Autonomous and Connected Vehicles Canadian Market Comprehensive Readiness Assessment

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ABSTRACT

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The arrival of the automobile changed the shape of 20th-century cities around the world, now in 21st-century, autonomous vehicles (AVs) and connected vehicles (CVs) will change the shape and culture of the world's cities once more. AVs and CVs are being deployed all around the world; the reason for this rapid development is that AVs and CVs enrich societies and industries with substantial benefits such as environmental effects, reducing Urbain's noise and air pollution, safety, mobility for everyone, transportation as-a-service, smart transportation, etc. A market readiness assessment is a way to evaluate and identify that the market is prepared for launching technology and also whether the market will respond positively to that technology or not.

The objectives of this research are to enhance Canadian society and policymakers' knowledge and understanding of AVs and CVs technologies and examine the maturity of the Canadian market for obtaining the most benefits from these technologies. The four main pillars include policy and legislation, technology and innovation, infrastructure, and customer acceptance. A readiness score model was provided to calculate the four main pillars readiness score regarding AVs and CVs technologies in Canada.

The results of this study show that the Canadian government has not taken specific actions to enhance public awareness about AVs and CVs technologies, road quality and EVs charging stations should be considered the main challenges in the infrastructure pillar, the absence of OEMs headquarters, low investment of companies, and absence of R&D cores were obstacles and challenges for the technology and innovation sector regarding AVs and CVs technologies.

Keywords: Autonomous Vehicles, Connected Vehicles, Market readiness assessment.

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List of Acronyms

AVs - Autonomous Vehicles

CVs - Connected Vehicles

DAS - Driver Assistance Systems

V2I - Vehicle to Infrastructure

V2V -Vehicle to Vehicle

V2C - Vehicle to Cloud

V2P - Vehicle to Pedestrian

V2X - Vehicle to Everything

NHTSA - The USA National Highway Traffic Safety Administration

BASt - the Federal Highway Research Institute

SAE - the Society of Automobile Engineers

GM - General Motors

DARPA - the US Defense Advanced Research Projects Agency

EVs - Electric Vehicles

AI - Artificial Intelligent

LIDARs - Light Detection and Ranging Technology

DNNs - Deep Neural Networks

CNNs - Convolutional Neural Networks

ML - Machine Learning

TRLs - Technology Readiness Levels

SRLs - System Readiness Levels

IRLs - Integration Readiness Levels

MRLs - Manufacturing Readiness Levels

DRLs - Demand Readiness Levels

AVRI - Autonomous Vehicles Readiness Index

ICTC - the Information and Communication Technology Council

CAVCOE - The Canadian Automated Vehicles Center of Excellence

CCMTA - the Canadain Council of Motor Transport Administrators

TC - Transport Canada

DOT - U.S. Department of Transportation

HTA - Highway Traffic Act

AVIN - Autonomous Vehicle Innovation Network

WatCAR - University of Waterloo center of Automotive Research

OEM - Original Equipment Manufacturers

WEF - World Economic Forum

IoT - Internet of Things

ITU - International Telecommunication Union

GCI - Global Cybersecurity Index

ESL - Estimated Service Life

Chapter one

Introduction

1.1 Research Problem

The Automobile industry has been one of the most important tech fields for decades; the arrival of the automobile changed the shape of 20th-century cities around the world, now in 21st-century, autonomous vehicles (AVs) and connected vehicles (CVs) will change the shape and culture of the world's cities once more. However, the advent of the automobile has been bringing a huge amount of benefits for decades, the challenges are also there such as air pollution, lack of parking space, enormous numbers of road fatalities, and so on. The AVs and CVs technologies will be a great chance to overcome 21st-century cities' challenges with automobiles [1,2].

In the last decades, AVs and CVs technologies have developed rapidly beside its related technologies such as computer science, artificial intelligence, mobile connection, telematics, and so on; nowadays, not only it seems more feasible to have high-end AVs and CVs on road, but also many on-road automobiles gain the benefit of driver assistance systems (DAS) and also low levels AVs and Cvs technologies too [3,4,5].

AVs and CVs are being deployed all around the world; the reason for this rapid development is that AVs and CVs enrich societies and industries with substantial benefits; to illustrate, these technologies could save almost 40,000 lives and reduced enormous amount of fatalities which caused by car accidents only in the United States [6,7]. Besides, AVs and CVs will provide

benefits such as environmental effects, reducing Urbain's noise and air pollution, safety, mobility for everyone, transportation as-a-service, smart transportation, etc. [8,5]. In Canada, The process of deploying AVs and CVs have started since years ago; the Canada Government have been trying to establish a fertile environment for these technologies to enrich Canadian society with its countless benefits; the Government of Ontario was one of the first organization that announced a pilot project in October 2015 which would allow testing AVs on specific regulation in the province [9].

The success of AVs and CVs deployment in a country or city is a multi-stakeholders issue; what this means is that neither the Government actions, nor the technological developments, nor any other stakeholders impressions are not able to ensure the success of AVs and CVs implementation alone. A market readiness assessment is a way to evaluate and identify that the market is prepared for launching technology and also whether the market will respond positively to that technology or not. There are different approaches to readiness assessments, the assessment would focus on technology or demand aspect, on a qualitative or quantitative aspect which each of them has specified objective, but on topics such as AVs and CVs which contain a wide range of technologies and objects, may the best approach be qualitative with the focused area on required technologies and base market requirements [10].

For evaluating the Canadian market readiness on AVs and CVs subject, having a deep and clear understanding of criteria and factors which influence the subject is crucial for all stakeholders such as Canada Government, car manufacturers, universities and tech institutes, infrastructure providers, start-ups, and so on to guarantee that society and industry will benefit from AVs and

CVs technologies. The research proposed aims to identify and evaluate the factors and criteria which affect the Canada AVs and CVs market by identifying the best approach for each category of factors and criteria that itself contain a variety of objects and topics which should be addressed with the best approaches. Then, Identify strengths and threats of the Canadian market and eventually, provide suggestions to all stakeholders to provide a suitable playground for deploying AVs and CVs technologies.

1.2 Research Objective

The objectives of this research are to enhance Canadian society and policymakers' knowledge and understanding of AVs and CVs technologies, potential benefits for Canadian society, and the most important one the maturity of the Canadian market for obtaining the most benefits from these technologies and also provide and propose a deep understanding of Canadian market readiness and remediation for Canadian policymakers to have a clear perspective of Canada state on these technologies. To reach these objectives, the literature review has been conducted to not only examine previous studies and researches on AVs and CVs technologies but also to be a part of the research process. Based on the literature review, the parameters and stakeholders on AVs and CVs deployment identified and determined to with further analysis make a clear and detailed picture of Canadian market readiness.

1.3 Research Questions

The current research can be addressed in four main questions which each contains different stakeholders and parameters to examine. The research questions are as follow :

What is the Canadian government approach to AVs and CVs and how do their approaches affect the deployment of AVs and CVs?

What is the Canada readiness level on technology, innovation, and industrial partnership according to AVs and CVs?

What is Canadain society's perspective toward the AVs and CVs technologies, and what are their expectations?

What is the Canada readiness level on infrastructure and how much of the infrastructure adjusts with AVs and CVs technologies?

To answer these questions different approaches will be taken according to the fact that each of these questions contains wide and complex issues and stakeholders which each of them have unique inherent which will need special approaches and parameters for evaluating them. Findings from these evaluations will lead to a comprehensive assessment of the current situation of AVs and CVs Canadian market.

1.4 Report Structure

The following chapters will be as follows. In the second chapter, the fundamental definitions, and the literature review will be discussed, and in chapter three, research criteria and parameters will be identified and determined, and also the research methodology will be discussed. In the four next chapters, the four main questions will be discussed, and based on defined parameters

and criteria the research and results will be discussed and evaluated and will provide a deep understanding in responding to the main questions. Chapter 8 will provide the conclusion, limitations, and detailed picture of Canadian market readiness and also propose some recommendations for Canadian policymakers and politicians.

Chapter Two

Literature Review

The objective of this chapter is to provide a comprehensive literature review and a deep understanding of previous studies and researches in the field of AVs, CVs, and market readiness assessment. First of all, a definition and background on AVs and CVs will be provided, and also a brief on the benefits and technologies related to AVs and CVs technologies. After an accurate analysis of previous studies and researches, the parameters and criteria which impact the deployment of AVs and CVs will be identified, these factors will lead to answers to the four main questions of the proposed research.

2.1 Literature Research

A systematic literature review tries to gather definitive data by using a systematic procedure with accurate parameters to extract valid data for further evaluating and analysis [68]. The objective of a systematic literature review like any other literature review is to obtain a clear and profound understanding of known knowledge in a specific aspect. The literature review is not only evaluating the former works and researches but also can be considered as valuable research [67,69]. In this research, a systematic approach has been taken to find the papers and articles related to the keywords “autonomous vehicles”, “self-driving cars”, “ Market readiness assessment”, “ market maturity assessment”, and “Canada”.

The different databases have been used to find related papers and articles with mentioned keywords such as Google Scholar, IEEE Xplore, and Scopus. The results have been sorted by

different parameters to find valuable papers and articles. The obvious obtained point after searching different keywords and keywords combination was that there is a notable absence of research on market analyzing part of AVs technology. There are just a few studies and papers that were conducted in which most of them were focused on only one or two aspects or regions of the market, instead of comprehensive market analysis. When the keyword "Canada" has been used, the results contain a remarkable number of white papers on policies and frameworks for the deployment of au AVs in Canada, however, there is no reliable study on Canadian market maturity or related subjects.

After gathering and evaluating the results, as mentioned before, the lack of research and study on the market aspect of AVs technology was crystal clear. After an accurate analysis of each result, the most related ones to research keywords have been chosen and presented below.

2.2 Definition of AVs and CVs

AVs and CVs are names which are known to most of the societies around the world by now, However, there can be various definitions for these technological terms; there are some organizations which provide specific explanations for these terms. The Ontario Center of Excellence Connected Vehicle/Automated Vehicle Program define these technologies as the following,

"Connected Vehicles use wireless technology to connect with other vehicles [vehicle to vehicle, or V2V], transportation infrastructure [vehicle to infrastructure, V2I], and mobile devices [e.g., smart phones] to give motorists the information they need to drive more safely.

Automated Vehicles, also known as self-driving vehicles, rely on sensors [such as radar and cameras] and computer analytics to sense their environments and navigate without human input [11].”.

However this definition provides a more clear image of AVs and CVs technologies, the need for more accurate definitions seems vital for further development and research in this area. A CVs is a vehicle which can communicate bi-directionally with other vehicles infrastructure and also pedestrians [12,13,14], the CVs technology can be defined by defining the different types of connectivity as follows,

Vehicle to Infrastructure (V2I), the technology provides data sharing between vehicle and infrastructure which allows the vehicle to generate information to the driver about safety, mobility, and road conditions [18].

Vehicle to Vehicle (V2V), the technology provides data sharing mostly on Dedicated Short-Range Communications (DSRC) between vehicles within a range of 300 to 500 meters in order to avoid accidents, ease traffic congestions, etc [19,23].

Vehicle to Cloud (V2C), the technology exchange information and data between vehicle and cloud service which provides information from other sources such as car manufacturers, smart homes, cities transportation systems, etc [20].

Vehicle to Pedestrian (V2P), the technology provides more safety and smoother mobility on the road by sharing data and information among vehicles, infrastructure, and personal mobile devices [21].

Vehicle to Everything (V2X), technology makes connectivity among all types of vehicles, infrastructures, and other devices [22].

The USA National Highway Traffic Safety Administration (NHTSA) and the Federal Highway Research Institute (BASt) define five levels of automation for AVs; however, the Society of Automobile Engineers (SAE) defines six different levels of automation, but, depart from their differences in definitions all of these organization divide the levels based on the abilities of implemented technologies and human interaction in the control of the vehicle [15,16,17]. The following table will provide the six-level of automation based on the SAE definition. (Appendix A will provide the full SAE definition)

Table 2.1 - Levels of Automation (SAE)

Level	Name	Description
Level 0	No Automation	The driver has full control of the vehicle and performs all processes of driving.
Level 1	Driver Assistance	A driver assistance system (DAS) performs either steering or acceleration and the Driver is responsible for controlling the vehicle and performing other parts of the driving process.
Level 2	Partial Automation	Driver assistance systems perform **both** steering and acceleration and the Driver performs the rest of the driving aspects.
Level 3	Conditional Automation	The all driving process will be performed by an automated system, with the consideration that the Driver will respond properly to interaction requests.
Level 4	High Automation	The all driving process will be performed by an automated system, even if the Driver will not respond properly to interaction requests.
Level 5	Full Automation	An automated driving system has control of the vehicle the whole time of driving and also performs all aspects of driving in any environmental situation.

The table is prepared by the author based on SAE [15] information

According to AVs and CVs definitions, these technologies are not vital for the presence of each other, however, CVs technology can provide undeniable benefits to AVs; thus, the most development in one, the most benefits the other achieved. The big share of research and investments goes to the AVstechnologies most of the time due to the more space for development; in consequence, the term of AVs seem more familiar to the public [24,25].

2.3 Background of AVs and CVs

AVs and CVs seem brand new technologies, but in fact, the idea of one of these technologies start as early as the Second World War, where the Teetor Cruise Control was developed in 1945 which the driver could set the vehicle's speed automatically with help of a mechanical throttle; then, the researcher efforts in autonomous technology lead to Stanford Cart which was developed in 1961 for NASA in order to be the first rover to explore the moon surface. The Stanford Cart was able to be driven from a far distance, the farthest distance that possible at that time, but It had some delay on command and implementation. There are other innovations that helped the AVs technologies reach the point that today are; the Tsukuba Mechanical Engineering System in 1977 which detects the street markings while driving up to 32 KPh autonomously, VaMoRs in 1987 allowed the vehicle to detect the objects around the vehicles and even the General Atomics MQ-1 Predator which was the first autonomous drone [26].

Besides these innovations there are some actions that known as the first steps for CVs technologies; in 1996, OnStar as a part of one of the biggest car manufacturers in the US,

General Motors (GM), in cooperation with the giant technology company, Motorola, announced a cellular telephone call system which would be connected a call center where an agent will help the driver or passengers from distances, the purpose behind the system was safety which means get emergency help to the vehicle in accidents or emergency situations. Later, OnStar added the GPS service to the system which allowed the system to detect the location of the vehicle [27]. In 2014, Audi was named as the first car manufacturers which offer 4G LTE connection access, However, General Motors (GM) was the first company to mass deployment of 4G LTE connection access technology [28]. Nowadays, most car manufacturers deploy various types of Driver Assistance Systems (DAS) which are part of both AVs and CVs technologies.

In the last decade like any other aspect of the world, innovations in the AVs and CVs have been witnessing rapid development and advancement, and it has been more feasible to have an autonomous vehicle on the road soon. One of the reasons for this fast growth rate could be the DARPA Grand and Urban Challenges which have been held by the US Defense Advanced Research Projects Agency (DARPA) since 2004 [6,7,29]. On the other side, big tech companies and car manufacturers started to invest in AVs technologies, Google as one of the first companies in the AVs realm which started by hiring the DARPA Challenge winner in order to develop its first autonomous vehicle; by 2016, Google's autonomous vehicle successfully traveled for more than 3 million kilometers [30,31]. Tesla's Autopilot technology is one of the most popular AVs since its first appearance in 2015 [32]. Mercedes-Benz, Volvo, Nissan, BMW, Audi, and other car manufacturers have been investigating and testing their AVs during the last decades [33,34]. The AVs technology is not limited to car manufacturers or tech companies,

UBER and Lyft both launched their AVs taxi fleet, and also many small tech start-ups have revealed their products and technologies [35, 36].

2.4 Autonomous Vehicles Benefits

By increasing the possibility of the presence of AVs on roads, the more research according to its effects and benefits have been conducted, the more benefits and positive influences of AVs on all aspects of life revealed. Surprisingly, researches have been showing that these benefits will be change-makers in many ways in the modern world's societies.

The most mentioned benefit that is clearly cited as one of the most beneficial in many conducted studies and papers is safety. According to statistics of any country or society, each society has been witnessing a huge amount of fatalities and injuries caused by vehicle accidents, in addition, with analyzing the statistics the remarkable role of human error to cause most of the vehicle accidents is obvious. In Canada in 2014, from a total of 149,900 traffic injuries, 9,647 cases registered for serious injuries, and 1,834 fatalities. The primary parameters in traffic accidents related to deaths were related to human errors such as driver distraction, speeding, alcohol, drivers without license and etc [37,38].

Based on research results, AVs have a high potential to decrease vehicle and traffic collisions and it is crystal clear that sequentially the injuries and fatalities will decrease too. In such study revealed that if AVs took 10 percent of the vehicles market, this will reduce vehicle collisions and accident injuries up to 50 percent, if this deployment increased to 90 percent, the vehicle collisions and accident injuries will reduce up to 90 percent [39]. However, there are some

registered vehicle accidents involving AVs which raise this point that this technology has a way to get to its full potential.

Fuel economy is another area that has a great chance for improvements by AVs technology in a variety of ways such as managing vehicles acceleration and declaration in a most effective way to get the best fuel consumption [7], or managing traffic on the ways in order to avoid any sudden acceleration or declaration and use the phenomenon called “platooning” which means using the air gap that is made behind the car in order to have lower air resistance, and in addition, most recent activities in AVs are combined with electrical vehicles (EVs) which will provide remarkable improvements in case of fuel economy [40,41,42].

Enhancing accessibility and mobility may be the most beneficial and interesting point of the AVs technology for a noticeable part of Canadian society who are not able to get beneficial from personal vehicles or public transit due to several factors such as economic, geographic location, physical or cognitive limitation. To illustrate, according to research, it is projected that just in Toronto will have 75,000 senior residents with levels of disabilities which make it hard or impossible to use current public transit or personal vehicles, In addition, if count all the groups of people who have a problem in access to public transit and personal vehicles, the number will be a remarkable percentage of Canadian society who may privilege with potential abilities of AVs [37,43].

AVs will reduce driver stress, with a vehicle that is able to drive itself will provide a chance for passengers to use their time in the vehicle more productive rather than just focusing on the road.

Hence, driving during the long work trips or family trips will not be inefficient and stressful for drivers and passengers and will provide a pleasing time instead [44].

Car sharing and taxi system Areas can be beneficial from AVs significantly. AVs will reach a level of automation which makes them operate without any supervision; thus, they can easily move and pick up people, eliminate the need for parking space, and be more economically efficient [44].

2.5 Autonomous Vehicles Technologies

AVs technology's success relies on a variety of factors and parameters, and also, its own technology depends on some sub-technologies which are vital for a successful deployment of technology. The following will provide a simple explanation of key features and technologies behind the AVs.

The first and most known technology related to AVs can be artificial intelligence (AI). this technology makes the vehicle able to understand its environment by creating a 3D map based on information that comes from radars, LIDARs (Light Detection and Ranging Technology), sensors, cameras, and other data sources, by analyzing them based on deep learning algorithms such as deep neural networks (DNNs) or convolutional neural networks (CNNs), or other deep learning architectures. To illustrate, the input data of speed limit sign, each frame of data is divided into several tiles, each of them will examine and analyze based on certain features such as size, certain shapes, color, and etc., then, AI algorithms determine whether or not the input data as speed limit sign according to probabilities vectors [1,45,46,47].

However, the main operations of the driving process will run by AI, the human interface with AI is still critical and vital. The AI operating process should be crystal clear and transparent regarding the decision making and command line, the system should act according to passenger need and demand; in fact, the passenger should be able to trust the AI system decision making and control, and also can communicate and understand the AI system in the event that the passenger should respond or even take the control of the vehicle [48,49].

AVs need data to operate the driving process, the data is gathered not only by cameras, LIDAR, sensors, and other onboard types of equipment, but also data which provide by other vehicles (V2V), infrastructure (V2I), cloud (V2C), and everything (V2I) that surrounding the vehicle. As a result, the communication ability comes a must for AVs technology which can be provided by mobile networks. AVs technology uses a huge amount of data each second to provide a sufficient understanding of the vehicle environment; hence, the mobile network should have enough capacity for this rate of data transferring, the newest technology 5G, standing for fifth-generation, is currently available in some locations in Canada, has the potential speed and capacity for providing quick interact and communication for AVs [50,51].

LIDAR, Light Detection and Ranging can be named as the main technology that has been used as an eye for AVs lately. LIDAR is a detection system which has the same base as radar, however, instead of sound, LIDAR works by shooting the light to an object and measure the time and wavelength of response and based on that providing a precise 3D map of the surrounding

environment, while it has been a continuous process the vehicle can have information such as number, distance, speed, size, and density of objects and obstacles [52].

2.6 Market Readiness Assessment

A market readiness assessment is a vital and necessary factor for business operation; the process should be designed in the way by which company or organization ensure that their product or service will match the target market or boost the sales volumes [10, 53]; but, the term, market readiness assessment, is not a well defined scientific framework, and in many cases, the direct approach should be considered and specific factors and parameters determined, however, there are practical suggested frameworks known as readiness levels have been suggested and modified during last decades by different companies and organizations [54].

The first readiness levels framework introduced by NASA during the 1980s known as the technology readiness levels (TRLs) which was a systematic approach and framework to evaluate the maturity and development of specific technology. Later, in 1995, TRLs were expanded and improved to other industries with a well-defined framework for measuring and comprising different types of technologies or innovations. TRLs originally contained seven levels of readiness which later improved and modified to nine levels which start with level one, basic principles of the subject, and continue to level nine, practical product in the target environment regarding table 2. Nowadays, some researchers utilize the TRLs with 10 defined levels which have been provided in Appendix B [55, 56, 57].

Table 2.2 - Technology Readiness Levels (TRLs) description [79,61]

TRL	Description
1	Fundamental principles detected
2	Technology concept determined simulations and experiments have been conducted
3	Analytical investigation performed, technology concept proved
4	Technology components and subsystem have been validated in the lab environment
5	Technology components and subsystem have been validated in a relevant environment
6	A prototype has been demonstrated and tested in a relevant environment
7	Several prototypes have been demonstrated and utilized in an operational environment
8	The actual system has been qualified regarding expected conditions
9	The actual system successfully applied in an operational environment

The system readiness levels (SRLs) and integration readiness levels (IRLs) were proposed to fill limitations of the technology readiness framework; the technology framework has focused on technology and innovation processes just and only without considering the existing systems or its integration with other technologies and systems [61]. IRLs includes seven levels which will start by identifying an interface between technologies and systems with enough details for processing as level 1 and will end by verifying the integration as level 7; with comparison the IRLs and TRLs level definition, the obvious point is that IRLs can reach to level 7 with the developed prototype before the final product, thus, IRLs should be finished before the TRLs get to level 8 or higher. The IRLs definitions have been provided in table 3 [58,59].

Table 2.3 - Integration Readiness Levels (IRLs) definition [58,61]

IRL	Definition
1	An interface (i.e. physical connection) between technologies has been identified with sufficient detail to allow the characterization of the relationship.
2	There is some level of specificity to characterize the interaction (i.e. ability to influence) between technologies through their interface.
3	There is compatibility (i.e. common language) between technologies to orderly and efficiently integrate and interact
4	There is sufficient detail in the quality and assurance of the integration between technologies.
5	There is sufficient control between technologies necessary to establish, manage, and terminate the integration.
6	The integrating technologies can accept, translate, and structure information for its intended application.
7	The integration of technologies has been verified and validated with sufficient detail to be actionable.

the development of SRLs was motivated by the fact that both TRLs and IRLs frameworks provide poor performance in complex systems or system of systems, as result, the SRLs framework was developed to evaluate the whole system with all connected subsystems and give the decision-makers a deep understanding of the system risks and requirements. The SRLs contain a five-level description that starts with concepts and follows to the last level by which the company develops a support and maintenance program for the existing system [62,63]. Alongside the mentioned frameworks, the manufacturing readiness levels (MRLs) indicate the maturity of product to produce from approval of concept to mass production, forums the push part of the market which means the mentioned frameworks just covered half of the whole market. The SRLs and MRLs details have been provided in Tables 4 and 5 respectively [66,60].

Table 2.4 - System Readiness Levels (SRLs) definition [58,61]

SRL	Name	Definition
1	Concept Refinement	Refine the initial concept. Develop system/technology development strategy
2	Technology Development	Reduce technology risks and determine an appropriate set of technologies to integrate into a full system.
3	System Development and Demonstration	Develop a system or increment of capability; reduce integration and manufacturing risk; ensure operational supportability; reduce logistics footprint; implement human systems integration; design for producibility; ensure affordability and protection of critical program information; and demonstrate system integration, interoperability, safety, and utility
4	Production and Development	Achieve operational capability that satisfies mission needs
5	Operations and Support	Execute a support program that meets operational support performance requirements and sustains the system in the most cost-effective manner over its total life cycle.

Table 2.5 - Manufacturing Readiness Levels (MRLs) definition [66]

MRL	Phase	Definition
1	Concept Provement	Basic Manufacturing Implications Identified
2		Manufacturing Concepts Identified
3		Manufacturing Proof of Concept Developed
4	Prototypes	Capability to produce the technology in a laboratory environment
5		Capability to produce prototype components in a production relevant environment
6		Capability to produce a prototype system or subsystem in a production relevant environment
7		Capability to produce systems, subsystems, or components in a production representative environment
8	Production Implementation	Pilot line capability demonstrated; Ready to begin Low Rate Initial Production
9		Low rate production demonstrated; Capability in place to begin Full-Rate Production
10		Full Rate Production demonstrated and lean production practices in place

The following table will provide a comparison regarding readiness frameworks that have been covering the push side of the market.

Table 2.6 - The comparison of the existing readiness frameworks [58,61,62,66,79]

Readiness Framework	TRLs	IRLs	SRLs	MRLs
The focus of Measurement	A systematic approach to evaluate maturity and development of specific technology	To measure the capability of interrelation between technology components and discrete components	To evaluate the whole system with all connected subsystems to measure the system's risk and support requirements	To measure the maturity of a product and production facilities
The number of levels	9 levels	7 levels	5 levels	10 levels

Florin Paun proposed a readiness framework as an answer to the need for a readiness framework on the other side of the market, market pull. The demand readiness levels (DRLs) was developed to respond to TRLs and evaluate the market need and maturity in corresponding to the technology. Paun also mentioned that the technology transfer process should be initiated if the DRL + TRL gives a number equal to or higher than 10. Table 7 has been provided the DRLs definitions and paired TRLs [64,65]. Despite all these frameworks, there are no regular or defined ways to conduct a market readiness assessment, especially for AVs technology with a broad list of technologies, organizations, and stakeholders involved in its good deployment.

Table 2.7 - Demand Readiness Levels (DRLs) definition and paired TRLs [65]

DRL	DRL Definition	TRL
1	Feeling the lack of something	9
2	Need has been identified	8
3	Expected functionalities of new product or service have been identified	7
4	expected functionalities have been quantified	6
5	System capabilities have been identified	5
6	Expected functionalities have been transformed into needed capabilities	4
7	Necessary and sufficient resources and competencies have been defined	3
8	The experts possessing the competencies have been identified	2
9	Adapting answer to the expressed need	1

2.7 Previous Studies

The KPMG international cooperative is one of the biggest multinational service companies. The KPMG is one of the biggest accounting firms in the world, they also provide a line of services such as financial advisory, audit, tax consulting, and assurance from all around the world [70]. The KPMG has started to provide annual reports named "Autonomous Vehicles Readiness Index (AVRI)" since 2018, the AVRI reports aim to deepen the understanding of policy-makers and public sector organizations about AVs technology and their level of maturity regarding AVs readiness factors. The first report contained 20 countries which the Netherlands took a lead and Canada stand on rank 7; the report included the four main part and each part contained several factors, and also the evaluating factors on some levels combined with EVs data and factors, as a result, the report could consider as a combination of EVs and AVs readiness index[71]. The next

report covered more countries by 25 target countries and improved factors on some level, especially on customer acceptance. The Netherlands took the lead for the second year, however, Canada dropped from 7 ranks to 12 and had a 13 percent drop in the score which determined that Canadian Government policies responding to AVs did not have a positive and strong influence on the AVs sector [72].

The 2020 AVRI report covered 30 countries which Singapore leads the AVRI for the first time and overtook the Netherlands. Despite remaining in the same rank as last year on AVRI, Canada's rank has just improved in one section, "Infrastructure", and dropped in all 3 others, "Policy and Legislation, Technology and Innovation, Consumer Acceptance". According to the report, high performance in industry partnership, being the world-leading hub of AI, and high investments in AVs pilots are Canada's main strengths on AVs, however, 4G coverage, EVs charging stations, and technology infrastructure change readiness can be counted as Canada's weaknesses [78].

Capgemini Research Institute is a french based multinational company which provides consulting and outsourcing services on technologies and the digital sector. In 2019, Capgemini proposed research on a consumer perspective and acceptance towards AVs technology; the research contained more than 5,500 individual and executives surveys from around the world. The research aims to determine customer readiness and deepen the understanding of customer expectations, in addition, the research provides some recommendations based on survey results and companies' evaluations to organizations and companies to accelerate the path towards the AVs. The report shows the consumer feelings, awareness, and expectations and the difference

among the age range and also among urban and suburban dwellers as well as a comparison between consumers' and executives' perspectives towards AVs [73,74].

In 2017, the Information and Communication Technology Council (ICTC) of Canada released a report named "Autonomous vehicles and the future of work in Canada"; the report aimed to provide a profound understanding of the influence of AVs technology on Canada economic and job market, in-demand occupations, occupations displacement, employment and unemployment rate, wages and others. This report also provided a comprehensive background on Avs history, related technologies, benefits, and other relevant topics [1].

Mohamed Alawadhi et al in an article, "A systematic literature review of the factors influencing the adoption of autonomous driving", provides fourteen factors which are divided into four categories, based on evaluating over 80 previous studies and researches to smooth the path of future researches on the adaptation of AVs. However, the absence of frameworks or notes regarding addressing these factors are notable; the research addresses more studies and research to be done to obtain a deeper understanding of influencing stakeholder in AVs deployments [67].

In 2019, the Victoria Transport Policy Institute provided a report, "Autonomous vehicle implementation predictions", which aimed to predict the consequence, benefits, and challenges of AVs deployment based on experience from the development of other vehicle technologies in the past. The report proposed that in 10 years the societies will be able to be beneficial from some benefits of AVs, however, some benefits such as pollution reduction, energy conservation,

traffic reduction, and safety improvement may need more time to show significant impact in comparison to current situations [75].

The Canadian Automated Vehicles Center of Excellence (CAVCOE) prepared a white paper, “Preparing for autonomous vehicles in Canada”, for the government of Canada in 2015, aimed to provide 30 recommendation which covered different section of Canadian society such as the government of Canada, economy, transportation, and traffic, transit, health and quality of life, industries, oil and pipeline industries, national security and policing, Federal departments, and provincial. The white paper provides some potential positive impacts and benefits of AVs for Canadian society, on the other hand, this document did not provide a framework or road-map to implement these recommendations in the future [76].

In November 2016, the Canadain Council of Motor Transport Administrators (CCMTA) provided a high-level overview on AVs technology as a white paper named “Automated vehicles in Canada" which contained a variety of detailed information on subjects such as high detailed content on AVs definitions and benefits, regulatory considerations, research and innovation programs, and a deep evaluation on challenges and barriers which by the government of Canada face in the path of deployment the AVs technology. These challenges and barriers include privacy and data sharing, cybersecurity, labor market disruption, insurance industry and liability, ethical considerations, enforcement by policing, infrastructure, and weather [37].

Canada’s safety framework for automated and connected vehicles is an article that was prepared by Transport Canada (TC) in 2019 which aimed to give an accurate analysis of the current state

of AVs and CVs in Canada. This article provided a deep overview of current Canadian legislation, regulations and standards, and also non-regulatory guidance with a safety-focused approach for the stakeholder of TC and AVs deployment responsible organizations. This article also provided the future roadmap of TC due to ensure the continued safety of AVs and CVs development according to the complex rapidly evolving nature of Avs and Cvs technologies [77].

In September 2016, the Canadian Parliamentary Information and Research Service provided a background paper on automated and connected vehicles. The paper contains a comprehensive introduction to AVs and CVs and their potential benefits and also mentioned key policy challenges for the Canadian government and policymakers. The aim of Parliament Background Papers is to provide in-depth studies to parliamentarians and senate and the house of commons committees on policy issues [5].

Table 2.8 - Previous Studies Detailed Table

Year	Author	Subject	Advantages	Disadvantages
2018	KPMG	Providing Market Readiness Assessment and comparing on AVs leading countries	• Comprehensive market assessment • World wide coverage, 20 countries • Detailed ranking and the scoring structure	• No deep analysis of parameters results • No specific suggestion or framework
2019			• coverage to 25 countries • Adding milestone part • Improvement of parameters	
2020			• Increase the coverage to 30 countries • Improvement of parameters to 28 different measures • The section about benchmark cities	
2019	Capgemini	A worldwide survey on public and executives perspective toward AVs	• Global survey • Over 5,500 individuals and executives • Detailed results • Comprehensive analysis on consumer spectrum	• Just focused on customers perspectives • No maturity analysis on the preparedness of consumers or societies
2017	ICTC	Providing a comprehensive study on AVs and its impact	• The detailed definition of AVs	• The main focus on the labor market

		on the future of the job market in Canada	technologies ● Mentioning the potential influence of AVs on cities and societies ● A detailed and comprehensive evaluation of Canada labor market ● Analysis of potential job displacement and new occupation opportunities	● Brief information on other sections
2020	Mohamed Alawadhi et al	Providing 14 Factors influencing the adoption of autonomous driving	● Covering the 4 main readiness categories of AVs	● The parameters are so general ● No frameworks or measurements
2019	Victoria Transport Policy Institute	Examine the influence of AVs based on previous vehicle-related technologies experiences	● Providing a detailed analysis ● Mentioning AVs potential benefits	● Using car-related previous technologies experience to predict AVs future ● poor maturity analysis on AVs state
2015	CAVCOE	Providing 30 recommendation for Canadian government and policy-makers	● Giving practical recommendation to the Canadian government ● Mentioning potential AVs influence on Canadian society	● Providing no detail on recommendations ● No frameworks ● No maturity assessment on AVs state in Canada
2016	CCMTA	A high-level overview of AVs state and a	● A detailed overview of	● No recommendations

		head challenges for Candian government	challenges and barriers to AVs deployment ● Practical information as appendices ● A detailed overview of AVs potential benefits	or suggestions on AVs deployment ● No maturity assessment on AVs state in Canada ● No analysis of challenges and barriers to AVs deployment
2019	Canada Transport	Providing an assessment of AVs legislation and regulation state in Canada in 2019,	● Providing evaluation of current regulation and standards ● Providing suggestions and recommendation	● Brief explanations ● Limitation on subjects
2016	Canadian Parliamentary Information and Research Service	An introduction to AVs and CVs, and potential benefits and challenges	● Providing AVs potential benefits ● Mentioning possible Canadian government challenges toward AVs deployment	● Brief explanations ● No recommendation ● No suggested framework

Chapter Three

Research Methodology

The proposed research contains five main steps. In the first step, the main stakeholders of AVs and CVs technologies were determined based on the literature review. In the second step, the measures of each pillar were identified and described to provide an understanding of the desired data and information. In the third step, the desired data and information were collected by a suitable approach. In the fourth step, the data and information were analyzed and evaluated to provide a detailed picture of the current measures' situation and also to calculate the measures' readiness score which would lead to calculate the pillars' readiness score. In the last step, all pillars' readiness score and analysis would provide a deep and clear picture of Canadian AVs and CVs market state and also provide future scope for more studies.

3.1 Data Collecting

The data and information source are the fundamental part of market readiness assessment, however, this information and data source varies from topic to topic, but the collecting approach can be similar in many cases, the web is the first places that can provide a lot of information and data sets in any area, but, all the information which needs for a comprehensive market readiness assessment are provided for the public available on the web. Hence, other approaches should be considered for data collecting such as surveys, analytical analysis, experiments, and data collaboration with other related companies and institutes.

For selecting the best data collecting approaches, firstly, the environment and area of research should be identified and divided into some main categories which are variables that have a

remarkable effect on the subject. By categorizing the subject to main clusters the type of information in each cluster can be recognized and a suitable approach is selected for the data collecting. AVs and CVs technologies have multiple stakeholders that should be addressed to the desired cluster and proceed to the data collecting. As a result, this topic will divide into some main pillars, but each pillar itself contains a variety of measures that should be addressed to a suitable approach for data collecting.

3.2 Pillars

AVs and CVs technologies are the subject with a multivariable which has a vital and important rule on the potential success or failure of these technologies in different situations and cities or countries. Like any other new-generation technologies, these technologies rely on Machine Learning algorithms, mobile networks, communication technologies, and so on, thus, monitoring and evaluating the development of the computer and network technologies and researches is necessary to have a comprehensive perspective of the future of connected sustainable mobility systems.

For launching any product or technology at the very first steps examining and testing the required requirement of the market is essential to process for success, In other words, if the market requirements of the new technology are not available at the target market customer is not capable of using that technology, and according to that, the technology will fail. As a result, evaluating the main requirements for AVs and CVs technologies are vital to evaluate the preparedness of cities and countries for these kinds of technologies and what steps they should take due to gaining the most benefits of these technologies.

One of the most aspects that determines the success or failure of a product or new technology instead of its innovation or features or other points is customer acceptance, which means the customer is aware or prepared for using that technology or not. Many companies conduct surveys about their product and examine the market response to their product, however, many of them choose a sample from the target market and give their product to the cluster for primary evaluating and take feedback and modifying based on market sample response.

The government rule in the Avs and CVs technologies should be considered from different perspectives; first of all, mobility, transport, and data sharing all are the topics that in the modern world need regulations and frameworks to avoid fraud, lack of privacy, legal ambiguity and so on. So, the government is responsible to take necessary actions to update and generate new frameworks and regulations to prepare the law and society for gaining advantages of this technology. Secondly, the government considers the main investor for any new technology which provides benefits to the public. As a result, government policy for investing and supporting start-ups, companies, and academic studies on the specific topic is crucial for smoothing the path for maximizing development and innovation in that era.

Based on the mentioned above, the four main pillars were determined for evaluating the Canadian AVs and CVs market readiness. These pillars include policy and legislation, technology and innovation, infrastructure, and customer acceptance. The next step would be determining the measures for each pillar that would be providing a deep understanding of each pillar's current situation regarding AVs and CVs technologies.

3.2.1 Policy and Legislation

The AVs and CVs technologies would not match with current automotive regulations and standards, thus, the new frameworks and regulations would be necessary for successful deployment of AVs and CVs. the government's policies, frameworks, and approaches toward AVs and CVs technology should be considered as a vital parameter for successful deployment; thus, a comprehensive evaluating of the government performance would be conducted based on five measures which include AVs regulation and standard, AVs regulation change, AVs responsibilities structure, governmental AVs pilots, data sharing environment.

AVs regulation and the standard measure would evaluate the level of government's policies, frameworks, and regulation toward the AVs and CVs. examining the compatibility of Canadian regulations and standards related to AVsand CVs and the situation of AVs and CVs technologies in Canada. Regulation and standard in support of AVs and CVs development and testing would be awarded a higher score.

AVs regulation change measure would evaluate how AVs and CVs related regulations and standards have been changed or improved with AVs and CVs technologies state. The government and policy-makers actions and efforts regarding providing a suitable environment for AVs and CVs development and testing by monitoring, improving, and updating regulations and standards would be examined and evaluated. Regulations' and standards' changing and compatibility with AVs and CVs state would be awarded a higher score.

AVs responsibilities structure measure would evaluate the structure of government regarding AVs and CVs technologies. The communication between authorities is a vital parameter for a more agile and dynamic environment, the separate department in government for AVs and CVs would demonstrate more commitment and provide an agile and dynamic environment rather than sharing responsibilities among different authorities and departments and also would be awarded a higher score.

Governmental AVs pilots measure would evaluate the Canadian government regulations and frameworks for providing a suitable environment for AVs and CVs testing which could provide a deep understanding of AVs and CVs state, and regulations and standards. Pilot projects with less restriction and limitation in regulations and standards would be awarded a higher score.

Data sharing environment measure would evaluate the Canadian government approach toward open data and sharing data policies which could provide opportunities for industry and companies regarding AVs and CVs development and innovation. Policies and frameworks that provide an open approach regarding data sharing environments would be awarded a higher score.

3.2.2 Technology and innovation

AVs and CVs technologies have been composed of a variety of different developing technologies such as Machine Learning (ML), Artificial Intelligence (AI), LIDAR, Radar, sensors, and communication technologies. Despite AVs and CVs technologies accomplishments, AVs and CVs technologies are still under development, and innovation processes and AVs with SAE levels 4 and 5 have not been available yet; and companies and research institutes have been

working on operating systems that have been capable of operating without human supervision. Hence, technology and innovation are a vital part of these technologies and would be evaluated based on five measures which include university activities, technology, and innovation hubs, AVs related patent, technology and innovation capability, and cybersecurity.

University activities measure would evaluate the academic environment performance and policies regarding AVs and CVs development and innovation. Specific programs with focused areas related to AVs and CVs technologies development or deployment such as improving operating systems, communication systems, object detection algorithms, infrastructure technologies, and cybersecurity at universities would improve the development of AVs and CVs and also be awarded a higher score.

Technology and innovation hubs measure would evaluate companies and research institute R&D departments' performance regarding AVs and CVs technologies development. AVs and CVs technologies are still on the development and innovation path, Thus, the R&D cores would play a significant role in AVs and CVs development. Having an AVs and CVs R&D cores or centralized technology and innovation center would be awarded a higher score.

The AVs-related patent measure would evaluate Canada's performance regarding AVs and CVs related patent applications which would indicate the level of technology's innovation and development in Canada. The higher number of AVs and CVs related patent applications, the higher score would be awarded.

Technology and innovation capability measure would evaluate Canada's capability of being beneficial to new technologies and innovations from all around the world and inside of Canada. Availability of new technologies, R&D cores, Number of Patent applications, industry investment, and availability of high-speed internet would be parameters that could impact the technology and innovation capability of Canada. The higher performance in each sector, the higher score would be awarded to the measure.

Cybersecurity measure would evaluate the Canadian government's policies and actions regarding overall cybersecurity issues. The cybersecurity of AVs and CVs has been crucial issues since the rise of the AVs and CVs technologies, hence, cybersecurity would play a vital role in the successful deployment of AVs and CVs in the future.

3.2.3 Infrastructure

AVs and CVs technologies like any other technology need specific physical requirements that here means cities and countries' infrastructure. AVs and CVs technologies depend on technologies such as communication, LIDAR, radar, and AI which depend on the quality of some specific infrastructure such as mobile data network, road network, and traffic sign and technologies. As most AVs and CVs are likely to be EVs, the successful deployment of AVs and CVs require EVs infrastructure as well. Thus, the infrastructure readiness score would be calculated based on five measures which include mobile network coverage, mobile connection speed, road quality, EVs charging stations, and infrastructure technology change.

Mobile network coverage measure would evaluate the 4G coverage of Canadian mobile data network as the mobile data network is one of the fundamental technologies regarding AVs and CVs deployment due to need of transferring Huge amount of information and data among the vehicle, center cloud (V2C), infrastructure(V2I), other vehicles (V2V), and everything (V2X). the better mobile data network coverage, the higher score would be awarded.

Mobile connection speed measure would evaluate Canada's mobile internet connection speed due to the important role of the internet speed in operating the performance of AVs and CVs. AVs and CVs technologies need a high-speed internet connection to transfer a lot of data among vehicles and everything. Thus, the higher speed of mobile internet connection would be awarded a higher score.

Road quality measures would evaluate the quality of Canadian roads. The LIDAR, radar, and sensor technologies performance are based on specific road infrastructure requirements and conditions, as a result, the quality of roads would affect the performance of AVs' operating systems. The higher quality of roads would be awarded a higher score.

EVs charging stations measure would evaluate the performance of the Canadian government in providing sufficient EVs charging stations in Canada. As many car manufacturers develop both AVs/CVs and EVs technologies together and most of the big car manufacturers' introduced AVs/CVs are EVs, EVs infrastructure would play an important role in AVs and CVs deployment. The higher number of charging stations would be awarded a higher score.

Infrastructure technology change measure would evaluate the availability of the latest technology related to infrastructure in Canada. AVs and CVs technologies require some special infrastructure features and technologies especially in the communication sector, V2I, and also other sectors. A higher score would indicate the level of availability of the latest technologies.

3.2.4 Customer Acceptance

The customer of AVs and CVs technology would be all members of society and their awareness and willingness toward AVs and CVs technologies would play a significant role in the successful deployment of AVs and CVs. Customer acceptance pillar would examine the preparedness of Canadian society for being beneficial of fully automated and connected vehicles by conducting a survey; the participants would be Canadian who have an occupation related to automotive, AVs, and CVs related industries. The responses would be counted as measures for calculating the customer acceptance readiness score.

3.3 Readiness Score Model

Based on section 2.6 market readiness assessment, there are no well-defined frameworks or approaches for market readiness assessment, however, there are practical suggested frameworks known as readiness levels have been suggested and modified during last decades by different companies and organizations which each were focused on one sector of the market readiness assessment, thus, for this research the specific readiness score model were created which would be compatible with a variety of measures and parameters that would use to calculate the four main pillars readiness score regarding AVs and CVs technologies state in Canada.

Table 3.1 presents the readiness score model details. The score one would indicate that the least requirements, technologies, or infrastructure are available for target measure. The score two would indicate that the technologies, products, or services related to the target measure have been operational, but have not met the sufficient requirement to satisfy the need related to the target measure. A score of three would indicate that the technologies, products, or services related to the target measure have been operational and satisfied the need related to the target measure. A score of four would indicate that the technologies, products, or services related to the target measure have been nationally operational and also met requirements of the support program, but there are some gaps and limitations. A score of five would indicate that the technologies, products, or services related to the target measure have been operational at the high-end level.

Table 3.1 - Readiness Score Model

Readiness Score	Description
1	The least requirements have been satisfied
2	Operational level without meeting the minimum requirement
3	Operational level and satisfying the need
4	Operational level and execute a support program
5	Operational at the high-end level

Chapter Four

Policy and Legislation

The policy and legislation readiness score is calculated from five measures as mentioned in chapter three. Collected data and findings regarding five measures are presented and analyzed in this section to provide a clear picture of the Canadian Government and policy-makers performance regarding AVs and CVs technologies. These measures are AVs regulation and standard, AVs regulation change, AVs responsibilities structure, governmental AVs pilots, data sharing environment.

4.1 AVs Regulation and Standard

Transport Canada as a part of the Canadian government is responsible for transportation regulation, policies, and services. Transport Canada established the Canada-U.S. Regulatory Cooperation Council with the collaboration of the U.S. The Department of Transportation (DOT) aimed to increase regulatory cooperation between countries and also establish a working group focused on CVs technology in 2011. Transport Canada and DOT alignment were one of the first steps that the Canadian government took toward AVs and CVs deployment [98].

Later, the Canadian Government started to develop regulations and frameworks regarding AVs development and deployment. Canada divided the responsibilities among the federal government, provincial/territorial governments, and municipalities and also started to create working groups with specific focused areas. In 2014, the Canadian Council of Motor Transport Administrators (CCMTA) working group was created to monitor AVs technology development

and also develop regulations and standards regarding Avs related issues. Later in 2015, CAVCOE prepared a white paper with the title of "Preparing for Autonomous Vehicles in Canada" which contains a 30 recommendation to the Canadian government regarding AVs policies and frameworks and potential Challenges [37, 76, 98].

In 2016, a 10-year pilot regulation and frameworks for testing AVs in the operational environment was provided by the Ontario Provincial government for the first time in Canada. Later, Manitoba, Quebec, and Alberta provincial governments also announced their pilots for testing and developing of AVs in their province. In 2019, the Safety Assessment for Automated Driving systems in Canada and Canada's Safety Framework for Automated and Connected Vehicles were two documents that were provided by Transport Canada to provide a clear picture of Canada's state regarding legislation and regulatory standards on CVs and AVs [98, 99].

Canada was one of the first countries that started to prepare for CVs and AVs technology and also one of the first countries that provided regulation and framework for developing and testing CVs and AVs; however, there are some legislation and regulatory standards gap and lack regarding federal standards for some AVs and CVs safety features such as active driving features or collision avoidance features [99, 100].

4.2 AVs Regulation Change

In 2011, the Canadian government and DOT created a working group, the Council's connected Vehicles Working Group, which aimed to deploy V2V and V2I technologies within a four-part work plan. Later, Canada started to define regulation and standards regarding AVs and CVs

technologies, determined federal government, provincial/territorial governments, and municipalities responsibilities, created several working groups with specific focus areas, and have been providing documents on AVs and CVs state regarding legislation and regulatory standards which aimed to provide a deep understanding of AVs and CVs state for the Canadian government and policy-makers and provided regulation and frameworks for testing AVs and CVs on Canadian roads with special circumstances [98,99].

Besides all the above-mentioned actions, continuous improvement and monitoring is a vital part of the Canadian government's policies and frameworks toward AVs and CVs legislation and regulatory standards Canadian government has been trying to monitor and evaluate the AVs and CVs situation through all mentioned actions to keep their policies and framework updated to the current state of AVs and CVs. One of the remarkable examples of improvements in regulation and frameworks is the Ontario pilot which started with specific regulation toward AVs testing on roads in 2016, but later in 2018, Ontario provincial government lifted some limitations and expanded the regulation and standards to expand data reporting and ensure the safety of testing processes, in 2019, Ontario provincial government updated their regulation and frameworks again to enable companies to test AVs with SAE level 5 automation on public roads with specific conditions which ensure the safety of test environment, and also permitted companies for commercial activity regarding AVs with SAE level 3 automation which the registration limited to pilot participants only in the past [99,101].

The Canadian government has been trying to improve and modify the legislation and regulatory standards regarding AVs and CVs continuously which will help Canadian society to be beneficial to the full potential of AVs and CVs benefits.

4.3 AVs responsibilities structure

The AVs and CVs regulation and standards responsibilities are shared among the federal government, provincial/territorial governments, and municipalities due to Canadian government policies and power hierarchy orders. Table 4.1 presents the dedicated responsibilities to each level of the Canadian government [101].

Table 4.1 - Levels of Canadian governments and dedicated responsibilities [101]

Federal	Provincial/Territorial	Municipal
• Setting and enforcing motor vehicle safety standards for new or imported motor vehicles and motor vehicle equipment • Investigating and managing the recall and remedy of non-compliances and safety-related motor vehicle defects nationwide • Public education on motor vehicle safety issues • Monitoring and developing rules on privacy and cybersecurity • Setting and enforcing compliance with technical standards related to wireless technologies integrated into vehicles and roadside infrastructure • Relevant legislation: Motor Vehicle Safety Act	• Testing and licensing human drivers and registering motor vehicles in their jurisdictions • Enacting and enforcing traffic laws and regulations (including trials) • Conducting safety inspections • Regulating motor vehicle insurance and liability • Public education on motor vehicle safety • Adapting provincially owned infrastructure to support CAV deployment • Planning for future transportation projects (e.g., highway management, transit) • Relevant legislation: Highway Traffic Act	• Enacting and enforcing bylaws • Enforcing traffic laws and regulations • Adapting infrastructure to support CAV deployment • Managing passenger transportation (including public transit, taxis and ride-hailing services) • Managing and creating new logistics for traffic control and parking enforcement • Public education on motor vehicle safety • Relevant legislation: Municipal Code

Based on the KPMG AVRI 2020, a focused and separated department for AVs, CVs, and transportation technologies and innovations will perform a better performance rather than giving the responsibilities to existing departments or spreading the responsibilities among several departments and jurisdictions [78]. The Canadian government has a detached department and

ministry for transportation, however, the government structure leads to sharing the responsibilities based on power hierarchy orders among different levels of government as shown in table 4.1.

4.4 Governmental AVs Pilots

Based on table 4.1, the pilot's framework and regulation is a part of provincial government responsibilities. Canadian provincial governments started pilot projects in the Ontario province and expanded to other Canadian provinces with dedicated budgets from the Federal Government, Provincial Government, and Transport Canada. Based on KPMG AVRI 2020, Canada is a world leader for Government-Funded AVs pilots due to government-funded pilots in most of the major provinces that the test areas have covered 90 % or more of the Canadian population. The following presents some information on government-funded pilots in Canada [78, 98, 101].

4.4.1 Ontario Province

In 2016, Ontario was the first province to provide regulations and frameworks for AVs testing on Ontario's roads under the Highway Traffic Act (HTA), but later in 2018, Ontario provincial government expanded the regulation and standards to expand data reporting and ensure the safety of testing processes, in 2019, Ontario provincial government updated their regulation and frameworks and made three key enhancement to enable companies to test AVs with SAE level 5 automation on public roads with specific conditions which ensure the safety of test environment, also permitted companies for commercial activity regarding AVs with SAE level 3 automation which the registration limited to pilot participants only in the past and permitted truck platooning on Ontario's roads under specific and strict condition [99,101].

In 2017, Ontario launched a 5-year program with an 80$ million budget named Autonomous Vehicle Innovation Network (AVIN) which aimed to connect the academic environment, industry, and government together. AVIN contains six different focus areas, human-machine interface, multimodal and integrated mobility, vehicular networks and communications, vehicle cybersecurity and cross-border technologies, artificial intelligence, and high-definition mapping [98].

4.4.2 Quebec Province

In 2017, Quebec Provincial government introduced a pilot regulation and framework that allow for AVs and CVs testing and ensure the safety of the roads. A 2 kilometers route in Candiac, Quebec was the testing route for automated shuttles that served the public with stops at city hall and business places [101].

4.4.3 Manitoba Province

In 2018, the Manitoba Provincial government provided legislative amendments to HTA that allowed AVs with SAE level 3 to 5 testing on the province's roads with conditions that mentioned a human driver has to control the car physically. Also in 2019, Manitoba tested the first automated snowplow in North America at Winnipeg Richardson International Airport [98,101].

4.4.4 Saskatchewan Province

In 2019, the Saskatchewan provincial government has started to collaborate with technology companies to provide a framework for AVs and CVs development and testing under

Saskatchewan weather conditions in rural and urban areas. Transport Canada awarded the city of Saskatoon under the Advance Connectivity and Automation in the Transportation system [101].

4.4.5 Alberta and British Columbia Province

Alberta provincial government and British Columbia provincial government in collaboration with the University of Alberta, University of British Columbia, and Transport Canada created the ACTIVE-AURORA project to be an innovative approach research project based on Edmonton and Vancouver. Edmonton's test path contained 60 kilometers of public roads that were equipped with various equipment for testing a wide range of AVs and CVs technologies such as advisory driving speed, pedestrian warnings, high collision location warnings, and so on. Vancouver's bed test provided a controlled path with a network of connected cameras and roadside monitors for testing of different CVs technologies that are supposed to lead to safer and smarter transportation in British Columbia [98, 101].

4.5 Data Sharing environment

Based on World Wide Web Foundation Open Data Barometer 2018, Canada has performed a strong performance regarding digital areas such as government, social, and economic sectors due to a consistent political approach that has made Canada a top performer since 2013 and led the 2018 edition of Open Data Barometer report [102].

4.6 Policy and Legislation Readiness Score

In this section, the five mentioned measures would be evaluated and examined based on the provided readiness score model to provide a clear picture of Canada performance regarding

policy and legislation pillar. For this purpose the base requirements, the highest performance, and the support and maintenance programs and requirements for each measure would be identified and defined; in the next step, the measure readiness score would be calculated based on collected information.

Based on literature review, the all five measures of policy and legislation pillar have equal importance and playrole in this sector, thus, the equal weights would be applied to each measure to calculate the pillar readiness score.

4.6.1 AVs Regulation and Standards Measure Evaluation

The first measure is focused on regulation and standards. Based on literature review and collected information, the regulations and standards which provide a playground for developing and understanding AVs and CVs technologies would be considered as the least requirements for AVs regulation and standards measure. The regulation which not only provides a suitable playground for developing and testing AVs and CVs on public roads, but also provides adapted regulations and standards for each sector related to AVs and CVs technologies state would be considered as the highest level for this measure.

Based on section 4.1 AVs regulation and standards, Canada was one of the first countries that started to prepare for CVs and AVs technology and also one of the first countries that provided regulation and framework for developing and testing CVs and AVs; however, there are some legislation and regulatory standards gap and lack regarding federal standards for some AVs and CVs safety features such as active driving features or collision avoidance features [99, 100]. As a

result, the Canadian government performance regarding AVs and CVs regulation and standards would be calculated equal to score 4 based on readiness score model due to providing a suitable environment for developing and testing AVs and CVs and also monitoring the AVs and CVs state and also considering limitations and gaps.

4.6.2 AVs Regulation Change Measure Evaluation

The second measure is focused on regulation and standards change and updates. Based on literature review and collected information, the regulations and standards which are considered as requirements for AVs regulation and standard measure would be considered as requirements and base lines for this measure as well, but, in addition, the monitoring and modifying process and frameworks would be considered as supplementary requirements for this measure.

Based on section 4.2 AVs regulation change, The Canadian government has been improving and modifying the legislation and regulatory standards regarding AVs and CVs continuously by creating several working groups to monitor and provide reports on AVs and CVs state in Canada; however, there are some limitations and gaps in Canadian regulation and standards which need to be addressed. Hence, the AVs regulation change measure would be scored equal to 4 based on readiness score model.

4.6.3 AVs responsibilities Structure Measure Evaluation

The third measure is focused on power order and policy and decision making structure within Canadian government regarding AVs and CVs technologies. Based on literature review and collected information, giving the responsibilities to several existing departments or spreading the

responsibilities among several departments and jurisdictions would be satisfied the least requirements for this measure, however, a focused and separated department for AVs, CVs, and transportation technologies and innovations within the government which would cover all AVs and CVs related responsibilities would be considered as the best responsibilities structure and framework.

Based on section 4.3 AVs responsibilities structure, the Canadian government has a detached department and ministry for transportation, however, the government structure leads to sharing the responsibilities based on power hierarchy orders among different power levels within Canadian government. This structure would stand above least requirements level with a separated department, however, this structure also stands below the best level due to the power division within three different power levels of Canadian government. As a result, the Canadian government structure regarding AVs and CVs technologies readiness score would be calculated equal to 4 based on the readiness score model.

4.6.4Governmental AVs Pilots Measure Evaluation

The fourth measure would evaluate the Canadian government regulations and frameworks for providing a suitable environment for AVs and CVs testing within a framework known as Pilot projects. Based on literature review and collected information, a pilot project with resterict and limited regulation which would be provided a bed test for AVs and CVs would satisfy the least requirement for this measure. A pilot project with least restriction and limitation which provides a suitable playground not only for testing, but also for developing AVs and CVs technologies would be considered as the high level for this measure.

Based on section 4.4 governmental AVs pilots, Canada is a world leader for Government-Funded AVs pilots due to government-funded pilots in most of the major provinces with permission for on public road testing, and also commercial activities. Thus, the Canadian government performance regarding governmental AVs pilots would be calculated equal to score 5 based on readiness score model due to providing a suitable environment for developing and testing AVs and CVs with least restriction.

4.6.5 Data Sharing Environment Measure Evaluation

The fifth measure is focused on the Canadian government approach toward open data and sharing data policies. Based on literature review and collected information, possibility to access data and information based on restricted and limited approaches would be considered as the least requirements for data sharing measure. Open and non limited access to data and information for every one approach and environment would be considered as the best performance regarding data sharing environment measure.

Based on section 4.5 data sharing environment, Canada governments has performed a strong performance regarding digital areas such as government, social, and economic sectors due to a consistent political approach that has made Canada one of the best countries regarding open data and data sharing in the world. Thus, the data sharing environment measure readiness score would be calculated equal to 5 based on readiness score model.

4.6.6 Overall Readiness Score

Table 4.2 presents the policy and legislation readiness score and the measures' scores and weights. These measures include AVs regulation and standard, AVs regulation change, AVs responsibilities structure, governmental AVs pilots, data sharing environment.

Table 4.2 - Policy and Legislation Readiness Score

Measures	Score	Weight	Readiness Score
AVs Regulation and Standards	4	0.2	0.8
AVs Regulation Change	4	0.2	0.8
AVs Responsibilities Structure	4	0.2	0.8
Governmental AVs Pilots	5	0.2	1
Data Sharing Environment	5	0.2	1
Policy and Legislation Readiness Score			4.4/5

Chapter Five

Technology and Innovation

The technology and innovation readiness score is calculated from five measures as mentioned in chapter three. Collected data and findings regarding five measures are presented and analyzed in this section to provide a clear picture of the Canadian technology and innovation sector performance regarding AVs and CVs technologies. These measures are university activities, technology, and innovation hubs, AVs related patent, technology and innovation capability, and cybersecurity.

5.1 University Activities

Most AVs and CVs related activities in Canadian universities have been concentrated at Ontario's universities including the University of Toronto, University of Waterloo, and Carleton University, and only the ACTIVE-AURORA project that was conducted by the University of Alberta and University of British Columbia have been launched outside Ontario province with academic collaboration. The following presents some university research activities that were conducted by Canadian universities.

5.1.1 University of Alberta and University of British Columbia

In 2014, the University of Alberta, University of British Columbia, and provincial governments launched the ACTIVE-AURORA project which aimed to provide a bed test for CVs and AVs technologies in Edmonton and Vancouver. Edmonton's test path contained 60 kilometers of public roads that were equipped with various equipment for testing a wide range of AVs and

CVs technologies such as advisory driving speed, pedestrian warnings, high collision location warnings, and so on. Vancouver's bed test provided a controlled path with a network of connected cameras and roadside monitors for testing of different CVs technologies that are supposed to lead to safer and smarter transportation in British Columbia [98, 101].

5.1.2 University of Waterloo

The University of Waterloo has facilitated the collaboration between university faculty studies and the automotive industry by creating the University of Waterloo center of Automotive Research (WatCAR). The main research focus of WatCAR has been on Autonomoose which is a non-self-driving vehicle that equipped with various AVs controlling and navigation technologies, radar, sonar, lidar, inertial, and visions sensors that make it possible for Autonomoose to operate on SAE level 3 and will be able to operate on SAE level 4 soon. The WatCAR research contains improving AVs capabilities regarding special weather conditions of Canada, enhancing the fuel efficiency of AVs, reducing the emission of AVs, and providing better, safer, and robust operating methods for AVs [98].

5.1.3 University of Toronto

In 2017, the University of Toronto launched the iCity project which funded for 3 years a program to study social behavior regarding smart transportation technologies. The iCity Center for Automated and Transformative Transportation Systems (iCity-CATTS) has focused on developing analysis tools, methods, models, and decision support systems to measure the impact of automated and transformative transportation on Canadian society [98].

5.1.4 Carleton University

The Canadian federal government-funded Carleton University from the Federal Canadian Safety and Security Program regarding AVs cyber securities challenges in 2017. The program aimed to evaluate AVs cybersecurity vulnerabilities and risks, and provide solutions to identified challenges in collaboration with Transport Canada and BlackBerry QNX [98].

5.2 Technology and Innovation Hubs

Canada is considered as the largest automotive assembly base in North America, especially the Ontario province, however, the R & D hubs related to the automotive industry mostly created around automotive original equipment manufacturers (OEMs) headquarters which make it difficult for non-core places such as Canada to create Industrial R&D cores related to the automotive industry. The Canadian government, which has huge potential human resources of highly educated experts, has created an R & D hub based in Ontario with several programs which aimed to make Canada one of the leaders and pioneers in the AVs industry. The following presents two Canadian R&D programs in Ontario which are the base playgrounds of AVs and CVs technologies [103, 104].

5.2.1 AVIN

In 2017, Ontario launched a 5-year program in Stratford, Ontario, with an 80$ million budget named Autonomous Vehicle Innovation Network (AVIN) which aimed to connect the academic environment, industry, and government together. The AVIN should be considered as the most important action by the Canadian government to create an R&D hub related to AVs and CVs technologies separated from automotive industry R&D hubs. AVIN contains six different focus

areas, human-machine interface, multimodal and integrated mobility, vehicular networks and communications, vehicle cybersecurity and cross-border technologies, artificial intelligence, and high-definition mapping [98, 103].

5.2.2 Ottawa

The Ottawa city municipal and BlackBerry QNX Autonomous Vehicles Innovation Center created a bed test for AVs and CVs that has been located in Kanata North Technology Park which is known as Ottawa AVs hub with more than 70 companies involving AVs technology. Nokia has been providing LTE and 5G mobile connections for testing environments [98].

5.3 AVs Related Patent

Figure 5.1 presents the number of global automotive-related patents from 2001 to 2016, the number of automotive-related patents has grown significantly from 2010 to 2016. After 2010, the AVs and CVs R&D hubs have started to expand all around the world. As shown in figure 5.2, the number of AVs and CVs related patents has grown notably after 2010 with a higher growth rate rather than the general automotive-related patents growth rate for the same period.

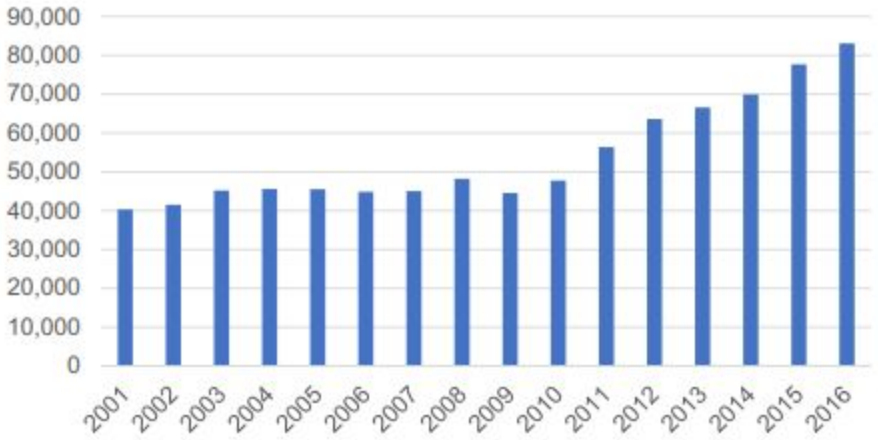

Figure 5.1 - Global Automotive Related Patent Applications 2001-2016 [103]

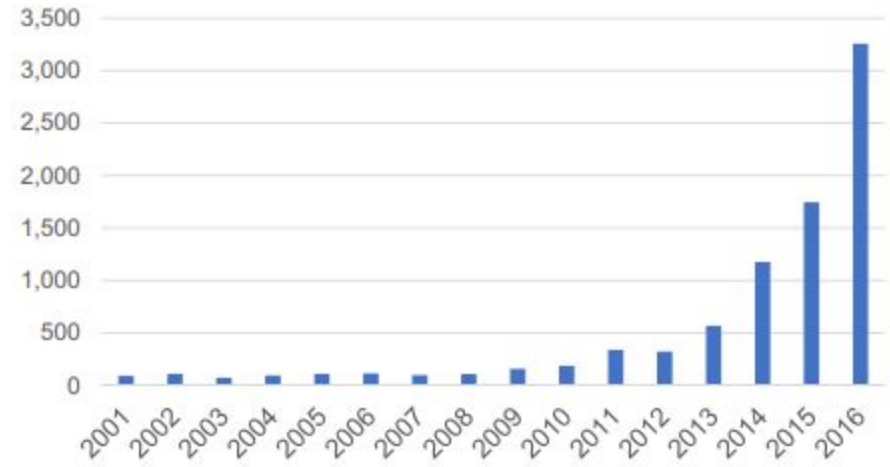

Figure 5.2 - Global AVs and CVs Related Patent Applications 2001-2016 [103]

However, The number of general automotive related patent applications has grown significantly, the average automotive-related patent application numbers have declined from 2001 to 2016 in Canada due to lack of automotive OEMs headquarters and industry-related R&D cores as shown in figure 5.3. According to figure 5.4, Canadian AVs and CVs related patent applications have

grown during recent decades, however, the Canadian share of the global AVs and CVs related patent and also general automotive patent applications has declined during the last decades as shown in figure 5.5.

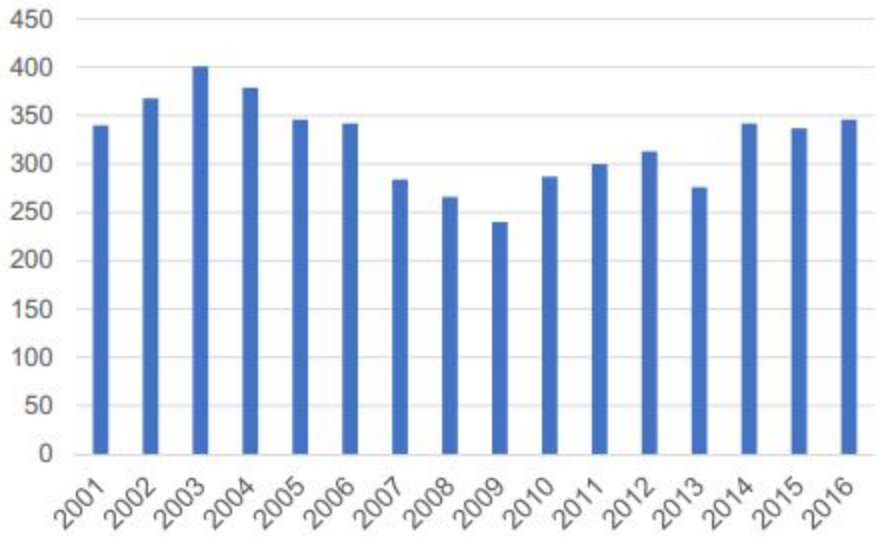

Figure 5.3 - Canadian Automotive Related Patent Applications 2001-2016 [103]

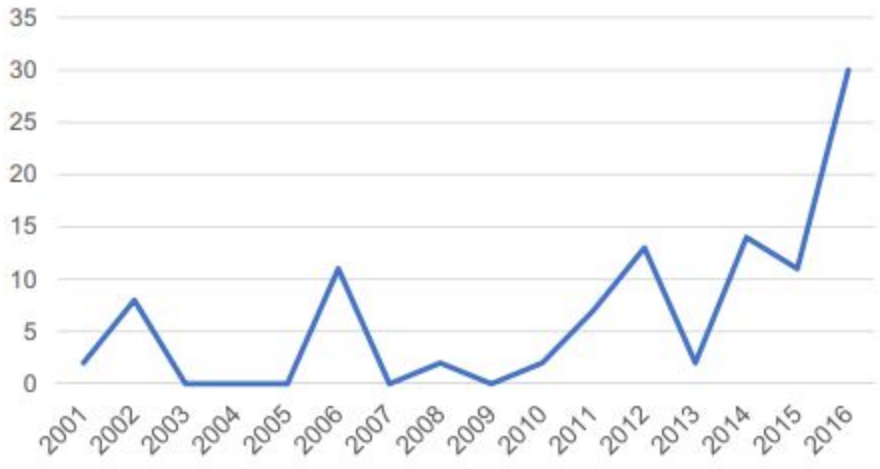

Figure 5.4 - Canadian AVs and CVs Related Patent Applications 2001-2016 [103]

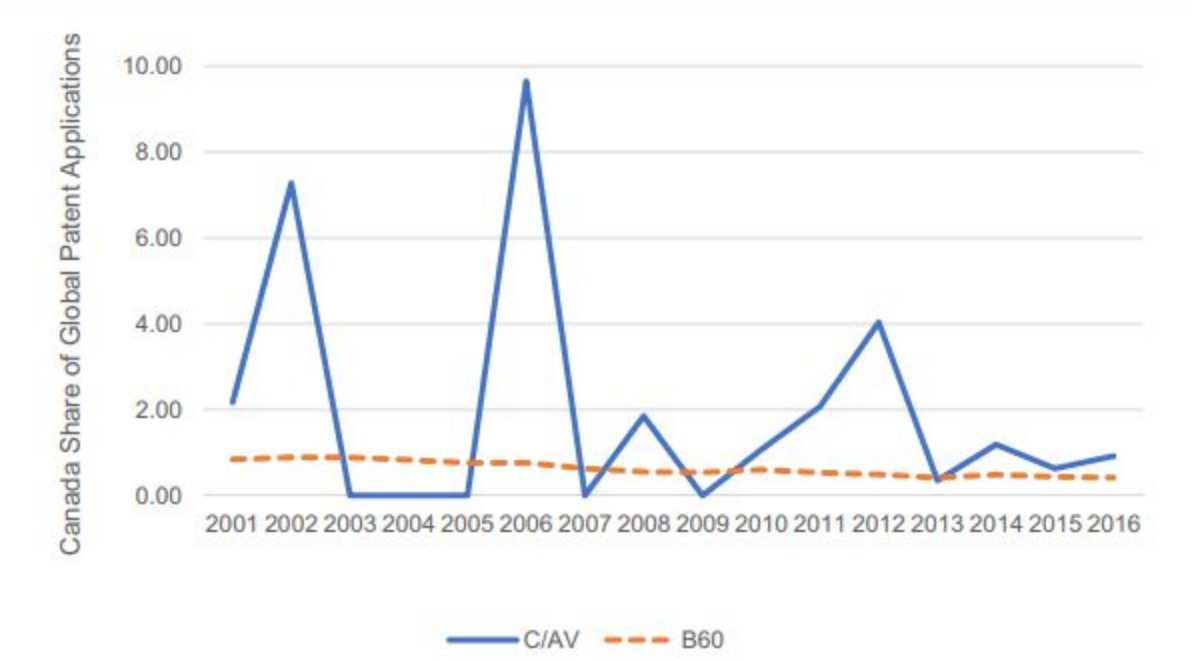

Figure 5.5 - Canadian Automotive (B60) and AVs/CVs Related Patent Applications' Share of Global Applications 2001-2016 [103]

According to figure 5.2 and 5.5, despite the significant growth rate of AVs and CVs related patent applications in Canada, the Canadian Share of global applications has declined notably during the last decades due to the high growth rate of global AVs and CVs related patent applications, especially the two traditionally automotive manufacturing countries, United States of America and Germany with more than 75 % share of global applications. It would be expected that Canada's share of global AVs and CVs related patent applications have been growing significantly after the Canadian government AVIN project was launched in 2016.

5.4 Technology and Innovation Capability

To evaluate this measure the 4 measures of innovation capability pillar from World Economic Forum (WEF) Global Competitiveness Report 2019 and 2018, 3 measures of technology

readiness from WEF Executive Opinion Survey for 2016-17, published in the Portulans Institute's 2019 Network Readiness Index, and 4 measures of Huawei Global Connectivity Index 2019 have been reviewed to evaluate the Canadian innovation environment and capability of being beneficial of latest technologies and innovations.

5.4.1 Global Competitiveness Report

Table 5.1 presents Canada's innovation capability scores and ranks according to the WEF global competitiveness report 2018 and 2019 which includes scientific publications, patent applications, R&D expenditures, and research institutions prominence.

Table 5.1 - Canada's Scores and ranks [89, 90]

Year	2018		2019	
Measures	Score	Rank	Score	Rank
Scientific Publication	100	4	100	4
Patent Applications	86.8	18	85.8	18
R&D Expenditures	53.8	23	51.0	23
Research Institutions Prominence	81.1	10	73.1	12

According to table 5.1, Canada's performance regarding the scientific publication and research institutions has been great with almost 1000 scientific publications each year, however, patent applications and R&D expenditures scores have been specified that Canada's technology and innovation sector separated from the academic environment has performed poorly. As mentioned before, creating an R&D center without the support of manufacturers' headquarters is difficult

and it is the point that makes it difficult for the Canadian technology and innovation sector to obtain more share of global patent applications and R&D cores.

5.4.2 Network Readiness Index

Based on WEF Executive opinion survey for 2016-17, published in the Portulans Institute's 2019 Network Readiness Index, three sub pillar access, content, and future technologies contained the technology sector which aimed to assess the countries' technology level regarding the network economy [105]. Table 5.2 presents part of Canada's scores and ranks in the Network readiness report 2019 that have the most related to this research content.

Table 5.2 - Canada's Scores and ranks [105]

Indicator	Score	Rank
Technology pillar	**73.13**	**13**
Sub Pillar: Access	81.47	28
Sub Pillar: Content	76.29	13
Sub Pillar: Future Technology	61.63	17
Sub Pillar: Access		
4G mobile Coverage	99.00	24
International Internet Bandwidth	70.35	46
Households with Internet Access	90.65	16
Sub Pillar: Content		
Digital Participation and Content Creation	-	-
Mobile Apps Development	84.15	20
Intellectual Property Receipts	5.29	20
Sub Pillar: Future Technology		
Availability of Latest Technologies	87.70	14
Company Investment in Emerging Technology	65.56	20
ICT PCT Patent Applications	60.60	15

According to table 5.2, Canada's scores for the access sub pillar measure have been high, but the ranking has indicated that the competition in the Access sub pillar was close, and most developed countries performed high performance regarding this measure. Canada has got a high score and rank in the availability of the latest technology measure and also Canada has performed above the average of high-income countries regarding the technology pillar index.

5.4.3 Global Connectivity Index

Based on Huawei Global Connectivity Index 2019, Canada has shown performance above the global average in all four technology enablers and also in all four pillars. Four measures of 40 measures have been chosen to evaluate Canada's technology and innovation capability, IT workforce, IoT potential, AI potential, and cloud potential. Canada has been considered one of the most educated countries in the world and has one of the highest rates of the professional workforce in the world. Hence, It is expected that Canada' score regarding IT workforce being high above the global average, however, Canada's scores regarding three other measures, IoT potential, AI potential, and cloud potential, just being equal to the global average which have indicated that Canada has performed poorly regarding these measures [106].

5.5 Cybersecurity

The International Telecommunication Union (ITU) provided a document, Global Cybersecurity Index (GCI) 2018, to evaluate countries' effort toward cybersecurity and enhance global cybersecurity awareness. GCI contained five major pillars, legal, technical, organizational, capacity building, and cooperation, that covered all aspects of cybersecurity such as, Policies, education, technologies, partnerships, and data sharing. Canada stood at second place after the United States in the American region and ninth place in the global ranking. The capacity building and cooperation were only pillars that Canada's performance was lower than the United State. Overall, Canada is one of the best countries regarding cybersecurity based on the GCI report [107].

5.6 Technology and Innovation Readiness Score

In this section, the five mentioned measures would be evaluated and examined based on the provided readiness score model to provide a clear picture of Canada performance regarding technology and innovation pillar. For this purpose the base requirements, the highest performance, and the support and maintenance programs and requirements for each measure would be identified and defined; in the next step, the measure readiness score would be calculated based on collected information.

Based on literature review, the all five measures of technology and innovation pillar have equal importance and playrole in this sector, thus, the equal weights would be applied to each measure to calculate the pillar readiness score.

5.6.1 University Activities Measure Evaluation

The first measure is focused on university activities related to AVs and CVs. Based on literature review and collected information, this measure would be evaluated based on two baseline which include evaluating each university activities and also evaluating academic environment performance regarding AVs and CVs technologies. A direct and comprehensive research programs within the university would be awarded the highest score, a direct but focused program to specific area or technology related to AVs and CVs would be considered as one step lower than the best performance, and a indirect related program to AVs and CVs would satisfied the the basic needs and requirements regarding AVs and CVs technologies development.

An approach and framework which would cover the most important research topics and subjects related to AVs and CVs technology and also create a network including all universities and research institutes would be considered as best performance of academic environment regarding AVs and CVs technologies. Separated but directed programs within major Canadian universities which satisfy the needs and requirements for AVs and CVs development would be considered as the baseline for this measure.

Based on section 5.1 university activities, most AVs and CVs related activities in Canadian universities have been concentrated at Ontario's universities including the University of Toronto, University of Waterloo, and Carleton University, and only the ACTIVE-AURORA project that was conducted by the University of Alberta and University of British Columbia have been launched outside Ontario province with academic collaboration. The University of Waterloo program and ACTIVE-AURORA project would be considered the highest performance regarding defined baselines, however, University of Toronto and Carleton University programs would satisfy the least requirements regarding AVs and CVs development and deployment. In addition, the academic approach and programs would satisfy the needs and requirements for AVs and CVs development by programs and projects related to AVs and CVs technologies within major Canadian universities.

The readiness score for each section would be calculated based on the readiness score model as follow:

- the University of Alberta, University of British Columbia program would be awarded a score equal to 5.

- The University of Waterloo program would be awarded a score equal to 5.
- The University of Toronto program would be awarded a score equal to 3.
- The Carleton University program would be awarded a score equal to 3.
- The Canadian academic environment approach and programs would be awarded a score equal to 3.

Based on mentioned scores, the university activities measure readiness score would be calculated equal to 3.5 due to average of universities program scores average and academic environment score.

5.6.2 Technology and Innovation Hubs Measure Evaluation

The second measure is focused on research and development centers related to AVs and CVs technologies. Based on literature review and collected information, a well established and comprehensive AVs and CVs related R&D core which has been supported by big and major automotive companies would be considered as the high end level for this measure. A research and development program which satisfies the least needs and requirements regarding development and deployment of AVs and CVs would satisfy the least needs regarding this measure.

Based on section 5.2 technology and innovation hubs, The Canadian government has created an R & D hub based in Ontario with several programs which aimed to make Canada one of the leaders and pioneers in the AVs industry. The AVIN should be considered as the most important action by the Canadian government to create an R&D hub related to AVs and CVs technologies

separated from automotive industry R&D hubs. The technology and innovation hubs measure's score would be calculated equal to 4 based on the readiness score model.

5.6.3 AVs Related Patent Measure Evaluation

The third measure is focused on Canada's performance regarding AVs and CVs technologies according to registered patent applications. Based on literature review and collected information, the average global performance would be considered as the performance which would satisfy the needs and requirements regarding this measure. The performance of traditional automotive manufacturing countries such as Germany and the United States would be considered as the best in class performance due to almost 75 % share of global registered patent applications related to AVs, CVs and automotive technologies [103].

Based on section 5.3 AVs related Patent, despite the significant growth rate of AVs and CVs related patent applications in Canada, the Canadian Share of global applications has declined notably during the last decades due to the high growth rate of global AVs and CVs related patent applications [103]. Canada's performance regarding AVs and CVs related patent applications would be calculated equal to score 3 based on readiness score model due to Canada average performance regarding global statistics.

5.6.4 Technology and Innovation Capability Measure Evaluation

The fourth measure is focused on Canada's capability of being beneficial to new technologies and innovations from all around the world and inside of Canada. Three different source have been used for this measure which should be evaluated separately, but for all three measures the

same baseline would be used which would been considering the global average performance as the need satisfying level based on readiness score model and also the global top performer would be considered as the best in class performance regarding this measure.

Based on section 5.4 technology and innovation capability, Canada's performance has been around the global average regarding chosen measures according to Network Readiness Index and Global Connectivity Index reports and also table 5.2. According to the Global Competitiveness report, Canada's performance in 4 chosen measures has been more than the global average regarding two measures, Scientific Publication and Research Institutions Prominence, which have indicated the top performance, however, Canada's performance has been around global average regarding two other measures. Thus, the readiness score for this measure according to Network Readiness Index and Global Connectivity Index would be equal 3, and according to Global Competitiveness would be equal 4 which have led to readiness score equal 3.3 for technology and innovation capability measure based on the readiness score model.

5.6.5 Cybersecurity Measure Evaluation

The fifth measure is focused on Canadian government's policies and actions regarding overall cybersecurity issues. ITU provided a document, GCI 2018, which has been used for evaluating this measure; hence, the global average would be considered as a least requirements and the global top performer's performance would be considered as best in class for this measure based on GCI report.

Based on section 5.5 cybersecurity, Canada is one of the best countries regarding cybersecurity subject; so, the cybersecurity measure readiness score would be awarded equal to 5 due to Canada's remarkable performance regarding cybersecurity.

5.6.6 Overall Readiness Score

Table 5.3 presents the technology and innovation readiness score and the measures' scores and weights. These measures include university activities, technology, and innovation hubs, AVs related patent, technology and innovation capability, and cybersecurity.

Table 5.3 - Technology and Innovation Readiness Score

Measures	Score	Weight	Readiness Score
University Activities	3.5	0.2	0.70
Technology and Innovation Hubs	4	0.2	0.80
AVs Related Patent	3	0.2	0.60
Technology and Innovation Capability	3.3	0.2	0.66
Cybersecurity	5	0.2	1.00
Technology and Innovation Readiness Score			3.76/5

Chapter Six

Infrastructure

The infrastructure readiness score is calculated from five measures as mentioned in chapter three. Collected data and findings regarding five measures are presented and analyzed in this section to provide a clear picture of the Canadian infrastructure readiness level regarding AVs and CVs technologies. These measures are mobile network coverage, mobile connection speed, road quality, electrical vehicles (EVs) charging station, and infrastructure technology change.

6.1 Mobile Network Coverage

The mobile data network is a fundamental technology for AVs development and deployment, thus, the mobile data network coverage should be considered as an important and vital parameter in the success of AVs and CVs deployment. AVs and CVs technologies need a fast data network regarding a Huge amount of information and data which has to transfer among the vehicle, V2C, V2I, V2V, and V2X, hence, the 4G (LTE) coverage has been playing the vital role in AVs deployment as the least requirement. Based on information from the Ookla Speedtest Global Index September 2020, Ookla coverage maps, GSMA coverage maps, Npref coverage maps, and Open Signal Canada Mobile Network Experience Report August 2020, the mobile coverage readiness score will be calculated.

6.1.1 Ookla

Based on Ookla Speedtest Global Index September 2020 and Ookla coverage maps, Bell, Telus, and Rogers are the top three Canadian mobile data network operators regarding 4G availability.

However, Canada's vast land is a challenging parameter for any mobile data network operator; as a result, most parts of the Canada lands are not covered sufficiently by a mobile data network. Figure 6.1 presents the coverage map of the 3G and 4G networks of Telus mobile network operator [80].

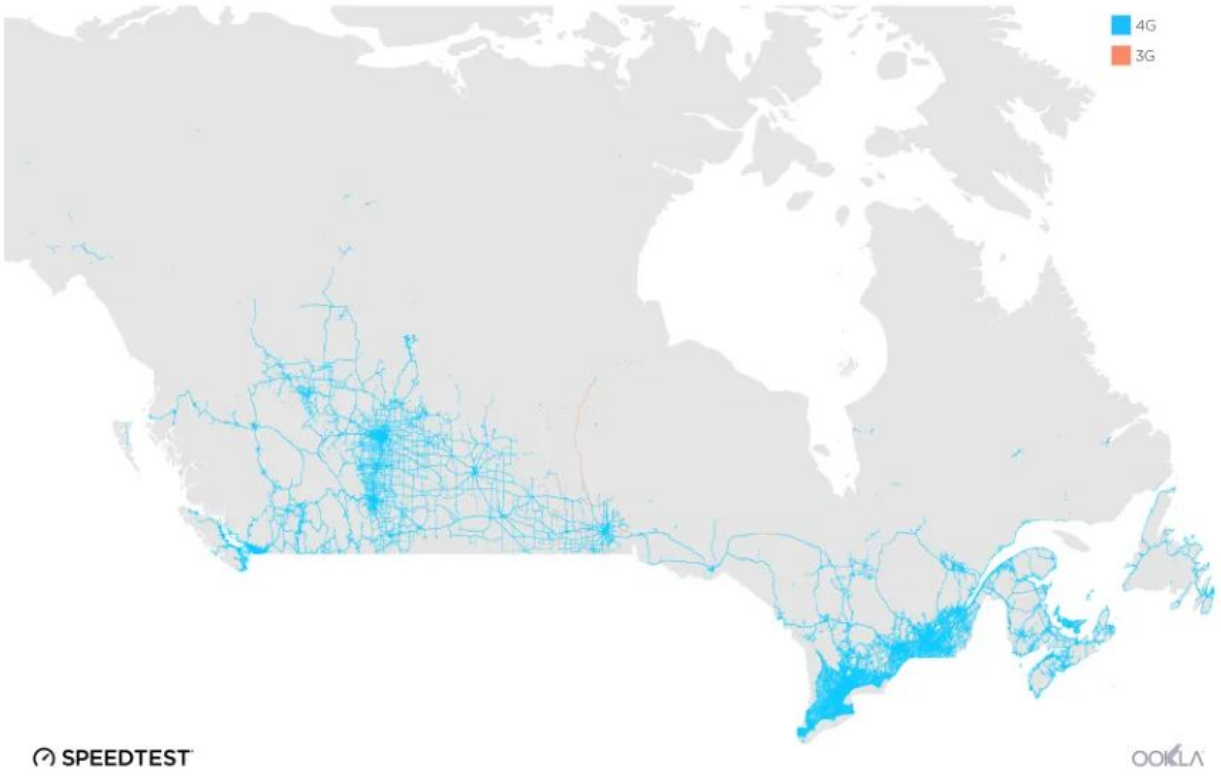

Figure 6.1 - Telus mobile data network coverage [81]

According to figure 6.1, the vast part of Canada's lands has poor or none mobile coverage, however, most major cities and roads have been covered by sufficient 4G mobile network coverage. The two other main mobile data network operators, Bell and Rogers, show almost the same coverage pattern according to Ookla coverage maps. Other Ookla coverage maps figures are provided in appendix C.

6.1.2 GSMA

Based on the GSMA network coverage maps, Bell, Rogers, and Telus, respectively provide the highest 4G mobile data coverage among Canadian mobile data network operators. Figure 6.2 presents the coverage map of the 4G network of Bell mobile network operator [82].

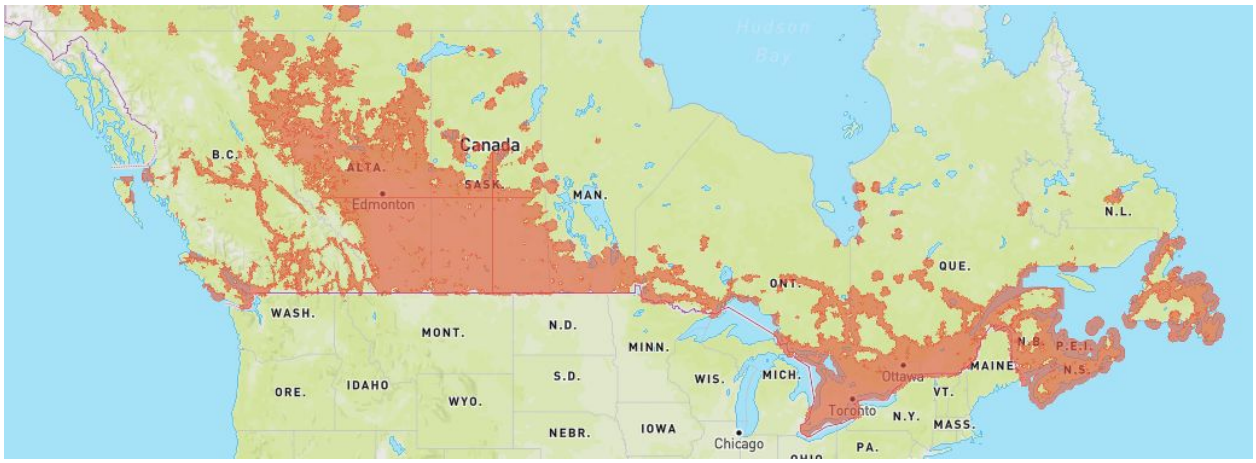

Figure 6.2 - Bell mobile data network coverage [82]

The middle part of Canada has poor 4G mobile network coverage and also British Columbia province has poor or none 4G mobile network coverage regarding figure 6.2. Rogers mobile network almost shows the same pattern and coverage area. But, Telus network Shows noticeable less coverage on the western lands of Canada according to GSMA network coverage maps. According to three main mobile data network operator 4G availabilities, major Canadian cities, and roads have sufficient mobile data network coverage for successful AVs and CVs deployment in major cities. Other GSMA coverage maps figures are provided in appendix D.

6.1.3 Npref

Based on Npref coverage maps, Telus provides the highest mobile data network coverage among other Canadian mobile data network operators. Figure 6.3 presents the coverage map of the data network of the Telus mobile network operator [83].

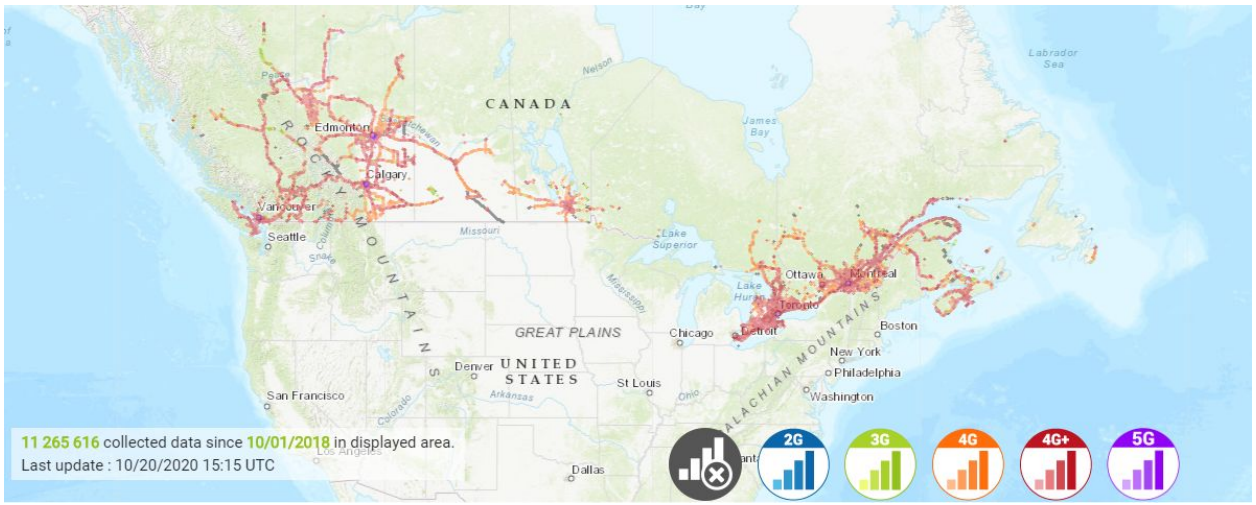

Figure 6.3 - Telus mobile data network coverage [83]

According to figure 6.3, the middle lands of Canada have poor or none mobile data network coverage in most areas which indicates the point that AVs deployment will face challenges regarding national deployment. However, the major cities have been covered by sufficient mobile data network, sufficient mobile data network coverage in all Canadian cities and roads should be considered as vital parameters for successful AVs and CVs deployment. Other Npref coverage maps figures are provided in appendix E.

6.1.4 Open Signal

Based on the Open Signal report, “Canada mobile network experience report August 2020”, the report provided a comparison between three main mobile network operators in Canada, Telus, Bell, and Rogers. The result indicated all three mobile network operators have been providing 4G availability scores higher than 90 % for their users. They also got the high scores on 4G coverage experience with which Telus and Bell got 9.6 and Rogers got 8.3 from 10. Figures 6.4 and 6.5 show the three main mobile network operators’ scores regarding the Open Signal report in August 2020 [84].

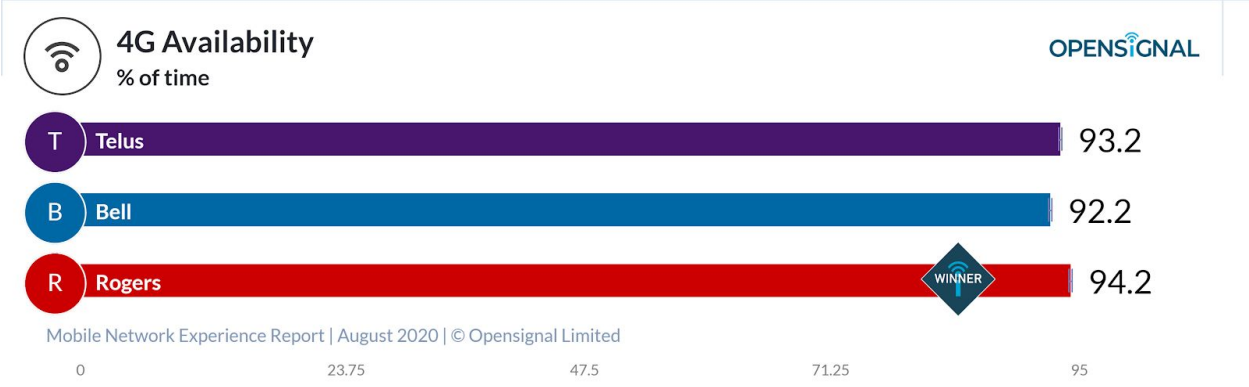

Figure 6.4 - 4G availability scores Open signal report august 2020 [84]

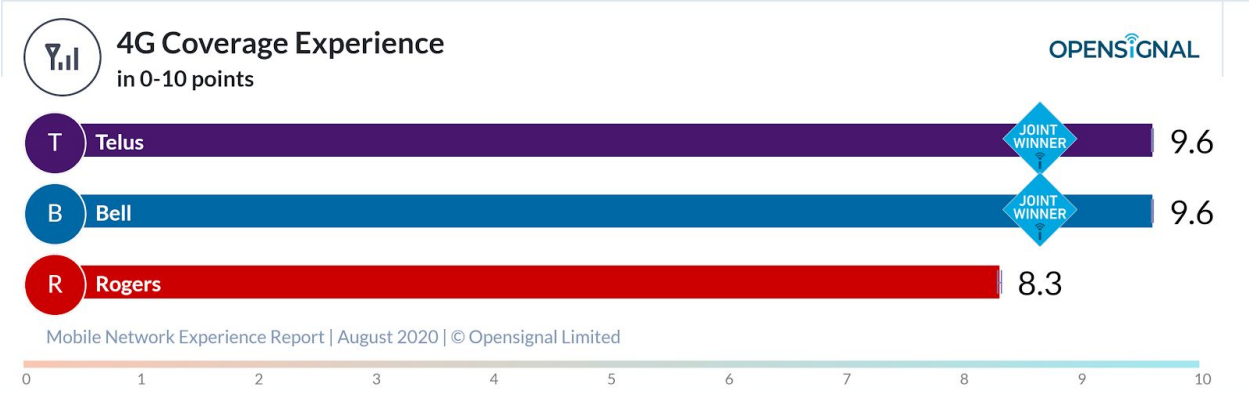

Figure 6.5 - 4G Coverage Experience scores Open signal report august 2020 [84]

6.1.5 5G Coverage

Regarding the huge amount of data and information transferring each second in the automated driving process, the network connection speed is a vital parameter. 5G mobile network technology promised to bring a hundred times faster transferring speed rather than 4G technology. 4G technology provides sufficient speed for AVs technology development and testing, however, AVs national deployment will need a faster and broader connection technology; thus, 5G technology will play a significant role in AVsand CVs technologies deployment in the future. Figure 6.6 provides a coverage map of 5G technology based on information from the Npref 5G coverage map [85].

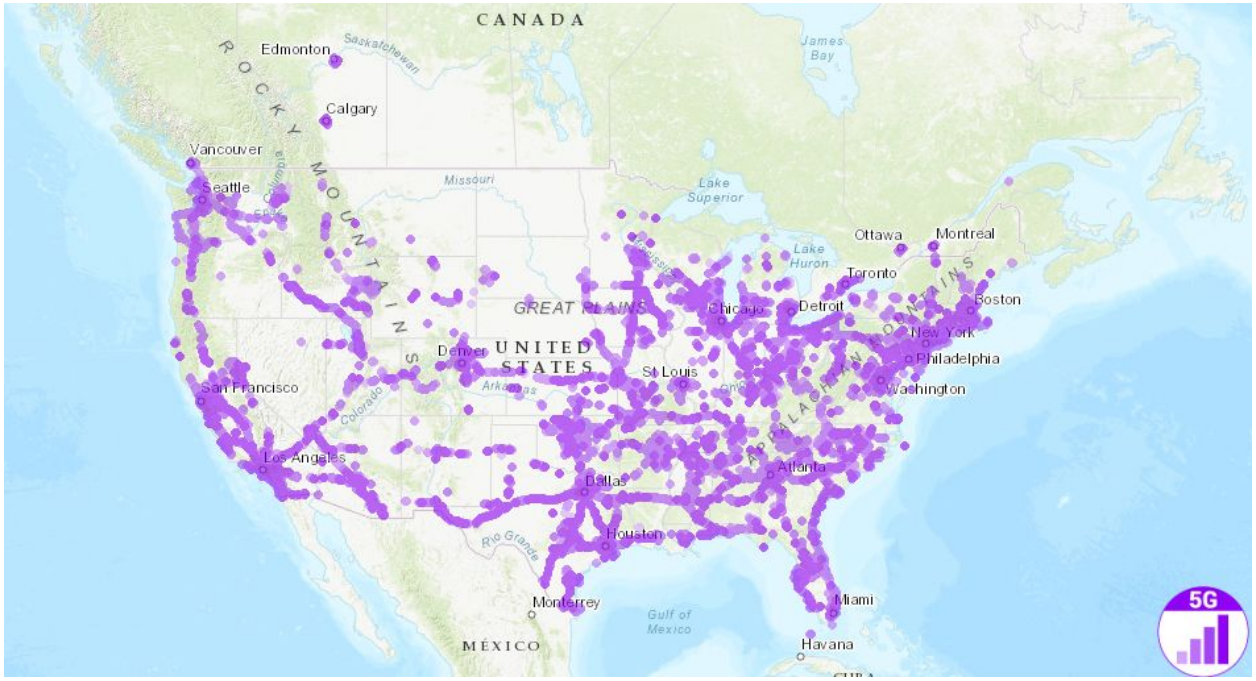

Figure 6.6 - Canada and the United States 5G mobile network coverage map [85]

The clear difference between the United States and Canada 5G mobile network coverage which is shown in figure 6.6, indicates that the Canadian mobile network operators should invest and

consider more effort regarding 5G technology. According to figure 6.6, only Canadian in major cities has been beneficial to 5G technology, however, AVs deployment relies on stable and wide coverage of the mobile data network and 5G technology current coverage state provides poor support to AVs technology.

6.2 Mobile Connection Speed

As mentioned before, the mobile data network has been playing one of the main roles in AVs and CVs technologies development. The coverage and speed are the two main mobile data network parameters that influence AVs and CVs technologies development and deployment. In the previous section, the information regarding the mobile data network coverage has been provided. Based on Ookla Speedtest Global Index September 2020, Open Signal Canada Mobile Network Experience Report August 2020, Open Signal Global Mobile Network Experience Award 2020, and Open Signal report "the State of Mobile Network Experience 2020, One Year into the 5G Era", Canadian mobile data network users have been witnessing the one of the highest download speed in the world. Each document will be examined separately in the following.

6.2.1 Ookla

Based on Ookla Speedtest Global Index September 2020, Canada has the eighth fastest mobile data network in the world with an average download speed equal to 75.71Mbps, upload speed equal to 12.68 Mbps, and latency of 37 ms. According to the index, Telus mobile network operator provides not only the fastest mobile internet speed among Canadian mobile networks

operators but also 95.5 % 4G availability for its users. Figure 6.7 presents the changes in average mobile internet speed in Canada from September 2019 to September 2020 [80].

Figure 6.7 - Canada mobile data network speed changes from 09/2019 to 09/2020 [80]

6.2.2 Open Signal

Based on Open Signal Canada Mobile Network Experience Report August 2020, the three main Canadian mobile data network operators provide the following mobile internet speed for their users, download speed, Telus 72.7 Mbps, Bell 67.5 Mbps, and Rogers 53.9 Mbps. Figure 6.8 and 6.9 present respectively the download and upload mobile internet speed of three main Canadian mobile data network operators [84].

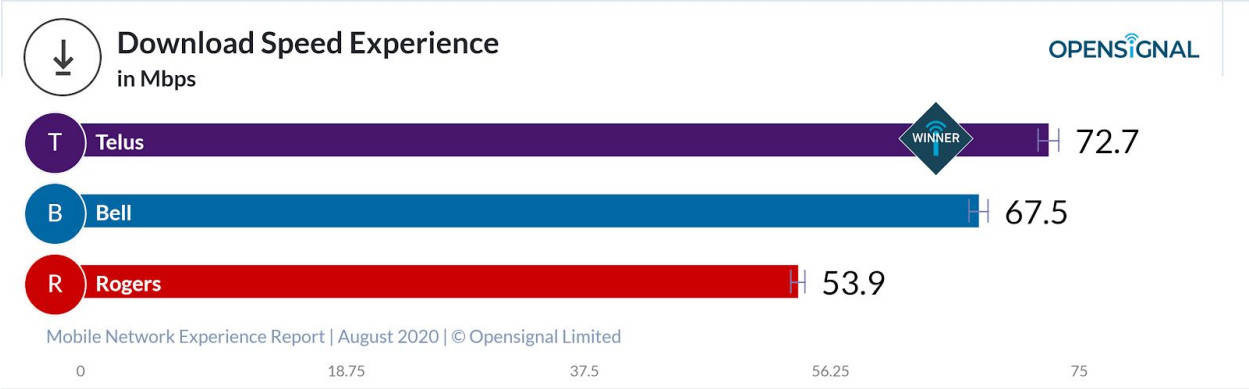

Figure 6.8 - Three main Canadian mobile data network operators download speed [84]

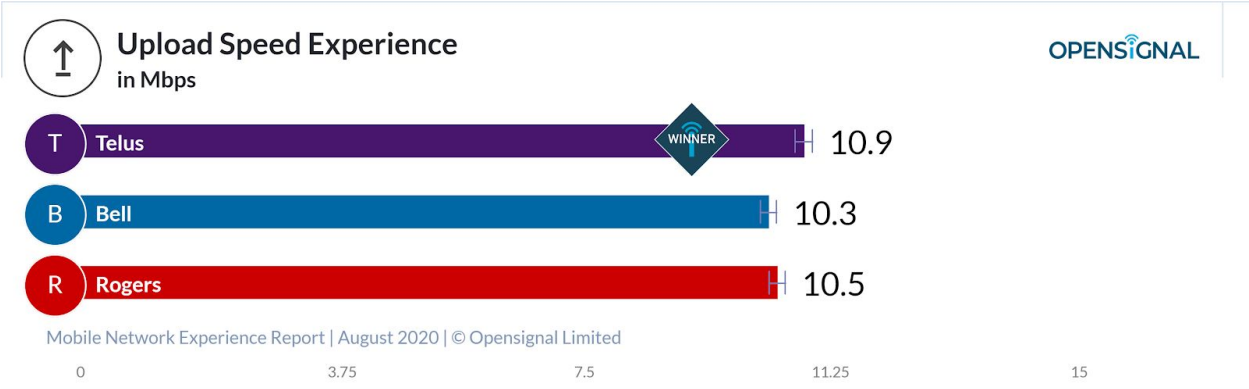

Figure 6.9 - Three main Canadian mobile data network operators upload speed [84]

Based on the Open Signal Global Mobile Network Experience Award 2020, Telus mobile data network operator won the fastest download speed experience award with the download speed equal to 75.8 Mbps [86]. Based on the Open Signal report "the State of Mobile Network Experience 2020, One Year into the 5G Era", Canada and South Korea were leaders regarding providing the highest global average download speeds for their users [87].

6.3 Road Quality

Canada's vast land from the Atlantic Ocean in the east to the Pacific Ocean in the west is a challenging parameter in most infrastructures measures, especially road quality maintenance. Road quality as the third measure of infrastructure readiness score aims to evaluate the level of quality and maintenance of Canadian roads. The Canadian Infrastructure Report Card 2019 and WEF Global Competitiveness Reports 2016/2017, 2017/2018, 2018, and 2019 have been used to calculate the Road quality readiness score. Based on the Canadian Infrastructure Report Card 2019, almost 50% of Canadian roads and bridges are in good or very good condition.

6.3.1 Canadian Infrastructure Report Card

According to figure 6.10, almost 80 % of Canadian roads and bridges were constructed before 1999 and an average of 35 % to 40 % of these assets was constructed from 1970 to 1990. According to Figure 6.11, the quality of roads after 75 % of their life will decrease at a notable rate. There is a term known as Estimated Service Life (ESL) which indicates the practical or in-use lifetime of a product. According to the Canadian Infrastructure Report Card 2019, roads, sidewalks, Bridges ESL respectively equals 20-40, 50, and 50 years. As mentioned before, almost 80 % of Canadian roads and bridges were constructed before 1999; thus, almost 80 % of Canadian roads and bridges have been in service for more than 20 years, and around 15 % of these assets have been in service for more than 80 years due to the construction year before 1940. As a result, it is expected that a huge percentage of Canadian roads and bridges were not in good condition [88].

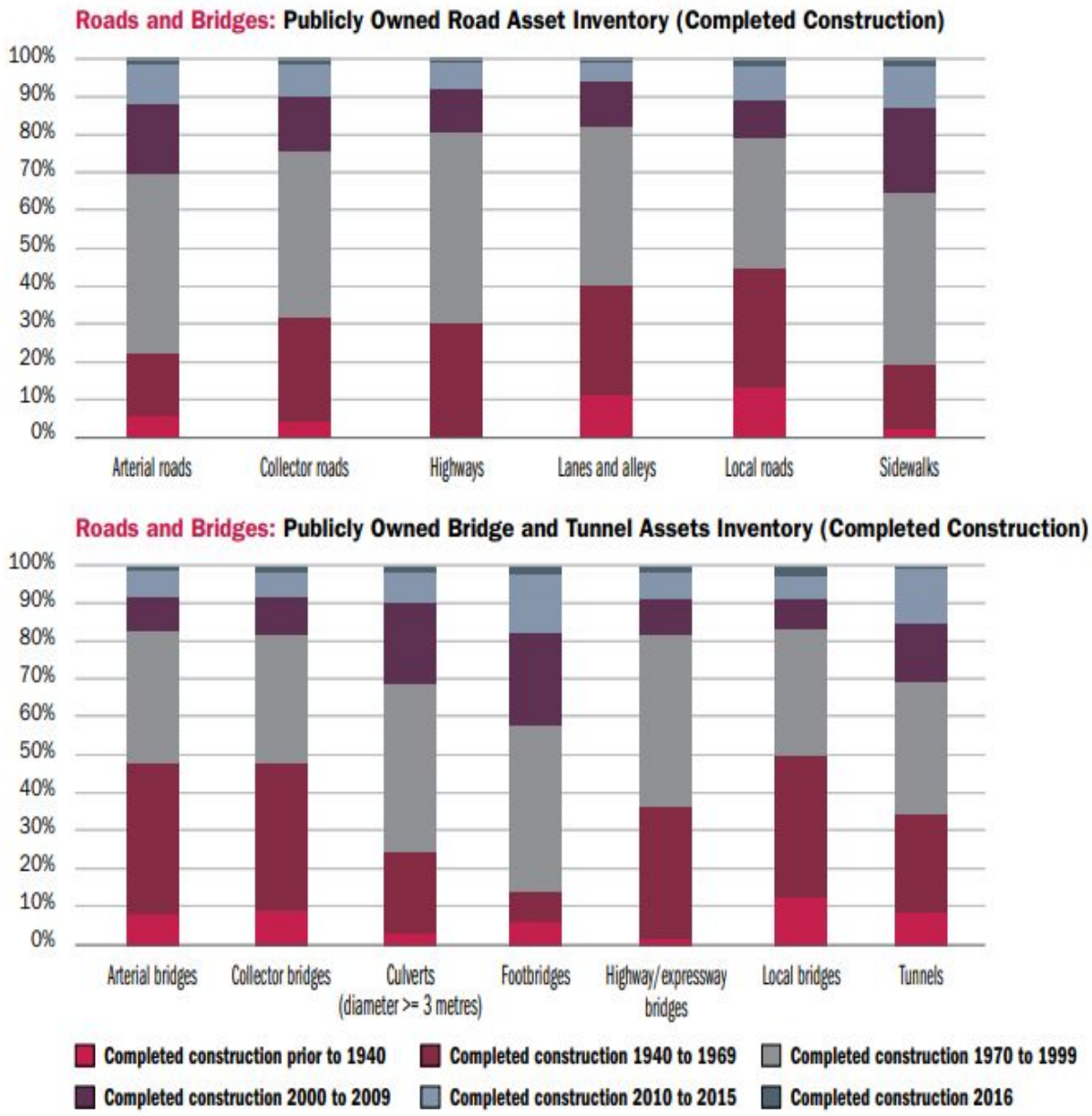

Figure 6.10 - Canadian roads and bridges construction year [88]

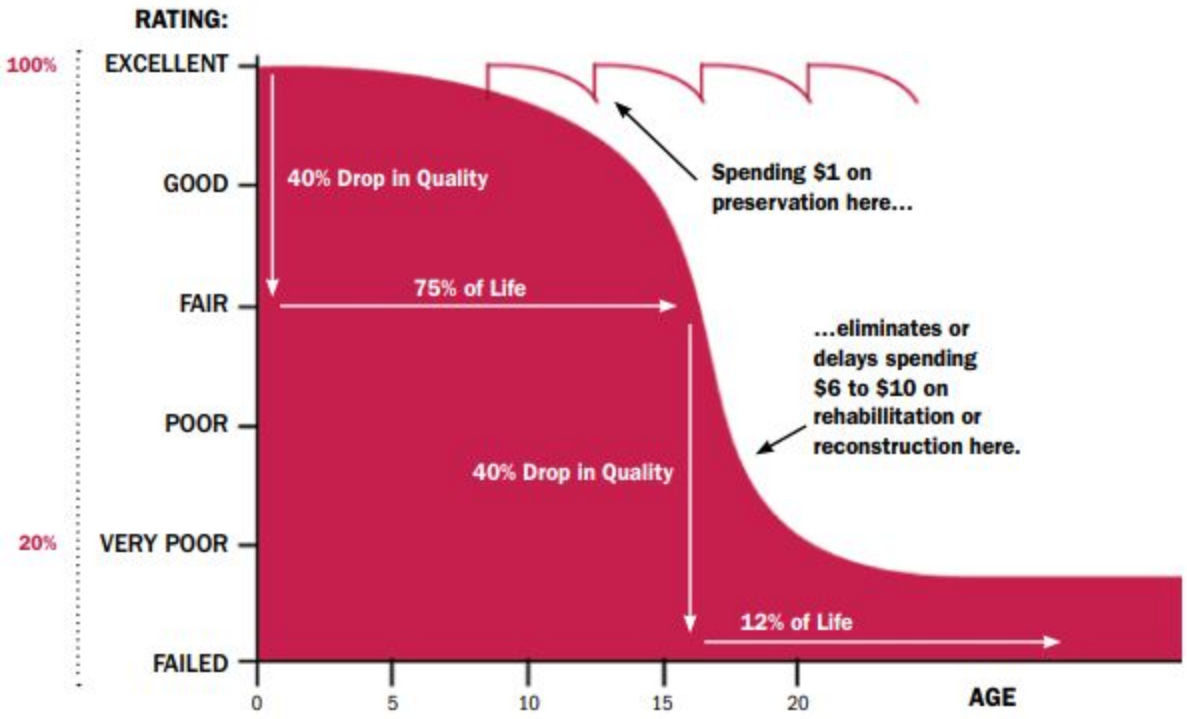

Figure 6.11 - Example of asset deterioration curve (Roads) [88]

According to figure 6.12, 52 % of roads and 60 % of bridges were in good and very good condition, and 39 % of roads and 37 % of bridges were in fair or worse condition in 2019. With a comparison between the data from 2019 and 2016, it is clear that the percentage of roads and bridges with good and very good conditions dropped by almost 15 % in roads and 17 % in bridges and also the percentage of roads and bridges with poor and very poor conditions increased by almost 5 % in roads and 10 % in bridges. It will be predictable that the percentage of roads and bridges with poor and very poor condition exceed the 50 % in next decade according to the service life and current conditions of Canadian roads and bridges and also the infrastructure nurture is a slow and time consuming as any infrastructure construction, or maintenance process can require several years of action and planning.

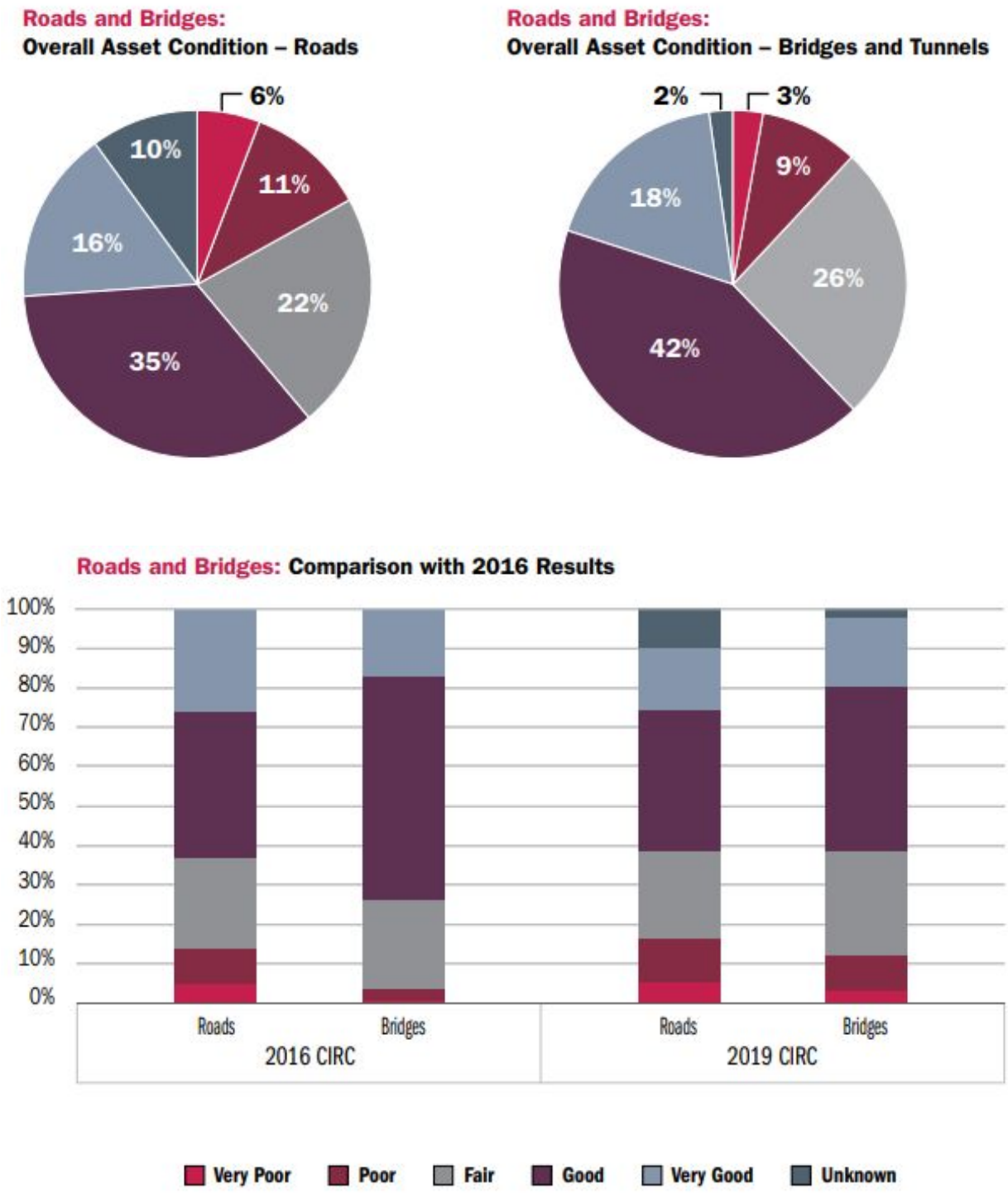

Figure 6.12 - Canadian roads and bridges overall condition [88]

6.3.2 World Economic Forum

Based on the WEF Global competitiveness index 2019, the Road Connectivity (Quality of Road Network) index has aimed to evaluate the speed of driving and straightness of driving among the largest cities in each country which account for at least 15 % of the economy's total population. The Quality of Road Infrastructure has aimed to evaluate the road infrastructure conditions from extremely poor or one to extremely good or seven [89]. The following table presents the Canada ranking and score regarding these two indexes in the last four years report, 2016/2017, 2017/2018, 2018, and 2019.

Table 6.1 -Canada ranking and score regarding World Economic Forum Reports [89, 90, 91, 92]

Year	2019	2018	2017/2018	2016/2017
Overall Rank	14	12	14	15
Road Connectivity rank	4	8	-	-
Road Connectivity score	98.7	93.4	-	-
Quality of Road Infrastructure rank	30	25	22	22
Quality of Road Infrastructure score	5	5.2	5.4	5.3

According to table 6.1, Canada score regarding Road Connectivity index indicates that Canada has one of the best roads networks in the world and also the score and ranking have increased dramatically, however, Canadian roads quality has been on the opposite path and Canada rank has dropped by 8 places in the last three years.

6.4 Electrical Vehicles (EVs) Charging Stations

Based on Natural Resources Canada data, Canada has 5,246 EVs charging stations which contain 42 level 1, 4,618 level 2, and 892 DC fast EVs charging stations in September 2020 [93]. Based on Natural Resources Canada data of 2018 and 2020, and the International Energy Agency's Global EV outlook 2019 and the International Energy Agency's Global EV outlook of 2018 and 2019, table 6.2 has been provided.

Table 6.2 - Canada and the Netherlands EVs charging Station Comparison [93, 94, 95]

Country	Canada		Netherland	
Year	2018	2020	2018	2019
Population (million)	37.06	37.59	17.18	17.28
EVs Charging Station	4,710	5,246	32,875	51,840
EVs Charging Station per 1000 Residents	0.12	0.13	1.91	3
EVs Charging Station per 100 KMs of Road	0.56	0.62	23.5	37.05

Based on International Energy Agency's Global EV outlook 2019, The Netherlands leads the EVs infrastructure pillar, thus, the Netherlands has been used as a benchmark to evaluate the Canada data and performance regarding EVs charging infrastructure [95].

According to table 6.2, Canada's EVs charging station numbers increase by 11 % from 4,710 to 5,246 stations from 2018 to 2020; however, Comparing data of Canada and the Netherlands shows the fact that Canada's EVs charging station numbers are very low regarding the population and roads network's length. The Netherlands has 37.05 EVs charging stations per 100

kilometers of the road compared to Canada with 0.62 EVs charging stations per 100 kilometers of roads which is 50 times less than numbers of the Netherlands and also the Netherlands with 3 EVs charging stations per thousands of residents has almost 20 times more than Canada with only 0.13 EVs charging stations per thousands of residents. As most AVs are likely to be EVs, the success of AVs deployment in Canada will depend on sufficient EVs infrastructure which the most important one is EVs charging stations and Canada performs a poor performance regarding EVs charging stations.

6.5 Infrastructure Technology Change

Based on KPMG International's 2019 Change Readiness Index, Canada with a score of 0.378 out of 1 has poor performance regarding infrastructure technologies that would be able to support the deployment of AVs technology. Canada's score has dropped from 0.412 in the 2017 Change Readiness Index to 0.378 in the 2019 Change Readiness Index which indicates the poor performance of Canada regarding infrastructure policies and frameworks [96, 97].

6.6 Infrastructure Readiness Score

In this section, the five mentioned measures would be evaluated and examined based on the provided readiness score model to provide a clear picture of Canada performance regarding infrastructure pillar. For this purpose the base requirements, the highest performance, and the support and maintenance programs and requirements for each measure would be identified and defined; in the next step, the measure readiness score would be calculated based on collected information.

Based on literature review, the all five measures of technology and innovation pillar have different importance and playrole in this sector, thus, the mobile network coverage and mobile connection speed, which are fundamental requirement for AVs and CVs technologies, would cover 40 % of infrastructure pillar readiness score, the road quality, which is the fundamental for any vehicle, would cover 25 % of the readiness score, the electrical vehicles (EVs) charging stations measure as the only EVs infrastructure related measure would also cover 25 % of the readiness score, and the infrastructure technology change measure would cove 10 % of the readiness score.

6.6.1 Mobile Network Coverage Measure Evaluation

The first measure is focused on the 4G coverage of Canadian mobile data networks. Based on literature review and collected information, A mobile data network coverage which has been covering the major cities districts and also some major road systems would satisfy the least need and requirements regarding AVs and CVs development and deployment. A comprehensive and national mobile data network coverage which not only has been covering the major cities and road systems, but also has been covering rural roads and districts would be considered as the best performance regarding this measure.

Based on section 6.1 mobile network coverage, according to different mobile data network coverage maps, major cities, road systems, and most Canadian southern provinces areas have been covered by sufficient 4G mobile network coverage. As a result, the mobile network coverage measure readiness score would be calculated equal to 4 due to mobile data coverage in areas which contain the most population share of Canadian residences.

6.6.2 Mobile Connection Speed Measure Evaluation

The second measure is focused on Canada's mobile internet connection speed. Based on literature review and collected information, to determine and define the baseline for this measure the global average mobile internet speed connection and also the minimum speed requirements regarding the AVs and CVs technologies would be considered as the need satisfying level based on readiness score model. The world leader's performance would be considered as the best in class performance regarding mobile connection speed measure.

Based on section 6.2 mobile connection speed, Canada has been a leader regarding providing the highest global average download speeds for their users. Thus, mobile connection speed measure readiness score would be calculated equal to 5 due to Canada's high performance regarding mobile internet speed.

6.6.3 Road Quality Measure Evaluation

The third measure is focused on the quality of Canadian roads. Based on literature review and collected information, a road network, which has a high road and road infrastructure quality and has also used the latest infrastructure technologies, would be considered as the highest level regarding this measure. A well designed road network, which has fair road and road infrastructure quality, would satisfy the least needs and requirements regarding road quality measure.

Based on section 6.3 road quality, Canada has one of the best road networks in the world and almost 50 % of road systems have been in good or very good conditions, however, almost 50%

of roads systems have also been in fair and worse conditions and Canada has shown poor performance regarding deployment of new infrastructure technologies. Subsequently, the road quality measure readiness score would be calculated equal to 3 based on the readiness score model.

6.6.4 Electrical Vehicles (EVs) Charging Stations Measure Evaluation

The fourth measure is focussed on Canada's state and performance regarding EVs charging stations. Based on literature review and collected information, the world leader's performance such as the Netherlands would be considered as the best in class and measure for highest performance regarding this measure. An EVs charging stations structure and network which has been satisfying the current need and requirements of EVs in major cities and roads would be considered as the baseline for this measure.

Based on section 6.4 electrical vehicles (EVs) charging stations, Despite the increase in the number of EVs charging stations in Canada during the last couple of years, Canada's numbers have indicated the poor performance in comparison with the Netherlands' numbers. Subsequently, the electrical vehicles (EVs) charging stations measure readiness score would be calculated equal to 3 based on the readiness score model.

6.6.5 Infrastructure Technology Change Measure Evaluation

The fifth measure is focused on the availability of the latest technology related to infrastructure in Canada. KPMG International's 2019 Change Readiness Index report has been used for evaluating this measure; hence, the global average would be considered as a least requirements

and the global top performer's performance would be considered as best in class for this measure based on KPMG's report.

Based on section 6.5 infrastructure technology change, Canada has shown a poor performance regarding infrastructure policies and frameworks; so, the infrastructure technology change measure readiness score would be calculated equal to 3 based on the readiness score model.

6.6.6 Overall Readiness Score

Table 6.3 presents the infrastructure readiness score and the measures' scores and weights. These measures include mobile network coverage, mobile connection speed, road quality, electrical vehicles (EVs) charging stations, and infrastructure technology change.

Table 6.3 - Infrastructure Readiness Score

Measures	Score	Weight	Readiness Score
Mobile Network Coverage	4	0.2	0.8
Mobile Connection Speed	5	0.2	1
Road Quality	3	0.25	0.75
EVs Charging Station	3	0.25	0.75
Infrastructure Technology Change	3	0.1	0.3
Infrastructure Readiness Score			3.6/5

Chapter Seven

Customer Acceptance

The survey has been conducted to examine the Canadian AVs and CVs market maturity from the executors' perspective. The survey contains 13 questions which 12 of them are a linear scale question and the last one will be the most important benefit of AVs and CVs for Canadian society from the perspective of responders. The following sections will provide a deep analysis of responses to the survey. The survey's form is provided in appendix F.

The survey aims to provide a deeper understanding of the current state of AVs and CVs in Canada and also examine the level readiness of government and industry partnership, customer acceptance, and industry maturity. The LinkedIn social network structure has been used to find the survey target population based on keywords such as "Autonomous Vehicles", "Driverless Car", "Automated Vehicles/Car", and "Connected Vehicles/Car" and also the location filter has been used to separate the Canadian Cluster from the whole target population. According to Figure 1, most responses to questions have a normal distribution and focused means. The following provides the analysis for each question, and after that, these analyses will be used to make a comprehensive picture of customer acceptance regarding AVs and CVs current state in Canada.

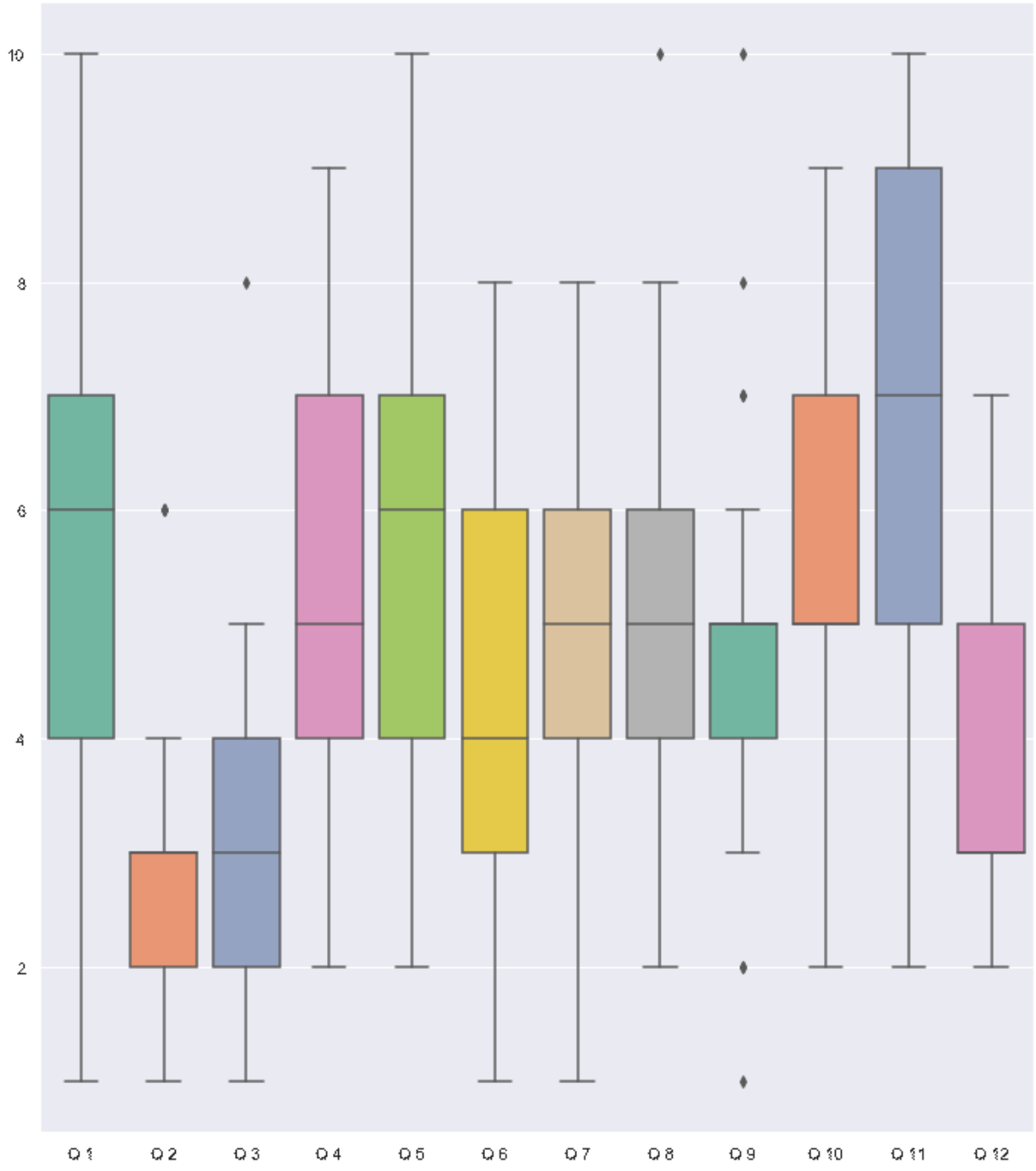

Figure 7.1 - Questions-Responses Box-Plot

7.1 Question one

"In your opinion, how long will it take Canadian society to have Autonomous Vehicles technology (Level 4 or 5)on the road?" aims to provide a clear picture of the population perspective toward the state of AVs in Canada before the whole survey; the question one, represents their opinion about how mature is the Canadian AVs market at the whole, without details which will be asked later.

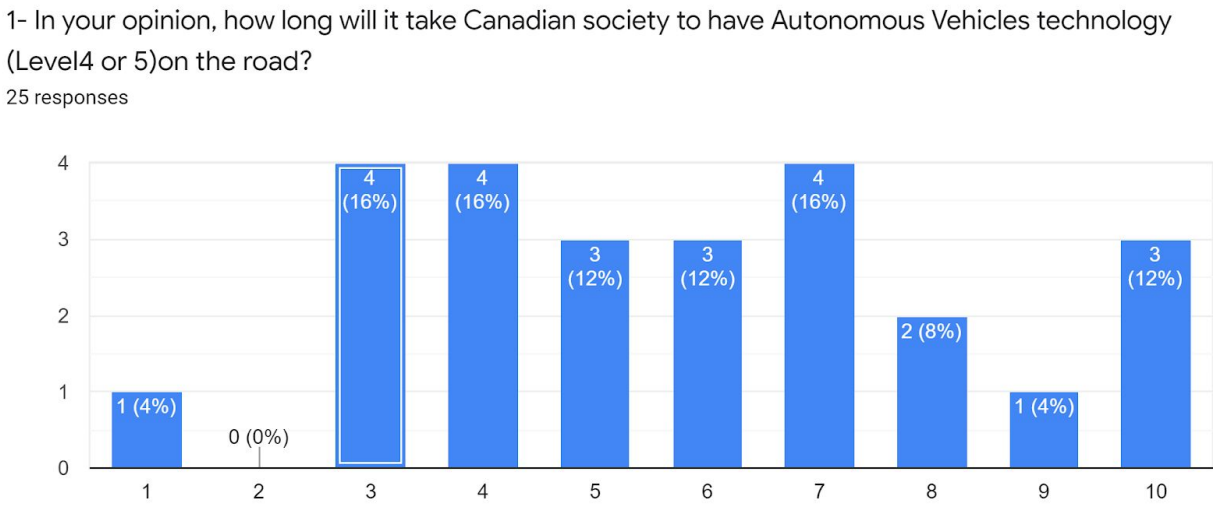

Figure 7.2 - Question 1

According to figure 7.2, there is a variety of opinions among the population which indicates that the AVs market in Canada did not get to a stable point and clear state yet. For sure, there are a lot of works and efforts to deploy and be beneficial to AVs technology from the Canadian government and industrial sector, however, these efforts could not be able to have a notable

impact on Canadian society or establish a stable development rate or reliable road map of the future of AVs in Canada.

Most answers indicate a time between 5 to 13 years needed for Canada may be able to be beneficial from AVs technology. The important point here is these years indicate that there are challenges and barriers which should solve and face to deploy AVs technology which current Canada is far from that.

7.2 Question Two

" In your mind, What portion of Canadians have sufficient knowledge about Autonomous Vehicles technology and it's benefiting?" will indicate the percentage of Canadian society who has sufficient knowledge about AVs; It means that the Canadian society has the information and data on the definitions, benefits, roles, and challenges related to AVs or there is a need for education and data sharing about AVs in society.

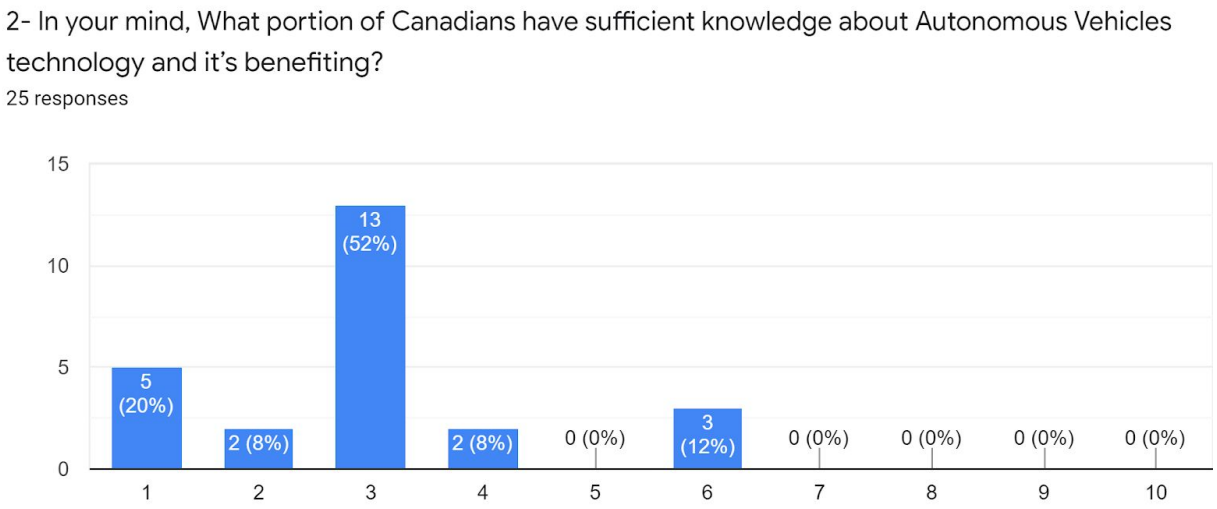

Figure 7.3 - Question 2

Less than one-third of Canadian society has sufficient knowledge about AVs technology according to the executors' perspective shown in figure 7.3. The result from question 2 specifies a vital need for improving Canadian society's knowledge about AVs. Society plays a significant role in the deployment of any new technology; they will make a demand on the market; the AVs technology deployment depends on multi-section stakeholders, however, the customer acceptance term should be considered as one of the most important ones they will be not only the customers of AVs technology but also they may be the supporters of the government actions toward AVs technology.

7.3 Question Three

"Do you think the Canada Government takes sufficient and influential actions to improve society's knowledge of AVs and CVs?" aims to deepen the understanding of the current situation of Canadian society toward AVs and CVs technologies, in combination with question 2. The responses will show the executors' opinion about the actions taken by the government to make a better interaction between Canadian society and AVs technology. These actions include any form of action that helps improve society's knowledge regarding AVs and CVs technologies such as seminars, testing trails, public education, and so on.

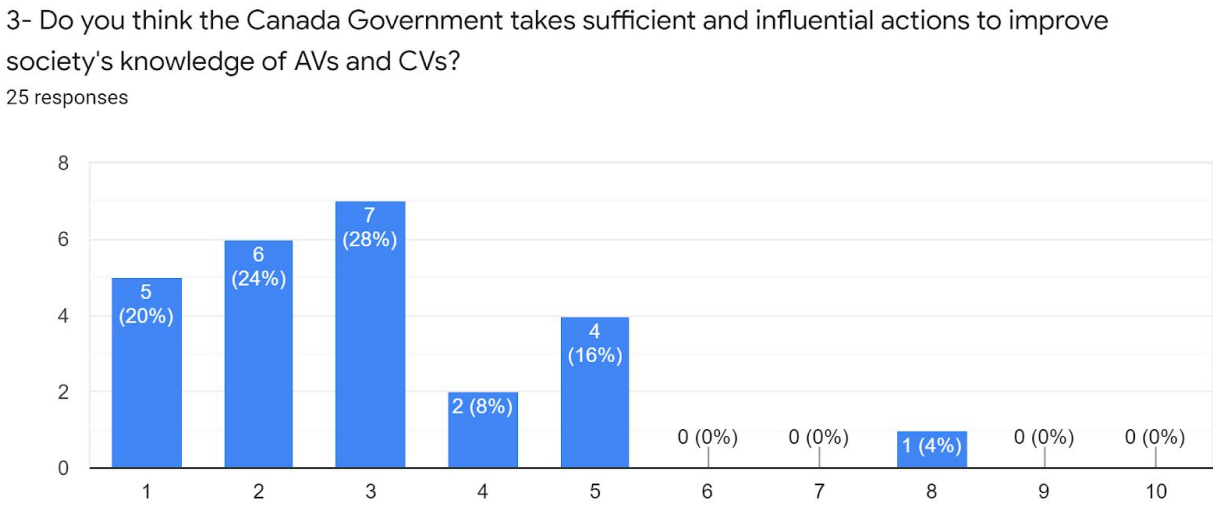

Figure 7.4 - Question 3

According to figure 7.4, the survey's population strongly believes that the Canadian government has poor performance to enhance Canadian society's awareness of AVs technology. The results from question 3 and 4 together provide a clear picture of Canadian society awareness about AVs

technology and also indicate an urgent need toward this gap between society and AVs technology. Thus, society's perspective toward AVs and CVs technologies must be improved and the governments should take action and prepare a detailed road map as soon as possible due to the fast state of AVs technology development and also the current state of AVs and CVs technologies in the Canadian market.

The Canadian government can take a variety of actions including any form of action that helps improve society's knowledge regarding AVs and CVs technologies such as seminars, testing trails, public education, and so on, but maybe the best option will be the provincial pilot projects. The Canadian government and provincial governments created pilot projects in major provinces for testing AVs and CVs related technologies, however, with new permissions in some provinces for testing the AVs and CVs on public roads, the Canadian government should consider the possibility of using the opportunity to improve society's awareness toward AVs and CVs Technology.

7.4 Question Four

"What is your opinion about university policies and frameworks regarding AVs and CVs technologies?", aims to evaluate the Canadian academic environment according to the technology readiness level related to AVs. question 4 examines the academic performance just based on its action, however, in combination with the result of question 5 which aims to evaluate the level of collaboration between the academic and industrial environment in Canada; these two

questions will provide a proper understanding of the current state of academic performance regarding AVs technology and development.

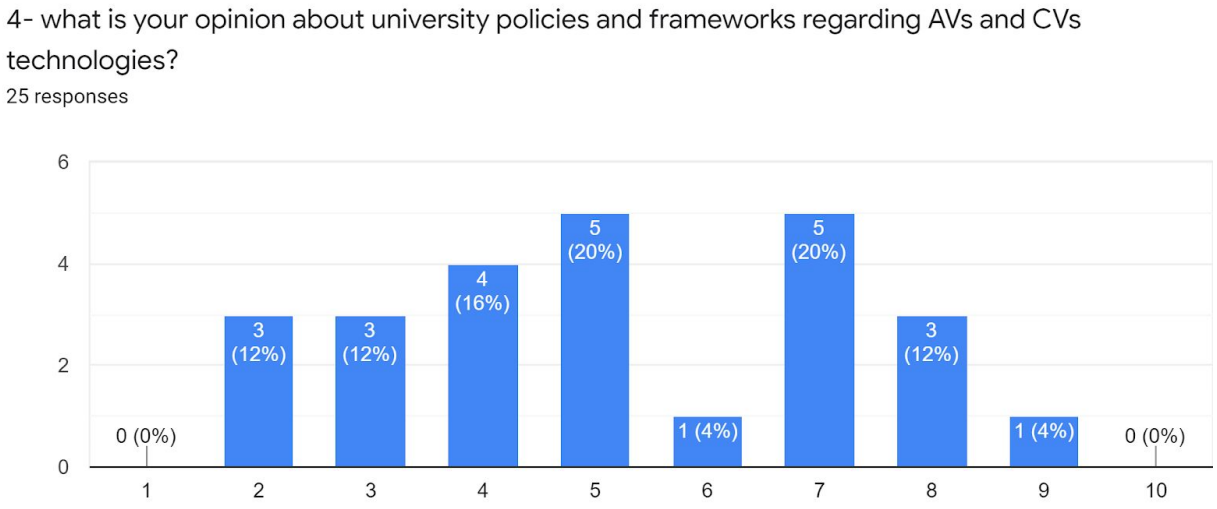

Figure 7.5 - Question 4

According to figure 7.5, the result shows a moderate performance for Canadian academic policymakers and executives, however, regarding the facts that the AVs technology is a global trend, its fast pace inherent, and the current state of the academic environment; the Canadian academia executives and policy-makers may need to improve and update their road map and frameworks to keep up the academia state with the global state of AVs technology.

According to section 5.1 university activities, the University of Toronto, University of Waterloo, and Carleton University are Ontario's universities with AVs and CVs related research programs. Most of the AVs and CVs research programs have been concentrated in Ontario, however, the

ACTIVE-AURORA project was the only project that was conducted by the University of Alberta and University of British Columbia outside the Ontario province [98, 101].

7.5 Question Five

"What is the level of collaboration between industry and academic research in AVs and CVs related subjects?", as mentioned earlier, this question aims to evaluate the level of collaboration between the academic and industrial environment in Canada. With the double cause and effect relationship between industry and academia, they both affect each other toward any technology development, hence, the performance of each part will be important not only by itself but also in cooperation with the other one.

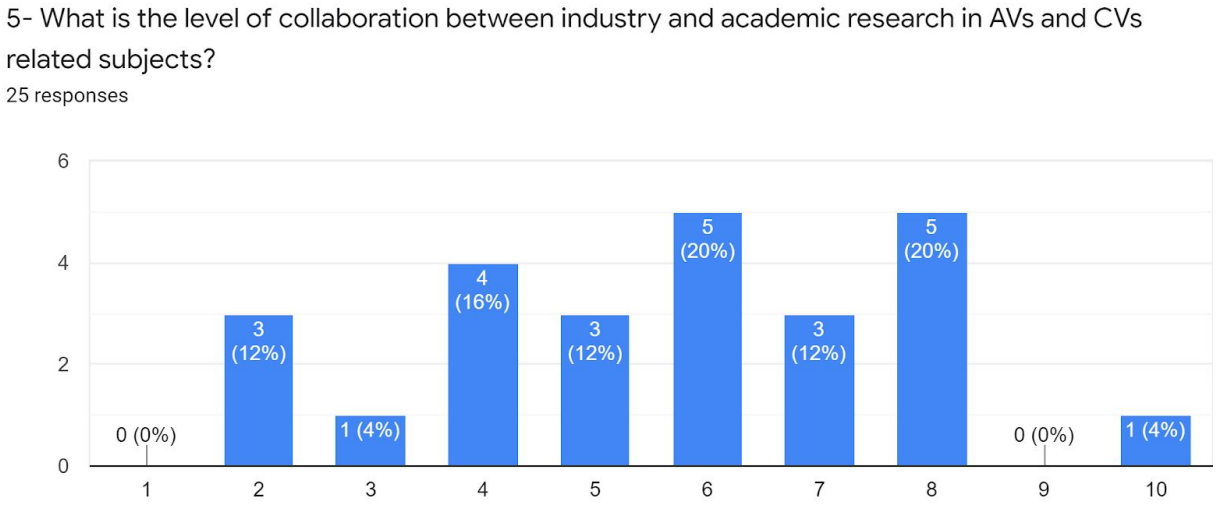

Figure 7.6 - Question 5

According to figure 7.6, the collaboration level between the Canadian academia and industry is at a moderate level which is insufficient regarding the current global state of AVs development

and innovation. Despite a lot of tested driverless vehicles and its manufacturing readiness level, AVs technology still has a huge path of challenges and technological barriers in front. Thus, excellent academia and industry collaboration is a must for the future of AVs in Canada. The combination of questions 4 and 5 results specifies that the change either in academia policies and frameworks or industry willingness to collaborate with universities and academic institutes can improve this relationship based on their cause and effect relation.

Carleton University and BlackBerry QNX launched a project that aimed to evaluate the cybersecurity risk and vulnerabilities of AVs and CVs, and also The University of Waterloo has facilitated the collaboration between university faculty researches and the automotive industry by creating the WatCAR, are examples of direct cooperation between Canadian universities and industry that have been limited to just some universities; but also the Mitacs projects environment with the support of Canadian government provides some opportunities for universities and industry collaboration [98, 101].

7.6 Question Six

“Do you think the Canadian Government's regulations and frameworks for AVs and CVs are up to date with the development of AVs technology?”, aims to examine Canadian government performance in terms of understanding the AVs’ state and take suitable actions based on that. The government regulations and frameworks have a direct impact on other stakeholders such as industry, academia, infrastructure, and consumer acceptance.

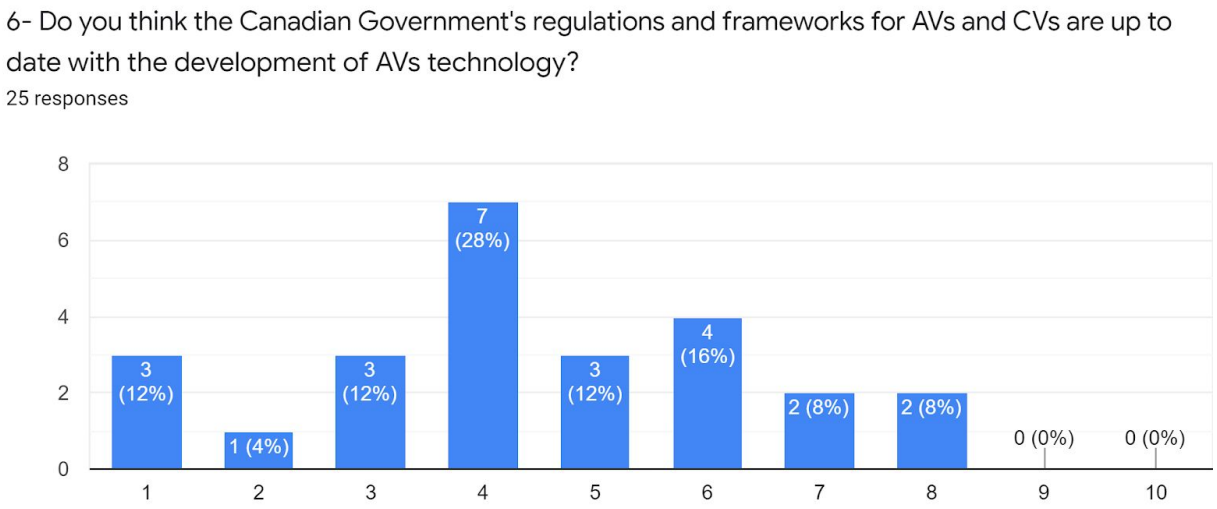

Figure 7.7 - Question 6

The Canadian government has moderate performance for providing regulations, legislations, and frameworks updated with the current global state of AVs according to the result from question 6 provided in figure 7.7. Nowadays, AVs technology is witnessing not only the extremely swift rate of development and innovation but also a high number of researches and papers related to the ethical and regulatory sectors of technology. Accordingly, a dynamic and agile framework and environment should be considered to help the whole system to manage the fast rate of changes, innovations, and new information easier and faster.

According to section 4.2 Avs regulation change, The Canadian government has been trying to improve and modify the legislation and regulatory standards regarding AVs and CVs continuously which will help Canadian society to be beneficial to the full potential of AVs and CVs benefits. The Canadian government created several working groups with specific focus

areas, which aimed to provide a deep understanding of AVs and CVs state for the Canadian government and policy-maker [99].

7.7 Question Seven

"In your opinion, Does the Canadian Government provide suitable support or collaboration with Companies and researchers related to AVs and CVs?", will provide a sight into the Canadian government's performance regarding collaboration and support with researches, institutes, and companies which are active on AVs realm; governmental financial and regulator support plays a vital role in the success and survives of most of the companies and researches, and on the other hand, the well-established collaboration and communication between industry, academia, and the government will lead to obtaining a better and deeper understanding of the state of technology for government, as a result, the government will be able to take adapted actions to the technology.

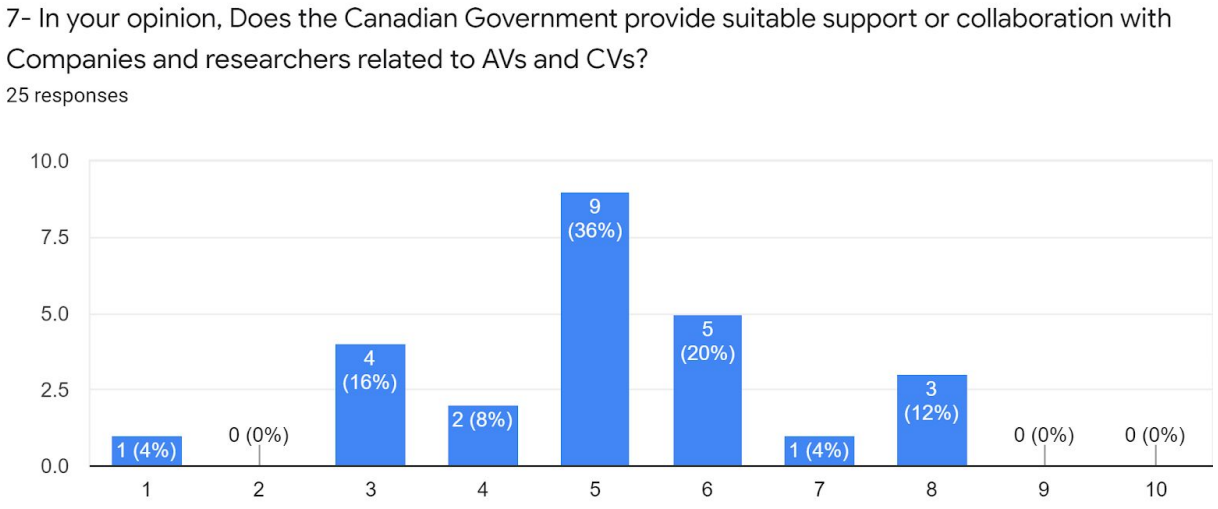

Figure 7.8 - Question 7

According to figure 7.8, the government performs a moderate and acceptable collaboration with companies and researches according to the executors' perspective, however, the government should take more steps to provide a well-established collaboration with industry and research institutes regarding providing a suitable environment which both sides can be beneficial of potential benefits. While the companies will be provided with expected support and collaboration, the government will be beneficial from not only more information about the current state of AVs technology, but also faster development and innovation rate in Canadian companies which will lead to fastening the deployment of AVs technology in Canada.

According to section 5.2 technology and innovation hubs, creating an R&D core in non-cores countries like Canada with lack of automotive OEMs headquarters have been difficult due to lack of support of OEMs headquarters, however, the Canadian government created the AVIN program which aimed to provide opportunities for companies and research institute related to AVs and CVs technologies to create an R&D core with support of big non-automotive technology companies and the Canadian government.

7.8 Question Eight

" Do you think Pilot projects have been positive or sufficient for the current situation of Avs and CVs in Canada?", aims to examine the performance of pilots projects which have been designed to provide a suitable playground for testing AVs, Preparing valid Data, developing AVs technology, examining the maturity of regulations and legislation, and in whole preparing Canda to be beneficial from AVs technology. The concept of pilot projects is a remarkable idea to

provide a lot of opportunities for developing AVs technology, but the performance of projects can be different from the ideal target which question 8 aims to find.

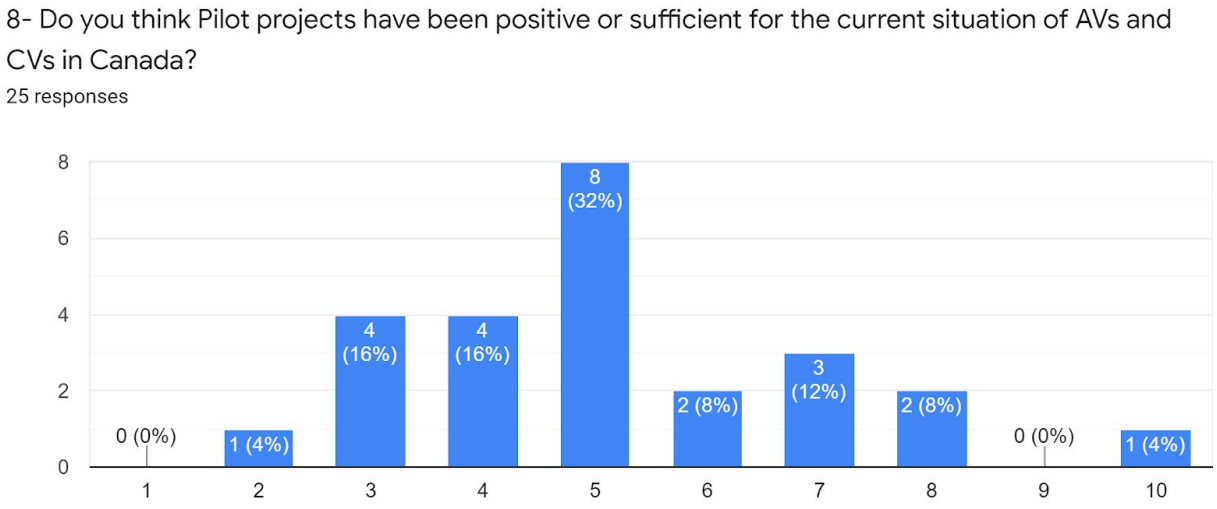

Figure 7.9 - Question 8

According to figure 7.9, the pilot projects have shown a moderate performance but away far from its ideal target; by enhancing the pilot projects there will be more possibilities and opportunities for AVs technology to experience faster development and deployment. The first aim of the pilot projects is to examine the potential of AVs technology in a safe place, however, the performance of these projects should be sufficient to provide a reliable playground for revealing the full potential of AVs programs and researches in Canada.

According to section 4.4 governmental AVs pilots, Provincial governments have been responsible for regulation and frameworks regarding pilot projects. Ontario was the first

province to provide regulations and frameworks for AVs testing on Ontario's roads under the Highway Traffic Act (HTA); Quebec, Manitoba, Saskatchewan, Alberta, and British Columbia also started pilot projects later. Based on KPMG AVRI 2020, Canada is a world leader for Government-Funded AVs pilots due to government-funded pilots in most of the major provinces that the test areas have covered 90 % or more of the Canadian population [98,78].

7.9 Question Nine

"What is your opinion about the Canadian Government's investment in AVs and CVs related to areas such as technologies, infrastructure, etc.?", aims to examine the financial actions which have been taken by the Canadian government regarding AVs technology. The successful deployment of AVs technology depends on various kinds of stakeholders and parameters and some of them rely on governmental policies, frameworks, and budgets; accordingly, the government's financial policies will have a remarkable impact on these parameters and AVs' future.

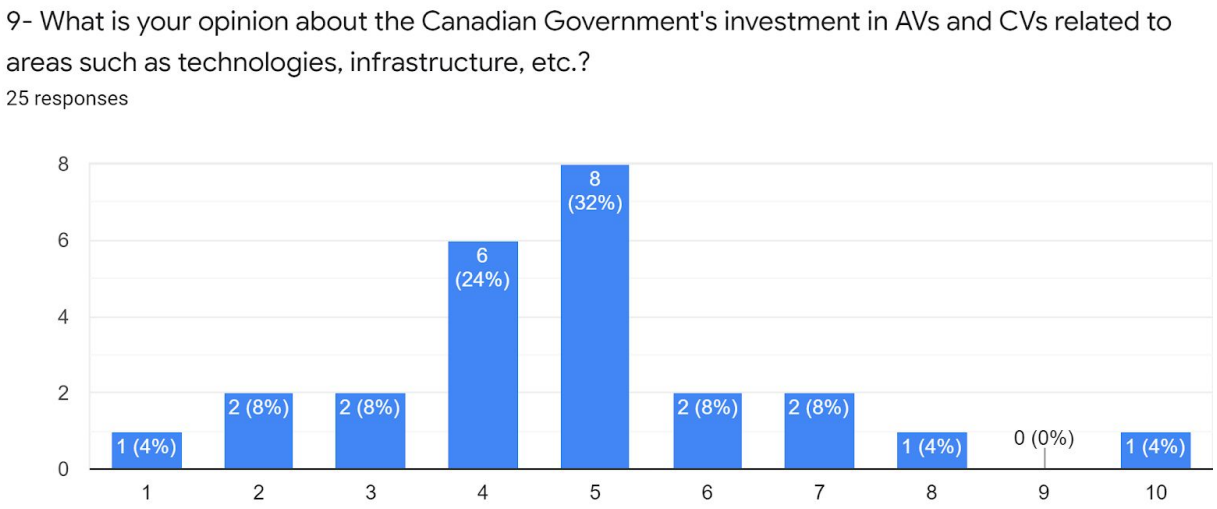

Figure 7.10 - Question 9

The same as other Canadian government performances regarding AVs technology, figure 7.10 shows a moderate or lower performance from the Canadian government in financial policies related to AVs technologies and infrastructure section. According to WEF annual reports in the last couple of years and the result of the infrastructure section on this report, Canada infrastructures need modification and improvement to be updated with AVs technology and make it possible to deploy AVs technology on Canadian roads. Thus, the Canadian government should examine and modify their current policies and frameworks to keep adapting the infrastructure with AVs technology. As mentioned in section 6.6 infrastructure readiness score, Canada has good mobile network infrastructure but also has a poor quantity of EVs charging stations and poor qualities of road infrastructure.

7.10 Question Ten

" How do you see the development and growth rate of AVs and CVs technologies in Canada?", aims to get a comprehensive view of the current AVs development state, after detailed questions on some main stakeholders. This question will provide a big picture of gathering the other questions' responses to the current AVs development state in Canada.

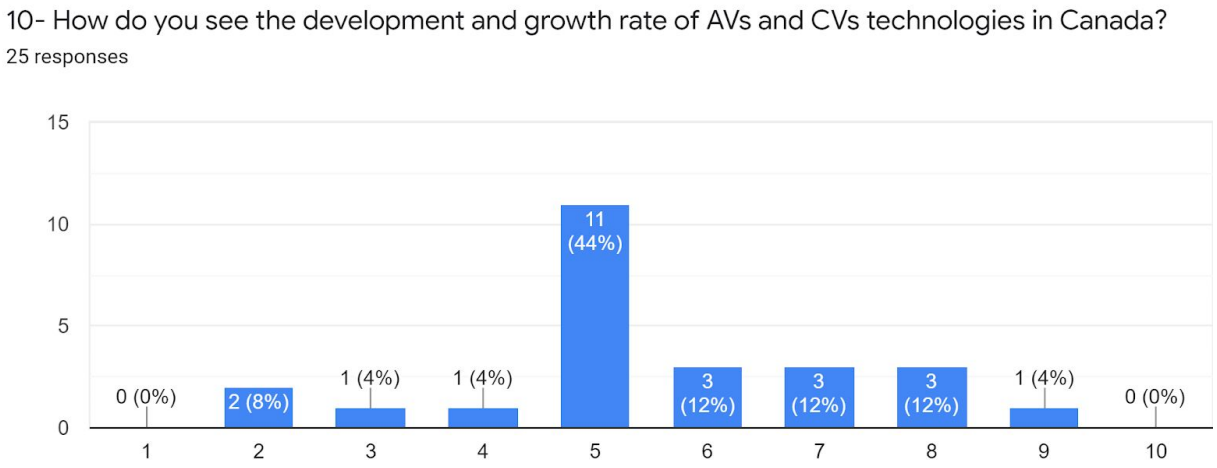

Figure 7.11 - Question 10

According to the previous questions' results, most sectors with high impact on AVs development have moderate or poor performances, as a result, it is expected as shown in figure 7.11 that Canada experiences a moderate development rate regarding AVs technology from the executors perspective. With the fast global peace of AVs technology, Canada may not be able to keep adapting to the global state of AVs technology due to its low or moderate development rate and also other poor performances in other sections regarding AVs technology.

7.11 Question Eleven

"How likely is it that Canadian car manufacturers and small companies will release fully automated vehicles by 2030?", aims to provide a perspective of AVs technology future based on Canadian car manufactures and small companies' actions from the executors perspective by asking their expectation of deployment of the fully automated vehicles period.

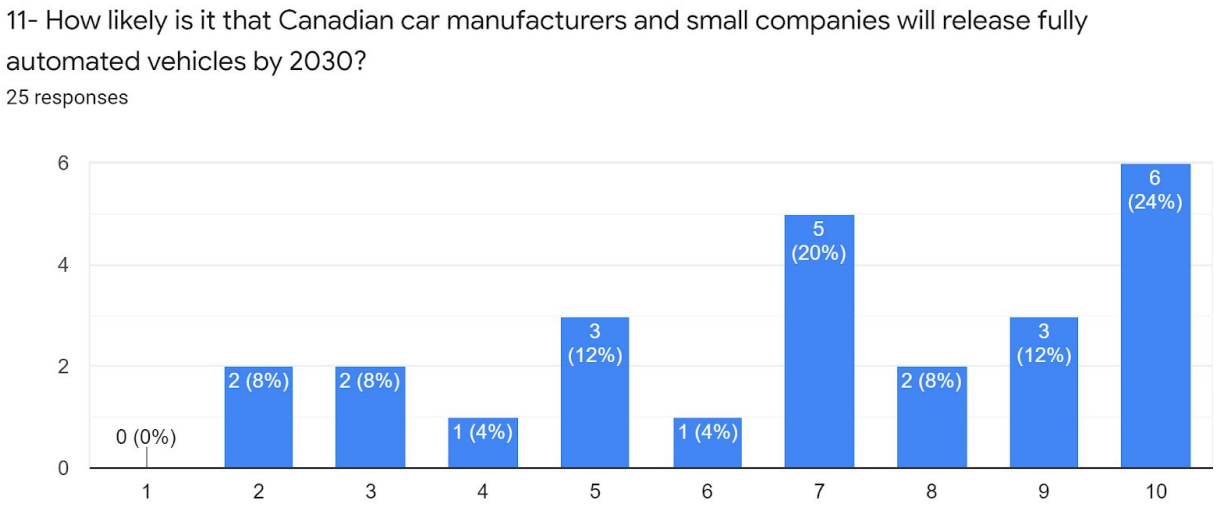

Figure 7.12 - Question 11

According to figure 7.12, responders perspective indicate that it seems most likely to have fully automated vehicles ready to be on the Canadian roads by next decade; however, this question just asked about automated vehicles without mentioning other stakeholder, technologies, and parameters which have vital impact on AVs nationally deployment around Canada. BlackBerry

QNX, Continental, Magna, and Uber are some examples of companies that have been testing AVs on Canadian roads.

7.12 Question Twelve

" In your opinion, how ready is the Canadian society for AVs and CVs on Candian roads?", aims to examine the society's maturity regarding the AVs technology. These last three questions will provide a clear picture of the AVs technology current state and expected future.

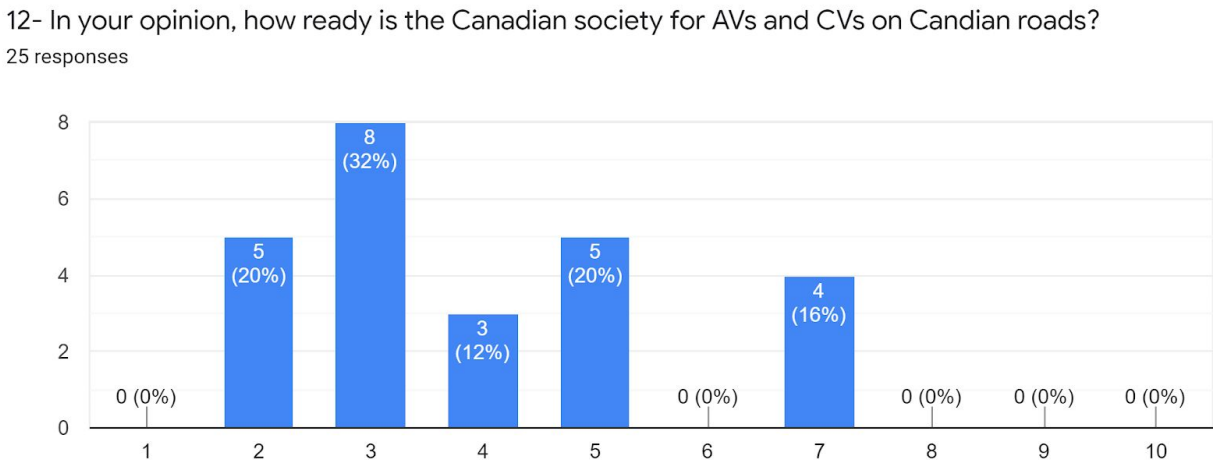

Figure 7.13 - Question 12

Canadian society is not prepared for being beneficial for full AVs' potential benefits regarding the responders' perspective as shown in figure 7.13. Based on Automated Vehicles in the Greater Toronto and Hamilton Area: Overview from a 2018 Consumer Survey, almost 75 % of the survey's population has not heard of Waymo, the googles' AV, by the time of the survey, and 48 % of participants have not been willing to purchase a fully driverless car, however, more than

half of participants have had positive feeling toward AVs. 17.2 % of survey participants have driven a semi-automated vehicle [108].

7.13 Question Thirteen

" In your opinion, which benefits of AVs and CVs will influence Canadian society the most? (Also feel free if you want to add additional thoughts/ statements/ suggestions for any questions above)", aims to find the most important and influential benefits of AVs for Canadian society, and also provide a space for responders to mention their additional thoughts, statements, and suggestions regarding the questionnaire.

According to table 1, safety is the most important and influential benefit for Canadian society that AVs technology will provide. The top 5 benefits according to table 1 are as follows, safety, economy, transportation, mobility for everyone, and productivity.

Table 7.1 - Question 13 responses categorization

Num	Safety	Economy	Transportation	Mobility for Everyone	Productivity	Urban Communication	Job Opportunities	Congestion Reduction	Environment
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
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24									
25									

7.14 Conclusion

Canada can expect to be benefited byAVs and CVs technologies on its roads by the next decade according to questions 1 and 11 which are shown in figures 7.2 and 17.2. On the other side, the results from questions 2, 3, and 12 specify that the Canadian society is not prepared for AVs technology; to illustrate, Canadian society not only has insufficient information and knowledge about AVs technology but also the Canadian government has shown a poor performance regarding educating and improving public awareness about AVs technology, however, this section is not the only section that Canada performs a moderate or poor performance; Canada government, Canada academic and industry Have been showing poor or moderate performances in most of the area related to AVs technology.

Canadian academic environment shows moderate performances in policies and frameworks, and also its collaboration with industry which can improve and change by actions from both side, to illustrate, the industry can improve or change the academic policies and frameworks by improving and increasing its collaboration with the academic environment, or changing and improving academic policies and frameworks may make more opportunities for collaboration between academia and industry. The important fact is AVs technology is still in the developing phase in many parts and with the fast pace of innovation and development regarding AVs technology all around the world, the collaboration between academia and industry should be considered as a vital parameter and must be performed at the level that both sides can be beneficial of their full potential.

The Canadian government has shown a moderate performance in all four questioned sections, Regulation and frameworks adaption, collaboration and supporting companies and researches, pilot projects, and investments on infrastructure and technologies. Canadian government performances indicate that the Canadian government needs a comprehensive improvement and modification in its fundamental policies and frameworks regarding AVs technology to adapt their policies and framework with fast global peace of AVs technology.

7.15 Customer Acceptance Readiness Score

The survey's questions will count as measures for evaluating the customer acceptance readiness score. The mean divided by two the responses will be used as the score of each measure and equal weights will apply to each measure. Table 7.2 presents the customer acceptance readiness score.

Table 7.2 - Customer Acceptance Readiness Score

Measures	Score	Weight	Readiness Score
Question One	2.9	0.083	0.2407
Question Two	1.48	0.083	0.1228
Question Three	1.48	0.083	0.1228
Question Four	2.6	0.083	0.2158
Question Five	2.82	0.083	0.2340
Question Six	2.22	0.083	0.1842
Question Seven	2.54	0.083	0.2108
Question Eight	2.58	0.083	0.2141
Question Nine	2.38	0.083	0.1975
Question Ten	2.76	0.083	0.2290
Question Eleven	3.46	0.083	0.2871
Question Twelve	1.98	0.083	0.1643
Customer Acceptance Readiness Score			2.4231/5

Chapter Eight

Conclusions and Future Scope

8.1 Conclusions

In this thesis, the Canadian AVs and CVs market readiness was evaluated to provide a clear picture of the current state of AVs and CVs. The literature review was conducted to provide a deep understanding of AVs and CVs background, related technologies, and potential benefits, and also evaluating and analyzing the previous studies and researches. The market readiness assessment topic and related readiness level frameworks were examined and evaluated to create a practical readiness score method that was suitable for the multistakeholder situation of AVs and CVs technologies. The four main pillars were identified and the related measures based on literature review defined, analyzed, and evaluated to calculate the readiness score regarding the main four pillars. Table 8.1 presents the AVs and CVs market readiness assessment scores for the main four pillars and their measures.

According to table 8.1, the policy and legislation pillar got the highest readiness score among all other pillars with 4.4 of 5, and the customer acceptance pillar got the lowest readiness score with 2.4 of 5. The Canadian government was one of the first countries that started to prepare for AVs and CVs deployment; by creating several working groups, the Canadian government has been trying to monitor and evaluate the AVs and CVs state in Canada. The Canadian government also by creating the provincial pilot projects and AVIN program has been providing a suitable environment for developing and testing AVs and CVs technologies.

Table 8.1 - Autonomous Vehicles and Connected Vehicles Market Readiness Assessment Scores

Pillars/Measures				Readiness Score
Policy and Legislation Readiness Score				4.4/5
Technology and Innovation Readiness Score				3.7/5
Infrastructure Readiness Score				3.6/5
Customer Acceptance Readiness Score				2.4/5
Pillar	Measures	Score	Weight	Readiness Score
Policy and Legislation	AVs Regulation and Standards	4	0.2	0.8
	AVs Regulation Change	4	0.2	0.8
	AVs responsibilities Structure	4	0.2	0.8
	Governmental AVs pilots	5	0.2	1
	Data Sharing Environment	5	0.2	1
Technology and Innovation	University Activities	3.5	0.2	0.70
	Technology and Innovation Hubs	4	0.2	0.80
	AVs Related Patent	3	0.2	0.60
	Technology and Innovation Capability	3.3	0.2	0.66
	Cybersecurity	5	0.2	1.00
Infrastructure	Mobile Coverage	4	0.2	0.8
	Mobile Connection Speed	5	0.2	1
	Road Quality	3	0.25	0.75
	EVs Charging Station	3	0.25	0.75
	Infrastructure Technology Change	3	0.1	0.3

Customer Acceptance	Question One	2.9	0.083	0.2407
	Question Two	1.48	0.083	0.1228
	Question Three	1.48	0.083	0.1228
	Question Four	2.6	0.083	0.2158
	Question Five	2.82	0.083	0.2340
	Question Six	2.22	0.083	0.1842
	Question Seven	2.54	0.083	0.2108
	Question Eight	2.58	0.083	0.2141
	Question Nine	2.38	0.083	0.1975
	Question Ten	2.76	0.083	0.2290
	Question Eleven	3.46	0.083	0.2871
	Question Twelve	1.98	0.083	0.1643

According to table 8.1, the customer acceptance pillar got the lowest readiness score due to the low scores in measures of society's awareness and preparedness toward AVs and CVs technologies due to poor knowledge of society about AVs and CVs technologies. The Canadian government has not taken specific actions to enhance public awareness about AVs and CVs technologies and their potential benefits.

Road quality and EVs charging stations should be considered the main challenges in the infrastructure pillar for the Canadian government due to the shortage of EVs charging stations in comparison with the size of the Canadian roads network and population, and also Canadian weather condition is a challenging parameter for quality of roads in Canada.

The absence of OEMs headquarters, low investment of companies, and absence of R&D cores were obstacles and challenges for the technology and innovation sector of the Canadian government, however, the Canadian government has been also trying to create R&D cores and encouraging companies and industry to investment by programs like AVIN program in Ontario province.

8.2 Limitations

The few numbers of responders and participants could be considered as the main problem due to a bias that might exist in response to some questions which could be possibly accrued due to the pandemic and national lockdown in Canada which has made it impossible for field surveys. The limitation in time, space, and purpose of the thesis has made it difficult to provide a deep analysis in each section to find the root problems, barriers, and challenges regarding each measure which some of them have been mentioned in future scoop. This research has been focused to evaluate the most essential and vital parameters which could have potential vital influence on AVs and CVs deployment and development in Canada based on literature review and collected data.

8.3 Future Scope

In this thesis, a qualitative market readiness assessment on Canadian AVs and CVs market has been conducted to provide a clear picture of the current situation of the Canadian AVs and CVs market.

- Future studies could be more detailed and more focused on each pillar, and analyze each pillar for root problems and challenges, and identify the potential opportunities in each pillar.
- More studies could be conducted on possible relations between different mentioned measures in the current research.
- Future studies could be done on potential relation between AVs and CVs deployment and deployment of other technologies such as EVs, 5G, and etc.
- Future studies could be conducted on other aspects and stakeholders of AVs and CVs technologies such as ethics, insurance policies, technologies, and etc.
- More studies on possible frameworks and programs regarding the academic environment could be conducted to enhance the AVs and CVs development rate and productivity of Canadian universities.
- The simulations of different deployment frameworks could be conducted to evaluate the barriers, challenges, potential benefits, and potential risks.
- More studies could be also conducted on possible frameworks for creating R&D cores across Canadian society to improve the development and innovation process of AVs and CVs.
- More Studies could be done on the possible approaches for enhancing public awareness about AVs and CVs technologies.
- More studies could be conducted on society behavioral change regarding AVs and CVs technologies.

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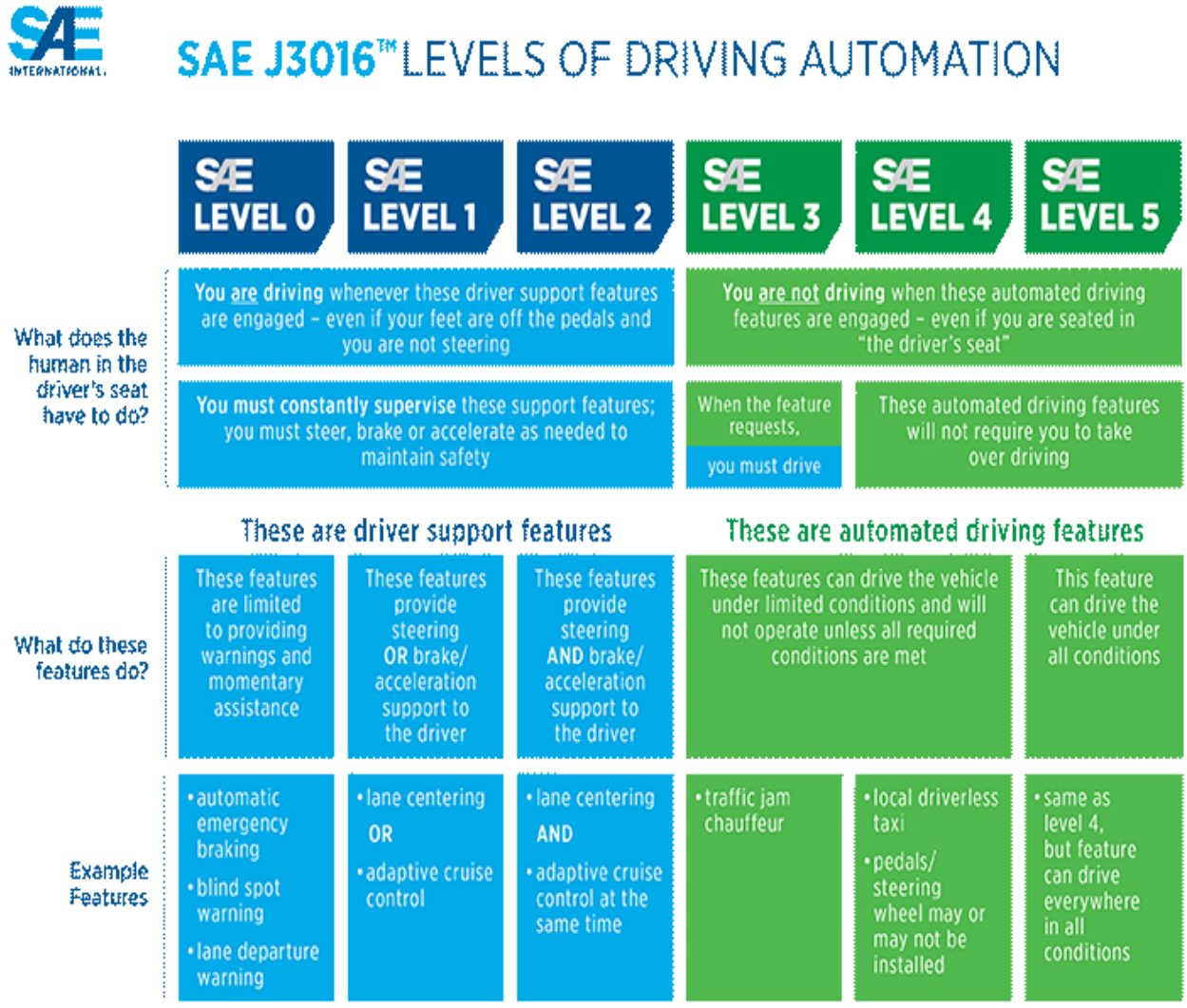
APPENDICES

Appendix A, SAE levels of driving automation [15]

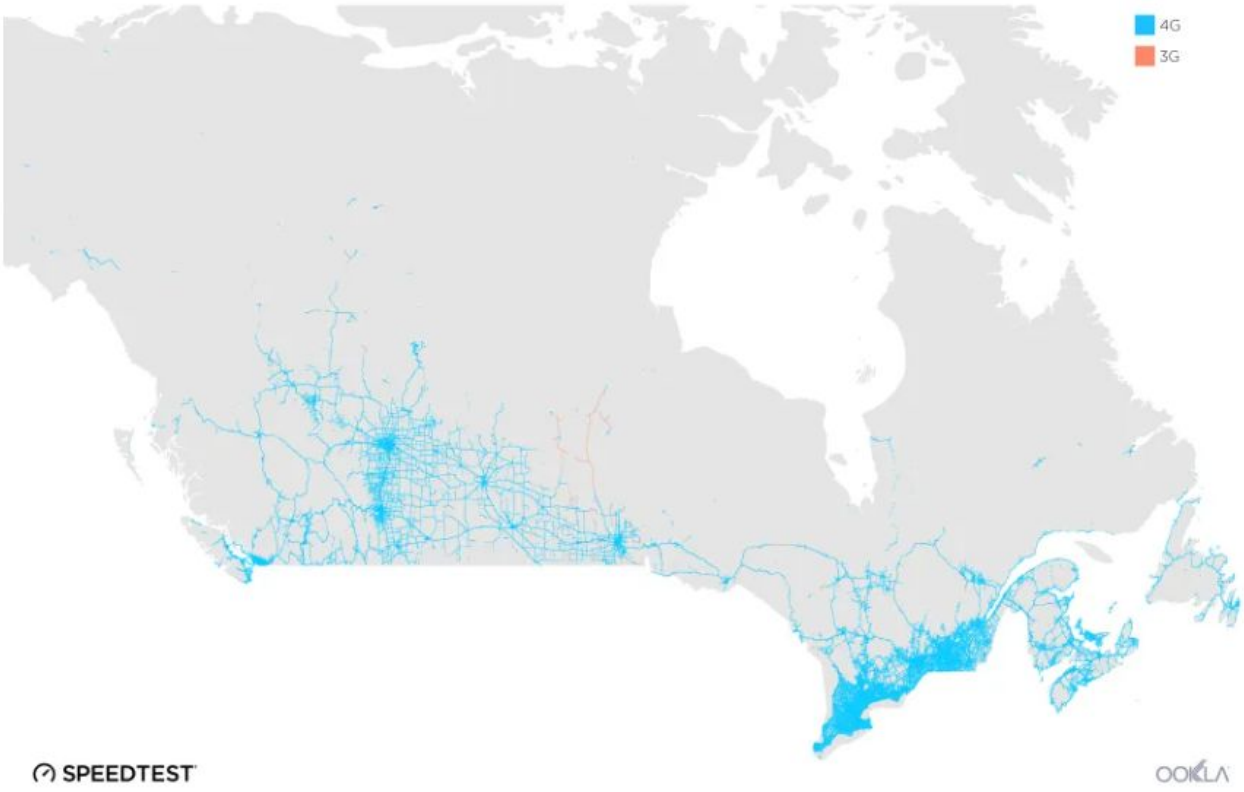


Appendix B, the technology readiness levels (TRLs) with 10 level of readiness [66]

Technology Readiness Levels		
Research	TRL 1	Paper studies and scientific experiments have taken place; Performance has been predicted;
	TRL 2	Application specific simulations or experiments have been undertaken; Performance predictions have been refined;
	TRL 3	Performance investigation using analytical experimentation and/or simulations is underway;
Demonstration	TRL 4	The technology component and/or basic subsystem have been validated in a laboratory or test house environment;
	TRL 5	The component and/or basic subsystem have been validated in a relevant environment, e.g. via a mule or adapted vehicle;
	TRL 6	A prototype of the system or subsystem has been demonstrated within a test house, test track or similar operational environment;
	TRL 7	Multiple prototypes have been demonstrated in an operational, on-vehicle environment;
Product Readiness	TRL 8	The technology has been proven to work in its final form and under expected conditions;
	TRL 9	The technology has been successfully applied in its final form and under real-world conditions
	TRL 10	The technology is successful in service in multiple application forms, vehicle platforms and regions;

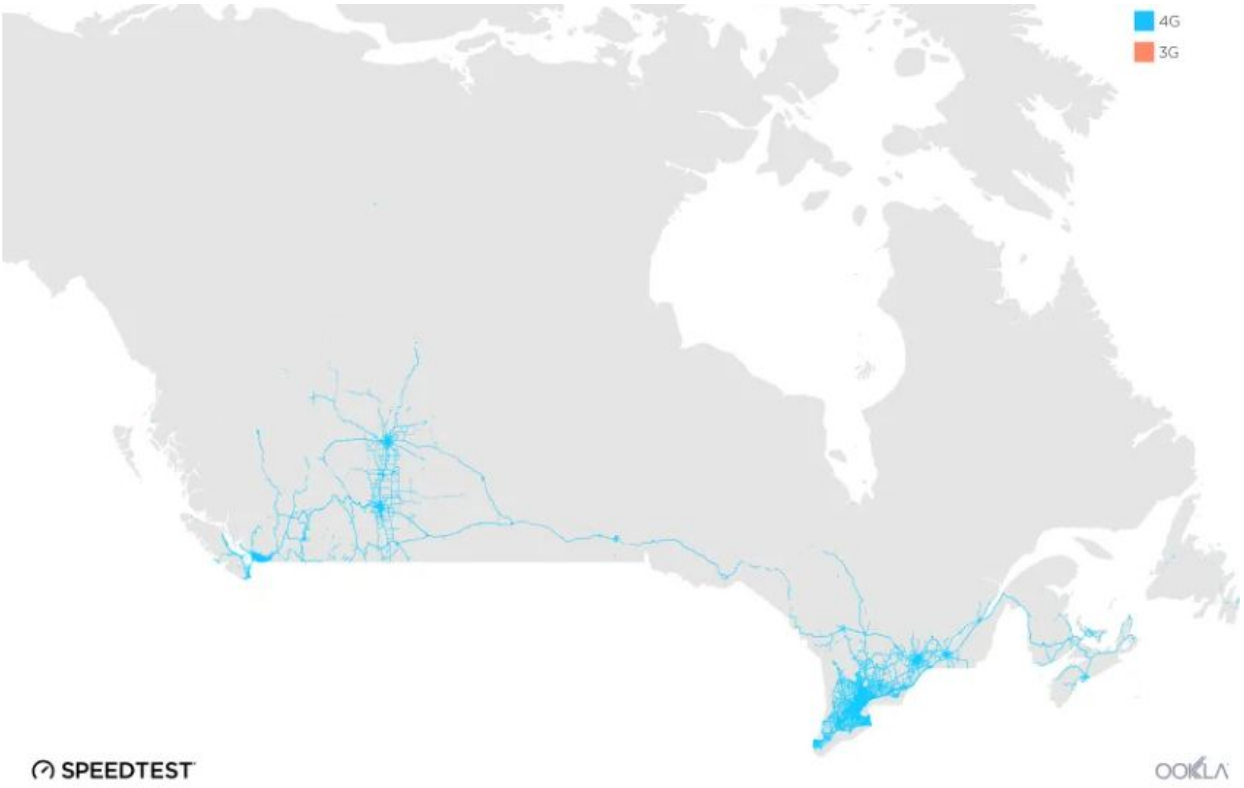
Appendix C, Oakla mobile data network coverage maps for different operators [81]

Bell

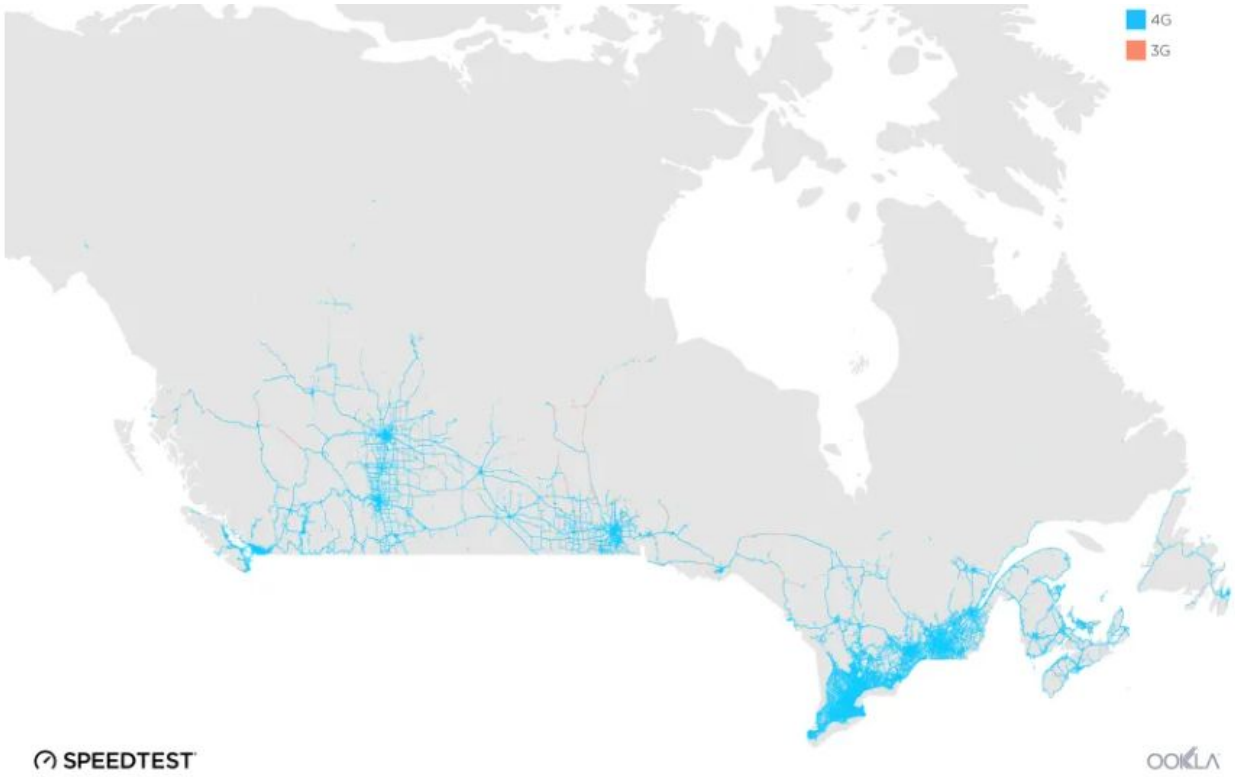


Fido

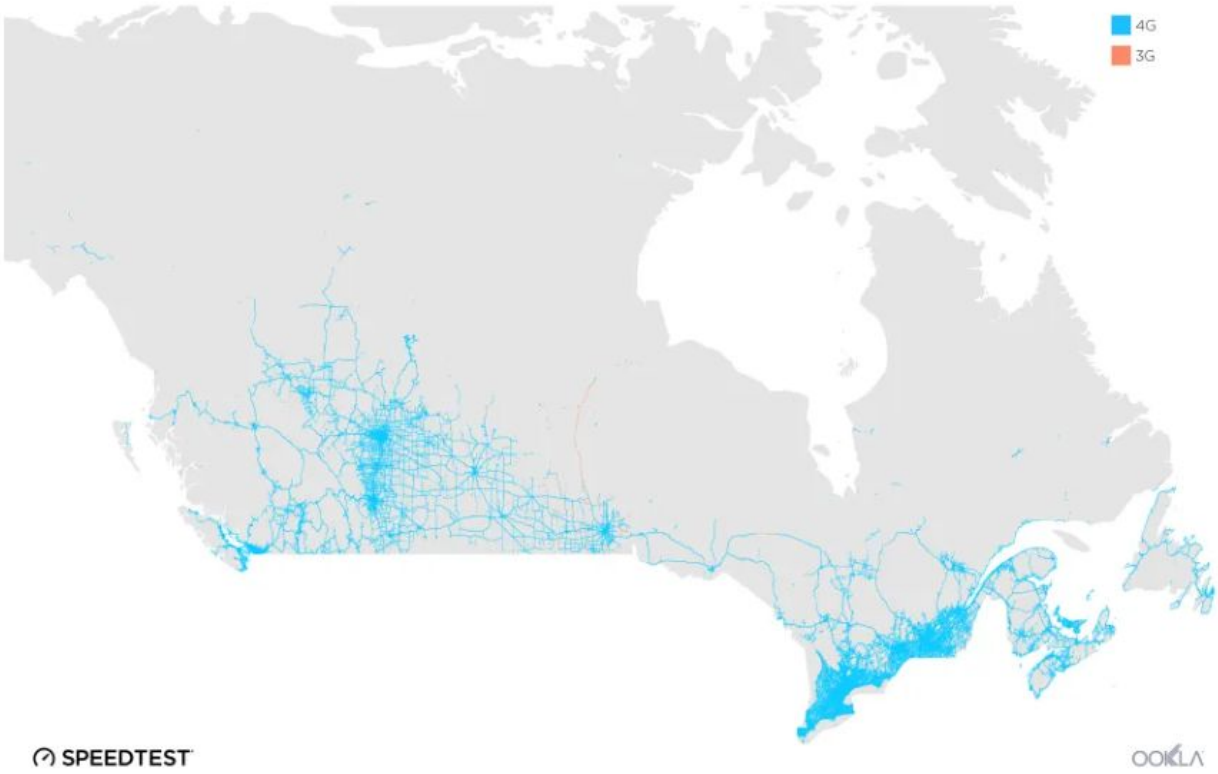
Freedom Mobile



Rogers



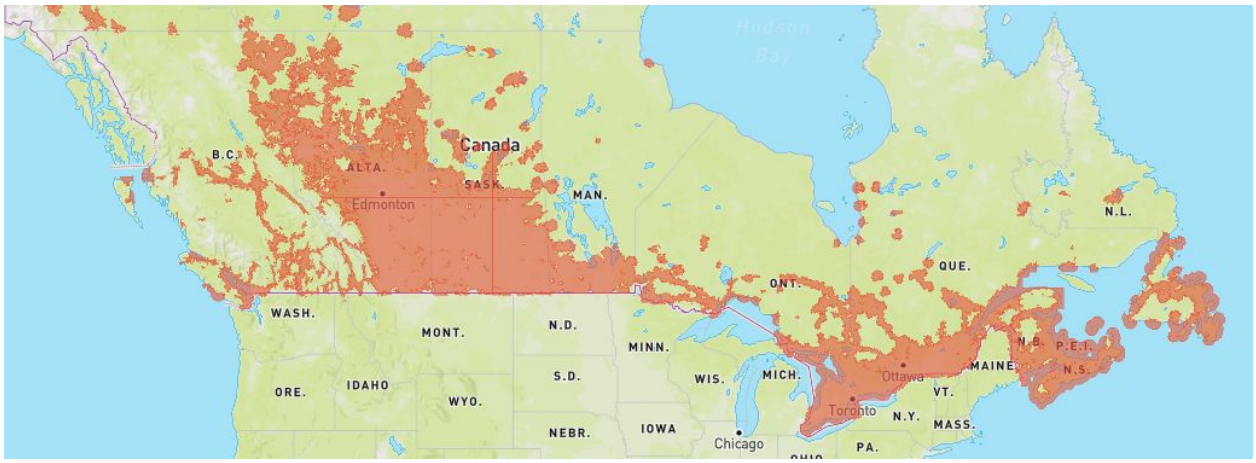
Telus



VedioTron

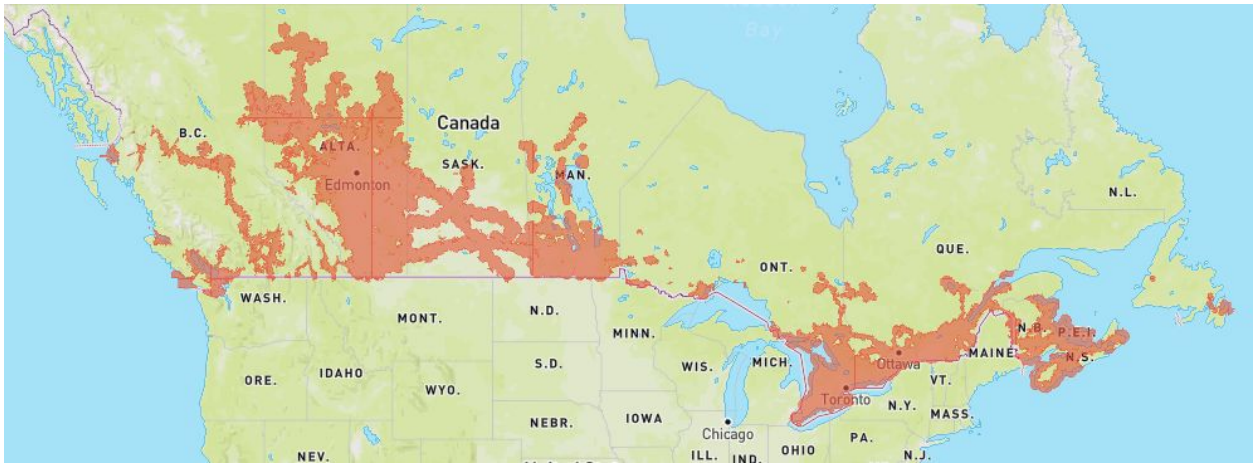
Appendix D, GSMA mobile data network coverage maps for different operators [82]

Bell

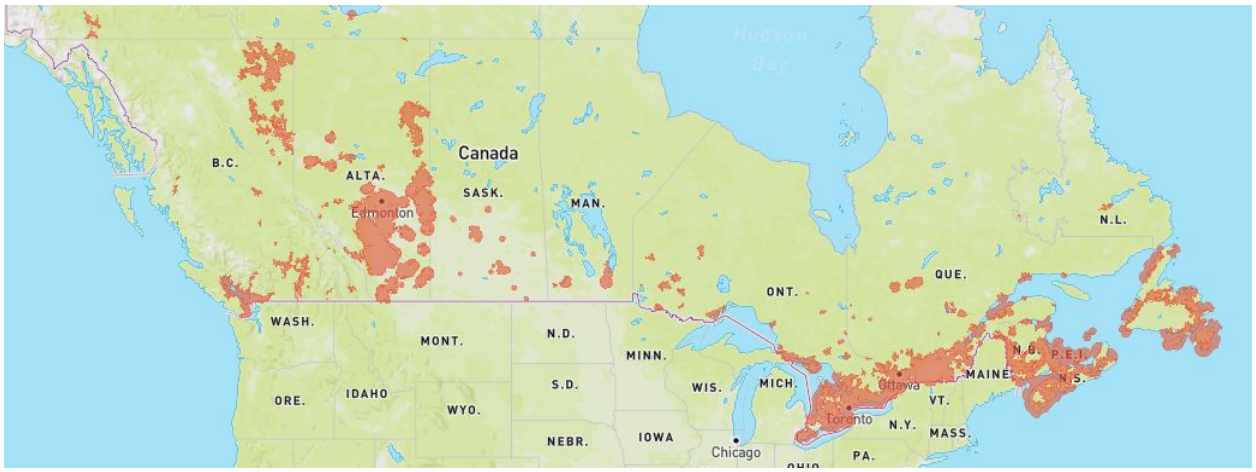


Freedom Mobile

Rogers

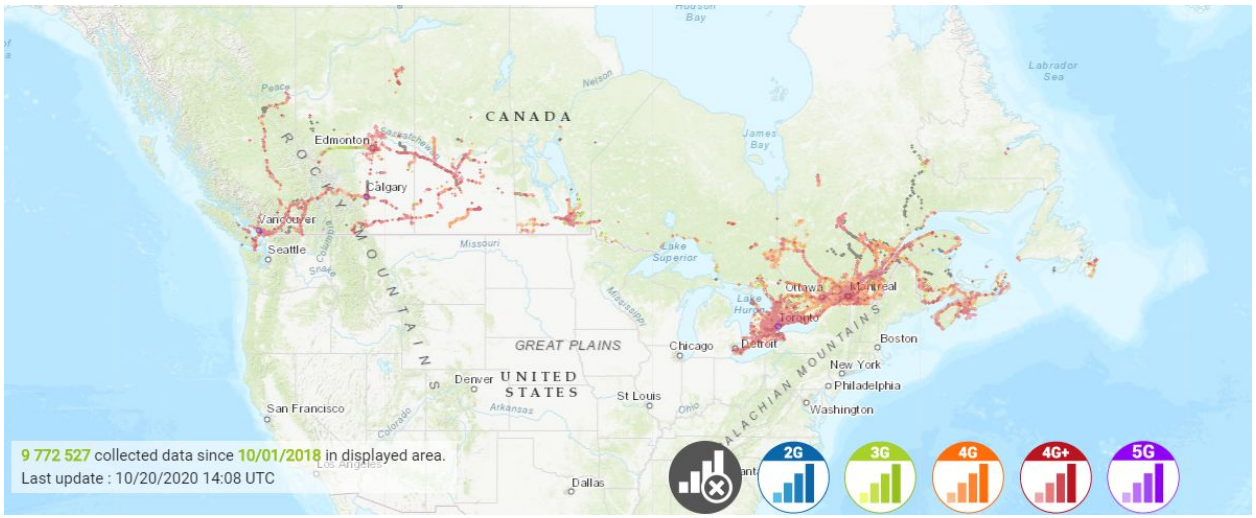


Telus

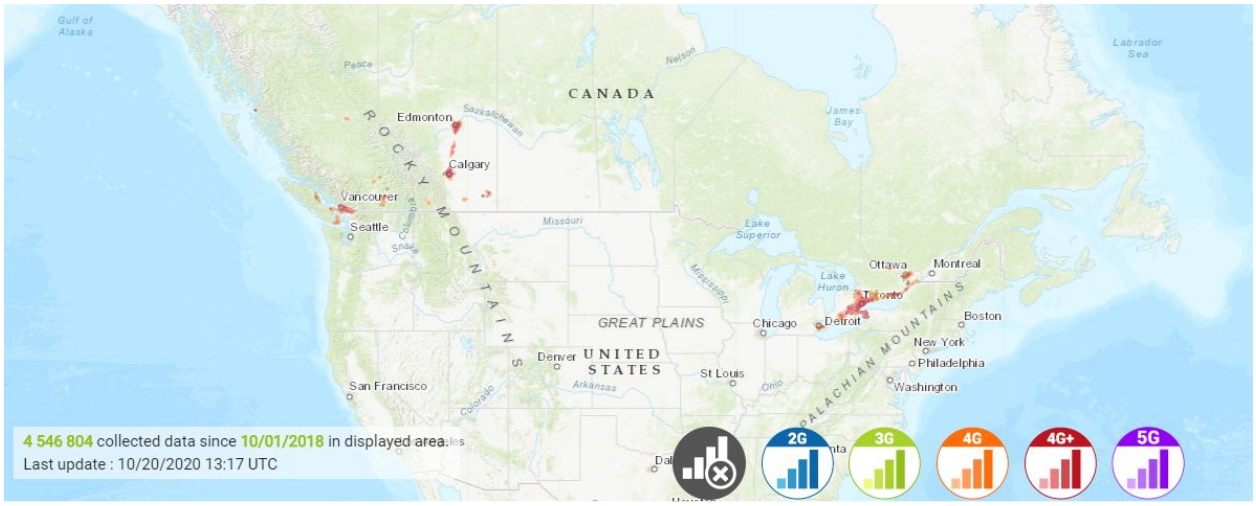


Appendix E, Npref mobile data network coverage maps for different operators [83]

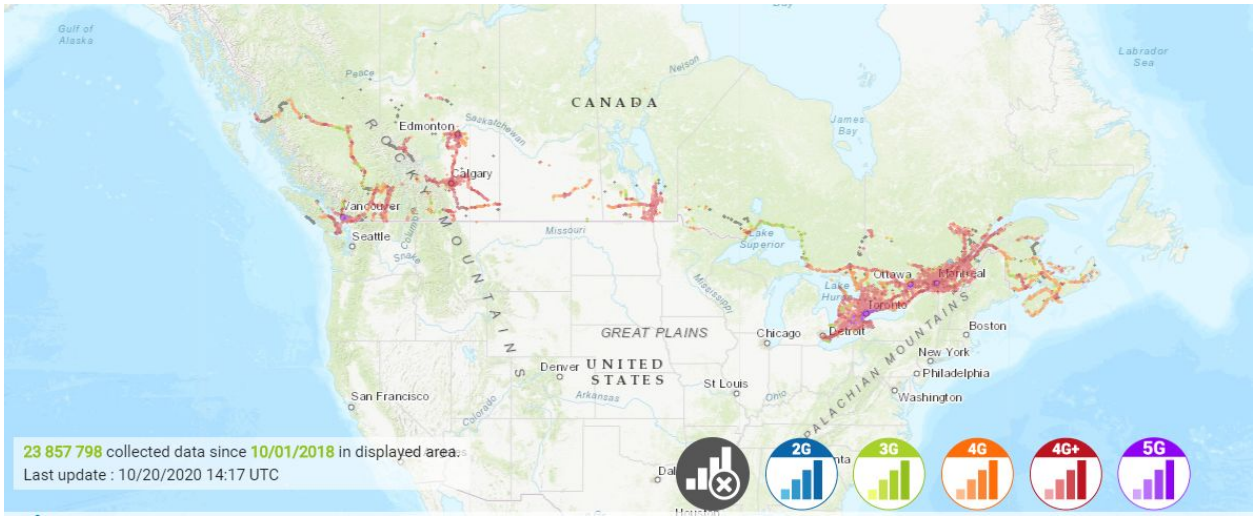
Bell



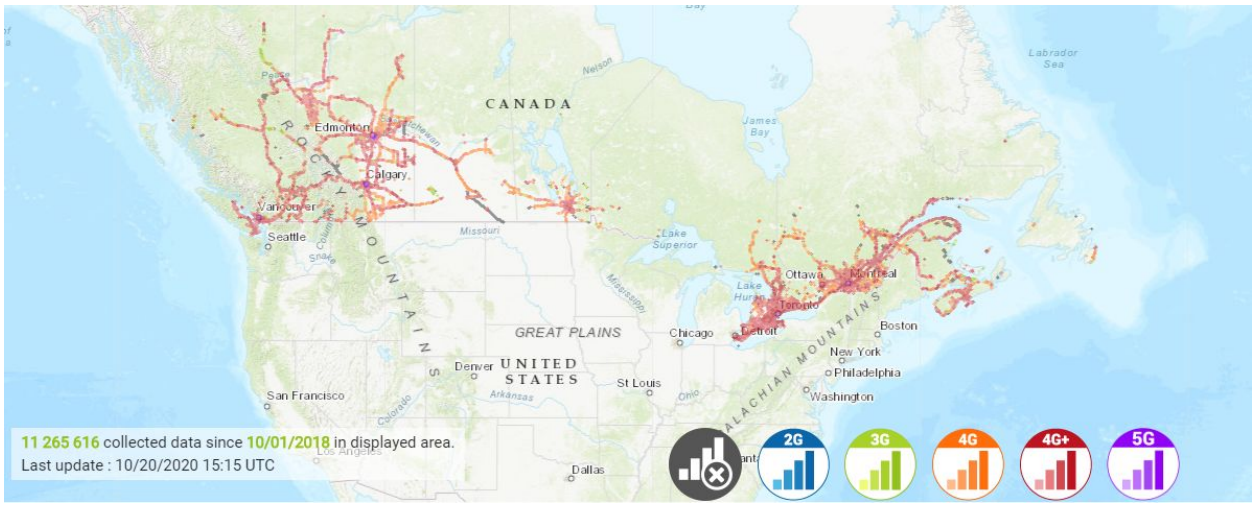
Freedom Mobile



Rogers



Telus



VedioTron


CANADA
Edmonton
Calgary
Vancouver
Seattle
San Francisco
Denver
UNITED STATES
GREAT PLAINS
Chicago
Detroit
Toronto
Ottawa
Montreal
Boston
New York
Philadelphia
Washington
St Louis
ROCKY MOUNTAINS
APPALACHIAN MOUNTAINS
3 607 625 collected data since 10/01/2018 in displayed area.
Last update : 10/20/2020 14:40 UTC
2G
3G
4G
4G+
5G

Appendix F, Autonomous vehicles customer acceptance survey

Autonomous Vehicles Customer Acceptance

Thank you for your collaboration in my research in advance. My name is Mehdi Azad, a master student of Quality Systems Engineering at Concordia University. I am currently doing my master thesis which is focused on Canada Autonomous Vehicles (AVs) and Connected Vehicles (CVs) Market Readiness Assessment as this technology will influence all aspects of modern societies and industries significantly. Thus, It is important to see how much this technology is accepted in Canadian society.

I appreciate your openness in this questionnaire; all the personal information such as e-mail address, name, and so on will not be published or released in any documents.

* Required

1. 1- In your opinion, how long will it take Canadian society to have Autonomous Vehicles technology (Level4 or 5)on the road? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
In 1 year	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	In 20 Years

2. 2- In your mind, What portion of Canadians have sufficient knowledge about Autonomous Vehicles technology and it's benefiting? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Less than 10%	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	above 90%

3. 3- Do you think the Canada Government takes sufficient and influential actions to improve society's knowledge of AVs and CVs? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Insufficient	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Outstanding

4. 4- what is your opinion about university policies and frameworks regarding AVs and CVs technologies? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Poor	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Excellent

5. 5- What is the level of collaboration between industry and academic research in AVs and CVs related subjects? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Poor	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Excellent

6. 6- Do you think the Canadian Government's regulations and frameworks for AVs and CVs are up to date with the development of AVs technology? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Poor	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Excellent

7. 7- In your opinion, Does the Canadian Government provide suitable support or collaboration with Companies and researchers related to AVs and CVs? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Poor	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Excellent

8. 8- Do you think Pilot projects have been positive or sufficient for the current situation of AVs and CVs in Canada? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Poor	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Excellent

9. 9- What is your opinion about the Canadian Government's investment in AVs and CVs related to areas such as technologies, infrastructure, etc.? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Poor	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Excellent

10. 10- How do you see the development and growth rate of AVs and CVs technologies in Canada? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Too Slow	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Very Fast

11. 11- How likely is it that Canadian car manufacturers and small companies will release fully automated vehicles by 2030? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not At All Likely	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Extremely Likely

12. 12- In your opinion, how ready is the Canadian society for AVs and CVs on Candian roads? *

Mark only one oval.

	1	2	3	4	5	6	7	8	9	10	
Not At All Likely	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Extremely Likely

13. 13- In your opinion, which benefits of AVs and CVs will influence Canadian society the most? (Also feel free if you want to add additional thoughts/ statements/ suggestions for any questions above) *