

AUTONOMOUS VEHICLES | AND THE FUTURE OF WORK IN CANADA



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AUTONOMOUS VEHICLES AND THE FUTURE OF WORK IN CANADA

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Preface

ICTC's trusted labour market research provides critical economic and labour market insights to inform innovative workforce and skills solutions, as well as practical policy advice. Together, these drive the development of a more prosperous Canadian workforce and industries in a global digital economy.

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FOREWORD

We are entering the dawn of the Autonomous Vehicle age. Just as the emergence of the automobile shaped the development of many 20th century cities, AVs will have an outsized impact on the growth of 21st-century cities. While the advent of the car brought enormous benefits, it also created a now widely acknowledged set of challenges: growing road fatalities, air pollution, ever-increasing traffic, and cities dominated by roads and parking. This new wave of vehicles presents us with a chance to seize on the upsides of a new technology while learning from our past mistakes.

First among those benefits, autonomous vehicles present an unparalleled opportunity to improve the safety of driving. Last year alone there were more than 37,000 road fatalities in the US, and more than 1,800 in Canada. Over 90% of those crashes were caused by human error. Autonomous driving has the chance to dramatically reduce those numbers.

But just like traditional passenger cars, AVs will not inevitably produce positive outcomes. **Everything will depend on how technology is deployed.** We strongly believe that a positive vision of the future requires autonomous vehicles to be both shared and, ultimately, electric. Only by combining these three transportation revolutions of sharing, automation, and electrification can we maximize the societal benefits of new technology.

If we simply transition from individual car ownership to individual autonomous car ownership, a huge opportunity will be missed. Today, cars sit idle approximately 95% of the time. And during the infrequent times when they are driven, they usually only have one person on board. Combined, that means that only one to two percent of their potential capacity is being used on a given day. Ridesharing provides a mechanism to improve not only the utilization of the overall vehicle but also the seats within it (from 1 rider to potentially 4+ riders). By transitioning from individual car ownership to autonomous fleets that pool passengers, cities can move far more people with far fewer cars and dramatically reduce demand for parking and other privately-owned and driven vehicle infrastructure.

That could have a big impact on cities. With less congestion, people can spend less time sitting in traffic and productivity will go up; with less parking, cities can reclaim valuable real estate for civic priorities like affordable housing or green space. Increasing seat utilization also has the virtuous circle effect of further bringing down overall transportation cost, which increases access to underserved communities.

It is also critical to note the synergies between increasing vehicle sharing and automation and increasing vehicle electrification. Vehicles powered by fossil fuels can contribute up to 75% of a city's local air pollution and often more than 50% of its carbon footprint. As cities face both significant population growth and an expected 300% increase in the demand for mobility, transportation systems dominated by combustion power will become untenable. New, cleaner technologies must be built for the new era; that means all-electric engines to eliminate tailpipe emissions, and driving greater shares of renewable energy into the electricity grids to dramatically reduce total pollution. This will both improve the day-to-day quality of life within cities as well as ensure a more sustainable approach to transportation on a global scale.

The three separate technologies of shared mobility, automation, and electrification are mutually reinforcing. Autonomy will both reduce direct costs as well as increase utilization by enabling vehicles to be operating continuously. The higher the utilization rate, the more it makes economic sense to switch to high-efficiency electric technologies rather than stick with combustion engines and fossil fuels. The lower the operating cost of rides, the higher the demand for rides which enables more pooling of passengers. The successful convergence of these three innovations is vital to the future of AVs, and deploying AVs thoughtfully is vital to the future of cities.

We must also recognise the possible impacts on jobs and the workforce. Innovations through history have often displaced workers, but also raised productivity and created new jobs, reshaping the labor market. We cannot predict exactly what the future will hold, and we should not make presumptions about the potential impacts. For Uber's part, we believe that in the future we will have more drivers using our apps, not fewer - and demand for ridesharing will continue to grow as people give up their personal cars. We should take these questions seriously, and are committed to playing a role in the policy debates.

Autonomous Vehicles and the Future of Work in Canada is the first study that not only evaluates the benefit of autonomous vehicles and their road to implementation, but also explores the relationship between this crucial technology and the Canadian labour market. Through collaboration and interaction with industry, policymakers, automotive leaders, as well as academia, the report showcases both the challenges and the immense opportunities that the Canadian labour market can expect, as a result of AVs.

Uber

EXECUTIVE SUMMARY

Technological advancements have been changing and restructuring lives throughout the course of human history. From the dawn of the Industrial Revolution, technology has been impacting, shaping and recalibrating various aspects of our lives and our societies, while making us more resourceful, informed, and more resilient in the process. While just one example of this change, autonomous vehicles (AVs) use technological innovations including LIDAR, 5G and artificial intelligence to reinvent the way we think of mobility and driving. Possessing the capacity to steer economic growth around the world, AVs are estimated to be the driving force behind the demand for more than 34,000 high-quality jobs over the next five years in Canada. Needless to say, autonomous vehicles are primed to be one of the most anticipated innovations of our time.

This report provides a synopsis of the impending impacts that autonomous road-based passenger vehicles will have on Canada's economy and the job market. The report is the result of a combination of the most recent secondary data, covering topics like in-demand occupations, employment rates, wages and others; complimented with a thorough literature review of the most recent and relevant studies; as well as primary analysis gathered through interviews and advisory groups with leaders and experts in the field. This in-depth analysis of various data is necessary to build an accurate picture of this environment and its context for Canada. That said, autonomous technology is a rapidly evolving landscape, with new developments that take place everyday. The fast rate of change inherent to this field inevitably results in the need for more research, including a time-based analysis capturing the various evolving trends and potential gains that this landscape can offer the Canadian economy. Of course, while this technology will be key in ushering in the growth of high-quality jobs across the Canadian labour market, as with any technological change, displacement of other occupations remains a valid concern. Policy measures to address transitional workforce strategies from low to high growth occupations, as well as enabling an inclusive approach to leveraging all human capital in Canada including underrepresented groups will be key going forward.

Though autonomous vehicles are still in their early stages, their track record is impressive. Showing the possibility of more than halving the occurrence of severe accidents on the road today, autonomous vehicles are gearing up to offer superior safety features across our cities and communities, while simultaneously supporting the growth of green energy, connectivity and inclusivity.

With nearly 2,000 Canadians currently involved in fatal accidents each year, global emission levels that are failing to drop fast enough, and the challenges that many experience with mobility and access, the first fully autonomous vehicles – that is, requiring no human interaction – are expected to hit our streets by 2022.

Providing improved access to mobility, AVs offer bolstered opportunities for inclusivity and economic participation. With better access to economic centres and high-growth areas, underrepresented groups in Canada, including persons with disabilities, individuals living in rural or remote areas – such as Indigenous peoples often residing there – will see an increased ability to participate. With this inclusion, autonomous vehicles not only offer a much-needed service, but they effectively grow total employment in the Canadian economy. Supporting the growth of the Canadian labour force, through skill development programs, increased collaboration between industry and academia, and other suitable policy solutions, increases our potential as a nation to leverage the opportunities of this innovative development and shape a workforce that is able to flourish under disruptions that emerge at the intersection with this very technology.

One of these intersections are with smart cities and communities. Smart city and community growth exemplify the notion of using technology to improve social, economic and community outcomes; and many would argue that autonomous vehicles will only be able to function at full capacity within a “smart” environment. Under this environment, the concepts of mobility, connectivity and new concepts of urban design bring out the best in one other: smart cities and communities will drive autonomous vehicle capacity; and through smart mobility, autonomous vehicles will serve as an essential component of our future urban and rural areas.

It is estimated that by 2035, the global market for autonomous vehicles will reach \$77B. In Canada, recent developments paint a promising picture of our national potential for progress in this field, and our ability to carve our share of this market. In early 2016, GM committed to hiring a new batch of engineers to work on autonomous vehicles in Ontario. This announcement was echoed by similar commitments from policymakers, including the Ontario government, as well as other industry leaders like QNX and Ford – all pledging to support accelerated research in the field. Steadily growing, Canada saw its first autonomous vehicle testing out the streets of Ottawa in October 2017.

With developments like these, the growing demand for workers in Canada's connected and autonomous vehicle (CAV) industries should be no surprise - and these changes are happening quickly. At 213,300 workers in 2016, Canada's CAV industries are set to see a rise in employment that will total 248,000 workers by 2021. This represents a growth of 34,700 and a compound annual growth rate (CAGR) of more than 3%. That is more than double the average growth seen across the entire Canadian economy. The range of AV applications and their impacts on the economy and society are far reaching, and capitalizing on the potential opportunities offered by this rapidly evolving technological landscape will be pivotal for Canada in the coming years.

INTRODUCTION

Affecting nearly all components of daily life, technology is shifting the way we work and ultimately, how we live. As a result, technological advancements and digitization are quickly taking root in a variety of industries, and are increasingly becoming the lifeblood of many top-ranking economies around the world. In Canada alone, the ICT sector [1] has accounted for a 5.2% growth in GDP since 2007 [2], culminating in a total of value of \$72.3 billion - 4.3% of the national GDP - in 2016 [3].

Working to improve efficiency, create new solutions for societal problems, and expand the power of product effectiveness, technological advancements are a principal source of productivity and economic growth [4]. This connection is quickly becoming an uncontested reality, with productivity levels and the revenue generation of a company, or even nation, increasingly tied to technological adoption. Comparing growth in the early days of the Internet, one study found that the main contributing factor to the US' accelerated productivity increase during 1995-2006 was their heightened ability to implement and utilize innovative technologies and grow their knowledge economy [5]. Compare this to the EU, which saw a decline in productivity during the same period, largely due to their slow entrance into this realm. More than 10 years later, the same considerations not only still apply, but are even more pertinent. Today, the ability of companies to effectively leverage innovative technologies is a cornerstone requirement of their development, their ability to generate high-quality jobs, and their overall economic success.

Autonomous vehicles [6] are a key example of a quickly developing technological innovation, with the ability to create profound impacts on economic development, labour market needs and productivity, alike. Autonomous vehicles (AVs) and their role in our communities are quickly altering consumer perceptions, and reshaping public policy considerations and decisions. With reach ranging from topics like job creation, skill development and training initiatives, to city infrastructure demand, cybersecurity, and even future legislative changes, AVs are revamping, reshaping and redesigning societal needs.

Utilizing a variety of technological advancements including artificial intelligence (AI), 5G, telematics and more, autonomous vehicles are undoubtedly one of the most anticipated innovations of our time.

The evolution of AVs, along with their impact on our increasingly connected societies will inevitably demand the creation of new business models and strategies. In some cases, these new models will conflict with the business-as-usual approaches of traditional economies, including the growing economic output resultant of the commoditization of data. Canada's ability to both compete in the growing market for AVs, while leveraging the corresponding cross-sector growth associated with them is crucial. Doing so means focusing on our ability to understand, embrace and value the benefits and opportunities that AVs offer to our economy, to our communities, and ultimately, to our lives.

Divided into four sections, this paper will underline some of the key considerations relating to the advent of autonomous vehicles and their implementation in Canada and around the world. Based on a deep analysis of AV technology, its impacts, and its job-creating potential, this paper will offer relevant insight related to: industry needs, infrastructure considerations, consumer perception, changing skill requirements, future labour demand, and more. The report will be comprised of the following sections:

Section One - Autonomous Vehicles: A Market Overview: This section will showcase the progression of AVs, from initial development to their future prospects. Touching on the technological composition of AVs - such as AI, 5G, and other relevant components - this section will analyze the broader implications of AVs on everyday life. These include key issues like cybersecurity and data protection, safety, consumer perception, insurance and regulation.

Section Two - Smart Cities: Using Technology to Generate Societal Solutions: This section will analyze the role and capacity of autonomous vehicles in the development and evolution of smart cities. This includes: the technological considerations of smart cities, infrastructure changes and key infrastructural needs for AVs within smart cities, as well as an analysis of in-demand occupations. This occupational analysis will include a list of current-day occupations that will become more prevalent with smart city growth, as well as a conceptual analysis of new occupations - ones that do not exist today - that may emerge as a result of smart cities.

Section Three - Autonomous Vehicles: A Canadian Market Analysis: This section will focus on identifying and underlining in-demand roles, roles that will require upskilling, roles relevant to the creation of smart cities, and roles that will eventually be phased out. This section will provide insights on labour force composition, wages, employment growth and specific skill needs based on a forecast of Level 2-5 automation of AVs and an assessment of “risk” associated with each occupation.

Section Four - Recommendations: Utilizing insights gained in Sections One through Three, this section will focus on a call to action, providing recommendations for policymakers and industry in Canada based on identified gaps in AV development and deployment. If implemented, these recommendations will assist with the growth of AV technology in Canada, while simultaneously helping to ensure that Canada remains competitive in this ever-growing and expanding market.

SECTION ONE: AUTONOMOUS VEHICLES: A MARKET OVERVIEW

Technology, Growth and Innovation in Canada: A Brief Overview

Shaped by a conservative business climate when it comes to risk-taking and investment [7], historically, innovation - including the realm of autonomous vehicles - is an area where Canada has moved at an arguably slower pace than some of its international counterparts. However, recent developments, including the federal government's commitment to the growth of the digital economy, have signaled a turn of events in this space. With a clear emphasis on forging the pathway for an innovative future in Canada, these changes began to take shape in 2016. Here, the Federal Budget approved the disbursement of \$7.3 million over two years to support the development of a regulatory framework that is tasked with monitoring emerging transportation technologies, including autonomous vehicles. This year, the 2017 Federal Budget further recognized the importance of innovation in ensuring Canada's future economic growth, and launched the National Innovation Agenda. This Agenda was marked by several forward-looking initiatives, including an investment of \$950 million over five years towards innovation "superclusters" - the term referring to areas within cities or communities that display both a high concentration of academic strength and business growth. Of further particular relevance to autonomous vehicles, the 2017 Budget also committed \$76.7 million towards the modernization of Canada's transportation system, with a portion of this investment used to fund the development of "regulations for the safe adoption of connected and autonomous vehicles" [8].

These and other notable investments represent important first steps that can help shape Canada into a world-class innovation hub, offering high-quality and sustainable employment prospects for Canadians across all industries. While some work will still be needed in order to put Canada on the map as an innovation leader, investments such as these point to a future where we will be better equipped to embrace technological advancements, drive innovation, and fully leverage the evolving benefits of the growing digital economy.

What are Autonomous Vehicles?

With recent developments from autonomous vehicle leaders like Tesla and Google, as well as the progress made by other established manufacturers, some would argue that the ultimate vision of a vehicle that can operate independently of human supervision, is becoming an increasingly plausible reality.

However, the capacity of complete autonomy among most vehicles on the road today is still far removed from this scenario. While many modern vehicles possess some level of connectivity, by and large, they still require human control and supervision. Autonomous vehicles operate based on a varied range of capability; starting at Level One, where a single function is automated [9], to Level Five, where all functions are automated. It is only under Level Five that a vehicle is fully autonomous, able to operate itself and conduct all necessary driving functions without any human assistance.

With many modern vehicles landing somewhere between Levels One and Three, most have come to possess several high-tech features, including in-car Internet access. Using the Internet to provide enhanced safety features and entertainment options, today's digitally-equipped cars are referred to as "connected vehicles". These vehicles include features like 4G, as well as improved safety mechanisms like crash detection sensors. Take for instance the 2015 Kia Sedona, with a trunk that can detect the owner's hands and open automatically. Similarly, the 2017 Ford Fusion, Toyota Prius and Lincoln MKZ, are all equipped with lane centering features, using onboard cameras and the brakes to maintain the vehicle's position in the center of the lane. Luxury auto manufacturers like BMW and Mercedes-Benz have also equipped their vehicles with sensors, along with systems that learn a driver's driving style and alert him or her in the event that reckless or unusual driving is detected. While these features may have been considered revolutionary only recently, for most vehicle manufacturers, the level of autonomous technology currently allows them to operate in the "connected" realm; rather than in a space where the role of the human driver can be eliminated completely.

A Brief History of Autonomous Vehicles

Despite recent innovations in the realm of connected and autonomous vehicles, this notion of a vehicle operating autonomously is not a new concept. In fact, the idea began to gain ground as early as the Second World War, with the invention of Teetor Cruise Control. Developed in 1945 and commercialized in 1958, Teetor Cruise Control was the first platform for autonomous driving, wherein a mechanical throttle allowed the driver to automatically set the vehicle's speed [10]. This invention was not only the first of its kind, but the first to change the way that the driving experience was perceived.

Another significant innovation in the space of autonomous technology is the Stanford Cart. Developed in 1961, this cart was the first rover to land on the moon. Equipped with cameras and a program that allowed it to autonomously follow a solid white line on the ground [11], the Stanford Cart represented the first discovery that took the idea of remotely controlling a vehicle, and created a device that was able to do so from the farthest distance possible at the time. Given the early nature of this technology, some notable challenges still existed, of course; the most prominent being the delay between the command centre sending out the signal, and the cart intercepting and interpreting it. However, situated during a time of vehement competition between the United States and the USSR during the Cold War, the Stanford Cart was a ground-breaking discovery in space technology, autonomous vehicle technology, and acted as a prime example of the kind of innovation that can be generated during pressing political, economic and cultural circumstances.

Other innovations also proved critical towards the shaping of our current-day understanding of autonomous vehicle technology. Some key developments include: the 1977 Tsukuba Mechanical Engineering system, able to autonomously recognize street markings while traveling at 20 mph [12]; the 1987 VaMoRs, allowing vehicles to autonomously detect objects on the road that were in front of or behind the vehicle [13]; the General Atomics MQ-1 Predator, the first mass-engineered autonomous drone [14]; and the 150-mile roadway for autonomous cars, developed in the US as a result of the DARPA Robotic Challenges in 2004-2013 [15]. All of these innovations helped to contribute towards the development of connected technology, and eventually paved the way for current-day autonomous vehicles like Google's Waymo and Tesla's Autopilot. As AVs become more developed, functional and responsive, governments around the world are beginning to take notice. To date, 33 US states have introduced legislation regarding autonomous vehicles, and as showcased under Budget 2017, Canada is beginning to shape the groundwork of this legislative foundation as well.

The Technologies behind Autonomous Vehicles

While the future of autonomous vehicles depends on several factors, ranging from technological development, regulation, government support and social acceptance [16], ultimately, their success is grounded in their ability to provide viable, safe, and convenient economical alternatives [17]. The following will showcase the key technologies at work behind autonomous vehicles.

Artificial Intelligence

Autonomous vehicles learn from their environments by effectively creating 3D maps of their surroundings. These maps allow AVs to gain a full picture of their whereabouts in real-time – a key feature that helps them make “better decisions than a human driver ever could” [18]. Precise 3D images are captured using a combination of radar and LIDAR – Light Detection and Ranging technology – the latter of which pulls light from a laser to measure ranges and distances [19]. Once these images are captured, it is up to the computer system to accurately interpret the meaning behind them and compute the value of the information it has gathered. This is where artificial intelligence (AI) comes in.

The computer utilizes “deep learning” – an agglomeration of machine algorithms that rely on layers of processing in order to extract characteristic features from pieces of information [20]. For example: when the computer receives a 3D image of a stop sign, its deep learning algorithms “chop up” the picture into several tiles, each of which are weighed and examined for certain features [21]. The processing layers will examine the color, the shape, the size, and other relevant aspects of the tiles captured. From here, the computer analyzes all of these characteristics to determine whether or not the object is a stop sign according to a probability vector, based on an established confidence level [22]. With the car’s cameras sending up to 30 images a second to the computer, the artificial intelligence system in the vehicle creates these probability vectors several times a second – a component allowing the vehicle to make split-second decisions. Deep learning architectures can take several forms, with some of the most common for autonomous vehicles being deep neural networks (DNNs), and convolutional neural networks (CNNs) [23]. Applying DNNs to autonomous vehicles allows them to “learn” to drive on various types of roads, and under a variety of climatic conditions.

Human Machine Cooperation

While AI is central to the machine’s ability to decipher the “meaning” behind information received, a well-functioning Human Machine Interface is critical to ensuring that the system works according to the needs of the human in the vehicle, and that the human understands the commands and/or requests that the machine is making. In short, a human in an autonomous vehicle may perform other activities while in the vehicle, however, he or she must be able to trust and understand the computer system in the event that he or she is required to respond [24]. This includes resuming driving in manual mode and taking control of the car, if necessary.

A high-performing HMI system must include transparency regarding the decision-making process of the machine, based on information that is commonly used by drivers. For example, if a vehicle foresees unfavorable weather along a course, a factor that may require the human to take control, its HMI system has to first analyze relevant data to determine a position, then expressing it in a way that is clear to the human. This allows each party to understand each others' decisions better [25], and as a result, creates less conflict and/or confusion regarding the best course of action on either end.

5G Mobile

One of the cornerstone components of autonomous vehicle design is their ability - and need - to communicate with other vehicles (V2V) as well as infrastructure (V2X). This communication is dependent on the transmission of large swaths of data in real-time. Knowing this requirement, today's current network speeds act as a bottleneck, and in many cases, prevent these vehicles from reaching their full potential [26]. When big data is captured, AVs use multi-sensor data fusion (MSDF), a platform that distills information from various sources, each holding different physical characteristics (i.e. buildings, other vehicles). MSDF collects and analyzes this data, enhancing the vehicle's understanding of its surroundings [27]. However, the ability for MSDF to function at optimal efficiency and without lags is dependent on the large-scale use and availability of 5G data flow.

5G, standing for fifth generation, is the newest mobile wireless standard that is currently in plans for wide-range rollout. According to current estimates, 5G is expected to be fully functional and available across Canada by 2020 [28]. 5G mobile will provide faster speeds - over 600 times faster than today's average LTE speeds - ultra-low latency, and vehicle-to-vehicle connectivity. Combined, these features will enable vehicles to communicate with one another, learn from each other, and interact with the environment around them [29]. With the availability of this technology, autonomous vehicles will be able to easily and quickly interact and communicate with their surroundings, as well as analyze and store the data they receive in a matter of seconds.

Telematics

Telematics refers to any integrated use of telecommunications with information and communications technology. In essence, this is the blend of technology that allows for the sending, receiving and storing of information on remote objects [30] such as phones, computers or in this case, vehicles.

Telematics is utilized in autonomous vehicles as a way of monitoring a given vehicle's location, movement, status, destination, speed and behaviour within a fleet [31]. In so doing, it uses a GPS receiver and an electronic-receiving device that allows it to interact with the user and a web-based software system [32]. Other services offered via telematics are convenience-based for both the user and manufacturer. For example, when it comes to AVs, telematics can be leveraged to gather varying data points. When this data is analyzed, the vehicle may then interact with the user; including notifying him or her when it is available for pre-booking, providing logistical data such as when it is arriving, or even information on when the vehicle needs to be serviced [33]. Many modern vehicles have some component of telematics technology built into their systems, making them "connected". Examples of telematics-enabled services in modern vehicles include Advanced Driver Assistance Systems (ADAS) such as adaptive cruise control, autonomous emergency braking, blind spot detection, pedestrian detection, lane departure warning, drowsiness monitoring [34] and many others.

Light Detection and Ranging (LIDAR)

LIDAR is an active form of remote sensing that generates precise and geographically-sound spatial information about the shape and composition of the Earth's surface. While LIDAR technology was initially used for the purpose of urban planning and archeology, recently, tech power-players like Google have begun using LIDAR for their autonomous vehicles. Google's autonomous vehicles are built with a revolving 360-degree LIDAR system that allows it to "see" the road and objects on it. In so doing, three types of information are collected: 1) the range from the car to the object on the road, 2) the speed that the object is travelling at, and 3) the chemical properties of the object. For autonomous vehicles to successfully function and avoid collisions, LIDAR and other sensors are essential. While some predominant challenges regarding the technology currently exist today - such as its inability to see behind solid objects [35] - advances in LIDAR are ongoing, making it only a matter of time before the technology is fully-functional.

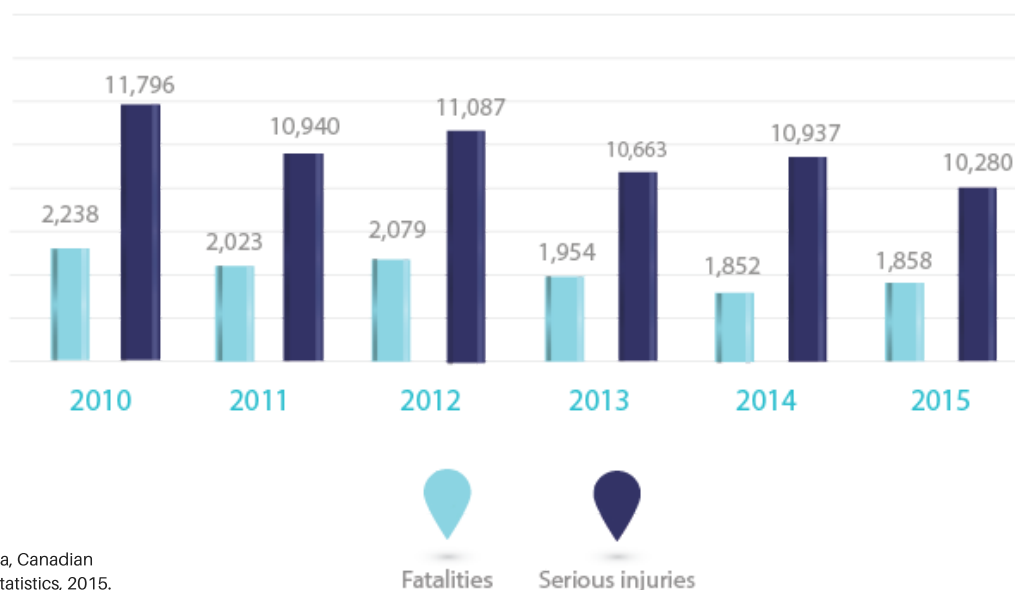
The Global Considerations of Autonomous Vehicles

Technology's influence on various sectors of the economy cannot be understated. Impacting sectors including manufacturing, financial services, retail, and transportation among others, technology is consistently challenging norms and ultimately, changing the way our world works. In particular, technology's influence on transportation continues to grow. With the influx of various mobility features such as telematics, ride-sharing, in-car entertainment and personalized road side assistance, traditional transportation models are undergoing a seismic shift. This is an inescapable change that is affecting the way vehicles are built, sold, and operated, as well as how and why we use them. One of the key disrupters propelling this shift forward are autonomous vehicles.

Money and Timeframes: How Much Revenue Will They Generate and When Can We Expect Them?

At times labeled the "future of global mobility" [36], autonomous vehicles can provide numerous benefits to our societies; one of the most profound being a drastic reduction in traffic collisions. In 2015, the number of motor vehicle fatalities in Canada totaled 1,858, up by 0.3% from 2014. When it came to serious injuries, that number ballooned to nearly 10x the fatality figure, totaling 10,280 [37]. Not only do these instances result in a reduction in quality of life - or the loss of it altogether - but they also come with a hefty price tag. Estimates put the total cost of traffic collisions in Canada at roughly \$46.7 billion per year [38].

Traffic Accidents in Canada

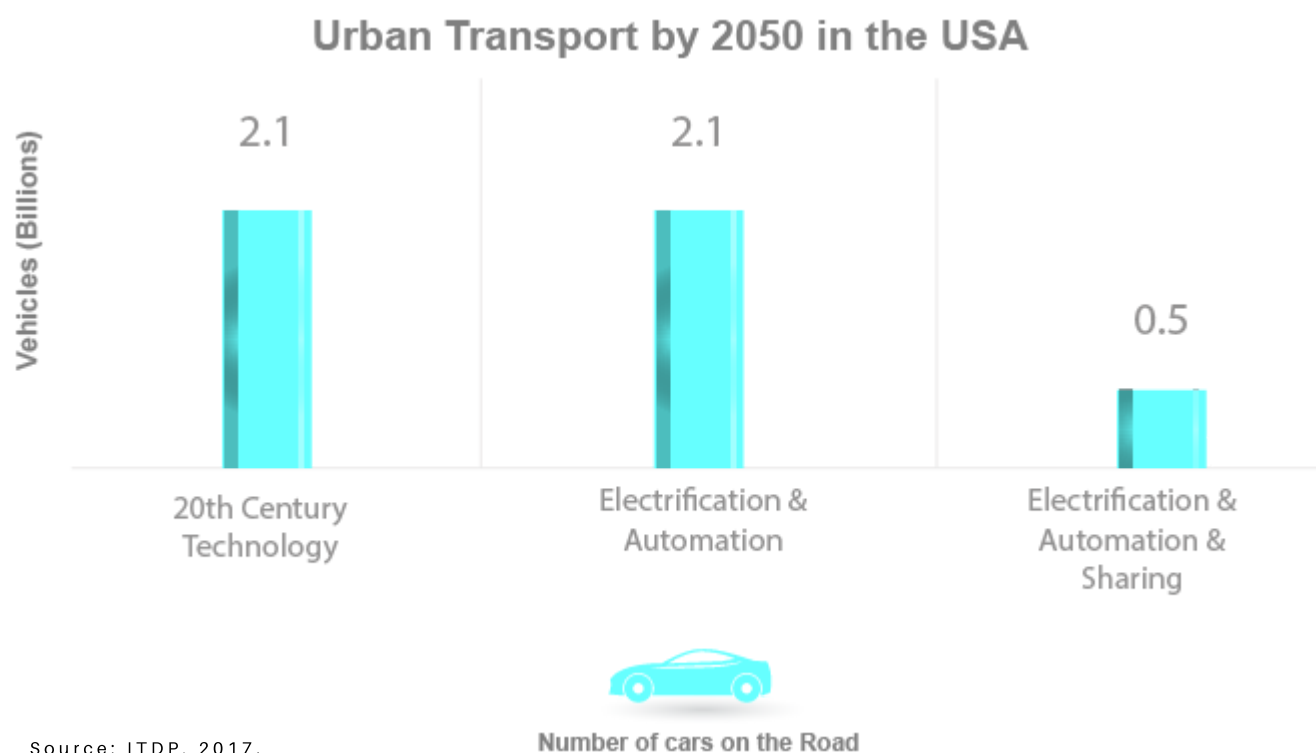


Source: Transport Canada, Canadian Motor Vehicle Collision Statistics, 2015.

By contrast, not only does the safety track record of autonomous vehicles showcase promising results, the economic output of this technology - including the reduction of expenses related to traffic accidents - is primed to be substantial. While no baseline results are currently available specifically for Canada, the Boston Consulting Group estimates that, with an average of 12 million vehicles sold each year around the world, the AV industry may be worth as much as \$77 billion by 2035. [39].

When it comes to roll-out timelines, a few predictions have hinted at the possibility of some manufacturers releasing fully-autonomous vehicles - requiring no human control - as early as 2022 [40]. However, most estimates indicate that the likelihood of full automation by this date is slim. Here, many suggest that while some versions of autonomous vehicles may hit the streets with relative frequency between 2020 to 2040, the majority of AV-related benefits, including improved safety, reduced congestion, and reduction in greenhouse gas emissions are more likely to be seen years later, between 2040-2060.

Other research suggests that by the time AV technology is fit for public use, original equipment manufacturers (OEMs) will no longer be the major players in the mobility realm. According to these predictions, AVs will also have to adapt to emerging trends in vehicle use, and fit into a society that prefers ride sharing platforms to outright vehicle ownership. In fact, some ride-sharing advocates take this argument one step further. Here, they suggest that not should AVs be predominantly shared, but that the development of this technology will *only* reach its full potential if they are shared. While AVs are primed to offer solutions to societal problems such as traffic accidents and congestion, ride sharing enthusiasts also suggest that if the goal is to reduce the volume of cars on the road, only through sharing will this be possible. Simply put, "unless we share them" they state "self-driving vehicles will just make traffic worse" [41].



Taking them for a Spin: Autonomous Vehicles, Safety and Consumer Perception

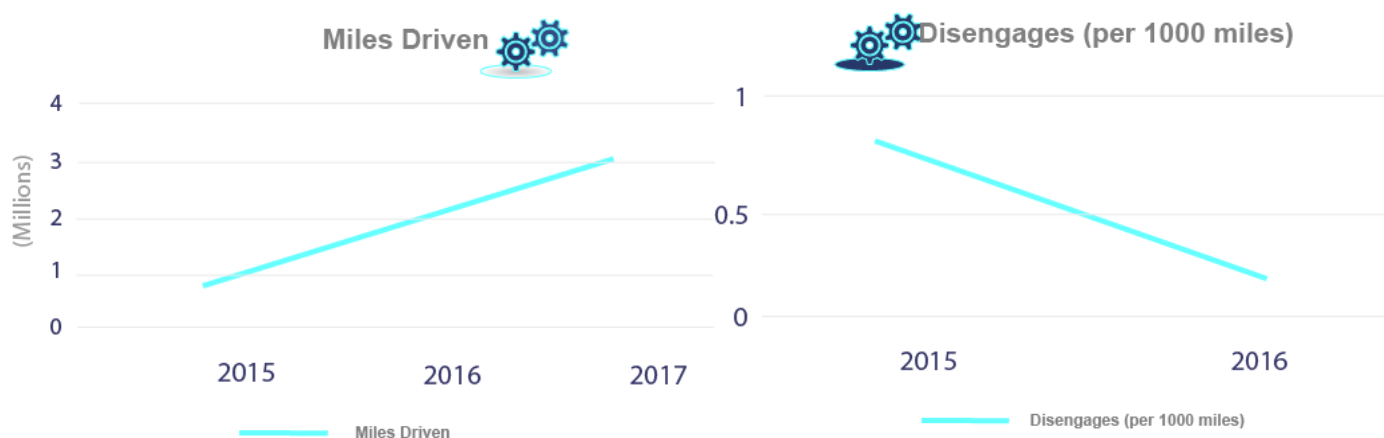
Similar to the 1,858 motor vehicle fatalities experienced in Canada during 2015 [42], according to the World Health Organization’s most recent estimates, roughly 3,400 people around the world are killed each day due to traffic-related accidents [43]. The need for improved vehicle and road safety mechanisms cannot be overstated.

While much of the technology behind autonomous vehicles is still in early phases, the notion of a car that drives itself may still cause a certain level of consumer discomfort. As a result, although many may understand the value of autonomous vehicles from a logical lens, few appear to be completely *comfortable* with it. Largely, consumers at this time are hesitant at the thought of using an unproven technology on a regular basis, with major concerns revolving around the possible unreliability of the technology and lack of quick response time [44].

These concerns were echoed under two global surveys released in 2011 and 2013 for the purpose of assessing public opinion when it came to autonomous vehicles. The first was conducted by Accenture, interviewing 2,006 consumers from the US and the UK. The results of this survey were split, with slightly less than half of respondents indicating that they would be comfortable using a driverless vehicle.

When asked for further detail, customers reported a sense of discomfort or uncertainty regarding surrendering control, suggesting that they would only use the vehicle if they had the option of taking control of it [45]. By contrast, the second survey conducted by JD Power and Associates surveyed 17,400 vehicle owners, worldwide. Under this survey, while users seemed more amenable to using a driverless car, only 37% indicated that they would be interested in actually owning one. That figure dropped to 20% with the introduction of the added costs associated with owning a vehicle of that nature [46]. This survey also showcased interesting trends specific to Canada. Here, while half of Canadians trusted autonomous vehicles to get them to their destination, only 30% would consider using one on a regular basis. On a regional perspective, survey results showcased Quebec respondents as holding the highest level of trust in autonomous vehicles, followed closely by respondents from Ontario. By contrast, the lowest rates of public acceptance for AVs were seen in Manitoba and Saskatchewan, with only 45% of respondents indicating a willingness to try the technology [47].

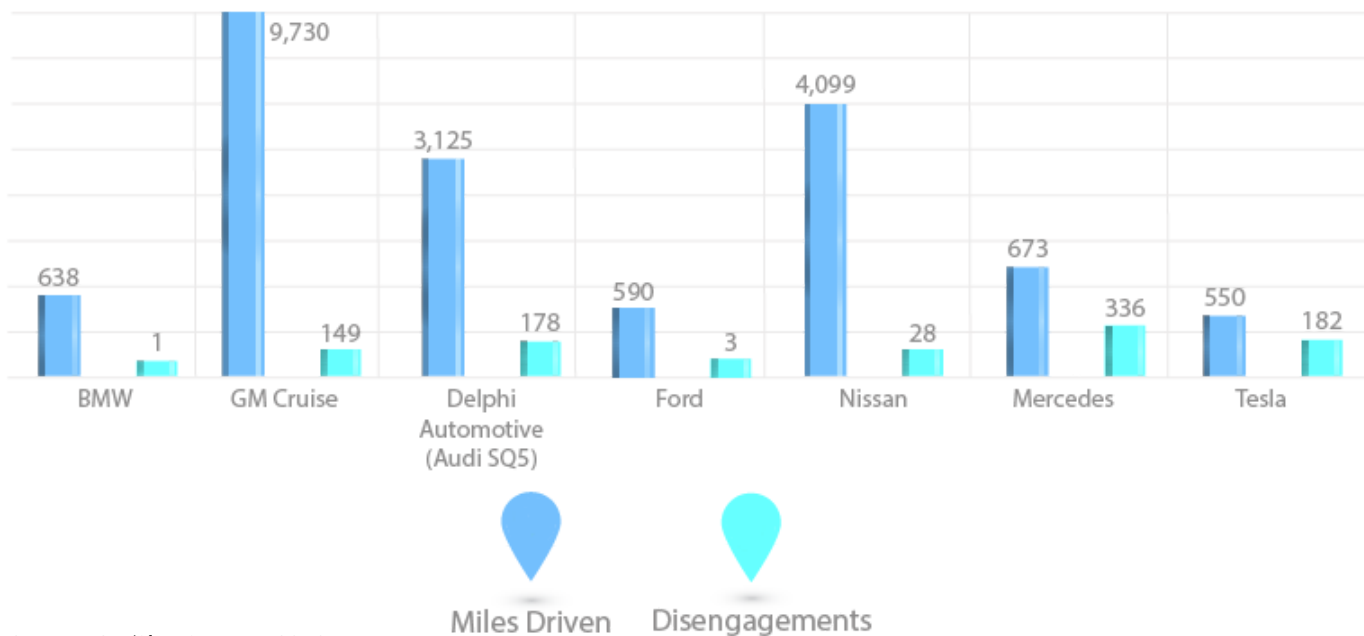
Despite this uncertain public opinion, the actual track record of the vehicles that have been tested on public roads has been impressive. For example, Waymo, Google’s autonomous vehicle unit, is currently operating in four cities across the US (Kirkland, WA, Phoenix, AZ, Austin, TX and Mountain View, CA) [48]. By the end of 2016, Waymo’s fleet had built a record of 3 million miles driven on city streets, with the rate of “disengages” - that is, where human drivers need to take control of the vehicle - totaling only 0.20 disengages per 1,000 miles [49]. Showcasing the technology’s rapid progress, this 2016 disengagement rate represents a significant drop from the year prior in 2015, where it totaled 0.80 per 1,000 miles.



Source: Google, 2017

While Waymo is no longer producing monthly collision reports, AV companies operating in California are legally required to produce annual reports to the California Department of Motor Vehicles, as a means of monitoring the technology and determining overall safety. In 2016, the DMV report submitted by Waymo found that of the 635,868 miles driven on California streets during that year, only 124 disengagements were noted [50]. Of those 124, the largest portion (51) were resultant of “software discrepancy”, followed by “unwanted maneuver of the vehicle” (30) and “perception discrepancy” (20) [51].

**Miles Driven & Disengagements
(California 2016)**



Source: California DMV, 2016.

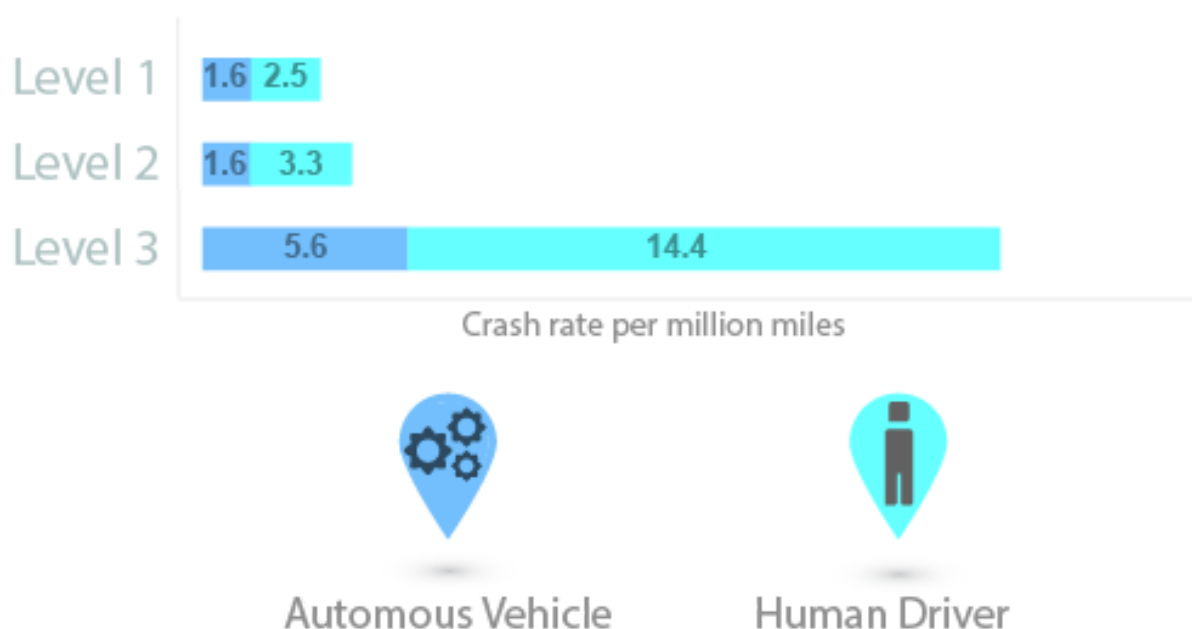
Compare these rates to the over 1.25 million people fatally injured each year around the world by traffic collisions [52]. With road traffic accidents being the leading cause of death among people aged 15-29 [53], autonomous vehicles have the potential to leverage the exponential power of artificial intelligence (AI) to mitigate collision-causing human error at a rate that the human brain can never achieve.

While the technology requires more research, along with the development of agreeable standards of use - i.e. what to do in the event of weather, often producing challenges for autonomous vehicles [54] - AVs present an incredible opportunity for economic output, loss prevention and improved quality of life. Although the idea of an autonomous vehicle may be a challenging one to accept from the onset, a simple side-by-side comparison helps to ease doubts.

AVs are never under the influence of alcohol, are never distracted or tired, often possess better perception (no blind spots), better decision-making capabilities (more accurate planning of complex driving maneuvers) and are quicker to execute actions (faster and more precise control of steering, brakes and acceleration) [55].

Those concerned about the use of autonomous vehicles will often argue that their safety records are still premature. Here, some state that AVs have yet to log enough driving hours to make the results relevant. However, a recent report by the Virginia Tech Transportation Institute discovered that compared across a time-based analysis with human drivers, autonomous vehicles are clearly safer. Analyzing data of Level 1-3 crashes (Level 1 being most severe; Level 3, the least severe), the report found that human-driven cars held substantially higher collision frequencies under each instance, and predominantly so when it came to Level 3 (most severe) cases. Under Level 1 cases, human drivers totaled 2.5 collisions per million miles vs. 1.6 for autonomous vehicles [56]. Likewise, for Levels 2 and 3, humans logged 3.3 and 14.4 collisions per million miles driven, whereas AVs logged 1.6 and 5.6, respectively [57]. Results like this paint a compelling picture. While there is no doubt that autonomous vehicles have some hurdles to overcome in order to showcase their full safety potential - including an increase in miles logged - at the current time, they appear to be off to a good start.

Crashes - Human vs. Autonomous Car



Source: Virginia Tech Transportation Institute, 2016.

From Hacking to Data Privacy: Autonomous Vehicles, Cybersecurity & Data Protection

Related to sentiments of apprehension about AV safety and reliability, the issue of cybersecurity plays a central role in the development of autonomous vehicle technology, as well as consumer perception. With the understanding that autonomous vehicles will rely on software to function, many link this reliance to the large transmission of data, and ultimately to the possibility of cyber attack (hacking). In the event that an autonomous vehicle were compromised (hacked), the attacker (hacker) may be able to take over the vehicle's functions, as well as access stores of personal data that the vehicle had been collecting [58]. In worst-case scenarios, the cyber attacker may even gain access to the databases of OEM suppliers, themselves [59]. Clearly, scenarios such as these are extremely undesirable and heavily feed into the feelings of uncertainty surrounding this technology.

One of the key factors causing autonomous vehicles to become susceptible to cyber attacks is the early stages of the technology, as well as the trends that are becoming increasingly evident with connected vehicles. That is, a situation where the OEM designs the basic construct and technology that the vehicle uses and relies on, however, third-party technology manufacturers - like app developers - can use the Internet to gain access to the vehicle [60]. For example, passenger that connects to the Internet in a connected vehicle in order to use a social media app may, in extreme cases, be putting the entire vehicle at risk in the event that the social media app is compromised. Effectively, while this is an unlikely scenario in most cases, the use of third-party applications in connected vehicles means that no single company is responsible for the data security of the vehicle itself [61]. This concern is even more pressing for autonomous vehicles, where the human driver is not regularly in "control" of the car.

Another central concern when it comes to AVs is the collection of large swaths of data. As noted in a previous section, autonomous vehicles collect information about the environment around them using a variety of sources including radar, LIDAR and 3D maps. However, their ability to continually collect this data is dependent on access to a wireless network, where the car can also transmit data about itself and its passengers in real time [62]. This data then goes back to the car's computer and potentially to an external hub that is controlled by the manufacturer [63]. In addition to this, driverless vehicles also must also continually interact with one another and the infrastructure - vehicle to vehicle (V2V) and vehicle to infrastructure (V2I).

Here, vehicles broadcast messages to other nearby vehicles and infrastructure at a rate that is up to ten times per second. In so doing, they access, store and display a variety of pieces of information, including their own vitals like acceleration and brake status [64], as well as biometric data about their passengers – including personal health records – for the purpose of monitoring temperament, alertness, and even preferences that are linked with accident-prevention [65].

It is not difficult to understand why this transmission of data can be worrisome. However, the ability to safeguard passenger data is, and will continue to remain a top priority for AV manufacturers. OEMs can take measures including integrating features into the base construct of the vehicle that users would often get from third-parties. This includes entertainment options, social media applications and streaming services, among others. This way, while likely less timely than with third-party applications, updates to these services would come directly from the OEM. This is a feature that significantly reduces risk of compromise. Likewise, regulators can also play a key role in ensuring safety and protection of personal data. They can do so by providing guidelines that help shape emerging technologies, such as autonomous vehicles. One key example of such an initiative is the Privacy by Design (PBD) movement, spearheaded by the Information and Privacy Commissioner of Ontario. By utilizing a variety of proactive measures during a product’s development, the privacy movement requires manufacturers and product designers to restrict their invasions of user privacy to the bare minimum [66]. This type of approach is similar the one being used by the European Union, with the idea that AVs and other key technological developments should not compromise the users’ privacy by transmitting information which can be used for “targeted marketing,” or “surveillance” [67].

Some of these concerns are easily mitigated, while others require more consideration. For example, AV accidents that are caused by obvious software malfunction or blatant design defect, may be attributed to manufacturers under a standard product liability regime. [68] With key organizations lobbying on behalf of consumers, companies can be pressured into undergoing resilient data management processes, including showcasing transparency on data use, and limiting the transmission of data where possible. At the current time, companies leading the development of autonomous vehicles are aware of these security implications and are taking active measures to combat them, without compromising the growth of the potential of the technology.

While it is impossible to guarantee that the software will always be free of any logic errors [69], several steps - including ingraining third-party apps into OEM infotainment factory settings of the vehicle, or running periodic diagnostic tests [70] - can be taken to mitigate these risks.

Who's at Fault: Autonomous Vehicles and the Insurance Industry

Between 1984 and 2013, Canada saw an estimated 94,000 vehicle fatalities and 6.7 million traffic injuries across the country [71]. Primed to deliver significant results in this area, the widespread adoption of autonomous vehicles has been estimated to significantly decrease traffic incidents [72]. Autonomous vehicles can come equipped with features that offer driving assistance applications, and use the data collected from these to produce analysis related to a vehicle's operation. Unlike current applications on the market that rely on relatively basic information such as stopping speed, acceleration, and turning radius to measure vehicle output, future insurers may be able to leverage the in-depth data that AVs generate to create streamlined and customer-specific policies.

Using AV data, insurers may gain access to more accurate information than existing solutions on whether or not safe braking distance was observed, if traffic laws were adhered to, how smoothly turns were handled, or other similar components of driving performance. In-car connectivity and telematics would also allow insurers to know whether the autonomous driver was de-activated at any time. Combined, these pieces of information strengthen the ability for insurance companies to calculate premiums and rates. According to industry analysis, insurers may be able to charge customers different rates based on how often they activated the autonomous driving features of the vehicle, or how often they drive. Assessing this behavior, insurance companies may also be able to offer flexible usage-based fees, like a "pay as you go and drive" [73] insurance.

According to Lyft's CEO Logan Green, ride share companies with autonomous vehicles may be heading down this route. These companies may adopt a subscription model similar to that of Spotify or Netflix, with a miles/month plan on the Lyft network, and multiple vehicles to choose from [74]. This kind of revolutionary change in the automotive industry will inevitably act as a significant disrupter to the insurance industry as we understand it today. Moreover, as manufacturers come to possess a greater volume of data about the operation of their vehicles, they will be in a better position to avoid potential risks going forward.

However, liability remains an important barrier for manufacturers and designers of autonomous vehicles. As autonomous cars become more prevalent, it is believed that the volume of collisions will decrease, however, it will remain impossible to guarantee total safety and zero collisions.

Even as the technology develops, autonomous vehicles will never be free of their own challenges. Serious accidents can be caused by glitches, viruses, network failures, and programming errors that have been known to afflict computer-run devices. Toyota recently settled a class action lawsuit stemming from several instances where the autonomous acceleration systems in certain models malfunctioned, causing the cars to rapidly and uncontrollably accelerate and crash. While these vehicles were not completely autonomous, these instances are serious examples of potential AV-related instances. Therefore, yes, the technology behind these vehicles needs to be refined, constantly tested and updated. However, with that, a set of standards, regulations and legislative frameworks need to be developed in order to ensure their optimal safety.

The majority of current legislation on this topic showcases an underpinning requirement of “every vehicle need[ing] to have a licensed operator”. This requirement exists for various reasons, including liability in the event of an accident. In the case of autonomous vehicles with no human driver, some experts have hinted at the possibility of holding the manufacturers liable. Others have suggested that the liability be shared between the owner of the vehicle and vehicle manufacturer, while many have proposed that courts adopt an all new liability scheme that assesses responsibility to the proper party by using product liability principles - a method that focuses on the driver’s level of reliance on the autonomous vehicle. While this issue is far from settled, experts maintain that holding manufacturers liable is the best option, particularly because it would ensure that they constantly improving and updating their systems for optimal use.

While various technical and policy barriers to widespread AV adoption remain, misguided regulation can function to delay or curtail the adoption of this important technology. As a result, policymakers should keep in mind that our institutions have gradually adapted to similar technological disruptions in the past an oftentimes, they have produced an improved outcome.

What would smartphones look like today, if the policy surrounding them were precautionary and restrictive, focusing only on warding off potential risks, instead of the immense value they can generate? Due diligence and risk assessment are crucial actions in the creation of sustainable and sound policy. They are the foundational groundwork that helps us deal with and benefit from these disruptions - and particularly when it comes to ones with such far-reaching and revolutionary potential. However, we must maintain that the economic growth, inclusive employment opportunities, and overall positive societal change that such innovations can bring aren't stifled in the process.

Expanding Reach: Autonomous Vehicles and Increased Mobility for All

One of the key changes that AVs can bring to our current societies is the improvement of options for mobility. This change is one that will prove particularly beneficial for individuals or demographic groups that currently experience challenges with driving. One key example is the rapidly aging population among OECD countries. In 2014, Japan had the highest elderly population (aged 65 and older) in the world, totaling over 25% - a figure grew by a nearly 10% since 2000 [75]. In Canada and the US, similar results are notable; the elderly population totaling approximately 16% in Canada during 2014 and 14% in the US during the same period [76]. Increased and improved options for sustainable transport solutions, including AVs, would drastically improve the quality of life for elderly populations around the world.

Another example of a demographic group that would benefit from AVs are individuals with disabilities. In 2012, nearly 14% of Canadians were identified as limited in their daily ability due to a disability, with over 11% of this population experiencing mobility or flexibility issues, specifically [77]. This figure is higher in the US, where approximately 1 in 5 people identify as having some form of disability, with nearly 1/4th of those respondents possessing a severe disability [78]. US statistics also showcase the highest level of unemployment is found among individuals with ambulatory difficulty - that is, a difficulty walking. Among individuals under this classification, fewer than 1/4th were found to be employed in 2016 [79]. With AVs providing access to mobility, they can not only improve the quality of life for this group, but potential open up avenues for employment.

Other groups that may benefit from the far-reaching potential of autonomous vehicles include individuals located in remote or rural locations, Indigenous peoples, and other groups that tend to live in areas with poor connectivity, socioeconomic challenges, and/or lack of access to suitable transportation. Today's options for transit present challenges for many Canadians. Autonomous vehicles, able to reach remote areas with efficiency, while also operating without the need for human involvement, would drastically improve the lives of many. These vehicles can be key in offering independence and increased diversity, while simultaneously creating pathways for boosting economic growth and productivity through inclusivity.

Automation and the Transportation Sector in Canada

In today's global and digitally-enabled economy, the occurrence of rising unemployment rates in some traditional industries is not a rare occurrence. However, as automation continues to displace some occupations, its overall job-creation potential is significant. This being said, some employers and industries are currently lagging behind in offering timely training opportunities in areas relevant to the future economy. This includes fields like robotics, artificial intelligence and many others. The solution to the displacement of some occupations isn't to halt technological growth and development. Rather, it's about long-term planning and equipping workers today with the skills they will need in the future [80]. In Canada, the importance of this type of thinking is even more pressing. Over the last 20 years, annual expenditures on learning and development have declined significantly. Totalling \$800 per employee in 2015, this figure represents a 40% decrease from the \$1,249 spent per employee in the early 1990s [81].

Although some barriers, including economic, social and technical currently exist delaying the full-scale implementation of autonomous vehicles, policy frameworks that deal with these issues are being developed around the world. With the understanding that it is only a matter of time before this technological revolution is commonplace, creating the frameworks to support it is crucial. At this moment alone, it is estimated that more than 30 companies around the globe are working on rolling out autonomous vehicles [82]. These companies range from traditional automobile manufacturing firms like BMW, Ford, Nissan and Volvo, to computer technology companies like Apple and Google [83], to rideshare companies like Uber and Lyft. As a result, the topic of this technology, as well as automation and its impact on jobs is increasingly becoming a hot topic.

The array of changes that automation brings to an economy is nothing new. The by-products of this transformation are already evident in many industries and jurisdictions in Canada, and around the world. Recently, the Bank of Canada highlighted that we must “brace [ourselves] for job losses and greater income inequality”, as a direct result of technological progress [84]. However this kind of alarmist reasoning is not only unnecessary, but also somewhat incomplete. While it’s true that technological progress may result in the displacement of some jobs, as professor Moretti articulates, it can also generate new and arguably better opportunities across the entire economy. These are opportunities that contribute to higher economic growth, improved healthcare and access to education, improved environmental quality, and the overall enhancement of social well-being.

Technology possesses the potential to increase efficiencies and create solutions to societal challenges. It also threatens to unravel, or at minimum, shift the way we currently conceive the responsibilities of many occupations, as well as how we as a nation operate in the global economy. Some planning for these inevitable socio-economic changes have already taken shape. Governments around the world have begun experimenting with the concept of universal basic income; others are focusing on education and retraining initiatives, ensuring that workers will remain employable under changing circumstances. These and other considerations are key in getting the discussion started. As the advent of autonomous vehicles will undoubtedly create new challenges to the existing structure of cities, economies and social systems around the world, Canada must begin working towards understanding not only these challenges, but preparing for the high-quality job opportunities that this technology will drive forward.

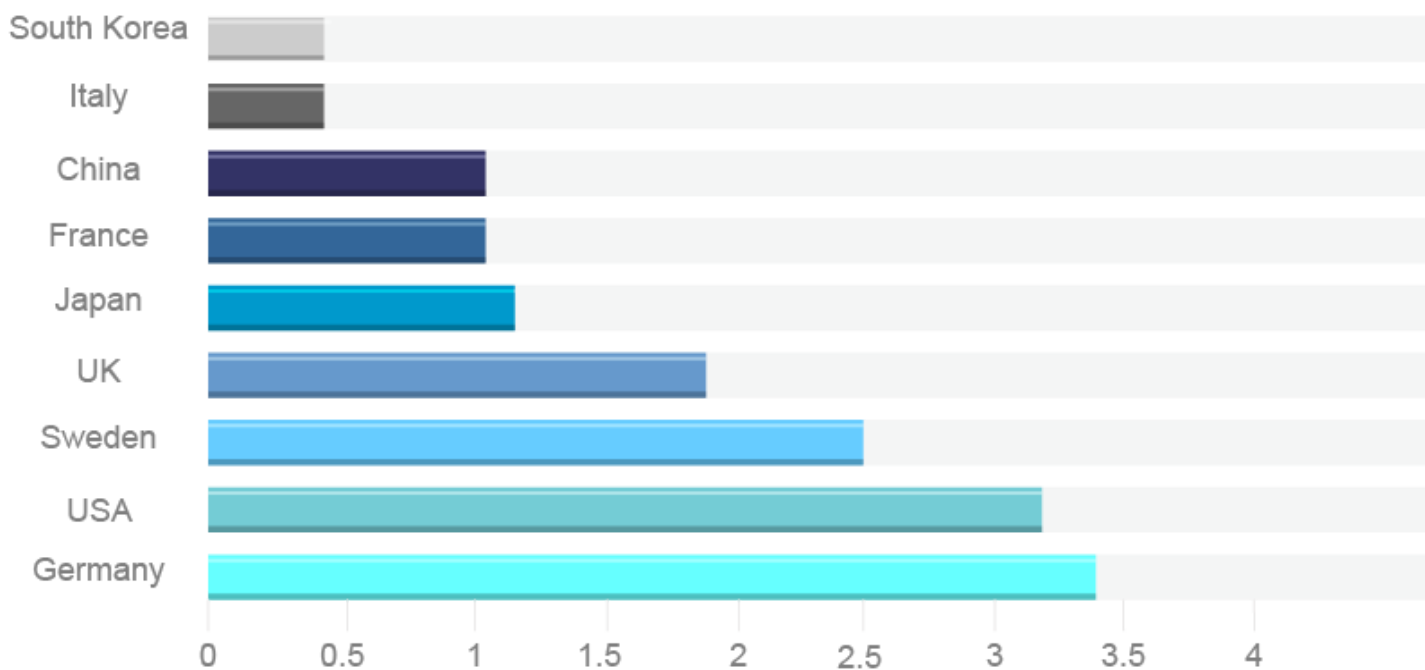
How Do We Rank? Global Advancements, Canada, and Autonomous Vehicle Progress

With tech pioneers like Google and Tesla, as well as OEMs like Ford and GM, it’s not surprising that many of today’s most significant advances in autonomous technology have come primarily from the United States. However, more and more, international players like Germany’s BWM and Japan’s Nissan, among several other key brands, have begun to make significant progress in the space. According to the most recent analysis of strength in this emerging market, a total of nine countries currently place on the Autonomous Vehicle (AV) Index.

The AV Index measures comparative positions of national automotive industries based on a) the state of technological developments made to vehicles designed by a country's OEMs, and b) the market size, measured by consumer demand and legislative support.

While the state of technological advancement is not fully inclusive, in that it focuses primarily on OEM growth and development despite the rising presence of non-OEM participants in this field, market share is calculated according to the relative need and/or want for advanced driver assistance systems, in combination with national progress on legislative frameworks surrounding autonomous vehicles [85]. According to the 2016 AV Index, the following nine countries were deemed to be at the forefront of this technology: Germany, US, Sweden, UK, Japan, France, China, Italy, and South Korea. Canada, with slow development in this space, did not make the list.

AV Index Rankings



Source: Forschungsgesellschaft Kraftfahrwesen Aachen (fka), 2016.

As of 2016, only one Canadian-based OEM (General Motors) has stated their intent to enter the autonomous vehicle space. With no companies currently testing this technology, there has also been little discussion on the development of legal frameworks to govern the use of these vehicles. Additionally – and possibly as a result of this slow progress – consumer demand and public perception of AVs remains relatively low in Canada. Under a study conducted by GfK in 2016, only 26% of Canadians were identified as finding the concept of a fully-autonomous vehicle appealing [86]. More, the study found that respondents used the worlds “anxious” and “powerless” the most frequently to describe their feelings on riding in an AV [87].

While Canada has pioneered some important technological developments in the past – including launching the first commercial geosynchronous communications satellite, and being the first country to install computerized traffic signals – in comparison to its international counterparts, Canada is currently lagging behind in AV technology development and adoption [88]. With the moderate pace of technological adoption among Canada’s SMEs, coupled with the slow movement of discussion on the topic, much work is needed to get Canada near the level of the world’s key AV players.

In 2015, the United States Department of Transportation (US DOT) announced several initiatives geared towards the development of an innovative transportation system. One such initiative was the Smart City Challenge, whose primary objective was to award \$40 million USD to the American city best able to serve as an example of innovation in the transportation sector [89]. Not only was this program a success on its own, but US cities ended up leveraging an additional \$500 million in private and public funding on their pathway to realizing this vision. Piggybacking on the popularity of this initiative, in October 2016, the US DOT announced an additional \$65 million in grants to support community-driven advanced technology for transportation projects in cities across the country. These are just a few examples of innovative transportation-related developments taking place around the world. Other global steps forward include Singapore’s interactive maps [90] and satellite navigation systems, as well as Germany’s reform of national traffic laws to accommodate AVs [91]. With initiatives such as these, it is clear that intelligent transport is a key consideration for many of the world’s top-ranking economies and innovative centres.

By comparison, Canada's approach to AV technology development, as well as progress in intelligent transport altogether, has been slow. Ontario is currently the only Canadian province credited with spearheading tangible pathways for autonomous vehicle testing. In 2016, Ontario became the first province to develop a pilot regulatory framework for testing autonomous vehicles and in April 2017, the province announced an \$80 million investment towards an autonomous vehicle demonstration facility in Stratford [92]. In late 2016, BlackBerry's QNX opened a research centre specifically for autonomous vehicles, with the first rounds of testing anticipated to start in Ottawa in the fall or winter of 2017 [93]. Other key steps forward in Ontario include developments at the Markham and Oshawa GM plants, where GM has committed to growing their fleet of engineers responsible for testing autonomous cars from 3,000 to 10,000 over the next few years [94]; as well as the announcement by Ford in early 2017 regarding the creation of a \$340 million new research facility for autonomous vehicles based out of Ottawa, with satellite offices in Oakville and Waterloo [95].

While progress has been slow outside of Ontario, other provinces have gradually begun to understand the value and pertinence of engaging in this space. In 2016, Google announced that it will be testing its first driverless cars in Richmond, British Columbia, in an effort to reduce the rate of collisions within the city [96]. Although B.C highways already feature some smart transport technologies, like variable speed signs that adjust to driving conditions, and infrared cameras that detect wildlife, the province will require additional infrastructural changes to accommodate AVs [97]. In Alberta, Edmonton has started drafting plans to create a single test track specifically for autonomous vehicles. According to Edmonton's Councillor Andrew Knack, "The first pilot project [led by the Centre for Smart Transportation] would likely involve a 10-person shuttle in a fenced-off portion of the University of Alberta's south campus" [98]. Current analysis points to the possibility of this development generating \$30 million in annual income for the city, measured by both new job opportunities and spinoff economic activities spurred by the initiative. [99] Similarly, in Calgary, a pilot project to begin testing low-speed autonomous shuttle service is currently pending approval.

Aside from the above, the most notable development across Canada was a preliminary discussion on AV transportation alternatives in Saskatchewan. While still in very early stages, the Mayor of Saskatoon has made repeated calls for infrastructure to be designed with the capability of supporting autonomous vehicles within the next 15 years [100].

As a result, while Ontario leads progress in this field, and some notable plans are being put forth in BC and Alberta, AV activity and development overall in Canada remains low. Meanwhile, Google's autonomous vehicle fleet have already driven more than 3 million miles on public roads in the US [101], and Germany has adopted the world's first ethical guidelines for self-driving cars [102]. In the face of these global developments, we are already trailing behind - a reality that is reinforced by the global AV Index. Remaining competitive in this market means getting Canada a seat at the table, and investing the time and resources to stay there.

SECTION TWO: SMART CITIES - USING TECHNOLOGY TO GENERATE SOCIETAL SOLUTIONS

Incorporating elements like technology, environmental sustainability, and accessibility, smart cities are increasingly becoming part of the common vernacular. By definition, a smart city is a "municipality that uses information and communication technologies to increase operational efficiency, share information with the public, and improve both the quality of government services and citizen welfare.[103]" As populations grow and urban sprawl becomes more prevalent, the ability to make the best use of urban space is critical.

The world around, it is clear that cities are the future of work and life. In 2016, approximately 55% of the world's populations were living in urban centres [104]. That figure grows to 82% for the US and Canada [105]. In Canada specifically, the 2016 Census placed more than one third of Canadians living in just 3 metropolitan areas: Toronto, Montreal, and Vancouver [106]. Both Canada and the US have some of the highest concentrations of urban populations in the G7; and many cities around the world are beginning to battle the challenges associated with urban sprawl and a growing population sizes.

Utilizing technology to improve the quality of life, smart cities benefit residents in a number of ways. They generate environmental improvements through a reliance on green energy; they save space, by using creative architectural solutions like stacked housing; they improve productivity, by creating mechanisms for the greater participation of all people into the economy, including improved mobility solutions like autonomous vehicles; and they even improve the quality of healthcare, through the use of e-health applications that allow for real-time symptom diagnosis [107]. These are just a few examples of the wide-ranging opportunities and benefits that our future smart cities may produce.

The potential of autonomous vehicles in a smart city are unbounded. More, many would argue that AVs will not be able to function at optimal performance without smart cities. Despite the technological potential of AVs, many indicate that “[...] they’ll only be as powerful as their surrounding allows [108].” Using the base principle of V2X, an AV must be able to communicate with a smart infrastructure – that is, infrastructure that can “talk” to them, though the use of sensors and transmission of data. This communication is crucial for the vehicles to become aware of obstacles along their paths, and utilize the most efficient ways to get to their destinations. Without these support mechanisms, they will likely get stuck. Taking this need for connectivity into account, it is clear that the success of AVs on a large-scale is inherently tied to the development and growth of smart cities.

Smart Cities & Autonomous Vehicles – How it works

Estimates place the full-scale use of AVs as causing a drop of up to 60% in the number of vehicles on city streets. This will create by-products including an 80% decrease in tailpipe emissions, and 90% fewer accidents on the road [109]. While we in Canada are far from this kind of AV adoption, paving the way there will be key in ushering in a variety of benefits to Canadians across all regions.

As mentioned, the large-scale adoption of AVs is dependent on having in the right infrastructure to support them. These include the technological developments needed for vehicles to communicate with their surroundings. To a degree, today’s modern vehicles already possess this capacity, in a rudimentary way. Vehicle diagnostic systems, in use since the early 90s [110], are able to read a vehicle’s basic composition and produce reports. Recent improvements have taken that concept and ramped it up through the use Wi-fi, 4G and LTE. For example, the Colombian product CarLock uses GPS and 4G to monitor a vehicle and send the driver alerts when it is moved, when the engine starts or if an unusual movement is detected [111]. It can even notify your emergency contacts via SMS in the event that it experiences a collision [112]. In the US, a similar product exists, called Zubie. Using the Internet and GPS, Zubie is able to deliver real-time location, trip history, maintenance alerts and engine diagnostics among other driving-insights, to the user [113]. With these and other developments, it is becoming increasingly evident that some of the technological changes needed to power connected vehicles in our future smart cities are already underway.

However, a truly “smart” city, able to integrate living space with efficient mobility solutions like AVs, will necessitate faster and better connectivity, as well as improved data storage solutions that far surpass currently-available options. Through the use of 5, 6 or even 7G, infrastructure that is complete with sensors will be able to capture traffic information and transmit this data to vehicles on the road. For example, a sensor-equipped traffic light would be able to send information about light changes to autonomous vehicles, allowing the latter to adjust their speed prior to encountering the light [114]. This communication, displayed between the convergence of infrastructure and vehicles exemplify the type of “connection” needed to propel our future cities. This connection is key to the development of intelligent transport systems, improved healthcare and education solutions, secure and efficient financial transactions, and many other elements of smart cities that incorporate efficiency, effectiveness and productivity for the purpose of improving the quality of life within our communities.

Infrastructure, People and Lifestyle - the “Look” of AV-equipped Smart Cities

There is no shortage of discussion on smart cities, these days. Many suggest that smart cities will be the key to ramping up productivity; others focus on how they will improve community relations and generally make our lives better. However, though all this discussion, one key question remains: *what will they actually look like?*

With more than 80% of today’s global GDP generated by cities [115], focusing on the future of our urban metros in Canada and around the world, is crucial. Based in the idea of “giving our huge urban areas a technological upgrade” [116], smart cities blend the use of technology to improve efficiency, effectiveness and quality of life. Smart cities will contain fully-integrated infrastructure, including smart transport services, smart water services, smart financial institutions, and many others, powered through connected electrical power grids [117]. In turn, these “smart” improvements are estimated to boost efficiency and productivity, while simultaneously improving quality of life.

Relying on AI to process the big data that is constantly being transmitted, smart cities will need to be equipped with a multitude of sensors. These sensors will then communicate information about the “health” and status of the city — including pollution levels, weather systems, and potential threats such as earthquakes, hurricanes and other disasters - to the infrastructure [118].

From here, the infrastructure will use AI to analyze the meaning behind this data, and take the appropriate actions.

As mentioned earlier, one of the key concepts of effective and smart cities are intelligent transportation solutions, including AVs. For these vehicles to effectively and efficiently travel on our city streets, several infrastructure changes will need to be made in order to accommodate them. One important change will be the implementation of roadside sensors along streets and highways, which will use networks like 5G to rapidly send key information to the vehicles. These roadside sensors will effectively act as the vehicles eyes, allowing them to “see” activity far ahead on their routes. This capability will not only allow vehicles to make the best traffic maneuvers possible to save time and energy, but it will also produce added safety features in the event that human intervention is required. Through the early receipt of these signals, passengers who may be eating, sleeping or watching a movie can have minutes rather than seconds of warning to engage the vehicle, if necessary [119]. Compare this to our current capacity, where roadside sensors do not widely exist. Here, car-mounted LIDAR sensors are used instead. These systems, offering a range of only 200 meters for passenger response means that the passenger will be given between 5-10 seconds of warning regarding an unusual situation up ahead [120]. In some cases, this presents a significant challenging for appropriate passenger response.

Other important infrastructural changes of smart cities include alterations to the use of space and traffic flow protocols. As it’s estimated that the smart cities of the future will most likely see the benefits of intelligent transport if autonomous vehicles are “rented” rather than purchased [121], the demand for parking or storage space for vehicles is expected to drastically decrease. In the US alone, expert analysis uncovered that the rise in driverless vehicles and increased adoption of ride sharing will cause a drop-in parking demand by over 5.7 billion square meters by 2035 [122]. According to a recent study completed by INRIX, an organization dedicated to research for intelligent movement of vehicles and people, the pains of seeking parking is a global phenomenon, with its consequences being anything but negligible. The study found that the economic burden of looking for parking was significant across several countries. Here, US, UK and German drivers were recorded as spending an average of 17, 44 and 41 hours a year looking for parking [123]. Viewed from the lens of impact on productivity, this wasted time translated to \$72.7 billion, £23.3 and €40.4 billion in revenue losses [124].

Other minor infrastructural changes needed for full AV functionality within a smart city include the improvement of paint jobs on the roads, and the development of street signage to help AVs “see” better [125]. Along with sensor-equipped traffic lights, these changes will help infrastructure effectively communicate with vehicles. According to Rutgers’ University chair of Electrical and Computer Engineering, smart cities are ones “where every device, every entity, and every object can connect for whatever the need” [126]. Combined, these revolutionary changes are ones that will undoubtedly produce far-reaching benefits across our many diverse global communities.

Smart Cities & Jobs: Which of Today’s Occupations Will be in Demand?

Currently, the idea of a smart city is one that many communities around the world are just beginning to grapple with. However, eventually, the time will come to turn the concept into reality. As a result, the methods and practices that we employ today – whether it be urban planning, city engineering or the social constructs that support cities and communities – will undergo a substantial change. With this change, the demand for certain occupations needed to propel these cities forward will inevitably grow.

Our research has identified a group of 11 National Occupational Categories (NOCs) (see Appendix III) that we believe will see rising demand in Canada as the concept of smart cities picks up steam and pathways for implementations are generated. For example, NOC 2131 and 2153, Civil Engineers and Urban and Land Use Planners, will be particularly relevant in the development of smart cities, namely when it comes to some of this group’s specific sub-occupations like Civil and Geodetic Engineers as well as Municipal and Urban Planners. Take for instance the development of “stacked” urban dwellings described earlier. These constructs are ones that can offer multi-use services, including living space, commercial space, and in some cases, even several storeys of vertical farmland. With the exception of some land-scarce cities like Singapore and Hong Kong that currently employ versions of stacked housing or urban stacked farming [127], the ability to combine living, commercial and farming space on a large scale is far from a ubiquitous concept on a global scale, and yet to be attempted in Canada. As a result, civil and geodetic engineers will be needed to conceptualize several features of these future structures: first, they will need to draft plans for how to actually build them, taking into account relevant gravitational and terrestrial considerations, among others; and second, they will need to design and construct them in a way that is architecturally sound and easily-maintained.

Complimenting the physical construction requirements of these buildings, land use and municipal planners will be needed to ensure that land is utilized in the most efficient and effective way, and that the structures are placed in locations that respond to the needs of the city - that is, near easy access to transit, community spaces, and even major shipping routes where the farming yield can be transported to.

Similarly, occupations under NOC 4161 Natural and Applied Science Policy Researchers, Consultants and Programs Officers, as well as NOC 4162 Economists and Economic Policy Researchers and Analysts will also be relevant in the smart city landscape. These occupations will assess and track the social, economic and political impacts of smart cities, helping to develop the groundwork needed to consistently support and implement improvements on an on-going basis. For example, with the accelerated use of clean energy solutions in cities, used to run everything from urban stacked buildings to autonomous vehicles, Energy Policy Analysts (under NOC 4161) will witness increasing labour demand, since these occupations will be key in assessing relevant policy implications linked to new energy sources. Similarly, Economic Policy Analysts (under NOC 4162) will be needed in order to analyse the economic impact of new energy solutions, as well as other smart city innovations such as intelligent transit.

These and other occupations, ranging from software developers who will design data-catching sensors, to construction managers who will physically construct our new buildings, will become increasingly relevant and in-demand as smart cities move from concept to reality. While we in Canada are only in very rudimentary phases of smart city design, staying ahead of the game will mean ensuring that we build the relevant talent base today, allowing us to smoothly and easily serve the needs of tomorrow.

Smart Cities & Future Jobs: Which Jobs Will Be Created?

For a city to truly become “smart”, it needs to build the infrastructure necessary to support this change. This means that not only will we see increasing demand for current-day occupations like urban planners, but we will also witness the development of completely new jobs as well - that is, ones with skills, titles and occupational classifications that do not currently exist today. While the very concept of smart cities has only recently come to fruition in many of the world’s metros, it is estimated that many of the future’s “smart” jobs will be derived from a set of core values including connectivity, efficiency, environmental sustainability and inclusivity.

Given this convergence, new jobs will need to be created to support this change and growth. While some future occupations will undoubtedly grow from the need for strong digital skills and expertise, others may emerge from the social considerations of smart city growth. Key predictions of in-demand future occupations include: telematics software architects, tasked with developing integrated mobile usage and autonomous vehicle monitoring systems; big data analysts, who will be responsible of analyzing the city's large data captures to generate improved practices; smart city planners, who will collaborate with other departments to minimize waste and improve city efficiency; and even a shared value officers, responsible for ensuring that all city ministries share the values of advancing sustainability practices to improve the quality of life for the city's residents [128].

While significantly more research is necessary in order to accurately estimate labour needs beyond these preliminary predictions - and in particular, as they relate to the specific needs of Canada - occupations like the above, along with many others, will sprout with the rise of smart cities. Focusing on the convergence between technology, sustainability and improved quality of life, smart cities will undoubtedly bring changes to our labour market and in many ways, they will accelerate the need for skilled talent. However, with these changes, smart cities will usher in endless opportunity. They will not only prove key to future technological growth and economic development, but they will be central to the overall sustainability and livability of our cities and communities in Canada and around the world.

SECTION THREE: AUTONOMOUS VEHICLES - A CANADIAN MARKET ANALYSIS

Autonomous Vehicles and Labour Market Changes

While Canada is not yet at the level of some global power players like the US, Germany or Japan in the AV space, our labour market will increasingly witness changes, disruptions, challenges and opportunities as AV technology becomes more developed, commonplace and accepted. Of course, these changes will take place neither drastically nor immediately. Instead, AVs will be rolled out in phases of automation, and with gradual testing and implementation.

This being said, the rise of this key technology will also usher in changes to our current labour market needs. This, similar to the result of many past technological advancements, is unavoidable. Therefore, while some jobs will see a rise in need, others will inevitably witness decline or in some cases, even displacement. However, these changes are far from beckoning the knell of the “jobpocalypse”. Autonomous vehicles may change certain occupational requirements, but they will in no way signal a large-scale loss of jobs, as is sometimes predicted. Instead, using technology that improves accessibility and inclusivity of mobility, AVs will be the source of several new and high-quality jobs created - both in the tech sector, and across the entire economy. For example, at the current time where AV technology remains fairly rudimentary in Canada, several key occupations specifically related to the field have already begun to emerge. Examples include: automotive advanced driver system engineers, automated vehicle research engineers, and autonomous vehicle trainers, among many others. At the same time, the rising need of these occupations have not functioned to displace traditional automotive-related jobs like mechanics or transit dispatchers, even though the skill needs of the latter may eventually change. This is only a glimpse into the job-creation potential that AVs can produce.

While AV-related occupations will largely facilitate the need for digitally-skilled talent, other industries will also see positive growth as a result. These include public planning, city planning, and even construction. As mentioned earlier, technology like autonomous vehicles will necessitate the redesigning of our current cities in order to operate at their optimal potential. The technological development of autonomous vehicles and the growth of smart cities are inherently linked. Moreover, AVs may also be fundamental in changing the way suburbs are structured. LinkedIn co-founder Marc Andreessen explains that autonomous vehicles may actually lead to the creation of “exurbs” - a layer beyond a city’s suburbs - the development of which will cause a significant boom in construction, effectively creating a strong need for many “non-AV” jobs [129].

AVs, Technological Advances and Occupational Change

While AVs will be the source of job creation, they will also usher in changes that will mean the reconceptualization of skills related to some of today’s occupations. For example, even though AVs will not displace police officers, they may cause the daily requirements of this role to change. With autonomous vehicles being free from human error or logic discrepancies, police officers will spend less time on highway patrols, dealing with traffic stops and - resultant of the reduced volume of collisions - investigating traffic incidents [130].

At the same time, police may be required to take on other responsibilities in the place of these - many of which will necessitate upskilling and/or retraining. Some examples of new responsibilities for police officers working with AVs may include the ability to identify, mitigate and effectively punish crimes related to cyber attacks (hacking), leading to the use of AVs for illicit purposes [131]. This is just one example of the far-reaching transformative potential of autonomous vehicles.

There is no doubt that far-reaching technological developments like autonomous vehicles will change the Canadian labour market and - in one way or another - impact numerous current-day occupations. As a result, while initially difficult to grapple with, it is likely that some jobs will be displaced due to this technology. However, the displacement of some jobs as a result of technological innovation is nothing new, and in most cases, is not a concept worth fearing. From the invention of the wheel, the first automobile, or the development of industrial farming equipment, technology has been a driver of change and growth. A 2015 Deloitte study, *Technology and People* suggests that by and large in the UK, technology has acted as a "job-creating machine" throughout human history [132]. The study asserts that over the course of the last 150 years, technology has been key in creating good-quality jobs for workers, while also being utilized to complete dangerous and/or laborious tasks in the place of humans [133]. During this time period, the most profound displacement of employment was seen across low-skilled occupations like foot-ware and leather workers, as well as weavers and knitters - both of which had seen employment decreases of 82% and 79%, from 1992 to 2014 [134]. However, while these occupations witnessed decline, the rise of high-quality jobs was exponential. Occupations in nursing, teaching, and business management had grown by 909%, 580% and 365% during the same time period [135]. Therefore, while it is inevitable that AV technology will bring forth transition and in a few cases, displacement of some jobs, the question that emerges is whether or not that is that necessarily a bad thing. Simply put: are the jobs that AVs may displace truly comparable to the high-quality opportunities that they will generate in their place?

Canadian Occupations Impacted by AV Technology

The impact that transformative technologies like AVs have on a given labour market is highly dependent on the stage at which the technology operates. While Canada still in the very early stages of AV technology, our research has identified the following characteristics that we expect to take place as connected and autonomous vehicles become more developed and utilized:

1. Occupations that are dependent on human drivers will be increasingly phased out, and eventually displaced. We anticipate that the need for these occupations will be scaled back under Level 3 automation, and fully displaced by Level 5. Appendix IV includes a list of the most relevant driver occupations in Canada, categorized by four National Occupational Codes (NOCs).

2. Some automotive-related occupations - such as mechanics - will require upskilling and/or retraining in order to provide the necessary services for autonomous vehicles. Appendix V includes a list relevant auto-related occupations in Canada, categorized by seven NOCs.

3. Some non-ICT occupations (herein referred to as auxiliary occupations) - such as police officers or EMTs - will be impacted, with many requiring upskilling and/or retraining to effectively respond to changes related to AV technology. Appendix VI includes a list of auxiliary occupations in Canada, categorized by sixteen NOCs.

4. Certain ICT jobs - such as software engineers - will see increased demand as a result of autonomous vehicle development and implantation. Appendix VII includes a list of key ICT occupations in Canada, characterized by sixteen NOCs.

Impacted Occupations: Labour Force & Employment Prospects in Canada - Considerations for Canadian Drivers

Despite the high growth witnessed in job-creating sectors like ICT and a few others, employment in industries outside of the service sector have seen little increase over the past few years. Totalling 531,283 workers in 2017, drivers - the most impacted occupational group by AV technology - comprised only 0.5% of the Canadian workforce. By comparison, ICT workers in key occupations [136] represented more than 5% of the Canadian workforce during the same period. While many occupations in sectors like ICT witness growth because they are contributing to innovation and technological development, growth and changes in other occupations like drivers can also be seen as a by-product of the development created by digitally-skilled workers.

For example, innovative services like Uber and Lyft have changed the way we think of and interact with taxis, chauffeurs and other similar roles. In January 2016, Uber accounted for a total of 22,000 drivers nationwide, 2,200 of which were female and in Toronto alone. With traditional taxi services being heavily dominated by men (over 90% of drivers [137], this represents not only a significant change in the demand for traditional taxi services, but also their very composition. Moreover, while innovative services like ride-sharing applications are changing the way we think of this industry, they also understand the long-term impact of autonomous vehicle technology. As a result, early transition plans for human drivers, like the ones highlighted by Uber, become that much more important.

While autonomous vehicle technology may eventually displace some driving occupations, it should be noted that others will take considerable time before they are significantly impacted. One key example is truck drivers. Currently, the market for professional truck drivers in Canada showcases a clear demand for these occupations. This demand is so acute that the Canadian Trucking Alliance recently released a report indicating an expected shortage of 34,000 professional truck drivers in Canada by 2024 [138]. Moreover, the demand for professional truckers is projected to continue to exceed supply in Canada for various reasons, including long distances, and extreme weather considerations specific to several Canadian provinces and territories [139]. Therefore, while companies like Uber, Tesla and Google have already piloted and begun testing prototypes for autonomous trucks [140], these are two key factors that will slow the integration of AV technology into the Canadian trucking industry. As a result, this will provide policymakers and industry a buffer of additional time in order to effectively plan appropriate training models for eventual transition.

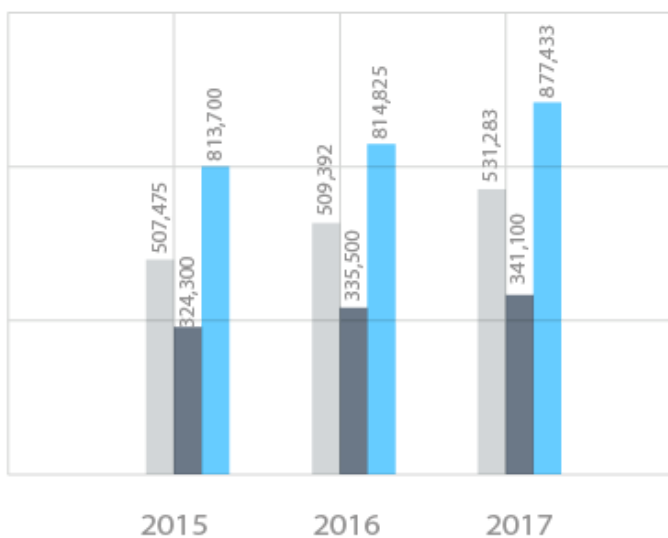
Unemployment & Labour Market Transition

As noted earlier, technological developments often create inverse impacts on the labour market. For example, while an innovative mobility solution like autonomous vehicles may eventually cause rising unemployment among human drivers, it will also spur significant growth among highly-skilled occupations such as software developers. Again, while nothing new, this is a trend that is echoed across the Canadian economy. According to Monster.ca, the Top 8 in-demand jobs in Canada's future are estimated to be: teacher, information security analyst, market research analyst, construction manager, lawyer, registered nurse, software developer and marketing manager [141]. All of these jobs are considered highly-skilled, with the majority requiring both high levels of educational attainment and experience.

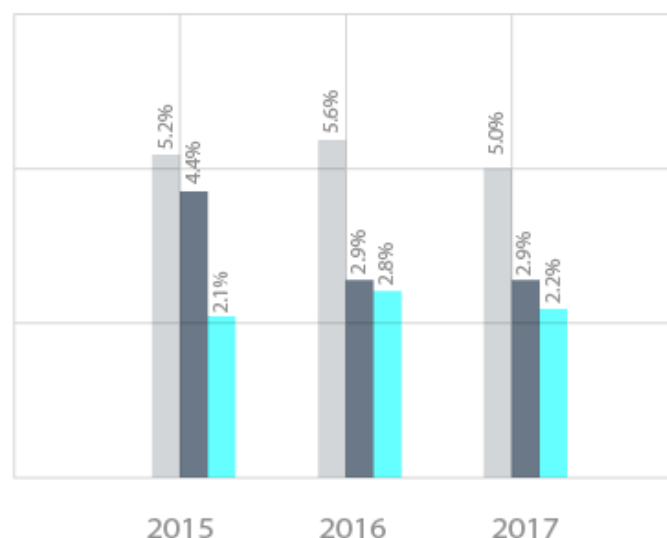
The story is no different when analyzing the current state of the Canadian labour market. When it came to top ICT occupations, overall employment grew to nearly 877,500 in 2017, with total unemployment levels dropping to 2.2%. This figure is less than 1/3rd the total unemployment rate in Canada.

Similarly, in reference to other auto-related skilled but non-ICT occupations, such as mechanics or autobody repairers, employment trends were also positive. Here, unemployment rates have dropped significantly over the past few years, totaling 2.9% in 2017, down from 4.4% only two years prior. Meanwhile, unemployment rates for low-skilled occupations such as drivers fluctuated, but overall, remained high in comparison to high-skilled occupations like the above. In 2015, unemployment rates among individuals in driver occupations totaled 5.2%. This figure continued to rise in 2016, culminating in a whopping 5.6%, prior to leveling out in 2017 at 5%. While still lower than the average unemployment rate across all industries in Canada, which in 2017 totaled 7.3%, unemployment rates tend to be higher among low-skilled occupations vs. highly-skilled ones. In the case of drivers, the unemployment rate has surpassed the rate of unemployment among ICT and auto-related occupations in each year, and more than doubled the rate of unemployment seen in the ICT sector.

Employment by Occupation



Unemployment Rates Across Occupations



Drivers
Auto-related occupations
ICT occupations
Drivers
Auto-related occupations
ICT occupations

Source: Statistics Canada, 2017.

Education Levels per Occupation Type

The results of prioritizing education in Canada are evident. Year after year, Canada has consistently topped OECD rankings for educational attainment. In 2015, Canada placed 3rd among countries with the highest level of post-secondary educated residents in the world. In 2015, nearly 60% of adults held tertiary qualifications in Canada, a figure that was more than 20% higher than the OECD average of 35% [142]. While levels of education range by region, occupation category and other identifying factors, we certainly have a lot to be proud of. More, with the understanding that individuals with advanced skills and education levels tend to do better in the labour market [143], we are on a strong pathway to ensuring continued employment for Canadians in the digital economy.

Among the occupations that our research has identified as being impacted by AV technology, the lowest levels of education were found among drivers. In 2017, 39% of Canadians employed in driver occupations noted that their highest level of education was a high school diploma. This figure was 18% higher than the national average of 21%. As a result, a relatively low percentage of individuals employed in driver occupations held a college diploma or certificate (39%) or bachelor degree (10%). Compare this to individuals employed in the most in-demand ICT roles related to autonomous vehicle technology. Here, 32% held college diplomas or certificates, 39% held bachelor degrees and another 19% held graduate university degrees. This educational discrepancy is evident across the board. While less extreme than with ICT workers, when came to auto-related occupations that will need upskilling, results indicate that 58% of employees in this group held a college diploma or certificate with another 14% holding bachelor degrees.

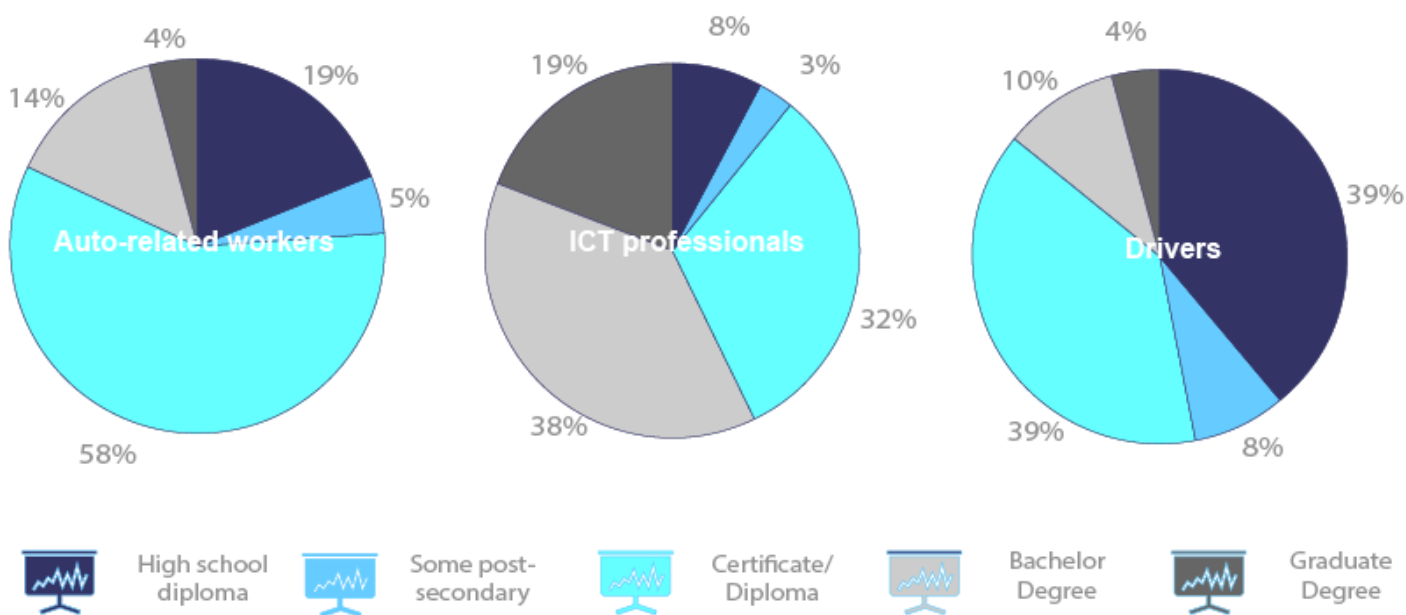
While post-secondary education is not always an indicator of success in the digital economy, with famous success stories including “Harvard’s most successful dropout” [144] Bill Gates, and Apple’s Steve Jobs, who dropped out of Reed College after only six months [145], it can often act as an influencer of future opportunities. Specifically, as referenced by Wilfrid Laurier University President Max Blouw, universities “provide the kind of broad intellectual and personal development that enables graduates to thrive in a world that is constantly changing, a world that demands innovation and adaptability [...]” [146].

The higher presence of base level post-secondary education seen among ICT and auto-related workers may very well serve as benefit in both ensuring employability in the digital economy, and leveraging relevant upskilling programs that will help them transition into an economy where AVs are prevalent.

For drivers, with considerably lower education levels, the prospects for retraining are more difficult.

Some companies, such as Uber, are already drafting plans to deal with this challenge. Indicating their willingness to provide the necessary training, including “vocational periods, education and transition periods [to help drivers deal with the rise of AV technology] way before the transition happens” [147], Uber is working on creating options for an occupation that will be impacted by new technology. By and large, it is no surprise that those employed in driver occupations will feel the first brunt of displacement as autonomous vehicles become part of our everyday lives. Compounding this reality, the relatively low level of education among this group creates an even greater sense of urgency in relation to designing and implementing training programs prior to this large-scale labour market transition.

Education Levels by Occupation



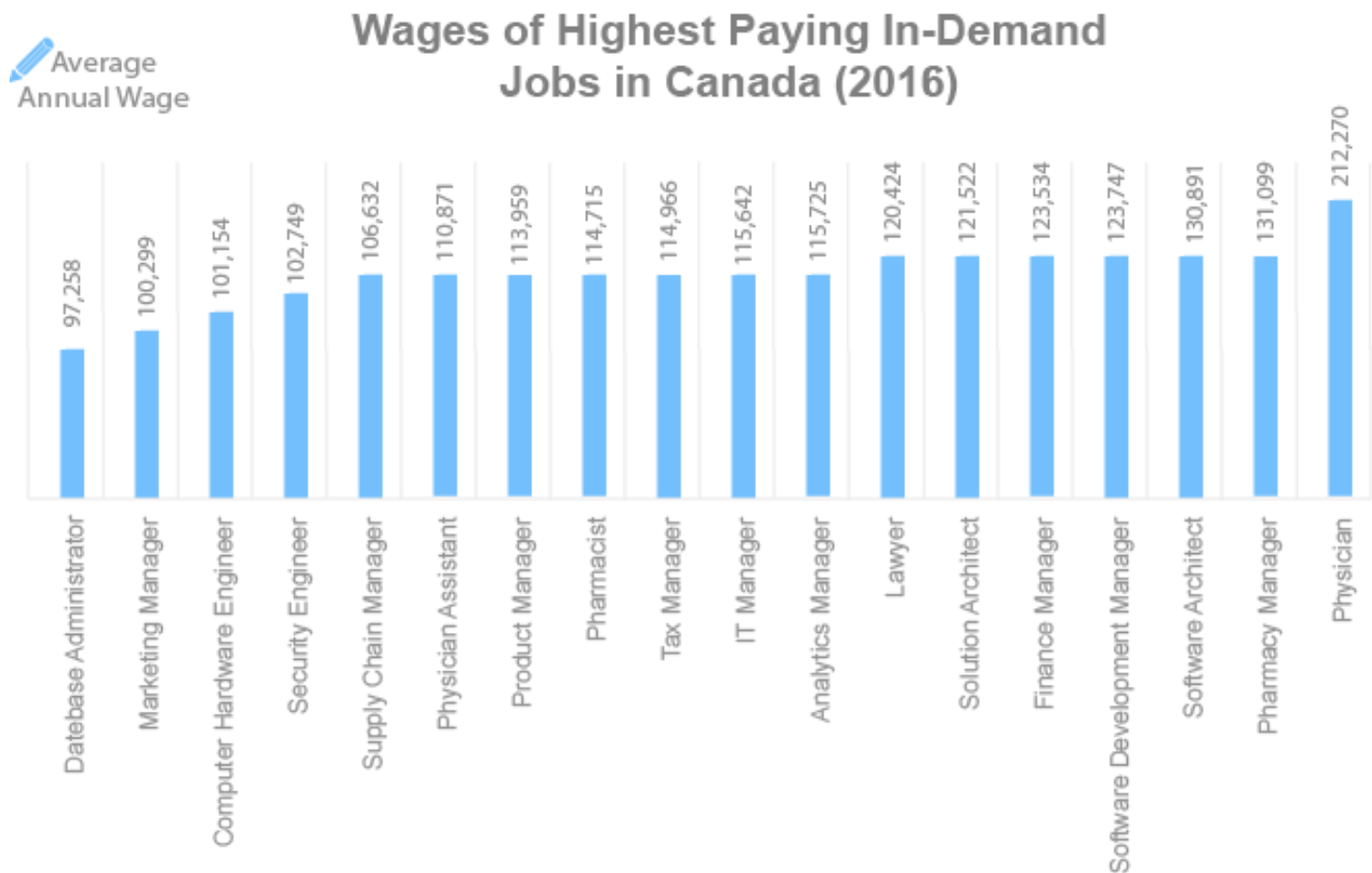
Source: Statistics Canada, 2017.

Wages, Education and Job Displacement: Who Will Feel the Brunt of Change?

With education often being so closely correlated with wages, it stands to reason that some of the highest-paid occupations would also require a high level of education. However, more and more, we are seeing that possibly just as important as the level of education, is the *type*. According to news network Slice.ca, nearly half of the 20 highest-paying in-demand occupations in Canada during 2016 were ICT-centric.

Another quarter were occupations in business and marketing. While both ICT and business employees tend to possess high levels of education, the demand for these occupations as digital transformation becomes more prevalent appears to continue to grow.

Compare the position “Computer Hardware Engineer” with an average annual salary of just over \$101,000. The minimum educational requirements for someone in this role is a Bachelor’s degree in computer engineering or a related field, while some roles may require a Master’s degree [148]. A similar trend is notable for the role of “Finance Manager”, earning an average salary of slightly over \$123,500 per year. For this role, the basic educational requirement is also a Bachelor’s degree in finance or business, while some employers may also require an MBA [149]. Both of these occupations are deemed highly in-demand.

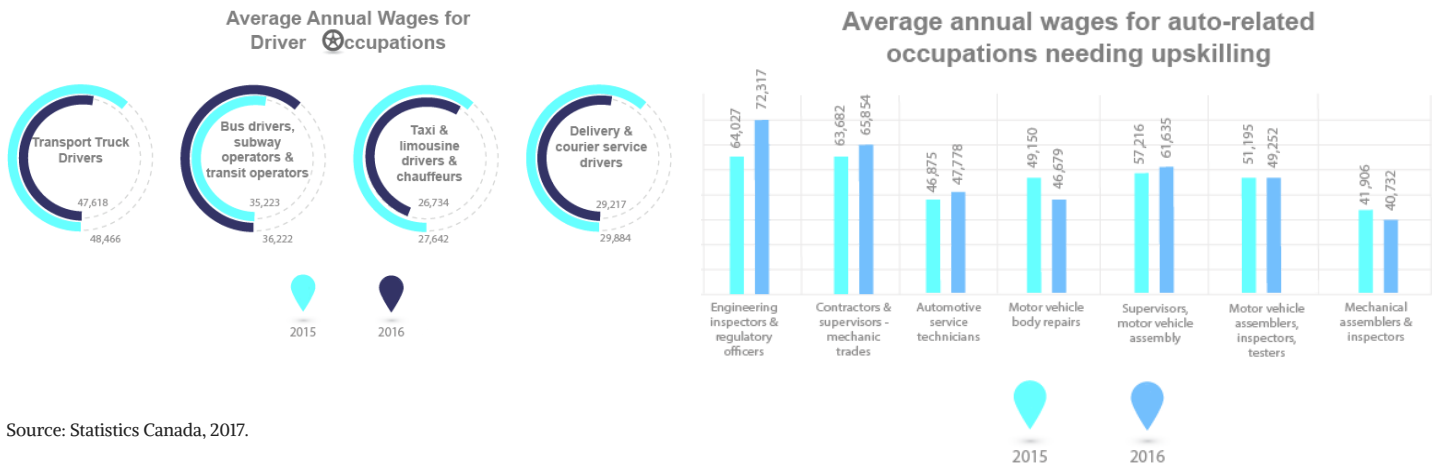


Source: Slice.ca (The Highest Paying in-demand jobs in Canada - 2016 Edition)

By contrast, the educational requirements for individuals employed in driving occupations, earning an average annual salary of \$34,948 in 2016, were much less stringent. Here, taxi drivers displayed the lowest educational base, with no formal education – secondary or post-secondary – required [150]. This corresponds to our research that suggests a high level of high school-educated individuals in this profession. Of course, this is not necessarily the norm for all driving occupations. When it came to educational requirements for truck drivers – the driving occupation that will see the slowest rate of displacement as a result of AV technology – these individuals are required to possess not only a high school diploma, but also a certificate allowing them to obtain a Class A Commercial Driver’s License (CDL) [151]. According to McKinsey Global Institute, the jobs most subject to automation are ones that are based in predictable physical work [152], and do not require in-depth analysis or social interaction. This means that while some driving occupations – such as long-haul trucker – will likely stave off displacement for the time being, occupations like taxi drivers or chauffeurs will not.

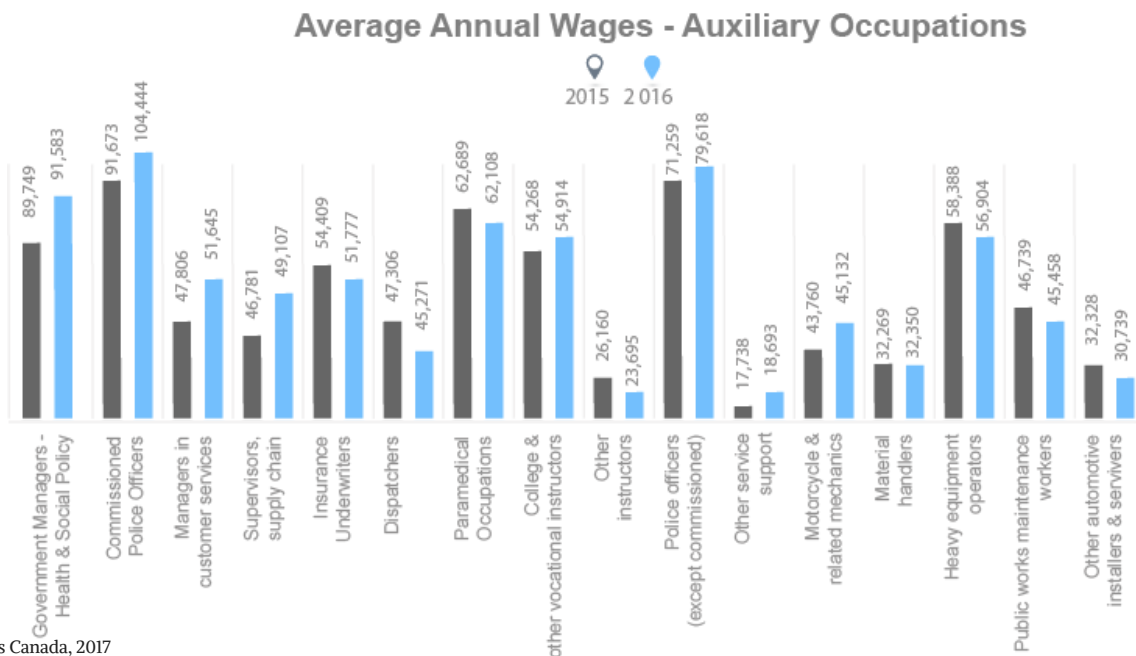
Wages Compared across Occupations: A Deeper Dive

Showing further discrepancy between driver occupations and other roles, average salaries among auto-related occupations totalled \$55,884 in 2015 and jumped by nearly 3.5% to \$57,690 in 2016 – a 65% increase from the average wage for drivers in 2016. Moreover, as AV technology becomes more robust and accepted, it is possible that the wages for these occupations will increase even further. With individuals employed in these roles receiving training opportunities specifically related to the maintenance of autonomous vehicles, the demand for these types of roles may also rise. Take for example occupations under NOC 7322 Motor Vehicle Body Repair. Individuals employed in these occupations will undoubtedly face a lull in need, when it comes to current skill sets. With fewer accidents, the traditional expertise of mechanics will become less valuable as their services are less demanded [153]. However, as workers in this field become retrained to accommodate changes that AVs will bring, this will change not only the nature of their work, but the repair process itself. For example, it is predicted that autonomous vehicles will be able to take themselves to the repair shop, inform the mechanic of what needs to be fixed, and even set a timeline for expected completion [154]. This means that traditional mechanics will need to be retrained in order to effectively and efficiently understand these vehicles, – including human machine interface training – to work with them, and to perform the necessary repairs.



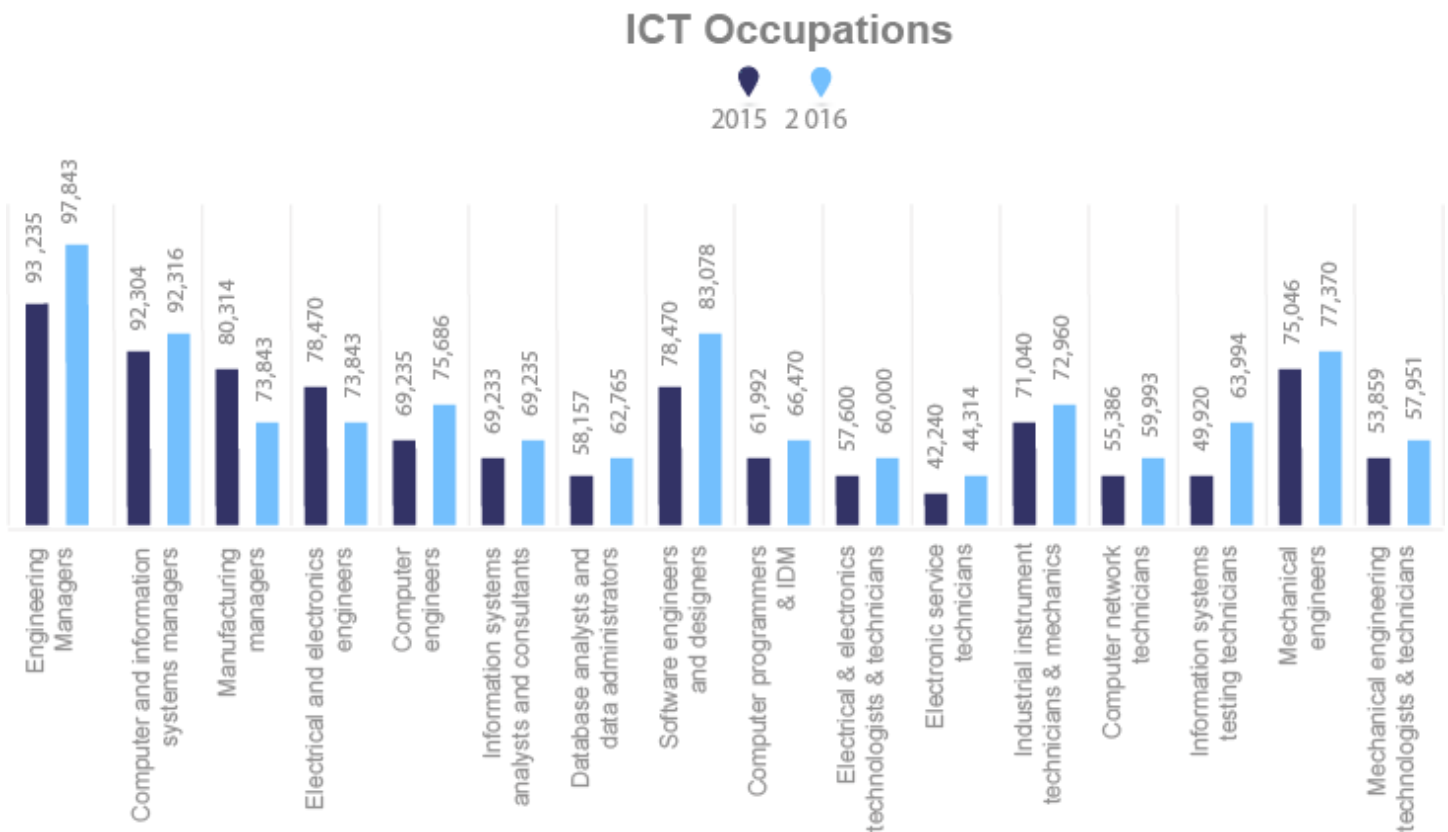
Source: Statistics Canada, 2017.

A similar trend is also possible for auxiliary workers, including occupations such as police officers, insurance underwriters and others. Averaging \$51,458 in 2015, wages for individuals employed in these occupations rose by nearly 2.5% to \$52,715 in 2016 - a 51% increase from the average annual wages of drivers. More, AV technology will inevitably change the demands and roles of some of these occupations. Take for example NOC 1313 Insurance Underwriters. Autonomous vehicles will not only change our city streets, but they will change the regulatory mechanisms and standards associated with all vehicles. As a result, insurance policies will need to be amended in order to accommodate vehicles that can drive themselves, and as a result are not subject to human error or personal characteristics - the bulk of data used to design current insurance policies. Therefore, insurance underwriters will need to be trained to identify new and different risks associated with AVs - such as software malfunction in bad weather, for example - rather than risks associated with the human in the vehicle. Once standardized, these entirely new risks can be compiled to determine premiums, the extent of coverage, rate tables and other key elements of the role.



Source: Statistics Canada, 2017

This being said, by far, the highest salaries were found to be among the most in-demand workers in the future of AV technology: ICT workers. In 2015, ICT wages totaled \$67,906, jumping to \$70,706 in 2016. At \$70,706, the wages of ICT workers were 102% higher than the average wage for drivers. More, as autonomous vehicle technology becomes more developed, more streamlined and implemented at a higher rate, the possibility of continued wage increase among occupations in this category is strong. ICT workers like software engineers, database analysts, computer engineers and others are cornerstone to the development and enhancement of autonomous vehicles. As a result, as the demand for these vehicles increases, so will the demand for the ICT occupations that support them. With increased job demand often comes increased wages.



Source: Statistics Canada, 2017

Skills, Talent and Changing Job Opportunities

In the AV space, a variety of skills – some vastly different from those currently available in the labour market – will be required to effectively design, develop and deploy autonomous vehicles effectively and safely. Undoubtedly, traditional Science, Technology, Engineering and Math (STEM) skills will still form an essential part of the equation, often acting as the foundation upon which extended skills such as artificial intelligence and deep learning can be based off of.

More specifically, components of current ICT roles, including cyber security, wireless data communications, machine learning and telematics will also be vital [155].

These changing skill requirements will work to generate new and shifting opportunities in several sectors of the economy, including manufacturing, transportation, engineering and the tech sector. With these opportunities, however, comes the challenge of ensuring that, a) individuals in in-demand roles possess the right combination of skills to grow the technology; b) individuals in roles that will require upskilling receive the new training they need to remain functional as the technology changes, and c) individuals in roles that will be increasingly phased out, are retrained now, in order to transition to new roles and continue to participate in the economy.

Appendix VIII provides a preliminary comparison of current-day AV occupations and their related skillsets.

Forecast: ICT Employment in Canada's AV Industry 2017-2021

The growth and expansion of autonomous vehicle technology around the world is something that is guaranteed to drive unprecedented change in the way we get around, the way we work and the way we live our lives. Canada, while not quite at the pace of AV powerhouses like the United States, Germany or Japan, has recently begun to etch the beginnings of a road forward in this revolutionary field. Through focusing on streamlining connected vehicles, and taking the first steps towards the development of AV technology, Canada is lighting its pathway in this crucial area of innovation.

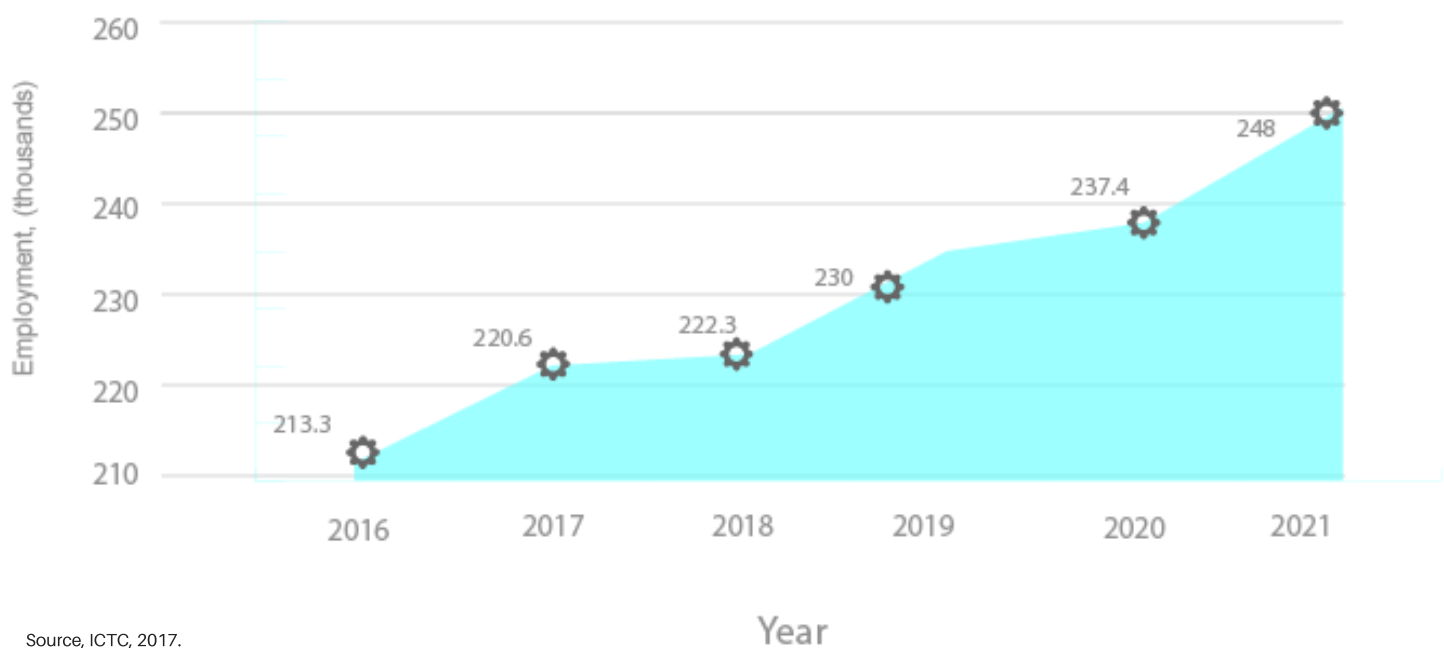
As a result, the demand for talent in this field is set to see considerable growth, and become more pronounced as we expand our capacity to participate on a global level. The rising need for ICT-skilled talent will vary, with abilities ranging from creating the software to operate the AI systems that run the vehicle, to network engineers who can manage the cloud computing system that stores and transmits the data, to mechanical and electrical engineers that will be needed to actually build and configure the vehicle.

Some of these occupations already exist, while some of them will emerge with the development of the technology. In 2016, our research indicates that there were approximately 213,300 engineers and ICT-skilled talent working in connected and autonomous vehicle (CAV) related industries in Canada.

With knowledge that these occupations will become more and more needed as AV technology continues to grow and develop, we have generated a forecast to estimate the demand for key ICT and engineering talent over the next 5 years.

Understanding that Canada will likely not reach Level 5 Automation within the next 5 years, we have analyzed the estimated growth rate of connected and autonomous vehicle technology (CAV) in Canada until 2021. Completing an analysis of the estimated market value of AV and connected vehicle technology in Canada, we have utilized 16 Top ICT and engineering occupational categories (NOCs), across a combination of industry categories that are relevant for the automotive sector in Canada. Under this methodology, our research indicates that Canada will see a growth of 34,700 new jobs in the connected and autonomous vehicle (CAV) industry by 2021, growing by a CAGR of more than 3% over the period.

**CAV Talent Employment Growth:
2017-2021**



Source, ICTC, 2017.

Given this increased demand, along with the growth and implementation of connected and autonomous vehicle technology, it is crucial that we take steps now in order to ensure that Canada remains competitive in this quickly-developing and revolutionary field.

Conclusion

Autonomous vehicles are born out of technology, but they are agents of change. They will alter the way our cities are structured, how we view workplace productivity, and ultimately, they will change how we live. Based in revolutionary features like telematics and 5G that collect and transmit data, to artificial intelligence that analyzes and interprets the meaning behind that data, AVs are quickly redefining the meaning of mobility. The implications of this are anything but negligible.

With the rise and development of their key technological components, autonomous vehicles are already showing impressive results. Recent studies highlight the safety advantages of AVs through performance comparisons with humans. Here, driving the same distance, the severe accident ratio for AVs was 1/4th that of the accident ratio of human drivers. Considering the nearly 2,000 Canadians that die each year due to car accidents, the safety assurance of AVs is compelling.

More, the rise of autonomous vehicles will be key in opening up pathways for inclusivity, improved diversity and broadened options for community and economic integration for many of Canada's underrepresented groups. Offering enhanced options for transit, AVs will provide avenues for economic entry, as well as community engagement for groups that are currently experiencing challenges with mobility. This includes the elderly, persons with disabilities, Indigenous peoples, individuals that live in rural or remote areas, and many others. Increasing inclusivity is key to not only in ensuring economic development and labour market success, but to securing the pathway for improved quality of life for all Canadians.

Of course, these changes won't happen overnight or in isolation. While we have quite a way to go before we can effectively compete with global AV leaders, we realize that this pathway must come equipped with changes to our cities and communities. For AVs to become a mobility leader in our societies, they will need to be supported by a smart city foundation. As a result, our cities will need to undertake some restructuring, including the development of smart infrastructure with the ability to effectively communicate with AVs at a fast speed. Key commitments seen in Budget 2017, including the Smart Cities Challenge, represent important first steps in this direction. Undoubtedly, the development of AV technology and the enhancing of connectivity within our cities must, in many ways, go hand in hand.

Discounting recent positive developments, many would argue that Canada's progress in the autonomous vehicle space has been slow, in comparison to other jurisdictions around the world. In the US, Google's Waymo has already driven more than 3 million miles. In Germany, the state has already enshrined legislation for the use of AVs on public streets. Compared to developments like these, Canada's progress seems sluggish. However, while we have a long way to go before we can compete with autonomous technology powerhouses like the US, Germany or Japan, positive trends are beginning to surface. 2016 and 2017 saw clear commitments to the development of AV technology in Canada. In early 2016, GM committed to hiring more than 1,000 new AV-specific positions over the next few years in Oshawa, while also opening an AV software development centre in Markham. A year later, the 2017 Ontario budget included funding for the development of an AV testing zone in Stratford, and later that year, significant investments were made by QNX and Ford. The former announced that they would begin testing AVs on Ottawa streets by fall or winter 2017. The latter committed nearly \$340 million towards the development of an AV research centre in Ottawa, that so far, has been primed to generate more than 300 new highly-skilled AV-related jobs in the city. And this is just the beginning.

Building on the recent investments made towards this technology, Canada is set to see considerable growth in the demand for ICT and engineering skilled occupations, vital to the development of our connected and autonomous vehicle (CAV) networks. Totalling a growth of 34,700 over the next 5 years, these include key roles like software developers, needed to create and refine the AI technology that helps AVs interpret the world around them; as well as mechanical engineers, needed to design and build the moving pieces of these vehicles. This development is one that will bring about significant positive change to the labour market in Canada, yet along with it, even introduce challenges including the eventual displacement of some occupations - the most obvious being drivers. However, as seen time and time again, technology has been a propellant of economic growth and the creation of high-quality jobs. Therefore, while AVs will usher in transformative elements to our labour market - some of which may be initially challenging - overall, this change will generate the development of high-paying, high-quality jobs for Canadians across all sectors.

Revolutionary innovations like autonomous vehicles are guaranteed to change the way we travel, the way we connect and communicate with one another, and the way we live our lives.

They will produce benefits including inclusivity and diversity, as well as increased productivity and enhanced road safety. Of course, at the same time, they will be central in the re-shaping of our cities and communities, as well as many of our occupations across industry lines. AVs mean that police officers will need to be retrained to focus on cybersecurity incidents, rather than traffic accidents. Mechanics will need to be retrained in order to effectively understand and communicate with AVs, and even seemingly unrelated occupations like policy analysts and economists will need to be trained to identify the key societal implications of AVs. These include the healthcare considerations resulting from a reduction in road accidents, and the GDP impact of increased economic participation of underrepresented groups. Needless to say, the rise of AVs will disrupt our current state of being significantly, and with this disruption, bring a wide array of opportunities, whose successful leveraging will be deeply tied to our ability to compete. Competing on a global scale means supporting growth and innovation. Leveraging future opportunities like the ones brought forth by autonomous vehicles, means preparing for them today.

SECTION FOUR: RECOMMENDATIONS

- 1.** Greater integration and discussion among policymakers, industry and academia is suggested in order to facilitate investments for the purpose of developing, testing and utilizing autonomous vehicle technology in Canada at a rate closer to our international competitors.
- 2.** Greater discussion and collaboration among policymakers and academia, as well as international subject matter experts, is suggested in order to properly identify options for regulatory standards needed to govern the use of autonomous vehicles on Canadian streets.
- 3.** Policymakers, in combination with industry, academia and other relevant parties, should work on furthering research necessary in order to identify the specific linkages between autonomous vehicles and smart city development in Canada. This includes the relative capacity for implementation of smart cities and communities across Canada, the key technologies needed to drive smart city growth and large-scale AV-adoption - including 5G, telematics, AI, sensors, and others - as well as the key labour market impacts of these developments across Canadian regions and municipalities.

4. Policymakers, in combination with industry, academia and/or other relevant parties should work on furthering research related to the identification of the total Canadian autonomous vehicle market share. This includes identifying the market activities of relevant companies working on developing autonomous vehicle technology, components and/or products. Doing so will allow for the generation of reliable and sustainable forecasting tools, able to generate a detailed understanding of AV job growth and skill needs across a long-term time frame.

5. Policymakers, in combination with industry, academia, and other relevant parties, should work on furthering research related to the broader social impacts of large-scale autonomous vehicle implementation in Canada. This includes the broad impacts of this technology on the integration of underrepresented groups into the labour market, and the furthering and promoting of diversity in our communities.

Appendix I: Research Methodology & Forecast

Research Methodology

In the interest of accurately understanding the development of autonomous vehicle technology, along with its impacts on the Canadian labour market, the methodological framework of this report utilized a combination of data sources and methods of analysis. These include: the most relevant and up to date secondary data related to components like occupational codes across a variety of industries; wages; educational backgrounds; employment rates; gender and age composition, among others. This data was extracted primarily via Statistics Canada's Labour Force Survey, and used to identify key labour market trends. Secondly, a thorough literature review was conducted in order to identify and analyze reports and other works displaying the most timely and relevant findings, as related to autonomous vehicles and smart cities, worldwide and in Canada. Lastly, these two data streams were supported and validated by key insights and feedback extracted through a) 3 advisory group meetings with leaders in the field of autonomous vehicle technology, as well as labour market experts; and b) 12 key informant interviews conducted with subject matter experts in the field.

The author and contributors of this report made every effort to ensure accuracy and timeliness of this research, while linking key developments to impacts on the Canadian labour market. That said, additional research is required in order to analyze time-based trends and developments going forward. Please see *Appendix II, Limitations of Research* for more details.

Forecast Methodology

With the aim of connecting the growth of autonomous vehicle technology in Canada to impacts on the labour market, we have completed a forecast of employment demand across top occupations related to the connected and autonomous vehicle (CAV) industry in Canada. Our research has identified the following ICT occupations - classified by National Occupational Codes (NOC)s - to be most in-demand in Canada, as CAV industries grow between 2017-2021:

- 0211** Engineering managers
- 0213** Computer and information systems managers
- 0911** Manufacturing managers
- 2132** Mechanical engineers
- 2133** Electrical and electronics engineers
- 2147** Computer engineers (except software engineers and designers)
- 2171** Information systems analysts and consultants
- 2172** Database analysts and data administrators
- 2173** Software engineers and designers
- 2174** Computer programmers and interactive media developers
- 2232** Mechanical engineering technologists and technicians
- 2241** Electrical and electronics engineering technologists and technicians
- 2242** Electronic service technicians (household and business equipment)
- 2243** Industrial instrument technicians and mechanics
- 2281** Computer network technicians
- 2283** Information systems testing technicians

While CAV technology will eventually reach and create impacts on a variety of industries across the Canadian economy, our research has suggested that, as a result of the rudimentary stages of this development in Canada, the significant labour market impacts of this technology will be primarily felt among the following industries - classified by the North American Industry Classification System (NAICS) - between 2017-2021:

NACIS 31-33 Manufacturing

NAICS 48-49 Transportation and warehousing

NAICS 51 Information and cultural industries

Painting the picture of the intersection between the most in-demand occupations across the most affected industries, we have utilized historical data from Statistics Canada's Labour Force Survey (2009 - 2016) to calculate the number the above-noted ICT CAV professionals (NOC codes) working in the above-noted CAV industries (NAICS). Smothers -based forecasting models and univariate time-series models were used to predict the labour demand for CAV talent. This projection is intended to act as a baseline estimation of talent needs in Canada due to autonomous vehicle technology growth and development. Additional research, including an in-depth understanding of AV market share and a time-based analysis of industry growth, is necessary to be able to accurately forecast labour needs across industries. Please see Appendix II, Limitations of Research, for more details.

Appendix II: Limitations of Research

Autonomous vehicle technology, as well as the implementation of these vehicles in real-life settings is still a relatively new concept. In fact, for most countries, this notion is considered uncharted territory. In Canada, we are only now becoming engaged with the foundational basis for autonomous technology, despite having contributed to the development of connected vehicles for some time. As a result, we have identified some key limitations of research throughout our study, specifically as they relate to accurately forecasting job growth. Additional time, research and AV-related developments by relevant contributors to the field are necessary to paint a detailed understanding of Canada's future labour needs in CAV industries.

Primarily, we were limited in our ability to forecast the labour market needs for occupations related only to autonomous vehicle technology beyond an educated estimation. As a result, our forecast is based on a combination of connected and autonomous vehicle market share. Under this methodology, we were able to estimate the potential impact of CAV technology on key sectors in Canada over the next 5-year period, based on primary research with relevant industry leaders. Once identified, we then facilitated our labour market intelligence as well as key insights derived from primary research in order to estimate labour demand for CAV talent over the next 5 years. Again, given that Canada's current role in this new industry is rudimentary, we are unable to forecast past this timeline. More research is required in order to forecast labour demand beyond this level and beyond this timeframe.

Secondly, given the rudimentary phase of AV technology in Canada, and a level of AV automation that has not surpassed Level 3 in any country, we are unable to realistically indicate an appropriate timeframe for further automation (i.e. to Level 4 and 5). As a result, we are unable to state with confidence which occupations will be most subject to risk, according to what timeline. Further research is required in order to identify a realistic timeline for automation levels applicable to autonomous vehicle technology both globally, as well as specific to Canada. Further research is also required to properly analyze and assess the development of smart cities, as they are directly tied to large-scale AV implementation. Lastly, further research is necessary in order to identify the characteristics that are unique Canada - including vast land masses, long travel distances, severe weather conditions, remote locations, and others - in order to accurately understand how those characteristics may impact the growth and progress of CAV technology nationally, as well as regionally and at municipal levels.

Appendix III: Table of in-demand Occupations for Smart Cities

NOC	NOC Title	Sample Occupations	Occupational changes due to Smart Cities
0016	Senior managers: construction, transportation, production and utilities	CFO – Urban transit system General manager – trucking company VP – electric power company	- Infrastructure sensor training - Electric use/monitoring training for autonomous vehicles, other intelligent transit options, and connected power grids
0212	Architecture & science managers	Architectural manager Landscape architecture manager Statistical service manager	- Architecture design training for stacked urban structures - Architecture design for vertical utilization of farm land - Statistical analysis training for increased efficiency in land use
0731	Managers in transportation	Distribution manager – logistics Freight forwarding manager Transportation department manager	- Autonomous and connected vehicle training - Logistical training related autonomous intelligent transit systems (buses, trains, etc.)

1526	Transportation route and crew schedulers	Crew scheduler – transportation Schedule analyst Transit scheduler	- Route planning and logistics training for autonomous and connected vehicles (including the analysis for planned routes, outcomes, traffic and weather incidents, etc.) *Over time, there will be a gradual displacement of these occupations
2131	Civil engineers	Civil Engineer Environmental Engineer Project Engineer – construction	- Design and structural integrity training related to stacked urban buildings - Environmental analytics training for clean energy use and monitoring in smart cities
2153	Urban and land use planners	Community and urban planner Environmental planner	- Surplus land use training, resultant of urban space conservation (stacked
		Municipal planner	dwelling, reduced need for parking space) - Best practice training for smart city grid development and multi-level connectivity (AVs, connected traffic lights, sensor-equipped buildings, etc.)
2231	Civil engineering technologists & technicians	Civil engineering technician Highway technician Structural investigator	- Highway construction and logistics training for use by autonomous vehicles - Structural training related highway design (significant reduction in road traffic with mass use of AVs)
2254	Land survey technologists & technicians	Engineering survey technologist Geomatics technologist – land surveying Land survey technician	- Land and spatial surveying training for optimization of available land masses

4161	Natural & applied science policy researchers, consultants & officers	Energy policy analyst Environmental impact analyst Transportation safety analyst	- Training for analysis of safety records and performance of autonomous vehicles - Training for analysis of outputs resultant of energy policies related to clean energy use in smart cities
4162	Economists & economic policy researchers & analysts	Economic advisor Economic policy analyst Industrial economist	- Economic analysis training for outputs of smart cities – i.e. how they impact productivity, efficiency, inclusivity, economic performance, GDP growth, etc.
7305	Supervisors, motor transit and other ground transit operators	Foreman/woman Urban transit system supervisor Supervisor, light rail transit operators	- Training for the supervision of autonomous vehicles used as urban transit *Over time, there will be a gradual displacement of these occupations

Appendix IV: Table of Driver Occupations to be Impacted by Autonomous Vehicles

NOC	NOC Title	Sample Occupations
7511	Transport truck drivers	Bulk goods truck driver Explosives truck driver Freight truck driver Long distance truck driver
7512	Bus drivers: subway operators and other transit operators	Bus driver Long distance bus driver Urban transit driver
7513	Taxi and limousine drivers and chauffeurs	Airport limousine driver Company chauffeur Taxi driver
7514	Delivery and courier service drivers	Courier service driver Delivery driver Mail service courier

Appendix V: Table of Auto-Related Occupations to be Impacted by Autonomous Vehicles

NOC	NOC Title	Sample Occupations	Occupational Changes with AV Technology
2262	Engineering inspectors and regulatory officers	<p>Engineering inspector</p> <p>Insurance loss prevention inspector</p> <p>Motor vehicle defects investigator</p>	<p>- Training related to the implementation of legislation and/or insurance amendments for autonomous vehicle use (i.e. liability in the event of a collision, regions for allowed use, etc.)</p> <p>- Training to facilitate the understanding of autonomous vehicle defects (as identified by the AV itself, and upon investigation) as well as limitations (as identified by</p>
			the manufacturer, according to version)
7301	Contractors and supervisors: mechanic trades	<p>Foreman/women – heavy-duty equipment mechanics</p> <p>Supervisor – motor vehicle repair shop</p> <p>Supervisor – small-engine repair shop</p>	<p>- Mechanic training for the identification, understanding and analysis of data regarding a repair as provided by the AV (i.e. human machine interface training)</p> <p>- Mechanic training in relation to how to properly repair an autonomous vehicle (including diagnostic testing, specific tool use, etc.)</p>

7321	Automotive service technicians: truck and bus mechanics and mechanical repairers	Automotive mechanic Automotive service technician Bus mechanic	- Mechanic training for the identification, understanding and analysis of data regarding a repair as provided by the AV (i.e. human machine interface training) - Mechanic training in relation to how to properly repair an autonomous vehicle (including diagnostic testing, specific tool use, etc.)
7322	Motor vehicle body repair	Foreman/woman – electrical mechanics Supervisor – industrial mechanics Supervisor – motor vehicle repair shop	- Mechanic training for the identification, understanding and analysis of data regarding a repair as provided by the AV (i.e. human machine interface training) - Supervisor training on diagnostic identification and testing compliance procedures
9221	Supervisors: motor vehicle assembling	Assembly foreman/woman – motor vehicle manufacturing Supervisor – assembly – motor vehicle manufacturing	- Assembler training on handling autonomous vehicle parts - Supervisor training on autonomous vehicle circuit
			board inspection and quality control procedures
9522	Motor vehicle assemblers, inspectors and testers	Car assembler Body assembler – motor vehicle manufacturing Auto assembly worker	- Assembler training on handling autonomous vehicle parts - Assembler training on quality control procedures
9526	Mechanical assemblers and inspectors	Truck assembler Mechanical assembler Transmission assembler	- Assembler training on handling autonomous truck parts

Appendix VI: Table of Auxiliary Occupations to be Impacted by Autonomous Vehicles

NOC	NOC Title	Sample Occupations	Occupational Changes with AV Technology
0411	Government managers: health and social policy development and program administration	Health program operations manager – government services City medical officer of health – government services Social services planning manager – government services	- Cybersecurity training related to handling and transmitting passenger health data received from and transmitted to autonomous vehicles - Training for long-term planning for social services that are impacted by autonomous vehicles (i.e. fewer collisions may result in a reduced need for spending on healthcare)
0431	Commissioned police officers	Deputy police chief Police chief RCMP	- Training related to the handling of cybersecurity/terrorism incidents as they correspond with the compromise of autonomous vehicles - Police training in relation to new legislation surrounding the
			appropriate use of autonomous vehicles on city streets
0651	Managers in customer and professional services, n.e.c. (driving school manager)	Driving school manager	- Driving school instructor training related to appropriate passenger procedure when traveling in an autonomous vehicle *Over time, there will be a gradual displacement of these occupations
1215	Supervisors: supply chain, tracking and scheduling co-ordination occupations	Dispatch logistician Lead shipper	- Logistical training and route design for optimal navigation by autonomous vehicles (i.e. avoiding bad weather, unpaved roads, etc.)

1313	Insurance underwriters	Group underwriter Insurance underwriter Liability underwriter	- Training in order to accommodate changes to insurance policies and liability constraints associated with autonomous vehicles - Identification of characteristics for analysis (of AVs) and analysis of individual usage, used to determine policy rules, premium rates, subscription needs
1525	Dispatchers	911 dispatcher Ambulance dispatcher Taxi dispatcher	- Logistical training and route planning for optimal time saving (i.e. avoidance of unpaved roads, roads that are not well lit, etc.) *Over time, there will be a gradual displacement of these occupations
3234	Paramedical occupations	Critical care paramedic Paramedic, emergency medical technician (EMT)	- Human machine interface training needed for EMT professionals to understand key diagnostics and/or data transmitted by the autonomous vehicle
			- Training related to route planning for optimal time savings
4021	College and other vocational instructors	College teacher Company trainer Lecturer – college	- Instructor training related to teaching material that touches on autonomous technology
4216	Other instructors	Driving instructor Motorcycle driving instructor	- Instructor training related to appropriate procedures for autonomous vehicle passengers *Over time, there will be a gradual displacement of these occupations

4311	Police officers	Constable Detective – police RCMP officer	- Training related to the handling of cybersecurity/terrorism incidents as they correspond with the compromise of autonomous vehicles - Police training in relation to new legislation surrounding the appropriate use of autonomous vehicles on city streets
6742	Other service support occupations, n.e.c.	Car jockey Parking lot attendant Hotel valet	- Training related to appropriate procedures for “summoning” and storing autonomous vehicles *Over time, there will be a gradual displacement of these occupations
7334	Motorcycle, all-terrain vehicle and other related mechanics	Industrial truck repairer Forklift mechanic, all-terrain vehicle repair	- Mechanic training related to the analysis of data and/or diagnostic reports sent by the vehicles (i.e. human machine interface training)
			- Mechanic training for heavy-duty autonomous vehicle repair procedures and tool usage
7452	Material handlers	Forklift truck operator Material handler Truck loader	- Training for loaders to understand the diagnostics and/or data transmitted by the vehicle (human machine interface training) *Over time, there will be a gradual displacement of these occupations
7521	Heavy equipment operators	Heavy equipment operator Excavator operator	- Training in relation the use of heavy-duty autonomous equipment *Over time, there will be a gradual displacement of these occupations

7522	Public works maintenance equipment operators and related workers	Garbage truck driver Salt truck operator Snow removal operator – public works	- Training for large autonomous vehicle operators to respond to incumbent weather (i.e. snow, sleet, ice, etc.)
7535	Other automotive mechanical installers and services	Heavy equipment servicer Tire repairer Muffler installer	- Mechanic training in relation to understanding the diagnostics and/or data that the autonomous vehicle is sending (human machine interface training) - Mechanic training in relation to the proper procedures for servicing a heavy-duty autonomous vehicle

Appendix VII: Table of ICT Occupations to Witness Increased Demand as a Result of Autonomous Vehicles

NOC Code	NOC Title	Sample Occupations	Occupational changes with AV Technology
0211	Engineering managers	Civil engineering division manager Production manager	- Training related to the management of prototype design and structural
		Service manager	analysis for autonomous vehicles - Quality assurance training related to the appropriate procedures for testing and inspection of autonomous vehicle parts
0213	Computer & information systems managers	Information systems manager Systems development manager Computer systems manager	- Training related to the cloud storage and transmission of passenger information data, in compliance with data protection legislation - Quality assurance training for large data storage

0911	Manufacturing managers	Automobile production manager Manufacturing plant manager	- Quality assurance training for autonomous vehicle body inspection and testing
2132	Mechanical engineers	Mechanical engineer Robotics engineer	- Training related to robotics and/or electrical systems testing in autonomous vehicles
2133	Electrical & electronics engineers	Control systems engineer Electrical engineer Electronics engineer	- Electrical wiring and configuration training in relation to the development and utilization of vehicle-mounted sensors - Electronic training for internal vehicle functionality
2147	Computer engineers (except software engineers & designers)	Computer hardware engineer Network test engineer Systems designer – hardware	- Training related to relevant programming languages (i.e. CAN, Flexray, etc.) - Training related to the development of strong human machine interface for autonomous vehicles - Training for diagnostic code testing and error identification among autonomous vehicle software
2171	Information systems analysts & consultants	Computer systems analyst Informatics security analyst Systems security analyst	- Cybersecurity training related to the appropriate transmission and storage of sensitive personal data captured from the autonomous vehicle on the passengers - Cybersecurity training for the early identification and mitigation of cyber attacks and/or data compromises - Training related to the compliance of relevant cybersecurity legislation regarding the use and storage of passenger data

2172	Database analysts & data administrators	Data administrator Database analyst Database architect	- Training related to the large-scale control and monitoring of autonomous vehicle databases (i.e. cloud databases, data transmitted from in-car sensors, transmitted passenger data)
2173	Software engineers and designers	Computer software engineer Embedded software engineer Software testing engineer	- Training related to diagnostic testing of autonomous vehicles - Training related to the use of artificial intelligence to interpret data for the facilitate improved response times, accurate decision-making and the improvement of safety features of autonomous vehicles
2174	Computer programmers & interactive media developers	Web programmer Systems programmer Computer programmer	- Training for the development of robust human machine interfaces - Diagnostic training for the testing of code used in autonomous vehicle software
2232	Mechanical engineering	Machine designer	- Training related to the use of car-mounted sensors
	technologists & technicians	Thermal station designer Mould designer	- Design training related to heat and thermal regulation in autonomous vehicles for optimal passenger comfort
2241	Electrical & electronics engineering technologists and technicians	Electrical engineering technician Electrical engineering technologist Electrical technician	- Electrical wiring and configuration training in relation to the development and utilization of vehicle-mounted sensors - Electronic training for internal vehicle functionality

2242	Electronic service technicians (household and business equipment)	Electronics technician Electronic equipment repairer Computer service technician	<ul style="list-style-type: none"> - Electrical wiring and configuration training in relation to the development and utilization of vehicle-mounted sensors - Electronic training for internal vehicle functionality - Electrical training to respond to household electrical requirements where autonomous vehicles are stored (i.e. in-home charging stations, etc.)
2243	Industrial instrument technicians and mechanics	Instrument technician Industrial instrument mechanic	<ul style="list-style-type: none"> - Mechanic training related to the diagnostic identification of industrial equipment (i.e. components of autonomous vehicles)
2281	Computer network technicians	Network administrator Computer network technician Systems administrator	<ul style="list-style-type: none"> - Training related to the development, use, large-scale implementation and monitoring of massive information-transfer networks such as 5G
2283	Information systems testing technicians	Application tester Systems tester Software tester	<ul style="list-style-type: none"> - Training related to the appropriate analysis of diagnostic messages - Training related to the development of procedures
			to respond to diagnostics and mitigate future instances

Appendix VIII: Table of Autonomous Vehicle Occupations and Corresponding Skill Requirements

Job Titles – In-demand Occupations	Skill Needs	“Nice to have” skills
Autonomous Systems Machine Learning Specialist Automated Driving Engineer Software Engineer – Robotics Vehicle Lab Manager Automated Driving Research Engineer – Embedded Software Autonomous Vehicle Platform Systems Engineer Software Engineer – Perception Operations Specialist – Autonomous Driving Test Test Driver ADAS Mechanical Engineer Fusion Algorithm Development Engineer Hardware Development Engineer – Robotics Vehicle Application Engineer	<ul style="list-style-type: none"> Widespread programming background (Java, Python, JavaScript, etc.) Cloud services development Machine Learning Java Spring framework Azure / AWS Messaging protocols (DDS, MQTT, AMQP) experience in testing Android experience with test automation framework, tool development Knowledge of Scrum/Agile software development process Embedded software development Experience with vehicle communication network protocols (CAN, MOST etc) Experience testing interactivity of desktop (Windows and OS X) controlling hardware products Automation tool and scripting experience for both front end and APIs (e.g. Python & Ruby, shell, etc.) Embedded C programming, Matlab/Simulink 	<ul style="list-style-type: none"> Robotics Sensor Systems Realtime Sensor Fusion SLAM Motion Planning and Control Theory Statics and Kinematics C++ Python C High Availability/Low Latency GPU/Parallel Computing Storm/Kafka/Akka/Zookeeper

<p>Autopilot Software Engineer</p> <p>Research Scientist – Behavior, Motion Planning and Control</p> <p>Self-driving Vehicle Operator</p> <p>Transportation Engineer</p> <p>Full Stack Software Developer</p> <p>Autonomous Driving Algorithms, AI & Deep Learning</p> <p>Machine Learning and AI Engineer</p> <p>Auto Mechanic – Autonomous Vehicles</p> <p>Diagnostic Repair Technician</p>	<p>modeling and code generation</p> <ul style="list-style-type: none"> • General knowledge of automotive systems (Powertrain, Chassis/Brakes, and CAN/LIN communication) • Experience with vehicle dynamics modeling and CarSim • Advanced statistical analysis, signals processing, filter design, optimization, system identification and state estimation • Data mining, Neural Networks, and supervised/unsupervised learning/classification methods • Basic experience with technology in LANs and vision systems • Experience with test and validation • Experience in developing and designing solutions for wireless power. • Experience with different coil structures for wireless power 	
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End Notes

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