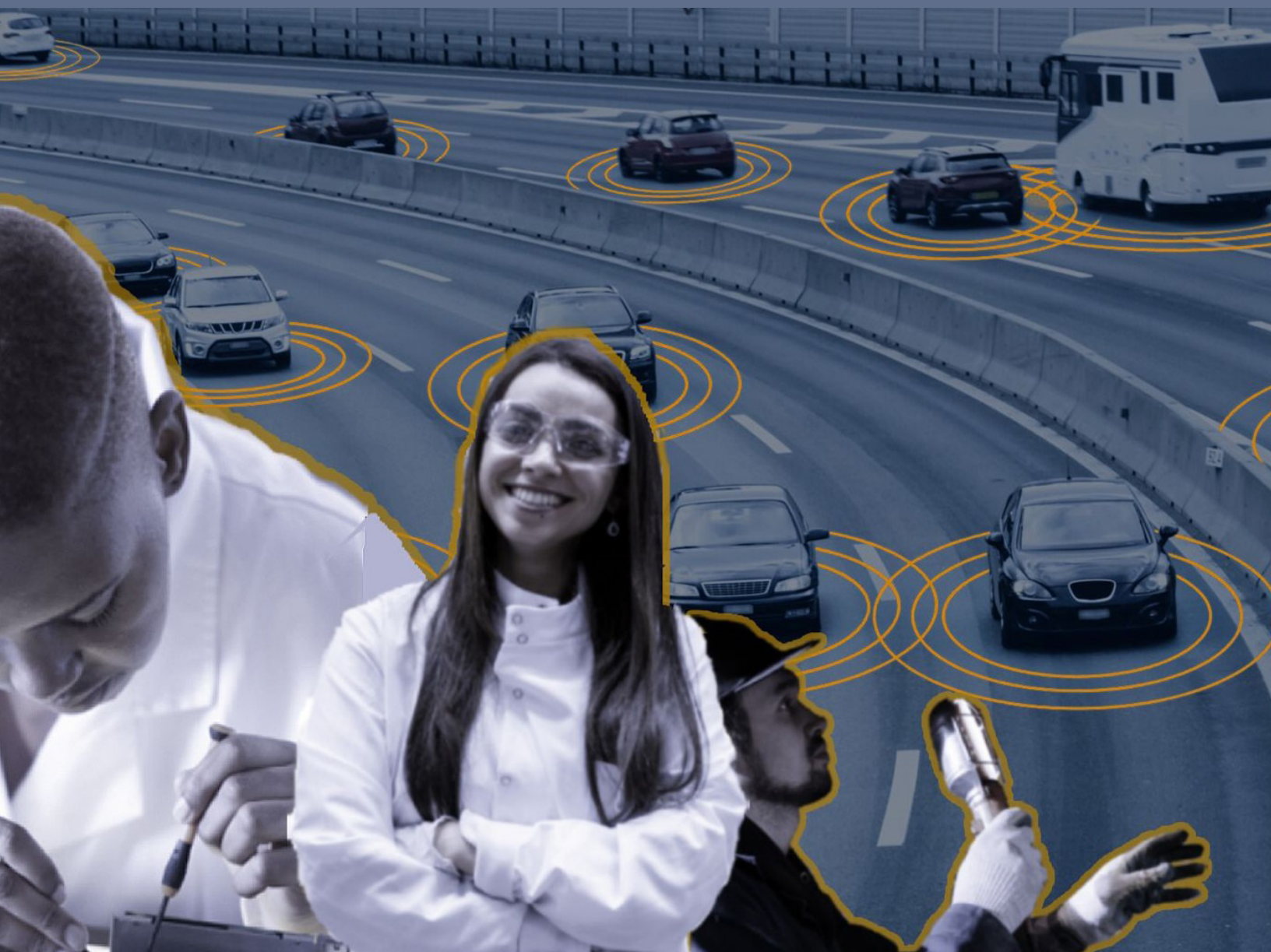
Transportation Association of Canada

Developing Highly Qualified Personnel for an Era of Connected and Automated Vehicles

April 2022



Transportation Association of Canada

Developing Highly Qualified Personnel for an Era of Connected and Automated Vehicles

April 2022

DISCLAIMER

This document is not intended to be used as a basis for establishing civil liability.

The material presented in this text was carefully researched and presented. However, no warranty expressed or implied is made on the accuracy of the contents or their extraction from reference to publications; nor shall the fact of distribution constitute responsibility by TAC or any researchers or contributors for omissions, errors or possible misrepresentations that may result from use or interpretation of the material contained herein.

Information within this report should be considered in the context of local legislation, regulation and policy.

401-1111 Prince of Wales Drive
Ottawa, ON | K2C 3T2
Tel. (613) 736-1350 | Fax (613) 736-1395
www.tac-atc.ca

ISBN# 978-1-55187-713-6
TAC Publication Code: PTM-DHQP-E

TAC report documentation form

<table>
<tr><td colspan="3">Title and Subtitle
Developing Highly Qualified Personnel for an Era of Connected and Automated Vehicles</td></tr>
<tr><td>Report Date
April 2022</td><td>Coordinating Agency and Address
Transportation Association of Canada
401-1111 Prince of Wales Drive
Ottawa, ON K2C 3T2</td><td>ITRD No.</td></tr>
<tr><td colspan="2">Author(s)
MORR Transportation Consulting Ltd.
• Jeannette Montufar, Ph.D., P.Eng., PTOE
• Jonathan D. Regehr, Ph.D., P.Eng.
• Sanjana Mada, M. Plan., B.Arch.
• Michael Olfert, B.Sc., EIT</td><td>Performing Agency Name and Address
MORR Transportation Consulting Ltd.
201 – 1465 Buffalo Place
Winnipeg, MB R3T 1L8</td></tr>
<tr><td colspan="2">Abstract
Connected and automated vehicles (CAVs) and other disruptive technologies offer the potential for a more effective, efficient and integrated transportation system. As connectivity, automation, sensing and artificial intelligence technologies permeate our transportation networks, and as the level of diffusion of CAVs grows, there will be significant changes in terms of the skills needed to plan, design, operate and maintain our transportation systems.

Because many CAV and other disruptive technologies are outside the scope of traditional transportation engineering, road authorities will face substantial challenges unless they are able to develop a suitable body of highly qualified personnel (HQP) that can work within this new ecosystem, offering the knowledge required to understand vulnerabilities and cybersecurity implications while working with legacy equipment that is brought online.

Based on a comprehensive literature review and engagement with road authorities, academics, professional organizations and other industry stakeholders, this report provides an action plan to help address the skills gap in Canada, with particular emphasis on domestic talent development, training of existing personnel, and staff recruitment and retention.</td><td>Keywords
Economics and administration
Vehicle design and safety
• Autonomous vehicle
• Connected vehicle
• Education
• Personnel
• Technology
• Transport authority</td></tr>
<tr><td colspan="3">Recommended citation
Montufar, J., Regehr, J., Mada, S., and Olfert, M. 2022. Developing Highly Qualified Personnel for an Era of Connected and Automated Vehicles. Ottawa, ON: Transportation Association of Canada.</td></tr>
</table>

Acknowledgements

Project Funding Partners

- British Columbia Ministry of Transportation and Infrastructure
- City of Ottawa
- City of Toronto
- Ministère des Transports du Québec
- Ontario Good Roads Association
- Transport Canada
- Yukon Highways and Public Works

Project Steering Committee

- Omar Choudhry, City of Ottawa (Co-Chair)
- Fahad Shuja, Ontario Good Roads Association (Co-Chair)
- Brigid Canil, British Columbia Ministry of Transportation and Infrastructure
- David Johnson, Ministère des Transports du Québec
- Ryan Lanyon, City of Toronto
- Adriana Lovric, Transport Canada
- Ken Moshi, Transport Canada
- Amanda Price, Yukon Highways and Public Works

Project Consultants

- Jeannette Montufar, MORR Transportation Consulting Ltd.
- Jonathan D. Regehr, MORR Transportation Consulting Ltd.
- Sanjana Mada, MORR Transportation Consulting Ltd.
- Michael Olfert, MORR Transportation Consulting Ltd.

This project was managed by Yuriy Shelkovyy of the Transportation Association of Canada.

Executive summary

Connected and automated vehicles (CAVs) and other disruptive technologies offer the potential for a more effective, efficient and integrated transportation system. As connectivity, automation, artificial intelligence (AI), and sensing technologies permeate our transportation networks, and as the adoption of CAVs grows, there will be significant changes in terms of the skillsets needed to plan, design, construct, operate and maintain our transportation systems.

Because many disruptive technologies are outside the scope of traditional transportation engineering, road authorities will face substantial challenges unless they are able to develop a suitable body of highly qualified personnel (HQP) who can work within this new ecosystem and have the knowledge needed to understand vulnerabilities and cybersecurity implications, while still working with legacy equipment that is brought online. This will require that agencies take an active role in fostering a pipeline of HQP talent, possibly collaborating with educational institutions, or implementing innovative approaches to workforce development.

This report recommends actions to help address the skills gap in Canada, with particular emphasis on domestic talent development, training of existing personnel, and staff recruitment and retention.

Findings from the literature

The following key findings emerged from a review of the literature conducted during this study:

- There will be significant changes to the transportation system in the next 20 years that will impact all aspects of a road authority's role in the planning, design, operation and maintenance of transportation infrastructure. While there are still many unknowns about the transition to CAVs and other disruptive technologies, much of the literature predicts some level of adoption of highly automated vehicles by 2040.
- Disruptive technologies will bring about continual change and growth in the workforce, and new skills will be required. Many practitioners will need greater knowledge related to computer programming, artificial intelligence, GIS, geomatics, big data analytics, cybersecurity and intelligent transportation systems. Many new technologies will generate massive amounts of data that agencies will have to manage effectively.
- University undergraduate core courses deal with traditional transportation topics such as traffic engineering, transportation planning, public transportation, and design; content related to disruptive technologies is taught within these courses. At the graduate level, it is more common to see specialized courses addressing advanced technologies.
- Critical workforce development challenges include a lack of understanding of technical positions, competing priorities for hiring between information technology (IT) and transportation departments, collective bargaining issues, the slow pace of government staffing changes, changing workplace demographics, rapid technological shifts, and unbalanced competition for skilled labour between the public and private sectors.
- Key opportunities to overcome workforce development challenges are grouped into four categories: workforce development partnerships; human resources and hiring processes; training and development programs; and promotion, recruitment and retention.

Findings from stakeholder engagement

The following key findings emerged from stakeholder engagement conducted during this study:

- Skillset gaps exist today in data analytics, computer programming, cybersecurity, traffic engineering and soft skills.
- While necessary future skills are being taught in computer science and electrical and computer engineering programs, this is not being done in sufficient depth.
- As technology becomes more complex, data management will require a variety of specialists such as data cleansing experts, data brokers and consortium managers.
- The lack of professionals with backgrounds in both transportation engineering and computer science is believed to be slowing innovation in the industry, and may be putting transportation systems at risk.
- It is unclear who should be taught the skills that are needed in the future, and the inflexibility of current academic curricula is a barrier to changes in the education of HQP.
- There is a mismatch between curriculum taught in high schools and the knowledge required at the university level.

Gap analysis

The gap analysis conducted based on information from the literature review and stakeholder engagement resulted in the identification of gaps in three key domains, as summarized in Table E1.

Table E1: Identified gap areas

Educating the future transportation workforce	Training the existing transportation workforce	Human resources practices and agency governance
• Technical skillset gaps • Non-technical skillset gaps • Coordination with primary and secondary educational curricula • Post-secondary curriculum design and professional accreditation standards • Linking graduates to jobs in the transportation industry	• Technical skillset gaps • Non-technical skillset gaps • Linkages with educational institutions • Mentorship and knowledge transfer • Development of professional networks	• Employee recruitment • Employee retention • Equity, diversity and inclusion (EDI) and HQP development • Barriers between functional areas within a road authority • Performance-based decision making and data governance • Procurement processes • Unionized workforces • Coordinated and reliable funding

Action plan

The report presents 35 recommended actions grouped in three major themes:

- Educating the future transportation workforce
- Training the existing transportation workforce
- Human resources practices and agency governance

Each recommended action includes a description, a list of gaps addressed, an implementation timeline, a list of principal enablers and supporting actors, and a list of Autonomous Vehicle Readiness Index (AVRI) categories addressed.

The list of recommended actions is followed by several guiding principles for implementation:

- ***Collaborate*** – Collaboration at an early stage of workforce development can help expand the pipeline of future HQP, as well as improve opportunities for training and retraining of existing HQP.
- ***Plan and evaluate*** – It is important that road authorities develop clear and realistic plans that will support workforce development in a way that supports technical and personal growth. The effectiveness of these plans should undergo continual evaluation to ensure success.
- ***Encourage growth*** – Strong performance should be recognized to ensure continued growth as well as to encourage others.
- ***Empower employees*** – Encourage and enable employees to act with respect to their professional and technical growth within the organization.

Finally, a number of organizations are identified as key enablers and supporting actors, and their roles are described briefly. In order of appearance, they are:

- Canadian Engineering Accreditation Board (CEAB)
- Educational institutions
- Provincial road authorities
- Private industry
- Engineering licensing bodies
- Professional organizations
- Transportation Association of Canada (TAC)
- Employment and Social Development Canada
- Transport Canada
- Natural Sciences and Engineering Research Council
- Immigration and Citizenship Canada
- TAC Foundation

TAC is not only implicated in several recommended actions, but it can play an overall enabling role in undertaking several higher-level “meta-actions”. Specifically, it can engage with partner and ally organizations to build their understanding of and commitment to shared objectives, possible actions and mutual benefits.

Glossary

Artificial intelligence. Artificial intelligence (AI) is a field that combines computer science and robust datasets to enable problem solving. It also encompasses sub-fields of machine learning and deep learning, which are frequently mentioned in conjunction with artificial intelligence. These disciplines are comprised of AI algorithms which seek to create expert systems that make predictions or classifications based on input data.

Connected and automated vehicles (CAVs). CAVs include features of connected vehicles and/or automated vehicles. A connected vehicle (CV) uses wireless communications technologies to communicate with its surroundings; depending on the features it has installed, a CV may be able to communicate with its occupants, other vehicles and road users, nearby transportation infrastructure including roadways and traffic signals, and/or the cloud. An automated vehicle (AV) uses a combination of sensors, controllers, onboard computers and sophisticated software to control some driving functions instead of a human driver (e.g., steering, braking, acceleration and checking/monitoring the driving environment).

Deep learning. Deep learning is a subset of machine learning, which is essentially a neural network with three or more layers. Neural networks attempt to simulate the behavior of the human brain—albeit far from matching its ability—and "learn" from large amounts of data. While a neural network with a single layer can still make approximate predictions, additional layers help optimize and refine for accuracy.

Disruptive technologies. Disruptive technologies include: (a) hardware or software considered foundational to CAV development and deployment; (b) hardware or software considered foundational to smart cities initiatives, including the internet of things and digital twinning; (c) technologies encompassed by ITS architectures; (d) the suite of advanced analytical approaches encompassed by AI (e.g. machine learning, big data analytics, applied statistics, computer programming, geo-spatial analysis) that independently or collectively support the foregoing technologies.

Highly qualified personnel (HQP). Highly qualified personnel have a tertiary education degree or at least five years of relevant professional experience that may also include doctoral training.

Intelligent transportation systems (ITS). ITS include electronics, communications or information processing used along or in combination to improve the efficiency or safety of a surface transportation system.

Internet of things (IoT). Internet of things (IoT) is a networking capability that allows information to be sent to and received from objects and devices (such as fixtures and kitchen appliances) via the Internet.

Machine learning. Machine learning is a branch of artificial intelligence (AI) and computer science that focuses on the use of data and algorithms to imitate the way that humans learn, gradually improving its accuracy.

Mobility-as-a-service (MaaS). Mobility-as-a-service (MaaS) packages multiple transport services into a single service that is accessible on demand. A typical MaaS operator offers a diverse menu of transport options such as public transit, taxi/ridehail, car rental, carsharing, or shared bikes or e-scooters.

Table of contents

List of figures

List of tables

1. Introduction

1.1 Context

Connected and automated vehicles (CAVs) and other disruptive technologies offer the potential for a more effective, efficient and integrated transportation system that can result in improved safety, reduced congestion, increased accessibility, and environmental benefits. As connectivity, automation, artificial intelligence (AI), and sensing technologies permeate our transportation networks, and as the adoption of CAVs grows, road authorities can expect to be affected by these technologies through new opportunities to leverage their benefits, new expectations in service delivery, and potential changes in resource allocation, while still operating and maintaining legacy systems that could have lifespans of several decades.

The adoption of these disruptive technologies will require a very different set of skills than those needed to support legacy systems. Research by Gringas (2016) states that CAVs will shift a significant proportion of jobs away from materials, mechanical, and manufacturing fields, and towards computer hardware, software, and information technology (IT) services. Further, Canada's Council of Ministers Responsible for Transportation and Highway Safety (2019) indicates that "in preparing for [CAVs], governments will have to rethink traditional forms of mobility and urban planning. We need to monitor potential impacts of [CAV] technologies to help us plan in the long term. Being proactive will help governments do their part to prepare the public domain for the promises of [CAVs]."

Because many disruptive technologies are outside the scope of traditional transportation engineering, the road authorities responsible for planning, assessing, integrating, managing, and deploying these technologies will face substantial challenges unless they are able to develop a suitable body of highly qualified personnel (HQP) who can work within this new ecosystem and have the knowledge needed to understand vulnerabilities and cybersecurity implications, while still working with legacy equipment that is brought online. This will require that agencies take an active role in fostering a pipeline of HQP talent, possibly collaborating with educational institutions, or implementing innovative approaches to workforce development.

1.2 Objectives and scope

This project was initiated to understand the skills gap faced by road authorities as rapid advances in connectivity, automation, artificial intelligence, and sensing technologies continue to permeate transportation systems. Its goal was to propose training and academic programs that could be implemented by Canadian stakeholders over the coming years to address that skills gap.

The following objectives were met as part of this project:

- Identify and explain the key technology and mobility trends that will impact road authorities over the next 20 years, to provide the context for a skills gap analysis.
- Outline and assess the HQP skillsets that road authorities need for future road infrastructure systems, and suggest whether those skillsets represent an incremental enhancement to existing job categories or whether they require the creation of new job categories or staff groups.

- Review reputable global ranking studies, to identify specific opportunities in HQP skills development that could enable Canada to become a leader in the provision of a safe, efficient, and environmentally friendly transportation system in a CAV world.
- Inventory university, college and professional training programs related to HQP skillset requirements in Canada, to identify gaps and help assess the extent to which Canada can develop that talent domestically.
- Examine how leading Canadian and international jurisdictions are approaching the skills gap (e.g. through training programs, academic collaboration, or recruitment and retention strategies), and what lessons may be learned from their efforts to meet HQP challenges arising from disruptive technologies in other sectors (e.g. digital government, e-services).
- Recommend actions over the short term (five years), medium term (10 years) and long term (20 years) to address the skills gap in Canada, with a particular emphasis on domestic talent development, training of existing personnel, and staff recruitment and retention.

While there are many important aspects of recruiting, training, diversifying, and retaining staff that are being reviewed and updated by road authorities, this study focused solely on the current and anticipated technical skills gaps in dealing with new innovations and technologies that are expected to affect transportation agencies' delivery of the following services: planning, design, construction, operations, maintenance, and management.

1.3 Approach

Literature review

A comprehensive review of national and international literature on future transportation technologies, workforce development challenges and opportunities, core competencies for HQP, and workforce training was conducted. The literature review included engineering periodicals, journals, readily available papers and texts, conference proceedings, academic reports, books, and government and industry reports. The literature review identified 123 publications that address the issues investigated in this project and after further examination of these documents, 75 were deemed to be uniquely applicable to this project. The results of the literature review are presented in Chapter 2.

Stakeholder engagement

Stakeholder engagement was a major component of this project, involving the participation of representatives from road authorities, academia, professional associations, and technology industry.

The intent of the engagement process was to assist with the following:

- Outline and assessment of future HQP skillset needs of road authorities.
- Inventory of university, college, and professional training programs related to HQP requirements in Canada to identify gaps and help assess to what extent Canada can develop the talent domestically.
- Examination of how leading Canadian and international jurisdictions are approaching the skills gap, and lessons learned from their efforts to meet HQP challenges arising from disruptive technologies in other sectors.

- Identification of existing opportunities for agencies to close the skillset gap and to meet HQP challenges arising from disruptive technologies in other sectors.

Chapter 3 of this report provides a detailed description about the engagement process for each of the stakeholder groups.

1.4 Organization of this report

Chapter 2 presents results of the literature review. It discusses the future of transportation technology, focusing on expected developments in the next 20 years and associated core competencies in a disruptive technology era. The chapter then discusses workforce development challenges and opportunities for road authorities. Throughout the chapter, each section starts with an overview of findings, followed by details from the literature review on the given topic.

Chapter 3 presents details associated with the stakeholder engagement process. Four different stakeholder groups were engaged as part of this project: road authorities, academics, professional associations, and the technology industry. For each stakeholder group, the chapter includes a description of the engagement approach and key findings pertaining to the engagement objectives for the given group.

Chapter 4 summarizes outcomes of a gap analysis that was based on information obtained from the stakeholder engagement process and the literature review. The chapter addresses the following issues: (1) whether the required skillsets by road authorities represent an incremental enhancement to existing job categories or the creation of new job categories or staff groups; (2) types of training and academic programs that are needed, and that could be implemented by Canadian stakeholders over the coming years; (3) issues that may prevent Canada from developing the HQP talent domestically, and associated opportunities to overcome these issues; and (4) issues in HQP skills development that could prevent Canada from becoming a leader in workforce development for a disruptive technology future, and associated opportunities.

Chapter 5 recommends actions for the short term (five years), medium term (10 years) and long term (20 years) to address the skills gap in Canada, with particular emphasis on domestic talent development, training of existing personnel, and staff recruitment and retention.

Note that this report is accompanied by two **technical appendices under separate cover**: Appendix A details the literature review discussed in Chapter 2, and Appendix B details the engagement process with road authorities discussed in Chapter 3.

2. Literature review

This chapter presents highlights of the literature review. It discusses national and international activities related to HQP training; the future of transportation technology, focusing on expected developments in the next 20 years and associated core competencies in a disruptive technology era; and workforce development challenges and opportunities for road authorities. Complete details of the literature review are included in the project appendices (published under separate cover).

2.1 Training highly qualified personnel

A skilled workforce is key to delivering effective transportation-related services across Canada. Due to the multidisciplinary nature of transportation, this workforce comprises people with backgrounds beyond transportation engineering and planning. The successful delivery of transportation systems requires at a minimum the following educational backgrounds: civil engineering, electrical engineering, geomatics engineering, mechanical engineering, computer science, environmental design, statistics, economics, transportation logistics, transportation planning, and others.

With increasing changes in technology, innovation growth, and public expectations regarding mobility, training of highly qualified personnel has become more important than ever. The challenge lies in ensuring that the training provided to new graduates will meet the future demands of transportation systems operating in a world of disruptive technologies.

A survey of Canadian post-secondary institutions and academics/instructors in transportation (TAC, 2020) found the following, based on responses from 64 instructors:

- The most commonly taught subject in transportation programs was reported to be transportation planning (55%). With respect to topics that are related to disruptive technologies, data analytics was reported as being taught by 52% of survey respondents, followed by ITS (38%), CAVs (22%), MaaS (13%), and zero-emission vehicles (8%).
- Data analytics was also identified by 55% of respondents as an important research area. Research in ITS was reported to be conducted by 47% of academics, research relating to CAVs was reported by 38% and research relating to MaaS and zero-emission vehicles was reported by 17% each.
- At the undergraduate level, most core courses deal with traditional transportation topics such as traffic engineering, transportation planning, public transportation, municipal design, and others. It is within these courses that the content of the topics related to disruptive technologies are taught. This means that while academics have reported to be teaching such material, it is not necessarily a full course on the topic but rather, some lectures in the core course. The same can be said about technical elective courses at the undergraduate level.
- At the graduate level, it is more common to see highly specialized courses that address advanced technologies. The following are examples of courses currently being taught by academics across the country at the graduate level:
  - Advanced GIS data modelling
  - Advanced satellite positioning

- Computer applications in traffic engineering
- Computer applications in transportation engineering
- Discrete modelling and simulation
- Intelligent transportation systems
- Spatiotemporal data analytics

As HQP training has become increasingly important, several efforts to improve this training have been implemented in Canada and abroad. The following sections provide information about national and international activities for HQP training for a future of disruptive technologies.

2.1.1 Training initiatives in Canada

National initiatives

At the national level, Canadian skill training is funded by the Employment and Social Development Canada (ESDC) through workforce development agreements with each province and territory. The department, guided by the Future Skills Council, has identified skills related to CAVs that are a key priority for development like AI, cybersecurity and data science. The department funds the Future Skills Center that funds various training programs including the upskilling of vulnerable population groups in Science, Technology, Engineering, and Math (STEM) fields (Core Skills and Rapid Response Program and STEM Skills and an Innovation Mindset for Youth). The center also funds the 'FUSION: Future Skills Innovation Network for Universities' program in six universities across Canada, helping universities bridge the gap between what students are taught and what skill are required in the current STEM workforce. The center also funds more targeted programs like the 'Upskilling Canadian Youth for In-Demand Tech Careers', which through the NPower Canada's Junior IT Analyst program launched low-income, diverse young adults into IT careers by providing no-cost professional and technical skills training, direct job placement, and five years of post-hire services including mentorship and continuing education for career advancement.

The center, through its programs, is developing resources, with the help of public and private partners, for the quicker adoption of digital technologies in Canada (Smart Systems and Digital Technologies for a New Era Program). Several programs related to upskilling the existing workforce have also been funded for industries affected by disruptive technologies, like manufacturing (The Autonomous Microfactory Program), aviation (Aiming Higher: Micro-Credential Training in Aviation and Aerospace Program), trucking (Building the Skills of the Trucking Industry), and computer science (From Data to Decision: AI Training and Professional Certification Program). The center also funds several programs to increase participation of vulnerable population groups like immigrants (Newfoundland Newcomer Employment Resilience Network Program), rural and remote locations (North Coast Skills Hub), and unemployed or under-employed youth (Future City Builders Program) in STEM fields.

CAV training research funding is also provided by the Natural Sciences and Engineering Research Council (NSERC) to various universities across Canada including University of British Columbia and Carleton University. The Council also funds the 'Building Trust in Connected and Autonomous Vehicles (TrustCAV)' Program that aims to attract, retain, and train Canada's future leaders in connected and autonomous vehicles (CAV), as well as address the technological and societal challenges associated with CAV through collaboration between public, academia (e.g. Carleton University, University of Waterloo, University of Ottawa, Queen's University, University of Windsor), and industry leaders (e.g. Blackberry, Nokia, Cohort Systems, Ericsson, and Solana Networks).

The Canadian federal government also provides workforce skills and training-related research and funding through Transport Canada. Automated and Connected Vehicles Gateway is an online platform of Transport Canada that aims to build a network of professionals in the federal government and beyond to share information and connect with subject matter experts across functional communities. Transport Canada has also initiated a Program to Advance Connectivity and Automation in the Transportation System (ACATS) to help to prepare Canada for the wider use of connected and automated vehicles on our roads. Through this program, Transport Canada has provided funding to the City of Saskatoon to support capacity building on connected and automated vehicles. In addition, the ACATS program is also leading the development of cybersecurity tools, guidance, and training for road infrastructure systems across Canada.

The federal government is also funding AI commercialization research, guided by the Artificial Intelligence (AI) Commercialization Working Group. Additionally, the Canadian Centre for Cybersecurity's Learning and Innovation Hub (LIH) provides training for mid to senior level practitioners and decision makers on how to apply cybersecurity solutions within their transportation engineering and administrative systems.

Provincial initiatives

Some provinces in Canada, like Ontario, have taken further steps to strengthen their transportation workforce by developing and implementing HQP training plans at the provincial level. The Driving Prosperity: The Future of Ontario's Automotive Sector Report emphasizes the need for a more modern skills trades apprenticeship system through initiatives like a micro credentialing pilot for skilled trades and technology and modernization of the apprenticeship program. The program also emphasizes the need for more STEM graduates with an understanding of disruptive technologies, particularly AI, through initiatives for re-employment for adversely impacted autoworkers, creation of online learning systems, and creation of industry internship and fellowship opportunities. The province also funds the Autonomous Vehicle Innovation Network (AVIN) initiative that supports the commercialization of best-in-class, made-in-Ontario solutions, and helps Ontario's transportation systems adapt to emerging technologies. One of the key programs of this initiative is the talent development program that funds a program that provides students and recent graduates from Ontario colleges and universities with real-world industry experience, by applying their expertise, leading-edge knowledge, and tools to solve industry problems related to CV/AV technologies. Provincial workforce development groups, like the Eastern Ontario Training Board, also provide upskilling and reskilling training and courses related to digital technologies.

Recognizing the need to invest in cybersecurity skills, the Province of Nova Scotia has invested in four universities to expand and enhance their computer science programs to increase related talents within the province in the future.

Educational institutions

Several Canadian universities, in partnership with public, private and NGO partners, have developed upskilling and reskilling programs for specific transportation sectors like the British Columbia Institute of Technology's (BCIT) EV Maintenance Training Program, funded by Clean B.C., that aims to help auto technicians develop skills required to work on EVs in service centres across B.C. The Southern Alberta Institute of Technology's Corporate Training Solutions Division, in collaboration with Alberta IoT, has created a Fast Track Program designed to help executives in established tech companies scale their

operations and accelerate growth by incorporating IoT technology. The Southern Alberta Institute of Technology also hosts the DX Talent Hub, which through its programs, provides a framework and the fundamental training necessary to help individuals and organizations overcome challenges associated with understanding, starting, and excelling in a digital world.

The University of Windsor in Ontario has launched the SHIELD Automotive Cybersecurity Centre of Excellence to build the skills, innovations, and policy to secure and protect connected and autonomous vehicles. The Automotive Parts Manufacturing Association (APMA) and SHIELD will collaborate to develop market-based cybersecurity technologies to meet the needs of producers and consumers of advanced transportation systems. Currently there are 125 cybersecurity and cybersecurity-related programs offered by sixty-one Canadian post-secondary institutions which is regularly updated on the Smart Cybersecurity Network.

Collaboration between public and private sectors

Increased collaboration between the public sector, private sector, and NGOs has resulted in several transportation skill development research activities and programs. Microsoft Inc. in collaboration with the federal government is providing skilling program to 20 schools in six provinces across Canada, enabling more students to graduate with in-demand data analytics, AI, and cloud certifications. Mitacs, a Canadian non-profit organization that works with 70 universities and both provincial and federal governments to deliver research and training programs, aims to provide a key link between industry and post-secondary institutions. Online course provider Coursera in 2019 partnered with the University of Toronto on a course that will include lessons on AV technologies that include LiDAR, software, motion planning, intersection management and safety.

Funding opportunities in Canada for skills training are constantly being updated and changing. Mentor Works, a Canadian organization, provides a platform to get real time information of available grants and funding opportunities that can be filtered by industry and topic of interest.

2.1.2 Training initiatives in the United States

Government initiatives

The United States government invests in skills training for the transportation sector through various departments and programs, sometimes in collaboration with state universities. The National Network for the Transportation Workforce (NNTW) funds the National Transportation Career Pathways Initiative that established a set of five transportation discipline-focused career pathways that could be deployed within post-secondary education/training institutions nationwide, to begin the development of forward-looking, technology-infused workforce pipelines that would lead students and job seekers into critical occupations within the highway transportation sector. The U.S. Department of Transportation (DOT) Center for Transportation Workforce Development provides national leadership, coordination, and assistance that supports initiatives to develop and expand the country's transportation workforce skills in STEM. The country is also aiming to provide career and technical education (CTE) programs for the nation’s youth and adults as per the Strengthening Career and Technical Education for the 21st Century Act through education-to-employment transition programs (Career Pathways System) and access to cybersecurity skills programs (CTE CyberNet).

The U.S. federal government also funds transportation-related programs and institutes that provide upskilling and reskilling programs in an era of disruptive technologies. Some of the skills covered by these programs include:

- Soft skills (Operations Academy Senior Management Program)
- Transportation systems operations and management (ITS Heartland's University and The National Operations Center of Excellence)
- Maintenance and operation of highways (Regional Operations Forums)
- Technical upskilling (National Highway Institute and U.S. DOT Center for Transportation Workforce Development)

Educational institutions

Several universities across U.S. have skills development and training programs and initiatives. The Pacific Northwest Transportation Consortium (PacTrans) of the universities in Washington, Idaho, Oregon, and Alaska launched the Workforce Development Institute (WDI) at the University of Washington that offers short-term training courses for transportation agency employees as well as students and professionals seeking transportation engineering jobs. The George Mason University (GMU) in Fairfax, Virginia, has provided and continues to provide cybersecurity training and research for several decades, including training for AVs and infrastructure. The Pima Community College in Tucson, Arizona, launched the first-ever autonomous driving certificate program for truck drivers in 2019, in partnership with self-driving truck company TuSimple. Additionally, the Rutgers Center for Advanced Infrastructure and Transportation (CAIT) is currently organizing the infrastructure cybersecurity and emergency preparedness training.

Increased collaboration between the public sector, industry leaders, educational institutions, professional organizations, and NGOs has increased intersectional training within the transportation sector. Professional organizations like the Consortium for Innovative Transportation Education (CITE), ITS Professional Capacity Building Program, American Society of Civil Engineers, Connected Vehicle Trade Association (CVTA), Small Urban and Rural Center on Mobility and Eno Center for Transportation are proving training key for disruptive technologies and the skillsets needed to plan, implement, and manage them. The Florida Local Technical Assistance Program (LTAP) Center, at the University of South Florida, is part of a national initiative to transfer transportation technology through training, technical assistance, and other customer services to local governments and metropolitan planning organizations (MPOs). The Florida Transportation Technology Transfer (T2) Center is part of the University of Florida Transportation Institute (UFTI) and provides workforce development and training, technical assistance, and technology transfer services to national, state, and local transportation and safety partners, and the public. The Transit Training Network (TTN) is part of an industry-wide effort aimed at strengthening transit training programs. It is designed and maintained by the Transportation Learning Center and provides a platform for industry occupational training committee members and local training practitioners to view the most updated industry training standards, and share and rate courseware, and engage in interactive discussion with peers on training related subjects.

2.1.3 Training initiatives in the United Kingdom

Government initiatives

The United Kingdom government has developed several programs and initiatives through its various transportation departments to upskill and re-skill existing workforce within the transportation sector, which is impacted by new disruptive technologies. Some of these include:

- The National Training Academy for Rail (NTAR) is a joint project between the National Skills Academy for Rail (NSAR), the Department for Business, Innovation and Skills (BIS) and the Department for Transport (DfT), with industry partner Siemens. The academy plays a leading role in the new railway skills development programs being driven by NSAR, working with the market to make sure that industry priorities are met.
- Track and Train is a rail paid work placement initiative led by Network Rail where recent graduates benefit from three six-month placements, one at Network Rail and two at either a passenger or freight operator or another company within the rail sector providing graduates with the all-important cross-industry experience to understand all aspects of the railway.
- Re-skilling programs like the Tideway 'returnships' programme, organized in partnership with Women Returners, aims at helping professionals back into work after a career break within the Tideway Tunnel project workforce. Another re-skilling program is the employment of ex-military personnel within the British Telecommunications (BT) business, Open Reach, as they are a unique workforce that is highly trained, highly motivated, highly productive, and therefore highly desirable.
- The National College for High Speed Rail (NCHSR), supported by HighSpeed2 Ltd, aims to train the next generation of engineers for a career in rail, and to upskill the existing workforce with skills for now and the future. The NCHSR is delivered on a hub-and-spoke model, forming links with other educational institutions and employer training facilities, creating a network for rail skills across the country.

Collaboration between public and private sectors

There are increased public sector, private sector, academic, and NGO partnerships that are further developing the transportation workforce in the U.K. The Knowledge Transfer Partnership (KTP) program is an Innovate U.K. initiative linking businesses with a university and a graduate to work on a specific specialized project. Another program is the Steps into Work 12-month programme which involves recent graduates completing three mainly office-based roles within Transport for London (TFL) to get industry experience while completing their post secondary education. Collaboration between Unite, ScotRail and local unions lead to the development of the Under the Union Learning Programme, an apprenticeship programme to facilitate progression paths through the engineering skills grades through workshops and short courses.

Local initiatives for skills training and education also exist like the partnership between Northwest Rail Industry Leaders Group and the Rail Forum East Midlands (RFM) that brings together businesses to support the rail industry in the region.

Initiatives to address supply chain, human resources and procurement challenges have also been introduced. The Railway Industry Association initiated the Value Improvement Program (VIP), which is a

workshop-based initiative aimed at increasing supply chain efficiency and performance by improving culture and behaviors within the organization. The Transport for London's (TfL) Supplier Skills Team (SST) works in partnership with the supply chain to address skills shortages within the transport and engineering sectors, supporting their suppliers to have the right people with the right skills to deliver TfL's business plan. Since the project was initiated in 2009, the SST has supported the supply chain to create over 4,500 apprenticeships and bring over 5,000 workless people into employment.

2.2 The future of transportation technology

There will be significant changes to the transportation system in the next 20 years that will impact all aspects of a road authorities' role in the planning, design, operation, and maintenance of their transportation infrastructure. While there are still many unknowns about the transition to CAVs and other disruptive technologies, much of the literature predicts some level of adoption of fully autonomous vehicles by 2040. At a high level the CAV ecosystem comprises internet-of-things (IoT) devices, networking capabilities, and telematics. Key CAV technology advancements in the next 20 years noted in the literature include:

- *Vehicle characteristics* – advanced battery technology and electric drive train systems
- *Computing* – software for real-time control, detect-and-avoid systems, artificial intelligence, machine learning, deep neural networks, onboard infotainment, and cybersecurity
- *Avoidance systems* – computer vision systems, short-range and long-range radar, light detection and ranging (LiDAR), photogrammetry, event data recorders, and dashboard cameras for 3-D reconstruction of collisions
- *Navigation systems* – simultaneous localization and mapping (SLAM), CV hardware to retrofit unconnected vehicles
- *Communication infrastructure connectivity* – wireless technologies like dedicated short-range communications (DSRC), 5G cellular, cellular vehicle-to-everything (C-V2X), and Bluetooth roadside beacons

In the future, it is also expected that road authorities will experience a gradual transition to "smart cities" to support the sharing of information between AVs and roadway infrastructure. For example, the deployment of roadside sensors that monitor real-time traffic operations and communicate information directly to AVs, helping them make routing decisions based on real-time traffic conditions.

This transition will be accompanied by increased requirements for collection and sharing of data in real time using various technologies and the application of big data for various applications such as safety analysis, mobility, asset management, and others.

From a road authority perspective, an important challenge will be related to cybersecurity. Road authorities will need to establish policies specifying the testing and deployment standards and regulations, as well as policies for data access and data sharing. There will also be a need to invest in operational devices and hardware systems that allow for the proper integration of new technologies within the network of connected infrastructure in a cyber secure manner.

2.3 Required core competencies

Emerging technologies from the CAV ecosystem will impact all aspects of the transportation system that may "cover a technical spectrum as broad as the engineering disciplines that are the foundation for these technologies" (ICTC & CAVCOE, 2020). Most of these potential impacts are important to consider because individual road authorities across Canada are responsible for a varying degree of the transportation system that may include regulation, policy, security, planning, design, construction, and maintenance. This excludes auto manufacturing, auto maintenance, and drivers.

Current skills needed

Currently, the following skills are required for existing occupations that involve disruptive technologies, as related to road authorities:

- Widespread programming background (e.g. Java, Python, JavaScript)
- Cloud service development
- Cloud database (e.g. SQL Server, MongoDB) administration on data cloud platform/services like Azure and AWS
- Machine learning
- Messaging protocols (DDS, MQTT, AMQP, NTCIP, TMDD, and various SAE and IEEE message and data sets)
- Knowledge of Scrum/Agile software development process
- Experience testing interactivity of desktop controlling hardware products
- Automation tool and scripting experience for both front end and APIs
- Advanced statistical analysis, signals processing, filter design, optimization, system identification, and state estimation
- Data mining, neural networks, and supervised/unsupervised leaning classification methods

Future skills needed

The gradual implementation of disruptive technologies will bring about continual change and growth in workforce requirements and with increased diffusion of these technologies, new skills will be necessary. As reported in the literature, people working with CAVs and other disruptive technologies in the future will need to have greater knowledge in the following key technical areas:

- Computer programming
- Artificial intelligence
- GIS, surveying, and geomatics
- Big data analytics, management, integration, storage and security
- Cybersecurity
- New construction technologies
- Intelligent transportation systems

In addition, the future calls for increased demand for the following non-technical skills:

- Critical thinking
- Communications (verbal and written)
- Complex problem solving
- Reading comprehension
- Decision making

Key occupations that will be required to support the CAV ecosystem identified in the literature include:

- In addition to the foundational training in transportation engineering and planning, civil engineers will need to have increased knowledge in computer-aided design (CAD), engineering design, inspection, construction management, civil 3D, and mathematics.
- Post-secondary graduates in information and communications technology occupations. Graduates can leverage upskilling throughout their careers to keep pace with evolving technologies.
- Mobility managers who understand the balance and needs of public, private, and social enterprise mobility providers. This will help to establish relationships that adequately address intellectual property, data sharing, data security, and public privacy. This leadership role would be able to negotiate contracts with private mobility provides that protect citizen safety and convenience.

The disruptive technology ecosystem will produce significant amounts of data that agencies will have to effectively manage. The occupations and skills required to manage data/information from collection to decision making are:

- *Chief data officers* – to lead agencies in organizing their data
- *Telematics software architects* – to develop integrated mobile usage and AV monitoring systems
- *Big data analysts* – to handle the large amount of data and improve practice
- *Data managers and administrators* – to administer cloud databases and development services
- *Database integration architects* – to handle storage, movement, and analysis of data
- *Software engineers, developers, and quality assurance analysts and testers* – to develop and maintain software programs
- *GIS specialists including analysts, programmers, and business intelligence specialists* – to develop and maintain geospatial location intelligence, a primary way of sharing data for project collaboration
- *Data scientists and analysts* – for supervised/unsupervised learning classification methods, advanced statistical analysis, signals processing, filter design, optimization, system identification, and state estimation
- *Machine learning engineers* – for artificial intelligence, data mining, deep learning, and neural networks
- *Application-based programmers* – with automation tools and scripting experience, for both front end and application programming interphase (APIs)

- *Survey and geomatics specialists* – to ensure a high level of ground precision in the construction road infrastructure to support AV navigation
- *Cybersecurity architects* – to create cybersecurity risk management plans, requiring expert knowledge on network security, cryptography, systems architecture, and information security
- *Cybersecurity engineers* – to mitigate cybersecurity vulnerabilities by managing cybersecurity architecture and managing system risk, with wired and wireless network and information security, programming and scripting skills, and solid knowledge of access control, authentication and cryptography
- *Vulnerability testers* – to conduct and document vulnerability tests, with experience in vulnerability assessment, penetration testing, networking protocols, data analytics, data management, data security, coding and scripting, access control, authentication protocols, cryptography, and intrusion detection and prevention systems
- *Cybersecurity incident analysts* – to monitor the cybersecurity health of operational technology and field systems, possessing the ability to respond to cybersecurity incidents including logging and initiating the incident response protocol from the risk management plan; also experienced in intrusion detection, prevention systems, and cybersecurity monitoring solutions

2.4 Key challenges and opportunities

Numerous workforce development challenges and opportunities were identified in the literature.

Challenges

- Lack of understanding of technical positions (e.g. technical skills, need for these skills, and compensation expectations). This is a problem when current managers are unfamiliar with data analysis and software and do not understand the need to hire these technical positions.
- Hiring of technical positions is handled by IT departments which have different objectives than transportation departments.
- Technical positions may fall under different unions than typical engineering/transportation positions or may not yet exist under any union.
- Large bureaucracies require time to implement staffing changes.
- Coinciding with the emergence of disruptive technologies is the significant shift of workplace demographics caused by an ageing population moving into retirement.
- The rapid change in technology outpaces the ability of traditional education programs to deliver consistently relevant materials.
- Public agencies struggle to compete with the private industry in workforce attraction due to salary disparity, career advancement, on-the-job training, flexible work schedules, employer branding and marketing, and opportunities for personal fulfillment. Public agencies are slower to adopt new forms of workforce engagement (e.g. LinkedIn, Twitter, Facebook) that have become the norm in attracting this dynamic labour market.

Partnership opportunities

- Consult regularly with government, educators, and other civic association to stay informed about technical workforce development issues.
- Establish a high-level team of public agency and university departments of civil, electrical, data science, and computer science to develop a plan to update university transportation programs and agency workforce development in coordination.
- Work with colleges and universities to help them develop real-time curriculum which could include conducting a capstone/research project with regional and local planning agencies for credits that are essential to fulfill the degree requirements.
- Develop targeted reskilling programs individually or through public-private partnerships.
- Transform work culture through industry innovation hubs, collaboration with start-ups, and company exchange programmes.

Human resources and hiring opportunities

- Remove barriers to worker mobility that include licensing and certification requirements that do not relate to public safety.
- Develop custom positions descriptions, core competencies, and recruitment strategies for new positions related to CAV technologies.
- Include knowledge transfer as a part of projects to have consultants train staff.
- Create a new model of procurement that enables the timely engagement of preapproved product and software companies as contractors to accomplish tasks on a week-by-week task order basis rather than a year-by-year RFP basis.
- Ensure that the correct key words are used in new position titles and that job postings actively appear on the top of search engine lists.

Training and development opportunities

- Develop a career training/paths program to provide a consistent level of service including necessary training opportunities at the right time by promoting competencies through accreditation/certification.
- Develop credentialed and stackable training programs to support organizational workforce development goals.
- Develop customizable training modules that include online training, classroom modules, on-the-job training, and mentorship programmes to meet industry-wide upskilling needs.
- Provide upskilling incentives and resources for employees to pursue continual training throughout their carriers. Consider developing a list of highly valuable emerging skills and the corresponding training that employees can pursue.
- Support apprenticeship programs that link practical work experience with training and coursework.
- Integrate technical studies and apprentice programs for high school and college students.
- Create or adopt skills taxonomies which will allow an evaluation of employees' current skills and mapping them against the skills that will be critical for the organization in the future.

- Initiate a data academy that provides tools and workshops for interested employees where they can learn a wide range of topics on data analysis and visualization. A significant biproduct of the data academy is the development of relationships founded on common data tools that are developed across many departments; this improves cross-departmental interoperability and collaboration on data analysis.

Promotion, recruitment and retention opportunities

- Raise awareness for the value and demand of skilled technical workers in cooperation with government, industry, trade, academic, and labour unions.
- Improve labour market information on the rapidly evolving requirements for skilled technical workers to ensure that workforce development algins with advancements in technology.
- Educate managers and those involved in staffing on the need for data analysis and software positions.
- Attract workforce through increased social media presence, quantification of overall benefit packages, implementation of flexible work schedules and telecommuting, clarification and restructuring of the promotions and incentives to reflect employee performance, and increased communication and feedback between staff and management.
- Target awareness programs for middle and high school students and teachers which could help spread awareness about the road transport industry. An important aspect of this is involving parents as they play a significant role in encouraging child to pursue certain careers.
- Focus recruitment efforts on other industries with similar, transferable skill sets.
- Provide training opportunities for underemployed population groups in the local community.
- Develop second careers in transportation for retirees.
- Promote transportation and technology careers to a young audience that includes K-12 schools.

3. Stakeholder engagement

This chapter presents the process of engaging four key stakeholder groups: road authorities, academics, professional associations and the technology industry (see Table 1). For each stakeholder group, the chapter includes a description of the engagement approach and key findings.

Table 1: Stakeholder engagement

Stakeholder group	Engagement objective	Engagement tool
Road authorities	To understand: • HQP skillsets needed to plan, design, build, manage, maintain and operate future road infrastructure systems • Current skillsets • How Canadian jurisdictions are approaching the skills gap (e.g. through training programs, academic collaboration, or recruitment and retention) • Lessons learned from agencies' efforts to meet HQP challenges arising from disruptive technologies in other sectors • Challenges and opportunities in HQP skills development • Challenges and opportunities to close the skillset gap between education/training and practice	Focus groups with small municipalities, medium municipalities, large municipalities, and highway agencies
Academics	To identify and understand: • University, college, and professional training programs • Current skills in academic programs • Feasibility of domestic talent development for future needs of road authorities • Specific actions to enhance the training of HQPs • Challenges and opportunities in HQP skills development • Challenges and opportunities to close the skillset gap between education/training and practice	Online survey Email Virtual workshop
Professional associations	To understand: • Key technology and mobility trends that will impact road authorities over the next 20 years • Required core competencies for a disrupted technology future in transportation • Workforce development needs for transportation agencies in the next 20 years • Skillset gaps pertaining to emerging CAV technology	Online survey
Technology industry	To obtain insight into: • Key technology trends that are likely to impact road authorities over the next 20 years • Challenges and opportunities to close the skillset gap resulting from disruptive technologies (lessons from other sectors) • Opportunities for HQP skills development where Canada could become a leader in workforce development for a disruptive technology transportation era	Telephone interviews

3.1 Road authorities

Engagement with road authorities involved four focus group sessions involving 25 agencies and 122 people (see Table 2):

- Large municipalities (March 10, 2021)
- Medium municipalities (March 11, 2021)
- Small municipalities (March 16, 2021)
- Provincial agencies (March 17, 2021)

The purpose of this engagement was to develop an understanding of HQP needs of Canadian road authorities. Selected municipalities were invited to the focus group discussions, ensuring that there was not only equal geographic coverage, but also representation from small, medium, and large municipalities, highway agencies, First Nations communities, and multimodal transportation authorities.

The following topics were addressed in each session:

- HQP skillsets needed to plan, design, manage, maintain and operate future road infrastructure systems, particularly in a disruptive technology era
- Currently available skillsets in the various agencies
- How different agencies are approaching the skills gap
- Challenges and opportunities in HQP skills development
- Challenges and opportunities to close the skillset gap between education/training and practice
- Procurement
- Level of readiness for an era of fully diffused disruptive technologies
- Plans for a future of disruptive technologies
- Canada's approach to become a leader in HQP development

Each session started with a 20-minute presentation on the topic, followed by 90-minute breakout sessions for each of planning and design, operations and management, and maintenance and construction.

Summaries of each breakout session are included in the project appendices (published under separate cover). This section presents key findings from the engagement with road authorities on each topic.

3.1.1 Current skillsets

Each group of road authorities agreed that their current workforce has some or many of the necessary skills to do their current jobs. However, there are marked differences between the nature of the skillset gaps between large municipalities and other agencies. While large municipalities appear to have sufficient personnel to deliver services, other agencies struggle with staffing levels. As a result, large municipalities experience a skillset gap resulting from the type of technical knowledge of their workforce, whereas in the case of other agencies, the skillset gap results from a lack of human resources.

Table 2: Agencies participating in focus groups

Large municipalities	City of Vancouver TransLink City of Calgary City of Edmonton City of Toronto City of Ottawa	**Provincial agencies**	Alberta Transportation B.C. Ministry of Transportation and Infrastructure Manitoba Infrastructure Ministry of Transportation of Ontario Ministère des Transports du Québec New Brunswick Department of Transportation and Infrastructure Newfoundland and Labrador Transportation and Infrastructure Northwest Territories Department of Infrastructure Nova Scotia Department of Public Works Saskatchewan Highways
Medium municipalities	City of Winnipeg City of London City of Hamilton Region of Waterloo Halifax Regional Municipality		
Small municipalities	City of Victoria City of Lethbridge City of Fredericton		

Regardless of the reason for the skillset gap and associated magnitude, all agencies have experienced a gradual change in the types of skills needed to deliver services. This has resulted in the following skillset gaps identified by all agencies:

- *Data analytics* – Agencies find they are increasingly having to handle large amounts of data, and the necessary skills are sometimes lacking. While many professionals can manipulate data using spreadsheets, once data sets get to a certain size, the need for big data analytics, coding, and others arise.
- *Computer programming* – Having the ability to write code is increasingly becoming a need equivalent to word processing or other similar skill.
- *Cybersecurity* – As systems become more complex, agencies are finding that only their IT departments can handle elements of network and cybersecurity.
- *General traffic engineering knowledge* – Agencies find that new recruits are not equipped with the technical traffic or transportation engineering knowledge to successfully complete tasks. At the same time, established workforce has difficulty keeping up to date with the most recent developments in traffic and transportation engineering.
- *Soft skills and oral communication* – Agencies often struggle finding people with the right combination of technical competencies and soft skills such as political acumen, communication, and relationship management. In some cases, people who have the technical background and appropriate training may not be properly equipped to communicate with the public, elected officials, senior staff or others.

In addition to the above skill gaps identified by all agencies, large municipalities also identified the following skillset gaps in their workforce:

- *General civil or transportation technology skills and equipment operators* – Agency workforces include people trained as civil or transportation technologists to support various technical

requirements. In addition, maintenance and construction tasks require skilled equipment operators.

- *Managerial and supervisory skills* – Agency workforces generally comprise people skilled at managing multiple projects. Many of these managerial skills are developed on-the-job through years of experience. These people are also often involved in supervising field sites.
- *Contract management* – Some of these agencies are increasingly relying on external services to assist with service delivery. This has resulted in increasing need for contract management skills, regardless of the technical background.
- *Contextualization and 'big picture' thinking* – In some situations where employees can manipulate large quantities of data and computer coding is not an issue, the challenge has been to draw meaningful conclusions resulting from the data analysis. In essence, a skillset that is missing is the ability to extract understanding from the information obtained through analysis of complex datasets.
- *Critical thinking* – While in some cases analysis can be conducted successfully, the reasonableness of the results is not questioned, even in situations where it is evident that the output from the analysis is wrong.
- *GIS and spatial thinking* – Cities are increasingly seeing a need for people that can take spatial data and manipulate it in GIS for better and more effective representation and analysis.

Medium municipalities identified the following additional skillset gaps:

- Electronics and electrical systems
- Any area where there has not been succession planning and the only person with the skills leaves for another job or retires

Provincial agencies identified the following additional skillset gaps:

- *ITS knowledge* – There has been an increasing number of projects involving intelligent transportation systems (ITS), which require knowledge that is currently not part of the agencies' toolbox. While some agencies have people who are dedicated to ITS, most agencies do not.
- *Electrical maintenance and electronics* – particularly for services in rural areas
- *Real-time data collection capabilities* – particularly by technicians who are used to collecting data manually
- Knowledge of specialized design software (integrated design software packages)

An important issue for most small and medium municipalities is that succession planning is not readily available; when people leave for another employer, their knowledge is lost. Further, there is concern that as that as cities grow there will not be enough capacity to take on more work.

3.1.2 Required skillsets

Most agencies, regardless of size, agree that in the future there will be a critical need for people who can manipulate and understand large quantities of data, and be knowledgeable about artificial intelligence, machine learning and cybersecurity. However, while large municipalities believe that they will be prepared for a disruptive technology future as it pertains to HQP, most other agencies believe that there is a high likelihood that they will not be prepared with the right set of skills. Part of the reason

for this is that they operate based on limited resources and following their own Council's directives. To date, elected officials have been more focused on topics such as road safety (e.g. Vision Zero), active transportation plans, and greenhouse gas emission reductions. Until elected officials direct them to investigate issues associated with disruptive technologies, resources may not be made available to approach this subject. In addition, small municipalities believe there are many unknowns regarding a future of disruptive technologies, which makes it difficult for them to know what types of skills will be needed. In their opinion, their workforce will have to evolve to meet any future needs, just like they have done to date with respect to other needs.

Skillsets that were identified by agencies as important in a disruptive technology era include:

- *The ability to lead and manage relevant pilot projects* – At least one city has engaged in a pilot project to evaluate autonomous snow-clearing equipment and requires people to work with the vendor at all stages of this type of project.
- *Cybersecurity knowledge*
- *IoT understanding* – including how to manage the various technological demands associated with it
- *Data science* – an essential skill for most services provided by road authorities
- *Ability to function in more than one technical domain* – e.g. C-V2X communications installation requires a mixture of transportation engineering, electrical engineering, and information technology skills
- *Strong computer programming skills*
- *Ability to engage with the public and stakeholders* – which is increasingly important at the planning level
- *Communication skills* – to help road authorities deliver clear messages to the public on highly technical subjects
- *Combined knowledge in traffic engineering and computer programming*

In general, there appears to be a current and future need for more well-rounded transportation practitioners who are also fluent in areas like computer programming, GIS, data analytics or cybersecurity.

3.1.3 Workforce development challenges

Three major workforce development challenges faced by the four road authority types are expected to intensify in a disruptive technology era: compensation, future skills requirements, and available candidate pool.

Compensation. With respect to compensation, large municipalities indicated that current government compensation structures vs. industry are making it increasingly difficult to attract and retain people with the necessary skills for the ever-evolving employment needs. It is expected that this will intensify in the future, particularly if greater levels of knowledge or specialization are needed. Some large municipalities have found that it is more challenging to recruit people with three or four years of industrial experience than recent graduates as their salary expectations rise significantly. For small and medium municipalities and highway agencies, compensation is also a recruitment and retention issue as they compete with larger municipalities and private industry for the same pool of candidates.

Future skills requirements. The second challenge is knowing what the future skill requirements are for a disruptive technology era. While this issue is of importance to large municipalities, it is not as significant as for smaller municipalities and highway agencies. Some medium municipalities expressed concern being able to write a job description to hire the right type of professional for a disruptive technology era, and small municipalities and some highway agencies indicated that the number of unknowns regarding a future of disruptive technologies prevents them from knowing what types of skills will be needed.

Available candidate pool. This challenge is different for the various agency types. In the case of some large municipalities, the challenge revolves around being able to find the right people in Canada. While in certain cases they can identify the right talent for a given position, many times this talent exists only outside of Canada. This is different for medium and small municipalities, who have indicated that in some cases, because of their unique location, recruitment can be a challenge as they are competing with large municipalities for the same potential employees. Similarly, for highway agencies, the challenge relates to the large rural nature of some jobs and potentially remote locations. Therefore, unless there is a captive recruitment pool, small and medium municipalities, and highway agencies can struggle attracting the right employees.

In addition to these common challenges, two other challenges were raised by at least three groups.

Limited funding for new positions. This issue was raised by all except large municipalities. Between hiring freezes and workforce reductions, some agencies expressed a lack of confidence in being able to function effectively in a future with more complex demands resulting from disruptive technologies.

Working in traditional agency silos. This issue was raised by all except small municipalities. In most cases, engineering departments are separate from IT departments, which does not allow for good communication and knowledge transfer. In addition, IT departments appear to be more concerned with the general business of the agency than with the delivery of transportation services, which hinders collaboration regarding technical issues.

Additional workforce development challenges that were raised include:

- Some road authorities agree that university education does not provide adequate training in transportation systems or the high-tech side of transportation. Many agencies agree that their new recruits tend to be generalists and can be difficult to fully integrate into the workforce right away. In addition, there is consensus that the traditional transportation engineer is not adequately prepared for the demands of today regarding advanced technologies (e.g. DSRC, 4G, 5G, big data analysis, cloud implementation). Similarly, the computer and electrical engineers who do understand these issues have no knowledge of traffic engineering. In a disruptive technology future, it will be challenging to find people who can bring together traditional knowledge about traffic engineering, as well as comprehensive understanding of data analytics, artificial intelligence, machine learning, and others.
- Technology is advancing too fast and there is not enough time to train people or enough graduates with the necessary skills.
- Human resources challenges can include:
    - Agency policies make it difficult to transition employees from temporary to permanent, or from part-time to full-time.
    - Staff turnover and retirements limit the amount of on-the-job experience that junior staff receive before being promoted to supervisory roles.

- Existing job classifications may not be well suited for the type of people that some agencies need to hire for a future of CAVs and smart cities, and there are administrative barriers to creating new job classifications.
- Collective agreements can influence job classifications or hiring decisions through 'line of progression' benefits.

3.1.4 Workforce development opportunities

Road authorities identified five key workforce development opportunities: collaboration with universities and technical colleges; collaboration with industry; outreach to young students; introduction of multi-disciplinary teams; and creation of centres of excellence.

Collaboration with universities and technical colleges. This opportunity involves a variety of elements ranging from collaboration for the purposes of recruitment, training of future graduates, and planning for the future in terms of potential curriculum modifications.

Agencies believe that having access to a strong student program is one way to develop a strong future workforce. As a result, there is an opportunity to work with these educational institutions to hire co-op students as a recruitment mechanism for the future. Similarly, collaborating with educational institutions on innovative projects that can help with student training can present an opportunity for future recruitment of graduates who will have been exposed to the road authority.

An important opportunity lies in establishing a coordinated approach to planning for a future of disrupted technologies jointly with educational institutions. The objective would be to ensure that students receive the necessary education for a future of disruptive technologies. Examples include ensuring that coding and data literacy become a general skill (much like word processing) for any sort of engineering, and ensuring that electricians receive training in computer programming.

Collaboration with industry. Like the opportunities raised with respect to educational institutions, there are similar opportunities for industry in the information and communication technology (ICT) sector. Some of the large municipalities see opportunities by partnering with industry to train existing employees in a variety of ways. For example, agencies can allow industry to test various technologies at select locations in exchange for mentorship/training of select government employees.

Outreach to young students. The targeting of youth is perceived as an opportunity to attract a new demographic into the field. Agencies believe that students need to be engaged at a much younger age (around junior high school level) with respect to computer programming and advanced technologies. The type of engagement at this level may be around the exciting future of advanced technologies and what a person can do if they work in that field. Further, high school students should be taught courses that increase their interest in computer programming and advanced technologies.

Introduction of multi-disciplinary teams. Some highway agencies have experienced success with the formation of multi-disciplinary teams to work on service provision. They see this as an opportunity that could be emulated in a future of disruptive technologies. One approach is to ensure that transportation and IT staff work together to develop standards, processes, and procedures jointly. By doing this, mutual understanding and knowledge about each other's technical issues evolves and learning occurs. Another approach is to pair IT staff with other specialties (e.g. electrical engineers) and transportation staff to stimulate knowledge transfer. This sometimes results in larger teams working together but the experience can be positive as everyone learns from everyone else.

Creation of centres of excellence. Agencies proposed the creation of centres of excellence for CAV and other disruptive technology research and development as a significant opportunity to develop HQP. By establishing centres of excellence at key locations across the country, there would be an opportunity for more formal training of the future and existing workforce. An important aspect of these centres of excellence would be their capability to conduct research and development on issues pertaining to the Canadian context, such as the operation of CAVs in winter. This would create opportunities for HQP development in a unique area of knowledge, over and above other technological issues.

3.1.5 Workforce development initiatives

The focus group discussions revealed several workforce development initiatives undertaken by road authorities. However, the intensity, extent, or frequency of these initiatives is affected by the available resources within agencies. Most medium and small municipalities expressed that available resources for workforce development are limited, which results in limited formal training. In some of these cases, workforce development takes place by employees engaging in self-learning of new skills. Despite these limited resources, however, one small municipality has found success in providing training to all new recruits by sending them on a two-week training course delivered by the Ontario Traffic Council. The reason this agency has chosen to invest in this type of training is that, in their opinion, civil engineering programs do not currently provide a strong enough foundation in transportation engineering for the type of work conducted by the municipality.

At the other end of the spectrum, some large municipalities and highway agencies have implemented programs to financially support staff interested in upskilling and professional training or certification. In addition, because of their unique relationships with industry, large municipalities have been able to assign employees to work with industry so that they can learn from the experts. That knowledge is then transferred back to the agency.

The following are examples of workforce development initiatives that have been found to be successful by many agencies.

Professional development. Opportunities such as conference attendance, short courses, or workshops are deemed to provide good return on investment. In many situations, people who attend conferences or other professional development events share what they learned through ‘lunch and learn’ activities, which are attended by other staff. This has proven to be a successful initiative by most agencies.

Specialized hiring or embedding of unique skills. Another successful initiative that has been implemented by some agencies consists of hiring (or embedding) an IT or GIS practitioner specifically in the unit, therefore ensuring that transportation has direct access to someone with those skills. In addition, collaborating with other branches, divisions, or departments has allowed some agencies to bring some of the highly specialized knowledge needed where it may be lacking.

Rotational training. Some agencies have implemented the practice of starting new recruits doing one specific task, and then they rotate to other groups, so that over time they become well rounded traffic engineers. This also includes being exposed to any new technological aspects in different types of jobs within the department.

Several other initiatives have been implemented informally, mainly by small and medium municipalities and highway agencies:

- Close collaboration with IT staff within the agency. This has allowed for some knowledge transfer regarding specific issues, including information security and how to assess vulnerabilities in their systems.
- Hiring summer students can sometimes help with training of future recruits by providing exposure that will be beneficial if these summer students are hired by the agency in the future.
- Encouraging staff to become involved in professional organizations to ensure they maintain currency is emerging trends.
- Some agencies offer in-house training for people working in the field, particularly those who operate special equipment.
- Internships and mentorship programs are important aspect of agencies' workforce development initiatives. In these cases, senior staff mentor junior staff until they are deemed to be competent in their job.
- Some agencies routinely sponsor capstone design projects to raise awareness about their agency's needs and opportunities amongst graduating students.

3.1.6 Procurement practices

There is consensus among agencies that while they may currently have adequate resources to procure most services, this will change. They are aware that technology will continue to advance and that they will need to have the knowledge in-house to be able to procure and manage contracts. Large municipalities have noticed that the vendor landscape has shifted from one which was primarily comprised of people with transportation backgrounds to big tech firms presenting new ideas but with little understanding about traffic engineering. This means that unless agencies are equipped with the necessary skills to communicate with these vendors, it will be difficult to determine whether these technologies have value and whether they are meeting certain thresholds of accuracy. This has been confirmed by smaller municipalities, who believe that at some point there will be a need for agencies to understand the commonly accepted architecture of how systems work and be able to communicate with vendors using their same language.

Some steps that agencies have taken to improve their procurement practices are:

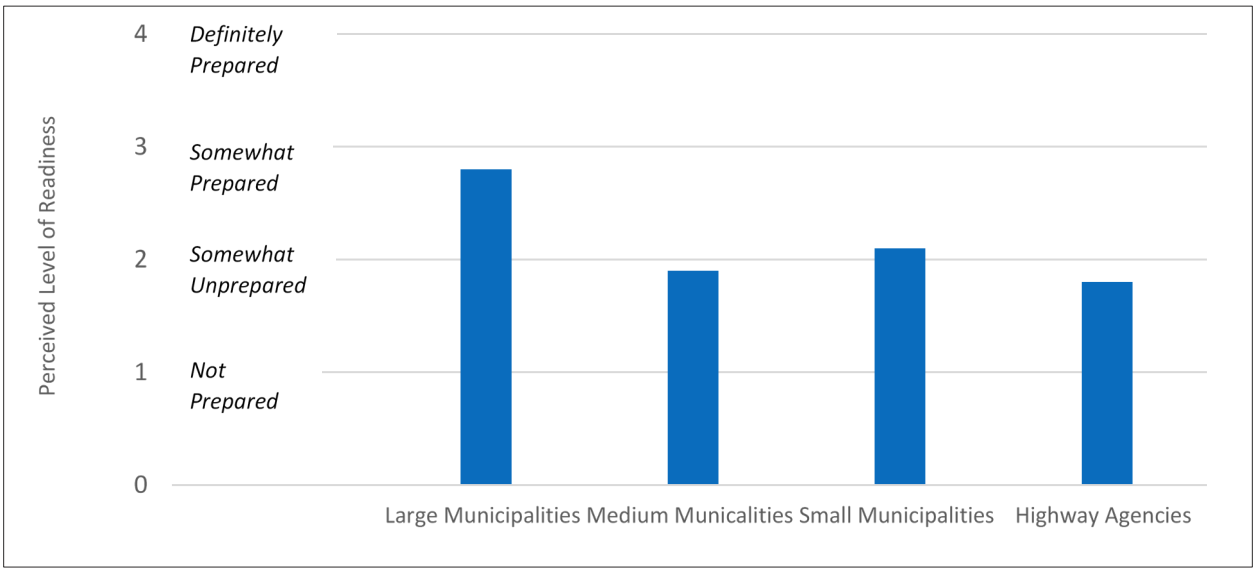
- Embedding procurement staff into their engineering group to assist with the process
- Issuing a request for information prior to a request for proposal to better prepare for appropriate evaluation of bids. However, this adds time to the procurement process
- Forming small working groups or evaluation panels to address procurement issues
- Procuring proof of concept projects where they work with the vendor to make sure that the technology works, and lessons are learned in the first six months of implementation prior to the next stage of a systemwide implementation
- Relying on vendors to assist them through the procurement and technology performance assessment process
- Challenge-based procurement to be able to evaluate novel technologies that have not been tested in the real world. By doing this, the agency can help the vendor understand their ecosystem while gaining comfort with the new technologies. This also poses an opportunity for Procuring future technologies that have not been widely deployed in the real world.

3.1.7 Readiness levels

Participants in each focus group were asked what they thought would be their agency's readiness level with respect to HQP when full diffusion of CAV and smart city technologies is realized. Figure 1 shows the average readiness level identified by each type of road authority.

As Figure 1 shows, only large municipalities believe they will be somewhat prepared. Most medium municipalities have not started planning for a future of CAVs and smart cities. They have not been directed by their councils to undertake work related to a future with disruptive technologies as, in many cases, the current areas of focus are related to road safety, rapid transit, and the environment.

Figure 1: Perceived level of readiness



Small municipalities indicated that there has been no planning for CAVs, smart cities, or any other type of future disruptive technologies. For one agency representative, this TAC project was the first time the topic of CAVs had been formally discussed. These agencies acknowledge the need to plan for disruptive technologies, as their emergence has the potential to drastically impact routine aspects of their jobs, however, there is consensus that there are too many unknowns regarding the future of CAVs or other disruptive technologies, which makes it difficult to plan for their future, particularly in a situation with very limited resources.

Most highway agencies have not engaged in any type of planning for CAVs or similar future disruptive technologies. In some cases, they are looking to other jurisdictions to learn from their experience. In some cases, they expect that the adoption of any disruptive technologies such as CAVs will reside within IT departments. Part of the reason for this is the cybersecurity demands and legal issues that may be associated with the implementation of these technologies. Some agencies, however, have been collaborating with local universities and private industry on demonstration projects (Level 4 systems) in closed geographic areas. One of the agencies has plans to enter a Phase 2 of demonstrations with the installation of sensors/transmitters along the road so that the traffic management centre can send messages directly to the vehicles through these transmitters. Another agency has been putting sensors in road construction barrels and roadside devices for communication with vehicles. One agency has

formed a working group to develop principles and policies needed for vehicle technology testing. There is also pending legislation to allow for this testing.

Actions undertaken by large municipalities to prepare for a future of CAVs and smart cities include:

- Creating CAV test beds
- Internal testing, as well as close collaboration with industry
- Strategic or tactical plans on the future of CAVs and/or smart cities
- Pilot projects with various industry partners
- Development of a digital infrastructure plan
- Planning for future bylaws and policies that will be required in a CAV world
- Evaluating potential implications of CAVs for sustainable transportation (e.g. urban walkability, curbside management)
- Hiring of staff dedicated to CAV preparedness

3.1.8 Opportunities for leadership

Road authorities made a number of suggestions:

- Make this topic a national priority, which ultimately requires sufficient funding.
- Form partnerships with universities.
- Encourage universities to partner with high schools to stimulate talent development and at younger ages.
- Establish partnerships across agencies, so that learning can happen from city to city.
- There needs to be political leadership to ensure this becomes a priority. And this likely happens only when there is public interest so that elected official's direct action.
- The issue needs to be given budgetary priority.
- The development of working groups comprising public sector and private sector representatives is essential.
- Establish centres of excellence in CAVs so that more people are trained in the field. This type of research and development effort might need to focus on issues pertaining to the Canadian context, such as the operation of CAVs in winter.
- Introduce graduate studies specific to CAVs and advanced disruptive technologies.
- Work with the private sector to learn about upcoming technologies and help with training of future professionals.
- Government support for universities to engage in more research, development, and training of HQP in this field.
- Financial incentives and support for students to enroll in these fields.
- Establish a baseline national level policy to incentivize CAV growth and investment across the provinces in a uniform manner. Such policy must be accompanied by appropriate federal funding.
- There may be a need for the introduction of legislation that elevates the importance of this issue as something of national interest.

- Canada needs to invest in companies that are leading the transition to CAVs. There is also opportunity to foster partnerships between the public and private sectors.
- Involve Engineers Canada in the discussion to ensure they know that changes may be needed to existing curricula for a future of disruptive technologies.
- There will be a need for better education and training opportunities. Universities and colleges need to incorporate more technology into basic programs, so students are better equipped when they enter the workforce. On-line education may be an ideal mechanism by which such partnerships could occur.
- Agencies need to engage in strategy development. This involves defining a mission statement, goals, and then determine those actions that can be meaningfully undertaken by provinces. Such actions must be appropriately funded.

3.2 Academics

The engagement of the Canadian academic community had the following objectives:

- Develop an inventory of university, college, and professional training programs.
- Identify current skills in academic programs.
- Understand the feasibility of domestic talent development for future needs of road authorities.
- Identify specific actions to enhance the training of HQPs for a disrupted technology era.
- Identify challenges and opportunities in HQP skills development.
- Identify challenges and opportunities to close the skillset gap between education/training and practice.

To meet these objectives, the project team surveyed academics, reviewed course outlines, and held a virtual workshop.

3.2.1 Survey of academics

In 2020, TAC developed an inventory of Canadian post-secondary institutions and academics/instructors that conduct teaching and/or research related to various transportation topics. This inventory was based on a comprehensive online survey of the academic community at Canadian universities and community colleges. The survey received a response rate of 50% (64 of 127).

As part of this project, the same online survey used for the 2020 inventory was distributed to academics who had not responded in 2020. The intent was to enhance the current inventory and to identify any additional academics who may be involved in teaching or conducting research in CAVs, data analytics, ITS, mobility-as-a-service, or zero-emission vehicles as these were topics of interest to the 2020 inventory and were topics of interest to this project. It is important to state that while there may be programs and courses that specifically address data analytics, computer programming, cybersecurity, and others, these are offered in programs outside of transportation engineering and planning. This survey was concerned only with what is currently being offered within transportation programs across the country.

From this survey, it was determined that 40 transportation academics from universities and community colleges across the country either teach or conduct research on the topics mentioned above (CAVs, data analytics, ITS, mobility-as-a-service, or zero-emission vehicles).

3.2.2 Course outlines

Following the analysis of the online survey, the 40 identified academics were contacted to request outlines of the courses that included the content they teach regarding CAVs, ITS, data analytics, MaaS, and zero-emission vehicles. The intent of this was to determine the extent to which current academic programs are developing necessary skills for future HQP. A total of 27 course outlines were returned from 10 universities. Of these, 14 course outlines were for graduate courses and 13 were for undergraduate courses. Table 3 summarizes the courses for which course outlines were provided.

To evaluate the relevance of the course content, a list of important skills was developed from the discussions with road authorities and literature review. Skills were categorized as hard and soft skills. Table 4 summarizes the skills by how often they were discussed as necessary for HQP in the future.

This summary shows that the two hard skills – data science and computer programming – were identified as important by all five sources and two more – traffic engineering knowledge and cybersecurity – were identified as important by three of five sources. These four skills are therefore considered to have high importance, as all other skills were each identified by only one or two sources. All soft skills were identified by two to three of the five sources.

Each of the 27 course outlines was reviewed for reference to each skill or other indications that that skill is taught. Because course outlines from most universities only indicate categories of hard skills, Table 5 summarizes the number of course outlines identifying each hard skill.

Table 3: Summary of course outlines

University	Courses	Course level
McGill University	Land Use and Transportation Planning	Graduate
McMaster University	Transportation Geography	Undergraduate
	Applied Spatial Statistics	Undergraduate
	Transport Policy	Undergraduate
University of Waterloo	Special Studies in Sensing in Civil Engineering: Machine Vision and Robotics for Construction and Management of Infrastructure	Graduate
University of Manitoba	Civil Engineering Geomatics	Undergraduate
	Transportation Engineering 1	Undergraduate
	Transportation Engineering 2	Undergraduate
	Transportation Systems	Undergraduate
	Statistics for Civil Engineers	Undergraduate
	Modern Railway Engineering	Graduate
	Analysis and Design of Freight Transport Systems	Graduate
University of Toronto	Introduction to Transportation Systems	Undergraduate
	Freight Transportation and ITS Applications	Graduate
Ryerson University	Transportation Planning	Undergraduate
	Data Science for MBAs	Graduate
	Quantitative Methods for Business	Graduate
	Real Estate Economics 1	Undergraduate
	Real Estate Research Methods	Graduate
	Applied Econometrics	Graduate
	Urban Transport Planning	Graduate
	Transportation and Urban Form	Graduate
Polytechnique Montréal	Data Management in Transport	Graduate
	Traffic Engineering	Undergraduate
York University	Transportation Engineering	Undergraduate
University of New Brunswick	Intelligent Transportation Systems	Graduate
University of Alberta	Transportation Planning	Graduate

Table 4: Important skills identified by road authorities and the literature

Skill	Importance of skill				
	Small municipalities	Medium municipalities	Large municipalities	Provincial agencies	Other literature
Hard skills					
Data science	■	■	■	■	■
Computer programming	■	■	■	■	■
Traffic engineering knowledge	■	■	■	■	
Cybersecurity		■		■	■
Civil engineering technology operation			■	■	
Electronics		■		■	
GIS and spatial thinking			■		■
ITS knowledge				■	■
Advanced data analysis (artificial intelligence, machine learning)			■		■
Knowledge of Internet of Things (IoT)			■		■
Blockchain		■			
Soft skills					
Managerial and supervisory skills			■	■	■
Contextualization			■		■
Critical thinking			■		■
Communication skills			■		■
Stakeholder and public engagement skills	■		■		

Table 5: Hard skills included in transportation course outlines

Skill	Number of course outlines identifying the skill		
	Undergraduate	Graduate	Total
General traffic engineering	8	10	18
Computer programming	5	7	12
Data science	4	6	10
GIS and spatial thinking	3	1	4
ITS knowledge	1	3	4
Civil engineering technology operation	1	-	1
Advanced data analysis (AI, machine learning)	-	1	1
Cybersecurity	-	-	-
Electronics	-	-	-
Blockchain	-	-	-
Knowledge of Internet of Things (IoT)	-	-	-

Table 5 reveals that while most (18 of 27) of the courses develop skills and knowledge in general traffic engineering and many (10 to 12 of 27) of the courses develop skills in data science and computer programming, none of the course outlines reference cybersecurity. Of the four skills of high importance, cybersecurity is therefore severely underserved in transport and data management courses. All four skills of high importance were represented approximately equally in undergraduate and graduate courses.

Of the remaining skills, three of seven of the skills are not referenced in any of the reviewed course outlines, and four of seven are referenced in one to four of the course outlines. Some of these skills, such as civil engineering technology operation and electronics, are not expected to be taught in most university programs, as they would more typically be taught in technical college programs. However, for others, such as GIS and spatial thinking, ITS knowledge, and advanced data analysis, their lack of presence in university programs indicates that these skills are largely excluded from all post-secondary education programs. It is also notable that one skill (ITS knowledge) was much better represented in graduate courses and one skill (GIS and spatial thinking) was much better represented in undergraduate courses. In addition, many of the courses focused on data science are business classes that may not be taken by many future transportation professionals. Due to this, though data science skills are taught in universities, they may not be developed sufficiently in future transportation HQP.

While the reviewed course outlines did not specifically indicate soft skills that were taught, descriptions of the types of assignments provided some insight into the courses' development of soft skills. All the courses contained an implicit focus on critical thinking, and communication skills were implicitly required for delivery of all class assignments. However, as the courses primarily relied on individual evaluation, development of managerial or supervisory skills was minimal, and stakeholder and public engagement was also not mentioned or implied by the courses' content. The skill of contextualization was not referenced but may be developed in some courses due to more open-ended assignments and discussions in graduate level courses but was again not a focus. Overall, the development of soft skills was not described in detail, but implied skills development only focused on some of the indicated skills required by future HQP.

Additional comments by one academic highlighted data science as a key skill area that can be represented in a six-step skill framework (Tyagi, 2021):

1. Computer programming
2. Data collection and cleaning
3. Exploratory data analysis and data visualization
4. Data engineering for big data
5. Applied statistics and mathematics
6. Machine learning and AI

Skills 1 and 6 from this list were already identified and analyzed in the course outline review, but it is notable that skills 2 to 4 were each mentioned in four or fewer graduate courses and no undergraduate courses, but that skill 5, applied statistics and mathematics, was mentioned in eight graduate courses and four undergraduate courses. This indicates that university programs provide a strong basis for some portions of a data science skill base, but do not provide a comprehensive approach to developing data science skill sets.

3.2.3 Virtual workshop

The engagement of academics was done through a focus group session on April 9, 2021. The purpose of this engagement was to develop an understanding of the following:

- Currently taught HQP skillsets needed to plan, design, manage, maintain, and operate future road infrastructure systems, particularly in a disruptive technology era
- Current gaps in transportation education for a future of systems with disruptive technologies
- Specific actions to enhance the training of HQP in a disruptive technology era
- Challenges and opportunities in HQP skills development
- Challenges and opportunities to close the skillset gap between education/training and practice
- Feasibility of developing talent domestically for future needs of road authorities
- The role of universities and colleges in workforce development
- Canada's approach to become a leader in HQP development

Selected academics were invited to the focus group discussion, ensuring that there was equal geographic coverage as well as representation from most major Canadian universities and technical colleges. A total of 15 people participated in the session, representing 11 universities:

- University of Alberta
- University of British Columbia
- Concordia University
- University of Calgary
- University of Manitoba
- McGill University
- Polytechnique Montréal
- University of New Brunswick
- Ryerson University
- Waterloo
- York University

Key findings from this session are discussed in the following paragraphs.

In general, academics agree that the domestic development of HQP for a future of connected and autonomous vehicles is feasible. However, the challenge lies in teaching the necessary skills to future engineering students given the finite number of courses available in an engineering degree. While it may only be possible to introduce new knowledge about selected topics in engineering curriculum, there may be an opportunity for HQP to develop that knowledge later, after their formal education.

It is feasible to develop domestic talent for future HQP because the skills required of future HQP are already being taught, they are just not being taught only to civil engineers or transportation engineers. Currently, skills in coding, data science, and advanced topics such as artificial intelligence are being taught in other programs such as computer engineering and computer science. To successfully develop future HQP talent, the existing personnel with necessary skills need to have their roles integrated with those with expertise in transportation and civil engineering.

Education gaps

The following gaps were identified:

- While the necessary skills for a future of CAVs are taught, this is not being done at the required depth. Engineering students are exposed to coding, data science, and other necessary skills and concepts, but not to the extent that they are able to establish themselves as fully competent in these areas.
- Computer programming is neglected in civil and transportation engineering curricula because it is seen as being within the domain of electrical/computer engineering and computer science. Current programs treat it as a specific skill rather than as a general problem-solving tool (e.g. math) which is the role it will take in the future. This education gap creates further gaps by denying students the skills necessary to learn about additional subjects such as artificial intelligence.
- Currently, engineering students are not exposed to enough case studies that look at larger systems. Exposure to these kind of case studies would allow students to see how different disciplines come together to solve systemwide problems and would allow them to see what skills are relevant now and what skills will be relevant in the future.
- Engineering education currently focuses on probability as a focus of statistics courses. This is a focus that serves a historical context where data was not available in sufficient quantity, requiring statistical analysis to make up for that deficiency. However, the amount of data collected and available for engineering analysis has increased significantly, decreasing the need for probability, and increasing the need for data science. As a result, data science is currently underserved in engineering education.

Opportunities

Regarding potential opportunities to enhance HQP training, the following key issues were identified:

- A potential solution to lack of sufficiently trained HQP in disruptive technologies could be not only to train civil engineers in programming and similar skills, but to train computer scientists and engineers in transportation engineering principles.
- Professional development for engineers may allow key knowledge gaps to be filled. Traditional 12-week course models are not able to serve all kinds of skill development, and by focusing on continuous professional development, HQP may be better developed to fill roles as the requirement of those roles are established.
- As HQP will require specialized skills not required of all engineers, not every university will have the capacity to offer courses in these specialized areas, particularly as part of an undergraduate program. Allowing students to take courses from other universities would allow the program of studies for each student to be expanded to include specialized skillsets that will be required of HQP in the future.
- At least one Canadian university offers a minor in artificial intelligence. Offering minors in this and other areas allows and incentivizes interested students to develop skills they would not normally receive from the traditional civil engineering stream.
- Encouraging direct interaction between road authorities and university programs will allow students more exposure to transportation as a profession and the skill requirements that come

with those jobs. There is currently more opportunity for this at the graduate level in the form of research partnerships. These opportunities could be expanded at the undergraduate level going beyond co-op placements.

- Offering post-degree certificates in relevant fields, such as ITS, would allow the necessary future skills to be taught without disrupting the existing civil engineering undergraduate program. Some universities in the United States currently offer a certificate program in ITS.
- Recently, undergraduate interest in transportation engineering has been growing; limitations on the number of courses offered are primarily due to faculty numbers, not student interest. Based on this, if more courses in transportation and related skills were offered, they would be supported by student enrollment. Further, given sufficient demand, dedicated transportation engineering undergraduate programs could be developed in selected Canadian universities to accelerate HQP development for a disruptive technology future.
- Teaching undergraduate students early in their education about what is required of transportation engineers would both increase interest in transportation engineering and allow students to focus on developing those relevant skills throughout their degree. This could be in addition to encouraging students to participate in student chapters and obtain student memberships in transportation-related professional organizations.
- Technology for distance education is at a point where students may take individual courses from universities other than the one they attend. Given the correct cooperation between the university programs, this can allow more students to have access to courses in specialized skillsets.

Challenges

The following challenges were identified for skill development for a future of disruptive technologies:

- Though professors and universities may want to change curricula to teach new skills that will be relevant in the future, they are required to teach content that provides a basis for an engineering education, which decreases program time available for additional skills that will be more specifically targeted to the future. The Canadian Engineering Accreditation Board has determined that this basis is found in an understanding of engineering design, rather than specific skills, so courses are limited in how they can change their content as universities must maintain their accreditation.
- Undergraduate programs do not currently have much of a focus on transportation engineering, and that is not likely to change due to the required broad range of topics in a civil engineering degree. Graduate students in transportation engineering receive a lot of exposure in transportation engineering, but the future workforce cannot be comprised of only graduate students. Therefore, short-term expectations of civil engineering graduates in transportation jobs must be tempered as these students learn on the job.
- The competency gap between high school graduate and employable engineer is getting increasingly wide, and the engineering undergraduate program is therefore being stretched increasingly thin in its attempt to bridge this gap. This means that professors teaching at the undergraduate level are faced with high school graduates who are less and less prepared for the rigour of engineering programs. This poses a significant challenge for academics.

- The context of transportation engineering is changing in many areas, not only in technology. Current transportation engineering courses function in many ways as urban planning courses, and as societal concerns shift from urban sprawl to environmental and equity concerns, these perspectives need to be added to the existing course content, which creates even less room to add skills that are specifically applicable to the technology of a CAV future or other disruptive technology future.

Leadership strategies

Academics offered the following strategies that could help Canada become a leader in HQP development for a disruptive technology world:

- There should be more emphasis of this issue as a political priority for the federal government.
- Canada's relatively small size puts it at a disadvantage to other nations with respect to the ability to offer specialized education programs. This disadvantage will be best overcome by pooling resources between universities and professional development programs, which will allow some institutions to take leadership in certain education areas and the country to have a more efficient overall approach to development of specialized HQP skillsets. A coordinated effort from the academic community across the country would allow knowledge sharing and program coordination on a practical level.

Role of institutions

Academics agree that the development of future workforce should not fall exclusively on the shoulders of educational institutions. They raised the following key points regarding the role of universities and colleges in workforce development:

- Undergraduate programs do not have the capacity to teach all necessary skills for future HQP. Undergraduate programs are required to teach students how to learn and problem solve, which allows them to develop the necessary job skills after graduation.
- Universities need to prepare students for jobs that exist, not jobs that may only exist in the future. Upon graduating, students should be skilled and knowledgeable so they can function effectively in the professional world.
- Engineering education should show students what skills will be needed for the future, even if it does not teach them all of those skills to a substantial extent. These skills do not need to be tailored to the specific needs of businesses.

3.3 Professional associations

The engagement of professional associations was done through an online survey that was open from April 8 to May 24, 2021. The purpose of this engagement was to develop an understanding of:

- The impact of disruptive transportation technologies on road authorities over the next 20 years
- The critical engineering and non-engineering skills and competencies required to overcome challenged presented by disruptive transportation technologies
- The current level of preparedness to overcome the challenges of future disruptive technologies

- The role of professional organizations in developing the future road transportation workforce

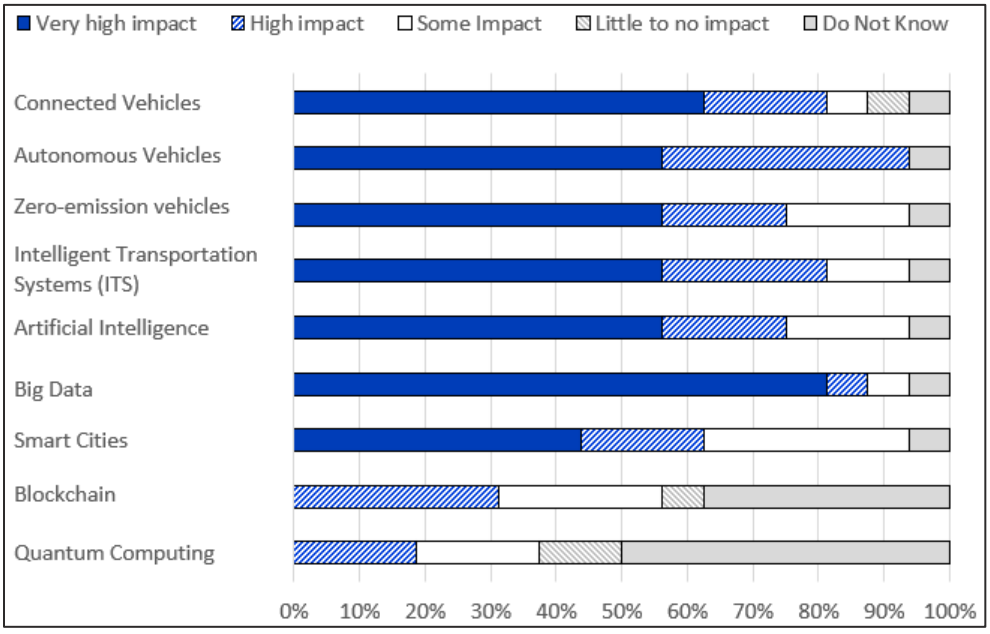
The survey was distributed to 29 Canadian and international associations, of which 11 replied:

- Canadian Institute of Planners (CIP)
- Ontario Good Roads Association (OGRA)
- Institute of Transportation Engineers (ITE)
- Canadian Institute of Transportation Engineers (CITE)
- Canadian Urban Transit Association (CUTA)
- Canadian Vehicle Manufacturers' Association (CVMA)
- National Association of City Transportation Officials (NACTO)
- National Research Council (NRC)
- Canadian Standards Association (CSA)
- Société de l'assurance automobile du Québec (SAAQ)
- Information and Communications Technology Council (ICTC)

Impact of technologies

Figure 2 shows the participants' ratings of the perceived level of impact that various disruptive technologies are expected to have on Canadian road authorities. As the figure illustrates, most participants (81%) noted big data as having very high impact on road authorities. In addition, over 75% identified connected vehicles, autonomous vehicles, zero-emission vehicles, ITS, and artificial intelligence as very-high or high impact technologies as well. Participants were divided about the impact of smart cities 63% rating it as very high to high impact and 37% rating it as low or with unknown impact. Over 40% of participants do not know the future impact of blockchain and quantum computing on Canadian road authorities.

Figure 2: Expected impact of disruptive technologies



Importance of competencies

The following technical and functional competencies and skills were classified by participants in terms of their relative level of importance in a future of disruptive transportation technologies for the engineering workforce:

- Technical competencies
  - Computer programming
  - Knowledge about AI/machine learning
  - Big data analytics
  - GIS, surveying, geomatics
  - Statistical analysis including SAS
  - Cybersecurity
  - Intelligent transportation systems
- Functional skills
  - Communication (verbal and written)
  - Problem solving
  - Critical thinking
  - Public and stakeholder engagement

As Figure 3 shows, over half of survey respondents rated ITS as extremely important, followed by big data analytics (43%) and cybersecurity (38%). The other core competency that was rated by over half of respondents as either extremely important or very important was GIS, surveying and geomatics. Participants were divided about the importance of computer programming, knowledge about artificial intelligence/machine learning, and statistical analysis. Half rated them as extremely to very important and the rest rated them as somewhat to not very important or unknown.

Figure 3: Importance of technical competencies for engineering workforce

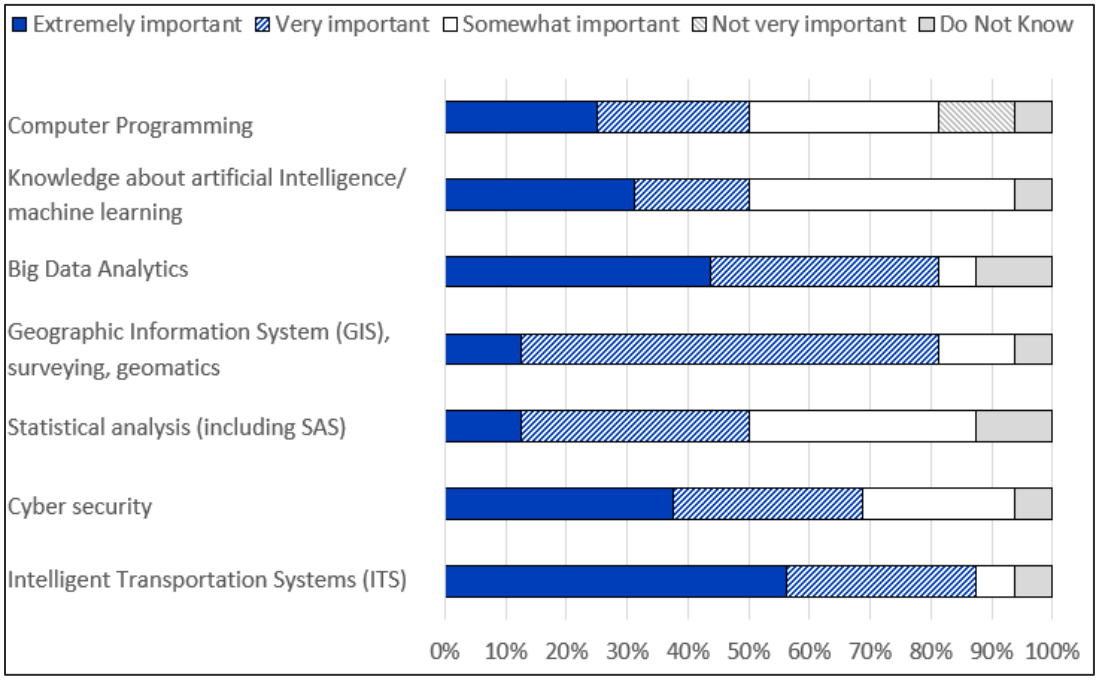
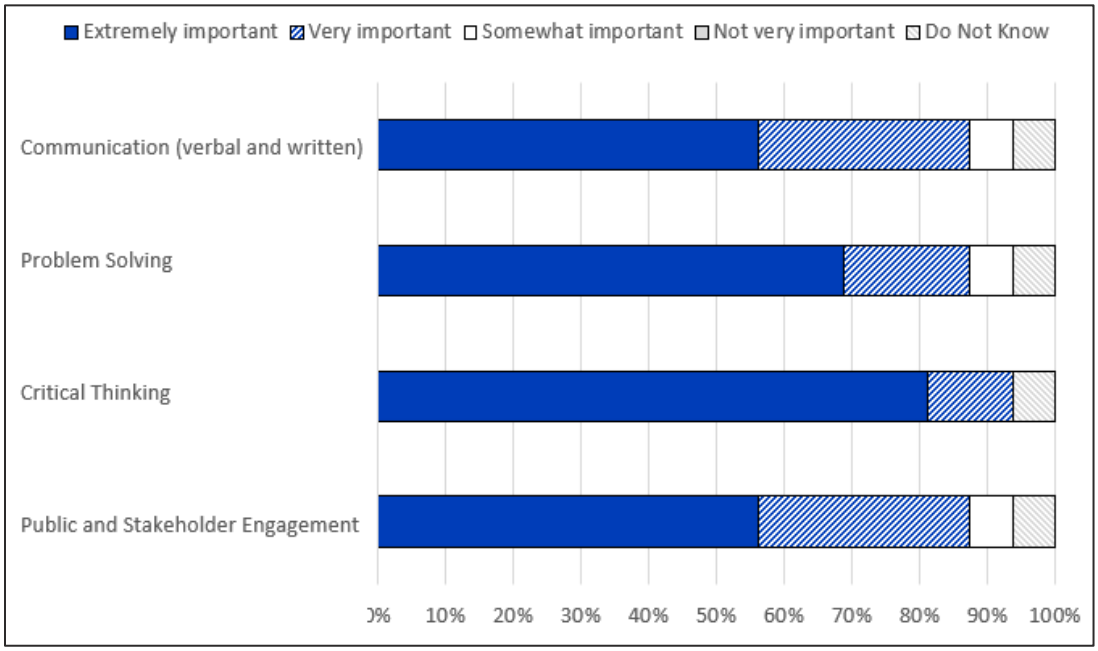


Figure 4 shows that most participants (over 85%) rated communication (verbal and written), problem solving, critical thinking, and public and stakeholder engagement as extremely or very important functional engineering skills for road authorities. In addition, participants also noted the following:

- The ability to assess risk and act with more efficient bureaucratic and administrative systems will be critical for the success of future disruptive technologies on Canadian roads.
- An understanding of the equity impacts of future transportation technology is a critical skill needed today.
- Ethics, moralizing technology and in turn, standardizing will also be critical skills and competencies to ensure equitable distribution of future disruptive technologies.
- Impact and importance of AI/machine learning is difficult to predict as it is still not clear if better detection and analysis software can deliver deployable CAV technology or if artificial intelligence and machine learning will be critical for its success.

Figure 4: Functional skills required for engineering workforce



Level of preparedness

Participants were asked to rate the level of preparedness of the previous technical and functional skills and competencies. Most participants (over 75%) rated the future workforce as being definitely to somewhat prepared for big data analytics; GIS, surveying and geomatics; and ITS. Participants were divided with respect to whether the future engineering workforce will be sufficiently prepared in computer programming, knowledge about artificial intelligence/machine learning, and statistical analysis (including SAS). Most participants rated the future engineering workforce as definitely unprepared to somewhat unprepared for cybersecurity skills and competencies.

With respect to functional skills, most participants (over 70%) rated the future engineering workforce as definitely to somewhat prepared with respect to communication (verbal and written), problem solving, critical thinking, and public and stakeholder engagement. Participants also noted the following:

- Administrative skills and competencies for a resilient disruptive technology future are currently insufficient. COVID-19 has emphasized this deficiency and the current upgrades are insufficient for a CAV future (e.g. moving from in-person to digital engagement).
- It is critical to develop experts in technical competencies in which road authorities and the private sector are currently deficient.
- Communication and collaboration between engineering and non-engineering workforce is a critical skillset for successful CAV deployment.
- Professional regulatory bodies are consistently lagging in new trends and technology disruptions and will need to keep pace with the technology for its safe and successful implementation.

Stakeholder roles

As different stakeholders have a role to play in developing the future transportation workforce, survey respondents were asked what their views were regarding this issue. Figure 5, Figure 6 and Figure 7 illustrate respondent views regarding the role that universities and colleges, road authorities, and professional associations could play in the development of the future transportation workforce.

Figure 5: Views of professional associations on the role of colleges and universities

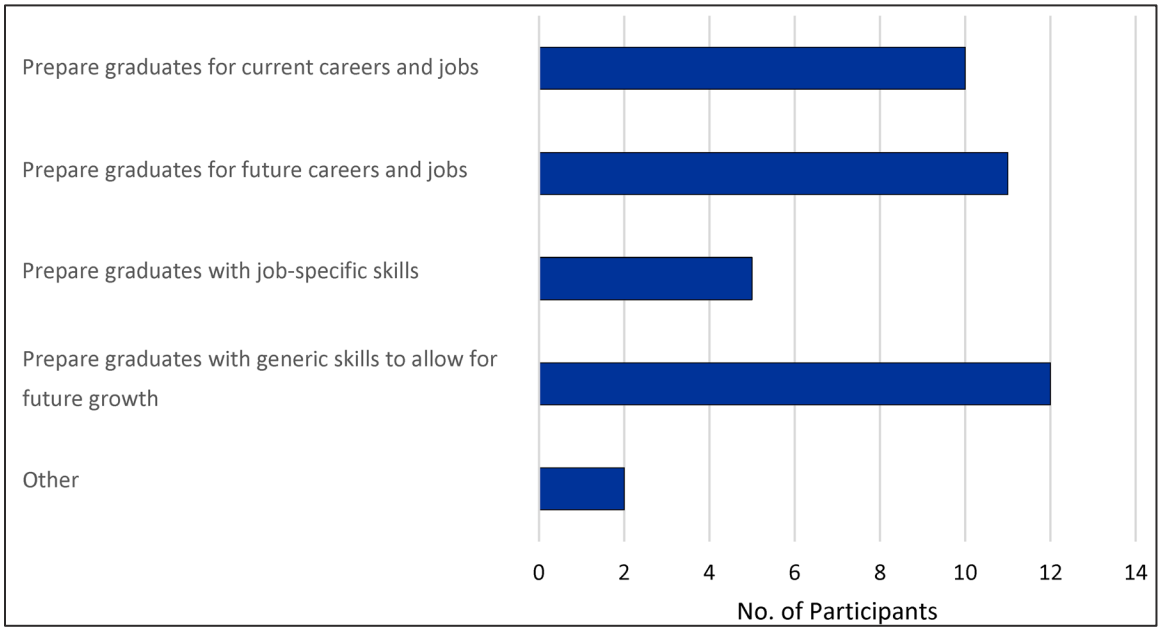


Figure 6: Views of professional associations on the role of road authorities

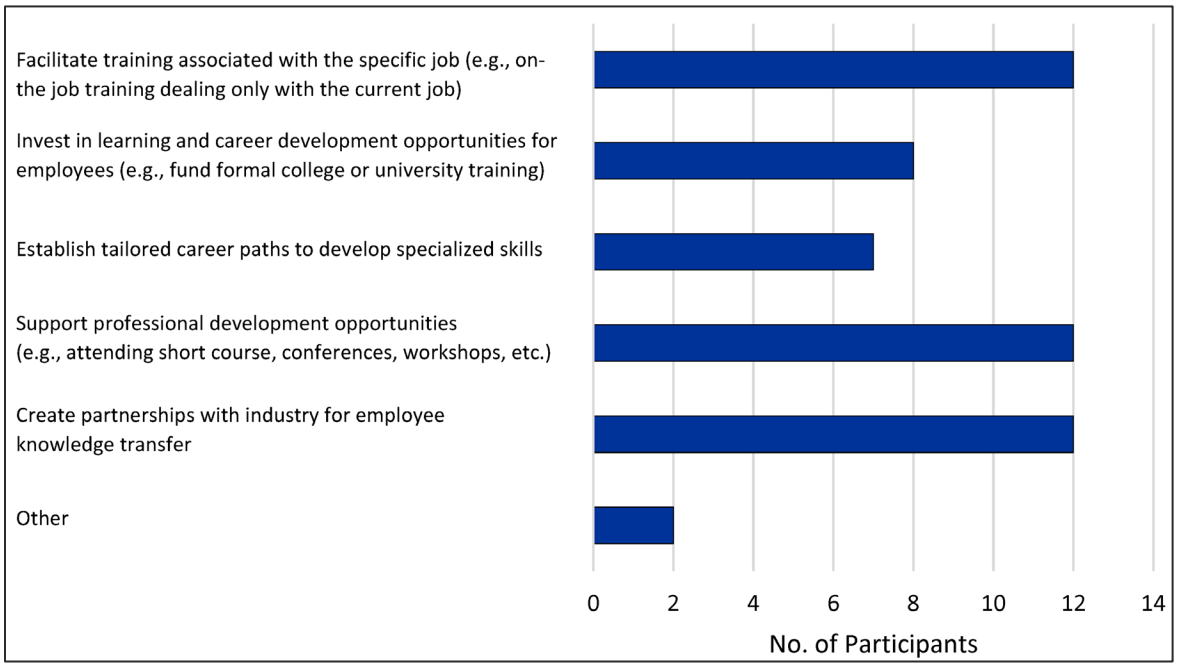
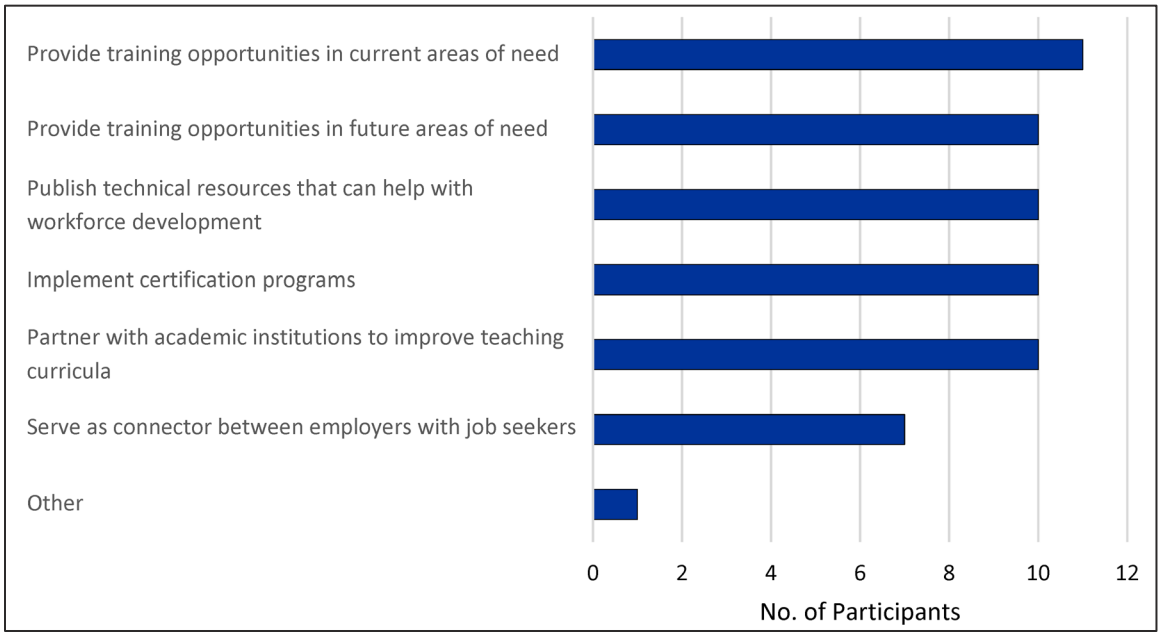


Figure 7: Views of professional associations on their own role



Most respondents (12 of 14) indicated that colleges and universities should prepare graduates with generic skills to allow for future growth. Additionally, participants noted that graduates should be adaptable and resilient to change, and should have basic coding knowledge.

Most respondents (12 of 14) said that road authorities should facilitate training associated with the specific job (e.g. on-the-job training dealing only with the current job), support professional development opportunities (e.g. attending short courses, conferences, seminars, workshops), and

create partnerships with industry for employee knowledge transfer for workforce development. Respondents also noted the need to create new job titles for future skills and competencies, to partner with other levels of government, and to promote knowledge exchange.

Most respondents (12 of 14) indicated that professional associations should provide training opportunities in current areas of need. Respondents also noted they should play a neutral role between the public and private sectors, and develop technical resources based on emerging technologies and tested best practices.

Leadership strategies

Professional associations suggested the following strategies to help Canada to become a leader in HQP development:

- Emphasize the need for standardized access to training funding to attract researchers to understand disruptive technologies in the local context that will guide the development of standards, guidelines, and best practices.
- Increase collaboration between the public sector, private industries, universities and colleges, and professional organizations.
- Reverse engineer global studies to determine metrics where Canada is currently falling short compared to other countries and identify actions that are required to successfully improve Canada's position when CAVs are deployed on Canadian roads.
- Support academic research into emerging technologies through funding and people.
- Establish methods of evaluating workforce readiness that do not require technical degrees (e.g. consider that HQP can be identified and trained outside of university pipelines).
- Provide opportunities for staff in "frontline" implementation and service roles (e.g. construction, maintenance, drivers, customer service staff) to acquire technical skills and bring more diversity of experience to assess the impacts of smart cities and disruptive technologies.
- Canada should play a key role in developing and adopting standards, training HQP, and further considering how international efforts align with Canadian requirements that enable the safe deployment of CAVs.

3.4 Technology industry

Telephone interviews were conducted between May 26 and June 9, 2021 with four industry firms in the CAV ecosystem: General Motors, BlackBerry, IBI Group, and the Autonomous Vehicle Innovation Network (AVIN). The purpose of these interviews was to obtain special insight into the following:

- Key technology trends that are likely to impact road authorities over the next 20 years
- Challenges and opportunities to close the skillset gap resulting from disruptive technologies
- Opportunities for HQP skills development where Canada could become a leader in workforce development for a disruptive technology transportation era

3.4.1 Technology trends and impacts

Technology changes are expected to bring about significant change to the way in which transportation systems are planned, designed, operated, and maintained. The following key points were raised by industry:

- It is difficult to say with certainty how exactly technology will change in the next two decades. However, some technological trends are evident:
  - Increasing deployment of CAVs and associated systems
  - Increasing deployment of IoT
  - Systems that will continue to produce large quantities of data
  - Systems that will introduce new methods of payment for different services
  - New mobility models and associated technologies
  - Increased connectivity between vehicles and infrastructure
- The extent to which some these technological trends will continue to grow will be largely dependent on the public as it is consumers who will determine what is needed in the future and what is accepted.
- The biggest trend in technology is related to IoT (smart cities, smart technology). Transportation is at the core of this vision, particularly from the smart mobility perspective. With this IoT trend, there will be a requirement for road authorities to understand how their infrastructure connects with the larger ecosystem of urban spaces, which will, in turn, require a paradigm shift in terms of their approach to service delivery. It will no longer be productive to work in silos, where road authorities only focus on the road infrastructure, but it will become necessary for road authorities to also consider how their networks interact with other components of the urban system. Future transportation technology will require that road authorities apply a systems approach to understanding transportation, roadside infrastructure, regulations, standards, and others.
- The future of transportation technology will be extensively focused on the development of an operating system that integrates the communication of all technology devices in an IoT world. Industry believes that there is currently a misconception among many in the transportation field that by embedding technology (e.g. IoT devices) into vehicles and traffic signals, for example, these devices will automatically communicate with each other. However, this is not the case and there are existing challenges to make this happen. Because of the significant implications that this would have in transportation (e.g. what operating system or systems will become the standard), road authorities must be aware of these developments given that any investment in roadside infrastructure will be affected by the operating system. Therefore, there will be a foundational need to understand how the system works and what can be built on it.
- Because of the large levels of disruptive technologies, cybersecurity will become a critical issue. While it is already an essential aspect of transportation systems, it will become more significant over time. It is expected that in a future of disruptive technologies, transportation will be a major target for cyber attacks because of many reasons, including the following: it will connect private systems with public systems, there is a high value attached to mobility, there are privacy issues, and data will be monetized. This will require road authorities to protect not only the functional safety of their systems, but also the cybersecurity of the transportation

infrastructure. This will require that road authorities develop standards, regulations, and policies that call for specific actions to protect infrastructure from cyber attacks.

- Another significant challenge for road authorities, associated with changing technologies will be funding, which will require identifying different revenue-generating streams. The management and use of large quantities of data be generated through the operation of systems for the movement of people and goods is also a challenge for road authorities but may provide a new source of revenue. For example, road authorities could consider charging for the ability to operate robotaxis in their jurisdiction. The currency would be data.
- Governments have the responsibility to provide safe, efficient, and cost-effective services as it relates to mobility. However, they may benefit from adopting a different role to what they have had to date and become the providers of standards, regulations, and controls, rather than the owners of technology.
- The impact of technology on how road authorities will need to plan, design, operate, and maintain their systems, and the extent of those systems, will depend on whether the locus of intelligence is the vehicle vs the road infrastructure. Because it would be cost-prohibitive to develop a system that is fully integrated with advanced vehicle technologies, companies like Waymo are developing technologies that are independent of public infrastructure. This is also being done because they believe that the likelihood of harmonization in the road infrastructure is minimal. Despite these investments in automotive technology, for any vehicle to be intelligent it will have to communicate with infrastructure around it and with the cloud.
- It is not in the interest of public agencies to bring all the needed skills into a public sector organization. Instead, the skillset gap should be closed by buying or leasing services associated with the management, maintenance, and operation of disruptive technologies and associated data. And while it is important for these agencies to have staff that can understand technology from the perspective of being able to buy a service, they do not have to be able to build the solutions themselves. The purchase of services can be further facilitated by engaging specialists that can provide strategic advice on a given topic and could also be the ones assembling procurement packages. However, while contracting out many of these services is an option, it is still essential that road authorities understand the risks, issues, opportunities, vulnerabilities, and other issues associated with their systems so that they can effectively develop the standards, regulations, and policies needed to address the various issues of importance (e.g. cybersecurity, AI implementation). This is the approach that the energy and defense sectors have taken for many years and will need to become part of a paradigm shift for road authorities.

3.4.2 Skillset development challenges

There is recognition that several challenges exist and will continue to exist regarding skillset development for a future of disruptive technologies. Examples identified by industry include:

- As technology evolves and becomes more complex, there will be several different sources of data, which will require experts in a variety of areas, for example, data cleansing experts, data brokerage, consortium managers.
- There are problems in the way people are currently trained regarding transportation engineering and artificial intelligence. While these two domains are important together, they are taught in different academic units. Transportation engineers are not exposed to AI, and

computer engineers or scientists are not trained in transportation engineering. Road authorities will need HQP who understand transportation (vehicles and infrastructure) but have a computer science or data science background. This requires that the two main streams (traditional transportation engineering and computer science/technology) come together as the traditional disciplinary approach will not be successful in a disruptive technology world.

- The lack of professionals with transportation engineering and computer science backgrounds is believed to be straining innovation within industry and is likely to be putting transportation systems at risk. There is also the belief that this gap may also be inhibiting consumers from fully trusting autonomous technologies.
- There is a dilemma regarding who should be taught the skills that will be needed in the future. One school of thought is that civil engineers should be taught skills in areas such as computer programming, AI and data analytics. Another school of thought is that computer engineers and computer scientists should be taught traffic engineering. However, some industry participants believe that civil engineers are better positioned to acquire additional skills that will be needed in a disruptive technology era as it pertains to road authorities. They are already taught the transportation engineering foundation that is essential for planning, design, operating, and maintaining transportation systems. In addition, it is believed that the amount of effort required to educate computer engineers and computer scientists in traffic engineering would be greater than the effort that would be required to teach civil engineers about data analytics and understanding of the fundamentals of AI.
- The lack of flexibility that currently exists to modify academic curricula poses a significant barrier to changes in the way HQP are trained.
- There is a mismatch between the curriculum taught at the high school level and the required knowledge at the university level. This results in significant challenges educating and training students for jobs of the future. This is further complicated by the fact that employers have high expectations regarding the types of skills that new employees should bring to their new jobs.
- It is important to get youth interested in technology to the point that they would consider formal education and a career in it. While many youth are attracted to technology from an early age, enrolling in engineering and technology programs is not as common as it could be.

3.4.3 Skillset development opportunities

The following opportunities were identified by industry participants to ensure road authorities are prepared for a disruptive technology future:

- Continue to foster collaboration between industry and educational institutions to ensure there is enough communication and understanding regarding industry's needs and the material being taught in the classroom. Industry is open to providing financial incentives for innovative ideas that bring different disciplines together. Industry is interested in helping shape curriculum. They want to be in the classroom and let people work with their technologies. They want students to become familiar with available technologies so that they can continue using those technologies as they enter the workforce.
- Workforce development could also occur through certification of emerging areas of interest. This can be done bringing together government, industry, and academia, possibly relying on Centres of excellence to lead that certification initiative.

- Road authorities could play a significant role supporting educational institutions to ensure there is continual training of future HQP. However, they should also invest in their existing work force to ensure there is always knowledge renewal.
- Work-integrated learning has proven to be successful in some industry sectors. With this, students can obtain a variety of skills that would not necessarily be taught in their respective academic programs. Work-integrated learning could also be used as an effective tool to help newcomers better integrate into the professional workforce.
- Short and micro courses can help respond to some of the needs for younger and mid career professionals with respect to knowledge gaps.
- The current generation cares significantly about the welfare of society. Road authorities could leverage the societal impact that advanced technologies can have and attract young students to career paths that include high tech.
- There will be an opportunity and need to bridge the gap that currently exists and will continue to exist between new hires and senior employees. Increased collaboration may help close that gap, hence, benefiting everyone.
- There may be an opportunity to develop a special degree or certification program that brings together a unique blend of transportation engineering and artificial intelligence.

3.4.4 Opportunities for leadership

The following opportunities were identified by industry participants for Canada to become a leader in workforce development:

- Better integrate immigrants into the Canadian workforce. There appears to be a disconnect between the qualification requirements to immigrate into Canada and the integration of these newcomers into the Canadian workforce. Showing evidence of high-quality training is an important aspect of qualification for immigration, yet, once people arrive in Canada, they encounter several barriers to successfully work in high skilled jobs. In many situations immigrants end up abandoning their area of technical expertise and taking survival jobs. When this happens, this talent is lost by society.
- The federal government needs to invest on workforce development in this space.
- The federal government needs to develop a strategy on workforce development. This strategy should not only focus on how to develop young people, but it should also include actions for retraining and retaining those that have been trained. The group between 30 and 55 years of age needs retraining given the significant changes in technology in the last 10 years. In addition, there is much competition for human resources in this area and Canada is losing many people to other countries.

3.5 Summary of findings

The stakeholder engagement revealed several issues and opportunities associated with the training of HQP for a future of disruptive technologies. In addition, a series of current skillset gaps and future required skills were identified for the provision of services in planning, design, operations, and management of transportation systems.

Skillset gaps

The following skillset gaps exist in today's workforce:

- Data analytics
- Computer programming
- Cybersecurity
- General traffic engineering knowledge
- Soft skills

While the necessary skills for a future of CAVs are already being taught in computer science and electrical/computer engineering programs, this is not being done at the required depth. Computer programming is neglected in civil and transportation engineering curricula because it is seen as being within the domain of electrical/computer engineering and computer science.

Challenges

Important challenges associated with HQP training for a future of disruptive technologies include:

- As technology evolves and becomes more complex, there will be several different sources of data that will require experts in a variety of areas, such as data cleansing experts, data brokerage, consortium managers.
- There are problems in the way people are currently trained regarding transportation engineering and artificial intelligence.
- The lack of professionals with transportation engineering and computer science backgrounds is likely straining innovation within industry and putting transportation systems at risk.
- There is a dilemma regarding who should be taught the skills that will be needed in the future.
- The lack of flexibility that currently exists to modify academic curricula poses a significant barrier to changes in the way HQP are trained.
- There is a mismatch between the curriculum taught at the high school level and the required knowledge at the university level.

Necessary skills

The following skills are considered necessary for a future of disruptive technologies:

- Ability to lead and manage relevant pilot projects
- Knowledge about cybersecurity
- Understanding the IoT and how to manage the various technological demands associated with it

- Data science
- Ability to function in more than one technical domain
- Strong computer programming skills
- Capability to engage with the public and stakeholders
- Traffic engineering knowledge combined with computer programming
- Communication (verbal and written)
- Problem solving
- Critical thinking
- Public and stakeholder engagement

Opportunities

Key opportunities identified to help close the current skillset gap include:

- Collaboration with universities and technical colleges
- Collaboration with industry
- Outreach to young students
- Introduction of multi-disciplinary teams
- Creation of centres of excellence
- Making workforce development in transportation technology a national priority, which ultimately requires sufficient funding
- Encouraging universities to partner with high schools to develop talent at younger ages
- Introduction of graduate studies specific to CAVs and advanced disruptive technologies
- Creating financial incentives and support for students to enroll in transportation technology fields
- Special training outside of formal engineering education
- Train civil engineers in programming and similar skills, and also train computer scientists and engineers in transportation engineering principles
- Professional development for engineering graduates beyond the traditional 12-week courses
- Allowing students to take courses from other universities and transfer to their home university
- Offering minors in areas of need (artificial intelligence, data science, and others)
- Expanding co-op placements
- Offering post-degree certificates in relevant fields
- Introducing dedicated transportation engineering undergraduate programs as an alternative to civil engineering for those who are interested in transportation and technology
- Distance education opportunities
- Introducing certification of emerging areas of interest
- Implementing work-integrated learning
- Better integrating immigrants into the Canadian workforce

4. Gap analysis

This chapter summarizes outcomes of a gap analysis based on the literature review and stakeholder engagement. It identifies gaps in three domains:

- *Domain 1: Educating the future transportation workforce* – The analysis identifies five gaps concerning technical skillsets; non-technical skillsets; coordination between primary, secondary, and university curricula; post-secondary curricula design and accreditation standards; and linking graduates at various levels to jobs in the transportation industry.
- *Domain 2: Training the existing transportation workforce* – The analysis identifies five gaps concerning technical skillsets; non-technical skillsets; linkages with educational institutions; mentorship and knowledge transfer; and development of professional networks.
- *Domain 3: Human resources practices and agency governance* – The analysis identifies eight gaps concerning recruitment; retention; equity, diversity, inclusion (EDI); barriers between functional areas within an agency; performance-based decision-making and data governance; procurement process; unionized workforces; and funding.

Each gap is assigned three digits: the first represents the associated domain (1, 2 or 3), the second represents a second-tier gap, and the third (where applicable) represents a third-tier gap. These codes are used to identify relationships between gaps across the three domains at the second-tier level, and are referenced in the action plan presented in the next chapter.

The analysis also considers the nature of the organization or jurisdiction that would likely be responsible for addressing each gap (i.e. institutional, municipal, provincial/territorial, or national). Institutional gaps refer to those relevant to universities, colleges and schools. National gaps are those that, if left unaddressed, could prevent the country as a whole from developing sufficient skills to meet future challenges.

4.1 Educating the future transportation workforce

While acknowledging the multidisciplinary nature of the transportation profession, the gaps identified in Table 6 focus on the civil engineering context, which represents the educational background for most people involved in the planning, operation, design, construction, maintenance and management of transportation systems in Canada. This context includes civil engineering programs typically offered at accredited universities and related engineering technology programs offered at technical post-secondary colleges and schools.

Table 6: Identified gaps – Educating the future transportation workforce

	Gap identification and description	Related gaps	Scale
1.1	**Technical (hard) skillset gaps:** This set of gaps comprises technical skillsets relevant to disruptive transportation technologies deemed to be insufficiently addressed in existing civil engineering curricula. In the context of most transportation agencies, gaps 1.1.1 (AI and its enabling skills of computer programming, machine learning techniques, statistics, and data mining) and 1.1.8 (information and communications technology and cybersecurity) represent new job categories, while the remaining gaps represent incremental enhancements of existing job categories. 1. Artificial intelligence and its enabling skills of computer programming, machine learning techniques, statistics, and data mining 2. Computer-aided design and transportation-specific software 3. General transportation engineering knowledge 4. Intelligent transportation systems 5. Applied mathematics and statistics 6. Spatial analysis, GIS, and geomatics 7. Construction technologies 8. Information and communications technology and cybersecurity	2.1 2.3 3.1	Institutional
1.2	**Non-technical (soft) skillset gaps:** This set of gaps comprises non-technical skillsets relevant to disruptive transportation technology deemed to be insufficiently addressed in existing civil engineering curricula. In the context of most transportation agencies, these gaps represent incremental enhancements of existing job categories. 1. Complex problem solving and 'big-picture' thinking, especially the integration of non-STEM epistemologies and ways of thinking 2. Critical thinking 3. Communication (writing and verbal) 4. Reading comprehension	2.2 2.3 3.1	Institutional
1.3	**Coordination with primary and secondary education curricula:** This set of gaps encompasses issues relating to primary and secondary education curricula and programs, especially but not solely in the STEM fields. 1. Lack of coordination between curricula expectations and the mathematics, statistics, and data analysis skills demanded by transportation technologies 2. Lack of integration between high school apprenticeships and post-secondary education programs 3. Minimal outreach about the transportation industry to primary and secondary students	2.1	Institutional Provincial

	Gap identification and description	Related gaps	Scale
1.4	**Post-secondary curriculum design and professional accreditation standards:** Recognizing the need for educational programs to meet relevant accreditation standards, there are gaps associated with designing curricula that meet those standards while appropriately evolving to fulfill the desired outcomes for transportation professionals. 1. Limited credit hours at the undergraduate level to expand transportation-related technical skills 2. Competing demands for credit hours to focus on non-technical skills and other important issues such as the integration of Indigenous content and equity 3. Institutional processes to approve curriculum changes may not respond quickly to evolving technological needs 4. Limited opportunities to provide interdisciplinary education (e.g. civil engineering and computer engineering, civil engineering and city planning) 5. Limited opportunities to integrate civil engineering degree and civil engineering technology programs 6. Lack of emphasis within curricula on practical applications and case studies	2.3 3.3	Institutional National
1.5	**Linking graduates to jobs in the transportation industry:** There is a need to improve opportunities for students and program graduates at various levels to meaningfully engage with the workforce. 1. There is a need to expand co-operative work programs, including internships and apprenticeships. 2. For students graduating with advanced research degrees (especially doctoral degrees and post-doctoral researchers), there is a lack of access and/or awareness of job opportunities outside of academia. 3. Lack of integrated learning environments (e.g. online courses, certification programs) by which students and practicing professionals could learn and interact together.	2.3 3.1	Institutional

4.2 Training the existing transportation workforce

Table 7 identifies gaps pertaining to the training or professional development of the existing transportation workforce (Domain 2). While this portion of the gap analysis focuses principally on issues relevant to road authorities, many of the gaps may also be relevant to the private sector.

Table 7: Identified gaps – Training the existing transportation workforce

Gap identification and description	Related gaps	Scale
2.1 **Technical (hard) skillset gaps:** This set of gaps comprises technical skillsets relevant to disruptive transportation technology deemed to be insufficient within the existing transportation workforce. In the context of most transportation agencies, gaps 2.1.1 (AI and its enabling skills of computer programming, machine learning techniques, statistics, and data mining) and 2.1.9 (information and communications technology and cybersecurity) represent new job categories, while the remaining gaps represent incremental enhancements of existing job categories. 1. Artificial intelligence and its enabling skills of computer programming, machine learning techniques, statistics, and data mining 2. Computer-aided design and transportation-specific software 3. General transportation engineering knowledge 4. Intelligent transportation systems 5. Applied mathematics and statistics 6. Spatial analysis, GIS, and geomatics 7. Construction technologies 8. Equipment operations and electronics 9. Information and communications technology and cybersecurity	1.1 1.3 3.1 3.2 3.5	Municipal Provincial
2.2 **Non-technical (soft) skillset gaps:** This set of gaps comprises non-technical skillsets relevant to disruptive transportation technologies deemed to be insufficient within the existing transportation workforce. In the context of most transportation agencies, only gap 2.2.2 (ethical issues relating to data and technology) represents a new job category; the other gaps represent incremental enhancements of existing job categories. 1. Legal issues, liability, intellectual property, and insurance 2. Ethical issues relating to data and technology 3. Regulatory and policy analysis 4. Management and supervision 5. Contextualization and ‘big-picture’ thinking	1.2 3.1 3.2 3.5 3.6 3.7	Municipal Provincial

Gap identification and description	Related gaps	Scale
2.3 **Linkages with educational institutions:** Despite growing availability of training and professional development options, road authorities do not offer sufficient opportunities or incentives for employees to engage with these options. 1. On-line courses provided by universities, colleges, and professional associations. 2. Formal certification programs. 3. Formal degree programs, whereby employees return to school as mature students but retain their positions.	1.1 1.2 1.4 1.5 3.1	Municipal Provincial
2.4 **Mentorship and knowledge transfer:** This set of gaps encompasses the need for mentorship and other initiatives to retain or improve institutional knowledge. 1. Lack of formal mentoring programs available for new employees 2. Lack of knowledge transfer opportunities between employees 3. Lack of knowledge transfer opportunities between consultants and public agency employees (consultants training public agency employees)	1.5 3.1 3.2 3.4	Municipal Provincial National
2.5 **Development of professional networks:** Given the wide-scale needs associated with disruptive transportation technologies, there is a need for transportation professionals within the existing workforce to develop and engage with professional networks at municipal, provincial, national, and international scales.	3.2	Municipal Provincial National

4.3 Human resources practices and agency governance

Table 8 identifies gaps pertaining to human resources practices and transportation agency governance (Domain 3). While this portion of the gap analysis focuses principally on issues relevant to road authorities, many of the gaps may also be relevant to the private sector.

Table 8: Identified gaps – Human resources practices and agency governance

Gap identification and description	Related gaps	Scale
3.1 **Employee recruitment:** This set of gaps encompasses needs concerning employee recruitment. 1. Lack of understanding of technical skills and the need for those skills 2. Problem meeting compensation expectations of new applicants 3. Disparate hiring practices across agency departments 4. Filling vacant positions takes time within large agencies 5. Lack of integration with educational institutions, especially through delivery of course content and offering training opportunities 6. Lack of recruitment initiatives to attract highly skilled prospective employees, including those outside traditional recruitment venues 7. Presence of policies that do not allow for flexible hiring arrangements to help attract prospective employees	1.1 1.2 1.5 2.1 2.2 2.3 2.4	Municipal Provincial

Gap identification and description	Related gaps	Scale
3.2 **Employee retention:** While workforce training is an ongoing need, there are gaps associated with employee retention, especially within public agencies. 1. Growing disparity between public and private transportation sectors (salary gap, promotion, and/or worker mobility opportunities) 2. Competition for similar technical skillsets outside the transportation industry 3. Ageing workforce poses uncertainties regarding retirement timing and retention options	2.1 2.2 2.5	Municipal Provincial
3.3 **Equity, diversity, and inclusion (EDI) and HQP development:** This set of gaps acknowledges that some related to EDI issues persist within the transportation workforce. 1. Recruitment and retention of women 2. Recruitment and retention of Indigenous people 3. Recruitment and retention of internationally educated and trained transportation professionals 4. Problems integrating professional immigrants into the Canadian labour force	1.4	Municipal Provincial National
3.4 **Barriers between functional areas (silos) within a road authority:** Road authorities traditionally deliver services within well-defined functional areas, but there is an increasing need for decision-making across these areas. 1. Current organizational structures are not conducive to collaboration between functional areas. 2. Existing hiring practices assign employees to one specific functional area with little or no flexibility to move to other areas if needed.	2.4	Municipal Provincial
3.5 **Performance-based decision making and data governance:** As agencies evolve toward data-driven decision making, there are emerging needs related to data governance and stewardship. 1. Lack of formal decision-making authority and protocols 2. Need for data management structure to establish hierarchy and protocols between people involved in data governance 3. Need to improve data storage, retention, sharing, and security policies and practices	2.1 2.2	Municipal Provincial
3.6 **Procurement processes:** There is a need for procurement processes that enable timely engagement of companies and contractors.	2.2	Municipal Provincial
3.7 **Unionized workforces:** Acknowledging the important role of unions within road authorities, there are needs associated with the diverse requirements of different unions and uncertainties associated with the unionization of new positions.	2.2	Municipal Provincial
3.8 **Coordinated and reliable funding:** There is a broad need for dedicated and strategic funding to address the identified gaps.	All other gaps	Institutional Municipal Provincial National

5. Action plan

This chapter recommends an action plan to address the gaps identified in Chapter 4 over the short term (five years), medium term (10 years) and long term (20 years), with particular emphasis on domestic talent development, training of existing personnel, and staff recruitment and retention.

5.1 Recommended actions

The recommended actions emphasize domestic talent development, training of existing personnel, and staff recruitment and retention, in pursuit of three strategic goals:

- *Goal 1: Enhance the technical and soft skills of the future transportation workforce to improve job readiness* – This requires overcoming gaps in Domain 1 (see Section 4.1).
- *Goal 2: Increase the accessibility of education and training opportunities to support skills development for the existing transportation workforce* – This requires overcoming gaps in Domain 2 (see Section 4.2).
- *Goal 3: Improve existing human resources practices and governance processes related to workforce development* – This requires overcoming gaps in Domain 3 (see Section 4.3).

Recommended actions are presented in four tables:

- Table 9 identifies recommended actions for educating the future transportation workforce.
- Table 10 identifies recommended actions for training the existing transportation workforce.
- Table 11 identifies recommended actions related to human resources practices and agency governance.
- Table 12 identifies actions that are assigned to more than one theme.

Each table contains the following information about each action:

- *Action* – a unique identifier reflecting the major theme, and a concise description
- *Gap(s) addressed* – the gap addressed by the action (refer to Chapter 4)
- *Timeline* – an implementation timeline, either short term (five years), medium term (10 years), or long term (20 years)
- *Principal enabler* – the entity best positioned to make the action possible, given the support of others
- *Supporting actor(s)* – other entities that have a role to play in realizing the action
- *Autonomous Vehicle Readiness Index (AVRI) pillar(s)* – the related category(-ies) in KPMG's AVRI global ranking tool that measures a country's level of preparedness for the integration of autonomous vehicles based on four pillars (policy and legislation, technology and innovation,

infrastructure, and consumer acceptance; Canada ranked 12th in 2020). Categories that relate to HQP development are:

1. Policy and legislation pillar
    1a. AV regulations
    1b. Future orientation of government
    1c. Efficiency of legal system in challenging regulations
2. Technology and innovation pillar
    2a. AV-related patents
    2b. Availability of the latest technologies
    2c. Innovation capability
    2d. Assessment of cloud computing, AI and IoT
3. Infrastructure pillar
    3a. Technology infrastructure change readiness

Table 9: Recommended actions – Educating the future transportation workforce

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
EFW1	**Introduce data science content into statistics and probability courses**	The amount of data collected and available for engineering analysis has increased significantly, decreasing the need for extensive teaching of probability, and increasing the need for data science education. Statistics and Probability courses could be adapted to meet the current and future needs.	1.1	Short	**Canadian Engineering Accreditation Board (CEAB)**	Educational institutions	2a 2c 2d
EFW2	**Introduce minors in technology in civil engineering programs**	Offering minors in technology (specific topics to be selected based on industry needs) would incentivize interested students to develop skills they would not normally receive from the traditional civil engineering program and would make them more marketable for jobs that require a combination of civil engineering and advanced technology knowledge. Examples of minors could include data science, artificial intelligence, CAVs, cybersecurity, and ITS.	1.1	Medium	**Educational institutions**	Provincial road authorities Private industry	2a 2c 2d

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
EFW3	**Ensure that soft skills development occurs in all courses taught at undergraduate and graduate levels**	There is a current and future need for more well-rounded professionals and technologists. People who will be able to function within their own technical domains and who will also be able to think critically, communicate well, undertake complex problem solving, and have good decision-making skills. These soft skills could form part of all content taught at the graduate and undergraduate levels in educational institutions.	1.2	Short	**Educational institutions**	CEAB	2a 2c 2d
EFW4	**Engage students at a young age (junior high school or younger)**	By engaging students at a young age (around junior high school level) in computer programming and advanced technologies particularly pertaining to transportation, educational institutions, road authorities, and other stakeholders can improve the likelihood that these young people will choose careers that involve the application of technology, preferably in transportation. This could include increased outreach through National Engineering Week, class trips, and other extracurricular opportunities.	1.3	Medium	**Educational institutions**	Engineering licensing bodies Professional organizations	2a 2c 2d

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
EFW5	**Work with high schools to ensure successful transition of students into post-secondary STEM programs**	The competency gap between high school and post-graduate education could be bridged by coordinating with high schools so that students are taught courses that increase their capabilities in computer programming and advanced technologies.	1.3	Medium	**Educational institutions**	Engineering licensing bodies Professional organizations	2a 2c 2d
EFW6	**Create a repository of case studies involving transportation technology applications and practical examples for teaching purposes**	The creation of a national repository of case studies involving transportation technology applications and practical examples in transportation engineering and their application of technology could help professors at educational institutions share unique knowledge with students at the undergraduate or graduate levels.	1.4	Medium	**TAC**	Academics Provincial road authorities	2b
EFW7	**Implement flexible learning opportunities for students enrolled in selected STEM programs**	Since not every university has the capacity to offer courses in specialized technology areas, particularly as part of an undergraduate program, educational institutions should introduce flexibility into selected STEM programs by allowing students to take courses from other universities and easily transfer them to their home university. This could allow the program of studies for each student to be expanded to include specialized skillsets that will be required of HQP in the future.	1.4	Medium	**Educational institutions**	Private industry	2a 2c 2d

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
EFW8	**Collaborate with Engineers Canada and CEAB for curricula modifications**	Discuss changes to engineering curricula to ensure that CEAB and Engineers Canada understand the future of disruptive technologies and impact in workforce development.	1.4	Long	**TAC**	CEAB Educational institutions	2 2c 2d
EFW9	**Establish workforce development institutes**	To help meet both current and future transportation education needs in the workforce, short-term training courses could be offered by both professors and practitioners from private industry and the public sector to transportation agency employees and professionals seeking transportation engineering jobs.	1.4	Medium	**Employment and Social Development Canada**	Educational institutions Private industry Transport Canada	1a 1b 1c 2a 2c 2d 3a
EFW10	**Introduce programs in geomatics engineering**	Geomatics engineering provides the necessary skills for spatial thinking, GIS, and bid data analytics. While some universities and technical colleges offer programs in geomatics engineering, not all educational institutions do. Those institutions could benefit from expanding their undergraduate programs to include geomatics engineering.	1.1 1.2 1.3	Long	**Educational institutions**	CEAB	2a 2c 2d
EFW11	**Collaborate with educational institutions on curriculum updates**	Private industry and road authorities could collaborate with educational institutions on updates to the academic curricula to ensure their needs are served, thereby ensuring a continuous stream of talent.	1.1 1.2 1.3 1.4	Medium	**Educational institutions**	Private industry Provincial road authorities	2a 2c 2d

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
EFW12	**Introduce collaboration opportunities with industry and government**	Currently, engineering students are not exposed to enough case studies that look at larger systems or at transportation engineering issues in more detail. Educational institutions could collaborate with industry and government to expose students to these kinds of case studies that would enhance their training.	1.1 1.4	Short to medium	**Educational institutions**	Private industry Provincial road authorities	1a 1b 1c 2a 2c 2d 3a

Table 10: Recommended actions – Training the existing transportation workforce

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
ETW1	**Develop mentorship programs involving new employees and employees who are about to retire, to retain institutional knowledge**	With a large proportion of the workforce retiring soon, it is important to establish mechanisms that will ensure succession planning while providing mentorship opportunities for new employees. Road authorities could implement mentorship programs where new employees are paired with people who are about to retire to ensure knowledge transfer.	2.4	Short	**Provincial road authorities**	TAC	2a 2c 2d
ETW2	**Support and encourage upskilling of current workforce**	Road authorities could offer opportunities for apprenticeships to interested employees either by funding their programs or by offering part-time workload so that employees have the time and flexibility to pursue external education and training.	2.1 2.2 2.3	Short	**Provincial road authorities**	Educational institutions	2a 2c 2d
ETW3	**Support and encourage professional development within road authorities**	Opportunities such as conference attendance, short courses, or workshops are deemed to provide good return on investment. Road authorities could support and encourage employees to engage in professional development opportunities in transportation technology at least once per year.	2.1 2.3 2.5	Short	**Provincial road authorities**	Professional organizations	2a 2c 2d

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
ETW4	**Establish centres of excellence in major cities across the country**	By bringing together government, industry, and academia, the creation of centres of excellence for workforce development in disruptive transportation technologies could significantly contribute to HQP training. These centres of excellence could lead the development and administration of national certification programs, online training, and establishment of professional networks for collaboration between government, industry, and academia.	2.3 2.4 2.5	Medium to long	**Natural Sciences and Engineering Research Council (NSERC)**	Educational institutions Transport Canada Private industry	2a 2b 2c 2d

Table 11: Recommended actions – Human resources practices and agency governance

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
HR1	**Reassess current compensation structures**	Current compensation structures make it increasingly difficult to attract and retain people with the necessary skills for the ever-evolving employment needs. Reassessing existing compensation structures, road authorities can become more competitive with private industry as well as with other countries. Compensation can be monetary and non-monetary, and it could include items such as increased vacation time, remote work opportunities, special incentives for achieving certain milestones, flextime, and others.	3.2	Short	**Provincial road authorities**		1a 1b 1c 3a
HR2	**Develop and implement a strategy to better integrate immigrants into the Canadian workforce**	Many immigrants arrive in Canada with education and training in transportation technology or similar fields (this is because of the current immigration qualification process whereby skilled applicants are given preference under certain application streams). However, there is no established mechanism to help these newcomers to find employment once they arrive in Canada. While advanced foreign education was an asset for immigration, it is not easily recognized in Canada for employment purposes (e.g. in engineering and other highly specialized professional professions). A strategy for seamless integration of highly qualified immigrants into the Canadian workforce could ensure that a significant asset is fully utilized.	3.3	Medium to long	**Employment and Social Development Canada**	Immigration and Citizenship Canada Engineering licensing bodies	2a 2c 2d

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
HR3	**Work with Engineers Canada and local engineering profession regulators to address EDI issues in transportation engineering**	Engineers Canada is working with engineering licensing bodies across the country to increase the representation of women within engineering through its "30 by 30" initiative. The goal of this initiative is to raise the percentage of newly licensed engineers who are women to 30 per cent by the year 2030. Road authorities could become part of this initiative to ensure there is increased diversity in their workforce in the future (not only in transportation technology but in other areas of need).	3.3	Short	**Engineers Canada**	Engineering licensing bodies Educational institutions	1a 1b 1c 3a
HR4	**Create multidisciplinary teams to ensure knowledge transfer**	Formation of multi-disciplinary teams to work on service provision could help ensure that decision-making takes place involving multidisciplinary teams and that there is continual knowledge transfer. For example, transportation and IT staff could work together to develop standards, processes, and procedures. Another approach could be to pair IT staff with other specialties (e.g. electrical engineers) and transportation staff to stimulate knowledge transfer.	3.4	Short	**Provincial road authorities**		1a 1b 1c 2a 2c 2d 3a

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
HR5	**Develop and implement policies and protocols regarding data governance and use**	The continued implementation of disruptive technologies in transportation will result in the generation of large quantities of data. The use of this data may become a potential source of revenue for road authorities, but it will also be exposed to cybersecurity threats. It is important for road authorities to develop clear policies and protocols involving data governance and use to be able to continue to provide safe, cost-effective, and efficient services.	3.5	Short to medium	**Provincial road authorities**		1a 1b 1c 3a
HR6	**Develop policies and protocols for buying or leasing services associated with the management, maintenance, and operation of disruptive technologies and associated data**	The purchase of services can be facilitated by engaging specialists that can provide strategic advice on a given topic and who could also assemble procurement packages. To ensure this is done in an efficient and effective manner, road authorities could develop policies and protocols to engage the services of these specialists. However, while contracting out many of these services is an option, it is still essential that road authorities understand the risks, issues, opportunities, vulnerabilities, and other issues associated with their systems so that they can effectively develop the standards, regulations, and policies needed to address the various issues of importance (e.g. cybersecurity, AI implementation).	3.6	Medium	**Provincial road authorities**		1a 1b 1c 3a

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
HR7	**Develop and implement funding programs for workforce development**	Governments could develop and implement financial support to mature learners and professionals interested in upskilling or reskilling to ensure they can access in-person and/or online learning programs.	3.8	Short to medium	**Employment and Social Development Canada**	Transport Canada Private industry	1a 1b 1c 3a

Table 12: Recommended actions – Multiple themes

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
M1	**Fund research chairs in transportation technology**	The federal government and/or private industry could implement a program to fund Canada Research Chairs or Industrial Research Chairs in transportation technology that specifically address the workforce needs of a disruptive transportation technology future. These Chairs could be directly in CAVs, AI, Data Analytics, Data Science, Cybersecurity, or other topics of need.	1.1 1.2 1.3 1.5 3.1 3.3	Short to medium	**NSERC**	Private industry	1a 1b 1c 2b 3a
M2	**Expand co-op education opportunities and work-integrated learning programs in transport technology**	Having access to graduate and undergraduate students is one way to develop a strong future workforce. Road authorities could collaborate with educational institutions on work placements (e.g. co-op terms, internships, integrated learning program) as a recruitment mechanism for the future. Educational institutions could also enhance their current co-op and work integrated learning programs to focus on transportation technology to ensure students receive the necessary training for current and future jobs.	1.1 1.2 1.5 3.1	Medium	**Provincial road authorities**	Educational institutions Private industry	2a 2c 2d
M3	**Introduce an undergraduate program in transportation engineering**	Undergraduate interest in transportation engineering has been growing in the last decade, with continued growth expected in the transportation technology domain. Given sufficient demand, dedicated transportation engineering undergraduate programs (vs an undergraduate program in civil engineering) could be developed in selected Canadian universities to accelerate HQP development for a disruptive technology future.	1.1 1.2 2.1 2.2	Medium to long	**Educational institutions**	CEAB	2a 2c 2d

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
M4	**Collaborate with private industry to develop training opportunities for existing workforce**	Industry is investing extensively in disruptive transportation technologies while the need for HQP continues to grow. Educational institutions and road authorities could establish formal collaboration agreements whereby students and current employees can complete internships at technology companies.	1.1 1.2 2.1 2.2	Short	**Private industry**	Educational institutions Provincial road authorities	1a 1b 1c 2a 2c 2d 3a
M5	**Increase the number of technical electives in engineering programs**	By increasing the number of technical electives in engineering programs, the following specific knowledge gaps could be addressed: AI, CAD design and transportation-specific software, ITS, construction technologies, information and communication technologies, cybersecurity, GIS, and specialized transportation engineering.	1.1 2.1	Short to medium	**Educational institutions**	Private industry	2a 2c 2d
M6	**Work with the TAC Foundation to expand the scholarship program to target careers in transportation technology**	Leveraging the TAC Foundation Scholarship Program, top students (particularly from under-represented groups including women, Indigenous people, or immigrants) could be encouraged to pursue studies in transportation technology by offering them scholarships or internships. These could be created as new opportunities, or existing opportunities could be updated and enhanced to meet this goal.	1.3 3.3	Short	**TAC Foundation**	Provincial road authorities Transport Canada Private industry	2a 2c 2d

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
M7	**Develop and implement professional training programs for recent graduates and practicing professionals in the transportation/ technology fields**	Traditional 12-week course models are not able to serve all kinds of skill development. Professional associations could implement continuous professional development opportunities for people within the workforce. By accessing these opportunities, HQP may be better prepared to fill the skills gap for current and future jobs.	1.4 1.5 2.3	Short to medium	**TAC**	Professional associations Private industry	2a 2c 2d
M8	**Introduce certification programs on various technology topics**	There are limited opportunities for undergraduate and graduate students, as well as practicing professionals to obtain comprehensive education through established university/college degrees. By establishing online certificate programs on a variety of technology topics, professional associations could help the current and future workforce to stay at the leading edge of current and future technology topics.	1.5 2.3	Medium	**Professional organizations**	TAC	2a, 2c, 2d
M9	**Develop and implement a national strategy on workforce development**	The federal government could develop a strategy or incorporate transportation sector needs on workforce development for a future of disruptive transportation technologies. This strategy could not only focus on how to develop young people, but also include actions for retraining and retaining those that have been trained.	1.5 2.3 2.4 2.5 3.1 3.2 3.3 3.8	Short to medium	**Employment and Social Development Canada**	Transport Canada TAC	2a 2c 2d

Action		Description	Gap(s) addressed	Timeline	Principal enabler	Supporting actor(s)	AVRI pillar(s)
MD10	**Develop and implement local strategies on workforce development**	Individual road authorities need to develop a strategy on workforce development for a future of disruptive transportation technologies. This strategy could include actions on recruitment, retention, EDI, union issues, compensation, knowledge transfer, reskilling, and upskilling.	1.5 2.3 2.4 2.5 3.1 3.2 3.3 3.7	Short	**Provincial road authorities**	Employment and Social Development Canada	2a 2c 2d
MD11	**Implement rotational training within road authorities**	New hires could be placed in a rotational training program where they spend a few months in one department/division/branch, and then they rotate to other department/division/branch so that over time they become well rounded traffic engineers. This also includes being exposed to any new technological aspects in different types of jobs within the department.	2.1 2.2 2.4 3.4	Short	**Provincial road authorities**		2a 2c 2d
MD12	**Modernize apprenticeship training to make it more flexible and responsive to industry needs**	Governments need to invest in modernizing their apprenticeship training programs to make them more flexible and responsive to changes and needs related with disruptive transportation technologies	2.1 3.8	Short to medium	**Educational institutions**	Provincial road authorities	2a 2c 2d

5.2 Guiding principles and organizational roles

This section discusses considerations pertaining to the implementation of the action plan. It presents a set of guiding principles, organizations that could be involved and their roles, and identifies ways that TAC can initiate the action plan.

5.2.1 Guiding principles

The following principles can guide the implementation of the action plan contained in this chapter. The goal is that when addressing workforce development in a disruptive technology world, principal enablers and supporting actors will choose an approach that follows these principles.

Collaborate. In preparing for a future of disruptive technologies, workforce development will require extensive collaboration within road authorities and between road authorities and the private sector and educational institutions. In addition, there is a role for the federal government to play regarding workforce development opportunities that support provincial and territorial initiatives. Collaboration at an early stage of workforce development can help expand the pipeline of future HQP, as well as improve opportunities for training and retraining of existing HQP.

Plan and evaluate. The challenges associated with future transportation services in a disruptive technology environment are many. It is important that road authorities develop clear and realistic plans that will support workforce development in a way that supports technical and personal growth. The effectiveness of these plans should undergo continual evaluation to ensure success.

Encourage growth. As more advanced technologies permeate the transportation system it is important to encourage continual technical and professional development for current employees. Strong performance should be recognized to ensure continued growth as well as to encourage others.

Empower employees. Encourage and enable employees to act with respect to their professional and technical growth within the organization. As possible, provide financial support to help them advance their knowledge with respect to areas of need within the agency.

5.2.2 Key organizations and their roles

Given the complexity of this problem and following the principle of collaboration identified earlier, ensuring that the road authority workforce is ready for an era of disruptive technologies will require identification of principal enablers for each action, supporting actors who have a stake in a particular action, and the formation of partnerships to foster ongoing collaboration and overall governance of the action plan.

As shown in Tables 9 through 12, at least one principal enabler and supporting actor have been identified for each action. While this action plan has been developed through a funded project administered by TAC, it is acknowledged that successful implementation of the action plan necessarily involves other entities. Indeed, many of the actions identified fall outside the scope of TAC as an organization. To facilitate execution of the action plan, based on the extensive research and consultation conducted as part of this project, the table identifies a principal enabler that would most likely be able to help achieve each action. These principal enablers will need support and collaboration from other entities/actors to successfully implement the plan.

For example, Action EFW1 in Table 9 calls for the introduction of data science content into statistics and probability courses in engineering programs. While this is something that is under the jurisdiction of educational institutions rather than road authorities, it is something that needs to happen for the talent pipeline to head in the right direction. In this example, the table identifies the Canadian Engineering Accreditation Board as the entity that would most likely realize success for this action. Although each educational institution has a critical role to play in effecting the necessary curriculum changes, the CEAB has the authority to compel such changes through the accreditation process.

The action plan identifies the following principal enablers and supporting actors for the various recommended actions (listed in order of their appearance).

Canadian Engineering Accreditation Board. In its role as the entity responsible for accrediting undergraduate engineering programs in Canada, CEAB provides the academic requirements for licensure as professional engineers in the country. Any modifications to educational curricula would need to be done in collaboration and consultation with CEAB.

Educational institutions. All educational institutions (universities and technical colleges) are in a unique position to help advance workforce development in Canada and prepare graduates for a future of disruptive technologies in transportation. Many of the actions identified in the plan require input and leadership from educational institutions, as well as collaboration with private industry and government to ensure successful outcomes regarding HQP.

Provincial road authorities. Provincial road authorities are in a unique position to help with the implementation of various actions by helping to bring different provincial departments to the table on matters related to education or training. They can also collaborate with the various stakeholders coordinating the implementation of different actions and can help support internal skill development programs.

Private industry. Private industry is driving most technology developments that are currently and will continue to impact transportation in the future. As technology developers and potential employers, they have an important role to play in providing viable pathways into the workforce. Many of the actions included in this plan require participation from private industry, that can take many different forms (e.g. partnering with educational institutions, creating internal skills development programs, providing funding support for training).

Engineering licensing bodies. Engineering licensing bodies exist, among other reasons, to promote and increase the knowledge, skill, and competency of practitioners and students in all things relating to engineering. As such, these bodies, including Engineers Canada, can play a role in actions that require outreach to high school students, for example.

Professional organizations. Professional organizations such as the Canadian Institute of Transportation Engineers, Institute of Electrical and Electronics Engineers, Intelligent Transportation Systems Canada, Society of Automotive Engineers, and others can provide extensive support for actions involving special training outside of academic settings, upskilling, certification programs, and others.

TAC. TAC supports the development of a skilled, interdisciplinary workforce for Canada's transportation sector, and can facilitate collaboration among key stakeholders.

Employment and Social Development Canada. As the government agency responsible for improving the standard of living and quality of life for all Canadians by promoting a labour force that is highly skilled, ESD has a significant leadership role to play in the implementation of actions that have a national reach

or impact, such as helping to establish workforce development institutes, or working with other partners to improve the way in which immigrants are better integrated into the Canadian workforce.

Transport Canada. Like the provincial road authorities, Transport Canada is in a unique position to help with the implementation of various actions in this plan. In particular, Transport Canada can support actions of national impact.

Natural Sciences and Engineering Research Council. NSERC is Canada's largest supporter of discovery and innovation, working with universities, colleges, private industry, and not-for-profit organizations to develop opportunities and attract new expertise to advance Canada's research community. This positions them well to provide leadership on two of the actions involving future workforce development at the national level.

Immigration and Citizenship Canada. As the government agency that administers immigration programs such as Express Entry, which provides skilled immigrants who want to settle in Canada a seamless application process, there are opportunities for collaboration with other government agencies such as ESD to ensure that skilled newcomers can properly integrate into the workforce. Some actions in this plan call for improvements to the way in which skilled immigrants with expertise in disruptive technologies, can properly become part of the Canadian workforce.

TAC Foundation. As an important organization that supports the education and HQP development needs of the Canadian transportation industry, the TAC Foundation is well positioned to play a leadership role, in collaboration with other partners, in expanding the scholarship program to target careers in transportation technology.

5.2.3 Getting started

TAC can play a pivotal role in initiating many of the recommended actions, including a number of higher level "meta-actions" that could play an overall enabling role. It could:

- Raise awareness among its members and volunteer bodies about this report and its recommendations.
- Identify a selection of priority actions that it considers to be most critical.
- Develop information materials to engage partner and ally organizations, focusing on shared objectives, possible actions and mutual benefits.
- Convene a summit with partner and ally organizations to discuss the report and possible actions.

Bibliography

Adams, T., & Hart, M. (2017). *Region V Transportation Workforce Assessment and Summit.* NEXTRANS Center, Purdue University. (https://rosap.ntl.bts.gov/view/dot/35522)

Ahmadjian, C., Knodler, M., Fitzpatrick, C., Ryan, A., & Bouchard, C. (2018). Measuring the Effectiveness of Competency Models for Job-Specific Professional Development of Engineers & Engineering Technicians. Burlington: New England Transportation Consortium. (https://www.newenglandtransportationconsortium.org/wp-content/uploads/NETC_Final_14_1_updated-1.pdf)

Arcadis. (2017). *Sustainable Cities Mobility Index 2017: Bold Moves.* Arcadis. (https://www.arcadis.com/campaigns/scmi/index.html)

Bills, T. (2019). "Chapter 2: The great transformation: the future of the data-driven transportation workforce." In T. Reeb, *Empowering the New Mobility Workforce* (pp. 31-62). Elsevier.

Butler, J., & Harrington, M. (2018). *Workforce Challenges in Implementing Transportation System Management and Operations within Caltrans.* Berkeley: The University of California Institute of Transportation Studies. (https://escholarship.org/uc/item/4j3023xk)

California State University. (2019). *National Transportation Career Pathways Initiative: Final Project Report.* Long Beach: USDOT. (https://www.nntw.org/wp-content/uploads/2020/04/NTCPI-Year-Two-Report-final.pdf)

Centre for Connected and Autonomous Vehicles. (2018). *UK Connected & Autonomous Vehicle Research & Development Projects 2018.* London: Government of the United Kingdom. (https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/737778/ccav-research-and-development-projects.pdf)

Chang, K., Lutz, B., & Brown, S. (2019). Workforce Development Needs and Objectives of Today's Transportation Engineering Professional: A Regional Case Study. *2019 ASEE Annual Conference and Exposition* (13p.). Boulder, CO: American Society for Engineering Education. (https://peer.asee.org/33668)

City of Chandler. (2019). *Autonomous vehicle ride-hailing program.* Chandler, AZ. (https://www.chandleraz.gov/business/economic-development/key-industries-and-employers/autonomous-vehicle-r-d)

Contra Consta Transportation Authority. (2019). *3D Printed Self-Driving Shuttle, Olli, Undergoes Testing at GoMentum Station*. Retrieved January 26, 2021, from CCTA: https://ccta.net/2019/10/16/3d-printed-self-driving-shuttle-olli-undergoes-testing-at-gomentum-station

Cronin, B., & Alexander, A. (2019)."Chapter 6: Responding to the demographic and skill shifts in the mobility workforce." In T. Reeb, *Empowering the New Mobility Workforce* (pp. 125-148). Elsevier.

Cutean, A. (2017). *Autonomous Vehicles and the Future of Work in Canada.* Ottawa, Canada: Information and Communications Technology Council. (https://www.ictc-ctic.ca/wp-content/uploads/2018/01/ICTC_-Autonomous-Vehicles-and-The-Future-of-Work-in-Canada-1-1.pdf)

Deloitte. (2020). *2020 Global Automotive Consumer Study.* Deloitte. (https://www2.deloitte.com/xe/en/pages/consumer-business/articles/global-automotive-trends-millennials-consumer-study.html)

Eastern Ontario Training Board. (2021). *Eastern Ontario Training Board*. Retrieved from Eastern Ontario Training Board: https://eotb-cfeo.on.ca/

Ehteshami, G. R. (2020). Educational and workforce development through creation of programs in transportation to generate future careers for our students in Navajo Nation region. Baton Rouge: Transportation Consortium of South-Central States. (https://trid.trb.org/View/1716811)

Engineers Canada. (2015). *Engineering Labour Market in Canada: Projections to 2025.* (https://engineerscanada.ca/sites/default/files/Labour-Market-2015-e.pdf)

Executive Office of the President of United States. (2016). *Artificial Intelligence, Automation, and the Economy.* Washington D.C.: Executive Office of the President of United States. (https://obamawhitehouse.archives.gov/sites/whitehouse.gov/files/documents/Artificial-Intelligence-Automation-Economy.PDF)

Farah, H., Erkens, S., Alkim, T., & ven Arem, B. (2017). "Infrastructure for Automated and Connected Driving: State of the Art and Future Research Directions." In G. Meyer, & S. Beiker (eds), *Road Vehicle Automation 4. Lecture Notes in Mobility.* (pp. 187-197). Springer.

Future Skills Council. (2020). *Canada – A Learning Nation: a Skilled, Agile Workforce Ready to Shape the Future.* Ottawa: Employment and Social Development Canada, Government of Canada. (https://publications.gc.ca/collections/collection_2020/edsc-esdc/Em16-20-2020-eng.pdf)

Gerdes, J. (2018). *Not So Fast. Fully Autonomous Vehicles Are More Than a Decade Away, Experts Say*. Retrieved from GTM Mobility: https://www.greentechmedia.com/articles/read/fully-autonomous-vehicles-decade-away-experts#gs.MWDg6DE

Goldsmith, s., & Cmar, W. (2019). Chapter 3: Mobility management for smart cities professionals. In T. Reeb, *Empowering the New Mobility Workforce* (pp. 63-77). Elsevier.

Government of Canada. (2021, March 16). *Learning Hub*. Retrieved from Canadian Centre for Cyber Security: https://www.cyber.gc.ca/en/learning-hub

Hallmark, S., Veneziano, D., & Litteral, T. (2019). *Preparing Local Agencies for the Future of Connected and Autonomous Vehicles.* St. Paul, MN: Local Road Research Board, Minnesota Department of Transportation. (http://www.dot.state.mn.us/research/reports/2019/201918.pdf)

Harder, B., & Benke, R. (2005). NCHRP Synthesis 355: Transportation Technology Transfer: Successes, Challenges, and Needs. Washington D.C.: Transportation Research Board.

Harper, C., Halter, S., Kommalapati, R., & Choe, D. (2018). *Recruiting, Retaining, and Promoting for Construction Careers at Transportation Agencies.* Washington DC: United States of America Department of Transportation Research and Innovative Technology Administration. (https://trid.trb.org/View/1575961)

ICTC & CAVCOE. (2020). *Advances in Connected & Autonomous Vehicles: Current State and Future Trends.* Information and Communications Technology Council (ICTC). (https://www.ictc-ctic.ca/wp-content/uploads/2020/04/CAVs-ENG.Final_.0423.pdf)

Iowa DOT. (2017). *Interstate 80 Planning Study (PEL): Automated Corridors.* Ames: Iowa Department of Transportation, Office of Location and Environment. (https://iowadot.gov/interstatestudy/IADOT_PEL_80_AV_TechMemo_withAppendices_FINAL_20170629.pdf)

Johnson, C. (2017). *Readiness of the Road Network for Connected and Autonomous Vehicles.* London, UK: Royal Automobile Club Foundation for Motoring LTD. (http://www.racfoundation.org/assets/rac_foundation/content/downloadables/CAS_Readiness_of_the_road_network_April_2017.pdf)

Knapp, G., Bullock, M., & Stogios, C. (2020). *Connected and Automated Vehicle Technologies – Insights for Codes and Standards in Canada.* Canadian Standards Association (CSA Group).

KPMG. (2019). *Autonomous Vehicles Readiness Index.* KPMG. (https://assets.kpmg/content/dam/kpmg/xx/pdf/2019/02/2019-autonomous-vehicles-readiness-index.pdf)

KPMG. (2020). *2020 Autonomous Vehicle Readiness Index.* KPMG. (https://assets.kpmg/content/dam/kpmg/xx/pdf/2020/07/2020-autonomous-vehicles-readiness-index.pdf)

Lambert, L., & Roark, R. (2019). "Chapter 5: Anticipating and responding to changes in the mobility sector." In T. Reeb, *Empowering the New Mobility Workforce* (pp. 97-122). Elsevier.

Manitoba Infrastructure. (2017). "Manitoba Infrastructure Maintenance Career Training Program." In Investing in Transportation: Building Canada's Economy - - 2017 Conference and Exhibition of the Transportation Association of Canada. Ottawa, ON: Transportation Association of Canada. (https://www.tac-atc.ca/sites/default/files/conf_papers/manitoba_infrastructure_tac_eaa_submission.pdf)

Mentor Works. (2021). *Mentor Works*. Retrieved from Government Funding Directory: https://www.mentorworks.ca/government-funding/

Modi, S., Spulber, A., and Jin, J. (2018). *Impact of Automated, Connected, Electric, and Shared (ACES) Vehicles on Design, Materials, Manufacturing, and Business Models .* Ann Arbor, MI: Center for Automotive Research. (https://www.cargroup.org/wp-content/uploads/2018/07/Impact-of-ACES.pdf)

Motevalli, V., Potter, D., Meadows, J., & Galindo, C. (2019). *STEM in Motion at Tennessee Tech University.* Tennessee: Southeastern Transportation Research, Innovation, Development, and Education Center (STRIDE). (https://stride.ce.ufl.edu/wp-content/uploads/sites/153/2021/03/2019-STEM-in-Motion-K-12-TTU-Final-Report-with-technical-page.pdf)

National Academies of Sciences, Engineering, and Medicine. (2017). *Building America's Skilled Technical Workforce.* Washington DC: The National Academies Press. (https://www.nap.edu/catalog/23472/building-americas-skilled-technical-workforce)

NETWC, Northeast Transportation Workforce Center. (2016). *Transportation Job Needs and Priorities Report, Phase 1: Northeast Region.* Washington, DC: Federal Highway Administration, U.S. Department of Transportation. (https://rosap.ntl.bts.gov/view/dot/36132)

NETWC, Northeast Transportation Workforce Center. (2016). *Transportation Job Needs and Priorities Report, Phase 2: Northeast Region.* Washington, DC: Federal Highway Administration, U.S. Department of Transportation. (https://rosap.ntl.bts.gov/view/dot/36087)

NHTSA. (2005). *Event Data Recorder*. Retrieved from National Highway Traffic Satey Administration - Research Data: https://www.nhtsa.gov/research-data/event-data-recorder#overview-10516

NOCoE. (2016). *Transportation System Management & Operations (TSM&O) Workforce Development.* Washington D.C.: NOCoE. (https://transportationops.org/workforce)

O'Brien, T., Reeb, T., & Jaishankar, S. (2018). *Changing Workforce Development Needs for Regional Transportation Planning Agencies in California.* UC Davis: National Center for Sustainable Transportation. (https://escholarship.org/uc/item/3kk314sx)

Oliver Wyman Forum. (2019). *Urban Mobility Readiness Index.* Oliver Wyman Forum. (https://www.oliverwymanforum.com/mobility/urban-mobility-readiness-index-2019.html#)

PricewaterhouseCoopers. (2015). *Transportation & Logistics 2030 Volume 5: Winning the talent race.* PWC. (https://www.pwc.com/gx/en/transportation-logistics/pdf/pwc-tl-2030-volume-5.pdf)

Province of British Columbia. (2018). *CleanBC Plan.* Province of British Columbia. (https://cleanbc.gov.bc.ca/)

Province of Ontario. (2019). *Driving Prosperity: The Future of Ontario's Automotive Sector.* Ottawa: Province of Ontario. (https://www.ontario.ca/page/driving-prosperity-future-ontarios-automotive-sector)

Puentes, R., Grossman, A., Eby, B., and Bond, A. (2019). *NCHRP Synthesis 543: Transportation Workforce Planning and Development Strategies.* Washington D.C.: Transportation Research Board.

Reeb, T., & Olson, B. (2020). *Southern California Regional Transit Training Consortium: Skills Gap & Needs Assessment.* San José, CA: Mineta Transportation Institute. (https://transweb.sjsu.edu/research/1932-Southern-California-Regional-Transit-Training-Consortium-Needs-Assessment)

Ryan, A., Bouchard, C., Fitzpatrick, C., Knodler, M., & Ahmadjian, C. (2019). "Analytical Comparison of Core Competencies across Civil Engineering Positions within New England Department of Transportation Agencies." In *Transportation Research Record: Journal of the Transportation Research Board No. 2673*. Washington, DC: ranportatio Research Board of te National Academies, pp. 427-437. (https://journals.sagepub.com/doi/10.1177/0361198118822296)

Smart Cyber Security Network. (2020). *Cybersecurity programs*. Retrieved January 13, 2021, from Smart Cyber Security Network: https://www.serene-risc.ca/en/cybersecurity-programs

Southern Alberta Institute of Technology. (2020). *Southern Alberta Institute of Technology*. Retrieved from DX Talent Hub: https://www.sait.ca/about-sait/who-we-are/sait-schools/school-for-advanced-digital-technology

Southern Alberta Institute of Technology. (2021). *Southern Alberta Institute of Technology*. Retrieved from Corporate Training Program: https://www.sait.ca/corporate-training

Szymkowski, T., Ivey, S., Lopez, A., Noyes, P., Kehoe, N., & Redden, C. (2018). *NCHRP Project No. 20-07/Task 408*: *Transportation Systems Management and Operations Workforce Guidebook.* Pennsylvania:

National Cooperative Highway Research Program. (https://transportationops.org/tools/tsmo-workforce-guidebook)

Tyagi, H. (2021, February). *Data Science Learning Roadmap for 2021*. Retrieved from KDNuggets: https://www.kdnuggets.com/2021/02/data-science-learning-roadmap-2021.html

West Region Transportation Workforce Center. (2020). *University Partnership Playbook.* Bozeman: USDOT. (http://wrtwc.org/resources/university-partnership-playbook)

Workforce Intelligence Network. (2017). *Connected Automated Vehicles Skills Gap Analysis.* Detroit: Ralph C. Wilson, Jr. Foundation. (https://winintelligence.org/report/cav-report-2017/#full-report)

Workforce Intelligence Network. (2020). *Connected and Automated Vehicle (CAV) Skills Gap Analysis.* Southeast Michigan: Ralph C. Wilson, Jr. Foundation. (https://winintelligence.org/report/cav-report/#full-report)

World Economic Forum. (2019). *Towards a Reskilling Revolution: Industry Led Action for the Future of Work.* Switzerland: World Economic Forum. (https://www.weforum.org/reports/towards-a-reskilling-revolution)

Zhenzhen, Y., Donaldson, K., & Davidson, R. (2017). *Developing Cyber Talent for Canadian Road Authorities.* Ottawa: Information and Communications Technology Council. (https://www.ictc-ctic.ca/wp-content/uploads/2019/05/ICTC_Cyber-Talent-Transport_May28-2019.pdf)

401–1111 Prince of Wales Drive, Ottawa, ON K2C 3T2
(613) 736-1350 secretariat@tac-atc.ca

For more information about the Transportation Association of Canada and its activities, products and services, visit www.tac-atc.ca.