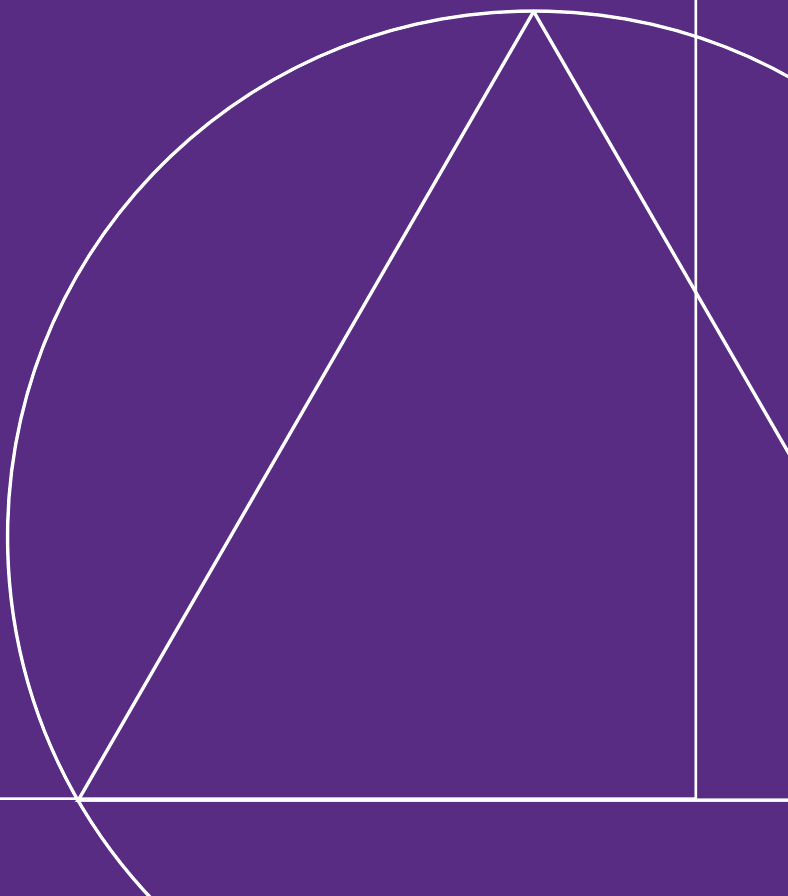
January 2023

Insight report: Innovation and R&D in construction

Construction 4.0 - continued



Canadian Construction Association

In this issue

Construction 4.0

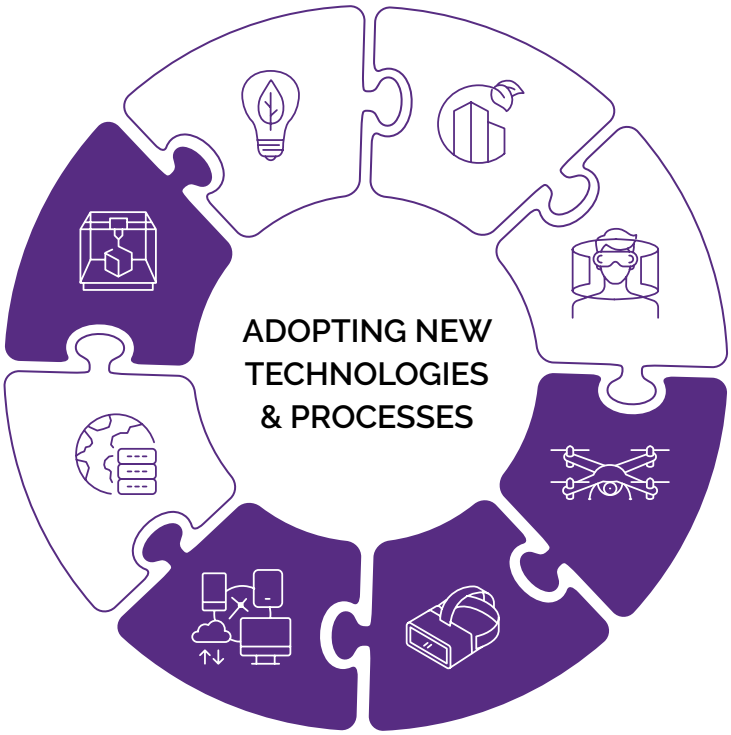
"Construction 4.0 is a paradigm that uses cyber-physical systems and the Internet of Things (IoT), data, and services to link the digital layer, consisting of Building Information Modeling (BIM), and the physical layer, consisting of the asset over its whole life, to create an interconnected environment integrating organizations, processes, and information to efficiently design, construct and operate assets."[1]

While construction 4.0 is still an evolving concept, this edition of the Insight report: Innovation and R&D in construction will focus on the following:

- IoT
- BIM
- Unmanned Aerial Vehicles / drones
- 3-D printing/additive manufacturing

Learn how each issue relates to construction. Explore the research that is being done by our universities. See how our industry is responding and where the benefits and challenges lie.

1. Tom Leathem (editor). Associated Schools of Construction Proceedings of the 56th Annual International Conference, vol 1, pages 301-309.



SMART MATERIAL
Designed materials with controllable and adjustable properties depending on external stimuli, such as stress, temperature, and moisture.

3D PRINTING
Adopting 3D printing to construct 3D objects/components by adding layer-upon-layer of materials such as plastic, metal or concrete.

BIG DATA, AI AND SMART MANAGEMENT
Smart construction management software equipped with big data/AI technology can store a vast amount of business and construction data to help automate operational and construction processes.

INTERNET OF THINGS (IoT)
Using cloud-based technologies and sensors in real-time to monitor structural conditions and to catch every signal of an upcoming threat to infrastructure.

GREEN BUILDING
A holistic approach towards a building/ structure and its full lifecycle aiming at being environmentally responsible ad resource-efficient.

VR AND AR
3D models in VR/AR allow to build, enhance or modify construction concepts. In addition, close-to-reality settings and environments can be simulated.

DRONES
A drone equipped with sensing technology can generate 3D models and data to improve the engineering process.

BIM
Building Information Modelling generates and manages digital representations of physical and functional characteristics of a structure/ building. Models can visualized, presented and exchanged.

SECTION ONE

Construction research at your fingertips

CCA and Cognit.ca launched the first ever Construction R&D Portal to help you navigate through the vast amount of research on construction within our university network.

$14 billion

of research performed by universities annually

100,000+

experts and research documents

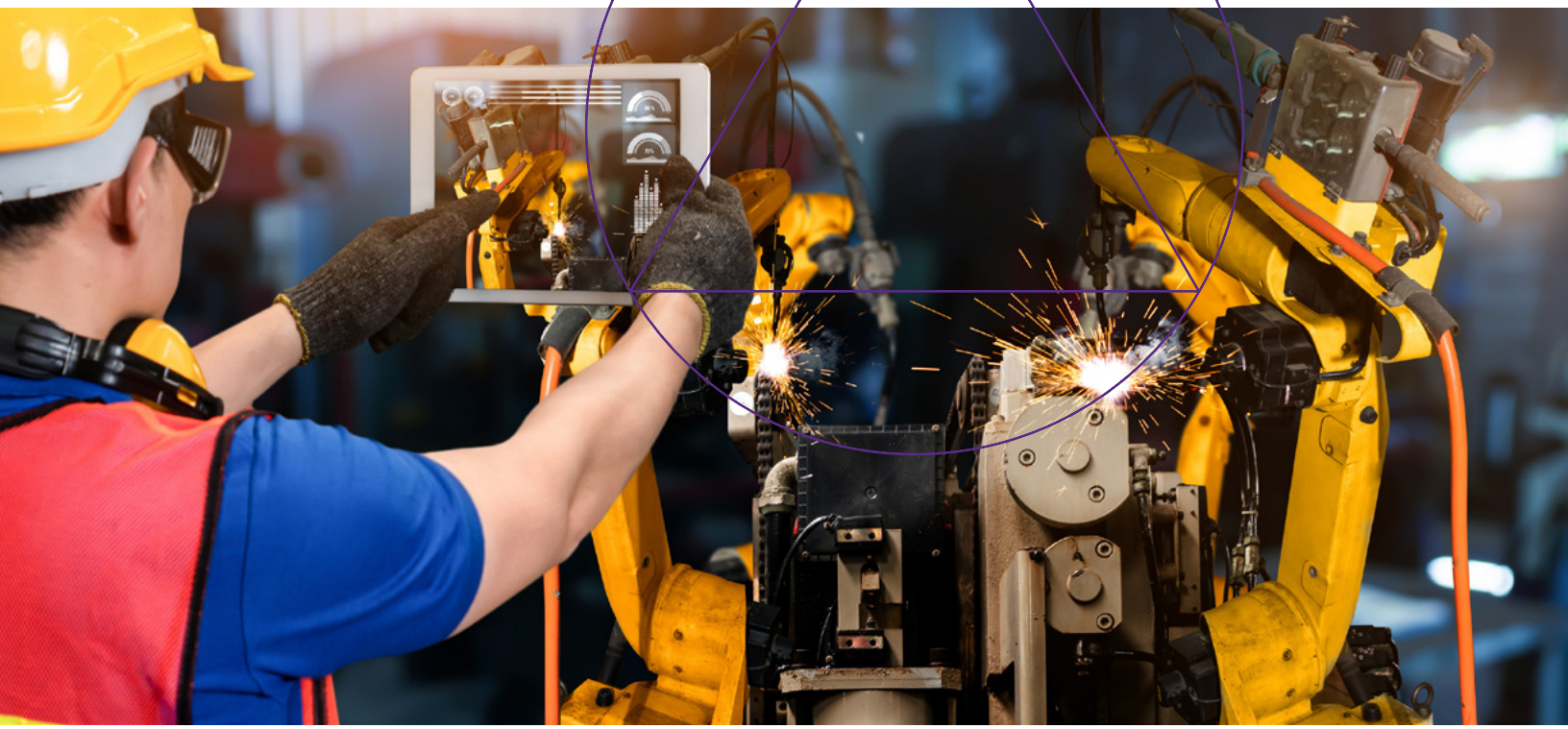
$225,000

research grants

Data provided is from the Cognit.ca tool and is for illustrative purposes. The searches may yield different results depending on the keywords used and the time the search was performed.

"The Canadian Construction Association (CCA) is the national advocate for the industry, working to ensure fair and transparent procurement, consistent and sufficient investment in infrastructure, and the recruitment and retention of a skilled and diverse workforce.

Our mission is to "inspire a progressive, innovative and sustainable construction industry that consistently acts with integrity."



SECTION TWO

Internet of Things (IoT)

2.1 Current state of the industry:

The number of connected smart devices has increased to an estimated 50 billion in 2020.[1]

The Canadian construction sector shows a higher rate of use of integrated Internet of Things (IoT) systems in 2017 (+3.8%) and 2019 (0.2%).

About 3.9 per cent of construction SMEs (<499 employees) reported adopting and using IoT systems in 2020, compared to 7.9 per cent of SMEs overall.[2]

[1] Yaïci, Wahiba & Krishnamurthy, Karthik & Entchev, E. & Longo, Michela. (2021). Recent Advances in Internet of Things (IoT) Infrastructures for Building Energy Systems: A Review. Sensors. 21. 2152. 10.3390s21062152.

[2] Statistics Canada. Table 33-10-0456-01 Advanced technology and website adoption for small and medium enterprises

[3] Anna Fredriksson, Ahmet Anil Sezer, Vangelis Angelakis, David Gundlegård, Construction related urban disturbances: Identification and linking with an IoT-model, Automation in Construction, Volume 134, 2022, 104038, ISSN 0926-5805, https://doi.org/10.1016/j.autcon.2021.104038

[3] Zinah Hussein Toman, Lazhar Hamel, Sarah Hussein Toman, Mohamed Graiet, Correct-by-Construction Approach for Formal Verification of IoT Architecture, Procedia Computer Science, Volume 207, 2022, Pages 2598-2609, ISSN 1877-0509, https://doi.org/10.1016/j.procs.2022.09.318

[4] Reem Ashima, Abid Haleem, Mohd Javaid, Shanay Rab, Understanding the role and capabilities of Internet of Things-enabled Additive Manufacturing through its application areas, Advanced Industrial and Engineering Polymer Research, Volume 5, Issue 3, 2022, Pages 137-142, ISSN 2542-5048, https://doi.org/10.1016/j.aiepr.2021.12.001

Where is IoT being used in construction?

- Data collection – smart devices use sensors to collect and store data on worksites, supporting decision-making and increasing cost effectiveness of data gathering.[3]
- Processing and analysis of data – controllers process data gathered and make decisions, with communication devices relaying the data to a user.[4]
- Enabling Additive Manufacturing (AM) processes and customization – decreasing material consumption and improving process efficiency and custom production environments on worksites.[5]
- Increasing energy effectiveness in buildings through the use of intelligent controls of HVAC, lighting, high-power appliances and hot water circulation, capable of remote actuation.[6]
- Geotechnical engineering - mapping and construction.[7]
- Supply chain supervision – real-time equipment status and inventory planning for construction supply chains.[8]

Benefits

The benefits of using IoT systems in the construction sector span the lifecycle of a building and infrastructure. Some examples of these benefits include:

- Improving equipment uptime by 30 to 50 per cent and increasing output by one to five per cent.[9]
- Improving operations on construction sites: E.g., increasing output by five to 10 per cent, reducing raw material cost by five to nine per cent, and improving personnel efficiency by seven to 15 per cent.[10]
- Safety: Wearable technologies have been used to notify workers of potential dangers or to report injuries in a specific location on the worksite.[11]
- Energy savings.[12]
- Optimized material, maintenance, and waste management.[13]

[6] Yaïci, Wahiba & Krishnamurthy, Karthik & Entchev, E. & Longo, Michela. (2021). Recent Advances in Internet of Things (IoT) Infrastructures for Building Energy Systems: A Review. Sensors. 21. 2152. 10.3390/s21062152.

[7] Honghu Zhu, Ankit Garg, Xiong (Bill) Yu, Hannah Wanhuan Zhou, Editorial for Internet of Things (IoT) and Artificial Intelligence (AI) in geotechnical engineering, Journal of Rock Mechanics and Geotechnical Engineering, Volume 14, Issue 4, 2022, Pages 1025-1027, ISSN 1674-7755, https://doi.org/10.1016/j.jrmge.2022.07.001.

[8] Yousaf Ali, Talal Bin Saad, Obaid ur Rehman, Integration of IoT technologies in construction supply chain networks; CPEC a case in point, Sustainable Operations and Computers, Volume 1, 2020, Pages 28-34, ISSN 2666-4127, https://doi.org/10.1016/j.susoc.2020.12.003.

[9] Chui Michael, Collins Mark, Mark Patel, The Internet of Things: Catching Up to an Accelerating Opportunity, McKinsey and Company, November 2021, *the-internet-of-things-catching-up-to-an-accelerating-opportunity-final.pdf (mckinsey.com). Accessed 10 October 2022.

[10] Chui Michael, Collins Mark, Mark Patel, The Internet of Things: Catching Up to an Accelerating Opportunity, McKinsey and Company, November 2021, *the-internet-of-things-catching-up-to-an-accelerating-opportunity-final.pdf (mckinsey.com). Accessed 10 October 2022.

[11] Forat AL-Sahar, Aleksandra Przegalińska, Michał Krzemiński, Risk assessment on the construction site with the use of wearable technologies, Ain Shams Engineering Journal, Volume 12, Issue 4, 2021, Pages 3411-3417, ISSN 2090-4479, https://doi.org/10.1016/j.asej.2021.04.006.

[12] [13] Foteini Setaki, Arjan van Timmeren, Disruptive technologies for a circular building industry, Building and Environment, Volume 223, 2022,109394, ISSN 0360-1323, https://doi.org/10.1016/j.buildenv.2022.109394.

2.2 Examples of projects on:

Construction R&D portal IoT

Study of advanced integrated piezoelectric sensor systems for the evaluation of structures and materials

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Discovery Grants Program - Individual

Year: 2014/15 to 2018/19

Total Funding: $120,000

Keywords

Engineering
Mechanical engineering
Solid Mechanics

Principle Investigator(s)

Xiaodong Wang
University of Alberta

High-precision digital sensor metrology for infrastructure modelling and mapping

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Discovery Grants Program - Individual

Year: 2011/12 - 2015/16

Total Funding: $120,000

Keywords

Civil engineering
Construction, urban & rural planning
Survey engineering & remote sensing
Surveying and photogrammetry

Principle Investigator(s)

Michael Chapman
Ryerson University

Location-Aware Construction

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Discovery Grants Program - Individual

Year: 2012/13 - 2017/18

Total Funding: $174,000

Keywords

Civil engineering
Construction engineering and management
Construction, transportation and comms
Northern development

Principle Investigator(s)

Saiedeh Razavi
McMaster University

Man Down Situation Detection Using an in-Ear Inertial Platform

Keywords

Chemical technology

Authors

Jérémie Voix
Université du Québec, École de technologie supérieure (ÉTS), Montréal, QC H3C 1K3, Canada

Alex Guilbeault-Sauvé
Université du Québec, École de technologie supérieure (ÉTS), Montréal, QC H3C 1K3, Canada

Bruno De Kelper
Université du Québec, École de technologie supérieure (ÉTS), Montréal, QC H3C 1K3, Canada

2.3 What is happening within the CCA family

Water IoT: A game-changing water monitoring technology for high-rise construction projects

In the insurance world, it's often said that 'water' is the new 'fire,' with the Insurance Bureau of Canada estimating that annual catastrophic losses related to water damage to be around $2 billion.

The problem is acute in high-rise construction projects, where it can be hard to pinpoint a leak, potentially turning a small leak into millions of dollars in damage during a project.

The impact on losses and project delays is why both the insurance and construction industries have begun seeking out risk mitigation strategies, such as water leak detection and monitoring technology.

How the technology works:

Since construction projects are unlikely to have internet connectivity, temperature, humidity, moisture, and water detection sensors are strategically placed around a building and communicate via a Long Range Wide Area Network (LoRaWAN).

The sensors are connected in real-time to a dashboard and mobile app, providing 24/7 monitoring. If water is detected where it shouldn't be, or water supply exceeds a predetermined parameter, alerts are sent to key contacts and water valves are shut off automatically or remotely through the app.

The technology is sophisticated enough to sense moisture levels and differentiate between normal and excess water flow for a duration of time. While it may not prevent a leak from happening, it can catch a leak in real-time to mitigate damage.

Learn how water monitoring technology can help keep projects on time and on budget by reading Northbridge Insurance's Water IoT: A game-changing water monitoring technology for high-rise construction projects

Mobile devices – connecting construction

IoT technology is emerging as a powerful tool for transforming the construction industry. IoT-enabled tags and sensors are currently being placed across construction sites, affixed to equipment and embedded within building materials, to help measure productivity, safety, and cost. The technology helps give construction professionals a more accurate and connected picture of on-site activity.

However, without a mobile device to access these insights, the data stands to be of little benefit to construction professionals making real-time decisions in the field. So, what should you look for in a mobile device? Some feature to consider include:

Connectivity

The increasing use of IoT products in construction means that companies want to access IoT enabled insights from any location. Devices with reliable connectivity, such as 5G and Wi-Fi 6E technology, can help ensure information is transmitted at fast speeds and with low latency. With remote operations being the largest application of IoT in the construction market in 2020, looking for a device with long battery life, optional replaceable batteries, and fast charging capabilities is also paramount.

Durability

There is a high probability that the mobile device will be exposed to extreme conditions on a worksite. Mobile devices that are military-grade certified to withstand drops, shocks and extreme temperatures, and that are IP68-rated for dust and water resistance, are your best bet to avoid potential breaks and damage.

Productivity

Look for a mobile device that allows you to do more with the IoT insights you collect. A device with programmable keys enables you to launch business apps or activate walkie-talkie functionality with the press of a button so you can communicate IoT insights to your teammates. Enhanced touch screen functionality means that work doesn't have to stop while you're wearing safety gloves.

Samsung Canada has been providing trusted hardware solutions to the construction sector for years through its lineup of Galaxy rugged mobile devices. Whether you're using IoT to track equipment, manage your supply chain more efficiently or make the work site more interactive with AR, Galaxy rugged devices allow you to access these insights with a press of a button.

See the newest Samsung Galaxy rugged mobile devices:

Galaxy XCover6 Pro

Galaxy Tab Active4 Pro

SECTION THREE

Building Information Modelling (BIM)

3.1 Current state of the industry:

Different stages of maturity exist for BIM technologies. Some are being swiftly embraced by the construction industry, such as augmented reality (AR), virtual reality (VR) and mixed reality (MR) technologies[14]

The 3rd Annual BIM report, a survey targeted at professionals in construction, stated that 90 per cent of organizations currently use BIM; and that the vast majority of participants agree that BIM adoption creates benefits in areas such as visualization, cost efficiency, profitability, and speed of project delivery.

Where is BIM being used in construction?

- BIM can be implemented in all phases of a project: planning, design, construction, operation, and maintenance.
- Digital models generated through the asset lifecycle create a digital record containing all the asset history to make efficient use of resources. The models are also used in the deconstruction strategies of the asset.[15]
- Analysis of all gathered data captured through the lifecycle of a project enables the examination and evaluation of the designs and models according to the expected requirements of the asset.
- It also allows all stakeholders to communicate and exchange data during the asset and materials lifecycles.

Benefits

- Increased efficiency of the construction process.
- Optimized design for material and waste management.
- Introduction of end-of-life plans for projects.
- BIM digital models provide project databases and data checking.
- Delivery of material banks and material circularity assessments.[16]

[13] Ahlem Talbi, Sassi Boudemagh Souad, Industry 4.0 in construction organization of a mega projects: a bibliometric analysis, Procedia Computer Science, Volume 204, 2022, Pages 524-531, ISSN 1877-0509, https://doi.org/10.1016/j.procs.2022.08.064.

[14] Charef, Rabia & Emmitt, Stephen. (2020). Uses of Building Information Modelling for overcoming barriers to a circular economy. Journal of Cleaner Production. 285. 10.1016/j.jclepro.2020.124854.

[16] Rabia Charef, Stephen Emmitt, Uses of building information modelling for overcoming barriers to a CE, J. Clean. Prod. 285 (2021).

3.2 Examples of projects on:

Construction R&D portal

BIM-driven productivity improvements for the Canadian construction industry

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Collaborative Research and Development Grants

Year: 2018/19

Total Funding: $392,858

Keywords

Civil engineering
Construction engineering and management
Construction, transportation and communications
Northern development

Principle Investigator(s)

Mccabe, Brenda
University of Toronto

BIM (Building Information Modelling) based Construction supply chain management under risk and uncertainty

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Discovery Grants Program - Individual

Year: 2018/19 - 2021/22

Total Funding: $104,000

Keywords

Construction, transportation and communications
Industrial engineering
Logistics
Northern development

Principle Investigator(s)

Chaabane, Amin
École de technologie supérieure

Integration of practices and technologies in construction

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Collaborative Research and Development Grants

Year: 2018/19

Total Funding: $392,858

Keywords

Civil engineering
Construction engineering and management
Construction, transportation and communications
Northern development

Principle Investigator(s)

Forgues, Daniel
École de technologie supérieure

Development of cloud-based collaborative BIM modelling software

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Collaborative Research and Development Grants

Year: 2017/18 - 2018/19

Total Funding: $200,000

Keywords

Civil engineering
Computer software
Construction engineering and management
Information and communication services

Principle Investigator(s)

AlHussein, Mohamed
University of Alberta

3.3 What is happening within the CCA family

Mindset. Process. Partnerships. These three organizational pillars are critical to effectively navigate our changing landscape. BIM and off-site construction, once reserved for only the most complex of projects or sophisticated of contractors, have become more common place.

The Victaulic journey: It's table stakes!

Victaulic began its journey with coordinated construction back in 1982 with a team then called the Technical Services Group, subsequently renamed Virtual Design & Construction (VDC). Technical Services offered customers a unique preplanning package that included an estimate, a comparison of available build methods, system layouts, a bill of materials, and complete job assembly drawings.

Forty years later, the VDC team is over 100 people strong and delivers turnkey modeling, project coordination, and fabriction-ready spooling to manufacturing level detail. As clients increasingly sought modeling coordination in Revit, Victaulic developed a suite of tools that enabled efficient mechanical, electrical, and plumbing engineering (MEP) modeling inside of native Revit. Victaulic now offers this Tools for Revit (VTFR) plugin for download alongside open-access training content hosted on YouTube, each tailor made to solve the unique challenges of modeling MEP in native Revit.

With the transfer of knowledge being a key driver of success in construction, Victaulic sought to capture the essence of 'lessons learned' into the native BIM process. Project Mentor was released as part of the VTFR toolbar to allow for the automatic capture of lessons learned. Imagine if every nuisance error turned lesson-learned, as defined by you, were caught on every job moving forward! That's Project Mentor.

BIM and coordinated construction have transformed our industry. From mega-hospitals to simpler low-rise multifamily units, BIM has become table stakes. The advantage lies in expert execution. Luckily, contractors need not go it alone.

Ledcor's first foray into BIM

Ledcor first leveraged BIM for the construction of the University of British Columbia (UBC)'s Pharmaceutical Sciences Building in 2010.

UBC Pharmaceutical Sciences Building

This project had an aggressive schedule, a unique design, and ambitious sustainability targets. It also involved multiple stakeholder groups and was situated on an operational campus for a major university. Minimizing the inconvenience to all users of the surrounding facilities was a primary goal of the project.

At the time, Ledcor hoped to leverage BIM technology to improve communications, mitigate risk, and enhance collaboration and project optimization

Fast forward to today – an increased appetite for BIM across a wide range of industries

Ledcor operates throughout North America. Their construction services specialize in building, civil, infrastructure, foundations, mining, industrial, and telecommunication projects. When virtual construction services were first offered, they were primarily requested by building construction clients.

However, requests for this technology are increasingly prevalent across the industrial and infrastructure sectors. They have expanded to include integration of this technology during the construction phase of a project.
This gradual adoption by clients can be interpreted as an indicator that the use of BIM technology will continue to play a critical role in construction. Exciting developments include:

- **Integration of drone data into the model:** Using photogrammetry to create and update a digital surface that can be incorporated into the overall project model. This digital surface and imagery can be used to calculate volumes, distances, locations, etc.

- **Adoption of technology across project sites:** Real-time updates to the model are pushed to tablets in the field, allowing supervisors to communicate the work to their crews. Additionally, Ledcor uses an augmented reality (AR) tool, which overlays the design model on the construction worksite using AR technology. This allows crews to understand the work to be performed, recognize potential hazards and conflicts, and plan work fronts. It also allows the user to do basic distance, location, and area calculations.

- **Energy modeling:** Use of the information available in the 3D model supports and increases the accuracy of energy modeling.

- **Logistics planning:** Analyzing the optimal locations for cranes, laydown areas, trailer compounds, snow management, and other temporary seasonal measures can have a significant impact to both productivity and fuel consumption over the lifetime of a project, particularly on sites with a large footprint.

BIM at work on the Haisla Bridge Replacement Project in Kitimat, BC

Ledcor is the design builder constructing a two-lane bridge to replace the existing infrastructure over the Kitimat River. Ledcor used BIM to implement several innovative solutions including:

- **Modeled work sequencing:** When planning the girder launch, a challenge was posed by the work area's space restrictions and proximity to live utilities. Input was gathered from the construction team on how much space was required to work safely. That information was used to work within the model to detail work sequencing within a fraction of an inch. The solution involved bath tubbing an area adjacent to the existing highway to accommodate the girder erection staging area, the addition of a shoring wall, and analysis to ensure that the launch occurred at the correct angle to account for deflection at the opposite pier. Planning in this manner, with the ability to see 360°, allowed the team to mitigate risk while safely and successfully completing the girder launch program.

- **Water elevation monitoring and real-time construction progress:** Providing safe access for heavy-duty machinery and cranes to the centre gravel bar is vital to key construction activities; however, the gravel bar for this project is a low-lying piece of land that floods periodically.

The project team developed a method to forecast the risk of a flood event by deploying water sensors and a 4K video camera system along the riverbank to monitor the water elevation. This monitoring system provides a real-time live feed of construction progress to the project stakeholders. The model was used during this process to identify the ideal placement of each piece of surveillance equipment to minimize adjustments during construction.

Looking to the future

The technology in this space is quickly evolving, and while this innovation can be exciting, it can also be challenging to identify new products to invest in and train staff to keep up with the changes.

Ledcor proactively address these issues by developing virtual construction personnel through extensive onboarding and annual training opportunities. They also deploy team members to the field as project coordinators with BIM capabilities, making it easier to incorporate new technology on project sites and increase familiarity with these tools.

SECTION FOUR

Unmanned Aerial Vehicles (UAV)/drones

4.1 Current state of the industry:

1.5%
increase in geomatic technologies

When compared to all other industries, the Canadian construction sector showed a slightly higher rate of use of geomatics or geospatial technology systems in 2017 (+0.1%)[17]. And by 2019, the rate of using these systems in the construction industry grew by 1.5 per cent more than the average of all other industries.

In 2021, Transport Canada, under the Aeronautics Act, released a drone strategy that aims to lay the foundation for drone adoption and the development of official regulations for their use in Canada.[18]

+17%
growth expected by 2027

The Canadian commercial market for drones is expected to grow more than 17 per cent by 2027.[19]

Where are drones being used in construction?

Drone and UAV surveillance	• Detect faults and other metrics • Site mapping and site surveying of worksites
Inspection techniques and damage detection	• Monitoring infrastructure • Collect geographical and imaging data • Environmental data collection • Analysis and detection of faults and capture of other metrics
Health and safety of worksites	• Monitoring safety conditions on the worksite • Maintenance, health and safety site inspections
3D modeling via thermography	• Model construction via laser scan • Model reconstruction though photogrammetry

[17] [18] Transport Canada's Drone Strategy to 2025

[19] Global Commercial Drones Industry (globenewswire.com).

[20] [21] Ambar Israr, Ghulam E. Mustafa Abro, M. Sadiq Ali Khan, Muhammad Farhan, Saif ul Azrin Bin Mohd Zulkifli, Internet of Things (IoT)-Enabled Unmanned Aerial Vehicles for the Inspection of Construction Sites: A Vision and Future Directions, Hindawi, Mathematical Problems in Engineering, Volume 2021, Internet of Things (IoT)-Enabled Unmanned Aerial Vehicles

[22] Alsamarraie, Mundher & Ghazali, Farid & Hatem, Zaid & Maeni, Alhamza. (2022). A REVIEW ON THE BENEFITS, BARRIERS OF THE DRONE EMPLOYMENT IN THE CONSTRUCTION SITE. Jurnal Teknologi. 84. 10.11113/jurnalteknologi.v84.17503.

Benefits

- Increased efficiency: a site-survey can be up to 400x quicker and can result in cost savings of up to 40 per cent.
- Drones can identify damages in high rise buildings and bridges, or other places that are hard for site workers to access.[20]
- Drones can scan hidden damages and areas using thermography to identify faults more accurately.[21]
- A research study surveying projects that adopted drone technologies reported that 85 per cent of respondents saw cost reductions in their operations, while 75 per cent used drones for quality control and 70 per cent used them for security purposes.[22]

4.2 Examples of projects on:

Construction R&D portal - Drones

Integration of Unmanned Systems over the Life Cycle of Construction Projects

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Applied Research and Development Grants - Level 2

Year: 2018/19

Total Funding: $75,000

Keywords

Civil engineering
Construction engineering and management
Construction, urban and rural planning

Lead Instituition

Southern Alberta Institute of Technology

Networked drones for concrete structure, environmental, and radiation surveys

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Applied Research and Development Grants - Level 2

Year: 2019/20

Total Funding: $168,910

Keywords

Construction, urban and rural planning
Robotics
Surveying and photogrammetry

Principle Investigator(s)

Schoellig, Angela
University of Toronto

A Drone-Enabled Approach For Gas Leak Detection Using Optical Flow Analysis

Keywords

Thermography
Video stabilization
Gas leakage detection
Unmanned aerial vehicle
Aerial inspection
Nondestructive testing

Authors

Parham Nooralishahi
Department of Electrical and Computer Engineering, Laval University,
Quebec City, QC
G1V 0A6, Canada

Fernando López
TORNGATS,
Quebec City, QC
G2E 5V9, Canada

Xavier Maldague
Department of Electrical and Computer Engineering, Laval University,
Quebec City, QC
G1V 0A6, Canada

A Comprehensive Survey of Digital Twins and Federated Learning for Industrial Internet of Things (IoT), Internet of Vehicles (IoV) and Internet of Drones (IoD)

Keywords

Digital twins
Internet of Vehicles
Federated learning
Internet of Drones
Industry 4.0
Cyber–physical system

Authors

Sonain Jamil
Department of Electronics Engineering, Sejong University, Seoul 05006, Korea

MuhibUr Rahman
Department of Electrical Engineering, Polytechnique Montreal, Montreal, QC
H3T 1J4, Canada

Fawad
Department of Telecommunication Engineering, University of Engineering and Technology, Taxila 47080, Pakistan

Pomerleau: Drones in high demand

Pomerleau began using drones in 2015. With photogrammetry still in its infancy, Pomerleau was in the exploratory phase knowing they wanted to integrate video data and photogrammetry into the planning, coordination, and documentation processes of a project – in short, do what they are doing now.

As with most technology, everything has since evolved – the drones, command platforms, interface, planning, and engagement. Clients don't wait for Pomerleau to offer drone services – they ask for it on their own. They want more data, a better quality of data, and the ability to track the progress of the project.

Key changes and improvements:

- **Enhanced quality and capabilities:** Drones have become more autonomous, secure, and resistant to different weather conditions. They can now also be equipped with infrared, lidar, and high-zoom cameras for inspections of bridges and other infrastructure without putting engineers at risk.

- **More precise data:** Pomerleau now uses GCPs (ground control points) and point clouds enabling more precise data, rather than only capturing orthophotos, images, and videos. Pomerleau is then able to extract quantities and see the elevations of the sites.

- **Legal framework adapting to new reality:** The planning process now includes authorizations in certain controlled areas, or coordination with control towers – even security has changed on the construction site because of drones.

Drone usage in the construction cycle

Pomerleau primarily uses drones in pre-planning and planning to inspect and analyze the layout of the construction site; map the environment, elevation and soil conditions; and extract quantities in the case of excavation or obtain a more accurate analysis of marine projects.

As the project moves forward, drones allow Pomerleau to also analyze execution, project progress, or maintenance. Not to mention the benefits in marketing and communication as they offer a great bird's-eye view showing the scale and specialties of extraordinary projects.

Challenges

Challenges are normal when we live in a world that is constantly evolving, sometimes faster than you expect. You must always keep an eye on what is new and analyze the opportunities for integrating these new technologies into your workflow.

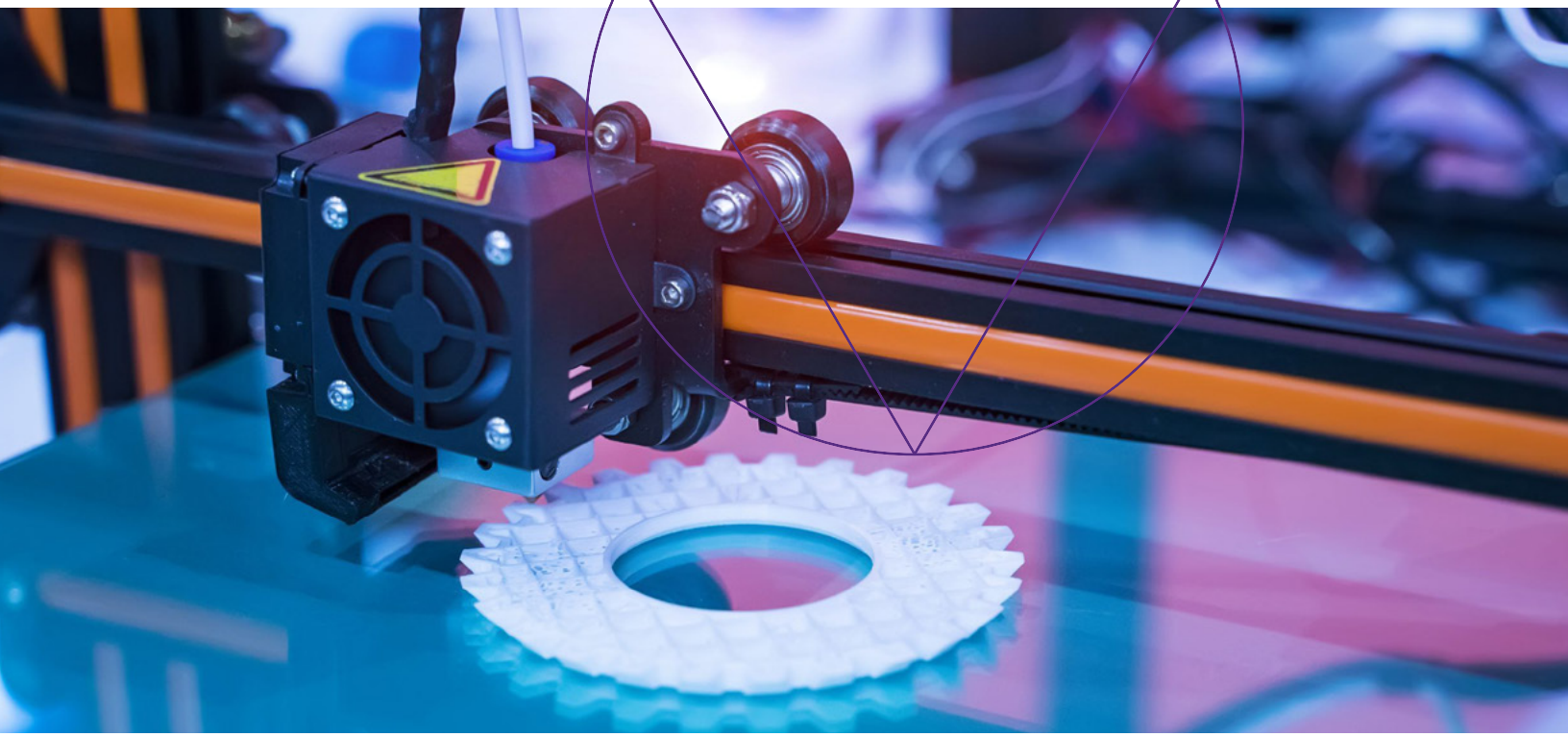
Like many other companies, Pomerleau is currently dealing with labour shortages, and it takes a long time to become an advanced drone pilot. Pomerleau does have a team of certified advanced pilots who can train new and inexperienced pilots; however, the automation of some processes is necessary so that we can use pilots for other tasks with added value.

Looking to the future

Pomerleau believes that drones will be more autonomous in the future, safe to perform many tasks alone without the constant supervision of the pilot. There will be boxes with integrated weather systems and inside will be autonomous drones capable of taking off by themselves, capturing the necessary data, and sending information to the cloud. An AI system will then process the data and send it to the pilot for analysis.

The pilot will ensure that everything works well, is secure, and that the legal framework is respected. They would also take care of planning and checking the data before sending it to the client. If necessary, the pilot will intervene remotely to adjust to certain situations. This will increase productivity since the pilot will be able to focus on specific value-added tasks and manage more projects simultaneously.

More than that, they believe that in the future all Pomerleau projects will involve the use of drones at least once in the life cycle of a construction project.



SECTION FIVE

3D printing – additive manufacturing

5.1 Current state of the industry:

Although 3D printing, otherwise known as Additive Construction (AC), is a relatively new field, its use is rapidly growing in North America.

- The first building permit for a 3D printed residential project in Canada was awarded to a residential project built in Procter, BC in 2021, the Fibonacci House.
- The project used 3D printing techniques to construct the walls and other parts of the house in a controlled environment, which was then taken to be assembled on site.
- A housing project for a two-storey house in Kingston, ON, which included a basement, was 3D printed in its entirety – the first of its kind in North America. The U.S. has yet to permit 3D construction of structures above one storey.
- The use of 3D printing technologies is expected to rise in the next few years thanks to new partnerships emerging between 3D printing enterprises and the private and public sector in Canada.

Where is 3D printing being used in construction?

3D printing is used in prototyping, making tools, fixtures, and spare parts, and producing parts and equipment repairs. Advancements in technology, materials and knowledge have enabled the construction of walls used in residential projects and a small concrete pedestrian bridge.[22]

Canada represents only two per cent of the global additive manufacturing ecosystem, and in North America, the U.S. alone accounts for 90 per cent of the additive manufacturing market. [23]

Benefits[24]

- Single step manufacturing enables optimized material use and waste minimization, reducing production costs
- The ability to create and produce complex shapes with significantly less material waste and energy use allow the potential for zero-waste construction.
- 3D printing advancements allow for cost-effective customization and personalization of products.
- Reduced carbon footprint: additive construction allows for the use of less materials and removes requirements for molding and casting operations. Less need for traffic also reduces transportation-related emissions.

[22] Mohammad S. Khan, Florence Sanchez, Hongyu Zhou, 3-D printing of concrete: Beyond horizons, Cement and Concrete Research, Volume 133, 2020, 106070, ISSN 0008-8846, https://doi.org/10.1016/j.cemconres.2020.106070.

[23] Herron, C.; Ivus, M.; Kotak, A. "Just Press 'Print': Canada's Additive Manufacturing Ecosystem," Information and Communications Technology Council (ICTC), March 2021, Ottawa, Canada

[24] Nils O.E. Olsson, Emrah Arica, Ruth Woods, Javier Alonso Madrid, Industry 4.0 in a project context: Introducing 3D printing in construction projects, Project Leadership and Society, Volume 2, 2021, 100033, ISSN 2666-7215, https://doi.org/10.1016/j.plas.2021.100033

5.2 Examples of projects on:

Construction R&D portal - 3D printing/additive manufacturing

NSERC Network for Holistic Innovation in Additive Manufacturing (HI-AM)

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Strategic Network Grants Program

Year: 2017/18 to 2019/20

Total Funding: $5,308,750

Keywords

Advanced manufacturing
Design and manufacturing
Engineering
advancement of knowledge

Principal Investigator(s)

Toyserkani, Ehsan
University of Waterloo

Additive manufacturing and automation in civil and construction engineering

Funding Details

Canada Foundation for Innovation

Year: 2018/19

Total Funding: $93,560

Keywords

Natural sciences and engineering
Civil engineering

Project Leader

Claudiane Ouellet-Plamondon
École de technologie supérieure

Optimizing the Properties of Polymers and Composites Made by Additive Manufacturing

Funding Details

Natural Sciences and Engineering Research Council of Canada

Grant type:
Discovery Grants Program - Individual

Year: 2015/16 - 2019/20

Total Funding: $125,000

Keywords

Manufacturing processes and products
Materials science and technology
Polymers and coatings

Principal Investigator(s)

Kortschot, Mark
University of Toronto

Additive Manufacturing in Off-Site Construction: Review and Future Directions

Keywords

Additive manufacturing
Off-site construction
Industry 4.0
Smart manufacturing

Project Leader(s)

Zhen Lei
Off-Site Construction Research Centre (OCRC), Department of Civil Engineering, University of New Brunswick, Fredericton, NB
E3B 5A3, Canada

Clodualdo Aranas
Department of Mechanical Engineering, University of New Brunswick, Fredericton, NB
E3B 5A3, Canada

Jubert Pasco
Department of Mechanical Engineering, University of New Brunswick, Fredericton, NB
E3B 5A3, Canada

5.3 What is happening within the CCA family

Are we there yet? PCL responds

As described in the state of the industry report on 3D printing/additive manufacturing, the technology is not seeing the same scale of use as Europe and Asia. CCA asked PCL about its exploration of 3D printing.

Jared Heinzerling, Integrated Construction Technology Specialist, PCL Construction, provided insight into PCL's position.

CCA: Is 3D printing on PCL's radar? If so, is there a particular area which is being explored?

PCL: 3D printers are on PCL's radar. Pieces are seldom 3D printed in large scale construction, even when prefabricated parts are complex and custom. Typically, when you do see 3D printing being used at large scale it is for the formwork for complex concrete geometries. The 3D printing industry has yet to create a more reliable and economical system for creating strong building components than the traditional method. And while there are "3D Printed Houses" in concrete, what is often overlooked in those novel creations is the need and use for reinforcement, MEP systems, and door and window detailing. It is much more complicated than it seems, and brings the question forward of "is this actually any better?"

PCL has utilized 3D printing on a small scale – models and visual devices to help elevate the conversation around a difficult space or coordination.

CCA: What does PCL see as the challenges to incorporating 3D printing into its business as well as the industrial, commercial, institutional and civil construction sector (ICIC)?

PCL: One of the biggest challenges is that it is cost prohibitive. When creating formwork for example, the question must be asked – is this cheaper and easier than wood? All but the most complex geometries can be created through means other than through 3D printing. So, what value does 3D printing add if it isn't cheaper or easier?

Hopefully 3D printing will one day be more prevalent and accessible. Only then will we start to cross the threshold of being able to use 3D printing in large scale construction more.

SECTION SIX

KPMG report

Execution efficiency: Better project delivery through technology

Construction sector labour productivity growth averages

< 1/3

of that of the manufacturing sector

With annual construction labour productivity growth averaging one per cent compared to 3.6 per cent in manufacturing[1], there is significant opportunity to leverage new technologies to improve the efficiency of project execution.

Introduction

When looking at the applications for new technologies in the construction space, much of the conversation is focused around better project management and leveraging project data to make better decisions. While this is a major potential source of value for contractors, it doesn't necessarily focus on a contractor's greatest cost category: labour.

In the current environment with shortages of skilled labour and rising labour costs, it is critical that contractors are able to maximize productivity and longevity of their current labour force and explore new opportunities to reduce the size of crews. Thanks to recent advancements in construction technology, there are already commercial available solutions that do just that:

Execution efficiency

- **Wearable IoT sensors**: Enhance labour productivity and safety by capturing data on travel times and locations
- **Exoskeletons**: Improve lifting capacity and ergonomics to minimize strain on workers while increasing productivity.
- **3D additive printing**: Reduce the need for large crews, long pours and erection sequences through automated in-situ casting.

As with most other metrics for construction projects, labour productivity in the construction sector severely lags behind that of manufacturing and other industries that have more fully embraced new technologies and ways of working. These technologies already have a proven track record in other industries and are already demonstrating significant value for early adopters in the construction sector.

1. McKinsey Global Institute: Reinventing Construction: A Route to Higher Productivity, 2017

Wearable IoT sensors

Projects can incur unnecessary cost and delays due to unproductive activities, with some projects experiencing

50 - 75%

Non-value adding activities[1]

This is often driven by:

- Incorrect materials
- Lack of appropriate tools and equipment
- Absent or incomplete design information
- Insufficiently qualified / trained personnel

Over the last 10 years, wearable sensors have increasingly become a normal part of our everyday lives, with sensors in phones, watches, and clothing tracking everything from location and movement to heart rate and blood pressure. On the construction site, these sensors can provide important insights into how, when, and where work is executed and highlight pain points that are hindering productivity.

While there are many applications for IoT sensors, we think are three key use cases in construction applications that present significant value to contractors:

- **Time and motion analysis**: Time and motion studies have long been a tool used to measure productivity and identify opportunities to improve operational efficiency. However, these studies can be time consuming and costly, and only provide a snapshot of work patterns at the time of the study. Wearable IoT sensors can enable real-time analysis of work performance and identification of pain points so that they can be quickly addressed. For example, tracking worker movement could highlight excessive travel times back and forth to the tool crib or break trailer, which could be addressed by moving or adding trailers.
- **Labour cost allocation:** Allocating and tracking labour costs at a high level of detail can be challenging due to the fluid nature of work on a site. IoT sensors can be used to track time spent in geofenced areas throughout the site in order to allocate labour costs by WBS work area, trade, and level to provide an important additional layer of insights. For example, the electrical labour may be on track overall, but a specific area is requiring more hours than planned. This enables steps to be taken to assess the issue and address the root cause.
- **H&S monitoring**: Of course, wearable IoT sensors have significant health and safety applications. Monitoring biometrics, body position, heart rate, blood pressure, body temperature, and other vital signs can be used to assess and minimize the risk of accidents, and quickly notify superintendents and HSE staff if an injury does occur. As with cost allocation, geofencing and worker location information can also be used to quickly notify site management of workers in high risk areas such as confined spaces or hot work areas.

Challenges:

1. **Organizational**: In the past, union groups have raised concerns around IoT monitoring devices and personal privacy. Other industries have been able to find agreeable solutions to this by anonymizing individual data points, and aggregating data together to the crew level to avoid singling out individuals.
2. **Technical**: IoT sensors typically require a good internet connection, which can be challenging on some construction sites. Contractors have seen success with the deployment of site-specific 5G networks to enable better communication and monitoring across the site.

1. Construction Institute: RT-265: How to Use Industrial Engineering/Manufacturing Techniques for Enhancing Project Performance

Construction workers experience work-related musculoskeletal injuries

16% more

than all other industry sectors[1]

Exoskeletons

On most construction sites today, there is a clear age gap in the workforce with less than 10 per cent of workers typically under the age of 25.[2] If trends continue, this gap is expected to worsen as young talent continues to flow to other industries. As such, investment in technologies that reduce the amount of long-term strain and keep people in the workforce longer will be critical. This may also have the added benefit of attracting new talent to the industry who are excited by the opportunities and possibilities offered by the industry.

One of the most exciting developments in the construction industry is the increasing adoption of exoskeletons to assist and augment skilled labour on site. These exoskeletons promise to increase workers' ability to lift heavy materials and tools, and help reduce stress and strain from working in difficult positions. There are two main categories of exoskeletons:

- **Mechanical exoskeleton** - Provides an external frame and mechanical supports that transfers load down to the ground more efficiently or provides a counterbalance, reducing stress and strain on the worker.
- **Electrical exoskeleton** - Uses electric motors to assist the worker, generally assuming the full load, thus enabling the worker to repeatedly lift heavy loads without injury.

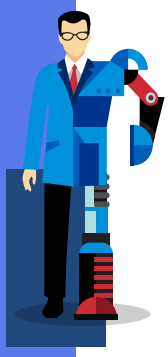
Currently, the industry is primarily focused on mechanical exoskeletons for construction applications as they are more cost effective ($2-3k) and less complex to maintain. Similarly, while the exoskeletons can be full-body, the majority of commercially available solutions focus on one area of the body, such as arms, hands, back, and legs.

Case study: Exoskeletons in action

Exoskeletons already have a proven track record in the manufacturing industry. In fact, one of the big automakers in Canada has been experimenting with the technology on many of its production lines since the early 2000s, and has a strategic partnership in place to deploy arm support exoskeletons across its operations around the world.

The employees in 15 plants across seven countries were part of a case study using exoskeletons to assist with physically demanding tasks. This includes overhead work, such as screwing in bolts to secure the car brace. Since 2005, lost time injury incidents have fallen by 75 per cent,[3] reducing worker downtime and contributing to lower workers compensation and insurance premiums.

1. Eskobionics, 5 Amazing ways to use exoskeletons for construction
2. Statistics Canada, Labour force characteristics by industry, 2022



Leveraging exoskeleton technologies will help workers do more with less physical effort, allowing more productive time per day and increasing the quality of workmanship, all while reducing risk of injury. In particular, as electronic exoskeletons progress and become more capable and cost effective, they will change our perspective of the types of tasks a single worker can undertake by augmenting the strength and skill of the worker, enabling them to move large materials and use heavy equipment alone.

3D printing in construction can provide:

Up to **80%** reduction in labour costs[2]

Up to **32%** reduction in direct construction costs

3D additive printing in construction

3D additive printing technology ("3D printing") has been around since the 1980s but it wasn't until 2008 that techniques were developed to enable concrete to be used as the printing material.[1] This advancement introduced new opportunities in the construction industry and opened the doors to new areas of research, with a wide array of applications including residential and public infrastructure construction.

In today's construction environment, the use of 3D printing provides several advantages over traditional construction:

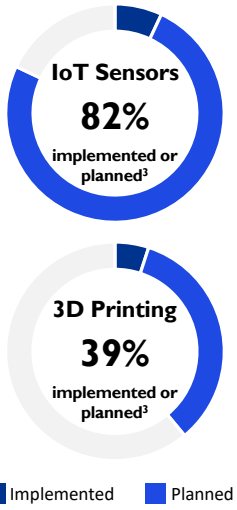
- **Schedule:** 3D printing has been used in single family home applications to compress construction time from several weeks to just 24 hours, thus significantly increasing production rates and potentially helping to address the current housing shortfall.[2]
- **Labour:** In addition to the reduced construction timeline, early adopters of 3D printing technologies have seen up to an 80 per cent reduction in labour costs, as the crew required on site can be limited to just two to three people.[2] With labour typically representing approximately 40 per cent of average building costs, this would correlate with a ~32 per cent reduction in total project cost.
- **Materials:** As much as 30 per cent of all building materials delivered to a typical construction site can end up as waste.[3] With the use of 3D printing, materials required for construction are well defined, thus reducing wastage and overall material costs.
- **Quality:** The use of 3D printing also provides opportunities to implement new designs and solutions that would be cost-prohibitive or potentially impossible to build using traditional construction materials and methodology, thus providing higher quality outcomes to owners.

Case Study: 3D printing in action

In December 2021, a notable nonprofit organization completed construction on a 3D printed home in Williamsburg, Virgina (USA). The 1,200 square foot three bedroom home was printed by *Alquist 3D* in 28 hours.

The use of 3D printing and concrete for the walls **reduced the construction schedule by approximately four weeks and saved an estimated 15 per cent in building costs**, compared to a typical project.

1. 3Dinsider. Applications of 3D printing in the Construction Industry
2. All3DP. Are 3D Printed Houses Cheaper?
3. Waste, A Handbook for Management. Chapter 15 – Construction Waste



The future of 3D printing

3D printing applications in construction to date have largely focused concrete buildings. However, use of materials such as steel and clay have opened new opportunities and applications for 3D printing, while providing many of the same cost, schedule, and quality benefits.

Amsterdam, 2021: The MX3D Bridge is the worlds first 3D printed steel bridge, spanning 39 feet over one of the oldest canals in the city. The bridge was constructed out of stainless steel using 3D printing robots over a period of six months in a factory setting. The bridge is outfitted with sensors that collect data to inform a digital twin and monitor the structural integrity.[1] The use of 3D printing allowed this bridge to be constructed with less material, minimal crews, and with a unique and technically complex profile.

Italy, 2021: TECLA (a combination of the words technology and clay) was 3D printed using materials sourced from riverbeds near the site in Massa Lombara. The home is comprised of two domes with ribbed outer walls, each with 350 stacked layers of 3D printed clay. Built in just 200 hours, this construction was part of a study which demonstrated the ability to construct low-carbon homes by combining ancient building materials with modern technology.[2]

Conclusions

These new technologies have demonstrated real-world value in terms of productivity improvements and labours savings, and already being embraced by the industry. In 2021, KPMG in Canada and CCA's joint survey of Canadian construction firms found that 82 per cent of respondents had either implemented or planned to implement IoT sensors, and 39 per cent had or planned to implement 3D printing technologies.[1] As we look to refresh this survey later this year, the focus will be on how quickly the industry is adopting these new technologies, the value that early-adopters are seeing from their investments, and critically, what the risk is to those companies that do not keep pace with their competition.

Have your say by taking our survey and help us capture the industry's journey to digital maturity.

Construction 4.0: The connected project

KPMG's Global Infrastructure Advisory team focuses on the development and construction of major projects and the forces of change on our industry. Learn more about the many new technologies poised to disrupt the construction industry and the way we deliver major projects **here**.

Jordan Thomson, P.Eng., MBA
Senior Manager
1 416 228 4320
jordanthomson@kpmg.ca

Kathleen Boyd, P.Eng., MBA
Senior Manager
1 416 777 8257
kathleenboyd@kpmg.ca

Renée LeBlanc-Smith , P.Eng.
Senior Consultant
1 416 777 3425
rleblancsmith@kpmg.ca

1. Dezeen. Joris Laarman's 3D-printed stainless steel bridge finally opens in Amsterdam 3. KPMG & CCA, Construction in a Digital World, 2020
2. Dezeen. Tecla house 3D printed from locally sourced clay

Canadian Construction Association

SECTION SEVEN

Bringing industry and academia face-to-face

Day 2 of the Transforming Construction with Reality Capture Technologies conference

In addition to our partnership with Cognit.ca, CCA was pleased to have supported an initiative bringing industry and academia together from the University of New Brunswick's Off-site Construction Research Centre. Taking place August 23-25, 2022, the Transforming Construction with Reality Capture Technologies conference explored the newest innovations and up-and-coming technologies from universities that would impact construction.

Transforming Construction with Reality Capture Technologies

The Off-site Construction Research Centre (OCRC) at the University of New Brunswick (UNB), in partnership with the Canadian Society for Civil Engineering (CSCE), held the first-of-its-kind Transforming Construction with Reality Capture Technologies. The event brought industry professionals and academia together to influence collaboration and bridge the gap between the physical and the digital world.

The conference showcased state-of-the-art technology, with Pomerleau bringing SPOT, the robot dog, and EAGLE GIS presen ting their 360 Mapping Vehicle mounted with their new Leica Pegasus. The New Brunswick Department of Transportation and Infrastructure also showcased their DJI Matrice 300 RTK along with Zenmuse H20T multisensor camera with Radiometric Thermal sensor, Wide Angle camera, Zoom camera (200x), and Laser Range Finder; Zenmuse P1, 45MP camera for high-resolution aerial surveying; and Zenmuse L1, LiDAR with RBG camera.

Mahsa Rezvani, 3rd place winner, 5-minute graduate student competition

A Five-Minute Graduate Student Competition was also held where post-graduate students from all engineering disciplines with research related to the conference theme presented their thesis in five minutes to a jury. Xin Wang, a Ph.D. student from the University of Wisconsin-Madison, took home first prize for his presentation on "Context Aware Human Intent Interpretation and Prediction in Construction." Angat Bhatia, a Ph.D. student from Concordia University, won second prize for his presentation on "Application of RFID in Planning and Scheduling for Modular Construction Manufacturing." Mahsa Rezvani, a student researcher at the OCRC and MScE student in construction engineering and management at the University of New Brunswick, won third prize for her presentation on "Assessing the User's Task Performance and the Usability of the Trimble Connect Mixed Reality Application on HoloLens 2 on the Quality Control Inspection Tasks of Precast Concrete Production."

Interested in learning more about Innovation in construction?

Contact:

Kenny Leon
Vice President, Marketing Innovation and Industry Collaboration
kleon@cca-acc.com

Or attend one of our webinars:
cca-acc.com/events/connected-webinars

Canadian Construction Association