

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

TECHNICAL APPENDICES

APPENDIX A – LITERATURE REVIEW

APPENDIX B – ENGAGEMENT WITH ROAD AUTHORITIES

By

MORR Transportation Consulting

For

Transportation Association of Canada

April 2022

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1 Summary

This appendix presents the results from the literature review. The appendix begins by laying the stage regarding HQP training in Canada. It then 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 appendix then discusses workforce development challenges and opportunities for road authorities.

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.

At universities, currently 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. At the graduate level, it is more common to see highly specialized courses that address advanced technologies. On the job training in Canada as well as Internationally in the United States, United Kingdom, and Australia is provided through government initiatives at the various levels of government, through universities and through collaboration between the two.

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 key technical areas like computer programming, artificial intelligence, GIS, geomatics, big data analytics, cyber security, new construction technologies and intelligent transportation systems. Specifically, 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 will need to be planned for.

Some critical workforce development challenges identified in the literature include lack of understanding of technical positions, varying hiring priorities between the IT and transportation departments within government, issues with unions, long timelines for government staffing changes, changing workplace demographics, rapid changing of technology and unbalanced competition between the public and private sectors for skilled labour. Key opportunities to overcome workforce development challenges is grouped into four categories (1) workforce development partnerships; (2) human resources and hiring process; (3) training and development programs; and (4) promotion, recruitment, and retention.

2 HQP training

2.1 Initiatives in Canada

- The primary source of federal funding for HQP training in Canada is Employment and Social Development Canada (ESDC) through Workforce Development Agreements with each province and territory. These funds are provided for the “development and delivery of programs and services that help Canadians get training, develop their skills and gain work experience.”
- The ESDC’s Future Skills Council (2020) put together a shared vision for how to make Canada a learning nation, outlining five priorities and recommendations to meet these priorities. Priority 5 relates directly to CAV workforce development and recommends the development and expansion of access to training for digital skills and emerging technologies in particular artificial intelligence. Specific actions include:
 - “Invest in digital skills: Offset the costs for SME employers and employees to develop the digital skills needed to lead to the adoption of new technologies and business practices.
 - Strengthen cybersecurity skills: Create a center of expertise on workplace cybersecurity that can provide reliable, user-friendly assistance and up-to-date information, training, and resources to all employers to support ongoing workforce skills development to emerging threats.
 - Integrate artificial intelligence (AI) into workforce development planning: Build business leaders skills regarding AI implications for organizational success and workforce development.
 - AI knowledge at all ages and stages: Integrate AI and data science knowledge and skills, including personal and societal implications, into all education programs, in all disciplines and fields, and at all levels, from K-12 through to post-secondary and adult education.”
- The ESDC Future Skills Centre (FSC) is a pan-Canadian organization dedicated to creating a future in which everyone has life-long access to high-quality career advice and learning opportunities. Their current innovation projects related to disruptive transportation technologies include:
 - *Newfoundland Newcomer Employment Resilience Network*: The Newcomer Employment Resilience Network NL (NERNNL) network will provide employment support and engage stakeholders, professional organizations, regulators, employers, and training providers to maximize highly skilled newcomers’ existing skills while developing the resilience sought by employers today and in the future. The network will foster collaboration and knowledge exchange across all three levels of the skills ecosystem (individual, organizational, systemic) to improve career pathways and foster new insights for immigrant professionals. Future Skills Centre is investing \$247,920 in this two-year project. This initiative addresses this gap in Canada’s employment and skills development landscape.
 - *Smart Systems and Digital Technologies for a New Era*: A network of resources created from industry, municipalities, and McMaster University to facilitate accelerated adoption of digital technologies. Future Skills Centre is investing \$906,917 in this 2-year project.

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- *The Autonomous Microfactory:* The pilot project focuses on skills training in digital fabrication, automation, and collaborative robotics. These collaborative robots augment human labour by automating repetitive, dangerous and monotonous tasks unlike industrial robots that simply remove and place human labour. Facilitated by the Ryerson University's Creative Technology Lab, this initiative confronts the accelerated reality of autonomous production by introducing technology, equipment, and processes essential to operating an agile microfactory. Future Skills Centre is investing \$129,363 in this two-year project. It features seven workshops that survey the realm of manufacturing and production.
 - *Core Skills and Rapid Response:* This pilot project of the Manitoba Institute of Trades and Technology (MITT), which benefits Indigenous youth, aims to develop a rapid customization and core skills training process in response to critical labour shortages during COVID-19. Indigenous youth experienced even higher unemployment during the pandemic. Priority sectors in Manitoba are service, construction, health care and manufacturing. Future Skills Centre is investing \$146,530 in this two-year project.
 - *Aiming Higher: Micro-Credential Training in Aviation and Aerospace:* The Canadian Council for Aviation & Aerospace (CCAA) is leading a consortium of employers to develop and pilot an innovative, national micro-credentialing training system to address the sector-wide need for skilled workers and help drive industry recovery and regrowth. Micro-credentialing is an effective way to train staff in a range of specific skills and facilitate training in remote regions. The CCAA's system is unique for aviation and aerospace in that it's based on competencies rather than instructional hours and leverages emerging technologies to deliver the skills training sought by industry. Future Skills Centre is investing \$ 1,535,595 in this two-year project.
 - *STEM Skills and an Innovation Mindset for Youth:* As part of MindFuel's Canada Tech Futures – Youth Innovation Gateway initiative, which aims to develop skills and an innovation mindset among Canada's high-school and post-secondary youth, this project strives to reduce barriers to education in STEM (science, technology, engineering and math) and increase resiliency and adaptability for Indigenous youth in rural areas of Alberta, British Columbia and Yukon. Future Skills Centre is investing \$756,000 in this two-year project.
 - *North Coast Skills Hub:* This virtual platform will serve as a skills training and career development tool that is accessible and relevant to people in small and remote northern communities in British Columbia. Future Skills Centre is investing \$182,935 in this one-year project. In partnership with Evergreen, they are committed to collaborating with young people to tackle the big challenges and equip participants with the skills and confidence to explore topics most relevant in our cities right now.
 - *Future City Builders:* Future City Builders empowers un- or under-employed youth (ages 18 to 29), equipping them to build their own social purpose projects and create their own job opportunities while addressing a social need.
 - *Upskilling Canadian Youth for In-Demand Tech Careers:* NPower Canada's Junior IT Analyst program launches low-income, diverse young adults into IT careers through 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. Future Skills Canada is investing over \$1.8 million allowing NPower

Canada to scale up its workforce development program within Ontario and Alberta while rigorously testing its ability to replicate and expand its model to two new provinces, British Columbia and Nova Scotia, in 2021.

- *From Data to Decision: AI Training and Professional Certification:* Future Skills Centre is investing \$1 million on an innovative project developed by IVADO and Université de Montréal that will offer a short-duration, online AI program. The training will be delivered nationally, in English and French, to provide mid-career professionals and leaders with training on how to integrate AI into organizations.
- *Future of Work Skills Development Program:* This project is designed to promote skills resilience and to future-proof the Canadian labour force through a 12-module program that addresses in-demand skills such as problem-solving, emotional intelligence, and creativity that will be needed in the workforce of tomorrow. This program is delivered in a model that emphasizes self-directed and active learning, experiential learning, and targeted skills training. Future Skills Centre is investing \$164,600 in this one-year project.
- *Building the Skills of the Trucking Industry:* The Trucking Human Resource Sector Council Atlantic and its partners have developed a skills enhancement program to 1) improve the productivity of drivers today and 2) prepare the workforce for future technological advancements. The project will leverage virtual reality technology to deliver training in a way that compliments varied learning styles. The virtual reality simulator is the first of its kind specifically designed for the trucking industry with AI technology and the ability to track the user's eyes and enhance their driving skills in the unlimited replays. The Future Skills Centre is investing \$693,420 in this two-year project, which will offer innovative teaching tools to a minimum of 150 professional drivers in Atlantic Canada, with a goal of testing how to support the retention of the existing workforce and the recruitment of new workers to the sector.
- *FUSION: Future Skills Innovation Network for Universities:* To help universities bridge the gap between what students are taught and what skill are required in the current workforce, the Future Skills Centre is investing \$2.5M over two years in FUSION, a national network of six universities — Concordia University, Simon Fraser University, University of Calgary, University of Saskatchewan, Carleton University, and Memorial University of Newfoundland. This initial funding supports FUSION's network model, which will foster collaboration around skills development and speed the diffusion of successful innovations.
- The Natural Sciences and Engineering Research Council (NSERC) has awarded over \$40 million in research funding to Canadian researchers working on developing and testing AV technologies between 2010 and 2020. A key element of this research funding is the training of HQP and some programs funded are:
 - Building Trust in Connected and Autonomous Vehicles (TrustCAV) is a program funded by NSERC 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. The vision of this CREATE program is to create a self-sustaining training and research hub for CAV professionals with connections throughout Canada and globally to provide expertise and training in the technical, legal, ethical, and regulatory challenges associated with trustworthy and dependable CAVs. It is offered

through 5 universities (i.e. Carleton University, the University of Waterloo, the University of Ottawa, Queen’s University, and the University of Windsor) and more than 10 industry partners (e.g., Blackberry, Nokia, Cohort Systems, Ericsson, Solana Networks, etc.). TrustCAV features up to 180 placements for students from undergraduate through PhD levels at different organizations. The program includes:

- Industrial internships as an opportunity to apply theoretical knowledge and gain better understanding of the methods as well as practical requirements for a successful CAV future.
 - Short courses (20 hours each) that include mini-technical courses on trustworthy and dependable CAVs hardware, software, programming, as well as courses focusing on the legal, ethical, and regulatory challenges.
 - Hands-on workshops (1/2 to full day) on a variety of emerging topics, such as quantum computing, blockchain, cybersecurity, compressed AI models, and federated learning.
 - Professional development seminar series covering topics relevant to careers in this area, e.g., undertaking public engagement and developing a communication strategy related to emerging technology.
 - Annual colloquium series featuring speakers from the vehicular technology and regulatory community at large.
- The NSERC of Canada awarded \$31,000 to the University of British Columbia to research and develop safe and robust autonomous vehicle technology.
 - The NECRC of Canada awarded \$25,000 to Carleton University to research multi-agent reinforcement learning for autonomous vehicles.
- Automated and Connected Vehicles Gateway is an online platform of Transport Canada that facilitates collaboration between technical and non-technical experts to help identify new combinations of ideas and practices. The Gateway 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 is providing \$2.9M in funding under the program to Advance Connectivity and Automation in the Transportation System in order to help Canadian jurisdictions prepare for connected and automated vehicles. Some of the programs funded include:
 - The City of Saskatoon was awarded \$25K in funding under this program to study capacity building on connected and automated vehicles.
 - Transport Canada is developing an approach to guide stakeholders in ensuring cyber security practices are incorporated into the design and deployment of AV/CVs. Initiatives may include stakeholder engagement with all levels of government and industry, development of flexible policies, guidance and non-regulatory tools, such as Canada-wide cyber security guidance for AV/CVs.
 - The Driving Prosperity: The Future of Ontario’s Automotive Sector report (2019) sets out a 10-year vision for how industry, the research and education sector, and all three levels of government can work together to strengthen the competitiveness of Ontario's auto sector. Phase one consists of immediate action items. Phase two will address longer-term challenges

and opportunities. CV/AVs feature prominently in phase one. Some of the ongoing CAV talent development initiatives include:

- Phasing out the Ontario College of Trades to create a modern skilled trades and apprenticeship system that will make it easier for employers to hire apprentices and for apprentices to get trained and certified quickly.
- Enhancing STEM and AI grads through Raise AI, a two-year commitment to the Vector Institute, and by enhancing the pipeline of STEM graduates by improving math teaching, Ontario is ensuring that the auto sector will have the talent it needs in the future.

The report also noted the following immediate future initiative to increase the CAV talent pipeline:

- A micro-credentials pilot to test the ability of short, employer-recognized credentials, including for skilled trades and technology, to help unemployed Ontarians and at-risk workers gain the skills they need to succeed.
 - Modernization apprenticeship training to make it more flexible and responsive to auto sector needs.
 - Development of a CAV talent roadmap and skills inventory. The talent roadmap will help identify current and future skills needs to support sector competitiveness.
 - Provision of re-employment support to auto workers impacted by closures, including those in the broader supply-chain.
 - Establishment of an online learning and training portal focused on the skills needed to succeed in manufacturing.
 - Creation of new internships and other experiential learning opportunities across all aspects of the auto sector, including parts suppliers.
 - Increase funding to AVIN's TalentEdge program to support internships and fellowships for Ontario students' research into connected and autonomous vehicles.
- The Autonomous Vehicle Innovation Network (AVIN) initiative is funded by the Government of Ontario. It supports the commercialization of best-in-class, made-in-Ontario solutions, and helps Ontario's transportation systems adapt to emerging technologies. AVIN is administered by Ontario Centres of Excellence (OCE). It comprises five distinct programs and a central hub that supports the delivery of AVIN programming and acts as a focal point to help coordinate activities among Ontario's CV/AV ecosystem. The AVIN programs are: AV Research and Development Partnership Fund, Talent Development, Demonstration Zone, Regional Technology Development Sites, and WinterTech AV Development. AVIN Talent Development Fund 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.
 - The Artificial Intelligence (AI) Commercialization Working Group was launched in August 2019 as part of the Government of Canada's Advisory Council on Artificial Intelligence, building on the work started by the Digital Industries Economic Strategies. The Commercialization Working Group's mandate is to examine ways to translate Canadian-owned artificial intelligence (AI) into economic growth that includes higher business productivity, benefits for consumers, and job creation. In 2020, the Working Group proposed key actions items to turn Canadian research and

Intellectual Property (IP) into valuable and responsible AI products and services, increase business adoption of AI, and encourage the rapid growth and scale up of Canadian AI firms. This report noted heightening access to AI skills and talent for industry as a key priority. It recommends expanding the Pan-Canadian AI Strategy to encompass knowledge transfer and mobilization within its strategy by providing financial support for these activities, including support for technologies with sector-agnostic commercialization potential.

- The Eastern Ontario Training Board is funded by the Government of Canada and the Government of Ontario and plays a leading role in labor force development in Eastern Ontario. It develops partnerships that address the socio-economic and workforce development needs of Cornwall and the Counties of Stormont, Dundas, Glengarry, Prescott, Russell and Akwesasne. Partners include employers, municipalities, not-for-profit corporations, schools, police forces, Ontario ministries and federal departments. The program aims to invest in skills required to meet the needs of the knowledge economy and facilitate the transition of educated youth who are experiencing unemployment through upskilling.
- The CleanBC Program (2018) invests in expanding job training for electric and zero-emissions vehicles within the province at key colleges and universities. The program aims to help auto technicians develop skills required to work on EVs in service centres across B.C. The program is currently being offered at British Columbia Institute of Technology (BCIT) as a pilot. With \$325,000 in provincial funding through CleanBC, BCIT has completed the first of two rounds of the pilot program with the City of Vancouver's green-fleet technicians. By working with the city, BCIT is able to develop and test an EV curriculum with 12 Red Seal mechanics. The EV Maintenance Training Program is available as a part-time studies course at BCIT. Additionally, with funding of \$440,000 through the Province's CleanBC Go Electric program, and in partnership with Trades Training BC (TTBC), the program will be offered at Okanagan College's Kelowna campus, College of New Caledonia's Prince George campus and Camosun College's Interurban campus in Victoria.
- The Province of Nova Scotia invested \$16.8 million in Dalhousie, Saint Mary's, St. Francis Xavier, and Acadia University to expand and enhance their computer science programs. This investment is a result of meetings that were held with university officials and representatives of government departments and organizations responsible for growth, education, and innovation in the province. This investment aims to produce more digital talent in Nova Scotia to strengthen its start-up ecosystem across all areas including the road transportation industry. Additionally, the province has also invested seven million dollars in the Nova Scotia Community College's Institute of Technology to address the growing demand for the College's information technology programs and included a three-storey, 21,000 square foot addition to their current campus.
- Southern Alberta Institute of Technology set up a Corporate Training Solutions Division to build action-based, applied learning programs for new and fast changing industries. Recently, the Corporate Training Solutions recently partnered with Alberta IoT, a local not-for-profit hoping to position Alberta as the worldwide center of excellence for the Internet of Things technology. The organization's Fast Track Program is designed to help executives in established tech companies scale their operations and accelerate growth.
- The DX Talent Hub at the Southern Alberta Institute of Technology responds to both current and future needs for digital transformation skills in Calgary's economy. The DX Talent Hub 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 hub is centered around four digital transformation pillars:

- Digital adoption training
 - DX youth programming
 - Experiential learning
 - Competency upskilling and pathways mapping
- The University of Windsor 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 cyber security technologies to meet the needs of producers and consumers of advanced transportation systems. Additionally, the Centre will also work with APMA to build academic programs that address the cyber security needs of road transportation industry. The center will also promote knowledge transfer among manufacturers, researchers, and the public to ensure that policies and standards reflect advances made in the field.
 - The Information and Communications Technology Council (2017) published a synopsis of the potential impact that autonomous road-based vehicles will have on the Canadian job market and economy. The publication indicates that as of 2016, Canada's federal government has committed to growth of the digital economy which includes regulations for the safe adoption of connected and autonomous vehicles.
 - Smart Cybersecurity Network identified a list of 125 cybersecurity and cybersecurity-related programs offered by sixty-one Canadian post-secondary institutions. Additionally, Smart Cybersecurity Network also provide professional cybersecurity skill development events and training for students and young professionals in the public and private sector. Additional information regarding the 125 programs is listed at <https://www.serene-risc.ca/en/cybersecurity-programs>.
 - The Canadian Centre for Cyber Security's trainings are available through their Learning and Innovation Hub (LIH). The LIH is featured in providing adaptable learning pathways which have been developed to help security practitioners, supervisors and managers identify learning activities that will support cybersecurity knowledge and skill development. Additionally, LIH has broadened their mandate to include cybersecurity curriculum guidance to academia and industry with a focus on critical infrastructure. Additional information about the trainings is listed at <https://www.cyber.gc.ca/en/learning-hub>.
 - 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, driving collaborations at home and abroad to develop projects which solve business challenges, and develop the nation's innovation capacity.
 - The Canada Skills Program funded by Microsoft Inc. extends skilling program to 20 schools in six provinces across Canada, enabling more students to graduate with in-demand data analytics, AI, and cloud certifications. Launched in fall of 2020, the program allows students to acquire this type of training alongside their institutions' credentials. The program aims to enhance the student's employability as they enter the job market. In the first six months, over 20,000 students participated. Additionally, Microsoft is partnering with the Digital Technology

Supercluster, Npower Canada and Blueprint to provide skills training to unemployed and underemployed youth from communities underrepresented in the digital economy.

- Mentor Works is a grant writing agency helping government institutions and private companies apply for Canadian government funded programs and grants. Additional information about the various emerging technology related programs is listed at <https://www.mentorworks.ca/government-funding/>.

2.2 International initiatives

- SAE International is a global association of more than 128,000 engineers and related technical experts in the aerospace, automotive and commercial-vehicle industries. The organization is committed to advancing mobility knowledge and solutions for the benefit of humanity. The organisation is the global leader in technical learning for the mobility industry and provides training for professional development and STEM education. The organisation provides certification in Internet of Things (IoT) analytics and online courses, some pertaining to disruptive technologies, like:
 - Robotics for Autonomous Vehicle Systems Bootcamp
 - Big Data Analytics for Connected, Autonomous Vehicles and Smart Cities
 - Autonomous Vehicles for Transportation Professionals
 - Introduction to Hybrid Electric Vehicle Systems
- The International Information System Security Certification Consortium ((ISC)²) Certified Information System Security Professional (CISSP) is designed for experienced security practitioners, manager, and executives, with a focus to equip them with a wide array of security practices and principles. Additionally, the (ISC)² also provides an engineering CISSP concentration that certifies applicants in the following knowledge streams related to cybersecurity in the engineering field:
 - Systems Security Engineering Foundations
 - Risk Management
 - Security Planning and Design
 - Systems Implementation, Verification and Validation
 - Secure Operations, Change Management and Disposal
- The Institute of Transportation Engineers (ITE) is an international membership association of transportation professionals who work to improve mobility and safety for all transportation system users and help build smart and livable communities. Through its products and services, ITE promotes professional development and career advancement for its members, supports and encourages education, identifies necessary research, develops technical resources including standards and recommended practices, develops public awareness programs, and serves as a conduit for the exchange of professional information. It currently offers live and on demand webinars, education certification courses and professional development courses. Some CAV and disruptive transportation technology related courses and webinars offered by them include:
 - ITS ePrimer: Connected Vehicles and Data in Decision Making

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- NaTMEC: Emerging Equipment, Technologies and Capabilities to Address Travel Monitoring Basics and Beyond
 - ITS ePrimer: Application of ITS in TSMO and ITS in Emergencies and Disasters
 - Sustainable Transportation: Advanced Vehicle Technologies, Electrification, and Next-Generation Mobility
 - Road Safety Fundamentals: ITS, TSMO, and Safety in Operations
 - CV/AV Needs Specific to Emergency Response

United States

- 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 in February 2021. The institute is intended to help meet both current and future transportation education needs in the workforce throughout the Pacific Northwest of the United States. This will be done through the offering of short-term training courses for transportation agency employees as well as students and professionals seeking transportation engineering jobs. The courses will be taught by both professors and practitioners from companies and agencies. One of the long-term plans of the WDI is to conduct K-12 outreach to educate youth about employment in the transportation industry.
- In October 2016, the California State University, Long Beach Research Foundation was awarded the \$1.25 million Transportation Workforce Strategic Initiative on behalf of the National Network for the Transportation Workforce (NNTW) to set up the National Transportation Career Pathways Initiative. Over the course of its two-year lifespan, this strategic initiative sought to establish 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.

To accommodate this enormous research effort, each NNTW Regional Center was assigned one of the five disciplinary focuses specified by the initiative as illustrated in Figure A-1.

The role of each Regional Center in the deployment of this workforce initiative is detailed below:

- *Southwest Transportation Workforce Center (SWTWC)*: Housed at the California State University at Long Beach, the SWTWC Regional Center acted as the initiative's programmatic lead while also researching and evaluating the "Transportation Planning" workforce discipline of NTCPI. Throughout the project, SWTWC worked to clarify the role of the transportation planner—as found in both public and private-sector employment—and the workplace competencies that are considered critical to the effective execution of the transportation planning function.
- *Southeast Transportation Workforce Center (SETWC)*: Housed at the University of Memphis in Tennessee, the SETWC Regional Center researched and evaluated the "Transportation Operations" workforce discipline. The transportation operations workforce is characterized by a diverse set of occupations supporting the safe, reliable, and efficient movement of people and goods. Central to their mission is the integration of transformative technologies to improve operational outcomes, and the necessity of a systems approach.

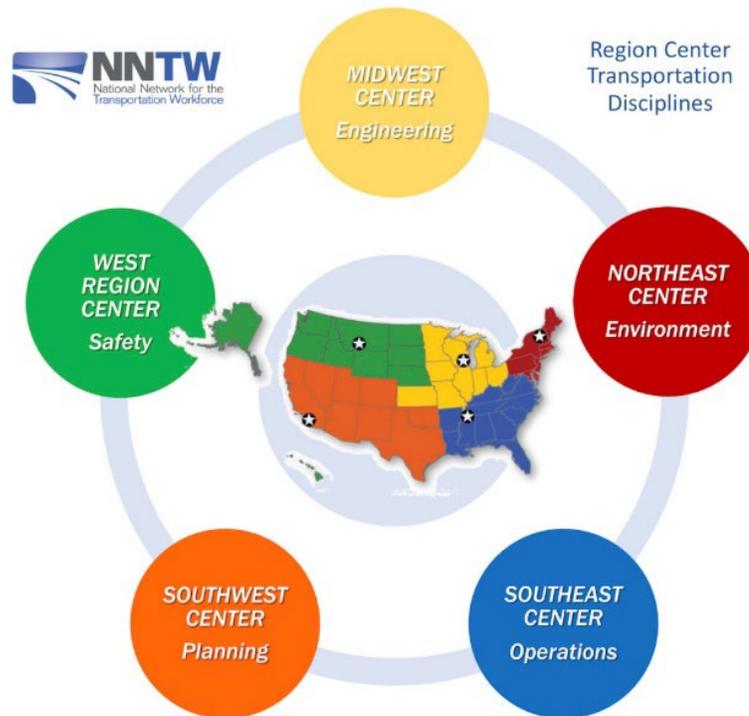


Figure A-1: National Network for the Transportation Workforce Regional Centers

- *Northeast Transportation Workforce Center (NETWC)*: Housed at the University of Vermont at Burlington, the NETWC Regional Center researched and evaluated the “Transportation Environment” workforce discipline of NTCPI. The environmental workforce in transportation emerges from highly inter-disciplinary knowledge sets, skills and backgrounds to take on a wide range of responsibilities and functions.
- *Midwest Transportation Workforce Center (MTWC)*: Housed at the University of Wisconsin at Madison, the MTWC Regional Center researched and evaluated the “Transportation Engineering” discipline, with a particular focus on the highway maintenance workforce.
- *West Region Transportation Workforce Center (WRTWC)*: Housed at the Montana State University at Bozeman, the WRTWC Regional Center researched and evaluated the “Transportation Safety” workforce discipline of NTCPI. The goal of road safety is for all transportation system users to travel freely without risk of harm or death.

The Center also developed the University Partnership Playbook (2020) using the EPIC model which makes university resources (faculty, students, laboratories, specialized and multidisciplinary expertise, etc.) available to public entities to help solve their priority challenges by creating mutually beneficial partnerships. The model provides a mechanism for public agencies to integrate a variety of project tasks into student coursework. In the process, the agency can expand its capacity dramatically from what otherwise might be possible with limited staff and available internal resources. The playbook also gives examples of success stories from different locations around USA, which highlight potential outcomes and benefits of the program.

The centers detailed their workforce findings in a comprehensive Career Pathway Report by California State University (2019) which includes plans for “Advancing Apprenticeships in Highway Maintenance Engineering.”

- The Florida Transportation Technology Transfer (T2) Center is part of the University of Florida Transportation Institute (UFTI), located in the Herbert Wertheim College of Engineering at the University of Florida. Since 1984, the UFTI-T2 Center has provided workforce development and training, technical assistance, and technology transfer services to national, state, and local transportation and safety partners, and the general public. Tech transfer helps develop resources to implement the new technology and assists with training the workforce for safe and effective application of the new technology.

UFTI-T2 Center provides training to transportation professionals in various public and private careers such as: oversized load pilots, traffic maintenance crews, designers, engineers, public officials, field personnel, roadway construction supervisors, commercial motor carriers, pilot escort vehicle operators, temporary traffic control designers, traffic control flagmen, consultants, contractors, and traffic signals maintenance crews. Additional information about the various trainings is listed at <https://xms.dce.ufl.edu/reg/groups/FT/>.

- The Florida Local Technical Assistance Program (LTAP) Center 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 mission of the Florida LTAP Center is to improve the skills and increase knowledge of the local and tribal transportation workforce through training, technical assistance, and technology transfer to foster a safe, efficient, and environmentally-sound surface transportation system. The program is overseen by the Center for Urban Transportation Research (CUTR) at the University of South Florida. The center provides scheduled and self-paced training programs and additional information about the various trainings and webinars available is listed at <https://floridaltap.org/training-and-events/>.
- Rutgers Center for Advanced Infrastructure and Transportation (CAIT) tackles some of the country’s most pressing infrastructure challenges, especially those that are endemic in high-volume multimodal corridors like the Northeast. CAIT research focuses on preserving, rehabilitating, and improving infrastructure; boosting network resilience; reducing life-cycle costs; and increasing mobility and safety. CAIT is currently organizing the Infrastructure cybersecurity and emergency preparedness training. Additional information about the various trainings are listed at <https://cait.rutgers.edu/events/>.
- Transportation Learning Center is the only national organization that focuses on the frontline workforce in public transportation and transportation in general. It is the only organization funded by the Federal Transit Administration, the US Department of Labor, and the Transit Cooperative Research Program to develop and support technical training partnerships for today’s and tomorrow’s front-line work force. As an advocate of the labor-management training partnership model, the Center supports its programs and mission through research and information ranging from broad overviews of public transportation, training, and partnerships to technical white papers to research briefs and metrics reports on the benefits of labor-management training partnerships.

Working with labor and management representatives, the Center develops national standards for workforce training in the following key areas of transit relevant to disruptive technologies:

-
- Bus maintenance
 - Rail vehicles
 - Rail signals
 - Traction power
 - Bus operator

Supported by the U.S. Department of Labor and the Federal Transit Administration, this project creates models for training and apprenticeship that can be used by systems across the country to address their training needs.

- 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.
- The Strengthening Career and Technical Education for the 21st Century Act (Perkins V) was signed into law and reauthorizes the Carl D. Perkins Career and Technical Education Act of 2006 (Perkins IV) and continues Congress' commitment to providing nearly \$1.3 billion annually for career and technical education (CTE) programs for our nation's youth and adults. Some national initiatives funded by this act pertinent to the transportation sector include:
 - *Career Pathways System*: This system integrates collections of strategic programs and services that help students and job seekers transition from education to employment. They connect the necessary adult basic education, occupational training, postsecondary education, career and academic advising, and support services so that students and workers can successfully prepare for, obtain, and progress in their career.
 - *CTE CyberNet*: The U.S. Department of Education is collaborating with other federal agencies on a national cybersecurity teacher professional development initiative — CTE CyberNet. This initiative seeks to increase the number of career and technical education (CTE) teachers who can effectively prepare students for cybersecurity education and careers. Through a localized academy approach, teachers will gain strategies and tools to deliver more rigorous, standards-aligned CTE cybersecurity programs of study, which prepare students for postsecondary education and/or work-based cybersecurity learning.
- The Consortium for Innovative Transportation Education (CITE) provides transportation engineering students and professionals with an integrated curriculum covering the technologies and management subjects associated with ITS training and education. The organization aims to increase overall number of properly educated transportation management and operations professionals through online training. Cite offers different type of online courses where students can choose to take the courses as an independent study or with blended instructions (independent study + instructor led) as per convenience. Upon satisfactory completion of a course and its evaluation, students will be awarded certificates and the appropriate Continuing Education Units (CEUs) from the University of Maryland. Some critical courses currently available through CITE are:

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- *Applications & Planning for CV Systems:* This course provides a foundation for why connected vehicle applications should be implemented and how they are connected to current transportation needs.
 - *Transportation Cyber Security:* CITE, in collaboration with the U.S. Department of Transportation, provides a cybersecurity course designed for professionals working with surface transportation systems, and is geared towards improving the understanding of the complex and rapidly changing technologies associated with the broad discipline of cybersecurity.
 - *Network Design and Deployment Considerations for TSMO Managers and Professionals:* This course provide a system-level understanding of the operation of modern broadband transportation communications networks. This course focuses on how to plan and implement telecommunications networks to support a major Intelligent Transportation System (ITS) infrastructure.
 - *Deploying ITS: Strategic Planning and Implementation:* This course provides a blueprint adopt a structured approach to deploying ITS systems in jurisdictions through a number of years of practical experience in assisting public agencies and private companies to conduct strategic planning for ITS
 - The Operations Academy Senior Management Program trains transportation leaders in transportation system management and operations strategies and its applications so that they are knowledgeable of the field and effectively advocate for it within their organization. Acceptance for the program is competitive, and requires the nomination of a local, State or Federal transportation agency. The program is funded by Eastern Transportation Coalition (formerly the I-95 Corridor Coalition), National Transportation Operations Coalition (NTOC), the Federal Highway Administration (FHWA), and the Institute of Transportation Engineers (ITE).
 - The ITS Heartland’s TSMO University operates the Regional Operations Forum Training Program (Train the Trainer) that educates state representatives on how they can deliver information about TSMO to various groups, from executive level leaders in their DOTs to operations staff, designers, contractors and maintenance personnel.
 - The National Operations Center of Excellence (NOCOe) is Federal program designed to offer a suite of resources to serve the transportation systems management and operations (TSMO) community. The center offers an array of technical services such as peer exchange workshops and webinars, ongoing assessments of best practices in the field, and on-call assistance. The Center also has a comprehensive and searchable database of TSMO industry trainings and courses. Additional information about the various TSMO workforce training related programs is listed at <https://transportationops.org/training>.
 - The Regional Operations Forums (ROFs) developed by the second Strategic Highway Research Program (SHRP2) and the Transportation Research Board (TRB), provide practitioners with new and innovative approaches for managing and operating the highway system, drawing from the cutting-edge work being carried out under the SHRP2 program and other national programs in the United States. The program is managed by the National Operations Center of Excellence. The forum aims to provide strategies, technologies and practices needed to advance the paradigm shift towards Advancing Systems Operations, Management, and Reliability.
 - The Eno Center for Transportation (Eno) provides government and industry leaders with timely research and an independent voice on policy issues related to transportation. Additionally,

through its professional development programs, Eno cultivates creative and visionary leadership by giving public and private transportation leaders the tools and training they need to succeed together. The Transportation Senior Executive (TSE) program aims to refine leadership and intrapersonal skills of transportation professionals, applying high-level strategic techniques to challenging real-world situations.

- The ITS Professional Capacity Building Program works with the managers of the ITS Program's research programs to devise, coordinate, and implement outreach and technology transfer activities. The program keeps transportation stakeholders informed about the progress in research and advances in ITS technologies and how they can be applied to solve real-world transportation challenges through online courses and webinars. To illustrate, to support USDOT's ambitious technology transfer effort for CAVs, ITS PCB Program is assisting by highlighting demonstrations of connected vehicle concepts and technologies, developing T3 webinars on lessons learned from the ITS Test beds and model deployment, and collecting audience needs for future connected vehicle training.
- The National Highway Institute is the training and education arm of the Federal Highway Administration (FHWA). NHI offers Instructor-led training from short, 1-day courses to multi-week sessions. Additionally, the NHI is recognized as an accredited training provider by the International Association of Continuing Education and Training (IACET), so participants can earn Continuing Education Units (CEUs) for NHI training courses. Additional information about the various NIH trainings is listed at <https://www.nhi.fhwa.dot.gov/course-search?tab=0&sf=1>.
- The American society of civil engineers represents more than 150,000 members of the civil engineering profession in 177 countries across the world. They provide some online training courses that aims to advances the educational and professional standards for civil engineers. Some courses relating to disruptive technologies are:
 - Connected Automated Vehicles Past, Present and Future
 - Connected Vehicles, Smarter Cities, & Modern Signal Timing - How Traffic Engineering Strategies Will Change in the Years Ahead
 - Automated Public Transit Systems: Best Practices and Potential Future
 - Foundation for Using GIS for Infrastructure Asset Management
 - Develop, Maintain, and Operate Asset Management Spatial Databases
 - Development of GIS Models for Asset Management
 - Digitization in the field of Civil Engineering
 - Foundation for Using GIS for Infrastructure Asset Management
 - Future World Vision: An Innovative Forward-Looking Tool for Resilient Future Infrastructure
- The Connected Vehicle Trade Association (CVTA) is a non-profit business league established to facilitate the interaction, and advance the interests, of the entities involved in the vehicle communication environment. The organization conducts the Connected Vehicle Professional™ (CVP) Credentialing Program, a comprehensive education and certification curriculum collaboratively launched between the Connected Vehicle Trade Association (CVTA) and The Next Education. The series of three courses enhances understanding around Vehicle-to-Vehicle, Vehicle-to-Infrastructure, and Vehicle-to-X connectivity inclusive to the rapidly advancing field

of Intelligent Transportation System (ITS) and Connected Vehicles. The courses are aimed towards experienced IT professional, software engineer, automotive engineer, information and vehicle technician, insurance and telecommunications professional, transportation staff and service professional looking to enhance their professional career in this growing sector.

- The Small Urban and Rural Center on Mobility develops and provides various training sessions for small urban and rural transit operators, local and regional transit associations, and state Departments of Transportation. Programs are delivered on-site and can be tailored to accommodate any learning environment. The following topics, pertaining to disruptive technologies and workforce development, are currently available:
 - Hiring and Retaining Great Transit Employees
 - Intelligent Transportation Systems
 - Managing Vehicle and Facility Maintenance Programs
 - Performance Measurement
- The USDOT Center for Transportation Workforce Development provides national leadership, coordination, and assistance that supports initiatives to develop and expand the nation's transportation workforce. From early education through ongoing professional development, the center provides program support, technical assistance, and workforce development activities in partnership with federal, state, and local agencies, industry organizations, schools, colleges and universities, and other education providers. Some of the programs and professional development initiatives developed by the center are:
 - *Highway Construction Workforce Partnership (HCWP) / Strategic Workforce Development (SWD)* aims to increase the capacity and capability of the highway construction workforce. By partnering with key organizations to develop and deploy highway construction training and placement programs, this initiative will increase the number of individuals trained and hired in highway construction trades and crafts.
 - *On-the-Job Training Supportive Services (OJT/SS)* are apprenticeship and training programs targeted at moving women, minorities, and disadvantaged persons into journey-level positions.
 - *Garrett A. Morgan Transportation Technology Education Program* improves the preparation of students, particularly women and minorities, in science, technology, engineering, and mathematics (STEM) through curriculum development and other activities related to transportation to fulfill the need for a highly skilled, diverse, and multi-disciplinary future transportation workforce.
 - *National Summer Transportation Institutes (NSTI)* is two-to-four-week Science, Technology, Engineering and Math (STEM) - focused program that exposes students to the transportation and encourages them to pursue transportation-related courses of study at the college and university level. Institutions of higher education host students to introduce them to all modes of transportation. Accredited colleges and universities are selected as host sites upon application to a State DOT, which provides oversight along with program support and guidance from the FHWA Division Office.

United Kingdom

- Regional development organizations, such as the North West Rail Industry Leaders Group and the Rail Forum East Midlands (RFM), brings together businesses to support the rail industry in the region. The groups have identified key issues such as, skills, promotion and integration, to focus on, with members including leading suppliers, operators, and research bodies, the group seeks to increase collaboration, integration and investment.

The RFM has close links with Midlands Connect, local councils, Local Enterprise Partnerships, Department for International Trade and other industry groups and stakeholders, including close co-operation agreements with the Railway Industry Association (RIA), the Rail Freight Group (RFG) and the Civil Engineering Contractor's Association (CECA). The agency also aims to drive and co-ordinate Midlands region school engagement and skills development initiatives to ensure member access to skills they need for the future coordinated by the People, Skills and Diversity Advisory Group. Additionally, they are partnering with the newly opened Derby University Technical College and has developed a pilot apprenticeship offering which will makes it easier for SMEs to recruit and train apprentices. Working with large employers, the forum identifies suitable surplus candidates and matches them with Small and medium-sized enterprises (SMEs) through recruitment and selection support. Support is also available to identify the best training programmes and partners to meet their skills needs using the new Apprenticeship Standards.

- One of the major causes of supply chain inefficiency and higher costs in the transportation sector is the adversarial nature of relationships that often exist between customer and supplier. To remediate this with increased collaboration the Railway Industry Association initiated the Value Improvement Program (VIP), a workshop-based initiative aimed at increasing efficiency and performance by improving culture and behaviors. This is adapted from an earlier successful aerospace model, founded upon an agreed industry Code of Practice and seeks to improve performance and efficiency through embedding collaborative behaviour in the supply chain Over 100 such workshops have so far been held, some on the rolling stock side, but mostly infrastructure-related with the support and endorsement of Network Rail.
- Under the Union Learning Programme, Unite and ScotRail organised an apprenticeship programme to facilitate progression paths through the engineering skills grades. Prior to the commencement of the apprenticeship, candidates undertook an Open College Network accredited 'Brush Up Your Skills Course' arranged and delivered by Unite. This course gave them the confidence and skills to undertake the National Certificate studies and the skills to compile the portfolio for the SVQ Levels 2 and 3, despite being away from the learning environment for many years.
- The Knowledge Transfer Partnership (KTP) program is an Innovate UK initiative linking businesses with a university and a graduate to work on a specific project which typically receives 50%-66% Innovate UK funding. LPA Connection Systems, manufacturers of inter-connection systems and electrical control boxes for railway rolling stock, entered into a KTP with the University of Essex in 2013 to develop their Ethernet Backbone project, which provides future-proofed Ethernet systems for trains.

LPA worked with a KTP graduate for two years to develop their technology, with a view to employing him full time at the end of the project. As a result of the KTP, LPA has been able to offer the world's first 10GbE bandwidth Ethernet train backbone over copper, providing bandwidth greater than current demand, avoiding costly upgrades to customers' installations as demand increases in the future. LPA launched the innovative technology 12 months after the

start of the KTP following successful demonstrations at rail industry trade shows and they received £1.0M of orders and £0.9M sales during the period of the KTP, with sales expected to continue growing with increasing demand for on board Wi-Fi.

- Network Rail has developed a programme on behalf of the industry to build eight new national training centres across the country ranging from Larbert in Scotland, Bristol in the West UK to Paddock Wood in East UK. Each of these centres takes the lead on a specific area of training such as third rail, overhead line equipment and operational training. By April 2016, the £55m investment programme completed generating 270,000 training days a year for 260 different railway companies. Over 300 courses including safety critical training is available to the industry. In addition, Network Rail recruits over 50 engineering graduates and 200 apprentices each year.
- 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. NTAR specializes in vital traction and rolling stock training offers unrivalled facilities and courses, with the Northampton center acting as a hub to support and deliver services to customers across the country. NTAR has been established to support all organizations across the industry: Train Operating Companies, Freight Operating Companies, Original Equipment Manufacturers, Rolling Stock Operating Companies, Network Rail and the wider supply chain. The courses and services are designed to address the development needs of a wide range of customers including young people setting out in their careers; existing teams of maintainers and technicians; rolling stock and rail systems engineers; career changers joining the industry; and supervisory and management teams.
- The National College for High Speed Rail (NCHSR) is supported by HS2 Ltd and 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 vision is to deliver a step change in vocational learning for the rail sector and attract a wider pool of talent into science, engineering, and technology to place the rail industry at the cutting edge of innovation. 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. Learners coming from the college will have undertaken study sponsored by employers and have had a third of their learning time in the workplace, developing both technical and employability skills.
- Track and Train is pan rail paid work placement scheme led by Network Rail. The scheme was launched in 2012 and ran with 2 cohorts. The scheme, which received more than 2,500 applications, provided an all-round industry experience over 18 months, where graduates benefitted from three 6-month placements – one at Network Rail and two at either a passenger or freight operator or another company within the rail sector. This provided the graduates with the all-important cross-industry experience to understand all aspects of the railway. The scheme was targeted at graduates who were either unemployed or more likely under employed in a non-graduate level role. Track and Train gave them an opportunity to gain valuable practical experience to then take the next step in their careers with the transport sector. In both schemes over 90% of participants secured permanent jobs – 80% of which were within the rail industry. 30% of the new recruits were female, which was really encouraging to see the industry attract talent from a wider pool of graduates than traditionally seen. The opportunity exists to revitalise a pan sector scheme such as Track and Train to provide the all-important work experience needed to secure a footing in building a career in transport.

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- Network Rail is moving from around 800 signal boxes (which deploy a range of technologies from Victorian mechanical levers to modern day computer-based interlocking) to ten Rail Operational Centres. This change will improve capacity and performance standards, while at the same time cutting the day-to-day cost of running the railway. It will also mean reducing the signaller workforce from approximately 6,000 to around 1,500. Network Rail is working with the trades unions to support those signallers who are displaced and provide opportunities for retraining those who would like to stay within the transport sector in other roles. This could include training as an apprentice to become a track maintenance technician or even training externally to become a train driver and utilise existing route knowledge.
 - The Tideway 'returnships' programme aims at helping professionals back into work after a career break. The programme, organised in partnership with Women Returners, offered 12 week paid opportunities in areas including engineering, business planning, legal, stakeholder engagement, operations management, and financial modelling. The returners received mentoring from Tideway employees, as well as support and advice to successfully make the transition back to full time work. All 7 women returners have now taken up positions in the company after completing the programme.

The programme gave access to an invaluable pool of talent which might otherwise have been overlooked and has given a boost to Tideway's efforts to increase diversity on the Thames Tideway Tunnel project where, currently, around 35% of the 400-strong team is female. As well as this, Tideway is dedicated to raising the bar for diversity even further. All staff are required to undertake diversity training while Tideway's inclusivity forum, Encompass, was set up to understand the barriers facing minority groups within the company and develop a strategy to address these.

- A British Telecommunications (BT) business, Open Reach, has started to realise the benefits that ex-military personnel can offer a commercial business. With millions of pounds being invested annually in training military staff to carry out several electrical and mechanical, telecoms, signalling and logistics roles, this unique workforce is highly trained, highly motivated, highly productive and therefore highly desirable.

BT have found that by educating their own recruitment teams on the many sought after characteristics of ex-military personnel, they are achieving high conversion rates with up to 87% of interviewees being offered full-time employment. They have found that it is the exceptional work ethic, commitment, experience of complex engineering tasks and ability to quickly assimilate into challenging and safety critical environments that makes ex-military personnel highly desirable. These personnel require just 6 weeks training before they can be used within the business. Open Reach is now working with CTP to recruit a further 500 ex-military personnel per year to help roll out broadband internet to millions of new homes.

- The Transport for London's (TfL) Supplier Skills Team (SST) works in partnership with the supply chain to address skills shortages in the transport and engineering sectors, supporting our suppliers to have in place 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. In the last three years of delivery, over 40% of apprentices that have declared their background are of BAME origin, and 15% are women. The SST implements Strategic Labour Needs and Training (SLNT) in relevant contracts, requiring suppliers to produce several skills and employment outputs in direct proportion to the contract value. Suppliers can select from a range of outputs including

school visits and offering placements and taster positions, to promote interest in and knowledge of the industry. However, at least 50% of outputs must be in the core areas of apprenticeships or workless job starts.

- Steps into Work is a 12-month programme. It involves participants completing 3 mainly office-based roles within Transport for London (TFL). Students also have the opportunity to complete an operational placement in a London Underground (LU) station. This provides them the chance to gain a unit of an NVQ level 2 in Rail Services qualification which focuses on customer services. While on the programme, participants are students of Barnet and Southgate College studying towards a BTEC level 1 in Work Skills.

Australia

- ITS Australia hosts the MAX: Michigan-Australia Exchange on Future Mobility, a partnership between the State of Michigan, a global leader in automotive manufacturing, and the Australian Government which known for its innovation in transport and ability to deploy new technologies successfully. Through this partnership the organization has researched and delivered the following educational webinars:
 - Pieces of the New Normal: What Does COVID-19 Mean for CAV and Emerging Transport Technology Deployments?
 - Infrastructure Readiness for Automated Vehicles
 - Test Beds for the Future: Latest Development Activities at Leading CAV/AV Test beds Around the World
 - Moving Freight with Intelligent Vehicle Systems
 - Workforce of the Future Supporting Secure Vehicle System Technologies
 - The Digital Vehicle of the Future: Machine vision, AI, connectivity and more
 - Building Tomorrow's Connected Road Networks
 - Rolling Out Safety Advances with C-ITS or V2X

3 The future of transportation technology

3.1 CAV technologies

Details from the literature review with respect to CAV technologies are presented below.

- Council of Canadian Academies (2021) indicates that as communication networks become more integrated and ubiquitous, vehicles will become more connected to other vehicles, infrastructure, and other road users in a variety of ways (e.g., vehicle components, smartphones, and wearable devices). This connectivity will be used to improve the transportation experience through traffic management, navigation features, infotainment, safety features, and others. The report also states that anticipated improvements in connectivity, artificial intelligence, and sensor technology will facilitate the operation of these vehicles in a safe and efficient manner under a wider range of conditions by coordinating their activity with other vehicles, communicating with traffic infrastructure, and accessing real time updates on traffic and road conditions, navigation maps, and software.
- Council of Canadian Academies (2021) raises concerns regarding the large volume of data generated by connected, autonomous, electric, and shared (CASE) vehicles. The authors highlight risks to personal privacy and vehicle cybersecurity, and state that while the vast amounts of data present opportunities for increased transportation safety and mobility coordination, as well as business opportunities for automakers, mobility service providers, auto insurers, and others in the private sector, the risks to privacy can be significant.
- Knapp et. al., (2020) indicate that connected vehicles (CV) and autonomous vehicles (AV) are complimentary, and it is expected that combined connected and autonomous vehicles (CAV) will be the more prominent in the future market when compared to CV and AV separately.
- The Information and Communications Technology Council & Canadian Automated Vehicles Centre of Excellence (2020) published a report that explores technological advancements of CAV and its broad impact on business, inclusion, accessibility, education, and training. The authors define CAV as a combination of internet-of-things (IoT) devices and networking capabilities. This CAV ecosystem also includes drones or unmanned aircraft systems (UAS). They define the common set of CAV technologies as:
 - Batteries and electric drive train systems.
 - Computing platforms, running software for real-time control, artificial intelligence, onboard infotainment, communications, cyber security.
 - Communication infrastructure connectivity. Wireless technologies like dedicated short-range communications (DSRC) is suited to basic safety data communication and 5G Cellular will enable advanced CAV features including rural highway travel.
 - Detect-and-avoid systems.
 - Navigation systems, including Simultaneous Localization and Mapping (SLAM).
 - Sensors, including vision systems, short-range and long-range radar, and Light Detection and Ranging (LiDAR).
- Hallmark et. al., (2019) indicate that road authorities can capture data created by CAV to enhance and optimize transportation networks which will require the ability to collect and share

data in real-time. They anticipate that the technology will be cellular, CV radios, or Bluetooth beacons on the side of the roadway.

- The City of Chandler (2019) in Arizona is partnering with Waymo to test, develop and implement an autonomous ride hailing program. In 2019, they launched an autonomous vehicle ride-hailing program for select City employees. The program evaluated employee productivity while commuting to and from off-site work meetings and potential fleet services cost savings.
- The Contra Costa Transportation Authority (2019) and AAA Northern California, in partnership with Local Motors tested their electric, 3D printed AV shuttle, Olli, at GoMentum Station in Contra Costa County, California with future plans of deployment near transit stations around Northern California.
- Bills (2019) indicates that LiDAR, photogrammetry, and 3D technologies are changing the way transportation data is collected.
- The Centre for Connected & Autonomous Vehicles (2018) provides a high-level summary of connected and autonomous vehicles project support by the UK Government between 2014 and 2017. Current research projects cover the following topics which provides an indication of where CAV technology is going.
 - Standardizing the way connected vehicles communicate and how the data is stored and processed to maximize value. Data communication and processing are critical to implementation of CAVs. Understanding of these data sets is important to enable integration with other transportation data sources to help understand traffic volume, congestion, safety, etc.
 - Pod-based autonomous transportation systems for campus mobility and last mile transit connectivity.
 - Autonomous vehicle platooning. Testing completed for 3 vehicles travelling 1 m apart at 70 mph.
 - Trial of fleet-wide level 4 connected autonomous vehicles.
 - Optimization of driving style for passenger comfort, fuel consumption, and travel time.
 - Developing a system to limit vehicle operating characteristics to ensure zero emissions in predefined areas. System would require direct communication with road authority servers that define zero emission areas.
 - Sensor technology to detect other road users and infrastructure. Common technologies include Radar, LiDar, and computer vision.
 - Multi-vehicle collisions avoidance systems for CAV considering human-controlled vehicles.
 - Autonomous vehicle asset inspection for transportation infrastructure.
 - Dashboard cameras to create a three-dimensional reconstruction of collisions.
 - Driver CAV interaction and experience to integrate autonomous aspects of the driving task into vehicles.
 - CAV cybersecurity assurance considering driver and insurer risk.

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- Personal connected vehicle hardware available to the public to upgrade their unconnected vehicle.
 - Using machine learning and AI to explore systems for costing and managing mobility as a service (MaaS).
 - Autonomous valet parking that would require detailed parking infrastructure inventory and potential to relocate parking further from destination entrances. “Once the customer is dropped off, where do vehicles go without clogging up the streets and who pays for the service? Public Sector on-street parking and Private Sector off-street car parks are different businesses and subject to different legislation, taxes, restrictions and tariffs.”
 - Traffic model simulation software that considers CAV fleet mix.
 - The Information and Communications Technology Council (2017) published a synopsis of the potential impact that autonomous road-based vehicles will have on the Canadian job market and economy. The publication identifies the following as key technologies behind autonomous vehicles.
 - Artificial Intelligence helps AV make better decisions than humans. It relies on real-time imagery to make near-instant driving decisions based on deep learning architecture like deep neural networks. Understanding how these decisions are made is important for road authorities that manage the infrastructure they operate on.
 - Human Machine Cooperation ensures that the system works according to the needs of the human in the vehicle.
 - 5G Mobile enables CAVs to communicate with other vehicles and infrastructure. Effective CAV deployment requires the transfer of very large amounts of data in real-time with no disruption or security breaches. Road authorities will have access to some of this real-time information for traffic operations and planning.
 - Telematics refers to the blend of technology that allows for the sending, receiving, and storing of information on CAVs. Many current vehicle features rely on telematics like adaptive cruise control and blind spot detection.
 - Light Detection and Ranging (LiDAR) is an active form of remote sensing that collects three pieces of information, range from the vehicle to an object, the speed of an object, and the chemical properties of the object. Roadway design and maintenance are important for supporting LiDAR capabilities.

The author concludes that *smart cities* are critical to reaching the full potential of AVs as they support the sharing of information between AVs and roadway infrastructure.

- Farah et. al., (2017) indicate that a road asset database inventory will be one of the most fundamental elements maintained by road authorities to support CAV. The database will require decimeter-level accuracy for traffic control marking and signs as well as detailed information on lane geometry and speed limits. They also indicate that traffic management centres will need to be capable of collecting and processing real-time data from infrastructure and vehicles in a CAV environment.
- Zhenzhen et al., (2017) noted the following cybersecurity challenges with the introduction of CAVs on Canadian roads:

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- The vehicles are vulnerable to remote access via cyber intrusions by exploiting system vulnerabilities as the level of connectivity increases. Cyber intrusions can cause forged vehicle communications, sensor jamming and blinding that may limit the vehicle’s awareness of its surroundings increasing the “potential to cause personal injury and significant damage to road transportation networks by way disrupting traffic flow and more importantly undermining the safety of the transport system as whole.”
 - To address safety issues relating to the testing and deployment of automated and connected vehicles on public roads, road authorities will have to establish policies specifying the testing and deployment standards and regulations.
 - To allow proper integration of new technologies within the network of connected infrastructure, road authorities will have to take a proactive approach, by investing in operational devices and hardware system.
 - “CAV systems collect large amount of user data and locations data that need to be exchanged between different systems and stored and can be accessed by unauthorized personnel in the event of a cyber intrusion.” Road authorities will also need to develop a comprehensive policy framework that sets out guidelines for access to and use of the data that is generated by these vehicles to protect the privacy rights of individuals.

3.2 Timeline for CAV adoption

Details from the literature review with respect to CAV adoption timeline are presented below.

- CCA (2021) states that while vehicular technologies are progressing towards complete automation, this is far in the future. While autonomous vehicles with limited operation already exist today in the form of prototypes or in testing programs (e.g., low-speed autonomous shuttles, robo-taxis, and autonomous delivery vehicles), the authors indicate that the full potential of CASE vehicles is unlikely to be realized for several decades mainly because of the need for overcoming significant technical and societal challenges partly due to the inherent uncertainty associated with technological change. The authors also indicate that early impacts of CASE vehicles in Canada will be concentrated in urban areas and the timing and approach to deploying CASE vehicles on Canadian roads will not be evenly distributed across the country, nor will all regions necessarily experience similar outcomes. The integration of CASE vehicles in different regions of the country is expected to be affected by mobility policy, public-private partnerships, infrastructure investments, and provincial, territorial, and municipal regulations.
- Hallmark et. al., (2019) indicate that dedicated CAV lanes will be needed in the short-term (2020) to optimize the benefit of CAV and dedicated lanes for human drivers will be needed in the long-term (2050). They suggest that cities will be ready to adopt fully autonomous vehicles in the next 5 to 10 years but roadways will remain relatively unchanged to continually accommodate human drivers. However, they also suggest that truck platooning technology will be adopted in the next 5 to 10 years.
- The Center for Automotive Research (2018) studied the impact of automated, connected, electric, and shared vehicles (ACES) on vehicle design, materials, manufacturing, and business models. The authors indicate that by 2040 there will be worldwide adoptions of robotaxis/automated shuttles and fully automated vehicles will be available for private ownership.

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- Gerdes (2018) reported on an informal poll of automotive, energy, and technology executives collected at the Future of Mobility Summit (Bloomberg New Energy Finance) that suggests commercial development of Level 4 AV will start around 2020 and Level 5 AV will debut five years later.
 - Johnson (2017) indicate that little is known about the likely implementation timeline for full automation with estimates ranging from a few years to 40 years. Because of this, the authors do not attempt to estimate the transition schedule of CAV.
 - The Iowa DOT (2017) forecasted different AV adoption scenarios with the most aggressive adoption scenario was projected to have 20% AV by 2025, 50% AV by 2030, and 85% AV by 2040. Their least aggressive adoption scenario was projected to have only 20% AV by 2040.

4 Required core competencies

4.1 Core competencies

Details from the literature review with respect to core competencies in a disruptive transportation technology era are presented below.

- Council of Canadian Academies (2021) indicates that connected, autonomous, shared and electric (CASE) vehicles will have a significant impact in the education system, and it will be important to predict the skills and training necessary for successful employment in the future, which includes consideration of elementary and secondary school, as well as college and university programs and curricula. In addition, investment in education, skills training, computer science, electrical engineering, and other areas related to CASE vehicles will be important to ensure that Canada remains relevant internationally with respect to workforce development.
- The Information and Communications Technology Council (ICTC) & CAVCOE (2020) published a report that explores technological advancements of CAV and its broad impact on business, inclusion, accessibility, education, and training. The authors indicate that the skills required for CAV development “cover a technical spectrum as broad as the engineering disciplines that are the foundation for these technologies” where each area will have many specializations where programming is simply a tool for expressing a solution.
- Bills (2019) indicates that the core business of state road authorities in the U.S. is shifting from construction to preservation of the transportation system while a greater emphasis on comprehensive knowledge of information systems is required to support decision making with continually constrained revenues. The author identifies the following as significant trends that are changing the way transportation professionals plan, construct, operate, and maintain transportation infrastructure:
 - Requirement for data-driven decision making.
 - Move to performance-based planning.
 - Digitization of the transportation processes.
 - Integrated management of previously siloed civil departments.
 - Greater emphasis on asset preservation.
 - Increased collaboration and public transparency.

The author indicates that these trends highlight the need for new workforce skills required to incorporate new technologies into business processes to develop robust, accessible information systems to support increasingly complex management and decision support processes. This work force will need to be able to implement whole life cycle information management which requires the following skills by task:

- Data collection: LiDAR, photogrammetry, and GIS.
- Data management and analysis: IT, communication, database management, data integration, programmers, data scientists, business intelligence analysts, cloud engineer, security analyst, machine learning engineer, computer vision engineer, GIS analysts, GIS programmers, GIS trained business intelligence analysts, and 3D design. Survey and

geomatics skills have become more critical and are now becoming required skills for road building.

- Operations and maintenance: asset management, ITS, CAV, DSRC communication, data scientists, data analysts, artificial intelligence, machine learning technologies, big data, and business analysts.

Bills (2019) also indicates that the U.S. Departments of Transportation (DOT) recognizes that information will be their greatest asset in the future and are aggressively organizing their data starting with geospatial data. Several DOT's have created a new position of Chief Data Officer to lead these efforts. This paradigm shift will require the future workforce much more versed in emerging technologies, in informational technology and good data management practice, and in data analysis and structured decision-making methodologies.

- Goldsmith and Cmar (2019) identify the need for a mobility manager position that understands the balance and needs of private mobility providers to establish relationships that adequately address things like intellectual property, data sharing, data security, and public privacy. This leadership role would be able to negotiate contracts with private mobility providers that protect citizen safety and convenience.
- Lambert and Roark (2019) caution that there is an “alarming gap of general employability skills or ‘soft skills’ within the millennial generation as evidenced by labor market research conducted at the Southwest Transportation Workforce Center (SWTWC).” These soft skills include basic language and communication skills, digital literacy, professional etiquette, interpersonal skills, time management best practices, teamwork and leadership, conflict management and resolution, and systematic thinking.
- O’Brien et al., (2018) reviewed how the sustainability mandates and targets in the state of California have changed the work force requirement and, in turn, workforce development for transportation planning agencies in the state. To meet current and future sustainability targets set at the federal, provincial, and local level, additional modeling and forecasting skills will be required which can be developed in-house or outsourced.
- Szymkowski, et al., (2018) “identified specific job positions required for a robust Transportation System Management and Operations (TSM&O) program, the knowledge, skills, and abilities required for those job positions, and recommendations tailored to hiring each position like:
 - Computer Engineer
 - Systems Engineer
 - Telecommunications Engineer
 - Traffic Incident Management Program Manager
 - Transportation Management Center Manager
 - Connected and Automated Vehicles Program Manager
 - Cyber Security Engineer
 - Data Management Specialist
 - Emerging Technologies Industry Liaison
 - Integrated Corridor Management Manager

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- Traffic Data Scientist/Statistician
 - Transportation Data Ethicist
 - Transportation Systems Performance Manager
 - TSM&O Modeling Specialist
 - TSM&O Program Manager
 - Visualization Specialist
 - Artificial Intelligence Scientist
 - Surface Weather Specialist
 - TSM&O Manager/Chief/Bureau Director
- The Information and Communications Technology Council (Cutean, 2017) published a synopsis of the potential impact that autonomous road-based vehicles will have on the Canadian job market and economy. The study indicates that while market saturation of fully autonomous vehicles may be far off, the gradual implementation of AV technologies will bring about continual change and growth in workforce requirements; they do not predict a single large-scale loss of jobs. They also note that while AV technology will directly result in the need for digitally skilled workers, it will also increase the demand for planning and construction personnel to redesign our cities to effectively accommodate AVs.

The publication identifies the development of *smart cities* as being the key contribution governments can make to support CAVs and other future technologies. The research identified 11 National Occupational Categories (NOCs) that will be needed to implement smart cities. The following are related to road authorities:

- Senior Managers (NOC 0016)
- Architecture and Science Managers (NOC 0212)
- Managers in Transportation (NOC 0731)
- Transportation Route and Crew Schedulers (NOC 1526)
- Civil Engineers (NOC 2131)
- Urban and Land Use Planners (NOC 2153)
- Civil Engineering Technologists and Technicians (NOC 2231)
- Land Survey Technologists and Technicians (NOC 2254)
- Energy Policy Analysts (NOC 4161)
- Economic Policy Analysts (NOC 4162)

The author also predicts future occupations that will be in high demand as:

- Telematics software architects, to develop integrated mobile usage and AV monitoring systems.
- Big Data Analysts, to analyze the large amount of data and improve city practice.
- Smart City Planners, to collaborate with city department to reduce waste and improve efficiency.

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- Shared Values Officer, to ensure that city ministries share the same sustainability and livability goals for the city.
 - The Information and Communications Technology Council (Cutean, 2017) indicate that the proportion of post-secondary graduates in Information and Communications Technologies occupations is growing. They point to the broad intellectual and personal development gained at a post-secondary institution as beneficial for adapting to a constantly evolving workforce; post-secondary graduates can leverage relevant upskilling programs throughout their career.

The authors further suggest that traditional Science, Technology, Engineering, and Math (STEM) skills will form the foundation that extended skills like AI, and deep learning will be based on. The publication lists the following as skill requirements of current AV occupations, as related to road authorities:

- Widespread programming background (Java, Python, JavaScript, etc.)
- Cloud service development
- Cloud database admin (Azure / AWS)
- Machine learning
- Messaging protocols (DDS, MQTT, AMQP)
- 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 learning classification methods.
- Zhenzhen et al., (2017) identifies the need for cybersecurity-related skills by Canadian road authorities to deploy, maintain, and protect road infrastructure systems. The study “uncovered significant gaps in Canada’s road transportation sector when it comes to building a sufficient and skilled cybersecurity talent pipeline.” The author lists the following unique cybersecurity challenges that Canadian road authorities will face:
 - *Unauthorized access to physical infrastructure* can make the physical infrastructure vulnerable as it is challenging to monitor and secure all the facilities, such as cameras, traffic signal control cabinets and variable-message signs.
 - *Multiple Interdependent Systems* can cause vulnerability in one system to weaken the security of all the systems that are interconnected.
 - *Integration of ITS into legacy systems* brings complexity to the overall system infrastructure. In turn, this system complexity creates issues with system recovery and redundancy, making it challenging to create automatic protections from new threats.
 - *Embedded software (Firmware) update challenges* as regular firmware updates are likely to introduce new cybersecurity vulnerabilities.

Through consultation with industry leaders the Information and Communication Technology Council suggests that Canadian road authorities develop the following for a safe and secure transportation system:

- An Operational Technology cybersecurity framework
- A cybersecurity risk management plan
- A cybersecurity protocol for legacy systems and ITS integration.

The author highlights the urgent need for government agencies to create a robust and effective system of cybersecurity practices as technology rapidly changes exposing the systems to new vulnerabilities. The author indicates that development, support, and emphasizing the need for skilled cyber-talent with competencies specific to road infrastructure is essential.

- Zhenzhen et al., (2017) conducted Key Informational Interviews (KIIs) with road authorities to identify cybersecurity challenges and talent development needs for Canadian road authorities. The authorities noted that currently their internal IT departments provide services and support like monitoring, investigating, and remediating cyber incidents. Due to the absence of an Operational Technology (OT) Cybersecurity framework road authorities are currently unable to distinguish between a cybersecurity breaches and common OT system failures like malfunctioning sensors or systems. "Online training and conferencing were the most common ways for Canadian road authorities consulted to get updates regarding new technologies and network development in the field." Road Authorities also noted that there is a need for industry specific cyber security training or programs that are currently not available.
- Zhenzhen et al., (2017) noted that cybersecurity needs for road authorities is unique and requires the following specific set of expertise:
 - Deep cybersecurity knowledge:
 - Network topology and security
 - Traditional cryptography and quantum-safe cryptography
 - Attack surface evaluation
 - Threat assessment
 - Intrusion detection
 - Operating system and programming language weaknesses
 - Expertise related to transportation and road security:
 - Security of field technology
 - Wireless protocols
 - Advanced traffic/transportation systems
 - The ability to adapt to the rapid rate of evolution of cybersecurity threats and technologies:
 - Staying current with cybersecurity resources like the Canadian Centre for Cyber Security and U.K.'s National Cyber Security Centre
 - Stay up to date with new developments in cybersecurity hardware, software, platforms and services

Taking this further, Zhenzhen et al., (2017) conducted KIs and secondary research, complemented with results from cybersecurity job postings from road authorities in other jurisdictions in Canada, and detailed a list of the most applicable cybersecurity roles for road authorities in Canada shown in Table A-1.

Table A-1: Cybersecurity roles for road authorities in Canada

<p>1. Cybersecurity Architect</p>
<ul style="list-style-type: none"> • Responsible for architecting and documenting the OTCF. The OTCF is the OT system map of the OT environment from a cybersecurity perspective. • Responsible for creating a cybersecurity Risk Management plan • Possesses deep knowledge of standards like ISO 27000, the NIST Framework for Improving Critical Infrastructure Cybersecurity Version 1.1, Canada’s CSA-led Industrial communication networks - Network and system security - Part 2-1: Establishing an industrial automation and control system security program CAN/CSA-IEC 62443-2-1, and the in-development standards like the Institute of Transportation Engineers (ITE)-led Roadway Transportation Systems Cybersecurity Framework. • Possesses industry certifications like the Global Information Assurance Certification (GIAC) for Critical Infrastructure Protection (GCIP), the ISACA Certified Information Systems Auditor (CISA), the ISACA Certified Information Security Manager (CISM), and the Security+ certifications. • Possesses expert knowledge on network security, cryptography, systems architecture, and information security. • Should have familiarity of transportation OTs.
<p>2. Cybersecurity Engineer</p>
<ul style="list-style-type: none"> • Responsible for mitigating cybersecurity vulnerabilities and managing cybersecurity architecture. • Possesses experience with and follow standards like ISO 27000, the NIST Framework for Improving Critical Infrastructure Cybersecurity Version 1.1, Canada’s CSA-led Industrial communication networks - Network and system security - Part 2-1: Establishing an industrial automation and control system security program CAN/CSA-IEC 62443-2-1, and the in-development standards like the Institute of Transportation Engineers (ITE)-led Roadway Transportation Systems Cybersecurity Framework. • Has industry certifications like the Global Information Assurance Certification (GIAC) for Critical Infrastructure Protection (GCIP), the (ISC) Certified Information System Security Professional (CISSP) and the Security+ certifications. • Should have experience managing risk management system. • Possesses hands-on experience with network (both wired and wireless) and information security, programming and scripting skills, solid knowledge of access control, authentication, and cryptography. • Should have familiarity of OT technologies and work closely with Transportation Engineers to better understand control centre and field OT technologies.

3. Vulnerability Tester
<ul style="list-style-type: none"> • Responsible for conducting and documenting vulnerability tests • Should have industry certifications like the Certified Ethical Hacker, the Licensed Penetration Tester, GIAC Web Application Penetration Tester (GWAPT), and the PenTest+. • Has experience with 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.
4. Cybersecurity Incident Analyst
<ul style="list-style-type: none"> • Responsible for monitoring the cybersecurity health of the OT operations and field systems. • Possesses the ability to respond to cybersecurity incidents, including logging and initiating the incident response protocol from the Risk Management plan. • Should have industry certification like GIAC’s Certified Incident Handler (GCIH)⁵⁸, the ECCouncil Certified Incident Handler (ECIH)⁵⁹ and the National Initiative for Cybersecurity Careers and Studies (NICCS) Certified Cyber Threat Analyst⁶⁰. • Has experience with Intrusion Detection and Prevention Systems and cybersecurity monitoring solutions.

- Adams and Hart (2017) applied criteria to prioritize key occupations in the Midwest to focus transportation workforce development efforts. The prioritization criteria targeted occupations that have increasing employee demand, established high employee demand, future employee demand, and current challenges in recruiting or retaining employees. The authors identified Civil Engineers as a key occupation that require the following skills: computer-aided design (CAD), engineering design, inspection, construction management, civil 3D, mathematics, critical thinking, complex problem solving, reasoning, and decision making. In addition, new transportation related occupations were introduced by the U.S. Bureau of Labor Statistics (BLS) that include Database Integration Architects, Software Developers, Software Quality Assurance Analysts and Testers, and Data Scientists. The authors identify that a major limitation in their study is that the BLS workforce project methodology does not account for advances in technology.
- The U.S. National Academies of Sciences, Engineering, and Medicine (2017) reveal that over the past 20 years routine cognitive and manual tasks are being replaced by non-routine analytical and personal tasks. The authors indicate that “STEM skills are essential components of the bundle of skills that define skilled technical occupations and qualify workers to succeed in these occupations.”
- The Northeast Transportation Workforce Center (2016) completed a study to identify areas in which skill development is most important for employees and transportation careers in the Northeast Region of the U.S. that should be the focus of workforce development over the next 10 years. Common skills that will be required from these key occupations are generally technical in nature and include GIS, data analysis software, ITS, and new construction technology. They identified key occupations in the region and the skill requirements for each; Table A-2 shows the technology related occupation skill sets.

Table A-2: Skill requirements for key technical occupations in the US Northeast

Key Occupations	Top Skills highlighted in Job Postings	Additional Required Skills
Computer and Information Systems Managers <i>Education: B.Sc.</i>	<ul style="list-style-type: none"> ▪ Business Process ▪ Oracle ▪ Collaboration ▪ Systems Development Life Cycle ▪ Scrum 	<ul style="list-style-type: none"> ▪ Reading Comprehension ▪ Active Listening ▪ Critical Thinking ▪ Complex Problem Solving ▪ Monitoring
Civil Engineers <i>Education: B.Sc.</i>	<ul style="list-style-type: none"> ▪ Civil Engineering ▪ AutoCAD ▪ Civil 3D ▪ Engineer in Training ▪ Storm Water Management 	<ul style="list-style-type: none"> ▪ Critical Thinking ▪ Reading Comprehension ▪ Active Listening ▪ Complex Problem Solving ▪ Mathematics
Surveyors <i>Education: B.Sc.</i>	<ul style="list-style-type: none"> ▪ Photovoltaic (PV) Systems ▪ Estimating ▪ Energy Efficiency ▪ Electrical Systems ▪ Hand Tools 	<ul style="list-style-type: none"> ▪ Reading Comprehension ▪ Mathematics ▪ Critical Thinking ▪ Speaking ▪ Writing
Urban and Regional Planners <i>Education: M.Sc.</i>	<ul style="list-style-type: none"> ▪ Urban Design ▪ Environmental Planning ▪ Historic Preservation ▪ Land Use ▪ Retail Sales 	<ul style="list-style-type: none"> ▪ Active Listening ▪ Reading Comprehension ▪ Critical Thinking ▪ Judgment & Decision Making ▪ Speaking
Surveying and Mapping Technicians <i>Education: High school diploma</i>	<ul style="list-style-type: none"> ▪ Schematic Diagrams ▪ Data Analysis ▪ Technical Drawings ▪ Dimensions ▪ Materials Testing ▪ Inspecting ▪ Blueprints 	<ul style="list-style-type: none"> ▪ Critical Thinking ▪ Active Listening ▪ Complex Problem Solving ▪ Mathematics ▪ Speaking ▪ Coordination
Operating Engineers and Other Construction Equipment Operators <i>Education: High school diploma</i>	<ul style="list-style-type: none"> ▪ Repair ▪ HVAC ▪ Boilers ▪ Decision Making 	<ul style="list-style-type: none"> ▪ Equipment Operation/Control ▪ Operation Monitoring ▪ Coordination ▪ Equipment Maintenance

Adapted from: FHWA (2016)

- The National Operations Center of Excellence (2016) studied the Transportation System Management and Operations (TSM&O) staff competencies and related education and training and summarized the need for the TSM&O roles and respective competency requirements shown in Table A-3 amidst rapidly changing transportation technology in the road transportation sector.

Table A-3 : Transportation system management and operations roles and competency requirements

Role	Functions/Positions Combinations	Criticality	Associated TSM&O Competencies	Complementary Skills
Leadership	Policy and Strategic: Top TSM&O Manager --HQ & Region <i>Industry Demand: Moderate</i>	Leadership: progress dependent on visionary leadership.	Mission/Policy Development Public Outreach Objectives/Strategy Development Organizational Change Management	Leadership, vision communications
Core in-house capacity	Real-time Operations: Sr. Program Management --HQ & Region <i>Industry Demand: Moderate</i>	Critical management capacity that integrates deep agency background, managerial capacity with program-specific knowledge that provides program directions, momentums.	TSM&O Strategies, Systems & Tech. Safety, security Performance Management	Program/Project Management Finance Communications
	Real-time Operations: Mid-level, program Managers, specialists <i>Industry Demand: High</i>			General Systems engineering Contract Management Outsourcing Contract Management Procurement In-House PM Risk Management Communications
	Program Planning: Senior and Mid-level <i>Industry Demand: High</i>	Core technical/specialist capacities needed to get the job done on a day-to day basis and maintain state of the practice.		Business Process Management Organization & Staffing Performance Measurement Link Between TSM&O & Planning
Other key technical capacities	Systems Engineering/Development: Mid-level -- project managers, specialists, operators <i>Industry Demand: Moderate</i>	Core technical/specialist capacities needed to get the job done on a day-to day basis and maintain state of the practice.	SE Process/Methods Communications, IT, GIS and related Database Management Programming Languages & Tech. Visualization Network Security	General Systems engineering
	Project Management: Mid-level and project <i>Industry Demand: High</i>			Contract Management Outsourcing Contract Management Procurement In-House PM Risk Management

Role	Functions/Positions Combinations	Criticality	Associated TSM&O Competencies	Complementary Skills
Technical Support	<i>Real-time Operations: Administration/Technician/Field (inside and outside)</i> <i>Industry Demand: Very High</i>	Day to day (24x7) workforce to get the job done	TSM&O Operations Strategies, Systems & Tech. Safety Security Management TSM&O Systems	Communications Data analysis

Adapted from: National Operations Center of Excellence (2016)

- The National Operations Center of Excellence (2016) highlights the need to invest in Operational Management Strategies like Transportation Systems Management and Operations (TSM&O) that combine advanced Intelligent Transportation Systems (ITS) Technology with real-time procedures, custom tailored for each cause of non-recurring congestion in our road systems. “TSM&O requires special systems engineering for communications information and control systems responding to rapidly changing technologies and impose requirements for 24 X 7 situational awareness, with related real time event responses using procedures and protocols developed in close collaboration with external partners.” TSM&O requires new workforce programs, organization and capabilities that do not fit into existing transportation agency organization structures and processes.
- National Operations Center of Excellence (2016) reviewed the state of TSM&O at U.S. road authorities and noted the following about the present state of the industry:
 - Lack of clear position of TSM&O in agency policy and in turn leading to short staffed TSM&O teams.
 - Absence of TSM&O Business Case to encourage formal agency support.
 - Investment into TSM&O needs are only made to respond to a specific traffic event like weather, emergency, or crashes.
 - There is currently limited to no ongoing financial commitment.
 - No formal TSM&O programs have been created detailing the plan, program, line-item budget and division status and staff development requirements.
 - TSM&O functions are often located in different agency units (ITS, operations, traffic engineering) – each involving a small staff at the middle management level in both headquarters and regions with attendant problems of coordination and authority.
 - There is lack of upward or outward accountability for operational performance of the network under any agency jurisdiction.

4.2 National competencies from global ranking studies

Details from the literature review with respect to competencies based on global ranking studies, are presented below.

- KPMG (2019) prepared the Autonomous Vehicle Readiness Index (AVRI) tool to measure 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 ranks 12th on the list based on high quality of its existing workforce, being an attractive destination for skilled immigrants, and strong leadership from government. The following key indicators used to evaluate AVRI reveal what road authorities need to consider for automated vehicle readiness:

- Open and shared government data to facilitate collaboration with the private sector.
 - High quality and coverage of mobile networks such as 5G. In the short-term high coverage of the 4G network is important.
 - High market share of electric cars as most autonomous vehicles will be electric.
 - High density of electric vehicle charging stations.
 - High quality road infrastructure improves autonomous vehicle performance.
 - High quality logistics network for the movement of freight.
- KPMG (2020) provided an update to their AVRI tool and using the same four-pillar framework ranked Canada 12th on the list again. Canada ranked 9th in policy and legislation and 13th in the other 3 pillars. Strong industry partnerships were a key point of Canadian strength, with Canada ranked as highest performing country in government-funded AV pilots, a top performing country in data-sharing environment. Specific Canadian workforce strengths referenced are AI, decision telematics, and lidar. While the key indicators used to evaluate AVRI are largely the same as in 2019, some points of evaluation were added, including:
 - Future orientation of government in terms of both policy and vision.
 - Cybersecurity of both industry and government organizations.
 - Assessment of cloud computing, artificial intelligence, and Internet of Things.
 - Digital skills amongst the general population.
 - The Oliver Wyman Forum (2019) prepared their Urban Mobility Readiness Index to compare various cities' capabilities to distinguish themselves in mobility as measured by five criteria: system efficiency, social impact, innovation, market attractiveness, and infrastructure. The criteria of innovation focused on a variety of relevant metrics, such as concentration of skilled workers and tech startups, electric vehicle market share, and government investment in CV/AV technologies. Out of thirty cities, the only Canadian city, Toronto, ranked 16th in innovation and 19th overall.
 - Deloitte (2020) performed their Global Automotive Consumer Study to measure consumer sentiment across 20 countries about issues in the automotive sector, including CV and AV technologies. The study revealed that consumers in most countries have a strong desire for increased adoption of EV technologies, but increased skepticism of CV and AV technologies, particularly in the United States. Furthermore, consumers' willingness to pay for new technologies (EV, CV, and AV) is limited in all countries.
 - Arcadis (2017) produced their Sustainable Cities Mobility Index, which evaluated current state of the mobility systems of 100 cities around the world. The Index's ranking was based on 23 indicators divided into the three categories of People, Planet, and Profit. These indicators considered various metrics of transportation equity, efficiency, and resilience; several of them focused on technology, such as Rider Connectivity, Transport Applications and Digital

Capabilities, and Electric Vehicle Incentives. Of 100 cities ranked, the three Canadian cities were Vancouver (rank 28), Montreal (rank 36), and Toronto (rank 54).

5 Workforce development challenges and opportunities

5.1 Challenges

Details from the literature review with respect to workforce development challenges in a disruptive transportation technology era are presented below.

- Reeb et al., (2020) Ahmadjian et al., (2018), and O'Brien (2018) conducted interviews with professionals in the transportation industry in the U.S. and noted the following about the present state of the road transportation industry in the country:
 - Workplace demographics are quickly shifting and changing rapidly. In the United States, “workforce growth rate has declined from a high of 2.6 percent in the 1980s to 1.2 percent between 2000 to 2015, and an expected growth rate of only 0.2 percent from 2015 to 2025 (Gee 2009).” “According to the U.S Departments of Education, Transportation, and Labor (2015), this trend continues, as more than 50 percent of transportation industry employees were older than 45 in 2014.” As the current workforce retires, a large amount of institutional knowledge will be lost. Although new hires will be brought in this trend will continue as they are equipped with new and different skills and knowledge. Given the essential increase of new hires, U.S. state DOT agencies should be prepared to handle gaps in skills and knowledge, as well as a multi-generational workforce and work environment.”
 - The public sector can meet the more altruistic needs of the workforce due to its perceived focus on public service and giving back to the community. Despite this, there is a growing industry expertise vacuum in the public sector due to the growing disparity in public and private transportation sector salaries and promotional opportunities, compounded by the ongoing wide-scale retirement. Where salaries are not competitive, private organizations try to offer employees other opportunities like career advancement, on-the-job training, flexible work schedules, and opportunities for personal fulfillment.
 - Due to trends in technology and service delivery transportation agencies are and will need to rethink their purposes. “Many new technologies and policies aim to improve work efficiency, safety, and capabilities. To make use of new technology advances, the transportation workforce must have the appropriate skills and abilities to utilize them.” Skills that were once considered functional, like project management, communications, knowledge of context sensitive solutions, etc., are becoming central to effectiveness of any transportation program.
 - Additionally, for the millennial population, quality and purpose of work is valued more than compensation offered. Employer brand is a key element in attracting and retaining young employees. However, currently, public-sector workspaces suffer from lack of brand identity. “Employers in the private sector are increasingly adopting digital platforms such as LinkedIn, Twitter, Facebook, and other forms of social media to garner and enhance brand image (Pricewaterhouse, 2015). This medium of hiring has become the new norm, and public-sector recruitment strategies, which must adhere to stricter process-driven guidelines, find it hard to compete in a dynamic labor market.”
 - The rapidly changing nature of the work within the road transportation industry currently outpaces the ability of the available education and training programs to

deliver consistently relevant curricular materials. “There is the gap between what is taught, what is desired, and the future skills required for a modern transportation workforce.” This gap has resulted in a scarcity of qualified employees who can plan for, design, operate, and direct transportation systems.

- Ryan, et al., (2019) conducted a quantitative analysis of existing job specifications and postings for civil engineers at various levels from six DOT within the New England region in the U.S. These specifications and posting were reviewed for core competencies in accordance with Bureau of Labor Statistics (BLS) and the American Association of Engineering Societies (AAES) competency model, as well as licensure requirements. The authors found:
 - Several competency gaps between job postings and positions across the DOT agencies.
 - Comparison of job specifications and postings against the BLS Competency model revealed that job specifications typically include more core competencies than job postings. Most job postings did not include all 17 BLS core competencies, which, according to the model, is a pre-requisite for all civil engineers, independent of their level.
 - Comparison of the job specifications against the AAES model revealed that no position level includes all the competencies at any tier level. In fact, some high-level positions required fewer core competencies than entry level positions. This discrepancy shows that several gaps in competencies exist.
 - Comparison of certification requirements at various civil engineering position levels revealed that not all DOT’s required civil engineers obtain EIT or PE certification, including majority of the highest civil engineering level at the respective DOTs. “Some job postings did not even state a preference for those applicants who have an EIT or PE.”
 - Variances in engineering competencies show that positions, at the same level, across the DOTs are not covering the same skills and knowledge as each other.

The authors made the following recommendations to overcome the challenges presented by the review:

- Each competency model created for civil engineers should follow the base of the AAES model until a new competency base model is created for the specific profession.
 - DOT civil engineering positions should be formed around each DOT’s strategic goals and objectives. Although their strategic goals and objectives may not be the same, it is expected that they be similar, and all DOT’s could use the same competency model to evaluate their job posting and specifications.
 - Agencies create the necessary developmental programs and guidelines to verify that their civil engineering employees can acquire the competencies needed for the next job level before obtaining the title.
- Ahmadjian et al., (2018) took the research done by Ryan, et al., (2019) further by interviewing five of the New England DOT Human Resources (HR) personnel about how their job postings are created and their hiring practices. They found that while each DOT’s hiring process varied, many were struggling with similar issues, such as retaining engineers after their PE was obtained, competing with the private sector and lack of flexibility with the hiring process. They found that

a competency model platform would be helpful for DOTs as they develop or change their specifications or job description process in the future.

- Butler and Harrington (2018), explored major impediments and opportunities to hiring data analysts and software engineers to ensure that California Transportation (Caltrans) evolves into a data driven organization. The authors found:
 - Current management are unfamiliar with data analysis and software and do not understand the need for data analysts and software engineers.
 - There is a belief that software engineers are not “real” engineers.
 - IT/Software personnel are hired by the IT department which has little direct interaction with Caltrans Operations.
 - The Caltrans engineering union does not include software engineers nor plans to.
 - The Information Technology personnel union includes software engineers, but all relevant positions are titled as Information Technology specialists.
 - Perception that software engineers are too expensive to be hired by the State.
 - There are no data analyst job descriptions.
 - Caltrans is part of a large state bureaucracy that is not well configured to engage with all stakeholders to address hiring issues.
- Harper et al., (2018) studied the practices in recruiting, training, and retaining qualified employees in construction careers at south-central state departments of transportation (DOTs). Interviews with nine human resource staff revealed that engineers and engineers-in-training were the most difficult positions to fill. In addition, these two positions have a high turn-over rate which is attributed to the wage gap between public and private industry positions.
- Zhenzhen et al., (2017) studied the job profiles of 103 self-identified U.S. transportation workers with some form of cybersecurity experience in the profile. The authors noted that Traditional IT security skills like network security and information security were best represented, yet desirable cybersecurity skills like risk assessment, vulnerability assessment, penetration testing and intrusion detection were not as well represented nor were the cybersecurity certifications including Certified Information Systems Security Professional (CISSP), Certified Ethical Hacker (CEH) and Security+. The authors also collected and studied transport sector cybersecurity and technical job postings and noted that very few job postings currently require cybersecurity skills.
- The Information and Communications Technology Council (Cutean, 2017) published a synopsis of the potential impact that autonomous road-based vehicles will have on the Canadian job market and economy. The publication indicates that annual expenditures on learning and development per employee have dropped from \$1,249 in the 1990s to \$800 in 2015.
- National Operations Center of Excellence (2016) reviewed the state of TSM&O at U.S. road authorities and noted the following staffing challenges:
 - Insufficient static staffing of critical capabilities essential to improve and expand TSM&O programs.
 - “High degree of dependence on the informal initiatives of middle management staff “champions” – who are often key players – but also vulnerable to retirement.”

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- Unclear core staff needs as TSM&O core staff Knowledge, Skills and Abilities (KSAs) are not well defined. This is critical as TSM&O programs need many atypical technical expertise -including systems engineering, electrical engineering, IT/communications, statistics/data management/analysis, GIS, computer/software, performance quality assurance, forecasting, design and control of operations systems- and non-technical expertise like policy, management, external communications, collaboration planning and scheduling, procurement, staffing, planning, programming, budgeting.
 - Lack of formal TSM&O inhouse training, and external education and training resources are limited. Training resources are especially lacking for non-technical skills.
 - Informal on-the-job training is critical for the development of TSM&O programs.
 - Lack of external university education programs focussing on TSM&O.
 - Lack of external TSM&O recruiting pool as most of the relevant TSM&O KSAs are acquired via on-the-job training or trial and error.
 - Unclear career track for staff specializing in operations who do not have a clear upward career vector and are often constrained by the lack of PE qualifications.
 - “In transportation agencies, permanent staff recruitment from outside appears rare. Many of the needed skills (systems engineering, information technology, communications, etc.) are addressed in educational institutions with little contact with the transportation sector. In the private sector as well (vendors, consultants, engineering), the relatively small and dispersed market constrains specialized staff development.”
 - Currently, when agencies require specialized TSM&O technical skills the skillsets are increasingly outsourced.
 - National Operations Center of Excellence (2016) summarized the following workforce development implications in the TSM&O sector at U.S. road authorities:
 - Workforce development for TSM&O skillsets at U.S. road authorities is critical and has a moderate staffing-up demand.
 - TSM&O position descriptions and their core competency requirements are currently not available and needs to be developed.
 - There are insufficient pre-employment education majors focusing on TSM&O.
 - There are several major gaps in formal post-employment TSM&O training as not all courses are developed to the same level of detail and in the same learning medium. “In addition, typical sequences of training – beginner, intermediate, advanced –are currently not defined to determine the priorities in gap filling.
 - “TSM&O staff involvement in training, mentoring, conferences and other support activities are primarily dependent on federal support. When budgets are constrained TSM&O operations are typically first to be scaled down as it is not formalised into a program.
 - There are a variety of traditional training modes but on-the-job training (mentorship, work-shadowing) and many of the newer IT-based knowledge transfer systems (content management, groupware, etc.) are not used.

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- Developing TSM&O core knowledge and complementary skills through on-the-job training is crucial and programs like the civil engineer-in-training program need to be developed for the TSM&O field.
 - TSM&O certification developed for pre- and post-employment contexts can help provide a measure of professional credibility and with recruitment.
 - The continuous movement of TSM&O staff between the public and private sector may be beneficial in terms of effective partnerships and knowledge transfer.

5.2 Opportunities

Details from the literature review with respect to workforce development opportunities are presented below.

- The Workforce Intelligence Network (2020) indicates that degree requirements should be made flexible when possible as the skills for many technology roles can be acquired through short-term training. The authors suggest that the expansion of these middle-skill positions has the potential to meet the workforce demand. In addition, upskilling existing production workers is still a major opportunity.
- Ehteshami (2020) analyzed the causes of workforce shortages in the transportation trades in the Navajo Nation. The Nations require increased opportunities in transportation research and teaching, so the authors noted the need to create educational programs in the transportation area at undergraduate and high school level, throughout the Navajo Nations. Additionally, creation of dual credit courses for transportation related topics will increase the educational options and opportunities for high school students, extend course availability, and increase access to college credit-bearing courses. This will also shorten the time to complete a college degree providing students the same opportunities as other students in the state, in urban and rural areas. Internships at local governing, research and private institutions also further help expose students at the Navajo Nations to the transportation sector. In conclusion, “it is essential to expose experts, teachers, the youth, and other members of the community to the transportation, science and technology, in order to improve the employment, aids, and skills of the members of understated groups in the Nation.”
- The National Cooperative Highway Research Program (2019) emphasizes the need for organizations to advance a clear definition and goals for transportation workforce development. A common definition and characterization would help clarify both the traditional needs inherent in workforce development as well as future trends. Greater attention is needed to determine the distinctions between workforce development, workforce planning, and succession planning.
- The World Economic Forum (2019) through the Future of Work project seeks to provide a platform for collaborative action among industry and other stakeholders to develop futureproof workforce strategies and support at-risk workers with reskilling and upskilling. The author interviewed and consulted 60 practitioners and experts from across five industries participating in the World Economic Forum’s Preparing for the Future of Work Industry Task Forces. Outlined below are the author’s range of strategic priority actions that industry players (public, private and the non-profit) can use to transform reskilling and upskilling opportunities to tangible action:

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- Leveraging Strategic Workforce Planning
 - To assess the overall level of the upskilling challenge for existing employees, create or adopt a scenario-based strategic workforce planning process involving “job taxonomy and identification of strategic job functions; consideration of workforce attrition and retirement rates and demographic supply side factors; as well as simulation of future talent demand under a range of different strategy and growth assumptions, including technology and productivity developments as well as global and local economic, social, political and demographic trends as driving factors.” Additionally, establish strategic skills/core competencies mapping within jobs by creating or adopting skills taxonomies which will allow an evaluation of employees’ current skills and mapping them against the skills that will be critical for the company in the future.
 - The public and private sector should cooperate to create adaptable tools to calculate changes in sector needs over the long term.
 - Provide targeted digital upskilling programs for management as it is crucial to any effort aimed at creating a workforce that is prepared for the future.
 - Shape the Future Talent Pipeline.
 - Develop targeted reskilling programs individually or through public-private partnership.
 - Hire experts in skills that are low in supply to work across an organization, rotating throughout different project teams and providing on-the-job training to their colleagues. This also provides an opportunity to identify high-potential employees suitable for future combination of targeted reskilling, shadowing, and mentoring to develop scarce skills internally.
 - Develop large-scale subsidized programmes through government, academic and private industry collaboration that address reskilling local at-risk workforces to create an environment where workforce employability is safeguarded, and societal and business benefits maximized.
 - To meet industry wide large-scale upskilling need, an organization should develop customizable training modules that include online training, classroom modules, on-the-job training, and mentorship programmes. To incentivise employees to upskill innovative and engaging training practices can be utilized: “micro-learning (small learning units which come in three-to-five-minute sessions and can be strung together at will), nudges (positive reinforcement and indirect suggestions as ways to encourage learning), badges (validated indicators of skill earned in the learning environment) and gamification (use of game elements in learning environments).”
 - Harmonize the skilling landscape by developing appropriate certifications at the industry or cross-industry level through stakeholder input.
 - Create advanced onboarding trainings that reduce the time to full productivity for new graduates.
 - Scale up internship and apprenticeship models, which can help teach additional relevant skills faster.

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- Within industry ecosystems, develop an industry-wide academy focussing on specific new skills key to growth.
 - Build long-term partnerships between the industry and universities and technical and community colleges, “which will in turn create adult education courses that are tailored to the needs of the industry.”
 - “Create an industry skill board at key academic institutions in a region, composed of HR experts from various companies, skills and training experts, trade union representatives and local policy-makers, to enable local educational institutions to collectively adapt their curricula to the needs of the local labour market and the most important skills that will be needed in the future.”
 - Optimize Talent Ecosystem Conditions
 - Rethink organizational structures to implement new and flexible ways of working.
 - Integrate platform workers into business models, enabling companies to reap the benefits of a wider labour ecosystem. To facilitate this, develop standardized processes for supporting functions to make possible common resources (platform workers) to serve the entire industry ecosystem.
 - Transform work culture to attract and retain the incoming Millennial and GenX workforce through industry innovation hubs, collaboration with start-ups and company exchange programmes.
 - To build a culture of life-long learning which allows employees to continuously improve their competencies, senior management should signal learning as a key new part of the company’s core culture. “These efforts should be accompanied by the creation of learning KPIs and dashboards for the assessment of managers so that learning becomes a key task for both employees and managers.”
 - Develop specific mentoring and leadership programmes for under-represented groups and design workforce recruitment processes that remove bias from the recruitment process.
 - Develop public private partnerships to support under-represented individuals in their “journeys from the educational system to their career and professional progress” to boost diversity within the industry.
 - Bills (2019) indicates that U.S. DOTs are recognizing that information will be their greatest asset in the future which will require a workforce with new skill sets to implement. Attracting, training, and developing the new workforce will be a central challenge for road authorities. Competition for technically skilled workers will be high as their skills will be required across all sectors of the economy. The author suggests that road authorities should work collaboratively with educational institutions to develop and attract employees with the following:
 - Integration of technical studies and apprentice programs for high school and college students.
 - Strengthen participation with universities through transportation-related research, courses, and internships.

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- Develop internal training and technological advancement programs for the more skilled technical positions.
 - Goldsmith and Cmar (2019) highlight the City of San Francisco as a leading authority on developing the desired skills within their organization. The City initiated its own Data Academy which provides tools and workshops for interested employees where they can learn a wide range of topics on data analysis and visualization. A significant byproduct of the Data Academy was the relationships founded on common data tools that were developed across many departments. This has improved the cross-departmental interoperability and collaboration of data analysis.
 - Goldsmith and Cmar (2019) identify the opportunity to leverage expertise from short-term contractors to build internal capacity. Similarly, they highlight how the Los Angeles Department of Transportation created a new model of procurement that enables them to commission one of almost 100 preapproved product and software companies to accomplish tasks on a week-by-week task order basis rather than a year-by-year RFP basis.
 - Lambert and Roark (2019) identify a unique program at Pima Community College in Tucson, Arizona that focuses on training indigenous populations in GIS and soft skills. Not only does this program increase the GIS workforce and youth engagement but it also attempts to geocode and document infrastructure on reserves in remote areas.
 - Cronin and Alexander (2019) indicate that focusing recruitment efforts on other industries with similar, transferable skill sets can be an effective strategy. This is particularly true if the parallel industry has a higher supply of skilled worker than demand. Another method to increase the employee pool is to provide training opportunities for underemployed population groups in the local community.
 - To enhance the workforce development potential in the transportation field by introducing transportation-related topics to middle school students, Montevalli, et al., (2019) conducted a program, titled *STEM in Motion*, “to provide teachers with the tools and resources necessary to incorporate transportation topics into their middle school science and mathematics lessons. In addition to using a transportation focus to enhance science and math learning via tangible applications, this method attempted to introduce transportation related career paths to students early on.”
 - Butler and Harrington (2018), explored major impediments and opportunities to hiring data analysts and software engineers to ensure that California Transportation (Caltrans) evolves into a data driven organization. They suggest the following actions can help overcome existing barriers:
 - “Develop appropriate salaries and/or recruitment strategies for software related positions.
 - Educate agency personnel on the need for data analysis and software skills.
 - Change the requirements for positions in Caltrans traffic operations.
 - Establish a management team to coordinate and support these efforts.”

However, they caution that education is a multi-year process that involves the entire transportation ecosystem, modifying salaries requires management approval and may take a long time, and management themselves must understand the need for these positions. The authors suggest “setting up a high-level team composed of Caltrans and the University of

California (UC) civil, electrical, data science and computer science departments to develop a plan for how to update university transportation programs and Caltrans' work force development programs to better reflect evolving workforce needs." Team goals would include:

- "Determine the best path for on-the-job education for Caltrans employees regarding data analytics and software.
 - Work at a high level on determining where these skills would be best used in the Caltrans organization.
 - To facilitate knowledge transfer, improve the quality of software systems within Caltrans and ultimately reduce costs, assign software engineers within Caltrans to work with software contractors.
 - Work with UC Berkeley initially, and then other educational institutions, on obtaining funding for the development of new courseware for teaching civil engineering undergraduate and graduate students in data analytics and software.
 - Engage the unions early on in these discussions."
- Harper et al., (2018) studied the practices in recruiting, training, and retaining qualified employees in construction careers at south-central state DOTs. Results from a survey of 1109 employees indicate that best practices to recruit and retain DOT employees includes 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.
 - O'Brien et al., (2018) reviewed the changing workforce development needs in California's transportation sector and recommended the following for regional transportation planning organizations to develop a more skilled workforce:
 - Target awareness programs for middle and high school students and teachers which could be help spread awareness about the road transport industry. For example, regional transportation planning organizations could be part of education programs aimed at creating curiosity in schools about city, transportation, and regional planning priorities and job opportunities.
 - Increase involvement and provide perspectives in curriculum development at urban planning school in the graduate and post-graduate level. Collaboration between the regional organizations and colleges "will ensure that the right material is taught using the latest technology, thereby keeping up with the changing needs of the job."
 - Increase "pathways for internships which run the course of the entire college year can yield better results in students graduating with real-time experiences and skill sets."
 - To ensure that students are graduating with an education that is relevant in a rapidly changing transportation industry, O'Brien et al., (2018) recommended the following for colleges and universities:
 - "Develop real-time curriculum, which could include conducting a capstone/research project with regional and local planning agencies for credit.
 - Creating externship programs with regional and local planning agencies.

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- Create a platform for students to experience the public planning process (i.e., attend city wide planning workshops, regional council meetings etc.).
 - Incorporate certification courses through recognised national organisations as part of the graduating curriculum, thereby making courses more professional.
 - Offer continuous learning opportunities for non-planner background candidates such as project managers, graphic designers, and programmers, with the opportunity of applying their skills to the transportation planning sector as well.
 - Ensure a hands-on approach to imparting knowledge using advanced software and analytics.
 - Consistently collaborate with national and state authorities responsible for transportation planning education.”
- Chang et. Al., (2018) suggest that recruitment efforts may be best spent on determining the appropriate key words for job positions and ensuring the postings actively appear on the top of search engine lists rather than focusing on development of the posting content itself.
 - Zhenzhen, et al., (2017) details a three-pillar approach to develop cyber security talent for Canadian road authorities to safeguard Operation Technology (OT) assets and Information Technology (IT) infrastructure.

Pillar 1. Cybersecurity Awareness Training and Education for Non-Cybersecurity Specific Talent

- Non-cybersecurity specific talent at Canadian road authorities, like road authority managers, OT and IT professionals, should have a basic cybersecurity awareness training. This training will give them a big picture understanding of the role and importance of cybersecurity in OT environments, identify threats alongside cybersecurity professionals and include cybersecurity considerations during the design of operations infrastructure and projects.
- During the author’s interviews with industry experts, they noted that risk management was an important skill for both transportation engineers and cybersecurity professionals as no OT-IT system that is a 100% secure, making it important to apply a risk management methodology, such as monitoring and reporting potential threats, to each instance.

Pillar 2. Establish Cybersecurity Framework and Protocol

- Create cybersecurity roles and hire cybersecurity specialists to create the cybersecurity framework and protocols for the organization.
- “Establish a baseline assessment of the existing OT systems and environment” and specifically, the OT-IT demilitarized zone (DMZ)/ boundary. This will result in the following two deliverables:
 - OT Cybersecurity Framework (OTCF) that maps all aspects of cybersecurity in the OT assets and infrastructure.
 - Cybersecurity Risk Management Plan that details all vulnerabilities, ranked by threat potential.

“These two deliverables set the foundation for the creation of all cybersecurity policies, processes and procedures.”

- Create a Cybersecurity Protocol for Legacy System and ITS integration.
- “Before CV infrastructure is fully deployed road authorities should acquire cybersecurity resources, either full-time or contract, that understand all wireless protocols” including 4G/LTE, 5G, and DSRC.

Pillar 3. Develop a Cybersecurity Resource Pool - External Experts

- The authors noted that larger U.S. state Departments of Transportation (DOTs) currently outsource a portion of their cybersecurity roles.
 - Encouraging the development of a cybersecurity consultant ecosystem, not necessarily full-time employees, can help add to and shape the road authority’s talent pool.
- Zhenzhen et al., (2017) conducted case studies of how the United Kingdom and the United States are approaching the need for cybersecurity talent development at road authorities and noted the following:
 - United Kingdom
 - Most UK based organizations have identified cybersecurity as a serious concern for their business’ future due to vulnerabilities in their website and social media pages, and cloud sharing and storage services.
 - Identify the need for senior leadership, someone who can influence decisions, overseeing the cybersecurity priorities for the organization.
 - With the goal of attracting fresh talent to the cybersecurity industry, the UK government, as a part of its National Cybersecurity Strategy, has collaborated with different government agencies, education institutions and private businesses to fund activities and create teaching materials promoting cybersecurity education and training in primary and secondary school.
 - The government has also funded internship and apprenticeship opportunities for graduate and post graduate students to provide real world experience and enhance the skillset of the incoming new workforce.
 - The UK government, to develop cutting edge research capacity, has designated universities which have faculty currently leading research and providing funding for post doctorate research in the field as centres of excellence for cybersecurity research, like Cambridge, Oxford, Edinburgh, and University of Birmingham.
 - Additionally, “The government has also provided funding for doctoral training to develop advanced skills and capacity building initiatives at the high-end of the skills spectrum. Specifically, the Research Council UK has been funding Centres of Doctoral Training (CDTs) tasked with delivering multidisciplinary training to the next generation of cybersecurity experts.”
 - United States
 - Currently, the U.S. has limited number of cybersecurity professionals employed at road authorities and with most of the larger agencies outsourcing their

cybersecurity requirements. Since smaller agencies do not have the resources to invest in cybersecurity professionals, they make do by following general IT best practices leaving their OT and IT assets vulnerable to attacks.

- To remediate these shortcomings, the U.S. has approved a National Cyber Strategy that prioritizes developing a highly skilled cybersecurity workforce. The plan encourages “investment in and enhancing programs that build the domestic talent pipeline from primary through to postsecondary education; and leveraging merit-based immigration reforms.”
 - The plan also emphasizes the importance of expanding cybersecurity reskilling and other educational opportunities for American workers.
 - The plan also notes the need for improving the recruitment process and retention of existing and new highly skilled cybersecurity professionals.
 - The government is also promoting improved compensation for federal workers with cybersecurity skills, along with unique training and operational opportunities to attract and retain critical cybersecurity talent.
- Zhenzhen et al., (2017) noted the following initiatives and policies that can help address the challenges in the development of skilled cybersecurity workforce at road authorities in Canada:
 - “Funding various activities that are geared towards promoting cybersecurity education and training in schools, such as CyberTitan.
 - Funding programs that offer cybersecurity internship opportunities for graduate and post graduate students.
 - Partnering with universities and colleges as well as professional development institutions in cybersecurity research. This will allow for greater knowledge sharing and transfer.
 - Investing in and enhancing programs that build the domestic talent pipeline from primary through postsecondary education levels.
 - Leveraging internationally trained professionals with cybersecurity skills.
 - Identifying reliable consulting groups that can serve as industry experts where needed.”
 - Adams and Hart (2017) and Workforce Intelligence Network (2017) assessed transportation workforce needs in the Midwest U.S. (Region V). The following are recommendations for advancing workforce development at transportation agencies that are relevant in Canada:
 - Organizations should collaborate and share workforce development practices that have worked well.
 - Develop credentialed and stackable training programs to support organizational workforce development goals.
 - Develop career pathways as a method of targeting specific population groups to unlock previously unengaged people. Career pathways retain employees longer.
 - Degree requirements should be made flexible when possible, allowing workers without a bachelor’s degree to enter the CAV workforce provided the right skills and training.

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- Education, internship, and apprenticeships to ensure new employees and current employees have the skills to handle new technology. Another strategy is to develop second careers in transportation for retirees.
 - Implement a Collective Impact initiative to understand the impact of K-12 activities. They recommend that the “transportation industry partner with a convening organization to pilot a gathering of broad-based transportation stakeholders.”
 - The National Academies of Sciences, Engineering, and Medicine (2017) completed a study that makes recommendations for growing the skilled technical workforce (defined as those with a high-level of technical knowledge but do not require a bachelor’s degree) in the U.S. The following are recommendations that are relevant in Canada:
 - Consult regularly with government, educators, and other civic association to stay informed about technical workforce development issues.
 - Provide incentives and resources for employees to pursue continual training throughout their carriers.
 - Support apprenticeship programs that link practical work experience with training and coursework.
 - 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 aligns with advancements in technology.
 - Remove barriers to worker mobility that include licensing and certification requirements that do not relate to public safety.
 - Manitoba Infrastructure (2017) developed the Maintenance Career Training (MCT) Program to provide a consistent level of service in maintenance field operations throughout Manitoba. The program provides necessary training opportunities at the right time by promoting competencies through accreditation/certification. The program consists of the following key features: training levels, organization, and certification.
 - Training is structured into levels that are progressive in nature. Each level has a combination of courses that develops the over-all understanding and knowledge base of the field staff, while exposing them to all aspects of equipment and operations relevant to the level.
 - Some courses must be completed to progress to the next MCT level or to receive pay increments. Additionally, Specialized and career development courses are also made available as required to fit the Resource Group or Regional needs.
 - Staff can achieve formal certification for each level by completing all essential courses, a written test and practical equipment operations proficiency test.
 - “The organizational component defines the roles and basic responsibilities for the various levels of staff within Maintenance Operations.”
 - Supervisors annually recommend training requested by field staff to the Regional Maintenance Management teams. The recommendations are based on an individual

training strategy informed by a review of training requirements and career goals, while taking into consideration the operational needs of the department and delivery of service.

- The Regional Maintenance Management teams approves based on operational needs, levels of service and resource constraints. An annual pre-scheduled training calendar can be produced to facilitate a highly organized, just in time approach to staff training while maximizing training resources.
- At the regional level, a designated training team participates in course development and training delivery.
- Maintenance engineers/managers form a training council who approve course content and training materials. “They also play a key role in the approval of testing criteria used in the Certification process.”
- “Provincial Maintenance Training Coordinator oversees and supports the process, assists in the development as well as maintains the training calendar, training materials and training records.”

The authors indicated that the program developed a highly skilled and fully engaged field staff. It benefited supervisors and management teams “through improved succession planning, a flexible work force, increased productivity and work quality as well as a reduction in accidents.”. Parallely, the program enabled a transfer of knowledge and experience from the senior staff to those just starting their careers while incorporating new technologies and ideas.

- The National Operations Center of Excellence (2016) conducted an informal survey of AASHTO TSM&O sub-committee members and noted the following opportunities for TSM&O workforce recruitment at U.S. road authorities:
 - Create a TSM&O branding strategy which includes a vision, business cases, contribution of career to social objectives, relationship to new technology and work environment opportunities.
 - Develop descriptions of TSM&O positions and core competencies.
 - Consolidate all TSM&O functions in to one program to provide visibility to increase marketability to new engineers.
 - Examine conventional hiring practices and streamline the process to enable the public sector to compete with the private sector for workforce talent.
 - Remove professional licensing requirements for entry level positions as the diversity of skills required in TSM&O are not all covered within these license requirements.
 - Provide competitive worker benefits to compete with the private sector for experienced senior TSM&O talent.
 - Create recruitment processes that appeal to the millennial and GenX workforce.
 - Continuously track current trends in technology and update knowledge, skills, and abilities (KSA).

The same author noted the following opportunities for TSM&O workforce retention at U.S. road authorities:

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- Empower TSM&O middle managers, who have difficulty in obtaining the priority, status, leverage, and authority within their organizations, to make changes in recruiting practices (internal or external) tailored to TSM&O that are exceptions to standardized legacy procedures.
 - Create a formal position mentoring program and clear succession planning for TSM&O positions.
 - Increase flexibility in job reassignment and job sharing.
 - Provide better compensation packages with benefits to compete with the private sector for skilled workforce creating a continuous turnover between the public and private sector.
 - Define the performance and review process for each TSM&O identified position.
 - Define a TSM&O post-employment training program that includes both rotational and specialty assignments, training courses and examination.
 - Maintain contact with the state of the practice through conferences, webinars, and professional association involvement as it is a significant component of job development and satisfaction.
 - Develop the capacity to retain retiring experts on a part-time basis.

Regarding workforce development, the National Operations Center of Excellence (2016) provides the following opportunities:

- Recognition of TSM&O as a professional discipline.
 - Establish clear career tracks for all TSM&O positions identified.
 - Develop formal succession planning as part of career tracking.
 - Provide clear career advancement with pay related to performance for TSM&O positions where appropriate.
 - Provide professional development resources and programs in special technical areas of TSM&O practice such as training, professional participation, and meeting attendance to maintain competencies.
 - Support wide involvement of any but the senior staff in national professional activities.
 - Identify/define the appropriate curricula (individual courses) for TSM&O career advancement.
 - Maintain a strong public-agency/university/industry professional interchange.
- The Northeast Transportation Workforce Center (2016) completed a study to identify workforce programs and partnerships to address gaps in the transportation workforce in the Northeast Region of the U.S. over the next 10 years. The resulting action plan involves the following programs:
 - Workforce Attraction Toolkit which outlines specific ways to engage various audiences that include education program directors, teachers, counselors, colleges and graduate schools, professional associations, and non-traditional application.

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- Transportation Career Paths to the Future promotes career advancement, skill development, and employee retention through the development of career path guidance.
 - Greener is Better: Promoting and Branding Transportation as a Green Career. This program seeks to brand transportation occupations as green to attract the younger generation that may be more environmentally conscious.
 - Implementing Succession Planning/KM to Increase Organizational Resilience. This program will focus on management and leadership training programs for employees at the entry level all the way to senior leaders to encourage career advancement. Knowledge management (i.e., mentorship programs intent on knowledge transfer between senior leaders and mid-career position) is also critical in ensuring that institutional knowledge is maintained when senior leaders retire.
 - Upskilling Transportation's Current Workforce to Meet Emerging Challenges and Opportunities. This program intends to develop a list of highly valuable emerging skills and the corresponding training that agencies should support their employees to pursue.
- Executive Office of the President of United States (2016) and Cronin and Alexander (2019) highlight the importance of promoting transportation and technology careers to a young audience that includes K-12 schools. Cronin and Alexander (2019) indicate that it is critical to reach youth early enough that they can take the specialized classes needed in college/university or even high school. "This involves strengthening relationships with education providers to influence curriculum, training courses, field trips, career fairs, and preparing materials for guidance counselors to offer to students." One important element is involving the parents in these discussions as they play a significant role in encouraging their children to pursue certain careers.

The authors also found that community and technical colleges are valuable sources of employees because they provide skills for a variety of transportation careers and work directly with employers.

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

APPENDIX B – ENGAGEMENT WITH ROAD AUTHORITIES

By

MORR Transportation Consulting

For

Transportation Association of

Canada

April 2022

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1 Introduction

This appendix contains the results from the engagement of road authorities. The engagement of road authorities was done through four focus group sessions as follows:

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

The purpose of this engagement was to develop an understanding of the following:

- HQP skillsets needed to plan, design, manage, maintain, and operate future road infrastructure systems, particularly in a disruptive technology era.
- Currently available skillsets.
- How leading Canadian jurisdictions are approaching the skills gap (e.g., through training programs, academic collaboration, or recruitment and retention strategies).
- 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.
- Procurement in a disruptive technology era.
- 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.

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.

A total of 122 people participated over the four days, representing 25 agencies as shown in Table B-1.

Each session started with a 20-minute presentation on the topic, followed by a 90-minute breakout session under the following three disciplines: planning and design, operations and management, and maintenance and construction.

Upon completion of each session, a summary of discussion was prepared. A summary of the overall findings is presented in Section 2 of this appendix. Section 3 discusses the results from the engagement of large municipalities, Section 4 (medium municipalities), Section 5 (small municipalities), and Section 6 (highway agencies).

Table B-1: Agencies Participating in Engagement Process

Large municipalities	Medium municipalities	Small municipalities	Highway agencies
<ul style="list-style-type: none"> • City of Vancouver • TransLink • City of Calgary • City of Edmonton • City of Toronto • City of Ottawa 	<ul style="list-style-type: none"> • City of Winnipeg • City of London • City of Hamilton • Region of Waterloo • Halifax Regional Municipality 	<ul style="list-style-type: none"> • City of Victoria • City of Lethbridge • City of Fredericton 	<ul style="list-style-type: none"> • B.C. Ministry of Transportation and Infrastructure • Alberta Transportation • Saskatchewan Highways • Manitoba Infrastructure • Ministry of Transportation of Ontario • Ministry of Transportation of Quebec • New Brunswick Department of Transportation and Infrastructure • Nova Scotia Department of Transportation and Active Transit • Newfoundland and Labrador Transportation and Infrastructure • Northwest Territories Department of Infrastructure

2 Summary of findings

The following key findings resulted from the engagement of road authorities.

- In all cases (large, medium, and small municipalities, as well as highway agencies), agencies agree 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.
- 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, be knowledgeable about artificial intelligence, machine learning, and cyber security. 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 (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.
- There are at least three workforce development challenges experienced by the four agency types and are expected to intensify in a disruptive technology era: compensation, future skills requirements, and available candidate pool. Agencies identified the following key workforce development opportunities for a future of disruptive technologies: (1) collaboration with universities and technical colleges; (2) collaboration with industry; (3) outreach to young students; (4) introduction of multi-disciplinary teams; and (5) creation of centres of excellence.
- 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 at the Ontario Traffic Institute. 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.

- There is consensus among agencies that while they may currently have adequate resources to procure most services, this will change in an era of disruptive technologies. 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.
- Participants 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. Only large municipalities believe they will be somewhat prepared with respect to HQP in a disruptive technology era. Other agencies are not confident they will be prepared. Participants also provided ideas to make Canada a leader in HQP development in a disruptive technology world.

3 Large municipalities

This section presents a summary of key points raised during the focus group discussions with representatives from large municipalities. A total of 30 people participated in this session representing the City of Vancouver, TransLink, City of Calgary, City of Edmonton, City of Toronto, and City of Ottawa. The following are key findings regarding each of the discussion topics.

3.1 Currently available skillsets

All agencies agree that their current workforce has some of the necessary skills to do their jobs. However, as there has been a gradual change in the types of skills needed to deliver services, some gaps have been identified. Skills gaps that appear to exist in these agencies include:

- General traffic engineering knowledge. In some cases, because recruits have not come directly from an engineering program, their depth and breadth of traffic engineering knowledge is limited. For example, in one of the agencies, many of the people they hire in a data science unit have prior degrees in subjects such as astronomy, GIS, energy, and others, and they have obtained training in transportation later on in their careers.
- 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.
- Soft skills. Agencies often struggle finding people with the right combination of technical competencies and soft skills such as political acumen (including being able to communicate with elected officials) and relationship management.
- Managerial and supervisory skills. Agency workforces generally comprise people skilled at managing multiple projects simultaneously. 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.
- The ability to handle large quantities of data (data analytics). 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. This is where some of these agencies are finding gaps in the skillset of current employees. Another situation where challenges are being faced is regarding big data in the planning process and long-range forecasting and modelling.
- 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.
- Oral communication. Agencies have found that oral communication has increasingly become a gap for some of their jobs. The issue is that 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.

3.2 Skillsets needed in a disruptive technology era

- Agencies agree that in the future, there will be a critical need for people who can manipulate and understand large quantities of data, be knowledgeable about artificial intelligence, machine learning, and others. However, they also agree that it will be very difficult to find people trained as transportation engineers, with this type of knowledge.
- There will also be a need for people with the skills to exploit the capabilities of all the systems that are currently in place for data collection. Many systems have been installed across many cities and their data collection capabilities have yet to be fully untapped.
- There is a general agreement that cross-cutting skillsets (i.e., skills that span across traditional knowledge domains) will be increasingly critical. For example, asset managers need to have working knowledge of infrastructure condition and deterioration mechanisms across traditional asset classes, as well as skills in data acquisition, storage, and analysis.
- According to these agencies, skillsets that will be needed in a disruptive technology era include:
 - An ability to lead and manage relevant pilot projects. For example, at least one city has engaged in a pilot project to evaluate autonomous snow clearing equipment. The agency requires people with skills to work with the vendor at all stages of this type of project.
 - Knowledge about cybersecurity.
 - Understanding of the Internet of Things and how to manage the various technological demands associated with it.
 - Data science. This will be an essential skill for most of the services provided by road authorities.
 - Ability to function in more than one technical domain. For example, the installation of 5G communications requires a mixture of transportation engineering (i.e., to ensure connectivity of traffic signals), electrical engineering, and information technology skills.

- Ability to understand evolving vehicle-infrastructure interactions. For example, there may be a need to change maintenance specifications, thresholds, and the general state-of-repair of infrastructure to ensure autonomous vehicles can safely navigate throughout the road network.
- Ability to operate new types of equipment.
- Ability to be competent with application-specific software that they may not have had prior training on.
- ‘Capability to engage with the public and stakeholders. This will become increasingly important at the planning level. One agency discussed their experience regarding the value that public engagement brought to their work on *smart cities*, where key questions were raised beyond the technology and more related to the social need and implications of the technology.
- Communication skills. As disruptive technologies permeate urban areas, road authorities will need to deliver clear messages to the public regarding various highly technical concepts.

3.3 Workforce development challenges

The following challenges were identified regarding workforce development, recruitment, and retention:

- In some cases, there is concern about not having the knowledge regarding the requirements of future technical positions. For example, not being able to write a job description to hire the right type of professional for a disruptive technology era.
- In some instances, basic HR challenges exist, for example, transitioning employees from part-time to full-time, or from temporary to full-time is difficult due to agency policies. Also, staff turnover and retirements sometimes limit the amount of on-the-job experience that junior staff might receive before being promoted to supervisory roles.
- Recruiting adequately skilled employees is a challenge. Some existing job classifications are not 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.
- Some agencies are having difficulty finding the right people in Canada. While they have identified the right talent, many times this talent exists in other countries but not in Canada.
- Some agencies are experiencing challenges regarding collaboration within or across units within the same department. The fact that different units work in silos has a negative impact on knowledge dissemination, hence hindering technical growth. One specific issue relates to the need to interface with enterprise-level information technology specialists regularly and effectively.
- Technology is advancing too fast and there is not enough time to train people or enough graduates with the necessary skills. It appears that in the case of traffic or software engineers, they will need to have constant upgrading to keep up with the latest technologies.

- 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.
- It will become increasingly difficult to engage in technical discussions with industry (e.g., Blackberry and QNX) if the level of knowledge about that ecosystem is not improved.
- Compensation structures and limits in government vs industry are making it increasingly difficult to hire people with the skills necessary for changing employment needs. It is expected that this will intensify in the future, particularly if greater levels of knowledge or specialization are needed. Compensation also impacts retention. Some agencies sense that young staff might be more attracted to the private sector than the public sector. One potential counter trend relates to the potential to recruit skilled employees from the oil and gas industry.
- Some agencies indicate challenges associated with hiring young, skilled interns in the context of a unionized workforce.
- Recruitment of qualified data scientists is more challenging when they have been in industry for three or four years versus hiring directly from university. The reason is mainly because of high salary expectations.

3.4 Workforce development opportunities

The following opportunities were identified for a future of disruptive technologies:

- Regular upgrading of technical skills, with special emphasis on data science.
- Continue to work with universities and colleges to hire coop students so that these people can become potential candidates for future recruitment. Having a strong student program is one way to really develop a strong future workforce.
- Collaborate with universities on innovative projects that can help train students who may later become agency employees.
- Partner 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.
- Promote the high-tech sector to young children so that they will become interested in this field.
- It will be important to update curricula at universities to ensure that coding and data literacy become a general skill (much like word processing) for any sort of engineering.
- Agencies need to be willing to commit to advanced technologies and the changes that come with them. If this happens, the necessary resources should be made available to ensure that the staff have the technical skills needed to provide services.
- Partner with academia and the private sector to discuss the future of transportation as a group and plan for that future, ensuring that students receive the necessary education.

- Some agencies noted the importance of accessing professional certification programs but admitted that there was relatively little emphasis on this.

3.5 Workforce development initiatives

The following initiatives have been implemented by agencies to help close the skillset gap that currently exists for successful service delivery:

- Training for new recruits to ensure they have the technical skills necessary for successful service delivery. However, during recruitment, an effort is made to find people who have at least two of the following skills: general traffic engineering knowledge, data analytics, GIS and spatial thinking. Other skills are acquired through special on-the-job training.
- Equipment operators have access to regular driver training programs.
- Hiring an IT person or GIS person specifically for the unit, therefore ensuring that city culture is preserved while having direct access to someone who has the necessary skills for those aspects of the job.
- Collaborating with other branches within the division or department to bring some of the highly specialized traffic engineering knowledge needed to operations where it may be lacking.
- Rotational training. Some agencies have implemented the practice of starting new recruits doing signal design or signal timing, 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.
- Regular training of technologists through programs offered by the International Municipal Signal Association (IMSA).
- Regular training by experts in the field. In some cases, the training may be online.
- Some employees have been assigned to work with industry such as Blackberry so that they can learn from the experts and that knowledge can be transferred back to the agency.
- One of the agencies has strived to serve as a 'competence centre for automation'. This initiative includes hosting training seminars on the future of automation for road authorities.
- One of the agencies indicated that, while they had several training initiatives available for staff to improve soft skills, there are relatively few opportunities focused on technical upskilling.
- Regular 'lunch and learn' events. Some agencies with limited resources have engaged in the practice of sharing knowledge during regularly scheduled events with staff or through events where experts are invited to deliver presentations on a particular issue of interest.

3.6 Employee recruitment sources

- In all cases, engineers are hired from universities and technologists from community colleges.
- One of the agencies focuses recruitment efforts on PhD and Master's graduates.

3.7 Procurement in a disruptive technology era

- Agencies agree 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.
- While some agencies are forming small working groups or evaluation panels to address procurement issues, others are procuring proof of concept projects where they work with the vendor to make sure that the technology works and learn lessons in the first six months of implementation prior to the next stage of a systemwide implementation, and others are relying on vendors to assist them through the procurement and technology performance assessment process.
- Some agencies indicate that they lack experience and expertise in developing proper specifications to procure advanced technologies.
- Challenge-based procurement has been implemented in one instance 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, and get comfort with the new technologies. This also poses an opportunity for procuring future technologies that have not been widely deployed in the real world.
- Agencies may need to formalize decision-making processes to determine what types of work should be kept in-house, and what will be outsourced.

3.8 Planning for a future with disruptive technologies

All the participating agencies have started planning for a future of CAVs and *smart cities*, as follows:

- Test beds for CAVs have been implemented.
- 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, and others).
- One agency has had three people dedicated to CAV preparedness for the last four years.

3.9 Level of readiness for an era of fully diffused disruptive technologies

Participants were asked what they thought would be their agency's readiness level when full diffusion of CAV and *smart city* technologies are here. The available options ranged from 1 to 4 as follows: (1) definitely not prepared; (2) somewhat unprepared; (3) somewhat prepared; and (4) definitely prepared.

The average level of readiness identified by large municipalities was 3 (somewhat prepared).

3.10 Canada as a leader in HQP development for a disruptive technology world

The following ideas were offered by these agencies:

- 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 younger ages.
- Establish partnerships across agencies, so that learning can happen from city to city. For example, the Cities of Calgary and Edmonton routinely connect to share their experiences.

4 Medium municipalities

This section presents a summary of key points raised during the focus group discussions with representatives from medium size municipalities. A total of 26 people participated in this session representing the following agencies: City of Winnipeg, City of London, City of Hamilton, Region of Waterloo, and Halifax Regional Municipality. The following are key findings regarding each of the discussion topics.

4.1 Currently available skillsets

- For the most part, agencies feel confident that their current workforce has the necessary skills to serve the public.
- Their main challenge identified by these agencies was related to staffing levels (limited human resources) to deliver services. While current employees have the required technical knowledge, agencies do not have enough staff to handle all tasks. In one case, for example, the same individual oversees traffic signals, street lighting, traffic signs, pavement markings, and electrical systems.
- As expected, agencies employ people with civil and transportation engineering skills, as well as those that come from technology backgrounds. For maintenance tasks, there are also numerous people backgrounds in the skilled trades.
- Supervisory and project management skills are viewed as particularly important and require on-the-job training to acquire.
- Some agencies highlighted the need for more generalists in leaderships positions who understand a wide range of disciplines and how they should work together to achieve agency goals.
- In many of these agencies, the current skillsets exist out of necessity. Having limited personnel has forced people to learn new skills outside of their area of expertise.
- Because of the short staffing challenge, succession planning is not readily available for most of these agencies. This becomes a significant issue when people leave for another employer. All the knowledge that resided with that person is lost.
- Because of the gradual change in the types of skills needed to deliver services, these agencies have identified the following areas where skills gaps exist:
 - 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.
 - Data science and data processing.
 - Computer programming.
 - Cybersecurity.

- Inter-agency coordination.
- Public engagement.

4.2 Skillsets needed in a disruptive technology era

Agencies agree that the following skillsets will be required in a disruptive technology era:

- Cryptography and cybersecurity.
- Understanding of blockchain technologies and systems.
- Strong computer programming skills.
- An ability to undertake pilot tests for emerging technologies.
- An ability to implement new technologies, even some basic technologies related to communication and reporting tasks.
- An ability to understand needs and develop associated infrastructure design and maintenance specifications.

4.3 Workforce development challenges

The following challenges were identified regarding workforce development, recruitment, and retention:

- Limited funding to hire additional positions. With an already stretched workforce, some of these agencies are not confident that they will be able to function effectively in a future with more complex demands resulting from disruptive technologies.
- Some agencies report facing challenges associated with an aging workforce—particularly as those with decades of experience retire without having appropriate opportunities to transfer their knowledge to younger employees and has impacted succession planning.
- Limited knowledge regarding future technical positions. For example, some agencies would not be able to write a job description to hire the right type of professional for a disruptive technology era.
- In some cases, because of their unique location, recruiting is a problem because these agencies are competing with large municipalities for the same graduates. Therefore, unless there is a captive source of recruitment, medium sized cities can struggle attracting the right employees if they must compete with other road authorities.
- In most cases, engineering departments are separate from IT departments. This segregation does not allow for good communication and knowledge dissemination. In addition, IT departments appear to be more concerned with the general business of the agency than with the delivery of transportation services.
- There seems to be some apprehension from IT departments to develop products in-house. In many cases, IT favours commercial off-the-shelf software over developing things in-house.

However, sometimes transportation groups may be better served by developing something in-house.

- The traditional transportation engineer is not adequately prepared for the demands of today regarding advanced technologies (e.g., DSRC, 4G, 5G). Similarly, computer and electrical engineers, who understand these issues have no knowledge about basic traffic engineering.
- Compensation appears to be an issue with respect to recruitment and retention. In this case, the competition includes larger municipalities or private industry.
- Succession planning is a challenge due to a mismatch in skillsets of the soon to retire workforce and the current incoming workforce.
- Unions can sometimes limit the way in which jobs are classified or can have an impact on the types of people that are hired for certain jobs (line of progression can be a problem).

4.4 Workforce development opportunities

The following opportunities were identified for a future of disruptive technologies:

- Hire IT staff to work directly with transportation employees to make sure that “learning takes place by osmosis”.
- Involve IT personnel in the procurement process to ensure the right language is used and evaluations benefit from people who may have high technical knowledge.
- Enhance the skills of electricians to include computer programming.
- Ensure that engineers learn computer programming as a general and basic skill.
- Implement an ‘engineer-in-training’ or an IT rotation program across different divisions and different departments so that new recruits can rotate between areas and learn different skills over a period of time.
- Document processes. This would be beneficial for new recruits but also for everyone in case people leave or retire.
- Long term planning is necessary. Agencies agree that in many cases they function in a reactive mode due to limited resources, but little time is spent planning.
- Partner with local universities for recruitment; this is seen as a critical avenue for action.
- Start engaging students at a much earlier age and getting them interested in computer programming and advanced technologies. Students in grades 7 and 8 would be prime targets to attract into this field.
- Review and align salary scales to improve the ability to attract and retain talent.

4.5 Workforce development initiatives

- Available resources for workforce development are limited in most agencies. As a result, not much formal training takes place, and many employees engage in self-learning of new skills.
- There has been some success realized through informal relationships that have developed into a series of successful hires of graduate students in transportation engineering.
- Several agencies note success associated with implementation of new technologies for reporting and communication tasks.
- Certain agencies have successfully hired data scientists focused on the transportation domain.
- There is some acknowledgement of the potential value of working more closely with colleges and universities to align training with industry needs, but relatively little formal action in this regard.
- Certain agencies have programs to financially support staff interested in upskilling and professional training/certification.
- The following initiatives have been implemented (informally) to help close the skillset gap that currently exists for successful service delivery:
 - 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. At the same time, these students provide good assistance to the overloaded staff.
 - Encouraging staff to become involved in professional organizations to ensure they maintain currency is emerging trends.
 - Collaboration with local university and private sector companies to identify and assess local CAV initiatives and associated challenges.
 - An engineering progression system for consistent mentoring and clear succession planning.

4.6 Employee recruitment sources

- In all cases, engineers are hired from local universities and technologists from local community colleges.
- Some agencies also recruit employees from places outside their own geographic area.

4.7 Procurement in a disruptive technology era

- Most agencies are not confident that they will have the necessary knowledge or will be ready to procure complex services or products related to disruptive technologies. Even today, with

changing technologies, some of these agencies are finding it difficult to stay current for informed procurement.

- Certain agencies have developed a successful approach in which they pilot test new technologies, not only to gain information about that technology, but also to gain internal skills that will help in developing appropriate requests for proposals after the pilot test.
- Some agencies have embedded procurement staff into their engineering group to assist with the process, however, the technical knowledge about the types of services may not be available.
- Other agencies are confident that they are sufficiently ready for today's procurement needs but procuring in the future may prove more challenging. In their view, 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.
- Agencies have experienced examples in which consultants or vendors have brought forward new technologies to execute transportation infrastructure projects. They view outsourcing as an essential strategy for adapting to new technologies. They are also very aware that large consulting firms can access multidisciplinary skillsets.
- Another challenge in some cities is that there may be discrepancies between consulting firms in terms of how equipped they would be to respond to a rapidly changing technological landscape. That could have important ramifications regarding how agencies procure services.

4.8 Planning for a future with disruptive technologies

- Most of the participating agencies have not started planning for a future of CAVs and *smart cities*. They have not been directed by their City Councils to undertake work related to a future with disruptive technologies. In many cases, the current areas of focus are related to road safety, rapid transit, and the environment.
- One agency has started developing a strategic plan for CAVs. However, there is no real urgency to complete the work yet.
- One agency is exploring a CAV shuttle pilot study in collaboration with the local university and private companies.
- There is some hesitancy to engage meaningfully with the CAV topic since the technologies are evolving so quickly. Currently, the users (general public) are not requiring urgent action. Additionally, most people do not have the time to consider these possibilities as part of their day-to-day duties.
- There has been some incremental progress toward the use of disruptive technologies, but limited experience in planning for major technological changes. Examples include some experience with tracking snow clearing equipment and more advanced signal timing.
- Agencies note that they are willing to absorb new technologies as they arrive and become mainstream but are unlikely to lead the deployment of new technologies.

- Agencies are aware of financial constraints and these are viewed as a barrier to planning and ultimately adopting disruptive technologies. They will make it a priority when it becomes a priority politically.

4.9 Level of readiness for an era of fully diffused disruptive technologies

Participants were asked what they thought would be their agency's readiness level when full diffusion of CAV and smart city technologies are here. The available options ranged from 1 to 4 as follows: (1) definitely not prepared; (2) somewhat unprepared; (3) somewhat prepared; and (4) definitely prepared.

The average level of readiness identified by medium municipalities was 2 (somewhat unprepared).

4.10 Canada as a leader in HQP development for a disruptive technology world

The following ideas were offered by these agencies:

- Make this topic a national priority. For disruptive technologies to take priority in every geographic region, it must be made a priority at the national level first.
- There needs to be political leadership to ensure this becomes a priority. And this likely happens only when Canadians identify that they really want this.
- The issue needs to be given budgetary priority.
- For medium size cities to be able to evolve in this domain, there must be public interest so that elected officials direct action.
- The development of working groups comprising public sector and private sector representatives would be critical.

5 Small municipalities

This section presents a summary of key points raised during the focus group discussions with representatives from small municipalities. A total of 16 people participated in this session representing the City of Victoria, City of Lethbridge, and City of Fredericton. The following are key findings regarding each of the discussion topics.

5.1 Currently available skillsets

- Agencies agree that, for the most part, they have the skills to provide the necessary services to the public, however, only for day-to-day operations. There is consensus that as cities grow, there will not be enough capacity to take on more work.
- Smaller agencies often require staff to work across multiple roles.
- Agency employees commonly engage with engineers, technologists, contractors, consultants, and laborers, many of whom work for external entities.
- Most agencies have observed gradual changes in the types of skills needed to deliver services. The following skillset gaps have been identified because of these changes:
 - Computer programming
 - Data analytics
 - Traffic engineering
 - Public engagement
 - Inter-governmental coordination
 - Ability to implement new technology

5.2 Skillsets needed in a disruptive technology era

- In general, agencies believe there are many unknowns regarding a future of disruptive technologies; therefore, it is hard 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.
- From a maintenance and construction perspective, agencies are seeing the emergence of vehicle/equipment automation. This trend will require agencies to ensure they have people who can sufficiently operate and maintain such fleets.
- Computer programming, cybersecurity and big data analytics are skills that agencies believe will be required in the future.

5.3 Workforce development challenges

The following challenges were identified regarding workforce development, recruitment, and retention:

- Most agencies agree that they are currently struggling with being able to have the personnel to manage the challenges of their transportation systems. There is no real opportunity or capacity to plan for *smart city* technologies and CAVs, or other future disruptive technologies.
- For smaller agencies, many staff work across multiple knowledge domains. Recruitment of these broad skillsets is increasingly difficult and there is a high reliance on training through on-the-job experience.
- When cities grow, there is a natural transition into more data intensive program delivery. Examples include transportation planning and asset management, where agencies recognized a need for better data but faced data management challenges.
- Most agencies noted having sufficient training and upskilling opportunities, but the lack of capacity prevents the application of these new skills that eventually never get utilized.
- Agencies report issues with limited human and financial resources. As cities have grown, infrastructure has continued to expand but there has been no associated growth in available human resources—in part because of financial constraints.
- Employee recruitment is a challenge for small agencies. In most cases, unless the person they are recruiting lives in the jurisdiction, it is difficult to attract people from outside as most will gravitate to larger municipalities.
- Agencies recognize the importance role that unions will play in the implementation of technologies. In some cases, it is difficult to redefine or reclassify jobs in a unionized environment.

5.4 Workforce development opportunities

The following opportunities were identified for a future of disruptive technologies:

- Work with universities or even high schools to hire summer students for potential future recruitment.
- Better communicate the advantages of working in a small municipal agency like work-life balance, contribution to the public realm, etc.

5.5 Workforce development initiatives

The following initiatives have been implemented by agencies to help close the skillset gap that currently exist for successful service delivery:

- One agency provides training opportunities by sending all new recruits on a two-week training course at the Ontario Traffic Institute. The reason they do this is that, in their opinion, civil

engineering programs do not provide a strong enough foundation in transportation engineering. By sending people on this course, they have obtained positive results.

- Other agencies make sure their employees attend selected conferences, webinars, or other similar professional development opportunities. In one instance, the agency holds ‘lunch and learn’ events where people who have attended a conference or have taken part in a special seminar share what they learned with the rest of the staff.
- In some agencies there is a conscious effort to share institutional and experiential knowledge amongst employees. This type of cross-functional collaboration and in-house training may be more easily facilitated within small agencies because of the smaller workforces and more diverse job descriptions.
- At least one agency has implemented a corporate leadership program. This has been viewed positively but is not directed at technical skills.
- In cases where new technologies are acquired by the agency, training specific to the technology is provided through the vendor, for staff who will be working with such technology.

5.6 Employee recruitment sources

In all cases, engineers are hired from universities and technologists from community colleges. In some cases, engineers and technologists are also hired from private consultants located locally or from neighboring regions.

5.7 Procurement in a disruptive technology era

- Agencies agree they are currently equipped to handle procurement of services. However, some of them are not sure whether they will be ready for a future of disruptive technologies, mainly because they are not sure what it is that they will be procuring.
- In some cases, agency representatives had little influence on the procurement process.
- There is hope that they will be able to learn from other municipalities when the time comes and apply that knowledge to their own situation.

5.8 Planning for a future with disruptive technologies

- In most cases, 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.
- Agency representatives acknowledge the need to plan for disruptive technologies, as their emergence has the potential to drastically impact routine aspects of their jobs (e.g., maintaining a certain infrastructure condition level, setting up a temporary work zone).
- One agency representative claimed that the roadway environment will continue to require interactivity with humans. A CAV might be considered as another type of user with which to communicate.

- One agency has started investing in electrification by installing charging stations in the municipality. However, this work is still in its infancy.
- Generally, agencies did not view their level technological innovation as relating to the advent of CAVs or *smart cities*. Example technologies that they had experience with included GPS tracking, variable message signs, and the use of road-weather information systems (RWIS).
- The consensus is 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.

5.9 Level of readiness for an era of fully diffused disruptive technologies

Participants were asked what they thought would be their agency's readiness level when full diffusion of CAV and smart city technologies are here. The available options ranged from 1 to 4 as follows: (1) definitely not prepared; (2) somewhat unprepared; (3) somewhat prepared; and (4) definitely prepared.

The average level of readiness identified by small municipalities was 2 (somewhat unprepared).

5.10 Canada as a leader in HQP development for a disruptive technology world

The following ideas were offered by these agencies:

- Agency representatives recognize the importance of TAC's involvement in helping them prepare for the emergence of disruptive technologies. This project is viewed as an important step, as it has provided a platform for cross-agency dialogue.
- 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.

6 Highway agencies

This section presents a summary of key points raised during the focus group discussions with representatives from highway agencies. A total of 50 people participated in this session representing the following agencies: B.C. Ministry of Transportation and Infrastructure, Alberta Infrastructure and Transportation, Saskatchewan Highways and Transportation, Manitoba Infrastructure, Ministry of Transportation of Ontario, Ministry of Transportation of Quebec, New Brunswick Department of Transportation and Infrastructure, Nova Scotia Department of Transportation and Active Transit, Newfoundland and Labrador Transportation and Infrastructure, and Northwest Territories Department of Infrastructure.

The following are key findings regarding each of the discussion topics.

6.1 Currently available skillsets

All agencies agree that while their workforce has many of the necessary skills to do their jobs, they need to develop some more. There has been a gradual change in the types of skills needed to deliver services, which has resulted in some of the following skills gaps:

- Data analytics and data management. Agencies are finding that they are increasingly having to handle large amounts of data and the necessary skill are sometimes lacking.
- Knowledge about ITS. 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.
- Network security and cybersecurity.
- Electrical maintenance and electronics. This is particularly a problem for services in rural areas.
- Real time data collection capabilities, particularly by technicians who have been used to collecting data manually.
- Knowledge of specialized design software (integrated design software packages)

6.2 Skillsets needed in a disruptive technology era

- Most agencies agree that there is a high likelihood that they will not be prepared with the right set of skills for a CAV or other disruptive technology future. Some of the required skillsets that agencies are expected will be needed in the future include the following:
 - Cybersecurity and communications technologies
 - Computer programming
 - Electronics
 - Civil engineering with IT knowledge, including systems integration
 - Traffic engineering knowledge combined with computer programming and electrical engineering
 - Data analytics and data management

- Geospatial analysis skills and data visualization
 - Soft skills (e.g., communication, collaboration, political acumen, and others)
 - Project management, particularly for construction work and successful implementation of new systems
- In general, there appears to be a current and future need for more well-rounded professionals and technologists. People who will be able to function within their own technical domains, but who will also be fluent in computer programming, GIS, and other similar skills.
 - For professionals who will be doing jobs that require interaction with the public, agencies agree that critical thinking, communication, and public engagement skills will be necessary. In many cases, planning or design jobs require not only a solid technical foundation, but also a good understanding of policies and implications of what is being proposed to the public.
 - Most agencies suggest that they do not face data shortages, but struggle to effectively mine the data to support decision-making.
 - From a maintenance perspective, agency representatives are uncertain how autonomous vehicles might interact with the infrastructure, so it is difficult to know how maintenance specifications might be required to change.

6.3 Workforce development challenges

The following challenges were identified regarding workforce development, recruitment, and retention:

- Because in many instances departments work in silos, there are communication barriers within the department or between departments. Finding the right people within departments to ensure progress continues has become a challenge in some instances. This problem is expected to become more pronounced and significant in an era of disruptive technologies.
- Communication and coordination between design teams and operations teams to implement new technologies appears to be a challenge for some agencies given the silo nature of service delivery. Some identified this as a real problem in a high-tech world, where there cannot be these types of barriers if success is important.
- Communication and coordination within large agencies can be a problem due to uncertainty regarding allocation of responsibility. Some agencies have experienced significant reorganization within their departments.
- Some agencies have identified problems with having the IT people and the engineering people working in separate divisions (or government departments) and not communicating on important service delivery issues. There can be misalignment between the IT area and transportation departments since IT has been centralized at a government level in many jurisdictions.
- Limited long-term planning. In many instances, particularly when it comes to new technologies, provinces have not adopted plans that look far into the future. The norm is to handle issues year

to year. Some provinces agree that they will not be the leaders in the adoption of new technologies and will rather rely on the experience gained by larger provinces.

- Some agencies have had trouble finding specialists in cybersecurity. Even identifying experts to deliver special training is a challenge.
- Limited funding for new positions and hiring and/or salary freezes. Many agencies are struggling with securing the right number of employees to deliver the necessary services. This situation has not changed for some time and is expected to continue to be a challenge in the foreseeable future.
- Some agencies believe that an important challenge is predicting the future and what the requirements will be from a workforce development perspective.
- Agencies recognize that a major challenge in the future will involve being able to keep up with the maintenance of technology that is installed. Having the right people in place to do carry out these tasks, as well as having the right number of people is expected to become a challenge.
- Succession planning has proven difficult. Because of the short staffing challenge and an aging workforce, succession planning is a problem for many agencies. This becomes a significant issue when people leave for another employer. All the knowledge that resided with that person is lost.
- For some agencies attraction and retention is a significant challenge due to the large rural nature of some jobs. Further, it is difficult to attract people to jurisdictions that are too remote, particularly because of other available opportunities for recent graduates (e.g., municipal agencies or private industry). In one case, an agency hired interns to attract them into public sector positions, but most of those left after only a short duration of service in the public sector.
- Compensation was identified by some agencies as a challenge for recruitment, particularly considering extended hiring and wage increase freezes in recent years.
- Some agencies agree that people going through university are not really being trained properly in transportation systems or the high-tech side of transportation. Many agencies agree that their new recruits are more 'generalists', which makes it difficult to fully integrate them into the work force immediately.
- Some agencies have downsized so much that they have ended up outsourcing most of their design work to consultants. This has resulted in few internal people having the knowledge to manage work being done by hired consultants.
- Centralization of HR services. Some agencies are adopting a more centralized approach to recruitment and hiring. The intent of this is to hire more generalists so that they can migrate between departments. However, this can also create potential problems when specific details (or skills) are required for a given job.
- Agencies recognize the important role unions play in workforce development.

- One agency representative distinguished between the need to upgrade systems and the need to better equip employees. In this regard, the representative noted that the major gap was with systems, rather than with employees' skillsets.

6.4 Workforce development opportunities

The following opportunities were identified for a future of disruptive technologies:

- Collaborate with schools, universities, and community colleges to identify potential recruits. This collaboration would also address areas of need in terms of knowledge gaps. For example, what does industry and government need now and will need in the future vs what is currently being taught? Curricula need to be updated to keep up with changing demands.
- Collaborate with community colleges to identify training opportunities that can help close the skillset gap in various areas of need. At least one agency has already started exploring this idea with professors and instructors from local colleges.
- Ensure that transportation and IT staff work together by being part of multi-disciplinary teams. Some agencies have had success by bring together multi-disciplinary teams to develop standards, processes, and procedures jointly. Other agencies 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 has been positive as everyone learns from everyone else.
- Create advisory groups to work with universities to identify the types of skills that will be needed by industry in the future. This should encourage alignment in terms of skills obtained by future graduates and areas of demand within industry and government.
- Establishment of centres of excellence at key locations across the country. This would allow for potential training opportunities for future recruits as well as for existing workforce.
- High school students should be engaged to increase their interest in computer programming and advanced technologies.
- Federal government grants earmarked to hire IT people or people with specific knowledge in advanced technologies could help increase the skills base within agencies.
- In cases where budget may be limited for in-house or any other type of training, agencies see an opportunity for hiring a third party for providing expertise in the interim.
- Certain agencies have already experienced significant staff turnover through retirements. This has led to a much younger workforce, which might be considered an asset in an era of emerging disruptive technologies.

6.5 Workforce development initiatives

The following initiatives have been implemented by agencies to help close the skillset gap that currently exists for successful service delivery:

- One agency has an ongoing collaboration with one of their major municipalities for the municipality to deliver services at the regional level. This is beneficial because the municipality has more resources than the highway agency and, in some instances, there are collaboration opportunities for knowledge sharing. The highway agency is currently pursuing a similar type of arrangement with another major municipality in the province.
- At least one agency has a formal graduate hiring program, in which graduating engineers are recruited and purposely exposed to various aspects of the agency's scope of responsibility, with the goal of producing engineers with well-rounded skillsets.
- One agency noted a program in which the employer, in exchange for an agreement related to employee retention, would pay retraining costs. The agency mentioned a case in which GIS specialists went back to university to gain computer science degrees.
- Another agency has been providing hands-on training to internal staff or, in some cases, to consultants, on electrical maintenance knowledge.
- 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. Others also have strong connections with local colleges.
- Online training is also an initiative that is gaining traction with some agencies.

6.6 Employee recruitment sources

- In all cases, engineers are hired from universities and technologists from community colleges. Some agencies also recruit from private industry but that is not very common.
- In some cases, particularly in rural areas and for certain types of jobs (e.g., maintenance and construction), recruits come from local high schools.

6.7 Procurement in a disruptive technology era

- Agencies agree that while they may currently have adequate resources to procure services, this will change in an era of disruptive technologies. 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.

- Certain agencies expressed confidence in their procurement process today and into the future, since there are formal, well-established procurement procedures in place.
- Some agencies acknowledge that the private sector responds more quickly to technological evolution than public sector.
- Issuing a request for information prior to a request for proposal can help agencies prepare for appropriate evaluation of bids. However, this adds time to the procurement process.
- Agencies acknowledge that they should not request a proposal unless they are able to evaluate it fairly and transparently.

6.8 Planning for a future with disruptive technologies

- Some agencies 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. As a result, not much planning has gone into this issue from the transportation perspective yet. There is also an expectation that if and when this happens, engineering departments will be required to work closely with IT departments to provide services.
- From a geometric design perspective, many agencies agree that not many changes will be generated due to CAVs or other disruptive technologies. The way in which design is done is not expected to change significantly. As a result, not much is being done in terms of preparing for that future from the design perspective.
- Some agencies 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 then 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.
- Most other 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 (e.g., Ontario, countries in Europe) to learn from their experience.
- Electrification of rest areas for commercial vehicle operations is an area of focus for at least one agency.
- Several agencies note that they have engaged in pilot projects focused on technological deployment. One example is the use of drones to support maintenance inspections.

6.9 Level of readiness for an era of fully diffused disruptive technologies

Participants were asked what they thought would be their agency's readiness level when full diffusion of CAV and smart city technologies are here. The available options ranged from 1 to 4 as follows: (1) definitely not prepared; (2) somewhat unprepared; (3) somewhat prepared; and (4) definitely prepared.

The average level of readiness identified by highway agencies was 2 (somewhat unprepared).

6.10 Canada as a leader in HQP development for a disruptive technology world

The following ideas were offered by these agencies:

- The federal government needs to lead the way regarding initiatives that advance HQP development in this field, whether it is a center of excellence or training programs or other.
- There needs to be consensus across the country regarding the importance of this issue and then, everyone needs to start working together to ensure that everyone focuses on this as a priority. Development of national-level goals and standards will be needed.
- 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.
- The federal government, through Transport Canada, could issue an annual or semi-annual report card on the deployment of transportation technologies.
- Provinces recognize that TAC can play an important role in this transition, especially through the Workforce Development Council, the CAV Task Force, and the Academic Roundtable.