lot of risks in tech adoption."

Markku Allison, vice president of strategy and innovation at Chandos Construction, described how "most traditional contracts are designed to transfer risk away from the owner to different members of the project team, and so anything that I do that is innovative, it is my risk."[18] In this context there is little benefit to taking on more risk directly by seeking to be innovative and increase their level of technological maturity. Nor are companies as likely to promote and encourage innovation within their supply chains.

Given the high stakes involved, the construction sector faces added regulatory oversight from government agencies, high insurance costs, and very strict requirements around what can and cannot be done. While these precautions are essential for ensuring safe and healthy workplaces and communities, such protections can also have unintended consequences, including important implications for the ability of construction companies to adopt new technologies. Markku Allison spoke of how historically, "a whole layer of risk aversion [was] encouraged by the insurance industry."[19]

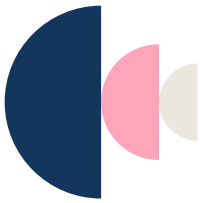
Even if a firm decides that the ROI is clear, the risk is worthwhile, and they want to invest in a new product, it is often difficult to do so. The process or regulatory review and certification can be drawn out, and, as Monty Chong-Walden described, can still face barriers on site when "building inspectors then really have to be able to understand how that technology is really functioning and be able to test it on site to know that they're not certifying a building that may or may not have been done properly."[20]

LONG TIMELINES

Construction is an industry where large commercial and residential projects take years to complete, often with dozens of companies being involved when one considers the intersections of developer(s), contractors, suppliers, and so on. These timelines and complexities directly contribute to the significant costs of projects and to the difficulty in increasing technological maturity at a firm level.

Innovation, whether process innovation or technological innovation, begins with trying something new, monitoring the effect, learning lessons, and modifying. When it can take years to finish a project, and when there are a very large number of actors and variables, these feedback loops are weak and drawn out. Necessarily, that process is extremely long in construction. Markku Allison stated how a typical project is "three to ten years from inception to completion [...] so if I'm really diligent within my own organization of learning from the projects I do, my cycle time for learning is, you know, at a three- to ten-year window".[21]

These long timelines create a particular bottleneck for the adoption of innovative physical technologies. As detailed above in the case of Carbon Upcycling Technologies, clients can often expect unrealistic real-world experience that is impossible for an innovation to have unless someone is willing to use it.[22] Bolis Ibrahim agreed with this, highlighting the "longer adoption cycles" for physical hardware in projects, with the additional high cost of installation. This even extends to software technologies when it comes to the "critical infrastructure" in a building, such as lighting systems, building control systems, and security.[23] A further issue for physical innovations is that firms are often competing on cost and aesthetics, with Monty Chong-Walden suggesting that developers "just want to see it look pretty at the end and not cost too much" with other benefits of new technologies, such as environmental benefits and efficiencies, as a lesser consideration.[24]



Clients "are really heads down trying to get the work done for the lowest cost possible, or to be the most competitive."

An important factor here is that while the costs for many systems and innovations are often borne up front by developers and contractors, the benefits are felt downstream by end users and tenants. For projects that already can cost in the tens of millions of dollars, and that have to take into account high material and labour costs, an investment in an innovation has to have a very clear and "as risk free as possible" return on investment. The thin margins that most construction firms face create an incentive structure whereby firms try to spend the least amount of time and money as possible to complete each contract.

In this environment, upfront investments in innovations that may well result in a better end-product or even create long-term savings in time and money, can be harder to justify over the short term. Kathleen Kewley, director of global business development at Esri, a Global Information Systems and Building Information Modelling firm described how many of the firms she deals with as clients "are really heads down trying to get the work done for the lowest cost possible, or to be the

most competitive, and sometimes that doesn't lend itself to take a break and come up and really start to think more holistically about processes and technology."[25] This viewpoint was also supported by Natalie Giglio of Carbon Upcycling Technologies, who pointed out that with "fairly low margins there's not a lot of room to play around with the budget" and that there is a desire to complete projects at the lowest price they can.[26]

CONTRACTUAL ENVIRONMENT

A final risk for the construction industry comes in the form of the inherent risk in signing contracts. Tight margins, high costs, and liability problems make many small firms in the production cycle of a project unable to sign contracts that allow for coordination, leading to a deeply fragmented environment. Convention would hold that competition would drive firms to seek out sources of competitive advantage, including that which comes from technology adoption, but in the case of the construction sector, industry participants note a much more complex dynamic. The main challenge that the industry faces is a lack of coordination and lack of information sharing. As Markku Allison said, "in North America alone, there are hundreds of thousands of companies that are all involved in this space, and they range in size with the very large majority being very, very small companies". This fragmentation and competition further creates "a contractual environment that historically discourages data sharing. Because of how our risk profiles are managed through contracts, it is not a good idea for the architect to share their data with the contractor for liability purposes."[27] Kate Murray, director of impact and Neil Vohrah, chief operating officer at TAS, a real estate development and impact company, also describe how this fragmented market makes identifying viable solutions difficult, citing it as a major challenge they face in their day-to-day management and operations.[28]

Such a large number of competing firms also contributes to some siloing themselves off to preserve their existing competitive advantages. Kathleen Kewley describes how firms "tend not to be as open to sharing things that are driving competitive advantage for them." She continued to say that many design and engineering firms are "much more open to sharing and talking about the success test that they've had and how their innovation has helped them improve ROI and increase efficiencies. Whereas in the construction world, we have pockets of customers who are doing some really interesting things, but may not be so open to sharing those successes with others. I see this beginning to change, which is a good thing."[29] These insights are somewhat counterintuitive to what we might think should result from a competitive environment, but the challenge is not necessarily unique to the industry. Further research is needed to more fully understand this contractual environment and how one might improve the situation for everyone.

Such a large number of competing firms also contributes to some siloing themselves off to preserve their existing competitive advantages.

Breaking Ground: Factors Contributing to Technological Maturity

CAREFUL PLANNING

WHILE THE TECHNOLOGICAL maturity of the construction industry is low, based on our sample there is at least a keen awareness of this situation and of the steps necessary to begin increasing it. Of the construction companies that were interviewed, all were in the process of improving their digital maturity, and some had come quite far. Chandos Construction, for example, already seems to have a reasonably full tech stack, using MS Office 365 and SharePoint for cloud storage and project management, Yammer for communication, and Viewpoint for accounting. They also use a suite of Autodesk products, and all onsite management has been using tablets for the last two years.[30]

Tridel has always been keen on improving their technology, but the pandemic created new needs that have accelerated technology adoption timelines. They have invested in Microsoft Teams for video conferencing and online project coordination and have issued requests for proposals for new software in customer relationship management (CRM), enterprise resource planning (ERP) and construction management and design.[31] The development firm TAS has a small technology suite to run its back office and a dedicated investor portal to handle relationships with all project and portfolio progress, each tracked on dashboards. They are also looking into updating their CRM as well as integrating Building Information Management (BIM) software and onsite monitoring into their projects.[32]

Interviewees describe how these improvements, both in the office and onsite, offer small, but important, increases that add up over time. For example, Vincent Plourd from Chandos Construction describes how tablets on site have saved time for forepersons because they "don't have to go back into the trailer to look at drawings." He goes on to describe how much time is saved by modeling software being used onsite. "I was out on site, there was a guy building a rainwater leader, and he didn't quite know where to build it. But the supervisor was able to go out and measure it on his device with the model in hand and describe exactly how far down it needed to go. The guy had to go back and recut the piece, which took an hour, and now every time that person needs to check something he always has a device on him to check the model, saving a whole lot of time in mistakes."

Moving forward in that technological maturity journey requires careful planning, being cognizant of what is actually needed and being flexible. For example, as discussed above, Tridel started their most recent technological push based on the need presented by the pandemic. In general,

we have heard that large enterprise solutions to every problem are harder to integrate and do not see as much effective use. Kathleen Kewley of Esri has found that "with construction specifically, selling almost-point solutions seems to be much more successful or easier for these companies to digest." She says that having conversations about large enterprise solutions "shuts down the conversation [...] it goes back to the fact that these guys are heads down, they're working on projects, and they want tools that are going to help them be more efficient next week, not big huge projects that take a lot of time and resources out of the gate."[33]

From the construction firm side, Markku Allison describes how the Chandos technology roadmap moves forward by nurturing innovation skills and instincts in individual teams building their own "guiding inspirations" about how they would like their work to integrate with technology, and what solutions they need. They can then "run a sort of science project with a team of volunteers from across the organization using a structured pilot around that technology. It has a timeframe, a hypothesis, and a plan for measurement, and at the end we can find out what actually happened. For the technologies that are successful, we can start having a conversation about how it rolled out."[34] This style of letting the team define their own aspirations also lets management think further down the line. Vincent Plourd, the director of virtual design and construction at Chandos Construction, describes how he has arrived at a point now where his team can focus on what they need in the near term allowing him to focus on what they will need "five years out from now", with a keen eye to strategies around "climate change and social procurement."[35]

FORWARD-THINKING LEADERSHIP AND FLEXIBLE CULTURE

Simply adopting a new technology is a necessary but not sufficient condition for reaching technological maturity. A culture that enables the successful integration and deployment of technology is equally essential. Research from BDC that explored the concept of digital maturity identified five key factors that are necessary to foster a technologically mature culture:

- A strong digital strategy and vision
- Support from leaders
- Appropriate planning
- An environment that rewards risk taking and collaboration
- A focus on training and continuous learning[36]

Not only are these features necessary for technological maturity, but in the construction industry they are also necessary for overcoming the risk to adopt in the first place, as described above. The construction firms that are successful in adopting new technologies are those that have the necessary culture and leadership.

All of the above applies to understanding the necessary building blocks for technological maturity in the construction industry but the technology adoption process often begins with a "champion." Companies interviewed that were selling innovative products often said that the

The construction firms that are successful in adopting new technologies are those that have the necessary culture and leadership.

companies most likely to adopt their technology were the ones where they could find such a person. A champion is anyone in the company's leadership or on staff who pushes for the adoption of a particular technology and is important not only in initially taking it on but also in creating the culture around its future use.

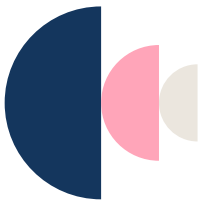
While generally this champion doesn't have to be in leadership, construction firms are often hierarchical and the decisions rest at the top. Indeed, a recent KPMG report shows that 41 percent of technology adoption decisions in construction firms are made at the CEO level and when counting other executive officers that number goes up to 71 percent.[37] When asked what makes a firm more likely to adopt their product, interviewees from construction and technology firms both agreed that a primary factor is the technological awareness of leadership and their openness to change.

41% of technology adoption decisions in construction firms are made at the CEO level.

Emelie Reis, who leads business development at Mitrex, a solar cladding company, describes the leader who is most likely to adopt technology as "forward thinking and innovative" or an "environmentalist." She describes how her firm's main challenge is finding these early adopters, those who are passionate and knowledgeable about green technology and so are willing to embrace change.[38] Graeme Armster from Tridel agrees, saying that you want leadership that "is calculating enough to minimize risk, knows how to utilize a new tool properly, and is not afraid of change."[39] Kate Murray and Neil Vohrah of TAS list a number of characteristics inherent in a leader that can adopt and use new technologies, such as "systems thinking, personal leadership, change management, project management, communication, technical and domain expertise, and ability to deal with ambiguity," but also argue that in the end what is more important is "the willingness to move with the times to innovate and resist the temptation to be stuck to the tried and tested."[40] Such leadership is paramount to *deciding* that adopting a certain technology is worth all the numerous risks associated with change in the construction industry.

However, when leadership is not interested in technology or lacks the time to pursue it, the level of control that senior leadership has over technological decision-making can manifest as a barrier in the construction industry. As Kasia Borowaska, director of Daisy AI, puts it, "I think it's because a lot of the construction companies are private and family-owned companies that were created in the 50s, and the 60s and haven't changed much since."[41] Many other interviewees also agreed with this assessment. Julie Scarcella, founder of EcoSpex Inc., pointed out how the boards of many construction firms "are heavily weighted with men that have been sitting at those appointed seats" for many years and there "needs to be diversity in gender, culture, and age on boards and technical teams to really make that shift" to technological maturity.[42] If a firm has been run the same way for a long time, by the same people and it has worked, there is not much incentive to take on the risk to change. Especially when a firm is smaller and family-run and there is no desire to expand.

The inertia facing firms who do things in ways that have always worked, and by and large are still



A culture that embraces disruption and the potential of technological maturing really requires a change at the leadership level.

working, is substantial. A culture that embraces disruption and the potential of technological maturing really requires a change at the leadership level. This was a consistent theme throughout our interviews, with interviewees often noting that a lack of digital skills was not necessarily a barrier, but a lack of a technologically-oriented culture certainly was. Daniel Gottfried of Highrise AI emphasized how "the company culture around innovation [...] really stems from the top. Like in any company, whatever happens there trickles down."[43]

"Culture eats technology for lunch."

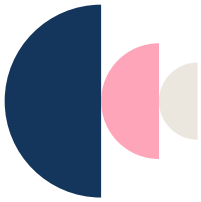
While champions are often in a leadership role, it does not seem that they need to be, even if it is the leadership team making final decisions. A more agile and devolved work environment allows an employee or a team to explore what solutions work for them, and then propose it to leadership for wider use. Kathleen Kewley of Esri explained how important it is "having people within the organizations who can be your champion, who will help take a new solution and really go and support others in the organization to help drive that adoption, because I've seen so many times where companies have purchased a technology and it's just falling flat. Why? Because you don't have the right people there who are really pushing it out and being champions. It's critical."[44]

Emelie Reis from Mitrex noted that it can be very difficult to find such a champion in giant construction firms, especially if the only people who can act as a champion are in leadership. She goes on to say it is easier, though, if the company structure is such that the employees are "constantly taking initiative" and if leadership trusts them to pass along the right information and opportunities.[45] Markku Allison and Vincent Plourd from Chandos Construction cite that the reason their employees are more likely to show such initiative is due to the incentive structure created by Chandos being employee-owned.

Firms that offer the trust and flexibility for their employees to try new things seem to more easily find, adopt, and then effectively use new technologies as well as innovate in general. Indeed, recent research from the Brookfield Institute, Mitacs, Innovation Policy Lab and Shift Insight describes innovation as a "team sport not an individual event." No one person can have all the knowledge, interest, or skills to find all the solutions, so it is instead important to have a mix of these attributes, and to allow those teams to experiment.[46]

This model only works if there is a culture in place that encourages innovation, embraces change, and gives opportunities to its employees. Markku Allison, paraphrasing a famous quote, said in an interview, "'Culture eats technology for lunch', because if people don't have the cultural proclivities to engage in the kinds of behaviors that technology supports, technology isn't necessarily going to solve that problem."[47]

There are a variety of reasons construction employees might not have that proclivity. As Vincent Plourd pointed out, "people get into construction because they like working with their hands" and often those who end up working in the back office eventually come from that background.[48] This can instill an organizational conservatism, with a preference for existing ways



"We're seeing more people coming out of school, who have been using technology since they were two and the dynamics within these companies I think are changing. For the positive? I think so."

of doing things. Plourd argues "the biggest thing is people being unwilling to change the way that they do their processes."[49] Kathleen Kewley also described how "a lot of people on the crews just want to keep their heads down; this is how they've always worked. And change can be hard sometimes." Though she argues that with the demographic changes in the industry, "we're seeing more people [...] coming out of school, who have been using technology since they were two [...] and the dynamics within these companies I think are changing. For the positive? I think so."[50]

It is important to emphasize that having this proclivity to engage with technology is the important factor, rather than necessarily having specific technical skills or knowledge. Kasia Borowaska from Daisy AI emphasizes that "We built it to be very self-explanatory, you press one button and Daisy does the work for you."[51] Many of those we interviewed from technology companies make the exact same argument, that their technologies are built to be easy, that that is the main task set out by the designer. They note that the challenge is in convincing people to change their practices to use it. Encouraging that willingness to adapt and to adopt new technologies and processes, and also giving individuals the freedom to experiment and champion new ideas, is crucial.

While elevated risk is a hurdle to adopting new technology, often it is new technology that can lower risk within the construction sector.

INDUSTRY-WIDE SOLUTIONS

While elevated risk is a hurdle to adopting new technology, often it is new technology that can lower risk within the construction sector. For example, a major problem in buildings, both during and after construction, is water penetration. It is a major cost to both developers and insurance companies, and on most sites, it is often a matter of luck as to whether a problem is even noticed in time, perhaps by someone happening to walk by. It is such a major problem that there are buildings in large cities, for example Toronto, that have become uninsurable due to high water-damage-related premiums. Even on sites with wireless sensors, most of these technologies are designed to only ping back periodically (in order to conserve battery life) and do not allow for real-time monitoring. Sensors paired with true real-time connectivity are constantly monitoring for water damage, and are integrated with high-level sensor coordination systems that could save projects millions of dollars and make insurance cheaper.[52]

Technologies can help mitigate commercial risks as well, increasing resilience. Previous to the pandemic, Tridel, like most developers, was using traditional/manual systems of accounting. The pandemic accelerated the digitalization of these processes, as accounting departments were transitioned to a work-from-home dominant environment, causing paper transactions to be replaced by electronic. The level of resilience and improved efficiency this brought to business processes is undeniable. Tridel's Graeme Armster

notes that the lesson learned is that "we need to make sure our protocols are in place, from a resilience perspective".[53]

Insurance companies increasingly recognize the importance of encouraging greater use of technologies such as sensors. For example, Markku Allison of Chandos Construction cited the example of one major insurer who convenes regular roundtables of Chief Information Officers (CIOs) from major general contractors across the United States and Canada in order to discuss innovation in the industry. Allison additionally points to another insurer-led program that recognizes that CIOs are regularly pitched up to 20 products a week, but that they are ill-equipped to understand every product's full benefits and risks. To compensate for this, the program vets technologies to recommend to clients who are then able to say "Okay, that's been vetted. I don't have to do all the testing myself, I can say, okay, that's probably a reliable technology."[54] These kinds of initiatives can help break down the silos between firms, enabling best practices and best-in-class technology solutions to reach a wider market quicker.

There are also coordination strategies between different construction stakeholders for information and risk sharing such as integrated project delivery (IPD), a system heavily used by Chandos Construction. The American Institute of Architects defines IPD as "a project delivery approach that integrates people, systems, business structures, and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction."[55] It is a system where instead of multiple contracts that keep various stakeholders siloed, there is a single agreement to design and deliver projects together. Each team has the freedom to choose their own processes, technologies, and how they want to work together, and it creates a platform for experimentation and information sharing.

Building to New Heights: What More Can Be Done to Boost Technology Adoption

CONTINUING TO IMPROVE technological maturity in the construction industry will have a number of significant impacts across the economy, given the essential role that this industry plays in dealing with public-interest challenges, such as providing an adequate supply of affordable housing in urban centres, enabling the development of cleaner transportation infrastructure, and reducing building emissions through the use of energy-efficient products, just to name a few. While this report has not presented a comprehensive examination of the different levers that could be deployed to increase technological maturity in Canada's construction sector, there are nevertheless a few key actions that have been identified as next steps towards this goal:

1. **Better utilize government procurement and regulation to encourage technological maturity**

A greater willingness from governments to experiment, work with, and take on some burden of risk with firms was also a cornerstone of interviewee suggestions. Natalie Giglio and Ryan Bourns from Carbon Upcycling Technologies pointed out that while they've been "very fortunate with the funding that has been provided by different levels of government [to develop technology] one frustrating thing that we've noticed is that they'll put the money into a project, or to help grow a technology, but don't put money into to help the business grow. So, the government puts money into helping us get to commercial scale, and we say 'great, can we now use our material in a government project, even at a very, very, very low risk level?' and they can't even entertain the thought because they have no idea who to speak to about that, or how to bring it about. And that's not to say that they're always going to have relevant technologies that they can actually utilize. But I would say concrete is one where they can."[56]

There are a number of ways that governments can encourage innovation and technological maturation. These include:

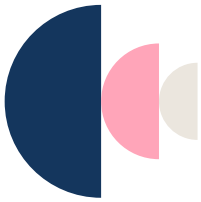
- integrating technologies into government-funded projects
- creating test-beds where experimental products can be tested
- enabling more flexible regulations that are more responsive to emerging technologies

As Natalie Giglio and Ryan Bourns also pointed out, "if you're focused on building bridges, we're okay with you being a little bit more conservative

than the folks that are building sidewalks, for example. I think there is unfortunately a kind of a blanket statement across the board and there isn't proportional flexibility to what you would expect for sidewalks versus bridges."[57]

Construction plays a major role in many of the policy areas of interest in Canada including the environment, housing, and infrastructure. As discussed above, adopting new technologies often works better when it is purpose-driven, and not just new technology for its own sake. This applies to how the government should be encouraging adoption as well. Technology adoption and integration is risky in construction, but it is worth it for governments to take on that risk instead of firms, if it is for important policy goals. A number of the firms we interviewed are focused on environmental technology, and they all emphasized the pressing need for Canada to act faster on reaching its 2030 goals, and to use the tools that Canadian companies are building.

A clear candidate for this effort would be the Canada Infrastructure Bank whose sole purpose is to invest in "revenue-generating infrastructure which benefits Canadians and attracts private capital." Prioritizing infrastructure projects that use new Canadian-made technologies not only would fulfill the bank's mandate in supporting the development industry to create revenue generating projects, but it would grow the technology industry as well, attracting private capital. Furthermore, the Canada Infrastructure Bank, along with other parts of both federal and provincial governments, could support construction firms to pay for Canadian-made green technologies in order to meet carbon net-zero goals that firms are struggling to meet on their own.



"When I moved to Canada, I was told by Canadians in the industry that the Canadian design and construction industry lagged the U.S. by about five to 10 years. And my experience has been that that is true."

2. Draw on international experimentation programs

In the effort to build policy that addresses digital maturity in construction, a good first step for policymakers may be to look internationally. Markku Allison of Chandos Construction said that when "I moved to Canada, I was told by Canadians in the industry that the Canadian design and construction industry lagged the U.S. by about five to 10 years. And my experience has been that that is true."[58] That Canada lags other countries was a commonly-shared sentiment among interviewees, though the scale of the gap was not always that extreme. A commonly cited reason, as discussed above, is a less flexible regulatory environment and less willingness from governments to experiment in partnership with firms. Other countries, such as the United Kingdom, have made strides with programs designed to work with various players in the industry to find, and support solutions. One example that Kathleen Kewley of Esri described is the Centre for Digital Built Britain, a government-funded partnership created to understand how the construction and infrastructure sectors could use a digital approach to better design, build, operate, and integrate the built environment.[59]

Another example, also from the UK, noted by Julie Scarcella of EcoSpex, is the Building Research

Establishment (BRE). The Innovation Park is designed to inspire and showcase the latest in technologies to support age-in-place, sustainable materials, and low carbon technologies, enabling the industry and government to fast-track to a net-zero economy. Additionally, the park will feature low-impact development, water and energy conservation, and green and healthy building standards. The building industry is in need of innovation to drive best practices to scale and showcase Canada's expertise. Innovation Park would help showcase this sector's outstanding Canadian talent to the global markets.

3. Encourage youth uptake skilled trades and building science programs

Another possible focus for the government is to continue encouraging more young people to join building sciences and skilled trades programs. As Julie Scarcella from EcoSpex notes, "there's a massive shortage of skilled trade in this country and we do not have enough qualified professionals to drive the built environment to include net-zero technologies necessary for meeting our GHG goals."[60] This is a problem that faces all skilled trades, with Canada facing a shortage of ten thousand Red Seal workers over the next five years. According to the RBC article *Powering Up,* this shortage is particularly severe in trades needed for the infrastructure boom, of which the construction industry is a major part. Investing in building science and skilled trades would not only increase the number of qualified people in the field, but it would also help to make the industry younger, and perhaps more technologically aware and willing to take risks. Both federal and provincial governments are aware of this problem, but face a number of challenges in addressing it. Such challenges include the stigmatization of skilled trades among young people, a lack of encouragement to go into trades after high school and how sensitive trade programs are to economic shocks. Clearer pathways need to be made for young people to get into these careers, in order to show them that they are attractive options.[61]

"There's a massive shortage of skilled trade in this country and we do not have enough qualified professionals to drive the built environment to include net-zero technologies necessary for meeting our GHG goals."

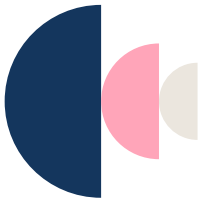
Curricula should also be reassessed in order to integrate more innovative and sustainable practices. This not only has the potential to attract more young people, but would ensure that workers in the future have the skills to reach sustainability goals. A barrier to this approach is what technologies regulators allow in construction in the first place. Taking tall timber as an example, engineering and design classes could teach its use, but that isn't something that schools teach given that regulators don't allow its use.

4. Build structures to share information

As discussed above, the construction industry is deeply fragmented due to high project and commercial risks. The various players often work in silos. A lack of coordination and information sharing, especially in a setting where innovation learning cycles are already so long and expensive, are a major barrier to technological maturity. Such a problem may be solved by "pre-competitive collaboration," a process whereby a group of competing companies come together to develop a solution for a problem that they all share, and from which none of them would gain a competitive advantage.[62] An article by Richard Holland on collaborative drug discovery describes how in the pharmaceutical industry "simply waiting for an existing group to come up with

something might appear to be risk-free, and certainly reduces effort, but passive bystanders to pre-competitive collaboration projects are actually losing out on much more than they think."

However, expecting individuals in the construction industry, who are already stretched thin to put in the time to do this work may be unrealistic. Larger organizations with a vested interest in the technological maturity of the industry, such as regulatory agencies or insurance firms, should be setting up such platforms. These platforms could have reviews of pre-tested technologies, opportunities for collaboration, and easy to access information. Such efforts are already underway by insurance companies like AXA XL or the Construction Data Trust in the UK, but these efforts need support to grow.



"Simply waiting for an existing group to come up with something might appear to be risk-free, and certainly reduces effort, but passive bystanders to pre-competitive collaboration projects are actually losing out on much more than they think."

Next Steps

THIS REPORT IS a compilation of insights from individuals steeped in the issue of technological maturity in the construction sector, and while that is an important step, there is still significant work to be done. In terms of further research, it will be useful to conduct a comprehensive review of the financial impact that the lack of technological investment has had on various players, and to develop more specific policy recommendations for the Canadian construction industry. Efforts need to be made in non-research activities as well, such as organizing round tables to discuss proposed solutions and come up with ideas. The Brookfield Institute is committed to continuing its work investigating these issues and partnering with industry organizations to find solutions.

Endnotes

1 Pierre-Olivier Bédard-Maltais, "Digitize Now: How to Make the Digital Shift in Your Business," *BDC*, October 2018, 4, https://www.bdc.ca/EN/Documents/analysis_research/how-to-make-the-digital-shift-in-your-business-study.pdf.

2 Interview: Kathleen Kewley, Esri.

3 PRISM Economics; Canadian Apprenticeship Forum, 2021 National Labour Market Information Report, https://caf-fca.org/wp-content/uploads/2021/05/CAF_Report_LMI-2021_EN_National_-FINAL-1.pdf.

4 Richard Holland, The Benefits of Pre-competitive Collaboration in the Pharmaceutical Industry, *Drug Discovery World (DDW)*, Oct. 6, 2015, https://www.ddw-online.com/the-benefits-of-pre-competitive-collaboration-in-the-pharmaceutical-industry-1310-201510/.

5 Samad M. E., Sepasgozar, Martin Loosemore, and Steven R. Davis. "Conceptualising Information and Equipment Technology Adoption in Construction: A Critical Review of Existing Research." *Engineering, Construction and Architectural Management* 23, no. 2 (March 21, 2016): 158–76. https://doi.org/10.1108/ECAM-05-2015-0083.

6 Samad M. E., Sepasgozar, and Steven Davis. "Construction Technology Adoption Cube: An Investigation on Process, Factors, Barriers, Drivers and Decision Makers Using NVivo and AHP Analysis." *Buildings* 8, no. 6 (June 2018): 74, https://doi.org/10.3390/buildings8060074; Kimberley Sargent, Paul Hyland, and Sukanlaya Sawang, "Factors Influencing the Adoption of Information Technology in a Construction Business." *Construction Economics and Building* 12, no. 2 (June 1, 2012): 86, https://doi.org/10.5130/AJCEB.v12i2.2448; Rudolf Faltinsky, and Galina Tokunova. "Information Technologies and Construction Sector: Why Construction Loses Competition for Innovations to Other Industries?" Edited by A. Sarygulov, V. Sergeev, L. Ungvári, and W. Semmler. *SHS Web of Conferences* 44 (2018): 00033, https://doi.org/10.1051/shsconf/20184400033.

7 Statistics Canada. Table 33-10-0327-01 Technologies Adopted or Incorporated, By Business Characteristics, First Quarter of 2021, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3310032701.

8 Lorne Burns et al., "Construction in a Digital World: A Deep Dive into Technological Adoption in Canada's Construction Industry," *KPMG*, May 2021, 3, https://assets.kpmg/content/dam/kpmg/ca/pdf/2021/05/construction-in-the-digital-age-report-en.pdf.

9 Statistics Canada. Table 14-10-0023-01 Labour Force Characteristics by Industry, Annual (*x* 1,000) https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1410002301.

10 Adapted from George Westerman et al., "The Digital Advantage: How Digital Leaders Outperform their Peers in every Industry", Capgemini Consulting & MITSloan Management, November 2012, https://www.capgemini.com/wp-content/uploads/2017/07/The_Digital_Advantage__How_Digital_Leaders_Outperform_their_Peers_in_Every_Industry.pdf.

11 Samad M. E. Sepasgozar and Steven Davis, "Construction Technology Adoption Cube: An Investigation on Process, Factors, Barriers, Drivers and Decision Makers Using NVivo and AHP Analysis." *Buildings* 8, no. 6 (June 2018): 74. https://doi.org/10.3390/buildings8060074.

12 Interview: Bolis Ibrahim, Argentum Electronics.

13 Interview: Natalie Giglio and Ryan Bourns, Carbon Upcycling Technologies.

14 Interview: Graeme Armster, Tridel.

15 Interview: Monty Chong-Walden, Calmura Natural Walls.

16 Lorne Burns et al., "Construction in a Digital World: A Deep Dive into Technological Adoption in Canada's Construction Industry," *KPMG*, May 2021, 2, https://assets.kpmg/content/dam/kpmg/ca/pdf/2021/05/construction-in-the-digital-age-report-en.pdf.

17 Interview: Daniel Gottfried, Highrise AI.

18 Interview: Markku Allison, Chandos Construction.

19 Interview: Markku Allison, Chandos Construction.

20 Interview: Monty Chong-Walden, Calmura Natural Walls.

21 Interview: Markku Allison, Chandos Construction.

22 Interview: Natalie Giglio and Ryan Bourns, Carbon Upcycling Technologies.

23 Interview: Bolis Ibrahim, Argentum Electronics.

24 Interview: Monty Chong-Walden, Calmura Natural Walls.

25 Interview: Kathleen Kewley, Esri.

26 Interview: Natalie Giglio and Ryan Bourns, Carbon Upcycling Technologies.

27 Interview: Markku Allison, Chandos Construction.

28 Interview: Kate Murray and Neil Vohrah, TAS.

29 Interview: Kathleen Kewley, Esri.

30 Interview: Markku Allison, Chandos Construction; Interview: Vincent Plourd, Chandos Construction.

31 Interview: Graeme Armster, Tridel.

32 Interview: Kate Murray and Neil Vohrah, TAS.

33 Interview: Kathleen Kewley, Esri.

34 Interview: Markku Allison, Chandos Construction.

35 Interview: Vincent Plourd, Chandos Construction.

36 Pierre-Olivier Bédard-Maltais, "Digitize Now: How to Make the Digital Shift in Your Business," *BDC*, October 2018, 4, https://www.bdc.ca/EN/Documents/analysis_research/how-to-make-the-digital-shift-in-your-business-study.pdf.

37 Lorne Burns et al., "Construction in a Digital World: A Deep Dive into Technological Adoption in Canada's Construction Industry," *KPMG*, May 2021, 5, https://assets.kpmg/content/dam/kpmg/ca/pdf/2021/05/construction-in-the-digital-age-report-en.pdf.

38 Interview: Emelie Reis, Mitrex.

39 Interview: Graeme Armster, Tridel.

40 Interview: Kate Murray and Neil Vohrah, TAS.

41 Interview: Kasia Borowska, Daisy AI.

42 Interview: Julie Scarcella, EcoSpex Inc.

43 Interview: Daniel Gottfried, Highrise AI.

44 Interview: Kathleen Kewley, Esri.

45 Interview: Emelie Reis, Mitrex.

46 Citation for Advantage Canada Sharpening Skills for Innovation.

47 Interview: Markku Allison, Chandos Construction.

48 Interview: Vincent Plourd, Chandos Construction.

49 Interview: Vincent Plourd, Chandos Construction.

50 Interview: Kathleen Kewley, Esri.

51 Interview: Kasia Borowaska, DAISY AI.

52 Interview: Daniel Gottfried, Highrise AI.

53 Interview: Graeme Armster, Tridel.

54 Interview: Markku Allison, Chandos Construction.

55 Andrew Wong and Ethan McCarthy, "Integrated Project Delivery Model in Canada: What You Need to Know." Osler, Hoskin & Harcourt LLP, November 23, 2018, http://www.osler.com/en/resources/transactions/2018/integrated-project-delivery-model-in-canada-what-you-need-to-know.

56 Interview: Natalie Giglio and Ryan Bourns, Carbon Upcycling Technologies.

57 Interview: Natalie Giglio and Ryan Bourns, Carbon Upcycling Technologies.

58 Interview: Markku Allison, Chandos Construction.

59 Interview: Kathleen Kewley, Esri.

60 Interview: Julie Scarcella, EcoSpex Inc.

61 PRISM Economics; Canadian Apprenticeship Forum, 2021 National Labour Market Information Report, https://caf-fca.org/wp-content/uploads/2021/05/CAF_Report_LMI-2021_EN_National_-FINAL-1.pdf.

62 Richard Holland, The Benefits of Pre-Competitive Collaboration in the Pharmaceutical Industry, *Drug Discovery World (DDW)*, Oct. 6, 2015, https://www.ddw-online.com/the-benefits-of-pre-competitive-collaboration-in-the-pharmaceutical-industry-1310-201510/;
Katelin Kennedy, Ceejay Girard and Seth Olson Best Practices to Harness the Power of Pre-Competitive Collaboration for Sustainable Supply Chains, *Resonance*, Jan. 8, 2021, https://www.resonanceglobal.com/blog/best-practices-to-harness-the-power-of-pre-competitive-collaboration-for-sustainable-supply-chains.