AVIN SPECIALIZED REPORTS

JANUARY 2020

WORKFORCE SKILLS AND TALENT FOR THE FUTURE MOBILITY ERA

Realizing Needs and Filling Gaps

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INTRODUCTION

The automotive and mobility industry has been experiencing one of its most significant transformations with the development of smart vehicles and innovative mobility services. In previous AVIN specialized reports, we have discussed how connected vehicles are able to bring broad service opportunities beyond transportation[1], and how autonomous vehicles are anticipated to transform the future of transportation and other vital sectors[2].

To be able to capitalize on all of the opportunities that this mobility revolution presents, new approaches to developing the future skills and talent are also needed.

Indeed, the worldwide job search engine reported in 2018 that searches for future mobility terms such as "autonomous vehicle" and "self-driving vehicle" had grown by 668% since 2015[3]. According to the recruitment firm ZipRecruiter, the number of job postings in the autonomous driving sector has increased by 27% year on year, with a 250% jump in the second quarter of 2018, compared to the same time in 2017[4].

" The industry is going to need an army of people to develop these autonomous systems[5] "

Dr. Graeme Smith, Senior VP of Oxbotica[6]

[1] **The Autonomous Vehicle Innovation Network. (2019). Opportunities for Connected Vehicles Beyond Transportation. Retrieved from** https://tinyurl.com/s8g6vq3

[2] **The Autonomous Vehicle Innovation Network. (2019). Autonomous Vehicles Reshaping the Future: Cross-Sector Opportunities and Considerations. Retrieved from** https://tinyurl.com/s5kurog

[3] **Indeed. (2018). Which Hiring Trends are Steering the Future of Self-Driving Vehicles? Retrieved from** http://blog.indeed.com/2018/10/11/autonomous-vehicles-hiring-trends/

[4] **ZipRecruiter. This is Who's Driving the Autonomous Car Revolution. Retrieved from** https://www.ziprecruiter.com/blog/this-is-whos-driving-the-autonomous-car-revolution/

[5] **Gray, R. (2018). Driving your career towards a booming sector. Retrieved from** https://www.bbc.com/worklife/article/20181029-driving-your-career-towards-a-boom-sector

[6] Oxbotica is a leading autonomous driving software company in the UK, founded in 2014 by a group of Oxford professors.

In addition to highlighting the booming demand for and high interest in future mobility roles, Indeed reported that, according to an analysis of job posts and data from recruiters, individuals interested in working in this rapidly evolving sector need to equip themselves with advanced skills. For example, most of the top skills listed in autonomous vehicle job postings are related to computer programming and artificial intelligence.

Despite the high interest of job searchers in automotive and mobility-related careers, companies and recruiters find it very challenging to acquire and retain qualified talent that possesses the specialized skill sets required for new mobility technologies[7]. This is attributed to an overall shortage in workers with digital skills, and, most importantly, to the advanced and broad combination of skill sets needed to develop the automotive and mobility technologies of the future.

As the automotive industry transforms, it is critical that Ontario has a workforce capable of developing new mobility technologies. In this report, we focus on delineating the workforce skills needed in the future mobility era as well as tactical solutions to fill the talent gaps. We cover the different science, technology, engineering and mathematics (STEM) skills needed for connected and autonomous vehicle (CAV) technologies as well as general skills needed for most industries including automotive and mobility. We also highlight the challenges leading to automotive and mobility talent gaps, and how companies, education and training providers, and governments can work collaboratively to fill these gaps. Although it is unclear when CAVs will be widespread, we strongly believe that tackling our automotive and mobility workforce talent gaps should start immediately in order to propel industry advancements and reap the benefits of these technologies and solutions.

[7] **Silver, D. (2018). Limited talent pool is standing in the way of driverless cars. Retrieved from** https://thenextweb.com/contributors/2018/01/20/limited-talent-pool-standing-way-driverless-cars/

SKILL SETS AND TALENT

TECHNOLOGY SKILLS

As emphasized by many job search engines, advanced technology skills are in high demand by automotive and mobility companies. This is mainly driven by the fact that future vehicles will no longer be mechanical engines operated by humans. They will be transformed into a system of automated systems controlled by in-vehicle computers. This advanced technology focus calls for a unique combination of different technology-related skills, described below, to support the development of these automated systems.

> **" Generally speaking, it's not enough to be just a programmer or an engineer. You might be hired to write the code or design the hardware, but they expect you to be able to understand the big picture[8]. "**

Dr. John M. Dolan, Principal Systems Scientist, Carnegie Mellon University

[8] **Waters, J. (2019). How to Prepare Students for Jobs in the Self-Driving-Car-Industry. Retrieved from** https://www.edsurge.com/news/2019-02-28-how-to-prepare-students-for-jobs-in-the-self-driving-car-industry

Computer Science

Programming

Autonomous driving is enabled by hundreds of millions of lines of code running in the vehicle systems to allow continuous perception of the surroundings and control of the vehicle operation. There are around 250 million lines of code in a today's autonomous vehicle, and this number is expected to increase as the vehicle becomes increasingly autonomous, connected, and electrified[9]. Beyond vehicle operations, systems used to design and manufacture these sophisticated vehicles are also heavily reliant on various programs made up of extensive segments of code.

This critical dependency on lines of code brings programming to the forefront when discussing the skills needed for developing the future mobility technologies. This was echoed by Indeed's analytics team who found that most of the top skills listed in autonomous vehicle job postings are related to programming[3]. The Indeed team identified the C++ and Python programming languages as the top coding skills required when it comes to working in the autonomous vehicle segment of the industry.

C++ is commonly used to program the hardware systems of autonomous vehicles. It is widely popular due to its efficiency and high performance in terms of speed and memory manipulation, which are two major considerations when dealing with real-time systems such as those operating in autonomous vehicles. Although C++ is known for its efficiency, learning only the language syntax is not enough. Top C++ developers usually emphasize that poorly written C++ code can perform worse than

[9] **NXP. (2017). Cars are made of code. Retrieved from** https://blog.nxp.com/automotive/cars-are-made-of-code

a well-written code in a less-efficient language. Therefore, learning **code optimization techniques** is essential to achieve the desired high-performance operations[10].

Python has also become very popular in developing autonomous vehicle technologies due to the availability of a considerable number of easy-to-use python libraries[11,12] for mathematics, data manipulation and visualization, machine learning, and computer vision. All of these areas are essential in the development of autonomous vehicles, as will be discussed later in this section.

It is worth mentioning that programming is at the heart of other technology-related skills. For example, as highlighted above, to develop machine learning (ML) models, ML scientists will have to code these models and likely build on the popular ML python libraries. Embedded systems[13] engineering is also mostly based on programming and debugging[14] the systems that are being developed.

Knowledge of programming basics is also an asset for anyone looking to work on autonomous vehicles, even if they are not working directly on the software side of the technology. Since vehicle components are so closely interconnected, having a complete picture of how the vehicle operates is important for designing underlying components that efficiently interact with one another.

Artificial Intelligence

Artificial intelligence (AI) is the foundation of autonomous vehicles and a paramount skill for talent working in this area. AI is commonly used so machines can perform tasks that humans perform. In the context of autonomous driving, AI is necessary to replicate human senses and reaction in order to allow vehicles to be driverless.

The prominent side of AI is the **machine learning** (ML) sub-field. Utilizing streams

[10] **Morales, M. (2017). But, Self-Driving Car Engineers don't need to know C/C++, right? Retrieved from** https://medium.com/@mimoralea/but-self-driving-car-engineers-dont-need-to-know-c-c-right-3230725a7542
[11] **scikit-learn: Machine Learning in Python. Retrieved from** https://scikit-learn.org/stable/
[12] **Open Source Computer Vision. OpenCV-Python Tutorials. Retrieved from** https://docs.opencv.org/master/index.html

[13] An embedded system is a microcontroller- or microprocessor-based system that is designed to perform a specific task, and usually has constrained computing resources. For example, the vehicle airbag system is an embedded system that is only responsible for controlling airbags.
[14] Debugging is the process of code troubleshooting to find out syntax and semantic bugs (i.e., errors).

of data continuously collected from on-board sensors and communication technologies, ML scientists develop models that perceive vehicle surroundings and make informed driving and control decisions accordingly. For a vehicle to be reliably autonomous, an extensive amount of training, testing, and validation must be completed for the deployed ML models to ensure they make the right decisions in every possible driving scenario. As mentioned earlier, many ML models are developed and freely offered as code libraries. Although it is possible to build on these libraries instead of developing models from scratch, ML talent is required to fundamentally understand the core of ML methods and concepts to be able to interpret the results of the models they develop and optimize their performance and accuracy.

Deep learning (DL) is a sub-class of machine learning based on artificial neural networks[15]. It is currently, and anticipated to continue to be, the most popular ML technique for autonomous driving systems. Deep learning dates back to 1986; however, it was popularized only a few years ago, facilitated by the availability of a myriad of data and advances in machine capacities and speeds. Given its popularity and superior performance, DL is one of the most sought-after skills when it comes to talent for autonomous driving workforce.

AI is also popularly used in automotive **human-machine interface** (HMI). It efficiently handles tasks such as speech and gesture recognition, driver monitoring, and virtual assistance. With the advances in HMI continuing to grow, the demand of AI talent in this area is anticipated to escalate[16].

Computer Vision

Computer vision is a sub-field of computer science that aims at making machines see and process images and videos the same way humans do. Computer vision is a major factor in autonomous driving, facilitated by the use of cameras, LiDAR, and radars. Skills in computer vision are necessary to develop critical functions such as object detection, classification, and tracking in very high precision.

[15] **Josh. (2015). Everything You Need to Know About Artificial Neural Networks. Retrieved from** https://medium.com/technology-invention-and-more/everything-you-need-to-know-about-artificial-neural-networks-57fac18245a1

[16] **Gadam, S. (2018). Artificial Intelligence and Autonomous Vehicles. Retrieved from** https://medium.com/datadriveninvestor/artificial-intelligence-and-autonomous-vehicles-ae877feb6cd2

Computer vision closely relates to AI since it mimics human vision. One of the major uses of deep learning in autonomous driving is for computer vision. It is for that reason that some people consider it a sub-field of AI. However, this assumption is not inclusively precise since computer vision also encompasses techniques used for **image and video processing**. In reality, it is a challenging task to enable machines to identify objects in images. To facilitate this task, image processing skills are needed to apply image manipulation and transformation techniques to the collected images, to be able to clearly extract object features from them. Examples of image and video processing techniques include camera calibration and distortion correction[17].

Data Analytics and Management

Connected and autonomous vehicles generate and process massive amounts of data. According to Intel[18], a CAV acquires around 4 terabytes of real-time data per day through its on-board sensors. This is equivalent to the data generated daily by almost 3,000 people. This data is analyzed and used for decision making and automation. Access to and dependency on large amounts of data bring data analytics and management to the top skills needed for future mobility talent.

With regards to **data science** skills, there is a growing need for data scientists and analysts who can design better data compilation, visualization, and analysis algorithms that can efficiently handle the vast amounts of data produced and collected by CAVs. Experience and proficiency with **big data analytics** is a considerable asset, and in some cases a requirement, for data analytics talent working on these smart automotive systems.

Having to deal with this massive amount of CAV data is also a major challenge for **data management and storage** in CAV developments and operations. Skills in these areas are substantially needed to build and manage high-performing and scalable data storage infrastructure to process and maintain data as required. This also entails an understanding of **edge**

[17] **The MathWorks, Inc. What Is Camera Calibration? Retrieved from** https://www.mathworks.com/help/vision/ug/camera-calibration.html

[18] **Krzanich, B. (2016). Data is the New Oil in the Future of Automated Driving. Retrieved from** https://newsroom.intel.com/editorials/krzanich-the-future-of-automated-driving/

and cloud computing concepts and techniques[19] as popular bases for providing this infrastructure.

Cybersecurity and Privacy

Due to the critical nature of most of the CAV applications, **cybersecurity** for automotive systems is needed to protect vehicular data and systems from cyberattacks. The different players of the CAV ecosystem, including researchers, technology providers, original equipment manufacturers (OEMs), standards organizations, and policy makers, are all bringing cybersecurity to the headlines due to the critical impact cybersecurity threats can have on the safety, privacy, and convenience of all road users. In this regard, skills and expertise in cybersecurity are notably in demand. Talent in this area is needed to investigate the hardware and software vulnerabilities of CAV systems, and to develop cybersecurity best practices and standards to fix these vulnerabilities and protect the CAV data and systems in materially different ways.

When dealing with data from personal devices such as vehicles, **privacy** is pivotal. CAV data may reveal personal information of the drivers and/or owners of these CAVs, which may result in legitimate concerns from users of these vehicles. To avoid facing data privacy issues, OEMs and automotive technology providers require talent with expertise in protecting data from breaches. These experts should be able to develop efficient data privacy solutions that ensure deidentification of personal traits in all data collected from CAVs, unless legal consent is obtained from their users.

Mapping, Localization, and Path Planning

Localization is a vital part of any autonomous vehicle, and it refers to the ability of the vehicle to accurately find and keep track of its current location. Localization is traditionally done through a global navigation satellite system (GNSS), with a marginal error of 1 to 10 meters. Although with conventional vehicles this margin of error can be acceptable, such an error range can lead to fatal consequences in autonomous vehicles (AVs). For safe operation, AVs require localization accuracy at the centimeter level. Such

[19] **Gyarmathy, K. (2019). Edge Computing vs. Cloud Computing: What You Need to Know. Retrieved from** https://www.vxchnge.com/blog/edge-computing-vs-cloud-computing

a need calls for skills and expertise in localization techniques to develop solutions for this challenge. These skills include a deep understanding of GNSS, Inertial Measurement Units (IMUs), LiDAR, radar, and cameras, along with algorithms such as Kalman Filters and Particle Filters[20]. Such a diversified knowledge base is required to develop solutions that can combine measurements from different units to achieve the desired accuracy.

High-Definition (HD) Mapping is an emerging technology area in autonomous vehicle developments. To augment safety, the ability for perception and awareness of the local driving environment, including traffic signs and road infrastructure, beyond sensor visibility is an integral piece for AVs. This detailed type of mapping for AVs allows high-precision localization, enhanced environment perception, and improved planning and decision making. In that regard, many OEMs and mobility companies have started to acquire and invest in talent for building very detailed maps known as “HD maps.” Many new companies have been established and are joining the market for HD mapping[21]. The growth of these companies in the industry has resulted in a high demand for skills related to building HD mapping technologies and integrating them with autonomous driving technologies.

Path Planning technologies for vehicle navigation are not new; however, the advances in localization and mapping technologies have called for advanced skills in this area. In addition to knowledge of common path-finding algorithms, skills are also needed to utilize high-precision localization and mapping technologies for building a real-time path that can locally and dynamically maximize the distance between a vehicle and its surroundings, while abiding by the road infrastructure and traffic rules[22].

Sensor Fusion

CAVs are equipped with many different sensors with a variety of capabilities[23]. These sensors complement one another to achieve critical missions for AVs. To

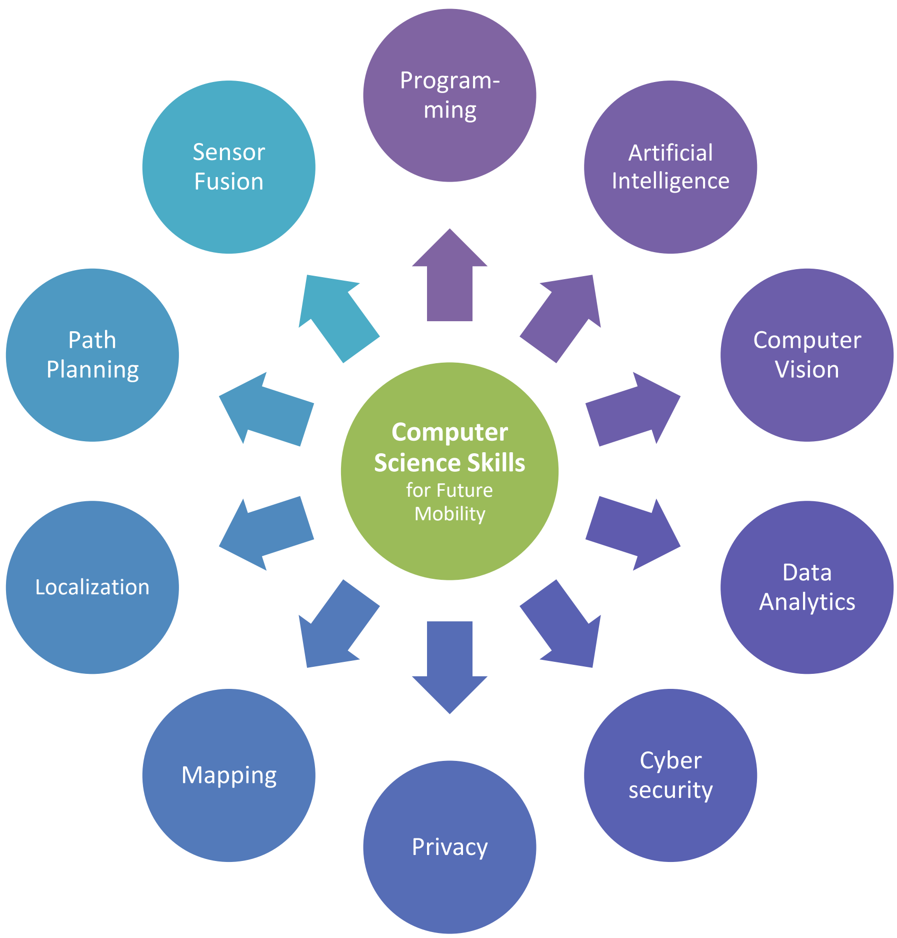
[20] **Cohen, J. (2018). Self-Driving Cars & Localization. Retrieved from** https://towardsdatascience.com/self-driving-car-localization-f800d4d8da49

[21] **Matthews, K. (2019). What are HD maps, and how will they get us closer to autonomous cars? Retrieved from** https://iot.eetimes.com/what-are-hd-maps-and-how-will-they-get-us-closer-to-autonomous-cars/

[22] **Ryabchuk, P. (2018). How Does Path Planning for Autonomous Vehicles Work? Retrieved from** https://dzone.com/articles/how-does-path-planning-for-autonomous-vehicles-wor

[23] **Abdelhamid, S.; Hassanein, H.; Takahara, G. (2014). Vehicle as a Mobile Sensor. Retrieved from** https://www.sciencedirect.com/science/article/pii/S1877050914008801

increase sensing accuracy and reliability, sensory data from these multiple sensors is combined. This is known as sensor fusion. Skills in this area are in high demand due to the great benefits sensor fusion techniques can achieve in critical functionalities such as perception and localization, through their ability to reduce uncertainty and improve measurement accuracy[24].



[24] **Intellias. (2018). How Sensor Fusion for Autonomous Cars Helps Avoid Deaths on the Road. Retrieved from** https://www.intellias.com/sensor-fusion-autonomous-cars-helps-avoid-deaths-road/

Engineering

Engineering has always been essential to the development of automotive technologies, and this will not change. OEMs and automotive technology companies will continue to rely on engineers to design, test, and validate reliable and efficient automotive systems. The need for engineers is not only critical for vehicle development. The physical and digital infrastructure needed to facilitate the operation of such vehicles is another prominent area where engineering expertise is highly sought after. As autonomous and connected vehicles become more prevalent, the need for efficient and well-designed road infrastructure will become indispensable.

Although autonomous vehicles are more advanced than the conventional ones driven today, they are still vehicles at the core. Consequently, most of the engineering-related skills that have always been needed for vehicle design and manufacturing will still be needed in the future of automotive and mobility. **Electrical**, **industrial**, **mechanical**, and **systems engineering** skills will always be in demand. However, as vehicles and automotive systems become more complex and digitized, other engineering specializations will become more prominent and sophisticated. We shed light on these vital specializations below.

Manufacturing and Production

According to a study[25] by a team of research scholars, many of the interviewed experts anticipated an increase in demand for manufacturing and production engineers. This was attributed to the increased complexity of vehicles and the additional components required for autonomous vehicle production, which would require a larger manufacturing and production workforce.

[25] **The American Center for Mobility. (2018). Preparing the Workforce for Automated Vehicles. Retrieved from** https://comartsci.msu.edu/sites/default/files/documents/MSU-TTI-Preparing-Workforce-for-AVs-and-Truck-Platooning-Reports%20.pdf

As mentioned earlier, engineering expertise for future mobility is not only required for vehicle development, but also for infrastructure building and management. Development of equipment needed for constructing, enhancing, and managing this infrastructure is anticipated to also increase the demand for manufacturing and production engineers.

Software

Demand for software engineering talent will considerably grow as a consequence of the increased focus on developing connected and autonomous vehicles. These smart vehicles are comprised of software systems that will continue to depend on critical software engineering expertise as the technology continues to evolve and grow in complexity.

Compared to traditional software engineering talent, the level of talent needed for developing autonomous vehicle software systems is much more advanced. This is due to the fact that in autonomous vehicles, many software systems of different types and specifications are needed, and they are required to interact with one another in a seamless, precise, and reliable manner. Speed and complexity constraints also have to be carefully taken into account in such real-time software systems. Furthermore, the different sources of software errors in autonomous vehicles (sensors, processors, networks, etc.) must all be considered in designing, testing, and integrating software systems for these vehicles, with the aim of avoiding software crashes and keeping autonomy disengagements (i.e., switching to a human driver to take the wheel) to a minimum.

Robotics

Autonomous vehicles are considered mobile robots programmed to do specific tasks in real-time situations. Accordingly, robotics engineering talent is needed for developing these vehicles. Robotics engineers work on both hardware and software systems, and require a combined skill set of electrical, systems, mechanical, and software engineering, along with a deep understanding of motion kinematics[26] and dynamics[27,28]. The speed, real-time, and strict safety constraints of AVs bring

[26] Kinematics describe the motion of points, objects, and systems without considering the forces of their motion. A kinematics model uses the geometry of the system and the initial conditions of its known parts to define position and/or acceleration information of unknown parts of the system.

[27] Dynamics is a branch of mechanics focuses on the study of forces and their effects on motion.

[28] **Park, F. C. and Lynch K. M. (2016). Introduction to Robotics: Mechanics, Planning, and Control. Retrieved from** http://hades.mech.northwestern.edu/images/2/2a/Park-lynch.pdf

demands for superior robotics engineering talent, compared to the talent needed for environment- and situation-restricted robotics.

Designing efficient **motion planning** models is a critical skill that a robotics engineer should have. It requires an understanding of mapping, localization, state estimation[29], and path planning to be able to utilize the output of these modules for creating a motion planning model. This model is essential for producing real-time speed and turning commands sent to the vehicle controllers to navigate the vehicle safely while abiding by traffic laws.

Signal Processing

Signal processing is a branch of electrical engineering concerned with understanding electrical signals and transforming them into digital data streams. It is also commonly used for reducing signal noise and distortion. Since autonomous vehicles heavily depend on the use of sensors that generate measurement signals in a high frequency, mastering signal processing is paramount for engineering talent working on developing these vehicles. Advanced signal processing algorithms need to be developed to reliably and accurately process the signals of the on-board sensors in real-time. These processed signals are subsequently fed into the in-vehicle systems for corresponding operations and actions.

Telecommunication

In-vehicle communication is a critical element of every current and future vehicle. In-vehicle systems use wired communication networks to exchange data and commands internally to control the vehicle operation. With the added complexity of additional connectivity requirements in future vehicles, telecommunication engineering skills will become more vital, demanding specialized and top talent.

The need for mastering telecommunication engineering skills is not only necessary for developing in-vehicle communication networks. Connected vehicles are currently creating a shift in mobility and will expand as a major part of the future of the sector. Working on the external connectivity elements of these vehicles requires a solid understanding and knowledge of the inter-vehicle communication technologies and

[29] State estimation refers to typically estimating the vehicle state as a combination of position, linear velocity, orientation and angular velocity.

standards, including Dedicated Short-Range Communication (DSRC) and Cellular Vehicle-to-Everything (C-V2X).

Safety Engineering

With the commencement of AV developments in the automotive sector, safety engineering has become high in demand. Most OEMs and technology companies working on AV technologies have been actively hiring safety engineers. Demand for this talent is anticipated to increase along with the rise and expansion of AV developments.

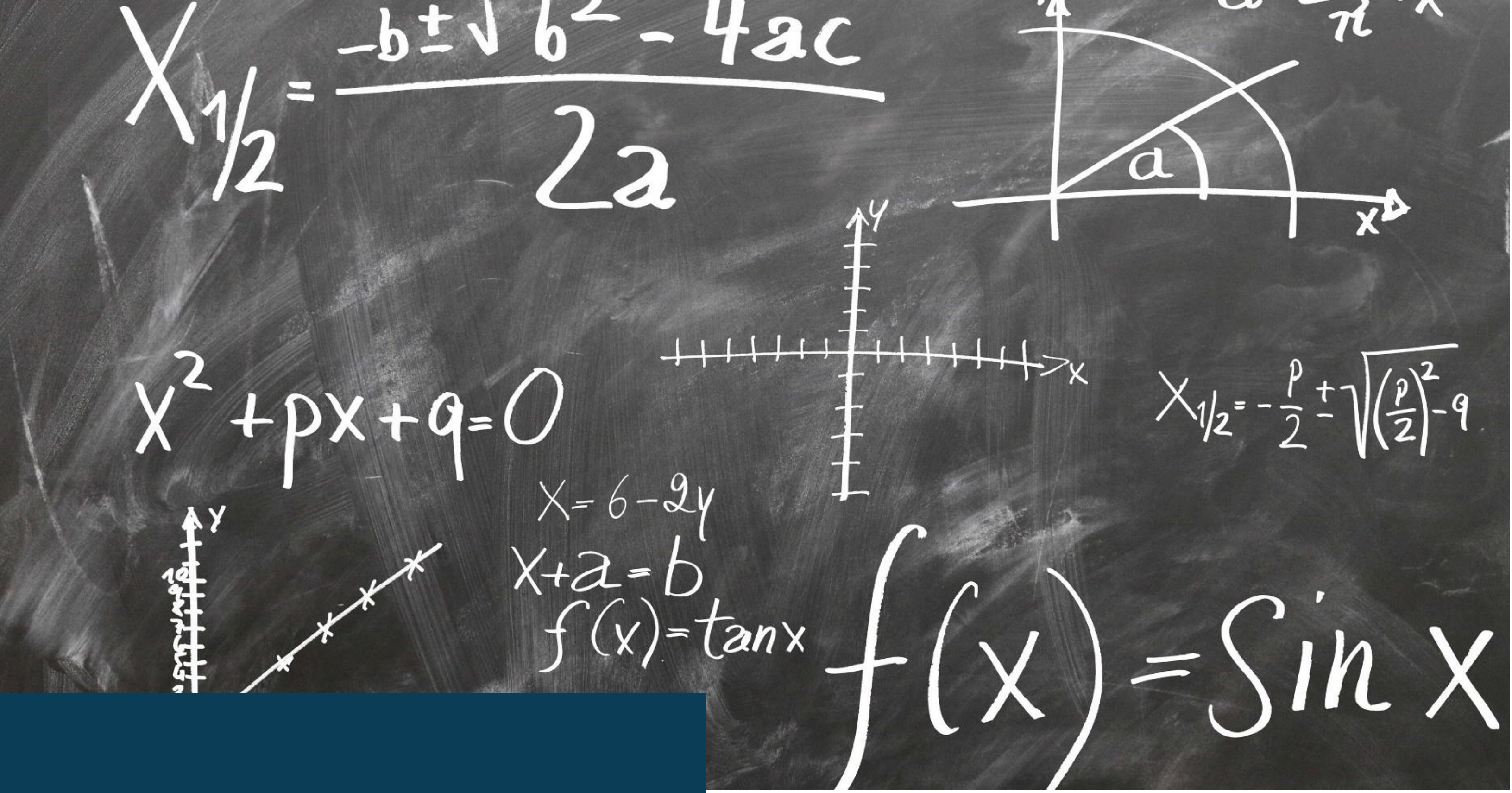
In non-autonomous vehicles, safety is assumed to be achieved when the vehicle correctly follows the control commands of human drivers. This same assumption is not valid with autonomous vehicles. Safety engineering measures for AVs have to consider the decision-making systems and validate their corresponding perception of the environment[30]. This adds complexity to the process and calls for safety engineering talent with advanced skills in functional safety, which include identifying and analyzing safety hazards and failure modes, creating safety measures, and developing functional safety requirements, cases, and processes.

Repair and Maintenance

Although the adoption of autonomous vehicles is anticipated to reduce vehicle repairs needed due to road collisions, the complexity of developing and operating these vehicles entails an increase in demand for specialized repair and maintenance **mechanics** and **technicians**. According to an analysis by the Boston Consulting Group[31], automotive companies in the US will need 10,000 more mechanics by 2028. This talent will need to acquire enough knowledge of AV technologies in order to be able to calibrate sensors, repair and test AV equipment, and perform related maintenance tasks. Thanks to remote connectivity on-board, it is anticipated that connected and autonomous vehicles will also boost demand for technicians that can perform remote diagnostics and maintenance.

[30] **Adler, R.; Feth, P.; Schneider, D. (2016). Safety Engineering for Autonomous Vehicles. Retrieved from** https://ieeexplore.ieee.org/document/7575374

[31] **Boston Consulting Group. (2019). The US Mobility Industry's Great Talent Hunt. Retrieved from** https://tinyurl.com/wyqywuk



MATHEMATICS SKILLS

Mathematics skills are at the core of most of the previously discussed technology skills. They are usually a prerequisite for mastering these technology skills and must-have when it comes to working in the autonomous vehicle industry. Below, we discuss the most prominent mathematics skills needed in the future automotive and mobility industry.

Linear Algebra

This is the top fundamental mathematics skill that talent interested in the industry should learn and have a deep understanding of. Familiarity with vectors and matrices and how to perform operations on them is mandatory to understand and develop machine learning algorithms[32]. Even if ML scientists can use libraries to develop ML models instead of coding them from scratch, they need an in-depth understanding of how these models work in order to be able to build on and optimize them. Strong knowledge of linear algebra also significantly affects how efficient an individual's computer science and engineering skills are. Understanding

[32] **Ritchie Ng. Linear Algebra for Machine Learning. Retrieved from** https://www.ritchieng.com/linear-algebra-machine-learning/

of linear algebra is also a necessity to master image processing skills, since images and operations performed on them are usually handled in the form of vectors and matrices.

Calculus

The understanding of differential equations, derivatives, integrals, and gradients is essential for understanding and building upon many popular ML algorithms and data science techniques[33]. Furthermore, mastering calculus helps understand optimization techniques. This is considered a major asset for the design of efficient and fast solutions.

Probability and Statistics

Knowledge of statistics concepts and methods is essential for working in any machine learning- or data science-related job. It helps drive observations from the data in hand and characterize the confidence of predictions[25]. This is very important when it comes to mobility data analysis and decision making.

With uncertainty in the behavior of vehicles and their surroundings, using probability is the only way automated systems can make decisions. Using collected data and reasoning algorithms, AVs calculate the probability of encountered scenarios, and make decisions accordingly[34].

Optimization Methods

Deep understanding of optimizers and optimization methods is a key qualification in hiring talent for automotive and mobility jobs that deal with the development of algorithms and models. Optimizing the performance of these developed solutions is a major objective, especially for autonomous vehicle operations that require optimal precision and decision making.

Geometry

Knowledge of geometry is considered an asset in the area of autonomous mobility. It helps improve computer vision techniques, design better motion planning and control models, and develop more accurate localization algorithms.

[33] **Malik, F. Calculus — Multivariate Calculus and Machine Learning. Retrieved from** https://medium.com/fintechexplained/calculus-multivariate-calculus-and-machine-learning-242b9efcb41c

[34] **Davey, T. (2017). How Self-Driving Cars Use Probability. Retrieved from** https://futureoflife.org/2017/03/13/self-driving-cars-probability/

GENERAL SKILLS

Aside from the specialized and unique skills discussed earlier, there are some general skills that are considered essential and common to most industries, including automotive and mobility.

Research Skills

In order to solve arising problems and introduce innovative solutions, research skills are must-have, especially in technology-related industries. In the automotive and mobility industry, **scientific research** is a major element of technology development. Most post-secondary institutions as well as companies in the sector are actively building research groups and labs to answer research questions, identify problems, and introduce innovative solutions and approaches. In the context of connected and autonomous vehicles, scientific research skills have been extensively called for to solve pressing challenges such as vehicle perception and localization, and to improve the performance of algorithms and techniques used in all technology areas.

Strategy and Policy Skills

Strategic thinking along with **strategy formulation and implementation** skills are fundamental assets for any organization in order to be able to differentiate itself, gain competitive advantage, and successfully sustain itself in a competitive market. This is particularly applicable to automotive and mobility companies that face the challenge of having to reinvent business and operating models in a rapidly evolving industry. Strategic agility is also relevant to governments keen on taking a leadership position in the development and deployment of technologies in this sector.

Advancements in and deployment of CAVs are largely dependent on government policies and regulations. Therefore, strong **policy development and policy advisement** skills are also required to take a leadership position in this evolving space. An understanding of the major challenges and impacts relating to the future mobility, such as safety, cybersecurity, privacy, and economic opportunities, is valuable for policy makers and advisors to effectively base their policy decisions on thorough analysis, and in alignment with market and consumer needs.

Soft Skills

To succeed in any career, talent should have well developed soft skills. In the qualification requirements of their posted roles, companies all over the world place emphasis on soft skills due to the ample benefits these skills offer on employee achievements and performance outcomes. In addition to the most common soft skills that companies usually call for such as **communication**, **problem-solving**, and **leadership** skills, companies in the automotive and mobility industry have also started to stress the need for having **visionary and creative thinking** skills to help develop innovative solutions in this rapidly advancing industry. Because of this rapid pace of the technology evolution and the dynamicity of technology developments, companies also prefer to acquire talent that is **eager to learn and adapt** to new technologies quickly and flexibly[35].

[35] **FISITA. (2018). Mobility Engineer 2030. Retrieved from** https://www.fisita.com/documents/FISITA_White_Paper_Mobility_Engineer_2030.pdf

CHALLENGES

Organizations interested in acquiring and securing talent for the future mobility era face some serious challenges, which are leading to significant talent gaps. In this section, we discuss these challenges and highlight them to the key players in the ecosystem who are focused on managing these gaps.

1. Digital Skills Gap

Countries all over the world are suffering from a lack of talent with digital skills. In a 2018 CEO survey by PwC, 72 percent of Canadian CEOs reported that they were concerned about the availability of digital skills in their industries[36]. Through a survey of more than 1,400 businesses across the UK, the British Chambers of Commerce found that more than three-in-four businesses have been facing a shortage of digital skills in their workforce[37]. For digital industries such as the future automotive and mobility industry, this shortage of digital skills has repercussions for finding the talent to support and drive industry developments.

The problem is mainly a matter of supply and demand. Most industries are currently moving towards digitalization. This has significantly increased the demand for technical skills in almost every industry. In the context of automotive and mobility, the ecosystem is also markedly expanding, with many new start-ups entering the field. Many well-established automotive and mobility companies have been also expanding their operations to cope with the future mobility race and ensure viability of their businesses. This major expansion of the industry has contributed to the heightened demand for technical talent, and it is anticipated to continue as technologies continue to evolve. This demand is growing at a much faster rate than the supply of talent with the desired technical skills. According to a recent analysis of the US mobility industry by the Boston Consulting Group[31], they predict that 30,000 new computer-related positions will be required by automakers in the next ten years, and that this number will be about six times the number of graduates with relevant degrees.

[36] **PwC. (2018). What's on the minds of Canadian CEOs in 2018? Retrieved from** https://www.pwc.com/ca/en/ceo-survey/publications/pwc-ceo-survey-2018-canadian-insights-EN.pdf

[37] **The British Chambers of Commerce. (2017). BCC: Shortage of digital skills hampering business productivity and growth. Retrieved from** https://www.britishchambers.org.uk/news/2017/04/bcc-shortage-of-digital-skills-hampering-business-productivity-and-growth

Another cause for the digital skills gap is **the rapid pace of technological changes and the ever-changing private sector needs**. Some educational institutions fail to keep pace with these rapid developments, resulting in curriculums that lag behind the requirements of the technical industries. Due to the high dynamicity of technologies and technical skills required, some talent fails to stay up-to-date and adapt to these changes. As a result, their technical skills become obsolete and are not required by industries anymore.

2. Competing on Talent

The second challenge in acquiring the desired talent is that **many of the skills needed by the automotive and mobility industry are common with other technology-related industries**. As a result, in addition to the competition for talent within the mobility ecosystem, other tech-related industries compete heavily with companies in the automotive and mobility industry to attract and acquire talent with technical skills. For example, programming is at the core of many other industries such as desktop and mobile application development, web development, and video gaming. Artificial intelligence has also been gaining popularity in most industries, with AI benefits being identified for various applications. Policy and strategy makers and advisors are also needed in every single industry. Low supply compared to the high demand is fueling cross-industry competition, creating a major challenge for all industries in need of these skills.

3. Cross Functional Requirements

As a unique challenge for the autonomous driving industry and workforce, developments in this industry require an understanding of and expertise in multiple advanced technologies. As discussed in the previous section, **many of the needed skills are related to one another**. Unlike other types of engineering and technical talent, a successful self-driving car engineer needs to acquire a combination of multi-disciplinary skill sets that include automotive and system engineering, robotics, mathematics, machine learning, programming, and more.

This requirement for multi-disciplinary and cross-functional skills has been a priority in hiring self-driving car engineers to make sure that the acquired talent can understand the system as a whole and realize the impact of a developed solution on other parts of that critical system. Unfortunately, as it stands, very few people have these multi-disciplinary knowledge and cross-functional skills, and such a combination is above and beyond what is being taught in traditional academic curriculums that usually focus on one specific domain.

" In our business, talent is paramount. We need problem solvers who have different sets of software and system engineering skills[38]. "

Grant Courville, VP Products and Strategy, BlackBerry QNX

[38] **Invest in Ontario. Ontario's BlackBerry QNX moves into high gear. Retrieved from** https://www.investinontario.com/success-stories/ontarios-blackberry-qnx-moves-high-gear

FILLING TALENT GAPS

Addressing the future mobility talent gaps should be seen as **a collaborative mission** that automotive and mobility companies, educational institutions, and governments all need to continually work on. Actions need to be taken immediately, otherwise, the gaps will continue to widen, and serious consequences will hit the workforce. In addition to the actions and activities that would be taken to **attract** and **build** talent, efforts should also be made to **retain** this talent within the sector and capitalize on any investments made to acquire and develop it. These talent gaps should also be viewed as **an opportunity** for education and training providers to step in and offer customized programs that address the workforce needs and cover the skills outlined earlier.

Companies

Automotive and mobility companies should **support the development of the talent they require** by advocating for education and training geared towards these needs. They can collaborate with educational institutions on reforming/introducing academic curriculums that serve their needs, thereby guaranteeing a continuous stream of talent with the skills and knowledge needed by the industry. They can also help these institutions attract top students by offering scholarships, internships, and other hands-on academic-industry collaboration tools, in addition to sponsoring and awarding relevant competitions. As another way of attracting talent and filling jobs, students achieving certain high grades in programs offered by these institutions can be guaranteed a full-time job with one of their partner companies after graduation. Companies can also consider hosting and sponsoring events showcasing career opportunities, incentives, and success stories.

Meanwhile, companies should focus on **reskilling and upskilling their current workforce** to equip them with the skills needed for developments in the industry. This can happen by offering opportunities for apprenticeships to current employees with a demonstrated passion for learning and proven capabilities. Another option is to offer these employees a part-time workload to give them the time and flexibility to pursue external educational and training programs[31]. Offering employees specialized boot camps is another option to provide intensive training and new skills, with minimal business disruption.

As an example of such **industrial talent-training initiatives**, Audi is offering its employees education programs that run in partnership with the Technical University of Ingolstadt. According to Audi, as a result of these programs, in 2018, the company managed to more than double its employees working on electric drives compared to the previous year[39]. Another example is the initiative taken by Infosys to partner with the online learning platform Udacity to offer Infosys employees a re-skilling and training program on self-driving car engineering. The program, known as Udacity Connect, is a combined in-person and online training program that consists of twenty weeks of advanced courses and six-week apprenticeships where program participants work on solutions for Infosys clients[40].

Education Providers

As mentioned earlier, **educational institutions** should work closely with automotive and mobility companies to thoroughly understand their skill and talent needs and adopt requirements into existing or new curriculums. These collaborations should be a continuous effort to guarantee that the curriculums they offer are always up-to-date and addressing industry requirements as technologies evolve.

Realizing the need to adapt curriculums to technological advances, some academic institutions have started to offer programs and courses specialized in future mobility technologies. For example, Cranfield University has started to offer a master's degree in Connected and Autonomous Vehicle Engineering[41], that has been designed to meet the specific needs of the workforce of these technologies. The University of Virginia offers the course "Autonomous Racing", where students work in teams to build autonomous race cars, while learning the principles of perception, planning, and control for AVs. Another example is the autonomous vehicle course offered by the Jacobs School of Engineering at the University of California San Diego to both undergraduate and postgraduate

[39] **Audi AG. (2018). Skilled for the future. Retrieved from** https://www.audi.com/en/experience-audi/mobility-and-trends/working-world/skilled-for-the-future.html
[40] **Infosys. (2017). Driving into the future: Infosys and Udacity partner to invest in autonomous vehicle education. Retrieved from** https://www.infosys.com/insights/ai-automation/Pages/driving-into-the-future.aspx
[41] **Cranfield University. (2019). Connected and Autonomous Vehicle Engineering (Automotive) MSc. Retrieved from** https://www.cranfield.ac.uk/courses/taught/connected-and-autonomous-vehicle-engineering-automotive

students[42]. This course focuses on hands-on learning by building a small robotic car and training it to run autonomously. In May 2019, the Michigan Mobility Institute announced a partnership with Wayne State University's College of Engineering to develop an advanced mobility educational curriculum[43].

It is worth mentioning that learning and training initiatives to fill skill set gaps should be extended beyond post-secondary institutions to include **primary and secondary schools** as well. As outlined earlier in the skill set section, mathematics are baseline skills needed for gaining and improving other technology skills. Acquiring mathematics skills can start through math classes at primary and secondary schools, followed by advanced courses in post-secondary education. Robotic camps for kids and teens have also recently become popular and are proving very helpful to give these young learners preliminary hands-on skills in programming, electronics, and mechanics.

Traditional academic institutions are currently not the only channels for providing education and training. **Online learning platforms** such as Udacity, Coursera, edX, and Udemy are gaining popularity and interest from learners due to the flexible and affordable means of learning and the high-quality courses they provide. These online learning platforms usually offer certificates, rather than academic degrees, which are currently acknowledged and well-received by employers as a quick and affordable way to earn workforce skills. Udacity was among the first learning providers to realize the need for specialized curriculums and skill sets for the workforce in future mobility. As a result, Udacity has been offering **a Self-Driving Car Engineer nanodegree**[44], that is currently one of the very popular resources to gain the cross-functional skills called for by companies working on autonomous vehicle technologies. To make sure that the content is current with what the automotive and mobility industry needs, this nanodegree has been built in

[42] **UC San Diego. (2018). Undergraduate engineers get hands-on experience with autonomous vehicles. Retrieved from** https://ucsdnews.ucsd.edu/feature/undergraduate-engineers-get-hands-on-experience-with-autonomous-vehicles

[43] **Wayne State University. (2019). Wayne State University, Michigan Mobility Institute announce development of advanced mobility curriculum. Retrieved from** https://today.wayne.edu/news/2019/05/21/wayne-state-university-michigan-mobility-institute-announce-development-of-advanced-mobility-curriculum-32124

[44] **Udacity. (2019). Self-Driving Car Engineer Nanodegree. Retrieved from** https://www.udacity.com/course/self-driving-car-engineer-nanodegree--nd013

partnership with notable companies in the space, including Mercedes-Benz, BMW, and Uber ATG. Likewise, Coursera, in partnership with the University of Toronto, is offering **a Self-Driving Cars specialization**[45] that covers prominent topics such as state estimation, localization, visual perception, and motion planning. EdX, in partnership with the Chalmers University of Technology, is offering **a MicroMasters program in Emerging Automotive Technologies**[46]. Learners who successfully earn the MicroMasters program certificate can also apply to Chalmers' Master of Science in Automotive Engineering or in Systems, Control and Mechatronics. If accepted, students' completion of the MicroMasters program is accredited towards the completion of their master's degree.

Governments

Governments play a key role in supporting talent development. Through **education and awareness initiatives**, governments can draw citizens' attention to workforce needs and promote opportunities in advancing industries such as the future mobility industry.

Governments can take lead on initiatives that identify industry needs in terms of skills and talent through **connecting with companies** in their region and analyzing their needs. After identifying the skills in demand, governments can support companies to develop talent through using tactics such as **offering these companies grants and incentives** to develop upskilling and reskilling programs. Governments can also connect companies to collaborate on developing common talent development programs. An example of such government support is the Maryland's Employment Advancement Right Now (EARN) program[47]. EARN is an industry-led workforce development grant program that targets investing in strategic industry partnerships to address the workforce needs of companies. Once a partnership is formed, the involved partners collaborate on developing plans to train, educate, and help workers secure

[45] **University of Toronto. (2019). Self-Driving Cars Specialization. Retrieved from**
https://www.coursera.org/specializations/self-driving-cars

[46] **edX. (2019). MicroMasters Program in Emerging Automotive Technologies. Retrieved from**
https://www.edx.org/micromasters/chalmersx-emerging-automotive-technologies

[47] **Maryland Department of Labor. EARN Maryland: Industry-Led Partnerships. Retrieved from**
https://www.dllr.state.md.us/earn/

employment, supported by grants from the Maryland Department of Labor.

Another approach followed by governments for talent development is to provide financial support and incentives to companies to offer hands-on internship, fellowship, and apprenticeship programs to promising talent. An example of this approach is the program created by South Carolina to offer employers that sponsor apprentices a tax credit, assistance from consultants, and access to the state's technical colleges[48]. Another example is the Talent Development program offered by the Government of Ontario through its Autonomous Vehicle Innovation Network[49]. This program is actively funding internships and fellowships at Ontario companies to offer hands-on CAV training and expertise to Ontario students and recent graduates.

Governments can also **offer financial support directly to learners and professionals** interested in upskilling or reskilling, so they can access in-person and/or online learning programs. An example is the learning initiative "Next Technology Leaders (NTL)"[50] offered by the Government of Egypt to build talent in the latest electronic, artificial intelligence, telecommunication, and information technologies. The NTL initiative is lead by the Ministry of Communications and Information Technology, and offers the top-ranked Udacity, Coursera, and edX learning programs free of charge to qualified learners.

Governments can also **work as a link between companies and academic institutions** to identify talent gaps and collaborate on developing curriculums that fill these gaps. Governments can further support talent development at academic institutions through offering **research and development (R&D) grants** to hire and train students for R&D projects focusing on the industry needs. To further support acquiring and retaining talent, **governments can offer and facilitate immigration programs** to workers holding the workforce skills in demand.

[48] **SC Technical College System. Apprenticeship Carolina. Retrieved from** https://www.apprenticeshipcarolina.com/

[49] **Ontario's Autonomous Vehicle Innovation Network. Talent Development. Retrieved from** https://www.avinhub.ca/talent-development/

[50] **Technology Innovation and Entrepreneurship Center. (2016). Be the Next Technology Leader. Retrieved from** http://techleaders.eg/

HIGHLIGHTS FROM ONTARIO

UNIVERSITY OF TORONTO

The University of Toronto is one of the world's leading universities, with distinguished faculty and researchers working on advancing CAV technologies and developing relevant talent by offering specialized courses and hands-on experience to undergraduate and postgraduate students.
In addition to on-campus programs, in partnership with Coursera, professors from the **Faculty of Applied Science and Engineering** are offering one of the first online learning specializations in self-driving cars. Moreover, the **Department of Computer Science**'s Dr. Raquel Urtasun is actively leading developing and mentoring future mobility talent through her role as a Chief Scientist and the Head of Uber ATG Toronto.

UNIVERSITY OF WATERLOO

The University of Waterloo's **Centre for Automotive Research (WatCAR)** is actively contributing to the development of educational programs for automotive and transportation systems including connected and autonomous vehicles. Artificial intelligence expertise from the University of Waterloo's **Artificial Intelligence Institute** complements the autonomous driving skills and expertise.

VECTOR INSTITUTE

The Vector Institute is based in Toronto and is a joint initiative by the Government of Canada and the Government of Ontario to globally lead in the field of artificial intelligence. Partners and researchers of the Vector Institute are building on a well-established foundation of globally recognized Canadian talent. As a part of its offerings, the institute supports students interested in pursuing education in AI to **work with a Vector-affiliated faculty**. The institute is also in the early stages of **building its own academic programs**.

AUTONOMOUS VEHICLE INNOVATION NETWORK

The Autonomous Vehicle Innovation Network (AVIN) is the Government of Ontario's initiative to support and lead the development and deployment of CAV technologies in Ontario. As a part of AVIN programs, a **Talent Development** stream is actively funding internships and fellowships for Ontario students and recent graduates to receive hands-on CAV training and expertise. Moreover, AVIN is currently building **a roadmap for both short-term and long-term automotive and mobility talent development activities in Ontario**, in collaboration with Ontario's companies and educational institutions. This report is the first step towards building this roadmap by scanning the future mobility skill and talent needs, identifying gaps, and proposing preliminary solutions.

CONCLUSIONS

In this report, we have discussed the various skill sets needed for the future mobility workforce. The aim is to provide a view of the solutions and opportunities available to organizations interested in developing future mobility talent as well as to prospective talent interested in pursuing a career in this exciting industry. We have first delineated the technology skills that are at the core of the automotive and mobility skill sets. We then have shed light on the mathematics skills needed to successfully acquire these technology skills. Finally, we have touched upon some general skills that are essential in most industries, including automotive and mobility.

Recognizing the significant talent gaps in the future mobility workforce, we have also highlighted the major challenges and causes of these gaps. We strongly believe that if these talent challenges are not addressed in the short-term, serious workforce consequences and further shortages will grow as the automotive and mobility technologies continue to evolve.

Motivated by the immediate need to address these talent challenges, we have concluded the discussion with some solutions and recommendations to help address these challenges and fill the talent gaps. We have broken down these solutions to reflect the various efforts, initiatives, and best practices that are currently underway, and those that can be taken on by automotive and mobility companies, education and training providers, and governments. While each of these stakeholders could play a significant role in addressing the talent gaps individually, we strongly believe that the optimal solutions involve all stakeholders working in a collaborative manner.

Although the solutions and suggestions discussed in this report might not be the complete answer, they can be considered as starting points for collaborative efforts that need to begin sooner rather than later. More recommendations and clearer directions are expected to emerge down the road as the industry evolves and opportunities arise.

We also know that creating talent development solutions, such as education and training programs, dedicated for CAV skill sets takes time and a great deal of resources; however, the benefits and gains of developing and adopting these future mobility technologies are worthwhile. Research studies have shown that the interest and demand is there, and that the automotive and mobility companies have been already starving for talent with future mobility skills and expertise. What is required now is solutions to provide them with the supply of that talent. From a talent perspective, acquiring these future mobility skills may seem like a large commitment and demand of time; however, the abundant opportunities, knowledge, and skills acquired by working on these interesting and life-changing technologies are priceless. These new industries are also proving to be lucrative, and salaries are encouraging.

Ontario is in a strong leadership position when it comes to preparing and building the talent needed for future mobility developments, with its world-renowned educational institutions that have already taken considerable steps to move the dial on developing talent. Ontario is also strongly supported by top automotive and mobility companies that have been producing and acquiring top talent across the world. The Government of Ontario considers building future mobility talent among its top priorities and opportunities for growth. This has been clearly reflected in Ontario's focus and immediate action areas on talent development highlighted in its "Driving Prosperity: The Future of Ontario's Automotive Sector" plans and initiatives[51]. In support of the province's strategy for workforce development, Ontario's Ministry of Labour, Training and Skills Development is currently running the RapidSkills pilot[52] and Skills Catalyst Fund[53] seeking proposals that support developing workforce skills and delivering demand-focused solutions for labour market challenges.

[51] **Ontario's Ministry of Economic Development, Job Creation and Trade. (2019). Driving Prosperity: The Future of Ontario's Automotive Sector. Retrieved from**
https://tinyurl.com/vgao85g

[52] **Ontario's Ministry of Labour, Training and Skills Development. (2020). RapidSkills 2019-20. Retrieved from**
grants.gov.on.ca/GrantsPortal/en/OntarioGrants/GrantOpportunities/PRDR020023

[53] **Ontario's Ministry of Labour, Training and Skills Development. (2020). Skills Catalyst Fund 2019-20. Retrieved from**
https://www.grants.gov.on.ca/GrantsPortal/en/OntarioGrants/GrantOpportunities/PRDR017888

GLOSSARY OF TECHNICAL TERMS

Artificial Intelligence
A branch of computer science concerned with imitating human intelligence processes by machines.

Artificial Neural Networks
Computing units that loosely model the neurons in a biological brain.

Camera Calibration
Estimating the parameters of a camera lens and image sensor, which can be used to fix lens distortion or measure the size of an object.

Cloud Computing
The availability of computing resources over the Internet for use on-demand by remote users.

Computer Vision
A sub-field of computer science that aims at making machines see and process images and videos the same way humans do.

Deep Learning
A sub-class of artificial intelligence that uses multiple layers to extract features from input data and produce output accordingly.

Edge Computing
Bringing remote computing resources closer to the location where it is needed, mainly to have faster response times and saved bandwidth.

Embedded System
A microcontroller- or microprocessor-based system that is designed to perform a specific task, and usually has constrained computing resources.

Inertial Measurement Units	A device capable of measuring an object's force, angular rate, and orientation.
Kalman Filter	An algorithm to provide a prediction of a future system state based on past estimations.
LiDAR	LiDAR stands for Light Detection and Ranging, and it is a sensing technology that uses laser to identify objects and measure the distance to them.
Machine Learning	A sub-field of artificial intelligence concerned with developing systems that can learn from data and make decisions with minimal human intervention.
Motion Dynamics	A branch of mechanics focuses on the study of forces and their effects on motion.
Motion Kinematics	Describing the motion of points, objects, and systems without considering the forces of their motion.
Particle Filter	An algorithm used to estimate the states of dynamic systems when partial observations are made, and uncertainty is present in the systems.
Sensor Fusion	The process of combining sensory data from multiple sensors.
State Estimation	Estimating the vehicle state as a combination of position, linear velocity, orientation, and angular velocity.

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ABOUT AVIN

The **Autonomous Vehicle Innovation Network (AVIN)** initiative is funded by the Government of Ontario to support Ontario’s competitive advantage in the automotive sector and to reinforce its position as a North American leader in advanced automotive and mobility technologies, including transportation and infrastructure systems.

This initiative capitalizes on the economic potential of connected and autonomous vehicle (CAV) technologies by supporting the commercialization of best-in-class, made-in-Ontario solutions that create jobs, drive economic growth and enhance global competitiveness. AVIN also helps Ontario’s transportation systems and infrastructure adapt to these emerging technologies.

AREAS OF FOCUS

AVIN programs focus on supporting the development and demonstration of CAV technologies in light vehicles (e.g., cars, trucks and vans), heavy-duty vehicles (commercial vehicles, trucks, buses and RVs), transportation infrastructure, intelligent transportation systems (ITS) and transit-supportive systems.

AVIN is administered on behalf of the Government of Ontario by Ontario Centres of Excellence (OCE). The initiative comprises five distinct programs and a central hub. The AVIN programs are:

- AV Research and Development Partnership Fund
- WinterTech
- Talent Development
- Demonstration Zone
- Regional Technology Development Sites

The AVIN Central Hub is a dedicated team that supports delivery and administration of AVIN programming, and provides the following key functions:

- Connect & Coordinate - a focal point to help coordinate activities among industry, academia, research organizations and governments, and connect interested stakeholders and members of the public;
- Opportunity Identification - knowledge translation, research, data/information, trend analysis, and acting as a bridge between technology and policy; and
- Awareness & Education - promote AVIN programs and Ontario's AV testing pilot and build awareness of Ontario's growing CAV community.

AVIN has five Objectives:

We would like to thank the Government of Ontario for supporting AVIN programs and activities.

We would also like to thank the partner organizations that work with OCE to deliver AVIN programs, including the Regional Technology Development Sites and the Demonstration Zone.