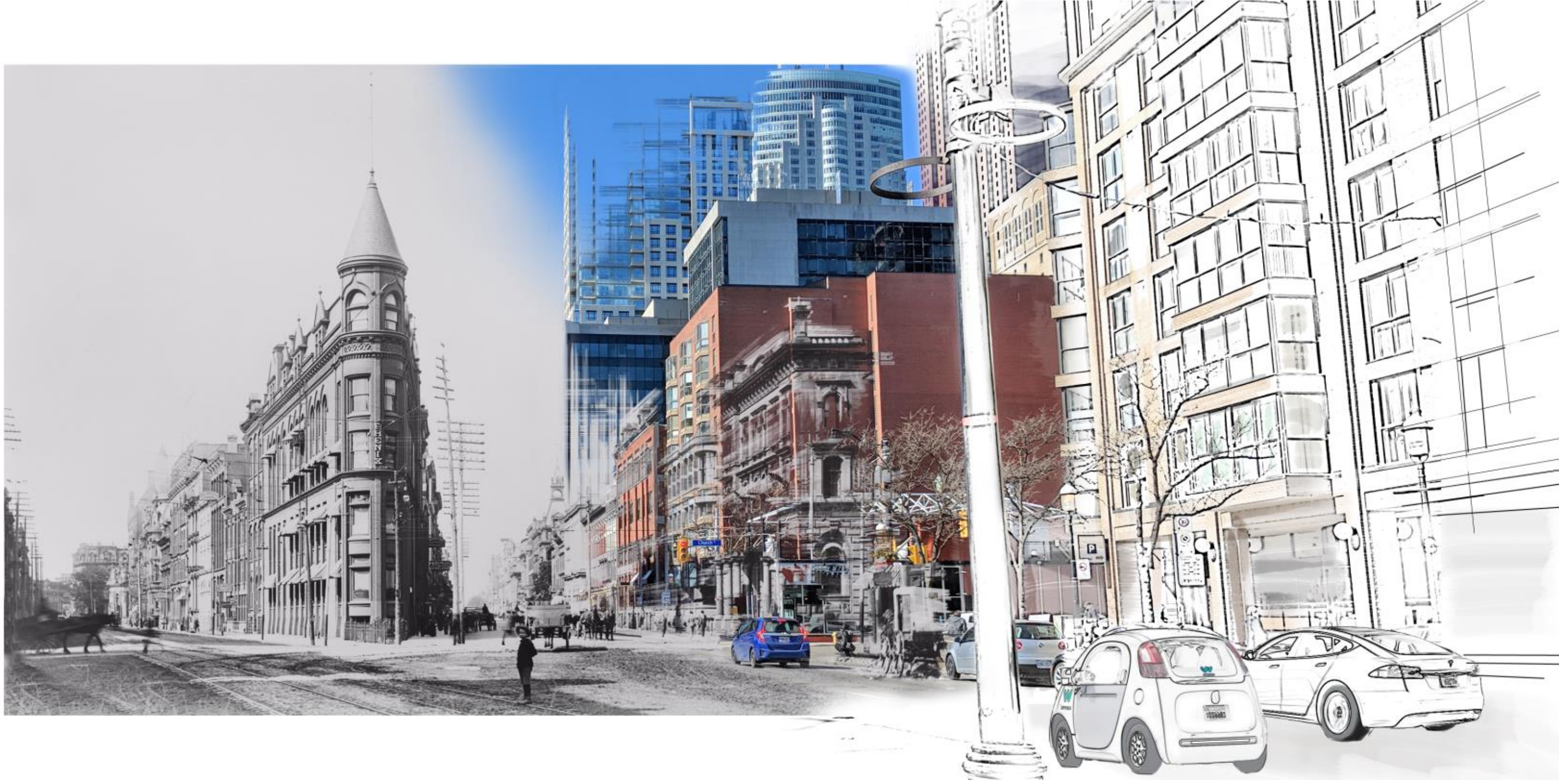

The Driverless City

How will AVs shape cities in the future?

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Abstract

Autonomous Vehicles (AVs) are poised to become the next revolution in mobility. Marketers and engineers enthusiastically promise numerous benefits that AVs will deliver in a future without human drivers: huge reductions in accidents, parking spots, congestion, even the elimination of the loathsome commute among many others. But there are as many, if not more potential ways that the AV revolution can also go wrong: *worsening* traffic and congestion, urban sprawl, and eroding public transit, for example.

How will Autonomous Vehicles shape cities in the future? The Driverless City is not one city: it is many. AVs could be a boon or a debacle. They could even be both at the same time. An extensive literature review revealed a broad cone of possibilities: a myriad different impacts that driverless vehicles could have on different aspects of a city. After synthesizing these into ten *main* areas of impact, key scenarios are expounded with supplemental foresight. This *top-down* approach is followed by a *bottom-up* research workshop where non-expert participants from the general public weighed in on the synthesis and scenarios, and expressed their own thoughts and concerns about what The Driverless City could be. Then, a group of experts helped narrow the cone of possibility into much tighter cones of probability using the Delphi research method. These forecasts and projections shine a spotlight on the key considerations that city planners, urban designers, policy makers and other decision-makers should be taking now to promote desirable outcomes for their city, and curtail undesirable ones.

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To my mom,

Alma Linda Sagástegui Garza

You were supposed to be a part of this...

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Glossary

ABS
Anti-lock Braking System

ADAS - Advanced Driver Assistance Systems
Vehicle systems designed to improve driving safety. Examples of ADAS include: adaptive cruise control, forward collision warning, blind spot monitoring, lane assist.

AI - Artificial intelligence:
Intelligence and decision-making that comes from a machine. It refers to the ability of machines to mimic "cognitive" functions that humans associate with human minds, such as learning and problem solving.

Algorithm
A sequence of instructions, rules, and calculations executed by a computer in a particular order to yield a result, typically an answer to a specified problem. Algorithms can be used in combination with other algorithms to solve complex problems.

AV - Interchangeably: **Automated Vehicle / Autonomous Vehicle**
A vehicle that is capable of driving itself, typically classified at levels 3, 4, or 5 for driving automation. See SAE Levels of Automated Driving and Automated vs. Autonomous below.

CAV
Connected Autonomous/Automated Vehicle

Cloud computing
Storing and accessing data and programs over the Internet. It is another way to refer to the internet, but is used more specifically to refer to software and services that run on the Internet, instead of locally on your computer. Interchangeably: **The Cloud**

CV - Connected Vehicle
A vehicle that can use wireless communication technology to communicate with other vehicles (V2V), roadside infrastructure (V2I) and the cloud (V2C)

DARPA
Defense Advanced Research Projects Agency (United States Department of Defense)

Deadheading
A vehicle travelling without passengers or goods.

Deep Learning
Is a subset of Machine Learning in Artificial Intelligence that has networks capable of learning, unsupervised, from data that is unstructured or unlabeled.

Disengagement reports
The number of times an AV has had to hand over control to a human driver in a determined period of time. This is a number used by some companies to measure progress or advancement of AV systems.

DOT
U.S. Department of Transportation

EV
Electric Vehicle

First mile / Last mile
Terms used to describe the movement of people and goods from a starting point (for example,. a home or business) to a transportation hub and from the hub to a final destination

GPS
Global Positioning Systems

Handoff
When the control of a vehicle is handed back to a human driver because the system encounters a situation it cannot handle. Interchangeably: **Handover**, **Disengagement**.

LIDAR - Light Detection and Ranging
A laser-based version of radar

LRT
Light-Rail Transit

MaaS - Mobility-as-a-Service
Describes a shift away from personally-owned modes of transportation and towards mobility provided as a service. This combines mobility services from public and private transportation providers in a unified gateway that creates and manages the trip, and allows payment with a single account.

Machine learning: A subset of artificial intelligence (AI) that gives machines the ability to learn on their own, resulting in algorithms that make data-driven decisions. See also AI; deep learning.

MSP - Mobility Service Provider
See *TNC*

NACTO
National Association of City Transportation Officials. A coalition of the Departments of Transportation and Agencies in North American cities

NHTSA
National Highway Traffic Safety Administration, part of the U.S. Department of Transportation

OEM - Original Equipment Manufacturer
Used to describe automobile manufacturers that assemble and market vehicles under their own brand, but also can describe a company that manufactures parts for use in commercial vehicles.

P2P
Interchangeably: Peer-to-Peer, Person to Person

P3
Public-Private Partnership

PKT
Interchangeably: Passenger Kilometres Travelled, Person Kilometres Travelled. PMT in the U.S. for miles.

PTC
Private Transportation Company (see *TNC*)

PUDO
Pick-Up Drop-Off. It can apply to both cargo and passengers, and refers to a location or a zone where they are picked up and/or dropped off. For AVs, the term is most frequently used when referring to passengers, see Battle for the Curb.

Ride-Hailing Service
See *TNC*

Ridesharing
The act of sharing a private vehicle and the cost of operating the vehicle with another passenger (for example: carpooling, Lyft Shared).

Robotaxi
A driverless vehicle providing rides on demand

SAE
Society of Automotive Engineers (SAE International)

SOV
Single-Occupant Vehicle

TNC - Transportation Network Company
A company that matches passengers with drivers (or eventually AVs) via websites and mobile apps. Usually paid for by a time- and/or distance-based fee (for example: Uber, Lyft, Didi). This term now excludes traditional taxis, limousines and public transportation. Interchangeably: **Private Transportation Company**, **Ride-Hailing Service**, **Mobility Service Provider**.

Transit Desert
An area lacking or with limited public transportation options. They may also have poor cycling and walking infrastructure.

Transit
Public Transport: A system of shared transport for passengers available for use by the general public. Commonly managed and operated by government agencies on scheduled and established routes. Typical modes include buses, tram or light rail, metros or subways. Interchangeably: **Public Transportation**, **Public Transit**, or **Mass Transit**

Unbanked
Refers to individuals who lack access to mainstream banking services. Also known as: financially excluded

V2C
Vehicle-to-Cloud

V2D
Vehicle-to-Device (handheld)

V2I
Vehicle-to-Infrastructure

V2V
Vehicle-to-Vehicle

V2X - Vehicle-to-everything:
The communication between a vehicle and the cloud, other cars (V2V), and infrastructure (V2I)

VKT
Vehicle Kilometres Travelled. VMT for miles in the U.S.

Introduction

THE NEXT REVOLUTION IN TRANSPORTATION

Autonomous Vehicles are poised to become the next revolution in mobility. A revolution in a scale that has not been seen since the automobile replaced the horse as personal means of transportation. This is one of the most significant arms of a greater revolution being brought forth by broader developments in Artificial Intelligence and Automation. Its repercussions will swathe all areas of human development including social, economical, and cultural.

The Promise of AVs

If you have been to any sort of conference or convention that focused or featured Autonomous Vehicles, you will have heard many of the wonderful things that self-driving vehicles will do. Among innumerable other benefits, marketers and engineers enthusiastically predict a huge reduction in accidents, congestion, parking spots, even the elimination of the loathsome commute.

In the City of Toronto, for example, if AVs reached a 90% penetration, this would result in annual savings of $6 billion, including $1.2 billion from reduced collisions, $1.6 billion from insurance, $2.7 billion from costs related to congestion, and $0.5 billion from parking fees and fines.[1]

If 94% of traffic collisions are caused by human error and poor decision-making,[2] [3] imagine how much safer roads could be if vehicles were driven with computer-like precision? How much smoother would traffic be? If cars can drop you off and drive themselves back home, and then come pick you up later, why would you need parking spots anymore? If you can take a nap, read a book or even get work done while driving to work, how much time could you save and how much sweeter would that ride be?

It has only been relatively recently that experts and academia have started to express rapidly growing concerns for the unintended consequences and implications of this technology. What if those computer systems crash or get hijacked just like other computer systems? What if everyone now wants to enjoy a hands-free, stress-free ride all the time and congestion only worsens? What happens to public transit? What if the enormous number of individual cars driving around empty brings traffic to a halt? What of urban sprawl and the strain on infrastructure when the comfort of the daily commute has everyone buying large, single-family homes far from city centres?

On top of that, if driverless vehicles can only take digital payment, what happens to the part of the population who is unbanked? If manufacturers aim for the greatest market efficiency and only produce vehicles suited for the majority of the population, what happens to those with physical disabilities and special needs?

There are many, many potential ways that the revolution brought forth by driverless vehicles can go wrong as much as it can go right. The Driverless City is not one city: it is many. It is a myriad of opportunities and perils. It can be a boon or a debacle. It can even be both at the same time. This is the

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[1] Ticoll, "Driving Changes: Automated Vehicles in Toronto."

[2] Standing Senate Committee on Transport and Communications Senate, "Driving Change-Technology and Future of Autonomous Vehicles."

[3] Kovacs, *Automated Vehicles, Implications for the Insurance Industry in Canada*.

first step. To be able to decide where we want to go and where we don't, we need to draw a map of all the places we *could* go. To do this we need to understand:

How will Autonomous Vehicles impact and shape the way cities are designed and built in the future?
What considerations should city planners, urban designers, policy makers and other decision-makers be taking?
What are the potential benefits and pitfalls?

This will allow us to decide what types of cities are the ones we want to head towards, and which are the ones we want to steer clear of. Then, we will actually need to *take the wheel*. Instead of letting the future simply happen to us, we need to collectively design the future that we want. This will begin by asking: What needs to be done now to promote desirable outcomes and curtail the undesirable ones?

Scope of this book

Thinking in Systems

A system is a group, assemblage or coordinated body of interacting / interrelated things that operate together and form a unitary or unified whole. The limits of a system — its boundary — is really a conceptual line that divides the system that is being observed / studied from its environment (or 'everything else'). A system's environment includes all the things that are not part of the system but can either affect or be affected by the system. Each of the components of a system can itself be a system, which will have their own boundaries, and be affected and affect its environment.

A simple analogy is to think of a human body as a system. It is comprised of other systems such as the circulatory or nervous systems. The nervous system can in turn be composed of other systems like the brain or the spinal cord. Likewise, the environment of a person's human body consists of larger systems, such as social, economic, geographic, etc. (e.g. the city they reside in, the political system, families and relatives, etc).

Systems Thinking is a holistic approach understanding how the parts of a system interrelate and work within the context of larger systems. It is mindful that the components of a system will act differently when isolated from the system's environment or other parts of the system. It focuses on exploring relationships, context, perspectives and boundaries.[4]

Systems Thinking is particularly useful in examining and working with *wicked problems*. It can help understand situations which are *complex* and messy. It helps see both the big picture and the details, and in doing so, identify leverage and intervention points. It is in a sense, a philosophy that brings awareness to structures and their roles, sensitivity to the circular nature of the world, and the potential for complicated, complex consequences to actions.[5]

There are obviously many challenging aspects to systems and systems thinking. A particularly challenging one, is knowing where the boundary that separates the system from its environment lies. This is the act of agreeing on scope and scale (even if it is just by and for yourself), and is entirely dependent on perspective.

The objective of this specific book and research project is to better understand the ways Autonomous Vehicles will impact and shape the way cities are designed and built in the future. The scope of which will remain entirely within the realm of urbanism, focusing on cities in the North American context. At a high level, this means that the following are in and out of scope:

Table 1. Scope

IN	**OUT**
• Urban Design & Planning	• Jobs & Employment
• Land use & zoning	• Data Privacy & Security
• Traffic	• Specific Technologies
• Transit	• Vehicle Safety
• Transportation of Goods & Services	• Business models
• Infrastructure	• Carbon, Climate & Environment

4 Learning for Sustainability, "Systems Thinking."

5 Goodman, "Systems Thinking."

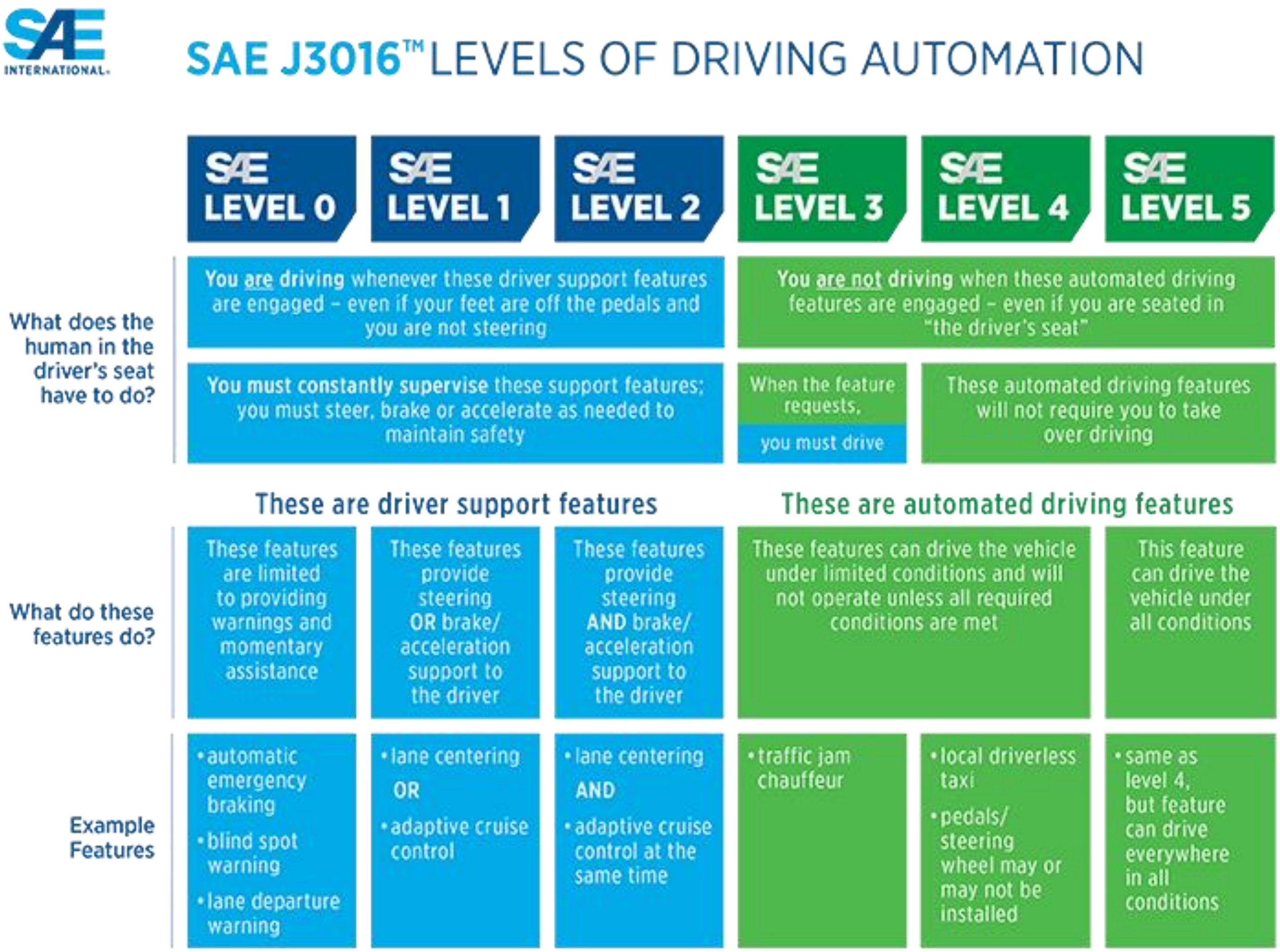
Level Setting

Concepts and Terms

SAE Levels of Automated Driving

When it comes to determining just how much a vehicle can drive itself, or its *level of automation,* the Society of Automotive Engineers International created a measure that has become the most widely adopted standard. It has been revised and updated a couple of times since its original publication in 2014. The most recent version is from June 2018, and is the one shown in *Table 2* below:

Table 2. SAE Levels of Driving Automation



Source: SAE International, https://www.sae.org/news/2019/01/sae-updates-j3016-automated-driving-graphic

For the purpose of this research and report, any reference to a Driverless Vehicle (AV) will mean an SAE Level 4 and/or 5 vehicle.

It is worth noting that while this is the most widely used scale, it is still descriptive and not prescriptive. Currently, there is no certification or testing that could officially designate a vehicle. However, current state and provincial legislatures very frequently use this scale to prescribe what is and is not allowed within their jurisdictions (and the specific conditions under which something may be allowed). Technically there is nothing stopping a developer from twisting the labeling of their vehicle into one level or another, depending on what is most convenient for them.

It is also worth noting that Level 3 is considered the most dangerous level of autonomy[6] Many developers have opted to skip or forego releasing vehicles with this technology and have decided to go straight to Level 4.[7] [8] This is due to the very serious issue with *handoff*: an automated vehicle encountering a situation it cannot handle and requiring a human driver to take over. Kiyotaka Ise, Toyota's chief safety technology officer, described it as "a limbo for several seconds between machine and human".[9] Research has shown that the longer drivers disregard control of the vehicle, the longer it takes to regain control. Psychologists call this "breakdown of vigilance" or "vigilance decrement", and studies of this it go as far back as World War II radar operators.[10] Anyone who has driven long, straight stretches of road is likely familiar with the lull that lack of stimulation brings. Worse, a person sitting in the driver's seat that was watching a video or checking email, someone that was not even paying attention to road conditions, would require significant more time to regain awareness of the road and understanding of the situation.[11] The infamous Uber crash that killed a pedestrian in March 2018 is testament to this.[12]

Automated vs. Autonomous

Wikipedia, the father of internet crowdsourcing and of standardization through community,[13] uses the terms autonomous, automated, self-driving, driverless, and even robo-car interchangeably.[14] This document, which is aimed at broad audiences including the general public, will do the same and treat them as interchangeable synonyms, just like the words *arcade*, *cloister* and *portico* would be understood as the same thing by the general population and used interchangeably. However, for someone in the architectural industry, these have very distinct meanings. Likewise, the meaning of each of these terms have technical differences as well. These differences are not relevant to the research but worth clarifying for future reference. (For additional information, see the University of Virginia's Center for Transportation Studies: *Glossary of Connected and Automated Vehicle Terms*)

Automatic refers to the most basic form of automation. The nature of which is purely mechanical or basic electronics. Anti-lock braking system, automatic transmission, cruise control, these are all automatic, SAE Level 0 systems.

Automated systems typically run within a well-defined set of parameters and are restricted in what tasks they can perform. The decisions made or actions taken by an automated system are based on predefined

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[6] Zon and Ditta, "Robot, Take the Wheel: Public Policy for Automated Vehicles."
[7] Bigelow, "Why Level 3 Automated Technology Has Failed to Take Hold."
[8] Hyatt and Paukert, "Self-Driving Cars."
[9] Capparella, "Toyota Is Uneasy about the Handoff between Automated Systems and Drivers."
[10] Ashley, "SAE Level 3 'Hand off' Is Challenging AI Researchers."
[11] Bigelow, "Why Level 3 Automated Technology Has Failed to Take Hold."
[12] Shepardson, "Uber, Distracted Backup Driver Cited by NTSB in Fatal Self-Driving Crash."
[13] HBS Alumni, "Wikipedia, the Father of Crowdsourcing – Digital Innovation and Transformation."
[14] Wikipedia, "Self-Driving Car."

heuristics.[15] Linguistically, it mainly refers to the range between SAE Level 1 to 4 (and arguably level 5, but this would depend on the specific limits and capabilities of the vehicle).

Self-driving refers to a vehicle that is able to drive itself, but this does not mean it won't ever require a driver.[16] It can describe SAE Level 3, but predominantly refers to Level 4 systems, and is a synonym of *automated* in that range.

Autonomous, from the Greek autonomous "with laws of one's own, independent," [17] is the result of AI's ability for Machine Learning and Deep Learning. This system learns and adapts to dynamic environments, and evolves as the environment around it changes. An autonomous system helps define what the right decision or action is under a changing, non-deterministic environment.[18] It is a vehicle that is capable of making its own driving decisions and this falls exclusively under SAE Level 5.

Driverless refers to a vehicle that has no driver and needs no driver. It needs to be fully automated and be able to do everything by itself, at least within the area it is designated. It can describe vehicles with SAE Level 4 automation (if it is within its limits) , or Level 5. In the latter, it is synonymous with *autonomous*.

Some of the experts that were consulted for the Delphi study argued that Automation will never be able to reach SAE Level 5. Still others argued that Level 5 need never be achieved: If high-capability Level 4 is able to operate in, and between all large, medium & small cities before 2030, it would reach more than 50% of the population.

Connected Vehicles

A Connected Vehicle is one that can communicate bidirectionally with other systems outside of it or to occupants within it through their devices. Applications include everything from traffic safety and efficiency, infotainment, parking assistance, roadside assistance, remote diagnostics, GPS and telematics among others. Connected vehicle safety applications are designed to increase situation awareness and mitigate traffic accidents through vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications.[19]

Vehicle connectivity can accentuate, assist, or be necessary for many of the promises that AVs are purporting. V2V communication technology could mitigate traffic collisions and improve traffic congestion by exchanging basic safety information such as location, speed, and direction between vehicles within range of each other. CV technologies could allow the exchange of sensor and awareness data among vehicles, with cooperative localization and map updating, as well as facilitate cooperative maneuvers between automated vehicles. When a vehicle breaks suddenly, it can transmit a notice to vehicles behind (V2V) that enable those vehicles to warn drivers to stop, or automatically apply brakes if a crash is imminent. A vehicle in an accident could transmit incident data — time of incident, type of crash, severity — through a roadside infrastructure device (V2I) to system operators who then broadcast

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[15] Matteson, "Autonomous versus Automated."
[16] Levinson, "On the Differences between Autonomous, Automated, Self-Driving, and Driverless Cars."
[17] Dictionary.com, "Definition of Autonomous | Dictionary.Com."
[18] Matteson, "Autonomous versus Automated."
[19] ITE, "Connected/Automated Vehicles."

regional warnings. Simultaneously, incident data could be transmitted directly to emergency dispatchers for emergency response.[20] [21]

A CV doesn't mean that the vehicle is making any choices for the driver. Rather, it supplies information to the driver, which could be a human or a computer.[22] ADAS technology can be based on V2V, or V2I systems or vision/camera systems and sensor technology. An Automated Vehicle, by definition, is one that can drive itself, irrespective of whether it is connected electronically to other vehicles or infrastructure. It depends on sensors in the vehicle to navigate its environment and make decisions, not wireless connectivity. Some vehicles, however, may require connectivity in order to operate without a driver (CAVs), which means they are not true AVs in the strictest of definitions, because they rely on and cannot operate without external systems.

While some aspects of *The Driverless City* may rely strongly on AVs being Connected (CAV),[23] the focus of this research are *vehicles that can drive themselves.* Therefore, *connectivity* is an incidental part of this document, with several elements well outside of scope.

Wicked Problems

Wicked Problems are social or cultural problems that are difficult or impossible to solve. Reasons for this include: they are hard to describe, have incomplete, contradictory, and changing requirements, the social complexity means that it has no determinable boundary, they have an interconnected nature with other problems. Complex interdependencies mean the effort to solve one aspect of a wicked problem may reveal or create other problems. There is no single solution to a wicked problem; and the term *wicked* denotes resistance to resolution.[24] [25]

Complex vs. Complicated

Although any thesaurus will treat these as synonyms, these words describe two very different things. While they both describe things that are hard, *Complicated* things refer to things in the sphere of *Exact Sciences*. These are things that have static rules and can be solved and addressed with formulas or recipes. Complicated things can have many layers and levels of difficulty, which is what makes them hard to figure out, but they ultimately can, and then the process can be repeated: like putting a man on the moon. *Complex* things refer to *Inexact Sciences*. Complex things have no degree of definiteness, they arise from networks with multiple interconnected causes, with no clearly distinguishable cause-and-effect pathways. They are continuously changing and even the very act of observing them, changes them.

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[20] IEEE, "Connected Vehicles - IEEE Connected Vehicles."

[21] ITE, "Connected/Automated Vehicles."

[22] Murtha, "Autonomous vs Connected Vehicles – What's the Difference?"

[23] PPSC - Policy and Planning Support Committee, "The Future of Automated Vehicles in Canada Report of the PPSC Working Group on Connected and Automated Vehicles."

[24] Camillus, "Strategy as a Wicked Problem."

[25] Austin Center for Design, "Wicked Problems: Problems Worth Solving - Wicked Problem."

Literature Review

What could cities look like?

Cities are highly complex systems with accompanying highly complex issues. They have evolved for thousands of years to powerful entities that some experts believe might soon have 'more power than countries' themselves.[26] [27] They are also growing in size fairly rapidly. It was only in 2007 when — for the first time — more people across the world lived in urban areas than in rural ones. Currently 55% of people live in cities, and this ratio is expected to reach 68% by 2050[28] Throughout the globe, investment is moving from highways and sprawl to transit and cities[29] However, after millennia of urban progress, cities peaked around 60 years ago. Instead of getting safer, healthier, more efficient, and more equitable, cities are arguably actually getting worse at all of these.[30] The role of automobiles in the development of cities is well described by John Urry in his paper, *The 'System' of Automobility* (edited for brevity):

> "The *'System of Automobility'* is the single most important cause of environmental resource-use, the results from the scale of material, space and power used in the manufacture of cars, roads and car-only environments, and in coping with the material, air quality, medical, social, ozone, visual, aural, spatial and temporal pollution of global automobility.
> Automobility has irreversibly set in train new socialities, of commuting, family life, community, leisure, the pleasures of movement, etc. Cars extend where people can go to and hence what they are literally able to do. Much 'social life' could not be undertaken without the flexibilities of the car and its 24-hour availability. It is possible to leave late by car, to miss connections, to travel in a relatively timeless fashion.
> Automobility divides workplaces from homes, producing lengthy commutes into and across the city. It splits homes and business districts, undermining local retail outlets to which one might have walked or cycled, eroding town-centres, non-car pathways and public spaces. It separates homes and leisure sites often only available by motorized transport. Members of families are split up since they live in distant places involving complex travel to meet up even intermittently.
> Automobility is thus a system that coerces people into an intense flexibility. Automobility involves an individualistic timetabling of many instants or fragments of time. The car-driver operates in instantaneous time rather than the official timetabling of mobility that accompanied the railways in the mid-19th century. Automobility thus produces desires for flexibility that so far only the car is able to satisfy. The seamlessness of the car journey makes other modes of travel inflexible and fragmented.
> Car travel interrupts the taskscapes of others (pedestrians, children going to school, postmen, garbage collectors, farmers, animals and so on), whose daily routines are obstacles to the high-speed traffic cutting mercilessly through slower-moving pathways and dwellings. Junctions, roundabouts, and ramps constitute obstacles to the car drivers

[26] Varinsky, "Cities Are Becoming More Powerful than Countries."
[27] Power, "Future Cities Could Be More Powerful than Countries."
[28] Ritchie and Roser, "Urbanization."
[29] NACTO, *Global Street Design Guide*.
[30] Stevens and Salmon, "Cities Are Complex Systems – Let's Start Looking at Them That Way."

> intent on returning to their normal cruising speed, deemed necessary in order to complete the day's complex tasks in time.
> Urban landscapes were built to facilitate automobility and to discourage other forms of human movement. Movement between private worlds is through dead public spaces by car. Path dependence is a process model in which systems develop irreversibly through a 'lock-in', but with only certain small causes being necessary to prompt their initiation, as with the contingent design of the QWERTY keyboard. The importance of the lock-in means that institutions matter a great deal to how systems develop over longer time periods. Social institutions such as suburban housing, oil companies, out of town shopping centres, can have the effect of producing a long-term irreversibility that is both more predictable and more difficult to reverse.
> Just as the Internet and the mobile phone came from 'nowhere', so the tipping point towards the 'post-car' will emerge unpredictably. It will probably arrive from a set of technologies or firms or governments that are currently not a centre of the car industry and culture, as with the Finnish toilet paper maker Nokia and the unexpected origins of the now ubiquitous mobile phone."[31]

For decades, the dreams about the next generation of mobility consisted quite predominantly of flying cars. It was only until the 90's that driverless vehicles began to be a futuristic feature of popular media. They competed with flying cars for almost two decades until the Darpa Grand Challenge made people realize that driverless cars were no longer science fiction, far into the future. In line with John Urry's predictions, 'out of nowhere', Artificial Intelligence and Robotics have 'unexpectedly' come to disrupt the system of automobility.

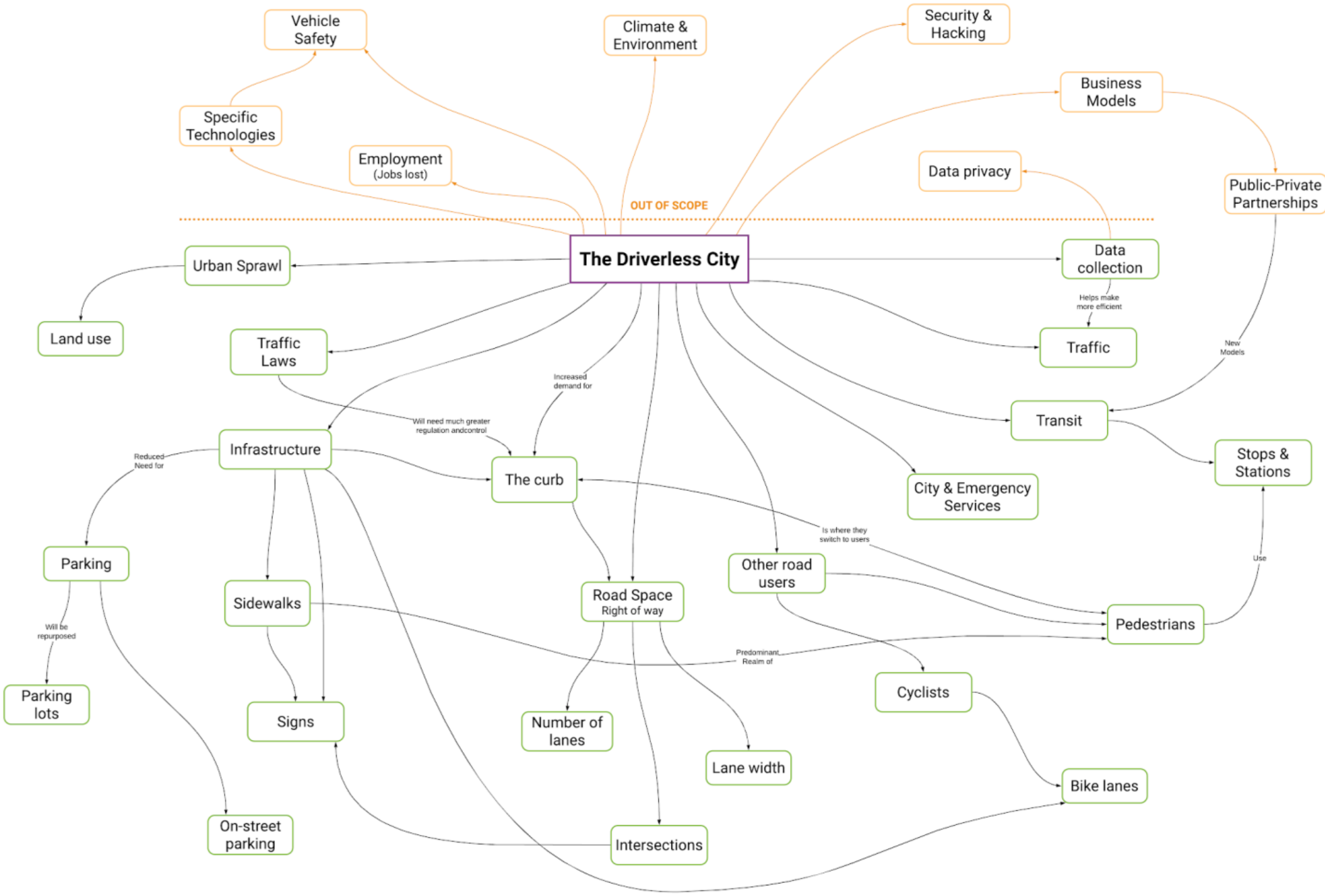
What does this mean for cities built on the 'System of Automobility'? What are the different ways that driverless vehicles could impact them? An extensive literature review has revealed a wide gamut of different city aspects that will be affected. There are countless future scenarios possible, each one with the technology enabling different practices and behaviours. All of these scenarios also have different outcomes; in each one the effects of the technology on cities is different.

The main aspects of the city that will be impacted, revealed in the literature scan, were plotted out in an initial concept map. As the review of the literature progressed, it revealed connections between them, drawing connections and showing clusters between various elements and components. It also emphasized their role and position relative to each other, including hierarchies. The resulting Concept Map is shown below in *Illustration 1*.

This book section is divided into the major aspects identified through this heuristic. These aspects are the ones that stem straight from and have a direct line to "The Driverless City" box in the center of *Illustration 1,* (they are also drawn the closest to it). Findings from the literature review have been divided and clustered around these major aspects, including other categories or elements that lie within these.

[31] Urry, "The 'System' of Automobility."

Illustration 1. Concept Map



Aspects

Battle for the Curb

The curb, or kerb as it is known outside of North America, was very aptly called a *liminal space* by one workshop participant. This label is appropriate, since the curb is the space where a pedestrian is transformed into a cyclist, and where a driver becomes a pedestrian. It is the threshold where walkers are converted into passengers, and vice versa. It is also where couriers pick up and drop off packages, where trucks deliver cargo and supplies and frequently where they collect them as well. For cities everywhere the world, the curb is an increasingly contested slice of real estate. It is increasingly under pressure from new demands created by new business models that compete with existing uses. All of these uses are also rapidly growing. The number of travelers and goods being transported, even the means by which they are moved, are growing rapidly. The number of different online shopping retailers delivering single packages, for example, has resulted in greater congestion from delivery vehicles. In the span of ten years between 2005 and 2015, the global number of parcels grew by 128%, to approximately 31 billion a year.[32] [33]

This issue is aggravated by the fact that, for many cities, curbs are very poorly managed. Many have managed these based on adjacent land use. They are also often a revenue source for municipalities through parking fees. However, highly desirable curbsides, such as those on shopping strips, have parking priced the same way as any other curb in the city, instead of being priced at rates high enough to encourage turnover and allow for as many human shoppers as possible.[34] [35] Fehr & Peers, with sponsorship from Uber, devised a Curb Productivity Index. This is a ratio of the amount of people using the curb per hour, per 20 foot or 6 meters segment of curb (the typical size of an on-street parking spot). Their studies of the cities of San Francisco and Cincinnati consistently revealed that the majority of curbside space is devoted to the least productive use: vehicle parking.[36] This is not a surprise, the fact that parking is enormously inefficient and consumes vast stretches of land, specifically taking up the majority of urban curb space, is known by many. And yet it is still an unquestioned practice of the majority of cities.[37]

A big promise of Automated Vehicles is the freeing up of on-street parking spots that will no longer be required. But AVs are also expected to create demand for pick-up and drop-off areas, especially ones that are as close as possible to the destinations of their passengers. Current street layouts and infrastructure were designed to accommodate private cars. If AVs make good on their promise of flipping the switch from private ownership to shared-use models (through PTC's) streets will need a different design. This will require less or no parking and more of the curb dedicated to safely pick up and drop off passengers in

[32] Deloitte, "Designing a Seamless Integrated Mobility System (SIMSystem) A Manifesto for Transforming Passenger and Goods Mobility."
[33] McAdam et al., "Curbside Management Practitioners Guide."
[34] Ibid.
[35] NACTO, *Blueprint for Autonomous Urbanism*.
[36] Fehr & Peers, "San Francisco Curb Study"; Fehr & Peers, "Cincinnati Curb Study."
[37] Blinick, "Sharing the Road."

a way that does not also interrupt traffic.[38] [39] [40] The demand for PUDO areas will also impact the design at sidewalk grade, affecting the form, location, and design of curb cuts and loading & unloading areas.[41] [42]

One scenario that is often referenced is the “Super Bowl” scenario, where every spectator wants to be picked up by their own autonomous vehicle, or one that they hailed from a TNC. And of course, each spectator wants to be picked up at the same time, and the closest to the exit as possible. What does a gridlock the size of 50,000 spectators look like? [43] [44]

This might be a design problem that could potentially be solved with just a little experimentation in arenas, movie theatres and big box stores that have swathes of parking surrounding them: private land readily available to be redesigned as sophisticated PUDO zones. However, streets and sidewalks on busy downtown cores are an entirely different challenge. Ride-hailing companies are heavily dependent on access to the curbside, and their growing popularity raises questions on the effectiveness of cities' curbside traffic and parking regulations. Already, data from many cities including Toronto, shows hotspots of pick-up and drop-off activity occurring in what should be no-stopping zones, during morning and evening rush hours. This data also highlights conflicts where pick-ups and drop-offs are occurring on transited bike lanes.[45]

A few cities around the world have begun addressing the current contests and conflicts between curbside users with different Curbside Management Strategies. However, the vast majority have yet to begin taking effective steps in this direction.[46] [47]

Changing how curb a curb operates, what is allowed and prohibited, is quite often politically contentious.[48] Changes would also require a strategic approach, instead of addressing hotspots as they pop up in a piecemeal way where public authorities only act when there is direct pressure from stakeholders[49] [50] In order to facilitate collaboration, governments will need to consolidate decisions. To that end, some jurisdictions have created a centralized office with a Chief Mobility Officer appointed to streamline and expedite these decisions[51]

However, many cities with proven curbside management plans and practices have different suggestions and best practices that others should begin incorporating now, before AVs become commonplace: Pricing strategies to reduce VMT and congestion. Creating detailed asset maps of curbs and curb-side

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[38] Ezike et al., “Where Are Self-Driving Cars Taking Us? Pivotal Choices That Will Shape DC's Transportation Future.”
[39] OECD/ITF, “The Shared-Use City: Managing the Curb.”
[40] McAdam et al., “Curbside Management Practitioners Guide.”
[41] Chapin et al., “Envisioning Florida's Future: Transportation and Land Use in an Automated Vehicle World.”
[42] Crute et al., *Planning for Autonomous Mobility*.
[43] Millard-Ball, “Pedestrians, Autonomous Vehicles, and Cities.”
[44] The City of Calgary Transportation department, “Future of Transportation in Calgary.”
[45] Big Data Innovation Team and University of Toronto Transportation Research Institute, “The Transportation Impacts of Vehicle-for-Hire in the City of Toronto.”
[46] Gray, “Curbside Management Strategy: Improving How Curbside Space Is Used.”
[47] Capano, “ITS Canada Parking Workshop - City of Toronto - Curbside Management Challenges.”
[48] McAdam et al., “Curbside Management Practitioners Guide.”
[49] OECD/ITF, “The Shared-Use City: Managing the Curb.”
[50] Ezike et al., “Where Are Self-Driving Cars Taking Us? Pivotal Choices That Will Shape DC's Transportation Future.”
[51] Deloitte, “Designing a Seamless Integrated Mobility System (SIMSystem) A Manifesto for Transforming Passenger and Goods Mobility.”

regulations in order to more effectively and efficiently regulate, maintain and manage them (this step is critical in order to eventually achieve digital enforcement). Requiring off-peak delivery hours to improve efficiency and manage congestion. Dynamic or *flex* curbs that could serve different uses and users at different times of day and night.[52] [53] [54]

Pricing the curb is one of the most highly recommended strategies: Pricing for both commercial and passenger vehicles. This involves the Use of Performance-Based Parking / Loading in dynamic zones (encouraging the use of off-peak hours). Cities that already have this in place charge a fee based on the time the curb space is occupied *and* what it is being used for. Things such as loading fees could be applied automatically or with a warning in freight and passenger pick-up/drop-off.[55] [56]

However, feasible enforcement of these measures is a digital task that requires a detailed curb asset inventory. Automated enforcement of regulations which discourage blockages is key to managing curbs to this degree of precision. The manual enforcement which is currently in use is time-intensive, costly, and ineffective. Automated enforcement will require a greater up-front investment in equipment and infrastructure, but can provide continuous, reliable enforcement. As GPS and sensor technologies develop, more opportunities will also open up for curb pricing and managing in the future. Real-time city curb management systems could allow automated vehicles to reserve slots in advance of their arrival. With real-time data, they could also manage curbsides in real-time, actively setting rates and changing uses with demand, and ensuring turnover.[57] [58] [59]

Road Space (ROW)

One popular prediction about Autonomous Vehicles, is that they will reduce the amount of space that they take up in the road. This is closely tied to the promised efficiencies in traffic flow and congestion, and assumes that vehicles driving with computer-precision will not require lanes as wide as humans do. Many experts are also forecasting a decrease in the size of the vehicles themselves, envisioning a more efficient mode of transportation from point A to point B. This prediction is also tied to the dominance of shared-used business models that would also decrease the total number of vehicles on the road. In addition, more road space is also predicted to be freed up if on-street parking is also no longer required and eliminated.[60]

In present-day engineering terms, road space requirements are directly related to the size and speed of vehicles. Faster-traveling vehicles need to leave greater distance between each other, as well between the vehicle and other objects. This is in direct correlation to the ability of a human driver to remain in control of the vehicle, and the reason highways with high *minimum* speeds have wider lanes than downtown streets with low speed limits. A person while standing still, requires around 10 square feet or 1 m^2 of space, and about 20 square feet or just under 2 m^2 while walking. (Think of how close you can

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[52] NACTO, *Blueprint for Autonomous Urbanism*.
[53] Ibid.
[54] Crute et al., *Planning for Autonomous Mobility*.
[55] NACTO, *Blueprint for Autonomous Urbanism*.
[56] Litman, “Implications for Transport Planning.”
[57] Ibid.
[58] McAdam et al., “Curbside Management Practitioners Guide.”
[59] NACTO, *Blueprint for Autonomous Urbanism*.
[60] Schlossberg et al., “RETHINKING THE STREET IN AN ERA OF DRIVERLESS CARS.”

comfortably stand next to other people while waiting in line, but how much space you need in front and behind you while walking). A bicycle requires 1-2 m^2 (10-20 square feet) when parked and about 4-5 m^2 (approximately 50 square feet) when traveling at 16 kmh /10 mph. Cars will typically occupy anywhere from 14 to 40 m^2 (roughly 150-400 square feet) when parked. But the same vehicle will require 140 m^2 (1,500 square feet) when traveling at 50 kmh (30 mph), and more than 460 m^2 (5,000 square feet) when traveling at 100 kmh (60 mph). As the image in the Public Transit section illustrates, a bus requires approximately 2-3 times as much space as an automobile, but can move up to 60 passengers at a time.[61]

Even if vehicles can drive closer together as a result of computerized efficiencies, there is not going to be a lot of road space opening up. Potentially, a 4-lane road could allow for a fifth lane to be added, although the smarter thing to do would be to allocate this space to the creation of new bike lanes. If on-street parking is freed up, the actual least likely thing to happen is for the curb to be extended. Moving the location of curbs is extremely expensive, as it involves adjusting several layers of underground infrastructure including stormwater drainage, electrical wiring and fire hydrants among other things. There will also be political pressure to relieve congestion through additional capacity for vehicles. Hence, in the best-case scenario, this freed up on-street parking gets converted to PUDO zones and bike lanes, but the chance of the curb getting extended has the odds stacked against it.[62]

In addition, the forecast of shrinking vehicles does not have strong foundations. The same vehicle manufacturers that are said to be talking about a shift to mobility services instead of vehicle sales, are the same ones churning out concepts and prototypes of convenience and luxury inside these vehicles. Indeed, when AVs remove the need for its users to drive, they could gradually shift users' preferences towards larger vehicles that would allow other activities such as sleeping, dining, and working. This means that vehicle size might actually grow to accommodate beds, showers, kitchens, or offices.[63]

Other ROW users

Currently when a pedestrian encounters a vehicle, the pedestrian invariably carries the heaviest, *deadliest* consequences if one of them fails to yield to the other. Although most jurisdictions in North America place preference on pedestrians, most still feel the need to make eye contact with the human driver of the vehicle to ensure that they will indeed stop for them. The possibility of them not seeing the pedestrian, or being distracted is very real. If they are also driving at a certain speed, and they make eye contact too late to stop without tires screeching (and the driver has not initiated crossing but is waiting on the cue), the driver can reasonably expect that the pedestrian won't step in their way, as again, this would cause far more injury to the pedestrian than the driver.

However, this situation reverses when it comes to Automated vehicles. If the speed and distance is enough for the vehicle to physically be able to stop, the pedestrian can trust that the AV will do that without exception. One future scenario suggests that pedestrians could act with impunity towards the vehicles, stepping onto streets without a second thought, constantly halting traffic. This scenario could then lead to laws being changed to reduce pedestrian priority, with the potential of physical obstructions put in place to prevent pedestrians from breaking these new rules (the vehicles cannot break them, since

[61] Litman, "Evaluating Policies and Practices That Affect the Amount of Land Devoted to Transportation Facilities."
[62] Lanyon, "Discussion - MRP," April 2020.
[63] Anderson et al., *Autonomous Vehicle Technology*.

they are already hard-coded in their system).[64] [65] Will pedestrian crosswalks at intersections remain the same in the future? An endless stream of pedestrians crossing continuously would bring vehicular traffic to a virtual halt. AVs making millimetrical maneuvers around pedestrians without slowing down will likely never sit well with pedestrians.

While a lot of the literature, including news articles, brings up a lot of questions about and focus on the safety of driverless vehicles, this is only a relatively short-term concern. This concern revolves around the current testing and upcoming initial integration periods that these vehicles will go through. Manufacturers are well aware that if AVs do not prove themselves to be safe (safer than human drivers even), mass adoption of these will never happen. It is safe to say that the issue of vehicle safety will eventually sort itself out; the industry itself will make sure of that. A clear testament is the setback of the public's opinion on the disproportionate reaction to Uber's driverless vehicle failing to stop and kill a pedestrian (compared to the numerous pedestrians killed daily by human-driven vehicles). The current energy and efforts of authorities should be focused on issues of inclusion, accessibility and fairness, issues that have historically been brushed aside or deprioritized. How will Automated Vehicles work with, and ensure not only the safety, but the inclusion of all other Right of Way users?

Infrastructure

A prevailing issue across Canadian and North America, is that while capital and infrastructure investment plans run several decades into the future, many of those announced in the last few years have barely acknowledged vehicle automation. If they were even considered at all. Substantial investments in public transit and plans for capital projects will span several decades between the time it takes to build them and their life expectancy, or the time they are projected to serve the public. And yet, how many of these still feature enormous, sprawling parking lots, for example? [66] [67] [68]
At the opposite end of the spectrum, there are city-building experts that are anticipating the need to retrofit infrastructure with technology that does not currently exist. Many of these technologies are ones you might have heard about already. These include 5G networks, DSRC (Dedicated Short-Range Communications), remote advanced sensing, hyper-precise GPS, image recognition cameras, and many others that would allow V2V, V2I (or plain V2X) communication. Even services such as MaaS are highly dependent on the availability of this infrastructure. In addition to communication technology, another important aspect of infrastructure that will be greatly impacted will be the city's power grid. If the expectation is for driverless vehicles to be EV's: entirely electric battery powered, then recharging stations of many shapes and sizes will be required throughout.[69] [70] However, the main barrier to updating infrastructure is that there are still no prevailing standards in the technology. Much like Beta vs VHS, or laserdiscs vs. DVDs, the competing formats and form factors are still in development and it will likely be several years before standards are established. So the ability for vehicles to communicate with traffic lights, at-grade train crossings, digital parking signs among other things, will have to wait. In order to avoid costly expenditures in the wrong technology, the prevailing wisdom among city builders is to not

[64] Millard-Ball, "Pedestrians, Autonomous Vehicles, and Cities."
[65] Ibid.
[66] Kovacs, *Automated Vehicles, Implications for the Insurance Industry in Canada*.
[67] Miller and Kang, "Ways to Consider Driverless Vehicles in Virginia Long-Range Travel Demand Models."
[68] Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation Part 2 How Skilled Governance Can Influence Its Outcome."
[69] Bertoncello and Wee, "Ten Ways Autonomous Driving Could Redefine the Automotive World | McKinsey."
[70] Falconer, Zhou, and Felder, "Mobility-as-a-Service The Value Proposition for the Public and Our Urban Systems."

worry about infrastructure now and wait and see what the standard will be, much to the chagrin of tech developers that are eager to make sales of their budding tech.[71]

Repurposed Parking

One of the most anticipated promises of Driverless Vehicles is the amount of parking space that will be freed up to be used for something else. This is one promise that has the potential to come true regardless of whether the shared-use or the private-ownership model prevails. In the shared model, vehicles would be in constant circulation, except for charging and maintenance at the fleet operator's facilities. In the private-use model, owners could send their vehicle back home or to park at a cheaper, more remote lots outside of the downtown area.[72] Current on-street parking alone accounts for a significant amount of a city's real estate. In some cities, this amounts to 20% of the curb-to-curb space, and some scenarios see 80% of these parking spots freed up.[73] [74] [75] At the same time, all this parking is also a significant source of revenue for most cities.[76]

A similar model showed that a reduced need for parking in the United States would free up more than 5.7 billion square meters. This model also considered that where AVs *do* need to park, they would not need space for passengers to open the door doors and get on or off, since the vehicle would pick them up elsewhere and park themselves, allowing for a 15% reduction in the required parking space .[77] [78] This would mean some, if not all of the parking levels on existing buildings could be converted to more useful spaces, including adding valuable retail and office space. Some experts have estimated the activity of parking vehicles accounts for anywhere from 30 - 60 % of downtown traffic. These are drivers circling around looking for parking and the delays and interruption to traffic by moving in and out of parking spots. So reduced parking would additionally help reduce congestion.[79]

Optimistic minds envision that the space that was taken up by parking could be used for purposes such as pedestrian walkways, cycle paths, parkettes and green spaces. Although, as discussed in the ROW section, on-street parking is more likely to be converted into additional thoroughfare. Ideally, this thoroughfare would include cycling as well as some PUDO zones, but odds are most will remain as vehicle thoroughfare.[80] [81]

However, the parking lots that do get freed-up, whether privately or publicly owned, will represent a once-in-a-lifetime opportunity for cities worldwide. They will have land available for development in dense,

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71 PPSC - Policy and Planning Support Committee, "The Future of Automated Vehicles in Canada Report of the PPSC Working Group on Connected and Automated Vehicles."
72 KPMG, "The Clockspeed Dilemma."
73 OECD/ITF, "Urban Mobility System Upgrade How Shared Self-Driving Cars Could Change City Traffic."
74 KPMG, "Islands of Autonomy."
75 Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation Part 2 How Skilled Governance Can Influence Its Outcome."
76 Robinson, "Vancouver Addicted to Parking Revenue."
77 Bertoncello and Wee, "Ten Ways Autonomous Driving Could Redefine the Automotive World | McKinsey."
78 PPSC - Policy and Planning Support Committee, "The Future of Automated Vehicles in Canada Report of the PPSC Working Group on Connected and Automated Vehicles."
79 KPMG, "I See. I Think. I Drive. (I Learn)."
80 Standing Senate Committee on Transport and Communications Senate, "Driving Change-Technology and Future of Autonomous Vehicles."
81 NACTO, *Blueprint for Autonomous Urbanism*.

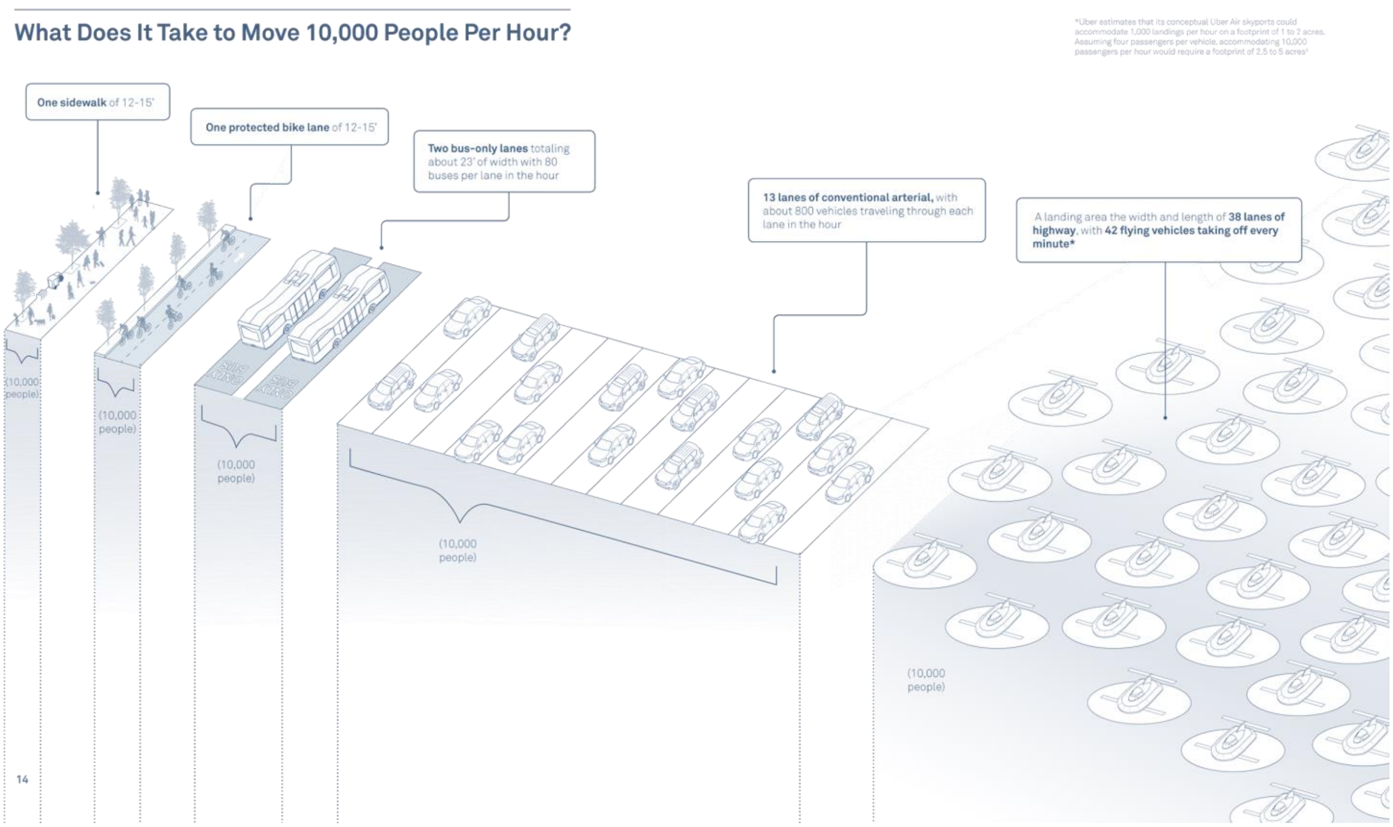
downtown areas where most lots are otherwise already densely developed. With regards to private, residential houses: If owners opt for the shared-use model, this would free up their driveways and garages, enabling them to expand their houses and build new living and working spaces in their homes.[82]

Public Transit

Transit moves more people.

For any given arterial width, transit moves more people per lane per hour. Only bike lanes and sidewalks have the ability to move more people through the same slice (width) of the right of way.[83]

Illustration 2. Space required to move 10,000 people per hour



Source: NACTO Blueprint for Autonomous Urbanism

Illustration 2 above shows these differences graphically. In the same space, private motor vehicles can move up to 1,600 people per hour while Frequent Buses in mixed traffic up to 2,800 people. However dedicated transit lanes can move a maximum of 8,000 people, and on-street transitways (bus or rail) up to 25,000 people per hour.[84]

[82] Waxman, "Will Autonomous Vehicles Lead to Greater Sprawl or Greater Density?"
[83] NACTO, *Blueprint for Autonomous Urbanism*.
[84] Ibid.

In the U.S. transit ridership has declined around 2% each year during the last four years due to declining investment in public transit. However, when transit is given priority when designing streets, ridership increases. In Toronto, the King Street pilot resulted in a 17% increase in transit ridership in just one year.[85]

The greatest fear of urban planners, authorities, and the broader body of experts is that automated vehicles will heavily reduce demand for public transit. Studies have already shown ride-hailing companies have drawn people not only from transit, but from taking other modes such as walking and cycling as well.[86] AVs reducing transit ridership would lead to a downward spiral of reduced service, which begets additional reduced ridership. This in turn hurts the finances of transit agencies and their ability to provide service (let alone less expand it) and thus the spiral continues downward. Degrading transit would stimulate more sprawled, automobile-dependent development, which again reduces transport options and increases VKT.[87] [88] [89] [90] [91]

One potential solution to this problem is embedding autonomy in transit itself. Automated trains have already been operating around the world for decades. Vancouver's SkyTrain illustrates this potential as North America's largest automated train system.[92] Full-size automated buses are currently being tested in different cities as well. For some regions, breaking from established routes and enabling on-demand public transit models on vehicles that don't require a fixed route could result in a *multiplication* in demand for public transit. A recent pilot project in the city of Belleville, had their public transit agency partner with the software company Pantonium. The resulting transformation on their night bus is the envy of transit agencies everywhere, having jumped from 45 riders per night on the traditional fixed route, to 250-300 riders per night using the on-demand model. Vehicle Automation systems are the ideal partner for technologies such as these, and could reverse the trend of public transit's erosion.[93]

Another idea is for automated vehicles to provide first-mile last-mile support to transit systems. These would be short AV trips that feed into transit networks, for example, from home to the station and from the other station to the workplace. The hope is that this would have AVs lead to an increased use of public transit[94] [95] Smaller AV shuttles that typically hold 8-12 people are being tested around the globe. A popular idea is to use these to alleviate transit deserts in cities and complement public transit by covering those first- and last-mile connections. There is also the possibility of incorporating AVs of all types in a Mobility-as-a-Service offering.[96]

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[85] Ibid.

[86] Falconer, Zhou, and Felder, "Mobility-as-a-Service The Value Proposition for the Public and Our Urban Systems."

[87] Litman, "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning," September 8, 2017.

[88] Litman, "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning," November 26, 2018.

[89] Laidlaw, Sweet, and Olsen, "Forecasting the Outlook for Automated Vehicles in the Greater Toronto and Hamilton Area Using a 2016 Consumer Survey."

[90] Litman, "Evaluating Policies and Practices That Affect the Amount of Land Devoted to Transportation Facilities."

[91] Comeau et al., "Benchmarking Public Opinion on Automated Vehicles: Comparing Toronto to Other Jurisdictions."

[92] NACTO, *Blueprint for Autonomous Urbanism*.

[93] Clean Air Partnership, *Smart Mobility for Public Transportation Webinar*.

[94] PPSC - Policy and Planning Support Committee, "The Future of Automated Vehicles in Canada Report of the PPSC Working Group on Connected and Automated Vehicles."

[95] Standing Senate Committee on Transport and Communications Senate, "Driving Change-Technology and Future of Autonomous Vehicles."

[96] City of Toronto, "Draft Automated Vehicles Tactical Plan."

The problem with these solutions, is that they don't make economic sense. If transit agencies across the world are not currently driving around smaller vans or shuttles to cover transit deserts, why would they suddenly start doing this with automated shuttles? If this modality is not something they can currently afford, how exactly would they be able to afford the driverless shuttles that are much more expensive to purchase and maintain? In a similar vein, people that are in transit deserts and hail rides from ride sharing services like Uber and Lyft, are not taking them to the nearest subway station. Since they are already spending significantly more on that ride than the cost of riding only transit, they need only to spend a little more to have their vehicle take them to their final destination. It does not make any sense to pay for a ride share and then be stuck an extra hour or more on the public transit system when the TNC can drop them on their destination in 30 minutes.

Without intervention, however, it is obvious that the business-as-usual path will result in increased congestion and sprawl, eroded transit and decreased cycling and walking.[97]

Transforming Traffic Laws

Some experts share the opinion that a revolution in mobility of this scale is an opportunity to revisit the paradigms and deeply entrenched assumptions regarding how streets should operate. AVs present a chance to question the rules of the road and to reconsider our priorities. The *System of Automobility* relegated everything to several ranks, all beneath the automobile, stranding the pedestrian dead last. When we examine new possible ways to design and operate streets, we should also examine what it is that we actually value and see that reflected in these designs and operations. Things like traffic signals, paint stripes and raised curbs were the product of the previous mobility revolution. They also required many periods of uncertainty and fluctuation before becoming standardized and reaching widespread adoption. Transforming traffic laws will require strategic thinking about people, behaviours and technology, and the new laws and policies that will be required to govern for this new normal.[98] [99]

So far, what little has changed in traffic laws has been limited to allow for the testing of AVs. Most of the recommendations found in the literature are focused on "unblocking innovation" and allowing testing to take place[100] [101] The Canadian Council of Motor Transport Administrators in their Canadian Jurisdictional Guidelines for the Safe Testing *and Deployment of Highly Automated Vehicles,* for example, focuses on easing the work of law enforcement during the testing phase, but provided very little suggestions regarding actual changes to laws. A couple of original suggestions included: Manufacturers should provide law enforcement and regulating entities with access to pre-crash/incident and post-crash/incident data for their completion of a proper investigation. It also brought to light the fact that jurisdictions will need to review their laws and regulations related to persons with physical or mental disabilities, and unsupervised children in motor vehicles, and adopt appropriate laws and regulations to ensure safety for this population at each level of automation.[102] [103]

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[97] Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation: Automated Vehicles Can Influence Urban Form, Congestion, and Infrastructure Delivery."

[98] Ibid.

[99] EastWest Institute, "Smart and Safe Risk Reduction in Tomorrow's Cities."

[100] KPMG, "2019 Autonomous Vehicles Readiness Index."

[101] CCMTA, *CANADIAN JURISDICTIONAL GUIDELINES FOR THE SAFE TESTING AND DEPLOYMENT OF HIGHLY AUTOMATED VEHICLES*.

[102] Ibid.

[103] KPMG, "2019 Autonomous Vehicles Readiness Index."

Of the few, more future-thinking pieces of literature, a few did bring up interesting scenarios: One scenario involved law enforcement, stipulated that fewer resources would be needed for policing when AVs are *programmed* to obey traffic laws.[104] [105] Another scenario brings up a conundrum around speed limits: These are sometimes artificially set low with the expectation drivers will be driving over the limit. Thus the question arises, at what speed should AVs drive? Should they travel at the legal speed limit and move slower than the flow of traffic, or should the move with the flow of traffic in spite of this being an act that breaks the law? Should manufacturers develop vehicles capable of violating speed limits and other traffic laws? If their computer systems are superior to human drivers, should they instead drive at the higher speed that their system is capable of?[106]

The popular expectation is that traffic laws and rules will become code and be hardwired in the vehicle systems. The vehicle can avoid crossing a double yellow lane boundary by simply encoding this boundary as a constraint in its motion. The same constraints would also be placed on either physical or ethical restrictions for the vehicle.[107] At the same however, these vehicles will need to be able to maneuver in emergency circumstances. These would be situations where the vehicle will have to perform maneuvers which would otherwise be a direct violation of traffic laws. They could be as simple as crossing a yellow divider line to avoid debris on the road, or more complex such as following the directions of police officers to drive on a sidewalk to avoid hazards such as a flooded road or a crash scene.[108]

Eventually, different jurisdictions will need to coordinate and work together to harmonize traffic, tort and liability laws in order to enable consistent safety standards for full AV deployment. It will also likely be prohibitively expensive and inefficient for smaller jurisdictions to individually develop their own regulations without established models.[109] [110] [111] Some of the necessary updates to laws will include shifting responsibility to the vehicle manufacturer instead of the driver, in the case of accidents. This implicates shifting the role of the “driver” to that of a passenger. It also necessitates the creation of a way to certify or license a vehicle to drive itself safely on the road. This would be required as substitution of traditional *driver licensing*. Policymakers will also need to look at behavior *directed* at autonomous vehicles. This could include modifying vehicular software or hardware, in both voluntary and involuntary cases, just like people today can voluntarily jailbreak their phone, or have it hacked involuntarily.[112]

City & Emergency Services

Coupled with the promise of AVs increasing the flow of traffic and reducing congestion, is the logical expectation that self-driving vehicles would also greatly increase the ability of emergency vehicles to

[104] Ibid.

[105] Corwin et al., “The Future of Mobility How Transportation Technology and Social Trends Are Creating a New Business Ecosystem.”

[106] Litman, “Autonomous Vehicle Implementation Predictions: Implications for Transport Planning,” September 8, 2017.

[107] Gerdes and Thornton, “Implementable Ethics for Autonomous Vehicles.”

[108] CCMTA, *CANADIAN JURISDICTIONAL GUIDELINES FOR THE SAFE TESTING AND DEPLOYMENT OF HIGHLY AUTOMATED VEHICLES*.

[109] Lewis, Rogers, and Turner, “Adopting and Adapting States and Automated Vehicle Policy.”

[110] Anderson et al., *Autonomous Vehicle Technology*.

[111] PPSC - Policy and Planning Support Committee, “The Future of Automated Vehicles in Canada Report of the PPSC Working Group on Connected and Automated Vehicles.”

[112] West, “Moving Forward: Self-Driving Vehicles in China, Europe, Japan, Korea, and the United States.”

move through traffic in order to rapidly arrive at their destination. The optimal “water parting before Moses” scenario can only realistically be realized through ubiquitous V2V and V2I connectivity. This is a scenario where vehicles can be made aware of an oncoming emergency vehicle even before it has left its garage door, having already plotted the quickest route on a map and communicated this to all vehicles that are on or near that route. This also follows the projection that traffic regulations will ultimately be replaced by protocols, hence automating the entire system itself.[113] [114]

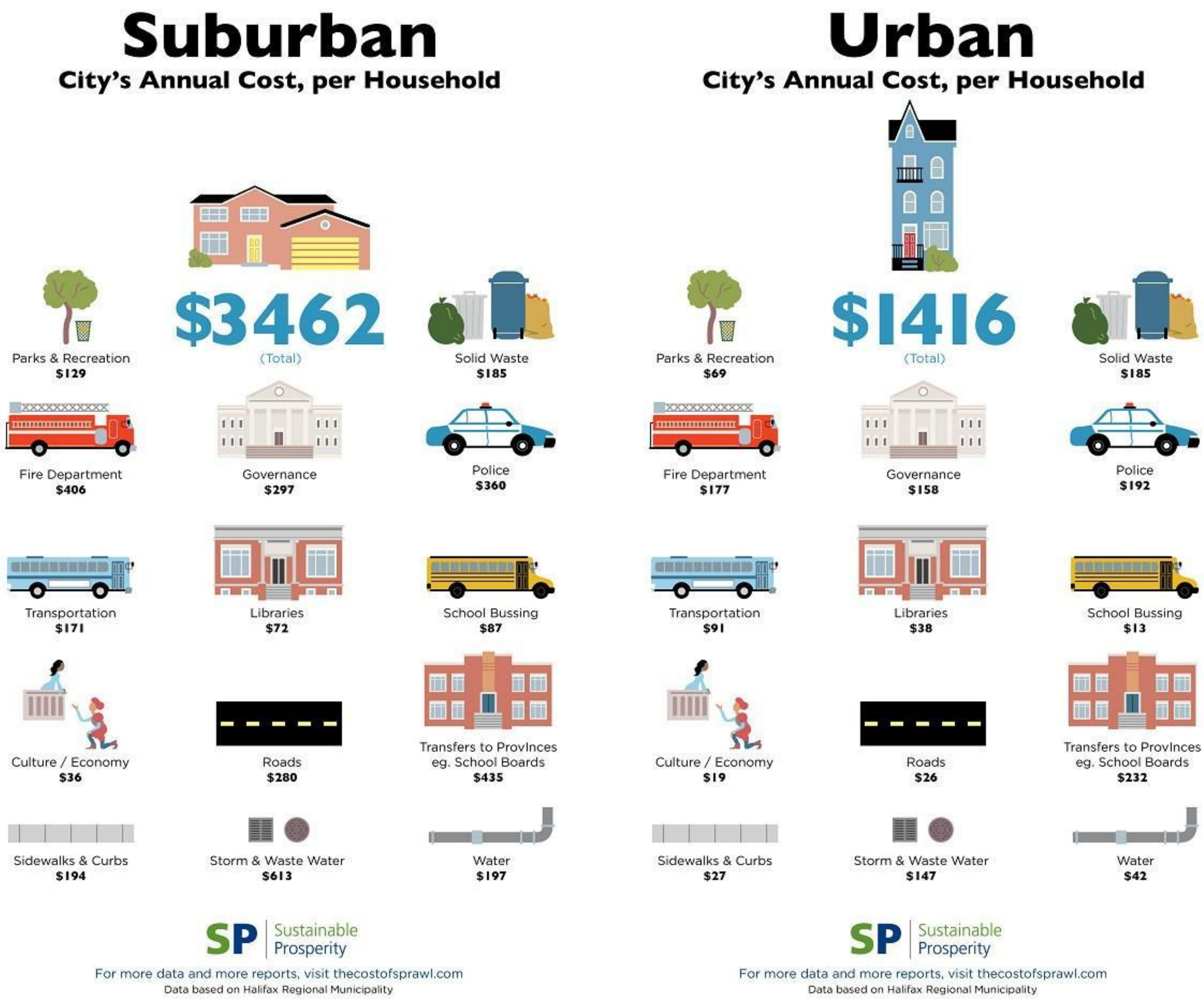
Thus, the real revolution will come when the emergency vehicles themselves are automated. An ambulance that drives itself would not only be able to get to the destination faster (by communicating with and coordinating with other vehicles at faster-than-human speeds). But this would allow both paramedics to be with the patient, tending to them.[115] A similar revolution will come to the rest of the services provided by the city through vehicles. Garbage collection, street sweepers, snow removal, and many other services that cities provide, could run unmanned. Although some of these are currently being tested in a few jurisdictions, actual deployment of these will still be quite some time *after* standard passenger and cargo AVs roll onto the streets. On top of being able to navigate streets, many of these vehicles will have additional layers of complexity involved in the automation of the rest of their functions (such as collecting garbage from bins without spilling any of its contents). Humans will likely still be riding in these vehicles for quite some time after the driving mechanism becomes automated. [116] [117]

Density vs Sprawl

The *System of Automobility* that ensured cars were at the center of North American urban design for the better half of the last century, brought with it a myriad of negative externalities. None of them however, are likely to have been as costly as Urban Sprawl.[118] [119] Defined as uncoordinated growth away from an urban centre into outlying areas, is often the result of housing developers with little to no concern for the real impacts it has on its dwellers, the environment, and infrastructure.[120] Infrastructure costs in particular, are disproportionate to those of urban developments. For a quick reference, *Illustration 3* below shows the results of a study by the Smart Prosperity Institute:

113 The City of Calgary Transportation department, “Future of Transportation in Calgary.”
114 KPMG, “2018 Autonomous Vehicles Readiness Index.”
115 Shepard, “In the Future Your Ambulance Could Be Driverless.”
116 CAVCOE, “Call for Participation – Student Autonomous Snow Plow Competition | Kanata North Business Association.”
117 Volvo, “Volvo Pioneers Autonomous, Self-Driving Refuse Truck.”
118 Urry, “The ‘System’ of Automobility.”
119 Sheller and Urry, “The City and the Car.”
120 Camargo, Artus, and Spiers, *Neuroscience for Cities*.

Illustration 3. City's Annual cost of Urban and Suburban areas



Source: Smart Prosperity Institute (2013), https://institute.smartprosperity.ca/library/publications/infographics-cost-sprawl

Marchetti's constant is a principle that was created in 1994 by an Italian physicist called Cesare Marchetti. This principle asserts that, throughout history, people have been willing to travel approximately 30 minutes to and from their home and work locations. That this means is that on average, people have been willing to live a half-our distance from their place of work. As transportation technology evolved, however, so did the spread and horizontal size of cities. As new means of transportation were able to ferry passengers over greater distances during the same period of time, people were also willing to live physically further away. As these modes of transportation became more convenient, so too did our comfort with physical distance.[121]

[121] English, "The History of Cities Is About How We Get to Work."

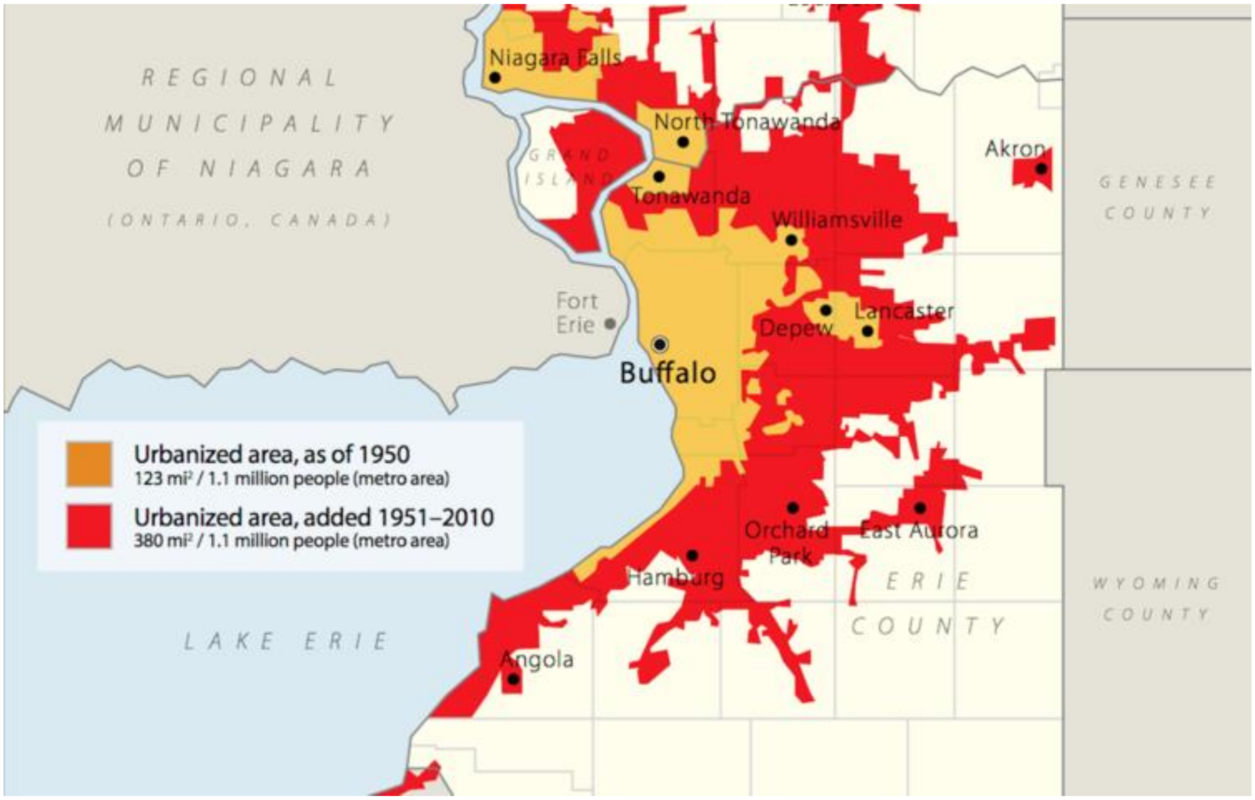
This reinforcing loop was cemented into our developments with the creation of the Automobile. Although not unique to, sprawling cities are very characteristic of North America. Instead of modernizing medieval cities, we felt believed we had the freedom to build new cities onto what seemed like endless open land. This resulted in cities like Atlanta, where only 4% of its population of 5.9 Million are within 600 meters of a metro station. Comparatively, Barcelona, with a similar population of 5.5 Million, has 60% of its population within 600 m of a metro station.[122]

This reinforcing downward spiral twisted our priorities. We arrange our lives with a 'travel time' budget in our minds, consistent with Marchetti's constant of how much time we're willing to spend in transit. So we prioritize mobility: how fast we can go is the measure of how far we can get from our location. We rank mobility itself higher than the places that we can get to *themselves*. Instead of access to destinations, we have prioritized mobility; making highways wider and faster. And yet, after more than a century since the creation of Ford's model-T, faster travel has done nothing to bring us closer to the places we desire to be at. It has actually done the opposite. The average amount of time people spend traveling has remained the same. In the U.S., the average commute is between 20 and 30 minutes, irrespective of city size. On the other hand, the average distance travelled in the U.S. *doubled* between 1982 and 2017.[123] Now, broad 'rivers' of asphalt divide neighborhoods and regions. What would normally have been a 5-minute walk to a store, is now completely impossible to accomplish on foot. Reaching this store now requires access to a vehicle and a 10-minute drive, or at least a 30-minute bus ride, including 2 exchanges. This vicious cycle has had cars make urban sprawl possible while at the same time making its residents dependent on those cars. Suburbia facilitates automobility *and* discourages other forms of movement.[124]

One particularly appalling example of this absurd behaviour lies in the development of the city of Buffalo, NY. For the last 60 years, the net population growth of the entire city was virtual zero. Yet, at the same time, the physical size of the city *tripled*. The exact same number of people are now taking up three times more space (see *Illustration 4* below).[125]

[122] Ramsey, "Urban Densification as a Strategy for Sustainability."
[123] Herriges, "The Mobility Trap."
[124] Sheller and Urry, "The City and the Car."
[125] Herriges, "The Mobility Trap."

Illustration 4. Buffalo, NY: Urbanized area from 1950 to 2010



Source: Daniel Herriges, *The Mobility Trap: Why We'll Never Fix Congestion by Speeding Up Traffic*
Author: Chuck Banas, *Rise Collaborative*

Although the *average* commute has been sustained at an average of half an hour, it can vary greatly between individuals. High-income urban areas with organized road traffic and subways can average significantly lower commute times. On the other hand, for low-income demographics living in a sprawling regions without access to fast-moving trains, forcing many to take minibuses, in gridlocked traffic, the average can shoot up to an hour and a half *each way*[126]

The greatest fear, because it is also what experts consider the most likely scenario, is that Automated Vehicles will greatly promote urban sprawl.[127] [128] [129] [130] [131] [132] If AVs provide a more convenient and cheaper commute, people might be a lot more willing to live further away from the city-centers where they work, especially when housing is a lot more affordable the further away it is from these urban centers. On top of this, if vehicles not only take away the stress of driving, but add conveniences such as the ability to sleep, work or watch a TV show while commuting, they are several times more likely to promote urban

126 McKinsey Global Institute, "SMART CITIES: DIGITAL SOLUTIONS FOR A MORE LIVABLE FUTURE."
127 Laidlaw, Sweet, and Olsen, "Forecasting the Outlook for Automated Vehicles in the Greater Toronto and Hamilton Area Using a 2016 Consumer Survey."
128 Ticoll, "Driving Changes: Automated Vehicles in Toronto."
129 Anderson et al., *Autonomous Vehicle Technology*.
130 Chan et al., "Shared Mobility in the Greater Toronto and Hamilton Area."
131 PPSC - Policy and Planning Support Committee, "The Future of Automated Vehicles in Canada Report of the PPSC Working Group on Connected and Automated Vehicles."
132 The City of Calgary Transportation department, "Future of Transportation in Calgary."

sprawl.[133] [134] [135] [136] [137] Residents of higher-income sprawling suburban areas cities are the likeliest to embrace autonomous vehicles. On the other hand, dense urban developments are also the places most likely to develop shared-use and *MaaS* models integrated with public transit. While affluent suburban residents may purchase personal AVs, urban dwellers, especially non-drivers, are more likely to use robotaxies. Repeatedly, studies on Automated Vehicles point to both possibilities: of them reigning in urban sprawl, and of them encouraging urban sprawl[138] [139] [140] Many experts consider that the answer hinges on whether the private ownership or shared model of driverless cars prevails. Private ownership would of course, promote suburban sprawl while shared models would promote more urban living.[141] [142] [143] [144]

The most likely scenario of the future of Driverless vehicles is what Jordan E. Waxman describes as the "Manhattanization" of urban areas. This is where *both* things occur: the urban core becomes more dense, while the surrounding suburbia also sprawls. This is shown in *Illustration 5* below, which compares New York to Los Angeles.[145] [146] [147]

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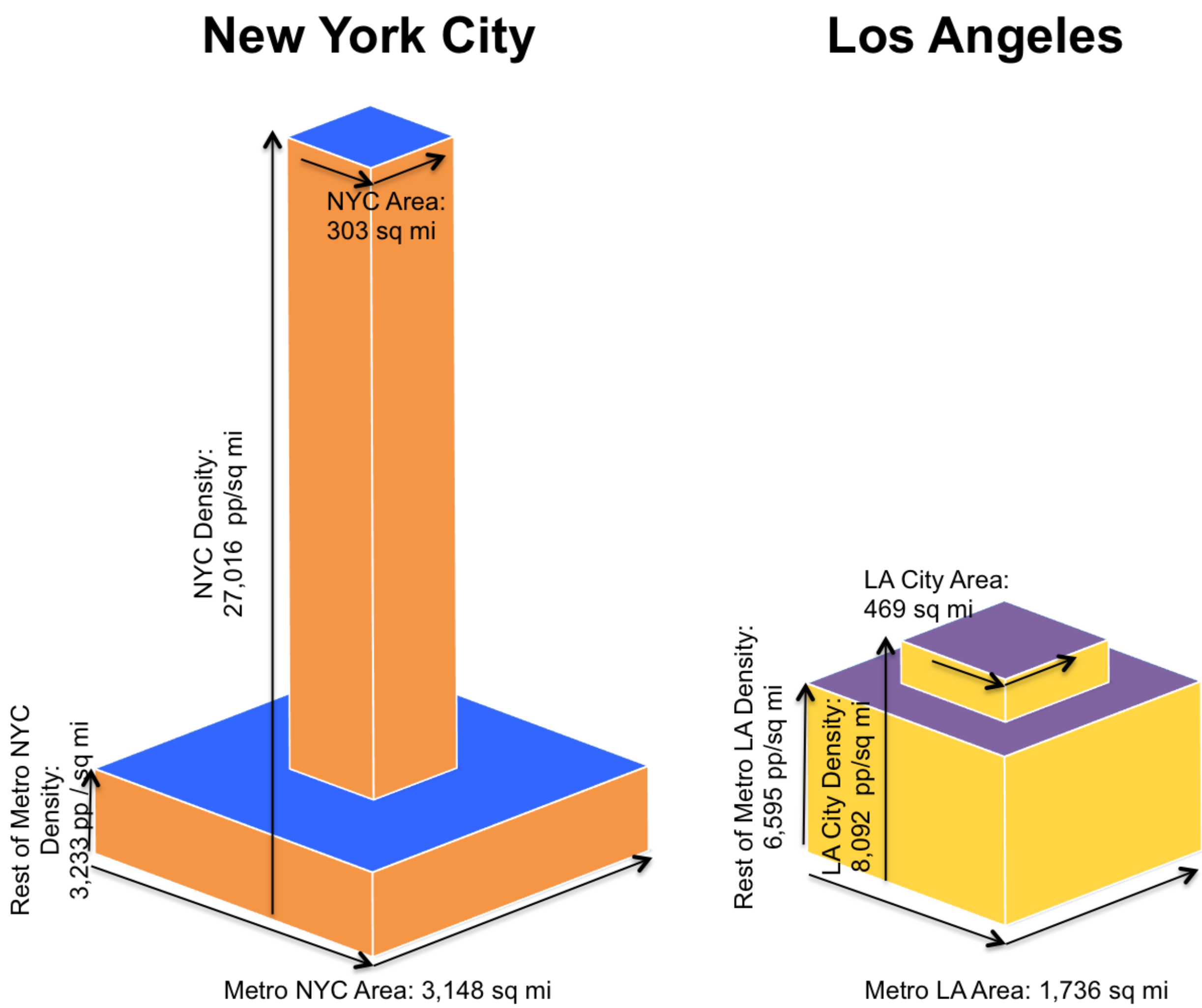
133 Lang et al., "Self Driving Vehicles, Robo-Taxis, and the Urban Mobility Revolution."
134 Townsend, "The Digital Transformation of Transportation in the United States."
135 Ibid.
136 Miller and Kang, "Ways to Consider Driverless Vehicles in Virginia Long-Range Travel Demand Models."
137 Kovacs, *Automated Vehicles, Implications for the Insurance Industry in Canada*.
138 McKinsey Global Institute, "SMART CITIES: DIGITAL SOLUTIONS FOR A MORE LIVABLE FUTURE."
139 Litman, "Implications for Transport Planning."
140 Soteropoulos, Berger, and Ciari, "Impacts of Automated Vehicles on Travel Behaviour and Land Use."
141 Olsen et al., "Driverless Cars in the Greater Toronto and Hamilton Area: Focus Group Findings."
142 Lanyon, "Preparing for Automated Vehicles at the City of Toronto."
143 Cohen and Hopkins, "Autonomous Vehicles and the Future of Urban Tourism."
144 Comeau et al., "Benchmarking Public Opinion on Automated Vehicles: Comparing Toronto to Other Jurisdictions."
145 Waxman, "Will Autonomous Vehicles Lead to Greater Sprawl or Greater Density?"
146 The Bloomberg Aspen Initiative on Cities and Autonomous Vehicles, *Taming the Autonomous Vehicle - A Primer for Cities*.
147 Standing Senate Committee on Transport and Communications Senate, "Driving Change-Technology and Future of Autonomous Vehicles."

Illustration 5. "Manhattanization": New York vs. Los Angeles



Source: Jordan Elpern Waxman, Will Autonomous Vehicles Lead to Greater Sprawl or Greater Density? Yes.

So how will authorities limit urban sprawl when on-demand mobility is convenient and cheap? Sprawl and other urban planning mistakes of the past may be deeply rooted and hard to overhaul. Aggressive construction projects are quite costly to governments as well as neighboring residents[148] [149] Additionally, without proper governance, AVs are a lot more likely to promote congestion and sprawl.[150] Staying on a business-as-usual route will most assuredly result in increasing congestion and sprawl, without realizing most of the promises of Automated Vehicles.[151] Without intervening and letting the market decide, the

[148] Waxman, "Will Autonomous Vehicles Lead to Greater Sprawl or Greater Density?"

[149] Ticoll, "Vehicle Automation: The Missing Piece in Canada's Green Infrastructure Puzzle - The Globe and Mail."

[150] Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation Part 2 How Skilled Governance Can Influence Its Outcome."

[151] Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation: Automated Vehicles Can Influence Urban Form, Congestion, and Infrastructure Delivery."

outcome is essentially what we have today: high ownership, low-use per vehicle, congestion, and sprawl.[152]

Congestion & Clogged Arteries

One of the biggest promises of Automated Vehicles, second only to improved safety, is the reduction of traffic and congestion. Both of these promises are based on the premise that computers will be much more effective and efficient than unpredictable human drivers at moving vehicles and will therefore improve the flow of traffic. Numerous publications for years have cited enormous costs that congestion is currently bringing to society. Therefore, the first caveat is directly in relation to the supposed millions and billions lost, quoted in these reports. Many calculate the value of time lost sitting in traffic based on hourly wages, which is a fallacy. Losing 30 minutes on your commute does not mean that you would otherwise have earned 30 additional minutes of pay. Nor is it true that all these people would be willing to spend the equivalent of 30 minutes worth of their wage to get to work 30 minutes faster. Existing studies have shown that people will pay, on average, closer to $3 an hour, which is nowhere near even minimum wage.[153]

Video representations of the future usually have AVs rapidly zooming and zipping by each other with extreme efficiency, net even needing to come to a stop at intersections. They are reminiscent of the blindingly fast shuffle of delivery packages in computerized sorting facilities (you can watch a sample video on this link), because that's what the model is based on. However, streets are nothing close to these clean, tidy, almost sterile sorting facilities.[154] [155]

In addition, a prerequisite of road efficiencies like these (that are too high-speed for humans) is connectivity. In order for vehicles to effectively navigate streets at promised speeds, they will need to communicate between themselves and the surrounding infrastructure. This promise of driverless efficiency therefore depends on the assumption that all the required infrastructure and connectivity is standardized and in place. But what about a scenario where vehicles of a particular manufacturer cooperate with each other at the expense of other road users? Imagine a Ford vehicle cutting in front of a Toyota, safe in the knowledge that these vehicles will stop and yield, while playing nice with other Ford vehicles.[156]

If Autonomous Vehicles increase traffic speeds and travel demand while at the same time pushing public transit to the side, AVs could actually worsen traffic congestion. If the tradition of pricing parking remains, but roads in turn are not priced, a self-driving vehicle could wander around the block to avoid paying for parking. Or, they could all be sent back to their owner's home, effectively *doubling* the duration and congestion of every morning and evening rush hour.[157] [158]

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[152] Kovacs, *Automated Vehicles, Implications for the Insurance Industry in Canada*.
[153] Herriges, "The Mobility Trap."
[154] Abuelsamid, Alexander, and Jerram, "Navigant Research Leaderboard Report: Automated Driving Assessment of Strategy and Execution for 18 Companies Developing Automated Driving Systems Section 1 EXECUTIVE SUMMARY 1.1 Market Introduction."
[155] Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation Part 2 How Skilled Governance Can Influence Its Outcome."
[156] Millard-Ball, "Pedestrians, Autonomous Vehicles, and Cities."
[157] Litman, "Implications for Transport Planning."
[158] Kovacs, *Automated Vehicles, Implications for the Insurance Industry in Canada*.

Number of Vehicles on the Road

The biggest factor that will affect whether congestion improves or worsens, is the number of driverless vehicles that will be on the road. And, the major factor that will affect the number of AVs on the road, is whether the private ownership or shared-use business model prevails. So while some experts argue that driverless technology will increase individual, private car ownership even further, putting more vehicles on the road, others expect that individual ownership will be prohibitively expensive, and therefore easier and more efficient to share cars, which would reduce total number vehicles circulating.[159]

Alongside the sheer number of vehicles on the road, many experts are additionally comparing the ratio of vehicle kilometers travelled (VKT) to passenger kilometers travelled (PKT) (Or VMT/PMT: for miles traveled in the U.S.). A scenario with increased congestion is one where vehicles are moving for more kilometers than passengers are. In essence, this means that vehicles are driving around empty a large portion of the time, racking up kilometers without passengers in them.[160]

Currently VKT vs. PKT is used to measure the congestion that TNC's, taxis and other 'passenger-only' vehicles add to cities by *deadheading*. This is the time the vehicles are on the road driving around waiting to pick up passengers or driving towards a passenger to pick them up; the time the vehicles are on the road *without* passengers. Numerous studies and reports have already proven that ride-sharing companies have worsened traffic in cities, in direct opposition to their initial promises of reducing it by encouraging less people to drive their private cars.[161] [162] [163] [164] [165] [166] One forecast expects VKT to double in the next 20 years worldwide, with the expectation that automated vehicles will increase VKT and congestion in the mid 2030s and beyond by converting and expanding the current model of individual car ownership.[167] [168] [169]

Nonetheless, many experts are expecting that the shared-use business model prevails. All the traditional car makers and OEM's are talking about shifts to mobility and providing services instead of manufacturing and selling vehicles. The shared-use model is essentially the current business models that Uber, Lyft, Didi and others share, but upgraded to self-driving vehicles. The predictions of these experts are based on several important considerations. First, the biggest expense these companies incur is paying the drivers, so eliminating the driver would eliminate most of the costs associated with the service, leaving only the costs of vehicle fuel and maintenance (although this is currently absorbed by the drivers and hence already part of their payment).[170] Indeed, going driverless may be the only way that these

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[159] Ibid.

[160] Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation: Automated Vehicles Can Influence Urban Form, Congestion, and Infrastructure Delivery."

[161] OECD/ITF, "The Shared-Use City: Managing the Curb."

[162] Schaller, "The New Automobility: Lyft, Uber and the Future of American Cities."

[163] Schaller, "Empty Seats, Full Streets: Fixing Manhattan's Traffic Problem."

[164] Erhardt et al., "Do Transportation Network Companies Decrease or Increase Congestion?"

[165] Fehr & Peers, "Estimated Percent of Total Driving by Lyft and Uber," August 6, 2019.

[166] Falconer, Zhou, and Felder, "Mobility-as-a-Service The Value Proposition for the Public and Our Urban Systems."

[167] Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation: Automated Vehicles Can Influence Urban Form, Congestion, and Infrastructure Delivery."

[168] Kovacs, *Automated Vehicles, Implications for the Insurance Industry in Canada*.

[169] Anderson et al., *Autonomous Vehicle Technology*.

[170] Rapier, "Your Uber Ride Could Get 80% Cheaper over the next Decade."

companies could actually turn a profit[171] Second, without reliable models, insurance companies might be unable to insure individual drivers — or if they could — it would be prohibitively expensive. However, they have already been able to insure AV developers testing these vehicles, including the very same TNC's. If ride-sharing companies are the first out the gate with an extremely cheap and convenient model, they could help create a shift toward a new norm.[172] Lastly, many are pointing to millennials and newer generations as signs of shifts in culture, since they are buying less cars than previous generations. Many news articles have claimed that they will bring the death of the auto industry like they have killed other industries.[173]

The first rebuttal to these arguments is that *the death of cars was greatly exaggerated*.[174] Several studies have already disproved this millennial myth (among other things that they failed to kill). It turns out that they were only slow to buy vehicles. In part this was due to the 2008 recession and other poor economic conditions they have been subjected to, but also because they have generally delayed and postponed many other things as well: They are less likely to be married by age 35, for example. However, a study by the National Bureau of Economic Research compared millennials to baby boomers controlling for 13 factors such as education, income, marital status, and number of children. It turns out, when controlling for these factors, Millennials are actually driving slightly *more* than Baby Boomers did.[175]

Table 2: Demographic variables included in models

Control Variables
Income
Household Size
Household Composition Effects$^{+,\dagger}$
Location: Urban v. Rural^{+}
Location: State Fixed Effects
Education
Survey Year
Age
Sex
Race
Family Life Cycle†
Marital Status*
Number of Children*

Source: Laura Bliss, Despite 'Car-Free' Hype, Millennials Drive a Lot
Author: National Bureau of Economic Research

The second counterargument is that there is an enormous segment of the population that are not at all likely to give up their private vehicle and what it affords them. These include motorists who travel a lot (more than 10,000 kilometers per year). They already reside in sprawled areas where public transit is deficient or completely absent, thus necessitating the use of cars. They also frequently leave items in their vehicles, or outright use them as portable storage: Think of people who carry tools, dirty loads, or

171 Aten, "Uber and Lyft Are Betting That Driverless Cars Will Help Them Finally Make Money. Here's Why It Won't Work."
172 Lanyon, "Discussion - MRP," April 2020.
173 Marshal, "The Death of Cars Was Greatly Exaggerated."
174 Ibid.
175 Bliss, "Despite 'Car-Free' Hype, Millennials Drive a Lot."

equipment for babies, infants and children as well as cleanup accessories and their toys. There are people who take pride in vehicles or value extra comfort (think of pick-up, SUV and luxury-car drivers) There are also those who place a high value on privacy, and would never be fully comfortable getting on a vehicle where they might be recorded in a myriad of ways.[176] Some disabled passengers would require special fittings and accessories in their vehicles, and potentially human assistants. Likewise, a fairly large percentage of the population will age out of their driving license but would still be able to own a vehicle and have it drive them around at their leisure, something they currently would not be able to do otherwise.[177]

Additionally, a TNC that becomes a fleet operator of driverless taxis will incur in additional costs beyond regular vehicular maintenance that the current drivers absorb. Taxis and rideshare vehicles already require frequent cleaning when passengers litter, smoke, or spill food and drinks, just like public transit vehicles. If the interiors of these vehicles are vandalized, they will also incur in cleaning and repair costs. These things happen while the vehicle owner and/or operator is physically present in the vehicle. Because there won't actually be a human present to curtail these behaviours, self-driving taxis will need smooth, hard surfaces to minimize these risks. Unlike most artist's renditions, there's no plush, comfortable interiors in robotaxis. Added security surveillance might mean passengers will need to accept that they will be constantly recorded. There also won't be drivers to help passengers with heavy luggage, help disabled passengers in and out of vehicles or ensure passenger safety.[178]

These compounding factors will most likely lead to a future where both the shared-use and private-ownership scenarios come true, but unlike the question of density vs. sprawl, these might not occur simultaneously but in succession:

Given that the cards are currently stacked in their favour, shared-use automated vehicles will indeed be the first ones out of the gate. This will help the public get comfortable with driverless vehicles. It will also help prove to everyone that they are indeed far safer than human-driven vehicles. Once safety is proven, insurance premiums would plummet. Because the insurance applied to the vehicle and its driverless systems, it is actually meant for and purchased by the manufacturer of the vehicle. The OEMs that make and sell these vehicles could get better deals buying it for their production lines and distributing the cost between larger numbers of individual vehicles. After their safety is proven superior to traditional vehicles, this will eventually lead to humans no longer being allowed to drive on public roads. This would in turn allow for huge cost savings in the manufacture of vehicles, allowing to remove outdated safety features and for the vehicles themselves to be made from cheaper materials such as plastic instead of steel. Then, the trend effectively reverses: With everyone now comfortable with AVs, and the vehicles being cheaper than cars are today, everyone buys one or two or three. This trend has repeated itself often in the history of technology: Originally, only big companies could afford to own a (giant) computer until personal computers rolled out. At that point every household was able to own one, but that was all they could also afford. Several years later, every person has at least one, but often more than one computer. The same things happened with cameras and televisions: It used to be that there was only one per household and people had to share and take turns. But then eventually they became cheap and accessible and everyone got one for themselves.

[176] Litman, "Implications for Transport Planning."

[177] Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation Part 2 How Skilled Governance Can Influence Its Outcome."

[178] Litman, "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning," September 8, 2017.

Methodology

How have Autonomous Vehicles shaped cities in the future? The initial secondary research from the literature scan was a *top-down* approach that revealed a broad range of potential ways that Automated Vehicles will affect cities. Although only a synthesis of these was presented, there are as many potential future scenarios as there are experts forecasting them.

For the next section, additional *bottom-up* and *top-down* study approaches were used to hone these findings. There are two separate parts to these primary research studies. The first seeks to balance the *top-down* opinions of experts through a *bottom-up* approach. A group of regular, city-dwellers were recruited to participate in a futures workshop. After reviewing the extensive opinions of experts, the intention of this exercise was to see if non-experts had different views than them or additional insights to the research.

The second study sought to get a better idea of *how much* Autonomous Vehicles will shape cities in the future. Another top-down approach, the Delphi research method was used in an attempt to narrow down some of the widely varied *how's* and bring some insight into *how much*.

Futures Workshop

For the bottom-up approach, an in-person design research study workshop was created with the following objectives:

- ➢ Identify potential gaps in the desk research (literature review) by leveraging the perspective of non-experts that will be impacted by AV technology.
- ➢ Rank and prioritize the potential impacts of AV technology as perceived by those that will be impacted themselves (as non-experts).

Workshop participants were recruited using free and paid postings on the following online platforms: LinkedIn, Facebook, Twitter, Kijiji and Craigslist. These participants had interest in, but were not experts on Autonomous Vehicles. A total of 10 individuals attended the workshop and participated in all the activities. Their demographic breakdown consisted of the following:

- Sex: 4 Women, 6 Men
- Ethnicity: 4 identified as White, 2 as East Asian, 2 as Brown (South Asian) 2 as other/mixed
- 6 Held valid a driver's license
- Main Commute: 4 used Transit, 3 Car, 2 Cycling, 1 Walking
- Secondary Commute: 3 used Transit, 2 Cycling, 2 Car, 2 Walking, 1 Uber
- 6 worked in the private sector, 3 in the non-profit sector, 1 in the public sector
- Only 3 worked in Automotive, Transportation or related industries

The workshop agenda and activities consisted of:

- → 30-minute presentation
- → Activity 1: Concept Map
- → Activity 2: "Do and Do Not"
- → Activity 3: Story Writing

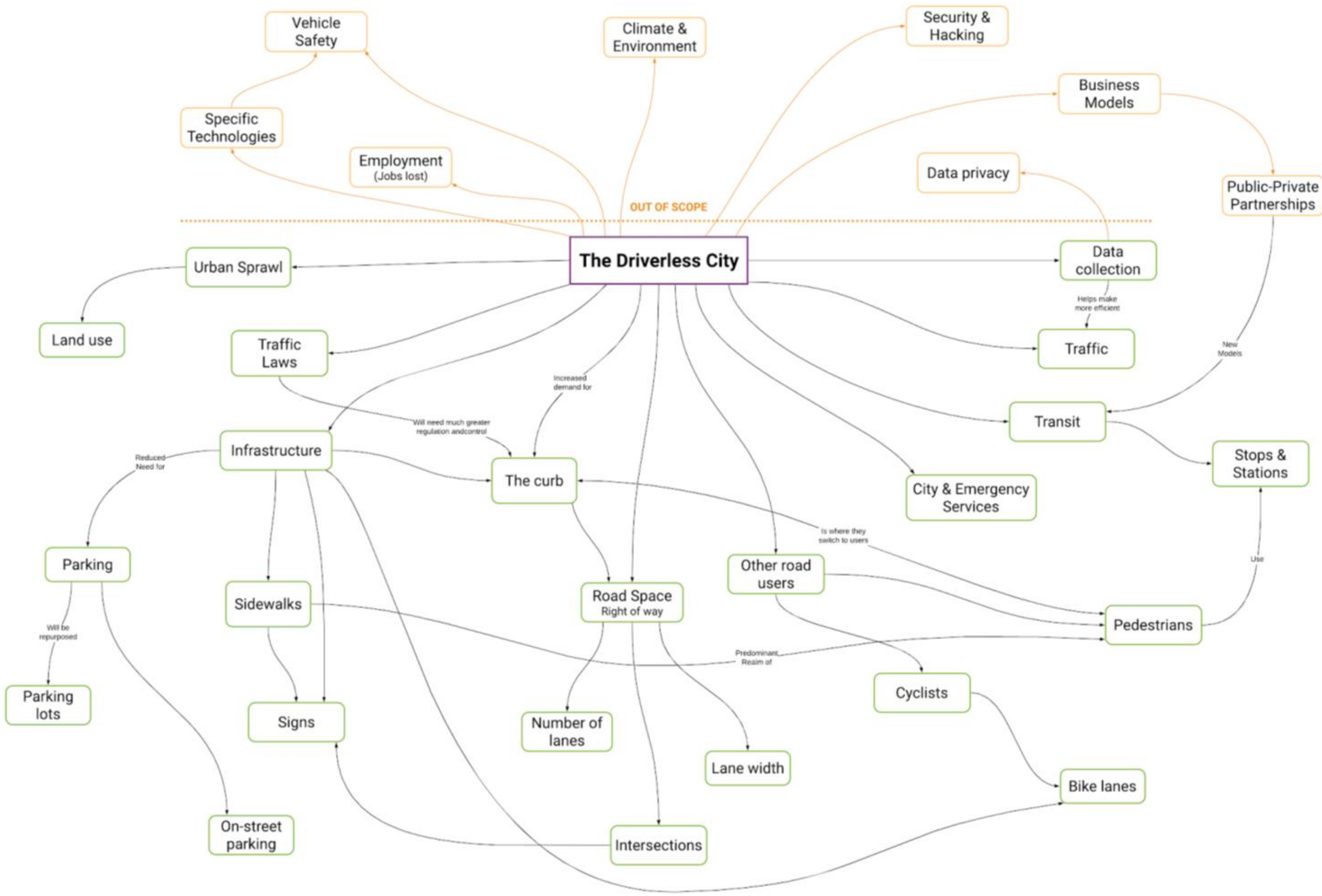
1. Presentation
   This presentation served as an introduction to Autonomous Vehicles for those less-versed in the subject, and helped level-set the group to ensure that everyone was on the same page. The presentation included SAE Levels, types of AVs, other terms and technology, a snapshot of the current status of AVs (at the time of the workshop) as well as the preliminary forecasts that resulted from the Delphi research.
   Another activity helped to warm up the participants' imaginations to help them envision scenarios for the future: Snippets of popular movies set in the future were shown. The scenes featured driverless vehicles as envisioned by the movies' creators. Although it was not originally planned as such, each snippet was followed by a brief discussion deconstructing and critiquing the portrayal of these vehicles. This discussion also touched on other technologies featured in the film. Though these were considered futuristic at the time the movies were released, many had already been achieved and still others are actually commonplace in the present day. The key here was for the participants to reflect on the differences and similarities between the visions the film creators had of the future and the reality that came to be, as they would themselves also be

envisioning the future.

2. “Concept Map” Activity (60min.)
The first activity had participants react to and provide feedback to the Concept Map that was developed from the literature review (shown again in *Illustration 1* below). Participants around each table were asked to highlight what they considered the most important elements through dot-voting, and identify what they felt was missing from the map by using Post-it notes and drawing it on the diagram themselves. This was done individually at first on separate sheets to reduce group-think and really capture independent thoughts.
After participants finished their individual exercise, they repeated the exercises on a larger, table-wide print out of the concept map. They used their individual responses to begin feeding the larger map, and an open discussion helped generate new ideas and ascertain the priorities / importance of the elements.

3. “Do and Do not” Activity (50 min.)
This activity had participants imagine they were 25 years into the future in the year 2045. This is a future where AVs are far more commonplace than all rideshare companies were in 2019: Anywhere from 15% to 75% of all vehicles are driverless. Participants in their 20’s would be mid-career and probably with kids in their teenage years. Their parents/uncles would likely be unable

Illustration 1. Concept Map



to drive by then. Participants with children would likely have them married and with children of their own. Participants over 40 would most likely be retired.

During this time, there are things that AVs will do and things they will not do by simple virtue of being an Autonomous Vehicle. A set of cards with a starting list of some of these things were handed to each table as prompts. They were asked to sort into either the AVs “Are / Do” or “ Are not / Do not” section and then color-code them as follows:.

→ Green: Positive
→ Red: Negative
→ Blue: Neutral
→ Black: Highly uncertain

They were also asked to fill out their own cards, and then sort and color code these as well.

4. Story Writing (15 minutes)
For this final activity, participants used blank storyboard templates to individually create and illustrate a short story. Stories did not require drawings or illustrations, although this was encouraged and space provided. The stories they created were asked to be about living in the city, about interacting with AVs in the same future year: 2045. The goal was to gather further insight into participants’ current beliefs, hopes and fears around the future of AVs

Research Outcomes

Part 1: Presentation

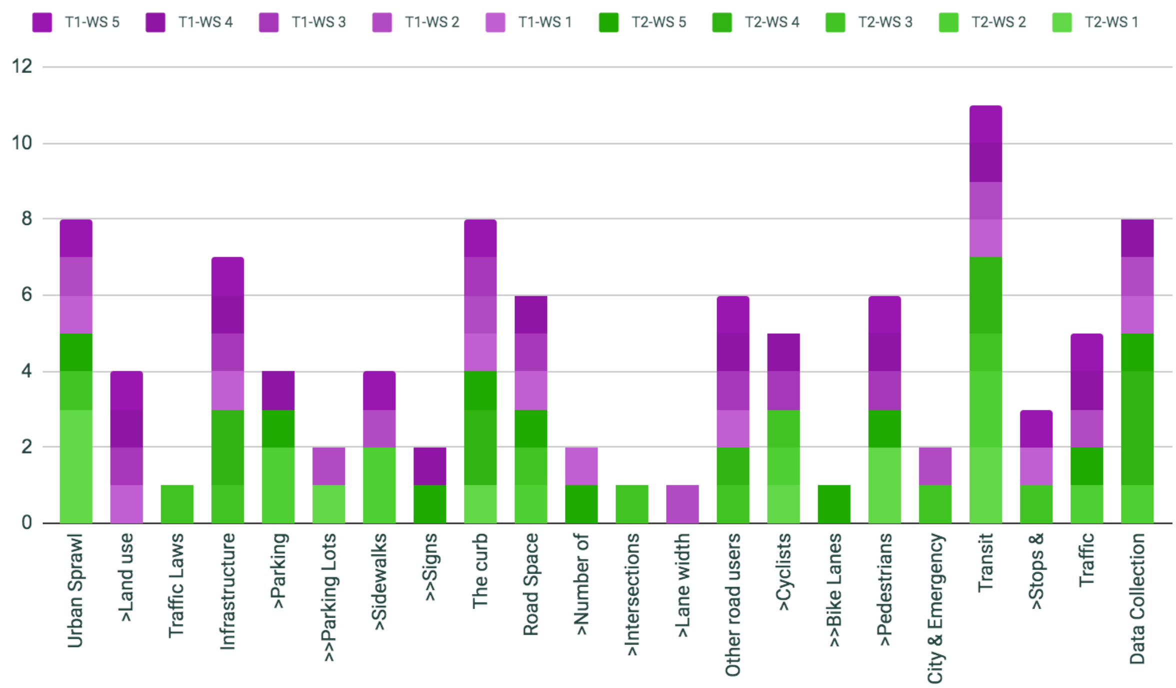
Participants had interesting comments and observations for the video clips of the movies shown. Some of the technology shown in them is meant to be in the future, but is already available today. Other technology is even commonplace, such as videoconferencing through a tablet. Participants noted the differences but also the similarities between futuristic visions of technology and current technology. They also noted inconsistencies due to several technologies in the movie behaving in a particular fashion in order to serve the fictional storyline rather than realism.

Part 2: Concept Map Activity

The next exercise consisted of providing individual feedback to the Driverless City Concept Map. The dot-voting exercise resulted in most participants placing single votes on the elements they considered more important. However, two participants considered some of these elements important enough to merit more than one vote. The combined results of the individual dot-voting exercise (before the table voted together on the larger map) are shown in *Figure 1* below.

As can be readily observed, Transit was the topmost concern for the participants. Additionally, some deemed it so important that they gave it two votes. Although the majority of the attendees voted for Transit, not every single one did. You can see this and additional details about the individual responses in Appendix C: Futures Workshop Concept Map Feedback

Figure 1. Dot Voting: Individual Sheets

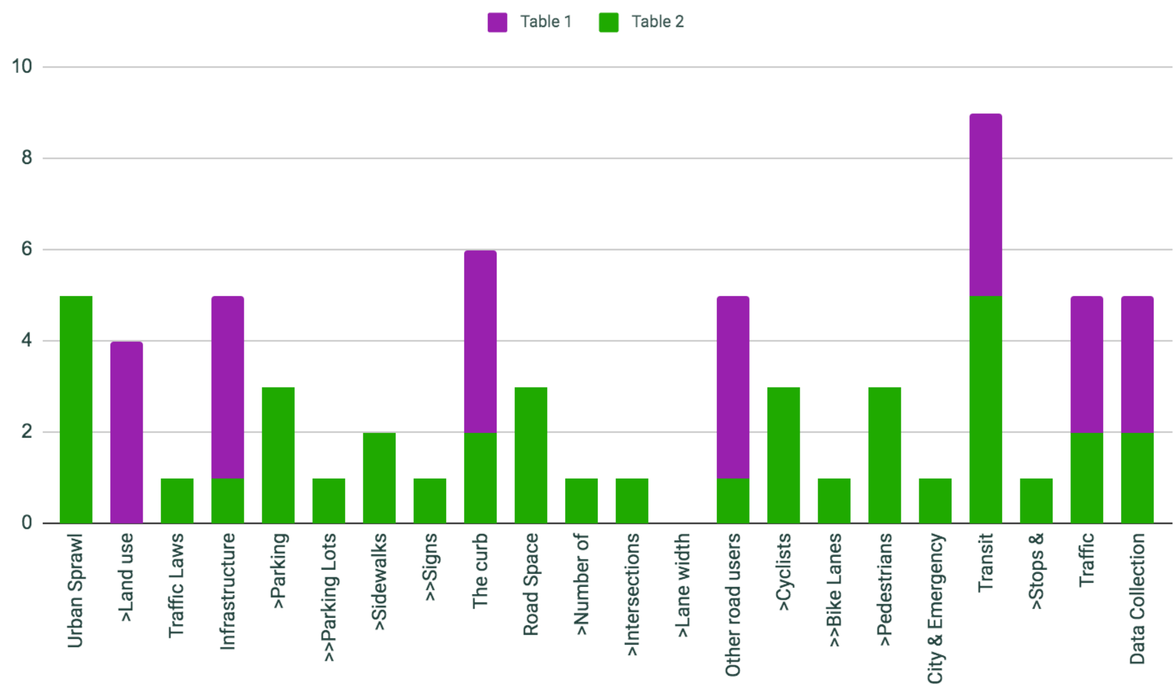


Next on their list of importance came Data Collection, Urban Sprawl, and The Curb. As discussed in the group exercise that followed, Data Collection was a concern for many participants following the attention that had been brought to it by Sidewalk Labs through the Sidewalk Toronto project. Many of the potential issues that AVs would bring to the Curbside were also top of mind for participants, most notably the interaction of AVs with Other Road Users (mainly Pedestrians and Cyclists, which also ranked highly as seen above). Because of this, one participant artfully described curbs as “Liminal spaces”. Urban Sprawl was equally concerning, a concern tied with infrastructure, roadspace, and to a slightly lesser degree, traffic.

Participant discuss the Concept Map across the table

When it came to the second part of this exercise which was to write down individual thoughts and comments on elements that they felt were missing from the map, half of the participants had a lot of feedback to provide, while half had very few items to add or critique. (See Appendix C: Futures Workshop Concept Map Feedback for details). However, when the exercise was opened up to a table-wide discussion, all participants across both tables had a lot more to say regarding the elements of a Driverless City. The discussion helped spark ideas from those who previously hadn’t written many down individually, as well as refine thoughts that others had already written down on their sheets. This discussion also led some to slightly adjust their voting, the results of which are captured in *Figure 2* below:

Figure 2. Dot Voting: Table



Transit received the most votes across both tables. Table 1, however, ranked Land Use, Infrastructure, The Curb and Other Road users just as important as Transit. Table 2, meanwhile, considered Urban Sprawl as crucial as Transit, while giving Parking, Road Space Cyclists and Pedestrians some, but not as much importance.

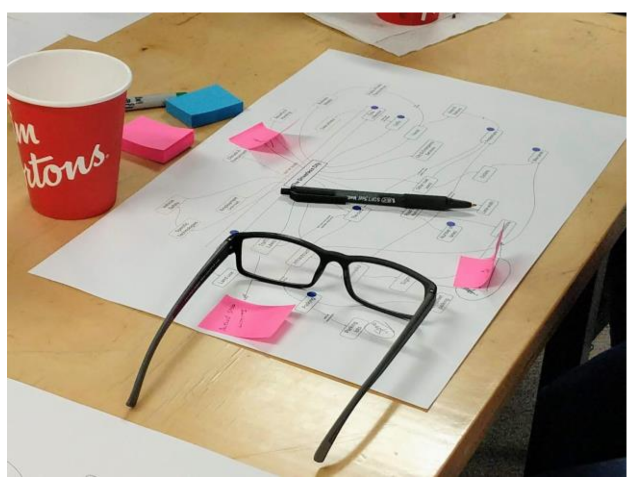
Together with the table-wide discussion on the relative importance of these elements, participants also discussed the elements and connections between these that they thought were missing and important to include as part of the overall map. A synthesis of both tables can be seen in *Illustration 7* below (for each table's individual worksheet, see Appendix C: Futures Workshop Concept Map Feedback)

The comments and feedback from the participants were then aggregated and synthesized based on the ranking and importance assigned to them during the workshop, including the rationale and arguments brought up during the discussion. *Illustration 6* below shows the aggregate of comments and feedback from both tables. (For each table's individual feedback on the Concept Map, see Appendix C: Futures Workshop Concept Map Feedback)

Very few of the additional lines and boxes to the Concept Map had votes to rank them, but the table-wide discussion highlights which of these had agreement and support from the participants. In addition, these comments were later cross-referenced with the literature after the workshop.

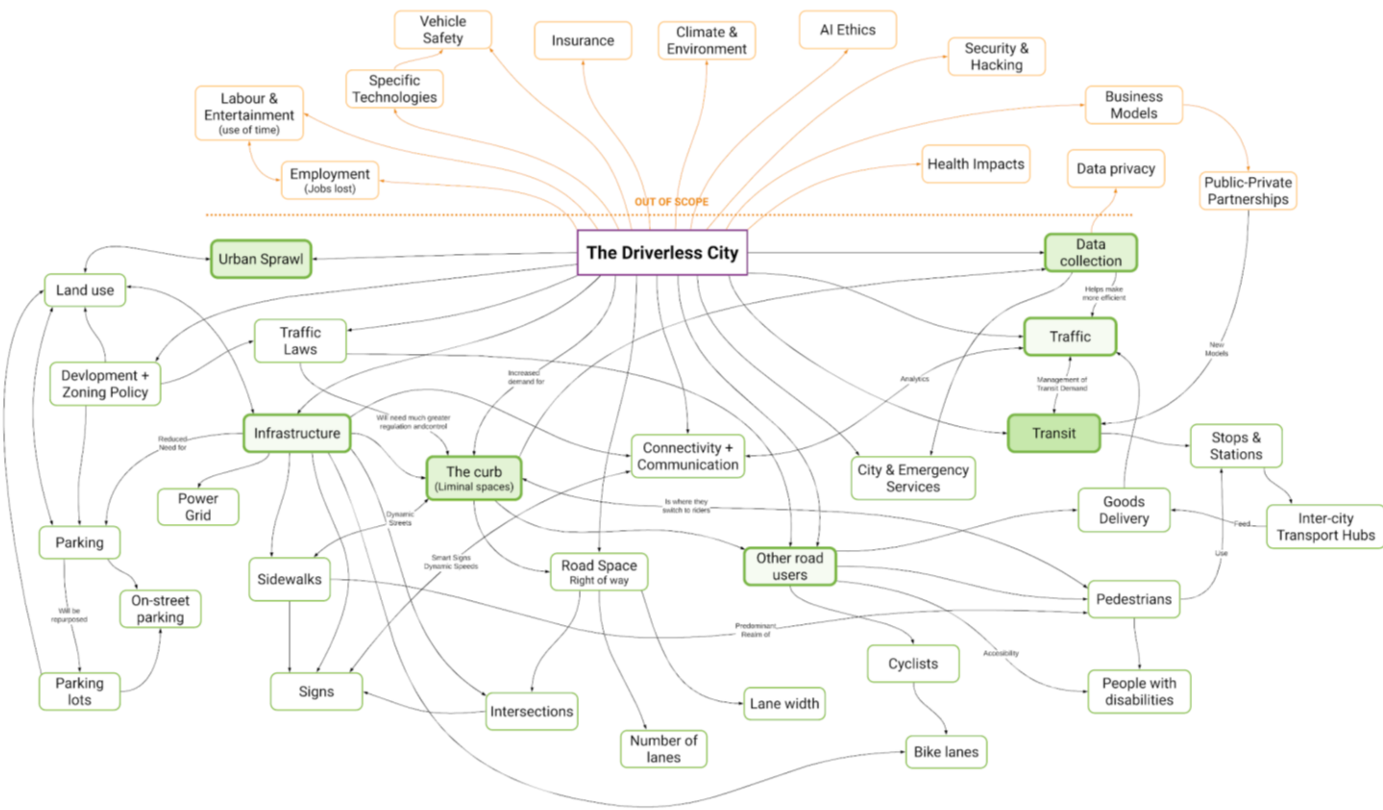
Illustration 6. Concept Map Worksheet Aggregate

After polishing the results of the synthesis, an updated version of the Concept Map was produced, seen in *Illustration 7*, below. This combines the top-down and bottom-up approach to the research. The elements of The Driverless City that were deemed the most important, key, or critical by the participants have been highlighted below: The higher rank they resulted, the darker, more intense the color of their box. Additional elements are shown as new boxes both within the area that is in scope, as well as the area that is outside of the project's scope. These latter elements are part of the system's environment that were considered to have significant influence on the in-scope elements



within the system. This is a call for additional research into these areas, as they will play an important role in the way the Driverless City will look in the future.

Illustration 7. Concept Map - Workshop Synthesis



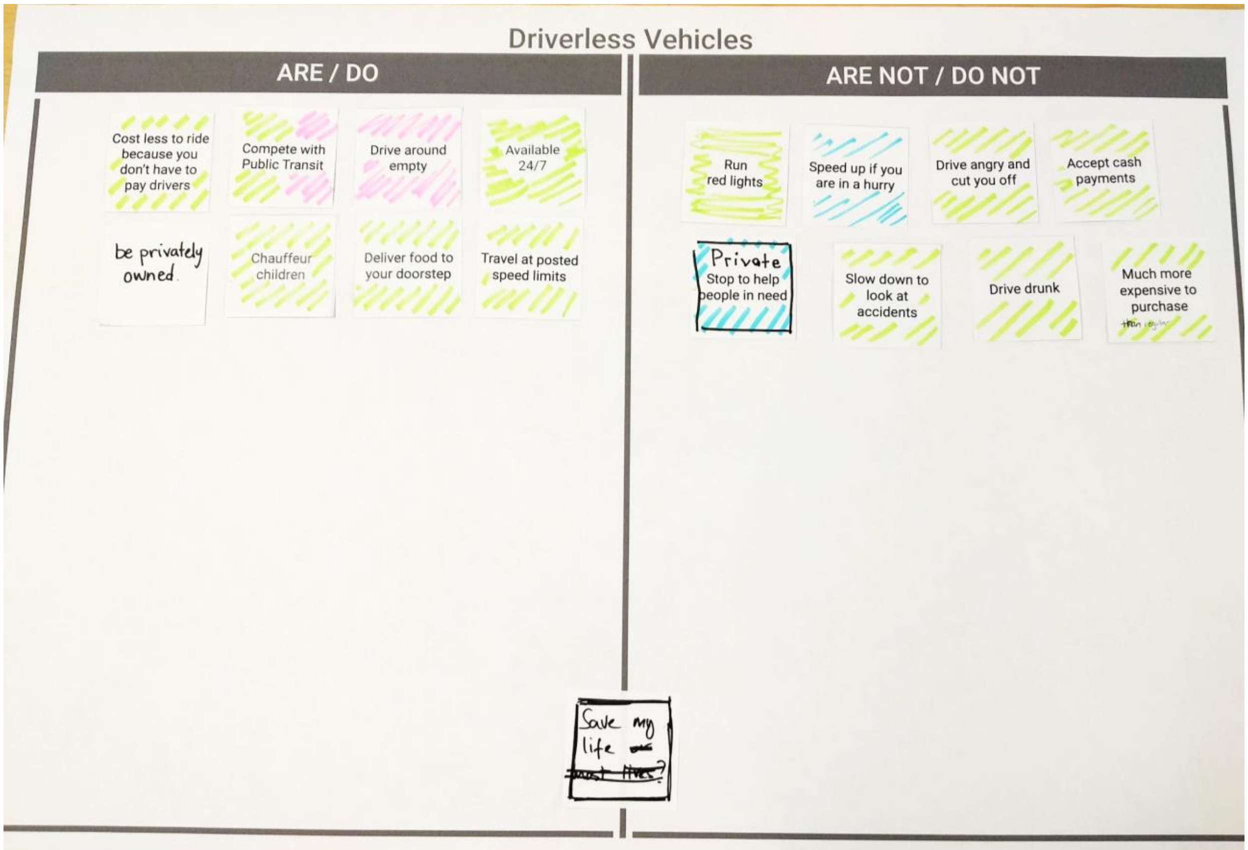
The elements and components that were added to the map include: Development + Zoning Policy, Power Grid, People with disabilities, Goods Delivery, Inter-City Transport Hubs, Connectivity & Communication Health Impacts, AI Ethics, Insurance, Labour & Entertainment

Part 3: “Do and Do Not” Activity

For the next activity in the workshop, each of the two tables sorted and categorized a starting set of cards, with prompts to add more of their own. Unlike the previous exercise, there was a lot more disparity in the way each table judged these cards as well as the new ones that got added. The results of each table can be seen in *Illustration 8* and *Illustration 9*, below

Both tables considered it a good thing that Driverless Vehicles would be available 24/7, cost less to ride because you don’t have to pay drivers and chauffeur children (Table 2 wasn’t in complete agreement on the latter). They also considered it a good thing that they would not slow down to look at accidents, drive angry and cut you off, or drive drunk. Both groups were also split on whether the vehicles would stop to help people in need. While both were unsure whether they would or not. Table 1 though they thought wouldn’t, were still unsure whether that would be positive or negative. Table two created additional cards for the conditions under which this would actually be something positive. This included medical emergencies where a person is still conscious, mechanical problems, extreme weather, and criminal problems.

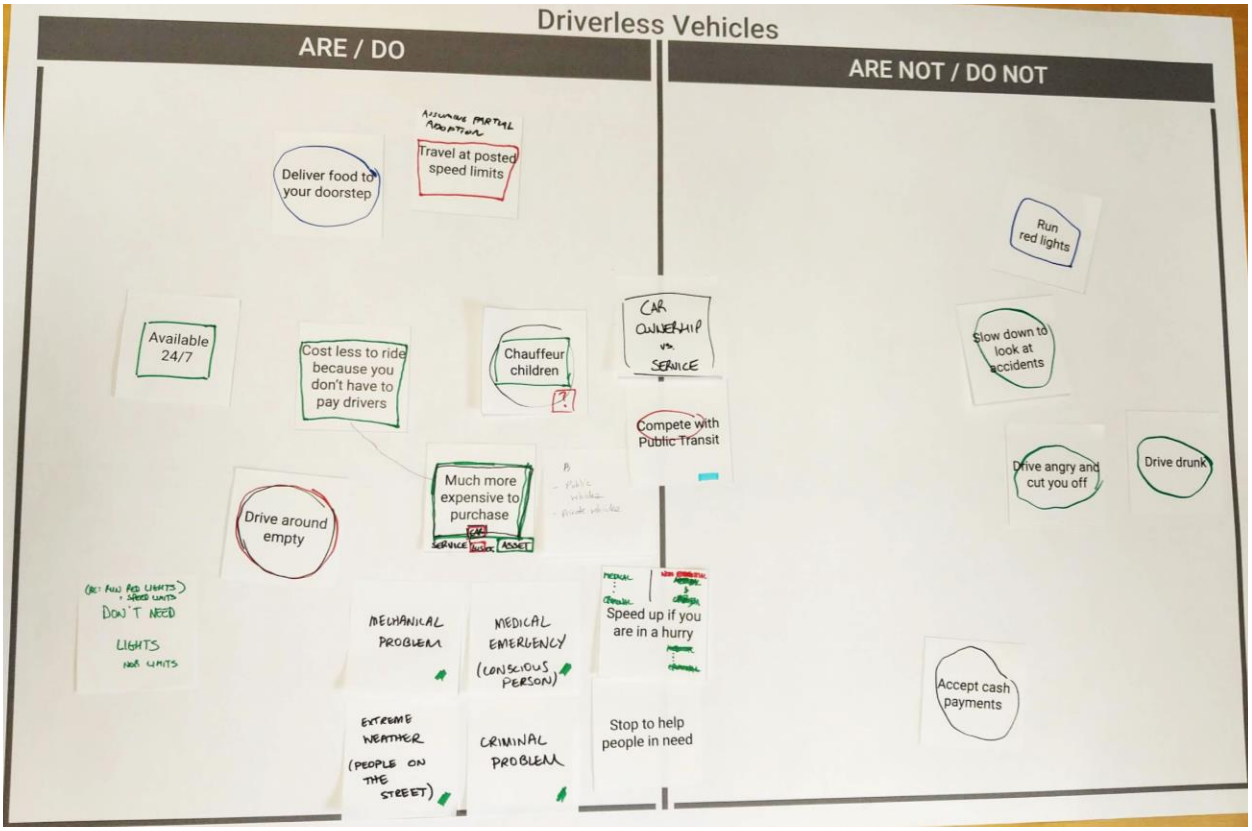
Illustration 8. Table 1 "Do / Do Not"



While both tables considered that Driverless Vehicles would deliver food to your doorstep and travel at posted speed limits, Table 1 considered this a good thing, while Table 2 felt neutral toward food delivery, but negatively towards obeying speed limits. This was because they felt that current speed limits are too slow for the future capabilities of driverless vehicles. Similarly, Table 1 thought that AVs would compete with public transit, and that had both positive and negative aspects to it, while Table 2 was not sure if it would, but specifically considered the competing aspect negatively. Both tables thought AVs would not run red lights, but Table 2 thought there could be situations where AVs should be able to do so. Both tables also thought the vehicles would not accept cash payments, although Table 2 was very unsure as to what this could mean for different demographics.

Items where tables completely disagreed included whether AVs would be more expensive to purchase. Table 1 thought that they would while Table 2 thought they wouldn't, yet they both considered this a good thing. Table 1's perspective was that pricier vehicles meant less individual ownership and them operating as a service model instead. Table 2 thought that lower price would keep them more accessible. Among the new things that AVs would or would not do, both tables added a card around private vehicle ownership They both expressed high uncertainty whether this would happen or not as well as whether this was positive or negative.

Illustration 9. Table 2 "Do / Do Not"



Overall, the results of this activity did not yield strong conclusions regarding the sorting of the specific potential behaviours of Automated Vehicles. Some activities were fairly obvious to sort and rank for both groups (such as "AVs do not drive drunk, and this is a good thing"). But other behaviours — that might've at first glance seemed obvious how they should be sorted — resulted in lengthy discussions on details and circumstances (such as "Travel at posted speed limits" and "Run red lights"). The activity did serve to have additional potential behaviours be brought to light by the participants, as well as moral debates on these. The broader lesson from this exercise is that many of the potential behaviours that Automated Vehicles will be capable or incapable of engaging in, will require a many more lengthy studies and discussions as to whether these should be allowed or not. This greatly underscores the need to shift the focus away from *Fake Ethical Dilemmas*[179] and start putting time, money and efforts into the *real ones*.

Part 4: Story Writing Activity

The final part of the workshop was an individual story-writing activity. After the previous activity had the participants think of many possible outcomes and scenarios, this activity had each participant individually write a short story in storyboard format about future city life where Driverless Vehicles are commonplace. Although the participants had very different stories to share, it is interesting that none of them were

[179] Lin, "Robot Cars And Fake Ethical Dilemmas."

dismal or negative. The overall outlook of the participants regarding the future was positive or quirky, but not terrible or dystopian.

It is also interesting that many of the participants included details about other aspects of life in the future. This was a strong reflection of some of their beliefs around these issues and technologies, in addition to driverless vehicles. Some were tied to the impacts of AVs but others were more an opportunity to express a parallel trend or driver that is present in the author’s mind (something that concerns them and their thoughts regarding what might happen if this is a driver to a specific direction in the future). The key features and details from each story are described below. For the complete stories and illustrations as jotted down by the participants, see Appendix E: Futures Workshop Story Writing.

In Story 1 the protagonist lives outside the GTHA because of cheaper rent. They use AVs for both the first and last mile, and took a cheaper train for the longest part of the commute. This story also featured driverless vehicles delivering groceries to their home in sync with their arrival time.

Story 2 presents a very quirky predicament, where a group that hail a cheaper, shared version of an AV service. They find that an unemployed man has been living inside the vehicle for a couple of days because renting the AV is cheaper than a hotel and car ownership is exorbitant.

Although Story 3 was unfinished, it did present the premise of a smart home that wakes them, and as it tells them about their day, has also scheduled an AV to pick them up for them to arrive on time to their first appointment.

The next story featured a driverless vehicle that was carrying unattended pets. It also showcases a situation where a child pedestrian interrupts the operation of the vehicle by attempting to gain access to it, (in a future where AVs stop at red light intersections). This paralyzes the vehicle and stops the flow of traffic directly behind it.

Story 5 features a vehicle that can switch between manual and autonomous driving. Manual driving still offers a lot of accident-avoidance features regardless, but the user can switch between them depending on preference or need. It also includes the concept of automatic grocery delivery, and accents the pleasure of occasionally doing things manually (like shopping and driving), in a future where automation is the default.

The following story also featured the use of an AV to get to a train. In this scenario, a family uses the time inside the AV to eat breakfast together. And, the train they take itself is autonomous

Story 7 imagines their future house has more green space in lieu of a driveway. They hail an AV through a smartphone, but since they are going to purchase furniture, the vehicle is asked to park and wait for them to load the purchase and take it home.

Story 8 features a privately-owned driverless vehicle that can make the owner money by having it sublet/outsourced to make deliveries when it is not being used by the owner.

In the future of Story 9, AVs co-exist with manually driven cars, but a blizzard demonstrates the superior driving ability of driverless vehicles. In this scenario, the inclement weather triggers the government-mandated temporary suspension of manually-driven vehicles.

Story 10 features food delivered right to their door in spite of them living in a condo tower. It also describes using the time inside an AV to hold work meetings while traveling to another city for an in-person appointment. In this future, a driverless vehicle can travel 1000 kms in one workday with time to spare. It is a future where one can make a trip in the convenience of their own vehicle that, in the present day, would have to be made using an airplane.

Overall, these stories feature life continuing pretty much as it does today, with the added *convenience* of Automated Vehicles. Many stories featured the AVs as advantageous to have or use, and superior to human drivers. Some feature integration with transit systems that are operating as well or even better than they are today. Most of the negative aspects of the stories were caused by humans, some of which saw the relief or answer to the situation in the shape of an AV. Some participants have certain concerns about the future, but these aspects (that become worse in the future, such as rising cost of housing and unemployment) are not related or attributed to AVs.

Although the participants had the opportunity and did express some worries and concerns during the previous exercises in the workshop, their visions of the future are still broadly positive, as reflected in the stories they chose to write. This underscores the fact that, unlike the experts who work in the field that were consulted for the Delphi study, the participants did not show that it is their responsibility to be concerned about the potential for broader negative outcomes and impacts of AVs. Their concerns are more personal and more immediate, and mostly regards the personal benefit they might receive from an AV. This emphasizes the complexity that will be involved in shaping the system.

Delphi

The Delphi Research Method is a systematic forecasting methodology developed by the RAND Corporation. The name itself originates from the Oracle of Delphi, a legendary prophesier. Created during the beginning of the Cold War to forecast the impact of technology on warfare, it was developed in response to the limits of the traditional forecasting methods available then, which are dependent on strict mathematical or scientific laws to extrapolate into the future.
The method involves a group of experts that answer a series of surveys or questionnaires. This panel of experts responds to each questionnaire individually. Responses are collected and then shared back anonymously with the panel, who are then able to provide a second response to the questionnaire and adjust their answers based on the responses and feedback of their peers. These rounds of sharing previous responses and questionnaires repeats several times with the objective of gradually obtaining a degree of consensus in the responses. The rationale behind keeping the responses to previous questionnaires anonymous is to reduce the chance of the responses from being swayed by personal charisma, reputation, or other personal reasons and instead attempt to focus the shift to more logical, technical arguments.[180]

For this research, initial outreach was done to 50 experts based in different cities across North America. Approximately half were already part of the Principal Investigator's extended network, and the other half were authors of books, articles or reports cited in this research but not at that time part of the network. An initial panel of 13 experts agreed to participate in the study, however 3 were unable to complete all rounds and only 10 concluded the study.
The following (Table 2) lists the experts that completed the study, including their roles and titles during the period that the research took place.

Table 3. Expert Panel - Delphi

Name	Role
Antoine Belaieff	Director, Regional Planning: Metrolinx
Jerry Boyer	Co-Founder: Harmonize Mobility
Shagithya Deivendran	Project Lead - Automated Vehicles: City of Toronto
Bern Grush	Author: End of Driving
Alec Knowles	Principal Consultant, Advisory Services: WSP, Ontario
John Niles	Principal and Co-Author: Grush Niles Strategic
Andrew Sedor	Business Development Coordinator, Transportation Strategy: City of Calgary
Karlyn D. Stanley	Senior Policy Analyst: RAND Corporation
David Thurlow	Program Director: Harmonize Mobility
Erin Toop	Senior Transportation Engineer: WSP, Alberta

[180] Helmer-Hirschberg, "Analysis of the Future: The Delphi Method."

Paul Godsmark, who is the Co-Founder & CTO of CAVCOE, participated in the first two rounds but was one of those experts who unfortunately were not able to complete the study. He did offer valuable feedback, which was shared with the other experts during the first 2 rounds. Some of his insights are provided in sections of the study, below.

For purposes of this survey, these experts were asked to consider the following:

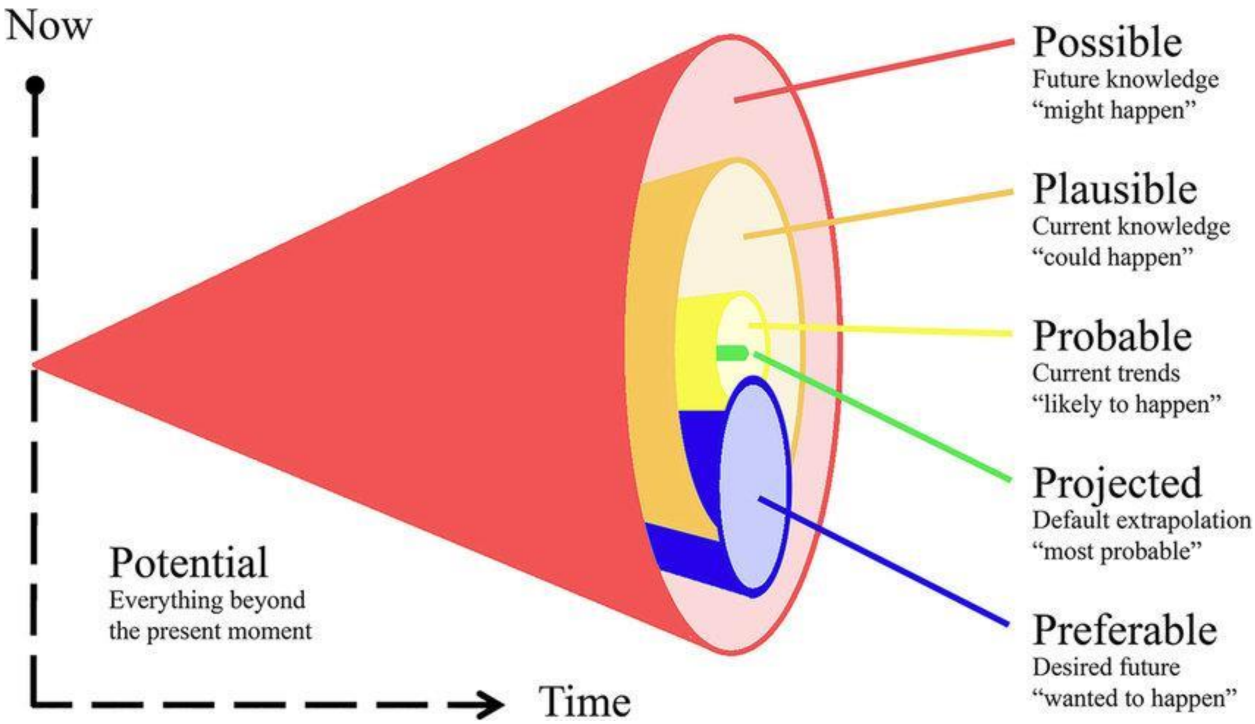
- ➢ That AVs (Driverless vehicles) referred to SAE levels 4 & 5
- ➢ That the geographic scope of the study is North America (Canada and the U.S., only)

They were each sent a link to an online survey which was divided into 2 sections:

- ❖ The first had 4 questions that dealt with circumstances that are certain to occur, but with high uncertainty regarding when and to what degree they will occur.
- ❖ The second section had 3 questions around circumstances that are very unlikely to remain the same as the present day. However, it is hard to envision how they will shift and in which direction the trend will follow. They are more contentious because there is high uncertainty regarding when and how much these issues will either accelerate or decelerate.

Experts were asked to respond to the questions by providing their professional estimate on specific impacts of AV technology. Stress was placed on them entering the most realistic and likely forecast instead of a positive or negative outlook. Their responses consisted of projections of changing ratios or percentiles through time. These were entered using a 100-point scale slider at each time interval. In addition, they were asked to provide any relevant comments or any supporting evidence after each question.

Illustration 10. Futures Cone



Source: Van Dorsser et al., Improving the Link between the Futures Field and Policymaking.

The Futures Cone shown in *Illustration 10* above, shows a conceptual model of all that is possible in the future as it moves forward through time from the present moment.[181] To help you understand this model, consider the following: If you are currently sitting in Toronto, you could not *possibly* find yourself in London, UK in the next 2 hours. This is completely impossible. You could find yourself in London, Ontario, *that is possible*. In the next 7 hours, you could find yourself in London, UK. While this is just barely inside the line of what is actually *possible*, it is not really *plausible*. This would have required you to actually be sitting in a plane taking off from Pearson Airport as you read this paragraph. Finding yourself in London, UK within 24 hours is definitely *plausible*, but not *likely*, since this would require you do several unlikely things such as drop everything in your work and life to purchase a ticket and board a plane. Finding yourself in London, UK within the next 6 months is something a lot more *likely* to happen and therefore *probable*, since you could very realistically plan for and schedule this event to happen (especially if things like work are likely to take you there). If you actually have already purchased a ticket for a conference there, then that would be the *projected* outcome; this will *most probably* happen. However, if what you really want is to be in Paris on vacation within 6 months, that would be the *preferable* scenario.

The nature of forecasting is such that it becomes increasingly difficult to do, the further into the future that you project;[182] uncertainty increases as the cone of possibility widens (while there is a limited number of places you could be within the next 2 hours, there are vastly more you could be within 6 months).[183] Therefore, each question of the forecast survey sent to the group of experts had a response slider for every year until the year 2025, then every 2.5 years until 2030, then every 5 years until 2050, and

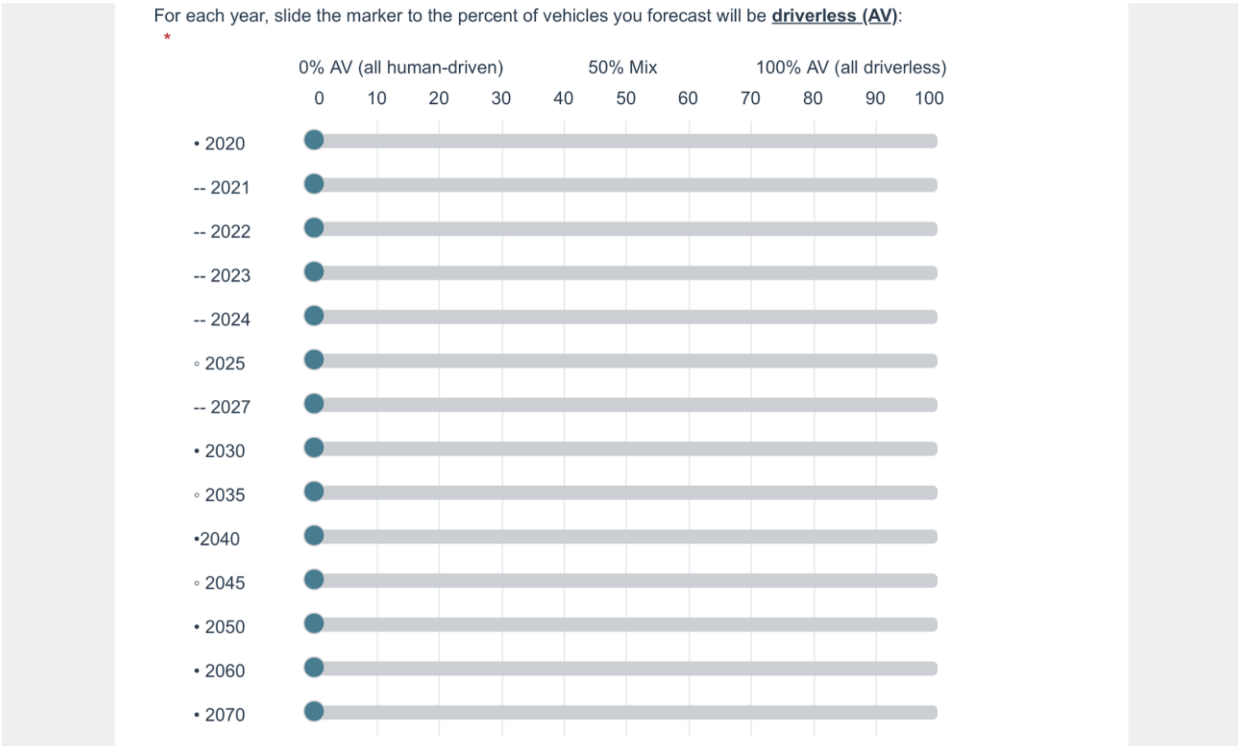
181 van Dorsser et al., "Improving the Link between the Futures Field and Policymaking."

182 Ramírez and Selin, "Plausibility and Probability in Scenario Planning."

183 Paul Saffo, "Six Rules for Effective Forecasting."

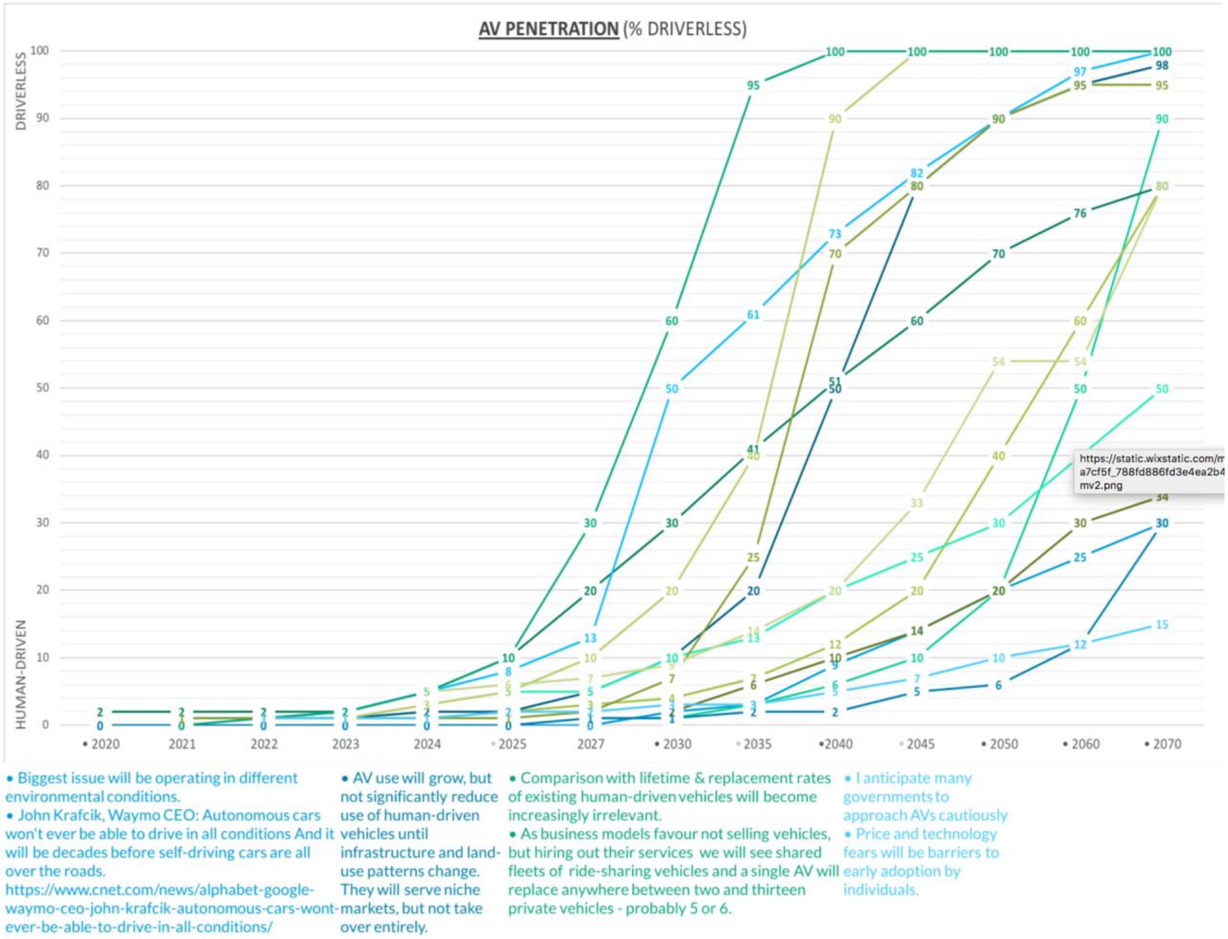
finally every decade until 2070. *Illustration 11*, below, shows the sliders used to capture the responses as seen by the participants:

Illustration 11. Survey Question Example - Delphi



As part of the questionnaires sent out in the subsequent 2nd and 3rd rounds, the responses from the preceding survey were shared back with each participant in an anonymous manner. The responses were presented as one graph that plotted all individual responses. If the experts provided any comments as part of their response, these were provided beneath the graph. The comments were color-coded to match the respondent's line in the graph, but were stripped of anything that could otherwise identify the respondent. *Illustration 12* below, is a snapshot of how the responses from the first survey were shared in the second round. The project's color template had not yet been selected, so the colors here are different from the result in later sections. However, as mentioned above, colors in the comments that matches the colors in the graph correspond to the same respondent.

Illustration 12. Sample Delphi Survey Response



Survey Questions

Section 1

This section of the survey dealt with circumstances that are highly certain to occur, but retain high uncertainty regarding when and to what degree they will occur.

1. PENETRATION

What percentage of vehicles on the road will be *human-driven* and what percent will be *driverless (AVs)*?

Panelists where provided with the following information as a level-setting starting point to their projections:[184]

- Average life expectancy of a vehicle in the U.S is 15.36 years
- Average life expectancy of a vehicle in Canada is 12.88 years
  - In 2000, 33.7 % of vehicles in Canada lasted at least 15 years
  - In 2017, 54 % of vehicles in Canada lasted at least 15 years

[184] Lantz, "Longer Vehicle Life Expectancy a Testament to Research and Technology."

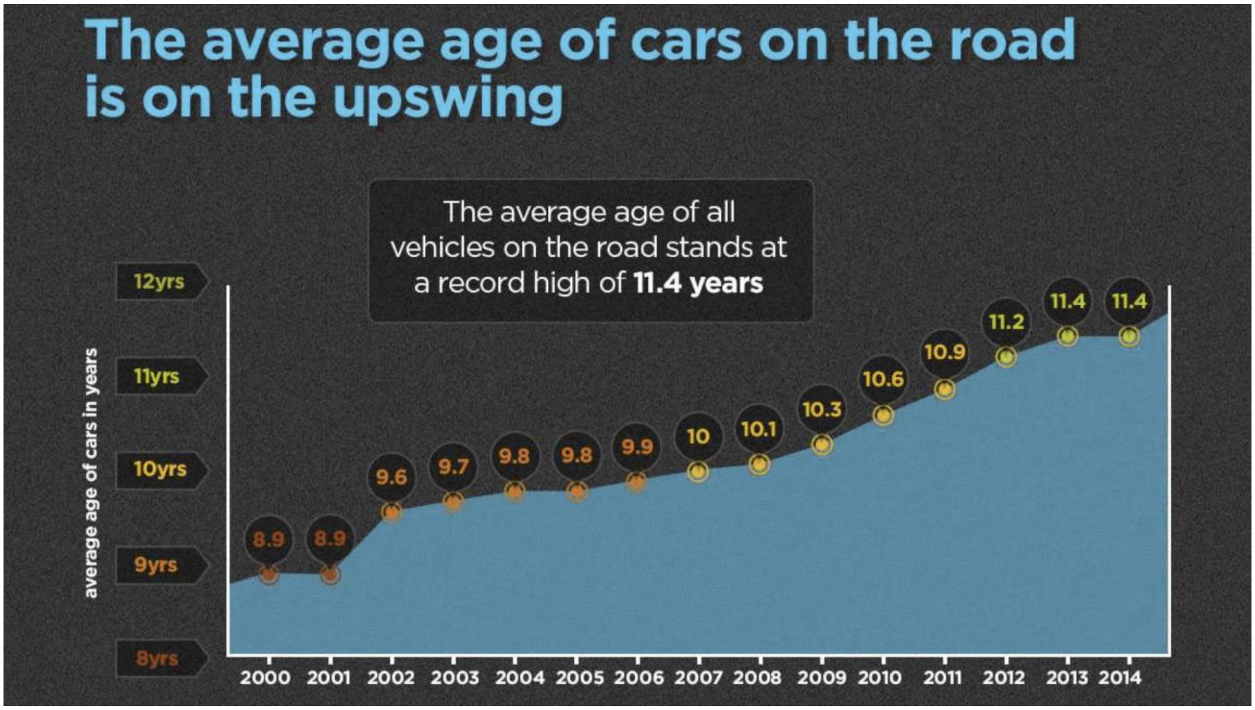


Image source: Nationwide[185]

2. MODALITY

What percentage of vehicles on the road will be *private* and what percentage will be *shared*?
These percentages are independent of the number or percent of AVs on the road.
(i.e.: You could have 1% of vehicles be AVs and be 100% shared, or 90% of vehicles be AV and be 10% shared)

Private vehicles include:
Status quo: individual or family ownership
Used exclusively by family and friends, but not open to the broader public.
"Shared" vehicles include:
Owned and managed as part of a fleet by an organization (e.g. a fleet of AVs owned and managed by Uber/Lyft/Zipcar/Flex).
Micro-fleets managed by a larger, city-wide platform (Privately owned, but used by the broader public. e.g. Turo)
Public transit vehicles (including shuttles and buses but excluding trains, subways and other vehicles on tracks and rails)

3. FUNCTION

What percentage of AVs on the road will transport *cargo* and what percentage will transport *human passengers*?
These percentages are independent of the number or percent of AVs on the road.

[185] Nationwide Mutual Insurance Company, "How Long Do Cars Last?"

Cargo vehicles include:
Mobile vending machines
Food and product delivery rovers.
Freight trucks that may tether or link to human drivers, but can't themselves hold one.
Human passenger AVs are designed and meant to carry people, regardless of whether they can also carry cargo or move empty. These include:
Privately or publicly owned vehicles transporting people (including robo-taxis and family cars)
Service and Delivery AVs that require a human operator or service person (such as driverless garbage truck with human collectors, or an ambulance with a paramedic and patient)

4. PARKING

What percentage of current parking space will *remain as parking space* and what percentage will be *repurposed*?
Different cities across Canada and the U.S. have different amounts of space dedicated to vehicle parking. They vary in how they are measured (total square meters/feet, density, total number of spaces, spaces per capita/household, etc.) and in what gets measured (public vs private, on street vs off). More importantly, the quantity itself varies greatly from city to city, as different laws, policies, and densities ask for different amounts of parking (this also includes the availability of options such as public transit and active mobility).

For this question, consider an average change in the amount of parking across all cities.

As AVs roll out and require less parking, this question intends to forecast how much of this land will be opened up for redevelopment or repurposing, and how much of it will need to remain as parking.

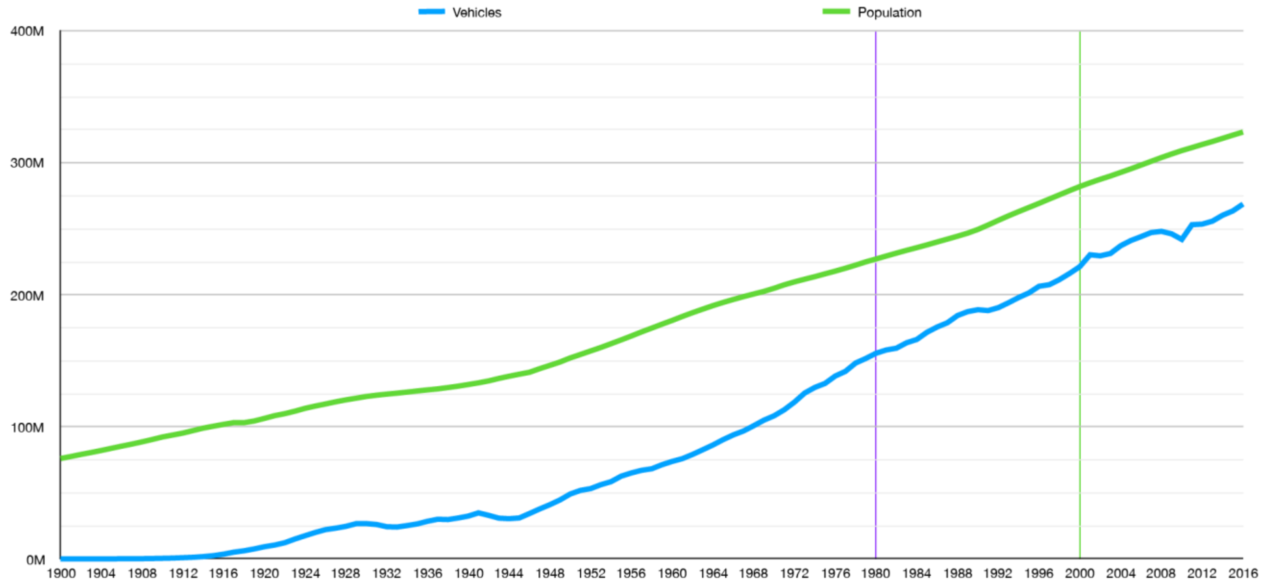
For each year, slide the marker to the percent of parking that will be repurposed:
Consider 2019 as a starting point at 0% (current state is 100% of existing parking - none has been transformed)

Section 2

This section of the survey deals with circumstances that are very unlikely to remain the same and continue as they have. However, they beget uncertainty regarding how they will shift; which direction the trend will follow.
They are more contentious because there is high uncertainty regarding when and how much these issues will either accelerate or decelerate.

5. AV POPULATION

How many road motor vehicles per 1,000 inhabitants will there be?



Source: U.S. Department of Transportation, Federal Highway Administration[186]; U.S. Department of Energy, Vehicle Technologies Office[187]; US Census Bureau[188]

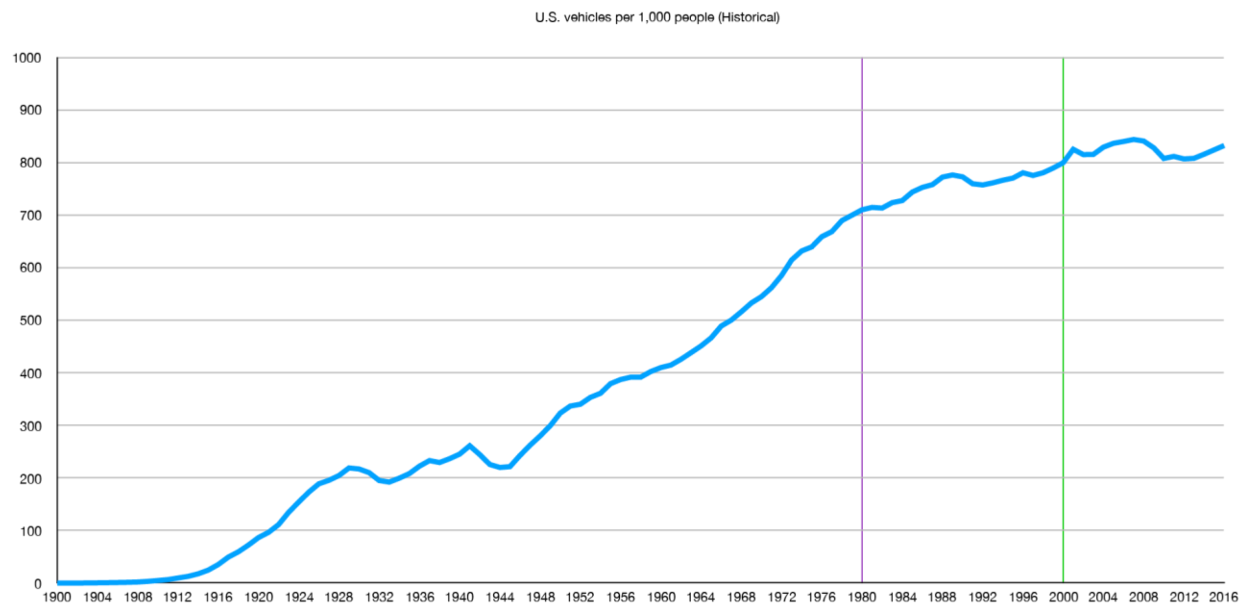
Total number of vehicles in circulation is too abstract and unrelatable a concept for most people to work with. A more pragmatic approach would be to use a percent or ratio: "Road Motor Vehicles per Thousand People". This ratio can very easily be converted to percentiles or palatable ratios. (e.g. Canada's latest 652 vehicles per 1000 people can be expressed as "0.65 vehicles per capita", "almost 2 cars for every 3 persons" or "there are 35% less cars than there are people"

NOTE: These counts include cars, vans, buses, and freight and other trucks; but excludes trailers, off-road, construction, farming, motorcycles and other two-wheelers.

The following graph demonstrates the historical Vehicles per 1000 people in the United States from 1900–2016 as a reference to North American trends and patterns (Canadian data was not found going this far back).

- The green line marks the starting point for the subsequent two graphs.
- The purple line marks 50 years into the past for reference.
(Comparatively, the survey you are completing now asks for a forecast 50 years into the future)

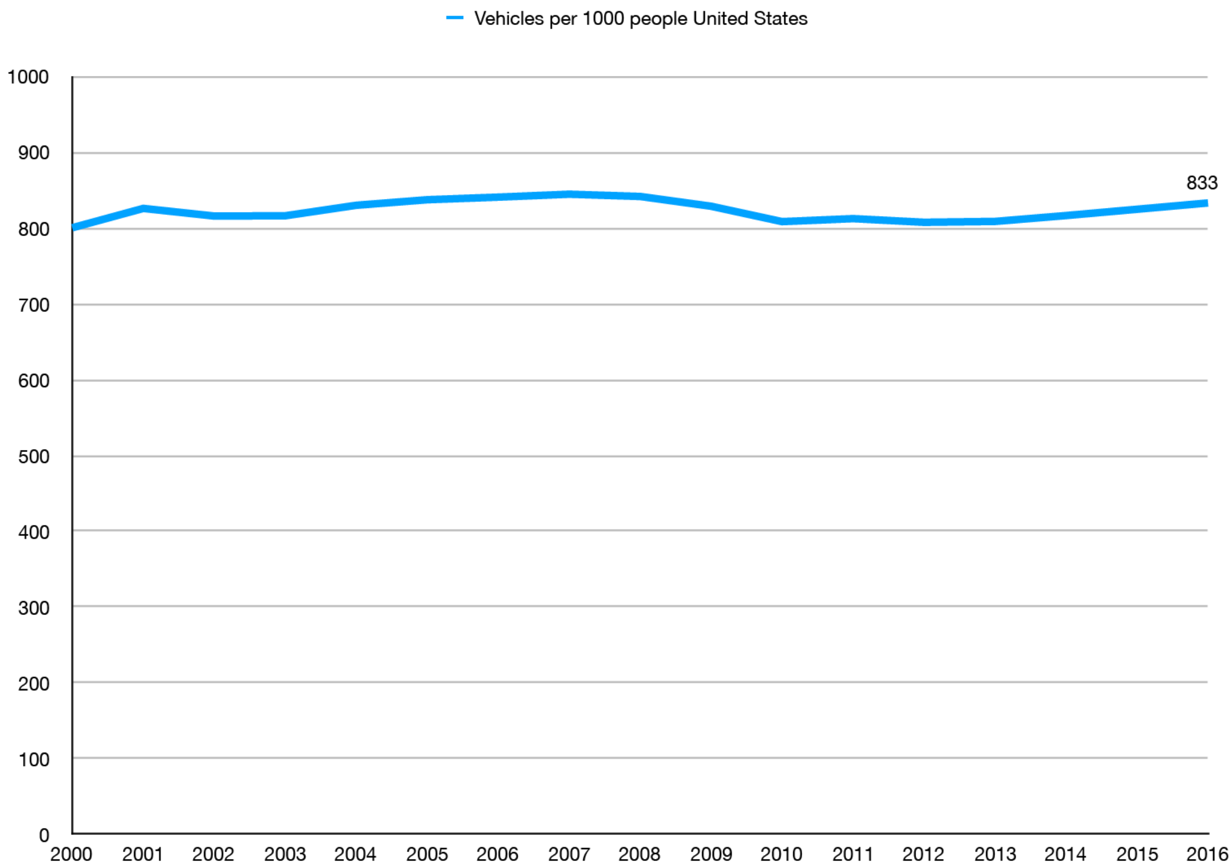
186 US Department of Transportation; Federal Highway Administration, “Number of Motor Vehicles Registered in the United States from 1990 to 2017 (in 1,000s).”
187 U.S. Department of Energy, Vehicle Technologies Office, “Fact #962.”
188 U.S. Census Bureau, “Historical National Population Estimates: July 1, 1900 to July 1, 1999.”



Source: U.S. Department of Energy's Office of Energy Vehicle Technologies Office[189]

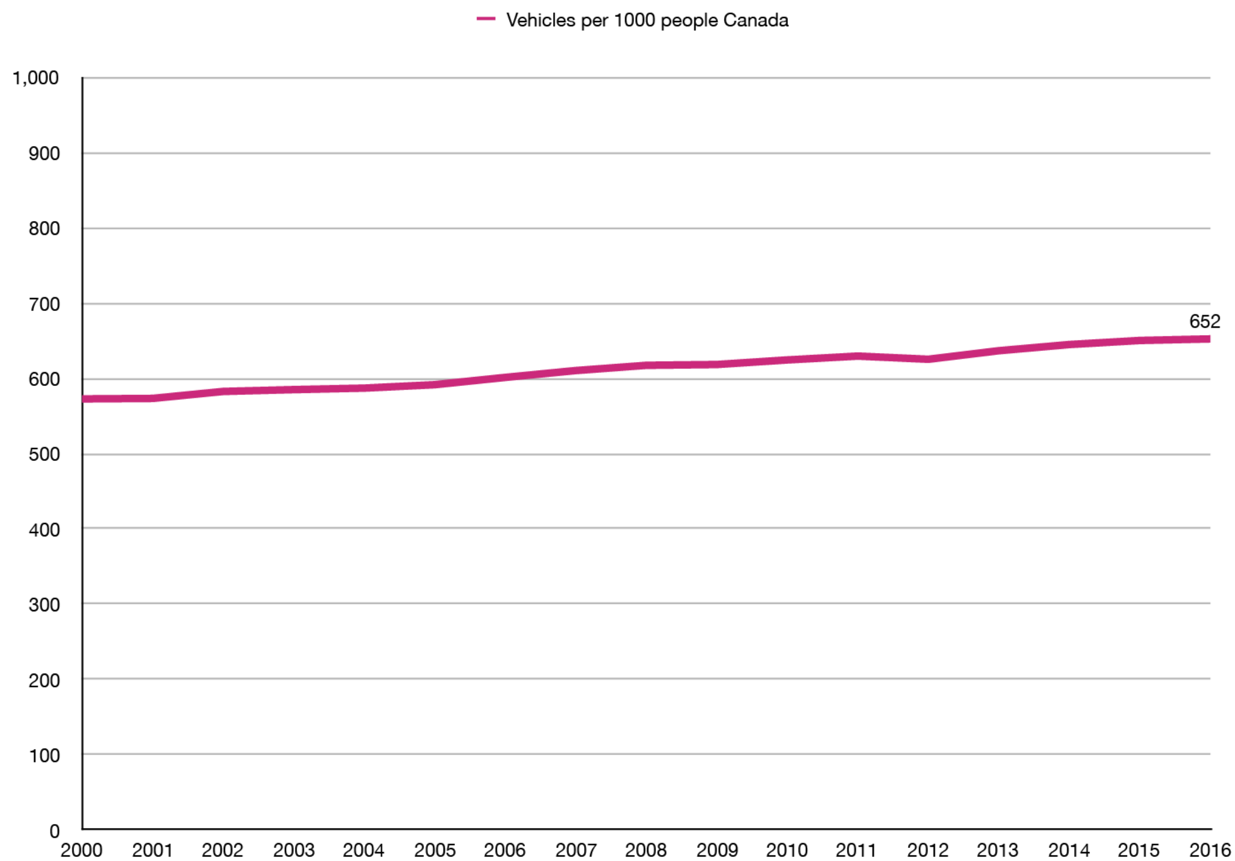
The following two graphs show the most complete data available for both Canada and the United States. Use these as your starting baseline for your corresponding forecast.
Data for 2017 and 2018 is incomplete and was not included for these reasons.

[189]Davis and Boundy, *Transportation Energy Data Book*.



Source: U.S. Department of Energy's Office of Energy Vehicle Technologies Office[190]

[190] Ibid.



Source: Statistics Canada.[191] [192]

2016 Starting points (previous marker as per charts and question above) are:

- Canada: 652
- United States: 833

6. URBAN SPRAWL

As AVs replace the conventional vehicles, will they induce *more sprawl* or will cities become more *compact and connected*?

Although there is no universal, agreed-upon way to measure Urban Sprawl, one of the most cited is the index created by Smart Growth America. Their report is based on research published by the Metropolitan Research Center at the University of Utah, prepared for the National Cancer Institute at the National Institutes of Health, and the Ford Foundation.

Metropolitan Statistical Areas and metropolitan counties were evaluated using four main factors:

1) development density
2) land use mix
3) activity centering
4) street accessibility

[191] Government of Canada, “Vehicle Registrations, by Type of Vehicle.”
[192] Government of Canada, “Population Estimates on July 1st, by Age and Sex.”

These factors are combined in equal weight and controlled for population to calculate each area's Sprawl Index score. The average index is 100, meaning areas with scores higher than 100 tend to be more compact and connected and areas with scores lower than 100 are more sprawling. You can see a list of highest and lowest scoring U.S. cities in their report, as well as the score of 221 metropolitan areas and 994 counties.

Whether you are familiar with the SGA index or not, the scale for this question is 100 points in either direction, which you can also consider percentile points.
Given the average city score is 100, keep in mind that a positive shift of 100 points would make that city as compact and connected as New York (which scored 203) and a (negative) shift of -50 would mean as sprawling as Nashville or Atlanta currently are.

For each year, slide the marker to the *average shift* of *all North American cities* towards either greater **sprawl** or more connected and **compact**:
Consider 2019 as a starting point of 0 (current state - no shift yet)

7. ROAD SPACE

Will an AV future require *less* or *more* road space?

Cities across Canada and the United States have different amounts of their total land area dedicated to road space. These percentages vary depending on whether measurements are made for the entire Right of Way, paved surfaces, or whether they exclude parking and other automobile related land uses. Example percentages include:
Vancouver with 26.5% used for roads, streets and alleys.
New York has 22%

For this question, consider the *average change* across cities in the amount of road space they will have because of AV technology
Make sure to consider other factors and technologies - effects could be negated and net shift equal 0 or move in the opposite direction. Please be sure to clarify considerations in the comments section.

For each year, slide the marker to **change in the percent** of land that is *used for roads*:
Consider 2019 as a starting point of 0% (current state - no change yet)

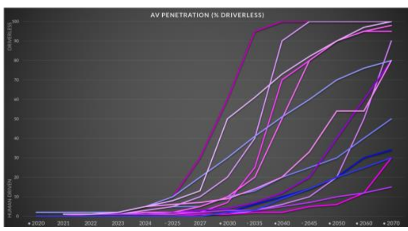
Research Outcomes

By overlaying or comparing the results of all three rounds side by side, it is easy to observe consensus forming to different degrees in each question. The 1st round responses showed a greater degree of divergence compared to the responses from the 3rd round, while the 2nd round is an in-between step evidencing a progression towards that consensus. In essence, the very wide cone of possibility narrowed to a more concise cone of probability. Some of the questions did result in narrowing the probable futures to a more focused range. Other questions tended to have the experts split into two different, sometimes opposing camps. These narrowed the probable futures into two different, but also more focused ranges.

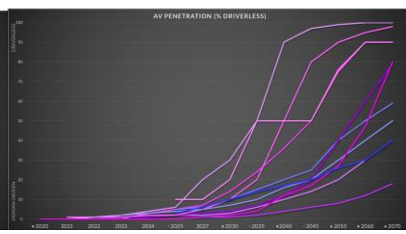
For all sections below, the three smaller graphics in the same row with dark background show these progressions. Time is distributed as per the survey's sliding scale tool: That is, there is equal distance between entries, but that means that the graph is showing the same distance between every one year on the left, and every ten on the right. The graph with the lighter background beneath them shows a more adequate representation of the timeline, with equal spacing between each year. This means that 'S' curves, as well as the formation of consensus, are more pronounced and noticeable in the format of the top row.

AV PENETRATION (% DRIVERLESS)

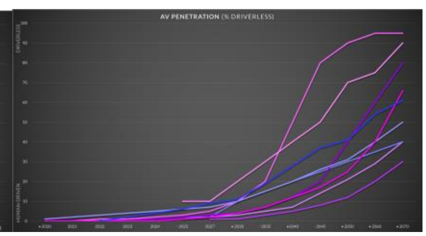
Figure 3



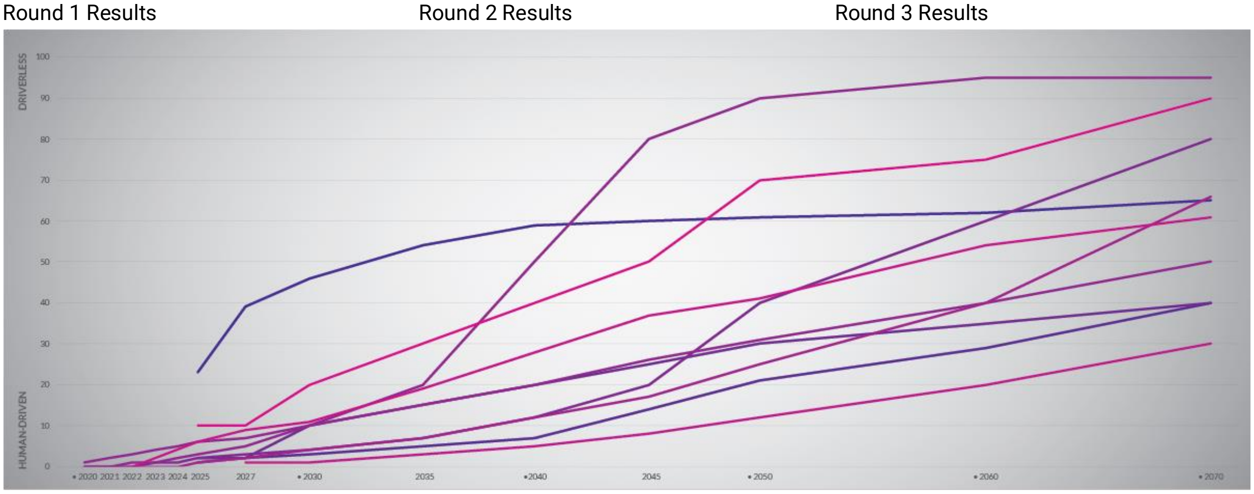
Round 1 Results



Round 2 Results



Round 3 Results



Final: Round 3 Results with time (years) equally spaced.

According to this pool of experts, the 2020's will definitely be the decade where driverless vehicles roll out onto city streets. Most experts are predicting that 10% of vehicles will be driverless by 2030, although another school of thought believes this will be closer to 3%.

Though still a very low percentage of total vehicles on the road, the scale of the potential disruption they will cause will still be a force to be reckoned with. Consider the following: On a given hour, the average number of cars on the road in the city of Toronto is around 107,200.[193] Uber reported that their average hourly number of drivers online in Toronto was under 3,500.[194] This means that in the city, Uber comprises just over 3% of vehicles on the road. Now think back to around 2015 and remember just how much disruption Uber brought to Toronto and cities worldwide. Think about how much it upset the taxi industry and public transit. Think about the gig economy, changes to existing business models and the creation of new ones. Think about how it changed our habits and expectation. Now, imagine the level of disruption that the same number of autonomous vehicles will bring. Finally, try imagining that disruption *threefold*.

By the year 2070 — 50 years from now — experts forecasted that the percentage of total vehicles that will be driverless will most likely be in the range of 40-60. The respondents cited several reasons why the forecast did not reach higher levels of penetration, these included:

- Many governments approach AVs cautiously
- Price and technology fears will be barriers to early adoption by individuals.
- Difference between considering goods movement and service vehicles (AVs that don't carry passengers) together vs. separately.

Although the study asked experts to consider all cities in North America, they ascertained that penetration will vary greatly from region to region, due to weather and local laws among other factors.

Additionally, although lifetime & replacement rates of existing human-driven vehicles were provided. Paul Godsmark argued that they will become increasingly irrelevant:

> "Market penetration of AVs will be highly leveraged as business models favour not selling vehicles, but hiring out their services - so we will see shared fleets of electric ride-sharing vehicles (and new modes that reinforce this business model) and a single AV will replace anywhere between two and thirteen private vehicles - probably 5 or 6."

An important note on the *perception* of the number of AVs on the road compared to regular vehicles came from Bern Grush who argued:

> "Each driverless vehicle will be doing perhaps 8-times the PKT (Passenger Kilometres Travelled) of what a non- / semi-automated vehicle is doing. So the 40%-driverless vehicles registered (in 2050) are doing 85% of PKT. "

Andrew Sedor also noted that:

> "Shared mobility will largely be dependent on the economics of using a driverless car vs a low paid human driver. It will also depend on insurance for AVs and one-off incidents like software update errors. Boeing is a recent great example of a simple technical error leading to a catastrophe and the depreciation of a large company. One error could erode trust and tank a company." (Andrew Sedor is referring to the infamous incidents that occurred with the Boeing 737 MAX involving an automated system failure).

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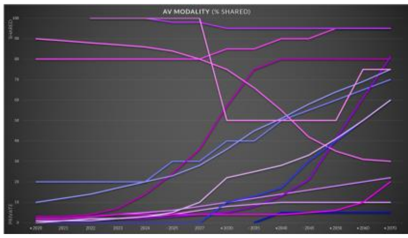
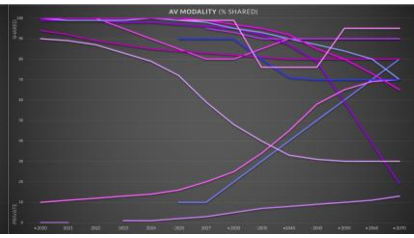
193 Ashby, "Transportation Tomorrow Survey 2016: 2016, 2011, 2006, 1996 AND 1986 TRAVEL SUMMARIES FOR THE GREATER TORONTO & HAMILTON AREA."
194 Blinick, "Sharing the Road."

AV MODALITY (% SHARED)

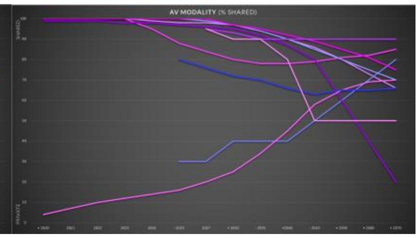
Figure 4



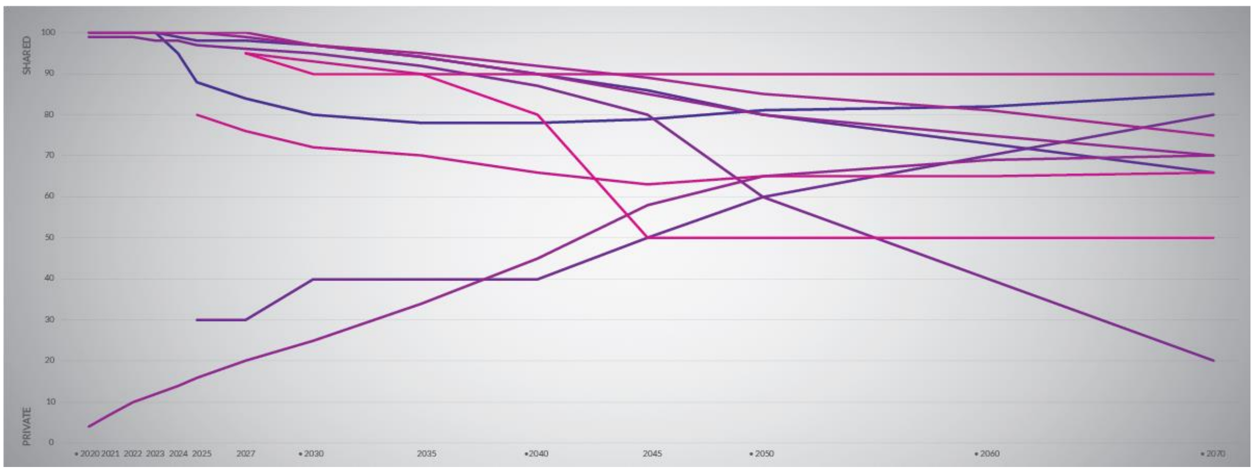
Round 1 Results



Round 2 Results



Round 3 Results



Final: Round 3 Results with time (years) equally spaced.

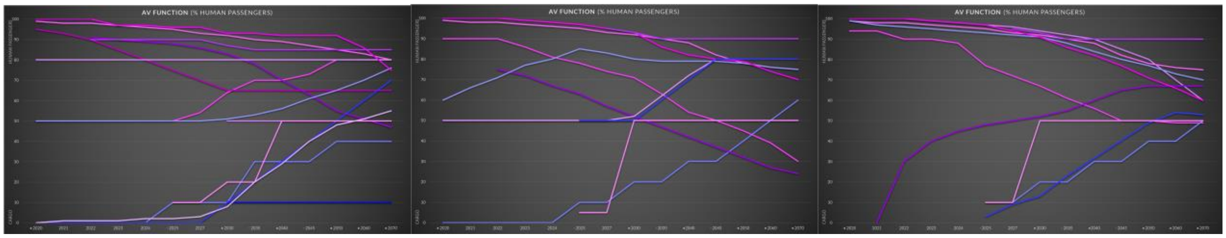
This question showed two different schools of thought that reached greater consensus than the previous question on Penetration did. While the several experts initially thought that the first vehicles on the roads would be under a private ownership model, most eventually shifted to the shared ownership model (Note: Some answered the first round incorrectly, so the change in their response is not a change in opinion. More on this in *Lessons Learned*). The resulting consensus was that by 2070, Autonomous Vehicles will be primarily under the shared-ownership model, with the probability ranging from 65-85%.

The reasons experts considered a “mostly-shared” modality included:

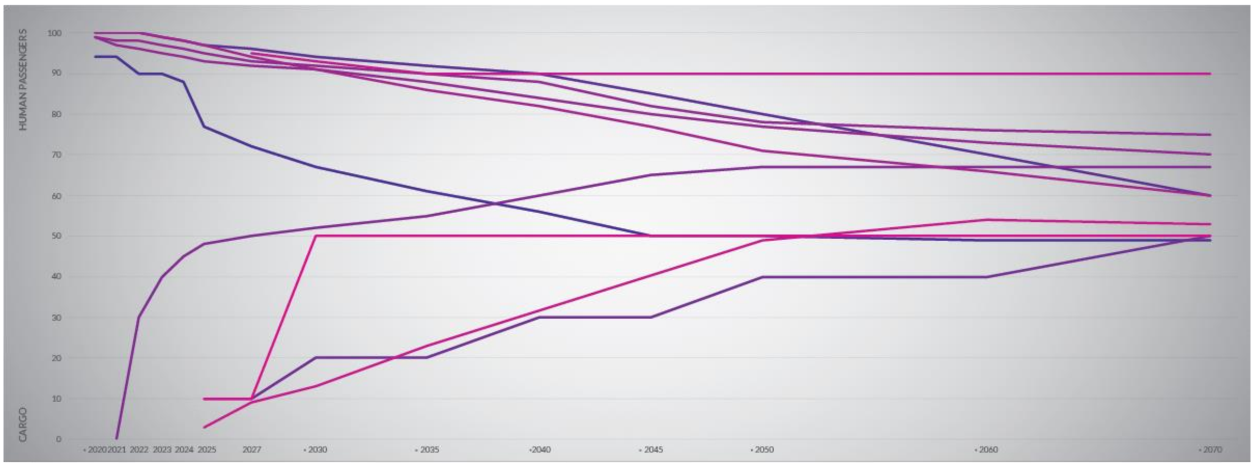
- Cost and liability. Offsetting risk, maintenance and the upfront capital cost will be done primarily by companies.
- Leading developers like Waymo, GM, Ford/Argo, Zoox, Uber, Lyft, Voyage etc. are not talking about selling vehicles, but offering a service first
- Through changing business models, manufacturers could profit more from subscription-based ride services than from selling vehicles.
- Optimistic predictions of sound policy decisions.

AV FUNCTION (% HUMAN PASSENGERS)

Figure 5



Round 1 Results Round 2 Results Round 3 Results



Final: Round 3 Results with time (years) equally spaced.

The question of whether a greater percentage of AVs would transport human passengers vs. non-human cargo, had even more divisive schools of thought for the start and initial years. However, it garnered slightly more consensus around what this scenario will look like by 2070.

Some of the arguments from those that leaned towards cargo-first were:

- There's a good business case to automate freight movement, and highways are an easier automation problem.
    - If the technology does fail with cargo, it is less likely to result in a loss of life.
- People will be hesitant about riding in AVs and giving up control - it will likely be decades before you have a mass population who are comfortable using the technology.

Some of the reasons that respondents thought AVs will primarily be passenger-first include:

- Although AVs will indeed be used to transport cargo, the majority of these use cases will still involve the aid of humans traveling with the vehicle. Cargo-only AVs will be slower to arrive as many non-passenger AV uses will still involve carrying human attendants

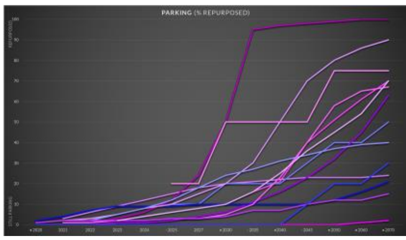
The original design and wording of the question unfortunately did not properly account for service vehicles (those that perform services but do not ferry cargo). The original intention was to pit vehicles carrying human passengers vs. those that don't. Some of the respondents considered these in their responses while others didn't.

Another key insight was captured by Bern Grush:

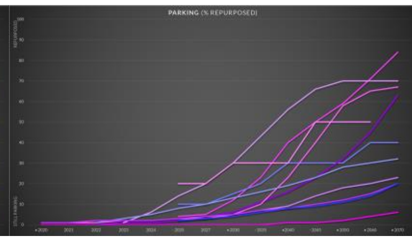
“A long time from now, many machines are smaller, ambulatory, carrying goods to my door. Am I counting those as a vehicle? A walking droid delivering my pizza? Yes, I will count those. These are in labs and looking promising for a decade out, already. They could be ubiquitous by 2040-50.
“So too, does a large step van with 2 ambulatory droids count as 3 vehicles? Small human-scale droids on wheels, legs or propellers will be the majority goods-vehicle registered count. These same vehicles will assist human police, as well. I am not counting those as goods or people movers. Just like video grew the web, goods transport will grow mobility.”

PARKING (% REPURPOSED)

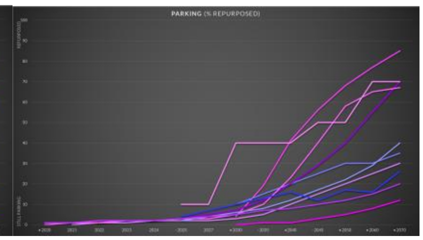
Figure 6



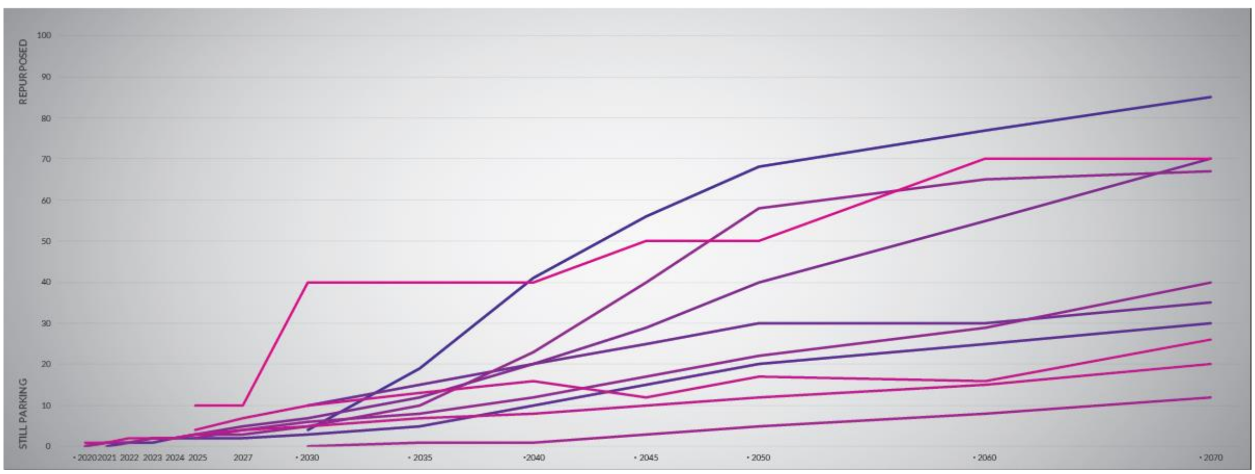
Round 1 Results



Round 2 Results



Round 3 Results



Final: Round 3 Results with time (years) equally spaced.

The forecast on parking getting repurposed (converted into anything that is not parking, including green space, private development and additional travel lanes) resulted in a graph that is somewhat the reverse of the previous ones. Like modality and function, it is easy to see consensus forming between the exercises as they progressed through the three rounds. However, in this case the two visible schools of thought formed towards the end of the graph in a gradual split from a more unified beginning.

Experts agreed that we are not likely to see any significant changes in parking before 2025; we are more likely to start to see a real shift around 2030. Around 2040 is when we can begin to see the two schools of thought aiming for different scenarios: One was of the belief that the majority of parking — more than ⅔ of it — would be repurposed by 2070. However, 60% of the experts did not think such a large amount of parking would end up getting transformed. They believed that a range from 10-40% was more likely.

Part of the reason behind the divergence in opinions might have been that different experts were considering different factors:

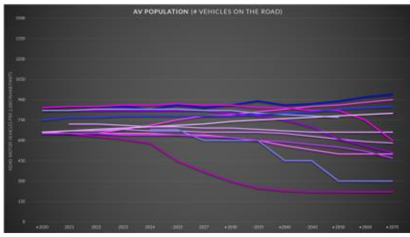
- Some experts included or excluded garages in households or parking within buildings.
- Others consider other city-building and mobility trends that would have parking repurposed whether AVs played a role or not. They mentioned governments that are starting to repurpose parking for city-building and place-making reasons, without the slightest thought of AVs.

Other rationale for the different forecasts included:

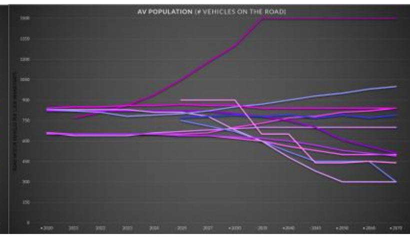
- Regulations requiring parking minimums are unlikely to change (politically) for at least a decade.
- There would need to be a dramatic shift to shared-vehicle use, one that exceeds increased parking demand from population growth.
- There will likely still be manually driven vehicles for a long time.
- In many cases, AVs could actually park, charge and wait to be called instead of circulating while waiting to be called.
- While a fair amount of parking would be repurposed, there would be new parking created in other areas like the periphery of a city, thereby not greatly affecting the total number of parking spots repurposed.
- In some dense urban areas, a continued increase in land values could incentivize repurposing, instead of a reduced demand for parking.

AV POPULATION (# VEHICLES ON THE ROAD)

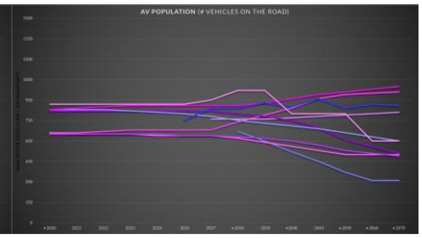
Figure 7



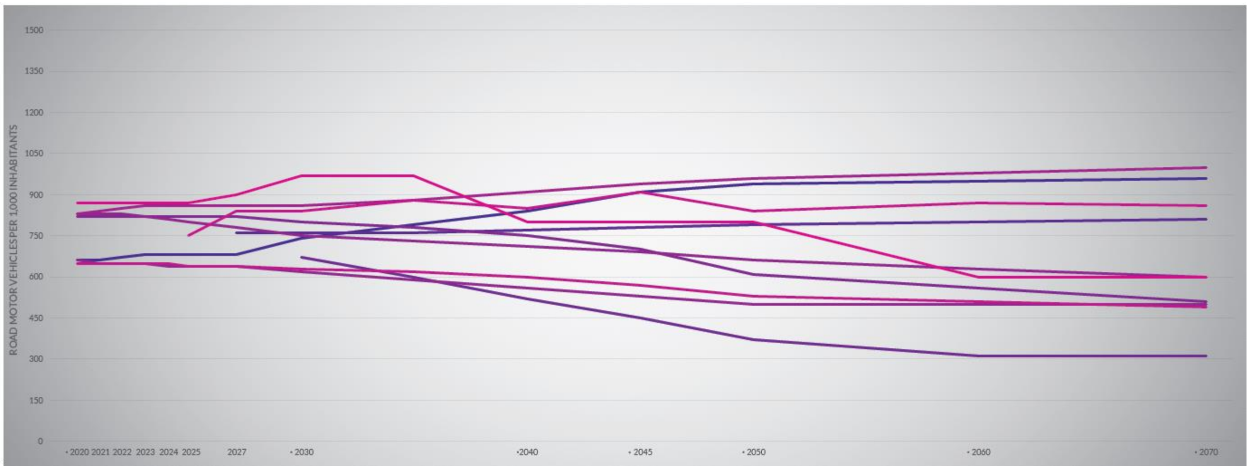
Round 1 Results



Round 2 Results



Round 3 Results



Final: Round 3 Results with time (years) equally spaced.

This graph is a little harder to read because by design, it had two different starting points: One was for the US vehicular population, for experts based in the US. The other was for the Canadian vehicular population, targeting experts that live in Canada. This led to two schools of thought by 2070, but consisted of mixed experts from both jurisdictions. So while several experts considered that the US ratio of vehicles per 1K inhabitants would decrease to be on par with Canadian projections, it is interesting that one expert in the Canadian context thought the vehicular population would grow to be on par with the higher-end projections of US-based experts. Whether the vehicle population increased or decreased, no one thought it would remain the same.

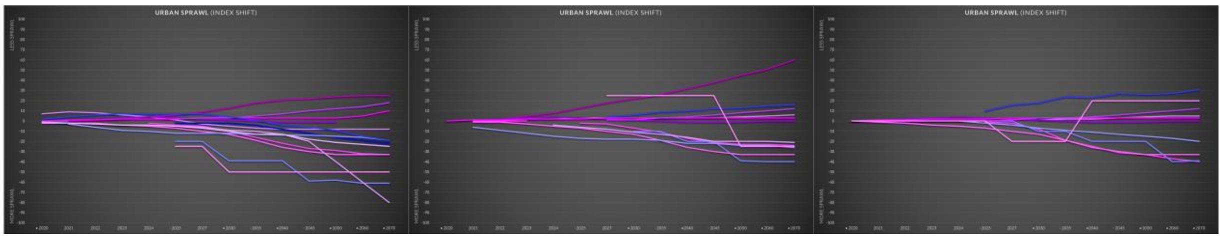
Like before, there were different factors that led to the different forecasts. These included:

- The fall in individual vehicles will be more than offset by the rise of delivery vehicles: i.e: the number of vehicles will increase dramatically but most will be used for goods movement.
    - One responded plotted where demand initially decreased but later surged because of delivery vehicles, including small delivery robots.
- Another respondent's graph considered vehicle count per capita dropping, and absolute vehicle counts staying the same.
- Answering the question only considering rubber-tired vehicles on stripped roads. i.e no ambulatory delivery droids.
    - Similarly, another respondent asked: At what point should we be considering robots operating on sidewalks that can also travel on roads as AVs?
- One expert's plotted graph appears to show that vehicle counts are dropping, However, they are not, due to growing population.

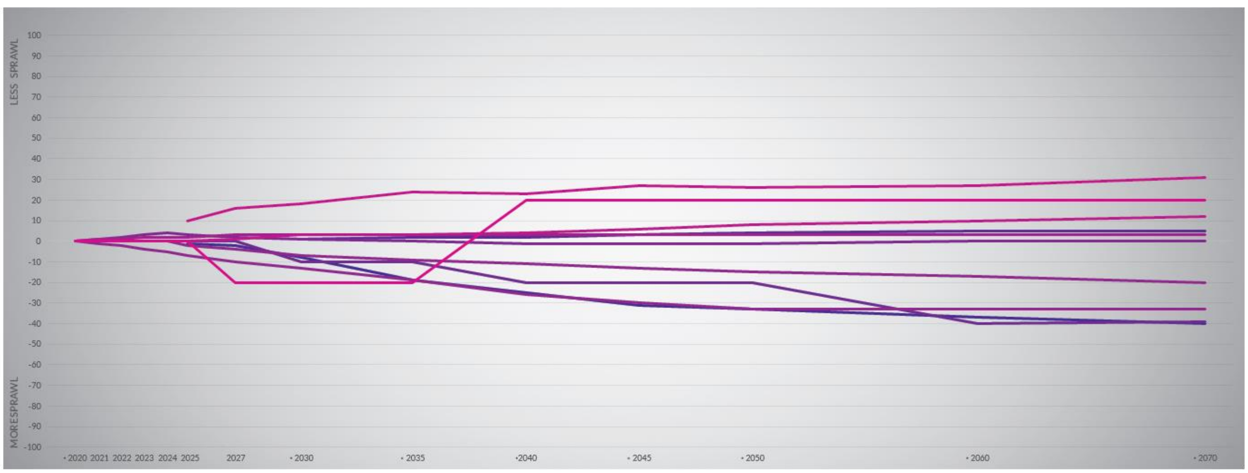
- The new business models that don’t use human drivers means that historical data on average vehicle age and replacement rates will be increasingly irrelevant with time.
- Hesitating to connect auto ownership too much with AVs. Many other factors including environmental, cost of owning a vehicle, urbanization, transportation alternatives and others will contribute to decreased auto ownership.

URBAN SPRAWL (INDEX SHIFT)

Figure 8



Round 1 Results Round 2 Results Round 3 Results



Final: Round 3 Results with time (years) equally spaced.

Like others before it, this graph led to two different ways of thinking about the outcome of this scenario in 2070. It is not as clear as previous graphs, but it is evident that one group of experts think AVs will reduce urban sprawl while others think that it will increase it. The method used to measure urban sprawl was the multi-factor index created by Smart Growth America.[195] The consensus that was generated through the three rounds of surveys gradually narrowed the range to between a +30 to -40 shift.

Some respondents qualified their response warning that this will depend enormously on policy, regulations and mobility pricing, and hence could go either way. A similar disclaimer is that there are other trends and factors affecting densification and sprawl, so these index shifts could occur irrespective of Autonomous Vehicles. Indeed, one respondent believed that AVs will not be the most influential factor in this metric.

The general thinking is that AVs will incentivize people to live further away (inducing sprawl) because you will keep all the convenience of your personal automobile while removing the inconvenience of driving

[195] Ewing and Hamidi, “Measuring Sprawl 2014.”

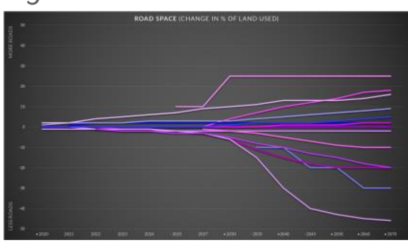
and being attentive, essentially gaining the ability to do other tasks. They warned that an important impact of AVs will be to lessen the focus on transit-oriented development, thus increasing sprawl.

For others, they thought shared AVs will decrease sprawl - as trips will likely be calculated by time or distance, making it more expensive to use AVs from greater distances.

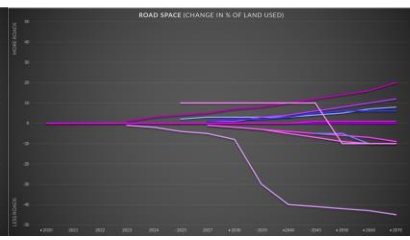
Some experts however, had a very interesting viewpoint: They plotted a relatively horizontal line with little or no net shift. This is misleading however. Their belief was that *both* things will likely occur: Some people will move further into the city, making downtowns more compact, while others will move further away, so the result will be more density *and* more sprawl with a net shift of about zero. Once AV technology allows it, some people could live further away, while other people might live in more compact areas and benefit from inexpensive car share trips. Nonetheless, even some experts aligned with this way of thinking believed that AVs will not be the biggest factor behind this trend.

ROAD SPACE (CHANGE IN % OF LAND USED)

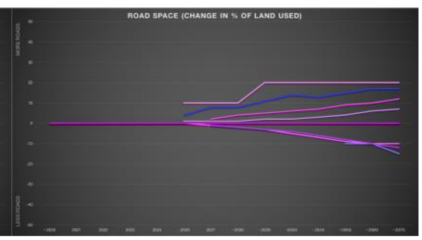
Figure 9



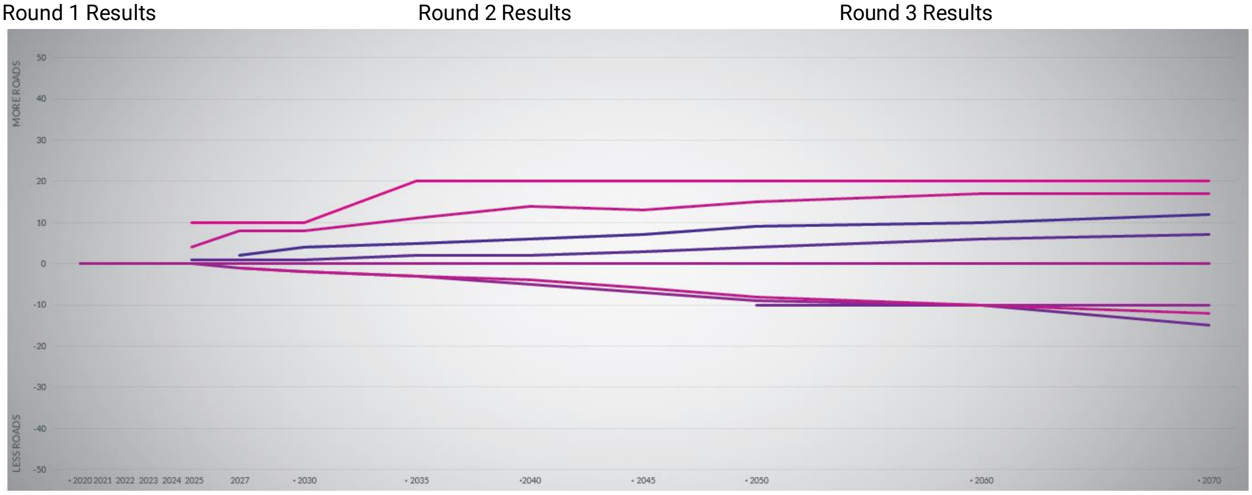
Round 1 Results



Round 2 Results



Round 3 Results



Final: Round 3 Results with time (years) equally spaced.

This final graph also showed two different schools of thought by 2070. However, one had a lot more precise of a prediction, in the range of -10 to -15 %. The other group of experts considered a range from 0 to +20%

Some respondents thought the change would be net zero or close to net zero for a variety of reasons:

- The principle of Induced Demand[196]: Any changes, like vehicles driving closer together will quickly be filled in by more vehicles
- Similar to the graph for parking, locations would be rearranged but ultimately the number remains the same: Things like street parking may evaporate but will be filled in with loading, active transport, street commerce, deliveries, and other spaces.
- Lanes (particularly on highways) may end up being reduced in width due to AV technology, but increased population and demand would just mean that more lanes would get added into the existing lanes. Similar thoughts were also expressed around new road spaces being created for new development: Although some roads could be redesigned with narrower lanes in the long-term, this will not make a significant difference to the total space used.

Others considered other trends unrelated to AVs such as Complete Streets, reduction in vehicle ownership, and transit investment.

An important observation came from Paul Godsmark, who mentioned:

> "This is challenging as, especially in cities, if population is increasing then Jevon's Paradox suggests that as AVs reduce the requirement for road space, population growth and other AV uses (services, good deliveries) will increase to soak up any available road space capacity. Overall I see road space reducing as human driving is banned, parking requirements plummet and shared and ride-sharing AVs make use of existing road space much more efficiently."
>
> "Once AVs are fully developed (high capability Level 4) then humans become sub-optimal. Cities will then be in a race to improve quality of life, to attract people, business and investment by banning human drivers to improve congestion, sustainability, safety, quality of life. So once a jurisdiction bans human drivers then the rules of the road can literally be re-written - in real time by a central control system. E.g. At certain times of day pedestrians and vulnerable road users always have priority. At other times, commuting vehicles might get priority on certain streets. Everything is negotiable, there will be little need for permanent road signs - or permanent lanes - infrastructure/rules needed for roads will be greatly reduced and variable to suit the greatest benefit at that time."

Interestingly enough, this move to ban drivers is not reflected in the penetration graph.

[196] Wikipedia, "Induced Demand."

So what? Now what?

Lessons Learned

Delphi Study

Exponential Growth
There is a very important caveat to the results of the Delphi study: Although the participants are experts in their fields, and all of their fields are related to mobility, none of them is futurist or has formal training in Strategic Foresight.

The projections made by the experts, even after reaching 'consensus', are still fairly linear and not actual 'S' curves. This is problematic for various reasons: When it comes to the adoption of technology, the *diffusion of innovation* always follows an 'S' shaped curve.[197] The majority of lines projected by the experts are more linear when the time intervals are evenly spaced, as can be observed in the right hand graph with light-grey background in *Illustration 14* below

You need look no further than the world's handling of COVID-19 to see just how extremely hard exponential growth is to grasp and visualize. The vast majority of people repeatedly and consistently default to linear growth when making models or projections. Even if you comprehend the logic of exponential growth, your mind will have an incredibly hard time visualizing it and internalizing it. The most recent result of this mistake is having country after country repeatedly misjudge the spread of the virus until the spread within their borders had accelerated beyond the measures being implemented. This happened almost as a *rule, even after having example after example of every country that made this mistake before them*.[198]

The concept of exponential growth, however, is nothing revolutionary or even new; It is the principle behind compound interest for example. It is intricately tied to a legend behind the invention of the game of chess dating back to the 6th century. This legend is also one of the best ways of explaining this common folly:[199]

The legend tells that the person who invented the game of chess so impressed the ruling king, that he offered to reward the inventor and even invited him to name a reward for creating the game. So, the inventor asks to be given grains of wheat (or rice, depending on the version of the tale) for 64 consecutive days (one day for each square on the board). He asks for a single grain to be given for the first square on day one. He then asks for 2 grains of wheat for the second square be given on day two, 4 grains to be

[197] Everett Mitchell Rogers, *Diffusion of Innovations*.
[198] JHU, "COVID-19 Map," 19.
[199] Jenkins, "The Second Half of the Chessboard | Jupiterjenkins.Com."

given on day three, 8 on day four, 16 on day five, 32 on day six, and so on: Receiving double the number of grains each day until reaching square/day 64.

The king laughs at such a meager request and readily agrees. If you were to do quick mental math, on the 8th day (8 squares or the first row) the result is 129 grains: barely enough to fill the palm of your hand. If you then decide to continue to do the math to day 16 (two rows), the result is 32,768 grains: somewhere between 3-6 cups. Like the king, you would probably be wondering why such a smart inventor asked for such a paltry reward. And like the king, you would likely agree to it, thankful they didn't ask for riches.[200]

But if you did the math as above, already it would be flawed: The result of the first line is 1 grain, + 2, + 4, + 8, + 16 + 32 + 64 + 128, which is equal to 255. This is just shy of *twice* the amount of grains given on the 8th day. By day 16, the king would have given the inventor 65,535 grains, also shy of twice the previous number, but really only 6-12 cups. Still not a big deal, since this just means the king would have gifted 2kg of rice instead of 1kg.

However, by day 32 (which is the time they would reach the halfway point through the chessboard) the king's advisors would probably already be in serious discussions with the king. By this point, the king would already have given the inventor close to 4.3 *billion* grains of wheat, which is the amount in an entire, large field of wheat.[201] If this were to continue all the way to square 64, the king would need to give the inventor 18,446,744,073,709,551,615 grains.

That is 18 billion *times one billion.* This amount of wheat would weigh about 1,199,000,000,000 metric tons (That's ~1.2 *trillion* tons).[202] *One billion* is already a number that is way too large to understand in pragmatic terms.[203] So to put *this* number in perspective, this amount of rice would require rice fields covering *twice* the entire surface area of the Earth (*including oceans*).[204] ***This is more rice than has ever been produced in the entire human history.***[205]

[200] Reference.com, "How Many Grains of Rice Are in a Cup?"
[201] Clustre, "Digital Abundance, and the Second Half of the Chessboard."
[202] Wikipedia, "Wheat and Chessboard Problem."
[203] Berkeley, "How Big Is a Billion?"
[204] Clustre, "Digital Abundance, and the Second Half of the Chessboard."
[205] Cooney, "Chessboards and Rice."

Illustration 13. Adoption of Technology Curves

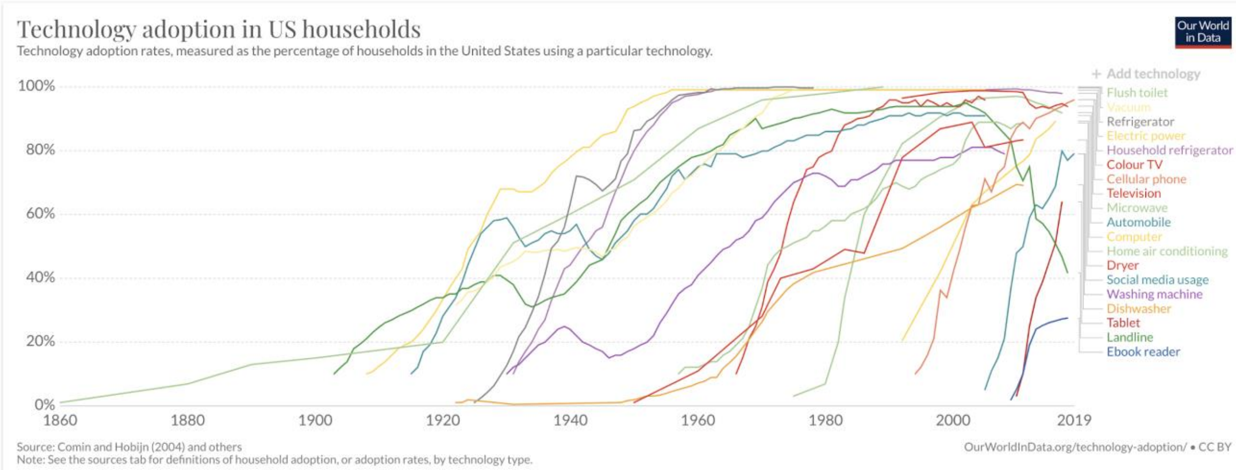


Image source: https://ourworldindata.org/grapher/technology-adoption-by-households-in-the-united-states[206]

Hopefully that exercise helps gain some understanding of the frequently egregious failure to comprehend exponential growth. Exponential growth is enshrined in behind Moore's Law. Named after Gordon Moore, the cofounder of Intel, who 55 years ago observed and predicted that the number of components per circuit doubles every one to two years.[207] This means that the amount of computing power one can buy for a given price will double every 1 - 2 years.[208]

Moore's Law is the link *Diffusion of Innovation* and *Adoption of Technology*.[209] As *Illustration 13* above shows, adoption of technology curves are irregular s-curves. Each specific technology is part of a larger, more complex system, which is why their adoption will never be a smooth curve. External factors such as the price of oil, gas or plastics, war, economic boons and depressions, even political and regulatory shifts are among the many causes that will affect the shape of these curves. Irrespective of these external factors, the second, more important thing to observe in *Illustration 13* above, is that the adoption of innovation is rapidly speeding up: the curves become increasingly compressed and vertical as time progresses. The s-curves for a technological innovation to be adopted used to span decades, but these innovations are now reaching saturation within a matter of years.

By comparison, the forecasts provided by the pool of experts in the Delphi study are much more horizontal and linear (see right-hand graph in *Illustration 14* below, with light-grey background). Recalling their comments from the Delphi section earlier, they cited that adoption of AVs would not be greater because: Many governments approach AVs cautiously and price & technology fears will be barriers to early adoption by individuals. They said, "People will be hesitant about riding in AVs and giving up control - it will likely be decades before you have a mass population who are comfortable using the technology." And while the first premise might hold water, the second doesn't, compared to any other *adoption of innovation* curve. The reason for this is that, pursuant to the *diffusion of innovation* theory is: once you reach a critical mass of early adopters that prove AVs to the rest of the population, adoption will

206 Our World in Data, "Technology Adoption in US Households."

207 Maidlow, "The Second Half of the Chess Board Intersects with Moore's Law in 2013."

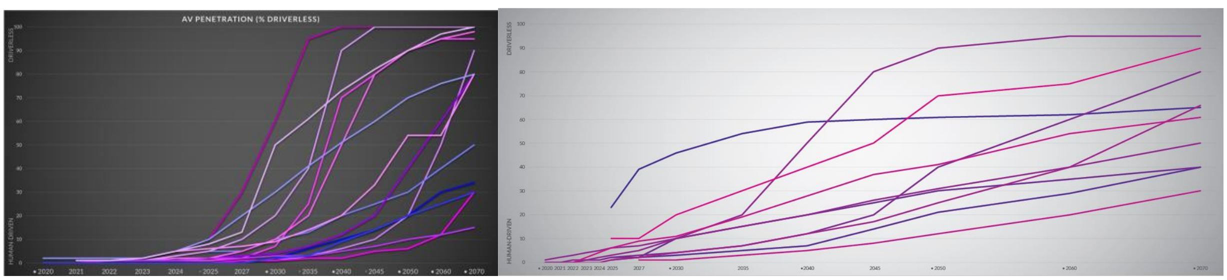
208 Cooney, "Chessboards and Rice."

209 Everett Mitchell Rogers, *Diffusion of Innovations*.

skyrocket.[210] Blockbuster did not react to Netflix until it was too late. Similarly, most cities did not react to TNC's until they were too deeply entrenched. None of them have any excuse, however. They all saw the metaphorical 'train' coming a mile away. Their failure arose from making judgments based on the speed of the innovation, instead of its rate of *acceleration*.

Another factor that also contributed to this difference was the online survey tool used to capture their forecast. The tool spaced each response slider equally, even though the spans of time kept increasing towards the end. This resulted in 'S' curves that are more clearly visible when the slider inputs are plotted exactly as they were captured (as seen in the graph on the left with the dark background of *Illustration 14* below). Once the distance between the responses was distributed so that the space between years was equal, this resulted in visibly more linear forecasts (seen on the graph to its right with the light background). It is very likely that these are not the shape of the forecasts that the experts originally intended, and given a more appropriate tool to capture their forecasts, might have changed these to look considerably different to the ones provided. For the next version of this Delphi Study, a more appropriate tool will need to be sought out and implemented. This one will need to provide better, more intuitive and undistorted feedback to the experts as they are entering their response.

Illustration 14. AV PENETRATION (% DRIVERLESS)



Round 1 Results

Final: Round 3 Results with time (years) equally spaced.

An additional drawback to this study was the lack of funding and backing by organizations with greater brand recognition and reputation in the industry. The results of this was a reduced number of experts that were willing to participate, and an increased number of those that did not conclude the study. In addition, the compressed timelines for the study prevented several experts from dedicating greater amounts of time and energy to their responses that they would have preferred. This time crunch also prevented a list of participating experts, with bios and credentials, from being shared with each other, so that they could understand and be reassured in the company of peers they were participating alongside. Though the responses throughout the cycles would have still remained anonymous, greater awareness and understanding of the strength and merit behind the other responses (as well as having more time to consider these opinions) would have very likely garnered more consensus among the responses.

In addition, the next iteration of this study would include greater visual cues and clarity around what each scale is measuring and what the opposite ends of it mean. This will avoid inflating a visual sense of consensus-forming that occurred when respondents realized that they had misunderstood the rubric and needed to switch over their responses for the previous round.

210 Ibid.

Another action to take, alongside this improvement, would be to user-test the questions ahead of the official launch. This could happen with a different group of experts (not involved in this version of the study) but could also be with the same pool of experts that will be participating in it. This could be in a type of soft-launch or preliminary round. This would not actually ask the experts to submit responses to the questions — or they could as a way of testing the tool used to collect them — but would not count towards the actual study. This would be an opportunity to ensure that the question is properly written out, and all factors are explicit and accounted for. In the case of the current study, several questions still had several loose ends: there were factors and uncertainties that hadn't been extensively considered for before sending out the first round, and this had the experts submit responses with different considerations. Examples include: The question about parking was not explicit about including individual parking garages. The question around function pitted passenger vs cargo vehicles, but missed service vehicles (another category of vehicles without passengers). And the question about urban sprawl did not specify whether this should be measured as a direct result of Autonomous Vehicles or whether it should consider and include other trends. A trial or test run of the survey would allow for all these errors, omissions or oversights to be brought to light and addressed. This way, when the time came for the experts to submit their responses, they would now all be exactly on the same page.

Futures Workshop

There were several limitations to the workshop component of this research project, and a few areas for improvement.

The first one was the small sample of the population that participated in the workshop (10 individuals). Ideally, a larger budget for production and outreach would result in multiple workshops being held on different days of the week and different times of day to accommodate a much wider variety of respondents. This, together with more thorough and effective outreach and promotion of the workshops, would result in greater diversity of voices and perspectives providing their input to the project. Because the scope of the project was cities in North America, the optimal scenario would be to have workshops across several different cities in the United States and Canada, including some small and mid-sized cities together with larger urban centers.

One area of the workshop that would require revisiting and re-designing would be the "Do and Do Not" card-sorting activity. For a large majority of the cards, the way the AV activity on it was written was much too broad and generic. Discussions ensued about specific scenarios with changing details, and each one had a different answer along the categories of: Do/Do Not, Positive/Negative/Neutral. One improvement to this activity would be to simply be more detailed and specific in the way the cards are written. However, this skirts the more important insight that the activity revealed around moral debate and the difficulty in collectively deciding which behaviours should be allowed and which shouldn't.

Fake Ethical Dilemmas

The "Do/Do Not" activity underscored the great need to shift the focus away from Fake Ethical Dilemmas and direct it into real ones. Experts and the public alike have been gripped by the primal, emotional appeal of *trolley problems*. However, their real, practical use for designing AV behaviour is null. Rodney Brooks, a former MIT robotics professor and founder of iRobot, best captured their futility in his blog:[211]

> "Here's a question to ask yourself. How many times when you have been driving have you had to make a forced decision on which group of people to drive into and kill? You know, the five nuns or the single child? Or the ten robbers or the single little old lady? For every time that you have faced such a decision, do you feel you made the right decision in the heat of the moment? Oh, you have never had to make that decision yourself? What about all your friends and relatives? Surely they have faced this issue?
>
> And that is my point. This is a made up question that will have no practical impact on any automobile or person for the foreseeable future. Just as these questions never come up for human drivers they won't come up for self-driving cars. It is pure mental masturbation dressed up as moral philosophy. You can set up web sites and argue about it all you want. None of that will have any practical impact, nor lead to any practical regulations about what can or cannot go into automobiles. The problem is both non-existent and irrelevant."

To add evidence to this and prove this point even further futility, a 2018 study published by the journal *Nature* confirmed that even morality is not universal, and human beings in different parts of the world have different opinions regarding what is right and wrong.[212] On top of this, the companies building these cars will really be "less concerned with esoteric questions of right and wrong than with concrete questions of predictive legal liability."[213] Instead of continuing to spend time and resources on these fruitless and hollow exercises, these resources should be devoted to figuring out what you want for *your* city. What practical, tangible things should AVs be allowed or prohibited from doing in your jurisdiction?

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[211] Brooks, "Unexpected Consequences of Self Driving Cars – Rodney Brooks."

[212] Maxmen, "Self-Driving Car Dilemmas Reveal That Moral Choices Are Not Universal."

[213] Davies, "What Is a Self-Driving Car?"

Next Steps

The scope and scale of this research was limited to studying what a city in a future of self-driving vehicles could look like. It explored the potential ways that different aspects of the cityscape might be affected and behave in the future. Now that you have read through and examined the possibilities, there are three very important steps to take:

Deep Dive into Causes

The first step is a call for additional studies and research. This report has only scratched the surface of the potential impacts that Driverless Vehicles will have on cities in the future. In order to better understand each of these impacts, we need to do a deeper dive into the components of the system they are a part of; the ways the components interrelate, how they interact with each other, and how they work together with larger systems. This is a complex, *wicked problem* after all.

There are multiple factors that will together affect the way AVs shape our urban context. At a high level, the most critical ones that will need additional study and research are:

Human Behavior

- ➢ Convenience
- ➢ Habits
- ➢ Culture of Automobility

Business Models & Behavioral Economics

Tied to very closely to the behaviours of groups of people as well as individuals, will be business models that incentivize certain types of behaviour. Issues can arise when these behaviours aggravate and deteriorate the Driverless City. Ryan Lanyon, Chair of the City of Toronto's Automated Vehicles Working Group, described the following scenario as an example:

> "One of our considerations is that the revenue generation might not be related to mobility at all - the companies will give transportation away for free in exchange for in-vehicle sales/service and user-generated data rights. Very similar to the social media and gaming models. 'Would you be willing to watch a 60-second advertisement in exchange for a free commute home? Don't mind if we monitor your heartbeat and eye movements to track your physiological reaction to the ad…' It's like being wrapped in an enormous smartphone. This will create huge demand and change travel patterns. It might also be a way to monetize *congestion* - the longer you're in the car, the more data you will generate."[214]

[214] Lanyon, "Discussion - MRP," April 2020.

Policy, Regulation, Incentives and Disincentives

Governments, Regulators and Legislators likely have the single most important role to play in shaping The Driverless City. With them lies the ability to allow or forbid, to tax or subsidize, to restrict or encourage any and all of the possible impacts of Automated Vehicles.

With this mobility revolution, there is an opportunity to avoid the mistakes of the past, the ones that the previous transportation revolution wreaked upon North American cities. Mistakes from half a century of car-oriented development that left economic and environmental challenges from congestion and sprawl.[215]

Technically, there are many factors that should discourage ownership but have only had a weak effect. Many car-owners rely on access to their vehicles for their jobs, absorbing creeping inconvenience and cost. They engage in behaviours such as buying used vehicles, keeping their cars longer, do not repair them as often, and circle for cheaper parking. Land zoning regulations that raise the price of housing result in families purchasing affordable homes in the outlying suburban areas, which demands increased car use and ownership. Ecological awareness and consciousness has not been a game-changer: the health of the planet is the last thing on most car-buyer's minds.[216]

Automation alone will not move people to the sharing model. Without alternatives and appropriate incentives and disincentives, Automated Vehicles will very likely have the opposite of the desired effect on congestion, parking, sprawl, and urban livability.[217]

It is hard to stress just how important and urgent it is to begin exploring policies now, and not when AVs are already widely circulating on our roads. As was mentioned in the AV PENETRATION (% DRIVERLESS) section of the Delphi Research Outcomes, Uber currently comprises a little over 3% of vehicles on the road in Toronto.[218] Think back again to 5 years ago and remember *just how much disruption* Uber and Lyft brought to cities worldwide, *with less than* 3% Penetration (back in 2015, Uber vehicles were quite less than 3% of the total number on the road) *Most of the experts consulted are predicting that 10% of vehicles will be driverless by 2030*. Although another school of thought believes this will be closer to 3%, the scale of their potential disruption will be a force to be reckoned with. *Imagine what 3 times that number of vehicles will bring*.

The data architecture that underpins the management of AVs has key implications for curbside management.[219] However, the regulatory and legislative process is infamously slow and traditionally does a poor job of keeping up with technology. Yet, there is an array of new approaches to regulatory innovations that are being developed and tested worldwide. Many of these approaches provide greatly

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[215] Zon and Ditta, "Robot, Take the Wheel: Public Policy for Automated Vehicles."

[216] Grush, Niles, and Baum, "Ontario Must Prepare for Vehicle Automation Part 2 How Skilled Governance Can Influence Its Outcome."

[217] Ibid.

[218] Blinick, "Sharing the Road."

[219] NACTO, *Blueprint for Autonomous Urbanism*.

increased speed and agility in developing policy.[220] A categorized list of some of these is provided below. For more information, see *Transport Canada - Regulatory Innovation Review* by MaRS Discovery District.

Approaches to Regulatory Innovation

- ❖ Digitization of Regulation
    - ➢ RegTech
    - ➢ Open Data Standards & Protocols
    - ➢ Rules as Code

- ❖ Strategic Regulating
    - ➢ Risk Management Framework
        - → Decision Tree
    - ➢ Forward Regulatory Planning
    - ➢ Foresight Research
    - ➢ Policy Pipeline - Agile
    - ➢ Outcomes-based regulation
    - ➢ Three Horizons

- ❖ Participatory
    - ➢ Early Engagement
    - ➢ Co-design / Co-creation
    - ➢ Systemic Design

- ❖ Experimentation
    - ➢ Prototyping
        - → Testing
        - → Iteration
    - ➢ Sandboxes
    - ➢ Pilots

- ❖ Iterative Learning and Evaluation
    - ➢ Developmental evaluation
    - ➢ Dynamic Regulation
    - ➢ Regular review periods

The agile approaches to Regulatory Experimentation such as Sandboxes and Pilots allow for flexibility and adaptation as situations emerge and circumstances change. But more importantly, it helps overcome the *analysis paralysis*[221] brought on by governments' hampering aversion to risk, *by reducing it*.[222]

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[220] Talusan, De Lara, and Zakhidova, "Environmental Scan."
[221] Wikipedia, "Analysis Paralysis."
[222] Talusan, De Lara, and Zakhidova, "Environmental Scan."

Another advantage is that some of the technology and infrastructure required is already in place. Uber and Lyft already have fleets of vehicles operating with advanced software in most cities of North America, and they have lots of detailed data to work with.[223]

An important experiment to do *now*, would be to test curbside pricing incentives and disincentives. This would consist of dynamically priced PUDO locations, based on demand, time of day, and divided into GPS-precise locations. The experiment would result in situations where (for example), if you want to be dropped off right in front of your downtown office tower during morning rush hour, you would have either a fixed or percentile surcharge (say, $30 or 100% on top of the regular cost of the ride) added to the company's cost of the ride. If you choose to be dropped off at the corner, that might be reduced slightly, but if you choose to be dropped off at a less busy side street, this would be a smaller fraction. Conversely if you live in the suburbs and choose to be dropped off at the nearest train station, your ride would have a discount applied to the base price (subsidized by the levies on downtown drop-offs). In addition, you could have specific regions *digitally* marked as no-stopping locations for drivers, essentially digitizing the city's signage. Drivers violating these rules would get applicable city fines and passengers might share the burden of these as well.

The City of San Francisco has done something similar with parking by using sensors and variable meter pricing to create a demand-based parking management system. It encourages parking turnover and has helped reduce both circling and double-parking. Drivers can find parking spaces via an app or a website.[224] The city of Pittsburg recently adopted a similar directive.[225]

An experiment of this nature — that is dynamically adjusted and evolves together with consumer behaviours — would not only reveal important lessons in how to influence these behaviours, but also help alleviate *current* problematic areas within cities.[226] This is a strategy repeatedly advised by multiple authorities such as NACTO, APA, and ITE, for both the present, but more importantly the future, in order to manage driverless vehicles. (See *Blueprint for Autonomous Urbanism,*[227] *CURB APPEAL: CURBSIDE MANAGEMENT STRATEGIES FOR IMPROVING TRANSIT RELIABILITY,*[228] *Planning for Autonomous Mobility,*[229] and *Curbside Management Practitioners Guide*[230]) The City of Toronto has received these recommendations several times, but no significant action has been taken to date.[231] [232]

Another important piece of legislation is to regulate the ***terminology*** around AVs and its use in marketing. SAE's five levels of autonomy do not require any testing or certification, yet some state and provincial legislation rely on the scale. This ultimately allows the developer to determine if it is going to call their vehicle an L2 or L3 or L4, depending on what is more convenient to them.

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223 Patel, "How Uber Uses Data to Improve Their Service and Create the New Wave of Mobility."
224 NACTO, *Blueprint for Autonomous Urbanism*.
225 William Peduto, Mayor of Pittsburgh, SELF-DRIVING VEHICLE TESTING AND OPERATIONS IN THE CITY OF PITTSBURGH.
226 NACTO, *Blueprint for Autonomous Urbanism*.
227 Ibid.
228 NACTO, "CURB APPEAL: CURBSIDE MANAGEMENT STRATEGIES FOR IMPROVING TRANSIT RELIABILITY."
229 Crute et al., *Planning for Autonomous Mobility*.
230 McAdam et al., "Curbside Management Practitioners Guide."
231 City of Toronto, "Draft Automated Vehicles Tactical Plan."
232 City of Toronto, "Downtown Mobility Strategy."

Terms such as “self-driving”, “driverless”, “autopilot”, etc. need to be regulated better than, or at least as thoroughly as terms like “organic”, “non-GMO”, “low-fat”, etc. are currently regulated by agencies across different countries. Egregiously misleading marketing using these terms has already led to multiple accidents and several deaths.[233] The broader public’s misunderstanding of these terms has, far from being corrected, been further stoked through the same marketing.[234] Different brands and companies competing instead of collaborating on safety, was a major historical flaw of the airline industry. They have long since learned from this very costly mistake, course-corrected and held steadfast to the new course where safety is not up for discussion. Yet, as manufacturers race to get these vehicles and systems out the door, studies and documentation are increasing about drivers over-relying on their car’s systems, ignoring alerts, or plain not understanding how the automation works. This is leading them to make dangerous assumptions about what the automation is capable of and what they drivers are now free to do when it is turned on.[235]

Design Thinking

Tim Brown, Executive Chair of Ideo, defines Design thinking as a human-centered approach to innovation that draws from the designer’s toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success[236] Design is frequently used to describe an end result, an object, but the strength of design lies in how effective it is as a process; an action, a verb instead of a noun.[237]

It is a methodology that has an important role to play in *all* of the steps to follow this research, including both *Diving Deep into the Causes* and *Regulatory Innovation*. However, it has a very important role to play in the design of the *physical spaces* of the Driverless City. This goes beyond traditional Architectural Design, Urban Design and Planning, which already uses design’s toolkit. This role is the *human-centered approach to innovation,* a cross-disciplinary, un-siloed approach that will be architected by generalists working with specialists in order to better orchestrate the components of the system into synergy. There are already several key aspects of a city that have a pressing need for their design to be revisited and for better designs to be explored. Chief among these are the Curb and other Pick Up and Drop Off locations:

PUDO Design

Alongside the regulatory experimentation described above, the physical and functional design of the Curb will also need intervention. Considering the cost and duration of infrastructure projects, this area is one where experiments need to be run now in order for optimal designs to surface and best practices to ensue. Initial designs have been published in the same curb management references cited above, but these are still very rudimentary and generic. (See NACTO: *Blueprint for Autonomous Urbanism,*[238] *CURB APPEAL: CURBSIDE MANAGEMENT STRATEGIES FOR IMPROVING TRANSIT RELIABILITY,*[239] APA:

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233 Center for Auto Safety and Consumer Watchdog, “Request for Investigation of Deceptive and Unfair Practices in Advertising and Marketing of the ‘Autopilot’ Feature Offered in Tesla Motor Vehicles,” May 23, 2018.

234 “INSIGHT.”

235 Casner and Hutchins, “What Do We Tell the Drivers?”

236 IDEO, “IDEO Design Thinking.”

237 Fast Company Staff, “Design Thinking… What Is That?”

238 NACTO, *Blueprint for Autonomous Urbanism*.

239 NACTO, “CURB APPEAL: CURBSIDE MANAGEMENT STRATEGIES FOR IMPROVING TRANSIT RELIABILITY.”

Planning for Autonomous Mobility,[240] and *Curbside Management Practitioners Guide*[241]). Different layouts will need to be designed for high-demand areas. A few of these, like Airports, Train stations and Sports fields, have already begun experimenting with different designs. However, most still rely largely on parking, and they also have ample private real estate to work and experiment with. Theaters, cinemas, restaurants, and other highly popular destinations located in a city's downtown core do not have anywhere near the same amount of room to play with.

In addition, Design and Regulation will have to walk down the path of discovery together. Many solutions could require reviewing curb and building standards and regulations. One example could be moving curbside uses onto private property. Thus, requiring buildings to be "double-loaded" so that they have pedestrian entrances on main streets, but vehicular access is on alleys or smaller back streets that can accommodate stopped vehicles.[242]

Concluding thoughts

There is yet ***a lot*** that needs to be figured out.
It is not going to be easy to figure out. It will take a lot of time and resources to discover, design and implement the urban solutions, programs, rules, incentives, disincentives, laws, and other drivers and shapers that will lead to the Driverless City that we aspire to be in.

But we are under the false impression that we still have a lot of time to figure this out.

There is a rapidly narrowing window of opportunity to course-correct the way we have been building cities and revert negative consequences and behaviours that were brought on by the 'System of Automobility'. "Business as usual" is very clearly the opposite of the solution.

COVID-19 should be a wakeup call.
A wake up call not only to the realization that business as usual *should not* continue, but also to the urgency which is required of us to act. We need to take steps now, before this has spiraled out of control. We have the opportunity to intervene before habits become entrenched and infrastructure is too deeply cemented.

240 Crute et al., *Planning for Autonomous Mobility*.
241 McAdam et al., "Curbside Management Practitioners Guide."
242 Lanyon, "Discussion - MRP," April 2020.

Bibliography

Abuelsamid, Sam, David Alexander, and Lisa Jerram. "Navigant Research Leaderboard Report: Automated Driving Assessment of Strategy and Execution for 18 Companies Developing Automated Driving Systems Section 1 EXECUTIVE SUMMARY 1.1 Market Introduction," 2017. http://62.nl.dealer-preview.co/SiteAssets/LB-AV-17-Navigant-Research_FINAL.pdf.

Anderson, James M., Nidhi Kalra, Karlyn D. Stanley, Paul Sorensen, Constantine Samaras, and A. Oluwatobi Oluwatola. *Autonomous Vehicle Technology: A Guide for Policymakers*. RAND Corporation, 2016. https://doi.org/10.7249/RR443-2.

Ashby, Bess. "Transportation Tomorrow Survey 2016: 2016, 2011, 2006, 1996 AND 1986 TRAVEL SUMMARIES FOR THE GREATER TORONTO & HAMILTON AREA." Malatest, March 2018.

Ashley, Steven. "SAE Level 3 'Hand off' Is Challenging AI Researchers." Accessed April 2, 2020. https://www.sae.org/news/2017/01/sae-level-3-hand-off-is-challenging-ai-researchers.

Aten, Jason. "Uber and Lyft Are Betting That Driverless Cars Will Help Them Finally Make Money. Here's Why It Won't Work." Inc.com, August 13, 2019. https://www.inc.com/jason-aten/uber-lyft-are-betting-that-driverless-cars-will-help-them-finally-make-money-heres-why-it-wont-work.html.

Austin Center for Design. "Wicked Problems: Problems Worth Solving - Wicked Problem." Accessed April 2, 2020. https://www.wickedproblems.com/1_wicked_problems.php.

Berkeley. "How Big Is a Billion?" Berkeley University of California. Accessed April 8, 2020. https://ucmp.berkeley.edu/education/explorations/tours/geotime/guide/billion.html.

Bertoncello, Michele, and Dominik Wee. "Ten Ways Autonomous Driving Could Redefine the Automotive World | McKinsey." *McKinsey & Company* (blog), June 2015. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/ten-ways-autonomous-driving-could-redefine-the-automotive-world.

Big Data Innovation Team, and University of Toronto Transportation Research Institute. "The Transportation Impacts of Vehicle-for-Hire in the City of Toronto." City of Toronto, June 2019.

Bigelow, Pete. "Why Level 3 Automated Technology Has Failed to Take Hold." *Automotive News*, July 21, 2019. https://www.autonews.com/shift/why-level-3-automated-technology-has-failed-take-hold.

Blinick, Adam. "Sharing the Road: Can We Tackle Traffic in Toronto? | Uber Newsroom Canada." *Uber Newsroom* (blog), December 3, 2018. https://www.uber.com/en-CA/newsroom/sharing-the-road-in-toronto/.

Bliss, Laura. "Despite 'Car-Free' Hype, Millennials Drive a Lot." *CityLab* (blog), March 27, 2019. https://www.citylab.com/transportation/2019/03/millennial-car-ownership-driving-behavior-vehicle-data/585667/.

Brooks, Rodney. "Unexpected Consequences of Self Driving Cars – Rodney Brooks." *Rodney Brooks* (blog), January 12, 2017. http://rodneybrooks.com/unexpected-consequences-of-self-driving-cars/.

Camargo, Araceli, Joshua Artus, and Hugo Spiers. *Neuroscience for Cities*. Future Cities Catapult, n.d.

Camillus, John C. "Strategy as a Wicked Problem." *Harvard Business Review*, May 1, 2008. https://hbr.org/2008/05/strategy-as-a-wicked-problem.

Capano, Nazzareno. "ITS Canada Parking Workshop - City of Toronto - Curbside Management Challenges." Toronto, November 27, 2018.

Capparella, Joseph. "Toyota Is Uneasy about the Handoff between Automated Systems and Drivers." *Car and Driver* (blog), November 3, 2017. https://www.caranddriver.com/news/a15339581/toyota-is-uneasy-about-the-handoff-between-automated-systems-and-drivers.

Casner, Stephen M., and Edwin L. Hutchins. "What Do We Tell the Drivers? Toward Minimum Driver Training Standards for Partially Automated Cars." *Journal of Cognitive Engineering and Decision Making* 13, no. 2 (June 2019): 55–66. https://doi.org/10.1177/1555343419830901.

CAVCOE. "Call for Participation – Student Autonomous Snow Plow Competition | Kanata North Business Association." Accessed April 25, 2020. https://www.kanatanorthba.com/event/call-for-participation-student-autonomous-snow-plow-competition/.

CCMTA. *CANADIAN JURISDICTIONAL GUIDELINES FOR THE SAFE TESTING AND DEPLOYMENT OF HIGHLY AUTOMATED VEHICLES*. Canadian Council of Motor Transport Administrators, 2018.

Center for Auto Safety, and Consumer Watchdog. "Request for Investigation of Deceptive and Unfair Practices in Advertising and Marketing of the 'Autopilot' Feature Offered in Tesla Motor Vehicles," May 23, 2018. https://www.autosafety.org/wp-content/uploads/2018/05/CAS-and-CW-Letter-to-FTC-on-Tesla-Deceptive-Advertising.pdf.

Chan, Kevin, Mark Sadoway, Josh Tzventarny, and Ersoy Gulecoglu. "Shared Mobility in the Greater Toronto and Hamilton Area." Toronto: Metrolinx, 2017.

Chapin, Tim, Lindsay Stevens, Jeremy Crute, Jordan Crandall, Anne Rokyta, and Alexandria Washington. "Envisioning Florida's Future: Transportation and Land Use in an Automated Vehicle World." Florida State University Department of Urban & Regional Planning, April 2016.

City of Toronto. "Downtown Mobility Strategy," n.d.

———. "Draft Automated Vehicles Tactical Plan," June 2019.

Clean Air Partnership. *Smart Mobility for Public Transportation Webinar*, 2019. https://vimeo.com/367126512.

Clustre. "Digital Abundance, and the Second Half of the Chessboard." *Clustre, The Innovation Brokers* (blog), September 7, 2015. https://www.clustre.net/digital-abundance-and-the-second-half-of-the-chessboard/.

Cohen, Scott A., and Debbie Hopkins. "Autonomous Vehicles and the Future of Urban Tourism." *Annals of Tourism Research* 74 (January 2019): 33–42. https://doi.org/10.1016/j.annals.2018.10.009.

Comeau, Elyse, Steven Coutts, Kasia Kmieć, Tyler Olsen, Safiyyah Saleh, James Schofield, and Josie Tavares. "Benchmarking Public Opinion on Automated Vehicles: Comparing Toronto to Other Jurisdictions," February 27, 2018.

Cooney, Patrick. "Chessboards and Rice: A Lesson for Exponential Growth." *Michigan Future Inc.* (blog), January 10, 2017. https://michiganfuture.org/01/2017/chessboards-and-rice/.

Corwin, Scott, Joe Vitale, Eamonn Kelly, and Elizabeth Cathles. "The Future of Mobility How Transportation Technology and Social Trends Are Creating a New Business Ecosystem." Deloitte University Press, 2015.

Crute, Jeremy, William Riggs, Timothy S. Chapin, and Lindsay Stevens. *Planning for Autonomous Mobility*. PAS Report 592. Chicago, IL: American Planning Association, 2018.

Davies, Alex. "What Is a Self-Driving Car? The Complete WIRED Guide." *Wired*, December 13, 2018. https://www.wired.com/story/guide-self-driving-cars/.

Davis, Stacy C., and Robert G. Boundy. *Transportation Energy Data Book*. 37th ed. U.S. DEPARTMENT OF ENERGY, 2019. cta.ornl.gov/data.

Deloitte. "Designing a Seamless Integrated Mobility System (SIMSystem) A Manifesto for Transforming Passenger and Goods Mobility." World Economic Forum, January 2018.

Dictionary.com. "Definition of Autonomous | Dictionary.Com." In *Www.Dictionary.Com*. Accessed April 2,

2020. https://www.dictionary.com/browse/autonomous.

Dorsser, Cornelis van, Warren E. Walker, Poonam Taneja, and Vincent A.W.J. Marchau. “Improving the Link between the Futures Field and Policymaking.” *Futures* 104 (December 2018): 75–84. https://doi.org/10.1016/j.futures.2018.05.004.

EastWest Institute. “Smart and Safe Risk Reduction in Tomorrow’s Cities.” Global Cooperation in Cyberspace. EastWest Institute, 2018.

English, Jonathan. “The History of Cities Is About How We Get to Work.” *CityLab* (blog), August 29, 2019. https://www.citylab.com/transportation/2019/08/commute-time-city-size-transportation-urban-planning-history/597055/.

Erhardt, Gregory D., Sneha Roy, Drew Cooper, Bhargava Sana, Mei Chen, and Joe Castiglione. “Do Transportation Network Companies Decrease or Increase Congestion?” *Science Advances* 5, no. 5 (May 2019): eaau2670. https://doi.org/10.1126/sciadv.aau2670.

Everett Mitchell Rogers. *Diffusion of Innovations*. 5th ed. New York, NY: Free Press, 2003.

Ewing, Reid, and Shima Hamidi. “Measuring Sprawl 2014.” Smart Growth America, April 2014.

Ezike, Richard, Jeremy Martin, Katherine Catalano, and Jesse Cohn. “Where Are Self-Driving Cars Taking Us? Pivotal Choices That Will Shape DC’s Transportation Future.” Union of Concerned Scientists, February 2019. www.ucsusa.org /AV-equity.

Falconer, Ryan, Taylor Zhou, and Melissa Felder. “Mobility-as-a-Service The Value Proposition for the Public and Our Urban Systems.” Arup, MaRS, March 2018.

Fast Company Staff. “Design Thinking… What Is That?” Fast Company, March 20, 2006. https://www.fastcompany.com/919258/design-thinking-what.

Fehr & Peers. “Cincinnati Curb Study.” Uber Technologies, January 2019. https://www.fehrandpeers.com/curbs-of-the-future/.

———. Memorandum. “Estimated Percent of Total Driving by Lyft and Uber In Six Major US Regions, September 2018.” Memorandum, August 6, 2019. https://drive.google.com/file/d/1FlUskVkj9lsAnWJQ6kLhAhNoVLjfFdx3/view.

———. “San Francisco Curb Study.” Uber Technologies, September 2018. https://www.fehrandpeers.com/curbs-of-the-future/.

Gerdes, J. Christian, and Sarah M. Thornton. “Implementable Ethics for Autonomous Vehicles.” In *Autonomous Driving*, edited by Markus Maurer, J. Christian Gerdes, Barbara Lenz, and Hermann Winner, 87–102. Berlin, Heidelberg: Springer Berlin Heidelberg, 2016. https://doi.org/10.1007/978-3-662-48847-8_5.

Goodman, Michael. “Systems Thinking: What, Why, When, Where, and How?” The Systems Thinker, February 27, 2016. https://thesystemsthinker.com/systems-thinking-what-why-when-where-and-how/.

Government of Canada, Statistics Canada. “Population Estimates on July 1st, by Age and Sex,” December 27, 2017. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000501.

———. “Vehicle Registrations, by Type of Vehicle,” December 27, 2017. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310006701.

Gray, Barbara. “Curbside Management Strategy: Improving How Curbside Space Is Used.” City of Toronto, November 14, 2017.

Grush, Bern, John Niles, and Edgar Baum. “Ontario Must Prepare for Vehicle Automation: Automated Vehicles Can Influence Urban Form, Congestion, and Infrastructure Delivery.” Residential and Civil Construction Alliance of Ontario (RCCAO), October 2016. http://rccao.com/research/files/RCCAO_Vehicle-Automation_OCT2016_WEB.pdf.

———. “Ontario Must Prepare for Vehicle Automation Part 2 How Skilled Governance Can Influence Its Outcome.” Residential and Civil Construction Alliance of Ontario (RCCAO), October 2017.

HBS Alumni. “Wikipedia, the Father of Crowdsourcing – Digital Innovation and Transformation.” Harvard Business School, October 31, 2015. https://digital.hbs.edu/platform-digit/submission/wikipedia-the-father-of-crowdsourcing/.

Helmer-Hirschberg, Olaf. “Analysis of the Future: The Delphi Method.” Santa Monica, California: RAND Corporation, March 1967. https://www.rand.org/pubs/papers/P3558.html.

Herriges, Daniel. “The Mobility Trap: Why We’ll Never Fix Congestion by Speeding Up Traffic.” *Strong Towns* (blog), August 28, 2019. https://www.strongtowns.org/journal/2019/8/28/the-mobility-trap-why-well-never-fix-congestion-by-speeding-up-traffic.

Hyatt, Kyle, and Chris Paukert. “Self-Driving Cars: A Level-by-Level Explainer of Autonomous Vehicles.” *Roadshow* (blog), March 29, 2018. https://www.cnet.com/roadshow/news/self-driving-car-guide-autonomous-explanation/.

IDEO. “IDEO Design Thinking.” IDEO | Design Thinking. Accessed April 10, 2020. https://designthinking.ideo.com/.

IEEE. “Connected Vehicles - IEEE Connected Vehicles.” IEEE Connected & Autonomous Vehicles. Accessed April 3, 2020. https://site.ieee.org/connected-vehicles/ieee-connected-vechicles/connected-vehicles/.

“INSIGHT: The Decade-Long Self-Driving Honeymoon Is Over. What’s Next?” Accessed March 5, 2020. https://news.bloomberglaw.com/tech-and-telecom-law/insight-the-decade-long-self-driving-honeymoon-is-over-whats-next.

ITE. “Connected/Automated Vehicles.” Institute of Transportation Engineers. Accessed April 3, 2020. https://www.ite.org/technical-resources/topics/connected-automated-vehicles/.

Jenkins, Stephen. “The Second Half of the Chessboard | Jupiterjenkins.Com.” Accessed April 8, 2020. http://www.jupiterjenkins.com/the-second-half-of-the-chessboard/.

JHU. “COVID-19 Map.” Johns Hopkins Coronavirus Resource Center. Accessed April 8, 2020. https://coronavirus.jhu.edu/map.html.

Kovacs, Paul. *Automated Vehicles, Implications for the Insurance Industry in Canada*. The Insurance Institute of Canada, 2016. https://search.informit.com.au/documentSummary;dn=365036984144993;res=IELENG.

KPMG. “2018 Autonomous Vehicles Readiness Index.” KPMG International, January 2018. https://assets.kpmg.com/content/dam/kpmg/nl/pdf/2018/sector/automotive/autonomous-vehicles-readiness-index.pdf.

———. “2019 Autonomous Vehicles Readiness Index.” KPMG International, March 2019.

———. “I See. I Think. I Drive. (I Learn).” KPMG LLP, 2016. http://services.igi-global.com/resolvedoi/resolve.aspx?doi=10.4018/978-1-5225-2808-1.ch004.

———. “Islands of Autonomy.” KPMG International, 2017. http://www.kpmg-institutes.com/content/dam/kpmg/manufacturing-institute/pdf/2017/islands-of-autonomy-web.pdf.

———. “The Clockspeed Dilemma.” KPMG, November 2015.

Laidlaw, Kailey, Matthias Sweet, and Tyler Olsen. “Forecasting the Outlook for Automated Vehicles in the Greater Toronto and Hamilton Area Using a 2016 Consumer Survey.” Ryesron School of Urban and Regional Planning, March 9, 2018.

Lang, Nikolaus, Michael Russmann, Antonella Mei-Pochtler, Thomas Dauner, Satoshi Komiya, Xavier Mosquet, Xanthi Doubara, and World Economic Forum. “Self Driving Vehicles, Robo-Taxis, and the

Urban Mobility Revolution." Boston Consulting Group, July 2016.

Lantz, Larry. "Longer Vehicle Life Expectancy a Testament to Research and Technology." *The Toronto Star*, March 23, 2018, sec. Autos. https://www.thestar.com/autos/opinion/2018/03/23/longer-vehicle-life-expectancy-a-testament-to-research-and-technology.html.

Lanyon, Ryan. "Discussion - MRP," April 2020.

———. "Preparing for Automated Vehicles at the City of Toronto." January 19, 2018. http://uttri.utoronto.ca/files/2017/01/Ryan-Lanyon-Transp-Serv-Toronto-27Jan17.pdf.

Learning for Sustainability. "Systems Thinking." *Learning for Sustainability* (blog). Accessed April 7, 2020. https://learningforsustainability.net/systems-thinking/.

Levinson, David. "On the Differences between Autonomous, Automated, Self-Driving, and Driverless Cars." *Transportist by David Levinson* (blog), June 28, 2017. https://transportist.org/2017/06/29/on-the-differences-between-autonomous-automated-self-driving-and-driverless-cars/.

Lewis, Paul, Gregory Rogers, and Stanford Turner. "Adopting and Adapting States and Automated Vehicle Policy." Eno Center for Transportation, June 2017.

Lin, Patrick. "Robot Cars And Fake Ethical Dilemmas." *Forbes*, April 3, 2017. https://www.forbes.com/sites/patricklin/2017/04/03/robot-cars-and-fake-ethical-dilemmas/.

Litman, Todd. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning." Victoria Transport Policy Institute, September 8, 2017.

———. "Autonomous Vehicle Implementation Predictions: Implications for Transport Planning." Victoria Transport Policy Institute, November 26, 2018.

———. "Evaluating Policies and Practices That Affect the Amount of Land Devoted to Transportation Facilities." Transportation Land Valuation. Victoria Transport Policy Institute, November 16, 2018.

———. "Implications for Transport Planning," n.d., 40.

Maidlow, Lance. "The Second Half of the Chess Board Intersects with Moore's Law in 2013." *Software Solutions for Drafting, Surveying, Site Design and the Field* (blog), September 11, 2013. https://chasmtech.wordpress.com/2013/09/11/the-second-half-of-the-chess-board-intersects-with-moores-law-in-2013/.

Marshal, AArian. "The Death of Cars Was Greatly Exaggerated." *Wired*, October 16, 2019. https://www.wired.com/story/death-cars-greatly-exaggerated/.

Matteson, Scott. "Autonomous versus Automated: What Each Means and Why It Matters." *TechRepublic* (blog), June 7, 2019. https://www.techrepublic.com/article/autonomous-versus-automated-what-each-means-and-why-it-matters/.

Maxmen, Amy. "Self-Driving Car Dilemmas Reveal That Moral Choices Are Not Universal." *Nature* 562, no. 7728 (October 24, 2018): 469–70. https://doi.org/10.1038/d41586-018-07135-0.

McAdam, Taylor, Peter Martin, Jodie Medeiros, Dan Nabors, Jamie Parks, Benito O Pérez, Catherine Prince, et al. "Curbside Management Practitioners Guide." Institute of Transportation Engineers (ITE), November 15, 2018.

McKinsey Global Institute. "SMART CITIES: DIGITAL SOLUTIONS FOR A MORE LIVABLE FUTURE," June 2018.

Millard-Ball, Adam. "Pedestrians, Autonomous Vehicles, and Cities." *Journal of Planning Education and Research* 38, no. 1 (March 2018): 6–12. https://doi.org/10.1177/0739456X16675674.

Miller, John S., and Di Kang. "Ways to Consider Driverless Vehicles in Virginia Long-Range Travel Demand Models." Virginia Transportation Research Council, March 2019. http://www.virginiadot.org/vtrc/main/online_reports/pdf/19-r11.pdf.

Murtha, Suzanne. “Autonomous vs Connected Vehicles – What’s the Difference?,” October 2, 2015. https://www.atkinsglobal.com/en-GB/angles/all-angles/autonomous-vs-connected-vehicles-whats-the-difference.

NACTO. *Blueprint for Autonomous Urbanism*. Second Edition. National Association of City Transportation Officials, 2019.

———. “CURB APPEAL: CURBSIDE MANAGEMENT STRATEGIES FOR IMPROVING TRANSIT RELIABILITY.” NACTO TRANSIT LEADERSHIP. National Association of City Transportation Officials, November 2017.

———. *Global Street Design Guide*. Edited by National Association of City Transportation Officials (NACTO). 2nd ed. Island Press, 2016.

Nationwide Mutual Insurance Company. “How Long Do Cars Last?” Now from Nationwide ®, June 10, 2017. https://blog.nationwide.com/how-long-cars-last-infographic/.

OECD/ITF. “The Shared-Use City: Managing the Curb.” Corporate Partnership Board Report. Organization for Economic Cooperation and Development and the International Transport Forum, 2018. https://bit.ly/2B8hLqG.

———. “Urban Mobility System Upgrade How Shared Self-Driving Cars Could Change City Traffic.” Corporate Partnership Board Report. Paris: OECD International Transport Forum, 2015.

Olsen, Tyler, Leah Birnbaum, Matthias Sweet, and Elyse Comeau. “Driverless Cars in the Greater Toronto and Hamilton Area: Focus Group Findings.” Ryesron School of Urban and Regional Planning, April 13, 2018.

Our World in Data. “Technology Adoption in US Households.” Our World in Data. Accessed March 3, 2020. https://ourworldindata.org/grapher/technology-adoption-by-households-in-the-united-states.

Patel, Neil. “How Uber Uses Data to Improve Their Service and Create the New Wave of Mobility.” Neil Patel, April 17, 2017. https://neilpatel.com/blog/how-uber-uses-data/.

Paul Saffo. “Six Rules for Effective Forecasting.” *Harvard Business Review*, July 1, 2007. https://hbr.org/2007/07/six-rules-for-effective-forecasting.

Power, Sarah. “Future Cities Could Be More Powerful than Countries.” *Factor* (blog), October 10, 2016. https://www.factor-tech.com/feature/future-cities-could-be-more-powerful-than-countries/.

PPSC - Policy and Planning Support Committee. “The Future of Automated Vehicles in Canada Report of the PPSC Working Group on Connected and Automated Vehicles.” Council of Ministers of Transportation and Highway Safety, January 29, 2018.

Ramírez, Rafael, and Cynthia Selin. “Plausibility and Probability in Scenario Planning.” *Foresight* 16, no. 1 (March 4, 2014): 54–74. https://doi.org/10.1108/FS-08-2012-0061.

Ramsey, Augustine. “Urban Densification as a Strategy for Sustainability.” 2016. https://slideplayer.com/slide/7258839/.

Rapier, Graham. “Your Uber Ride Could Get 80% Cheaper over the next Decade.” Business Insider. Accessed April 24, 2020. https://www.businessinsider.com/uber-lyft-fare-prices-could-fall-by-80-ubs-estimate-2019-5.

Reference.com. “How Many Grains of Rice Are in a Cup?” Reference. Accessed April 8, 2020. https://www.reference.com/world-view/many-grains-rice-cup-8758d757b7958a86.

Ritchie, Hannah, and Max Roser. “Urbanization.” *Our World in Data*, June 13, 2018. https://ourworldindata.org/urbanization.

Robinson, Matthew. “Vancouver Addicted to Parking Revenue.” www.vancouversun.com. Accessed April 25, 2020. http://www.vancouversun.com/news/vancouver+addicted+parking+revenue/11736950/story.ht ml.

Schaller, Bruce. “Empty Seats, Full Streets: Fixing Manhattan’s Traffic Problem.” Schaller Consulting, December 21, 2017.

———. “The New Automobility: Lyft, Uber and the Future of American Cities.” Brooklyn: Schaller Consulting, July 25, 2018.

Schlossberg, Marc, William Riggs, Adam Millard-Ball, and Elizabeth Shay. “RETHINKING THE STREET IN AN ERA OF DRIVERLESS CARS.” University of Oregon: Urbanism Next, January 26, 2018.

Sheller, Mimi, and John Urry. “The City and the Car.” *International Journal of Urban and Regional Research* 24, no. 4 (2000): 737–757. https://doi.org/10.1111/1468-2427.00276.

Shepard, Keegan Clay. “In the Future Your Ambulance Could Be Driverless.” *The Conversation* (blog). Accessed April 25, 2020. http://theconversation.com/in-the-future-your-ambulance-could-be-driverless-78974.

Shepardson, David. “Uber, Distracted Backup Driver Cited by NTSB in Fatal Self-Driving Crash.” *Reuters*, November 20, 2019. https://www.reuters.com/article/us-uber-crash-idUSKBN1XT2IL.

Soteropoulos, Aggelos, Martin Berger, and Francesco Ciari. “Impacts of Automated Vehicles on Travel Behaviour and Land Use: An International Review of Modelling Studies.” *Transport Reviews* 39, no. 1 (September 28, 2018): 29–49. https://doi.org/10.1080/01441647.2018.1523253.

Standing Senate Committee on Transport and Communications Senate. “Driving Change-Technology and Future of Autonomous Vehicles.” Ottawa: Senate, January 2018. sencanada.ca/trcm.

Stevens, Nicholas, and Paul Salmon. “Cities Are Complex Systems – Let’s Start Looking at Them That Way.” *The Conversation* (blog), April 25, 2017. http://theconversation.com/cities-are-complex-systems-lets-start-looking-at-them-that-way-72665.

Talusan, Sue, Sergio De Lara, and Khilola Zakhidova. “Environmental Scan.” In *Transport Canada - Regulatory Innovation Review*. MaRS Discovery District, 2020.

The Bloomberg Aspen Initiative on Cities and Autonomous Vehicles. *Taming the Autonomous Vehicle - A Primer for Cities*. Bloomberg Philantropies, Aspen Institute, 2017.

The City of Calgary Transportation department. “Future of Transportation in Calgary.” Calgary, 2017.

Ticoll, David. “Driving Changes: Automated Vehicles in Toronto.” Toronto: University of Toronto Transportation Research Institute, 2015. http://uttri.utoronto.ca/files/2017/01/Driving-Changes-Ticoll-David-Oct-2015.pdf https://munkschool.utoronto.ca/ipl/files/2016/03/Driving-Changes-Ticoll-2015.pdf.

———. “Vehicle Automation: The Missing Piece in Canada’s Green Infrastructure Puzzle - The Globe and Mail.” *The Globe and Mail*, June 9, 2016. https://www.theglobeandmail.com/report-on-business/rob-commentary/vehicle-automation-the-missing-piece-in-canadas-green-infrastructure-puzzle/article30357961/.

Townsend, Dr Anthony. “The Digital Transformation of Transportation in the United States,” 2014, 60.

Urry, John. “The ‘System’ of Automobility.” *Theory, Culture & Society* 21, no. 4–5 (October 2004): 25–39. https://doi.org/10.1177/0263276404046059.

U.S. Census Bureau. “Historical National Population Estimates: July 1, 1900 to July 1, 1999,” April 11, 2000. https://www.census.gov/population/estimates/nation/popclockest.txt.

U.S. Department of Energy, Vehicle Technologies Office. “Fact #962: January 30, 2017 Vehicles per Capita: Other Regions/Countries Compared to the United States.” Energy.gov, January 30, 2017. https://www.energy.gov/eere/vehicles/fact-962-january-30-2017-vehicles-capita-other-regionscountries-compared-united-states.

US Department of Transportation; Federal Highway Administration. “Number of Motor Vehicles Registered in the United States from 1990 to 2017 (in 1,000s).” US Department of Transportation; Federal Highway Administration, January 2019. https://www.statista.com/statistics/183505/number-of-vehicles-in-the-united-states-since-1990/.

Varinsky, Dana. “Cities Are Becoming More Powerful than Countries.” *Business Insider* (blog). Accessed April 11, 2020. https://www.businessinsider.com/why-cities-are-more-powerful-than-countries-2016-8.

Volvo. “Volvo Pioneers Autonomous, Self-Driving Refuse Truck,” May 17, 2017. https://www.volvogroup.com/en-en/news/2017/may/news-2561936.html.

Waxman, Jordan Elpern. “Will Autonomous Vehicles Lead to Greater Sprawl or Greater Density? Yes.” *Medium* (blog), November 17, 2016. https://medium.com/jordan-writes-about-cities/will-autonomous-vehicles-lead-to-greater-sprawl-or-greater-density-yes-4e32b0fb3d35.

West, Darrell M. “Moving Forward: Self-Driving Vehicles in China, Europe, Japan, Korea, and the United States.” *Center for Technology Innovation at Brookings*, September 2016, 32.

Wikipedia. “Analysis Paralysis.” In *Wikipedia*, March 29, 2020. https://en.wikipedia.org/w/index.php?title=Analysis_paralysis&oldid=947878609.

———. “Induced Demand.” In *Wikipedia*, February 24, 2020. https://en.wikipedia.org/w/index.php?title=Induced_demand&oldid=942454838.

———. “Self-Driving Car.” In *Wikipedia*, April 2, 2020. https://en.wikipedia.org/w/index.php?title=Self-driving_car&oldid=948727788.

———. “Wheat and Chessboard Problem.” In *Wikipedia*, April 4, 2020. https://en.wikipedia.org/w/index.php?title=Wheat_and_chessboard_problem&oldid=949117694.

William Peduto, Mayor of Pittsburgh. SELF-DRIVING VEHICLE TESTING AND OPERATIONS IN THE CITY OF PITTSBURGH (2019).

Zon, Noah, and Sara Ditta. “Robot, Take the Wheel: Public Policy for Automated Vehicles.” University of Toronto Mowat Centre, 2016.

Appendices

Appendix A: Futures Workshop Outline and Facilitator's guide

The Driverless City

Outline and Facilitator's guide

Objectives:

1. Identify potential gaps [in the research] by leveraging the perspective of non-experts that will be impacted by AV technology.
2. Rank and prioritize the potential impacts of AV technology as perceived by those that will be impacted themselves (as non-experts).

Facilitators:

- Re-explain the instructions for activities as needed, and answer any questions participants may have about the exercise (feel free to ask a Principal Investigator if you have activity or technical questions)
- Ensure participants write down their thoughts down (on sticky notes or the print-outs).
- Take notes on the table conversation. Make sure to write down important arguments/ reasonings behind key ideas that participants bring up. Write down any information from discussion at your table that you feel is pertinent (areas of contention, strong agreement, etc.). The more information we can collect from your table discussion, the better.
- Keep the group focused on the content of the discussion. Manage table discussions to stay collaborative and conducive to dialogue.
- Keep time (some people will talk more than others, drift off-topic, etc. – use gentle prompts, parking ideas, taking offline, etc. to move on, eg. "That's an important point you raised. Although it's not the current topic of discussion, I've made note of it and flagged it. Now, getting back to...")

Inventory

- Registration sheet
- 25 Consent forms
- Name tags
- Water, Coffee, Timbits, Chips, Juice
- 5 Balls of Yarn
- 5 Copies of 60cm x 90cm Concept Map
- 5 Copies of 60cm x 90cm "Do's & Don'ts"
- 5 sets of "Do's & Don'ts" prompt cards
- 25 Copies of Tabloid Concept map
- 35 Copies of Storyboards
- 1 set of small dot stickers
- 5 dozen white paper sheets

- 5 sets of sticky notes
- 6 sets of markers and pens
    - Black, blue, red, green
- 5 clear tape roll

Room Set-up

- Overhead projector and screen towards back of room
- Reception table inside room next to entrance
    - Registration sheet, Consent forms, name tags, markers
- Refreshments table
- (5) participant tables that seat 6
    - Up to 5 participants + 1 facilitator per table
    - 1 Ball of Yarn
    - 1 Copy of 60cm x 90cm concept map
    - 1 Copy of 60cm x 90cm “Do’s & Don’ts”
    - 5 Copies of Tabloid Concept map
    - 1 Set of “Do’s & Don’ts” prompt cards
    - 7 Copies of Storyboards
    - 5 sets of 10 small dot stickers
    - 1 dozen white paper sheets
    - 1 set of small sticky notes
    - 1 block of white sticky notes
    - 1 set of markers and pens
        - Black, blue, red, green
    - 1 clear tape roll

Agenda

1. Registration (9h00 - 30min.)

1.1.

1.1.1. Lead Facilitator (Principal Investigator) - standing

1.1.2. Assistant Facilitator - at reception table

1.1.3. Assistant facilitators at participant tables

1.2. Registration sheet

1.3. Consent Form

Participants will be greeted at the door, their identity will be confirmed and be given a Consent form to sign. Facilitators will answer questions regarding the consent form, encourage participants to create a name tag and help themselves to refreshments and make introductions between participants pre- ice-breaker.

2. Welcome / Introduction (9h30 - 30min.)

2.1. Housekeeping notes

2.2. Ice breaker (demonstration by facilitators)

2.2.1. 5-minute Ice-breaker per table (assistant facilitators)

2.2.1.1. Connected Web

Volunteer takes ball and starts telling the table a little about themselves. When someone hears something they share in common with that person, they shoot up their hand. First person holds on to end of string and throws ball to second person. That person starts telling a little about themselves until another person shoots hand up. Process continues until time or yarn runs out.

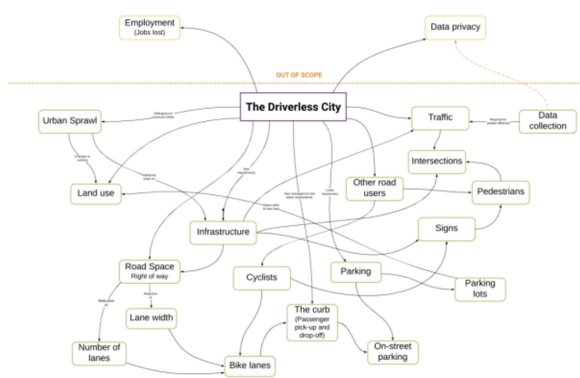
2.3. 20 minute presentation by Lead Facilitator (PI)

2.3.1. Layperson’s introduction to AVs, concepts and terminology

2.3.1.1. Quick clarifying questions.

2.3.2. Overview of concept map

3. Workshop P1 (10h00 - 80min.)



3.1. “Concept Map” Activity (60min.)

Assistant facilitators will ask the participants around the table to highlight the most important elements and identify what is missing from the map.

3.1.1. Individual Activities - Both done simultaneously (5 minutes)

3.1.1.1. Dot-voting - participants have 10 dots to vote on what they think are the most important/relevant/crucial aspects of the map. (They can vote on a connecting line if that is what's important to them, but concepts are the key)
Encourage them to assign more than 1 dot to a concept to highlight its importance

3.1.1.2. What's missing? - Silent brainstorm: have participants jot down one idea per post-it individually (If they feel inclined to, they can also cast their dot-votes to these new ideas)

3.1.2. Find patterns and collect themes. (Back together as a group)
Place post-its in corresponding areas of the map and draw the connecting lines to the rest of the map. If additional space is needed, use tape and blank sheets to extend the map in any direction.
Make sure to draw connecting lines.

3.1.3. Continue open discussion. Encourage participants to jot down their ideas as they speak and place them on the map, drawing the connecting lines. Use the following prompts to encourage more ideas:

3.1.3.1. Who
(...is the user, ...is affected, ...is in charge of deciding, etc.)

3.1.3.2. What
(...else, ...part, ...is not, etc.)

3.1.3.3. When
(now, in 10 years, next generation, during rush hour, on the weekends, etc.)

3.1.3.4. Where
(in the vehicle, on the street, on the sidewalk, in Canada, on the highway, etc.)

3.1.3.5. How
(consequences, effects, procedures, processes, requirements, needs, etc.)

3.1.3.6. Why
(expand on prompts above)

3.2. Tables report back to room (20min.)

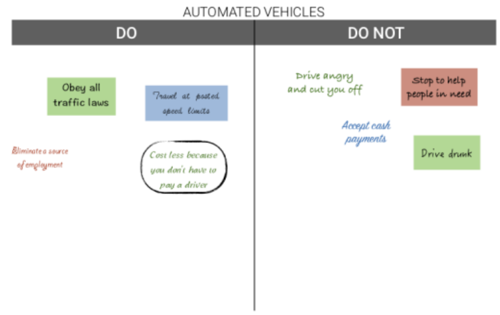
3.2.1. Ask a volunteer stand up and share back to the room the main points discussed at the table. (Defaults to facilitator if no participant volunteers)

4. Break (11h20 - 10min.)

4.1. Table facilitators will photograph the map at each of their table and then roll up and set aside at collection station. Lay out "Do's and Don'ts" sheets.

5. Workshop P2 (11h30 - 80min.)

5.1. “Do’s and Don'ts” Activity (50 min.)



5.1.1. Context setting - (5 minutes) Participants will imagine they are 25 years into the future. 2045, AVs are more ubiquitous than all rideshare companies were in 2019. Anywhere from 15% to 75% of all vehicles are driverless. Participants in their 20’s will be mid-career and probably with kids in their teenage years. Participants with children will likely have married and having children of their own. Participants over 40 will likely be retired and their parents/uncles will likely be unable to drive.

5.1.2. There are things that AVs will do and will not do by virtue of being AV. Each table has a set of cards for participants to start sorting and color-coding into each column.

5.1.3. Participants are then to continue to fill out their own post-it notes using the same color coding (An example will be demonstrated to the room):

5.1.3.1. Green marker/highlight/sticky note: Positive things

5.1.3.2. Red marker/highlight/sticky note: Negative things

5.1.3.3. Blue marker/highlight/sticky note: Neutral things

5.1.3.4. Circle with black marker: Things that are highly uncertain

5.1.4. Place or write them in corresponding side of the sheet. Find patterns and collect themes.

5.1.5. Continue open discussion. Encourage participants to jot down their ideas as they speak and place them on the sheet. Use the same prompts as above to encourage more ideas:

5.1.5.1. Who, What, When, Where, Why, How

5.2. Storywriting (15 minutes)

5.2.1. Participants will use the provided blank storyboard templates to create and illustrate a short story individually. The goal of this activity is to source insight into their <u>beliefs</u>, <u>hopes</u> and <u>fears</u>.

5.2.1.1. Stories do not require drawings or illustrations, but are encouraged and space is provided. Encourage them to put a title to their story on top, but that also is not required. They can also use more than 1 sheet if they would like.

5.2.1.2. Story should be about getting living in the city. It should not center around AVs, but interacting with them should be a feature. (Just like the movie clips where not about the vehicles themselves, encourage them to think broadly; imagination is good, but make sure Driverless Vehicles are a component)

5.3. Report back to group (20min.)

5.3.1. Round 1 - Ask a volunteer stand up and share back to the room the main points discussed at the table around “Do’s and Don’ts. (Defaults to facilitator if no participant volunteers)

5.3.2. Round 2 (optional) - Ask a volunteers stand up and share back to the room the story they wrote. (Not all tables need participate)

6. Closing (12h50 - 10min.)

Closing remarks from the workshop outcomes. Thank participants for attending and review consent terms and follow-up post data processing.

Appendix B: Futures Workshop Concept Map Feedback

Individual Concept Maps

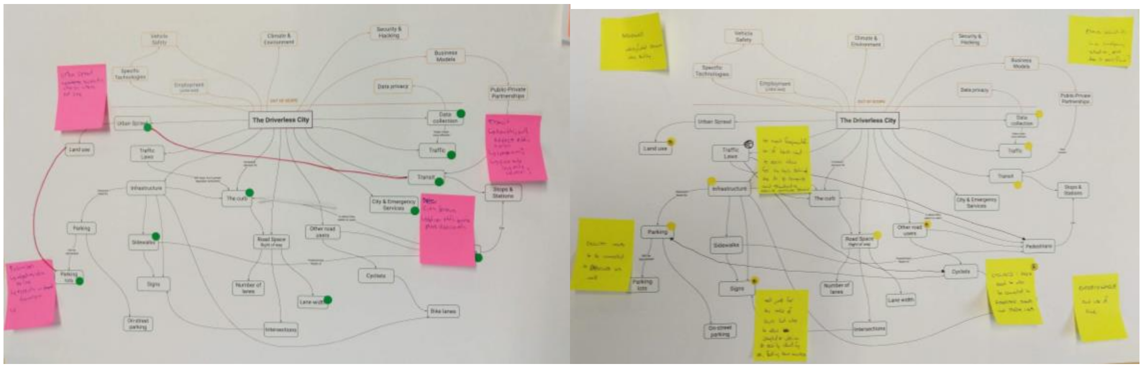


Table 1 Concept Map

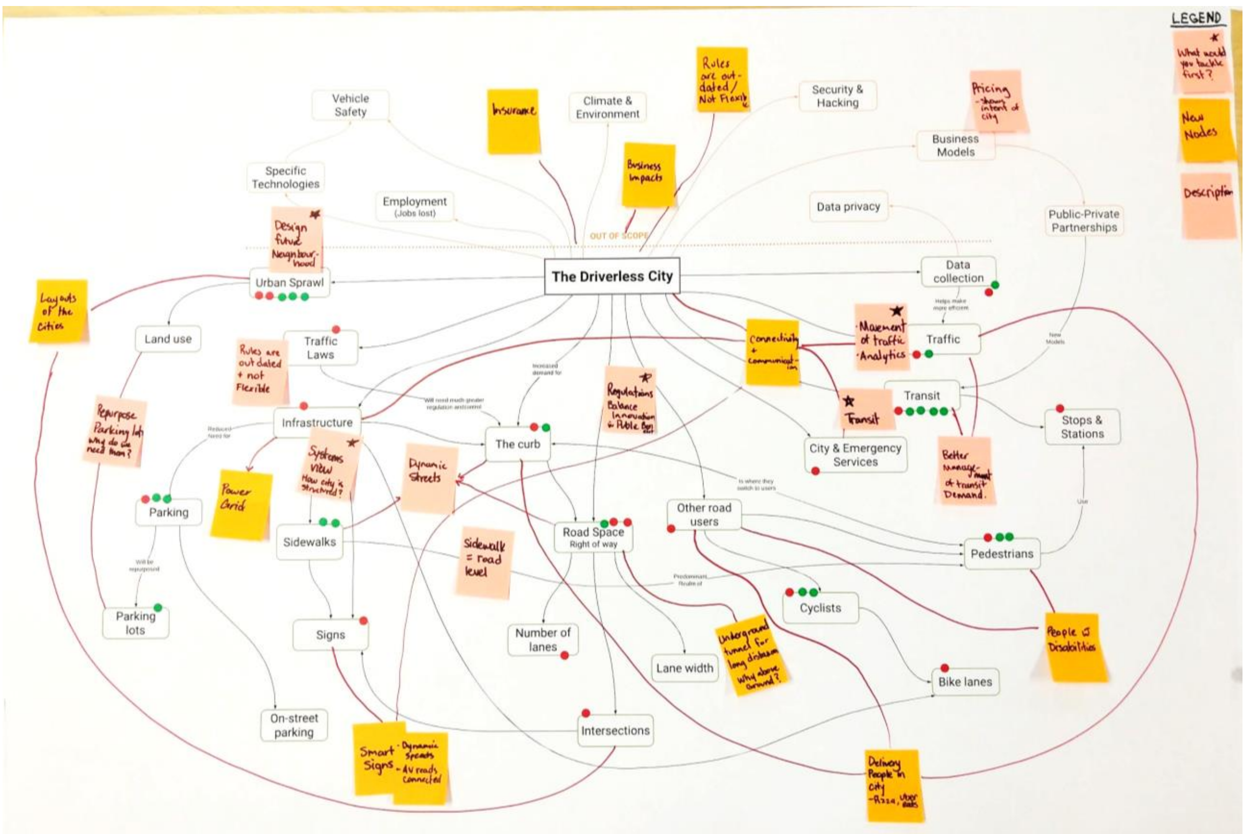
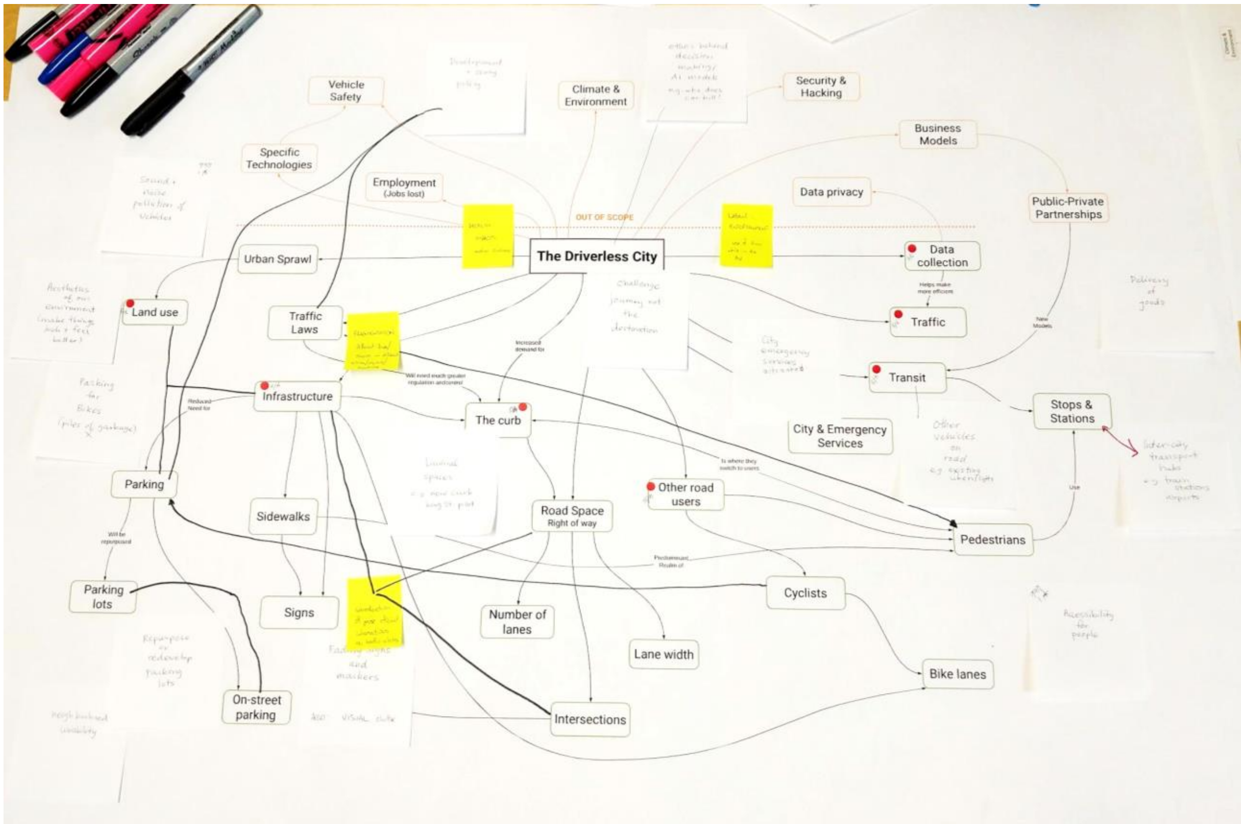


Table 2 Concept Map



The Driverless City
OUT OF SCOPE
Vehicle Safety
Climate & Environment
Security & Hacking
Business Models
Specific Technologies
Employment (Jobs lost)
Data privacy
Public-Private Partnerships
Urban Sprawl
Data collection
Land use
Traffic Laws
Traffic
Transit
Infrastructure
The curb
Stops & Stations
City & Emergency Services
Parking
Other road users
Sidewalks
Road Space Right of way
Pedestrians
Parking lots
Signs
Number of lanes
Cyclists
Lane width
Bike lanes
On-street parking
Intersections

Appendix C: Futures Workshop "Do/Don't" Notes

Delphi

- Q – what do diff colours rep? A – diff expert answers

Activity 1 (1 of 3)

- Q who is this (research) for? informing? A public, inform policy
- Q context? A cities in NA
- Q assuming insurance, ethics, AI out of scope? A – Y
- Q OOS? redesigning spaces e.g. taxes, funding > not here, next one

Discussion
- get people from A to B
  - agreed, but being in city > parts in between, the journey is the destination
  - ↔ socio-econ impact on sml businesses
- delivery of goods – what happens in pedestrian only spaces e.g. Spark St in Ottawa?
- drone delivery (air vs vehicle)
- how do transit hubs connect w/ this?
- how do old + new integrate?
- design for people not just to be fast + efficient
- laws for pedestrians on where / how walk bad
  - ↳ chaotic self expression should be allowed on foot + bike
  - ↳ conversation seating vs destination seating or see city in different way
  - ↳ being entertained on way vs @ destination
  - ↳ diff expectations on employees while traveling?
- parking lots > unlock their potential
  - generate revenue for services
- affect choices where people live
  - e.g. live downtown b/c no license, but if option to not drive to get to work effectively + timely + use time for other things – rent downtown $$$
- 1st/last mile solution for public transit? where exist
- delivery too – Amazon's biggest problem is last mile hub vs customer
- drudgery of things – tap w/ app, freed up time to do diff. things
  AV's save time + space / chg use of space
  political decision of parking lots vs on street vs green space conversion

Activity! 2-3

- tension > on street city parking vs private lots
  or bldgs w parking built e.g. condos
- design buildings meant to be repurposed > designed for
  future use (ramps bad)
- in-use car time > what is acceptable range to travel ~~to work~~
  to work? how can I use my time?
  - kiosks in car?
  - design better things to look @ out of car? e.g. flower beds
  - ads in car? trapped audience? pay for no ads?
- health impact > can't read in a car, motion sickness
  - directions of facing
- incentives designing in > buy more? do we want this
  - ↑ vehicle ownership (prefer no), time spent in vehicle
- pass cheapers rates on to consumer by having mass
  company purchase of vehicle vs private purchase
- but on all time? maintenance ↑ - new stns spfly for this
  political decisions on use across country e.g. France
- land use + systems chg a longer horizon than tech chg
- cleaning during the day, gross!
- perception of owning things > renting vs sharing
  ↳ how chg? less cost for things or more?
  ↳ pt friction > allow or don't allow certain things
- what if live in car, cheaper than hotel?
- use of living space? vs work space > spaces b/cm vacant for lg
  periods of time - chg in how relates to travel
  (blurred lines b/n live/work space)
- living + owning in a place - what does it mean to have an address?
- delivery of items > tied to you vs place
- curb > diff. b/n street + sidewalk - very interesting space
  e.g. Seattle e.g. canyons of the street - not for people
  vs Germany > Berlin + open space + options for use on rd.
  ↳ place to pick up + drop off people + stuff (delivery)
  - park @ airport?
  ↳ ~~safety~~ safety - concept of physical barrier vs marking on rd
  ↳ evolution of signage + usage e.g. for buses > flag vs a stop down
  ~~e.g.~~ - private buses vs public (e.g. Buenos Aires) (west vs not developed) developed
- designing for purpose vs afterthought e.g. bike lanes

E-3

- ~~quality~~ of life > vehicles running all the time?
    e.g. deliveries
- signage for humans > maybe soft for AVs, not needed for machines - don't need to
- switching from 4 way stops to traffic Os > AVs get it right?
  ↳ chg right of way for vehicles; pedestrians

~~surprised~~

- how does pick-up / drop-off model chg?
    e.g. drop kids to school; pick up visitors; drop-off items to someone who lost smthg; delivery of package
- autonomy to do action
- cost vs convenience > carbon footprint ↑?
    packaging?
- what happens when power fails?
    e.g. paying for beer - in fridge; reqs power to operate
    cash - what happens in a car > electricity use
    battery use + dev. of this tech y
- Q: how does adoption happen?
    - obselesence cycle?
- what is role of caregiver if dont drive anymore?
    → retrofit of car?
    → use of baby seats?
    - aging popn - how does this work with dementia?
- accessibily now becomes huge
    - model has to chg > many things need to chg for aging end users
        e.g. ... dots on phone (millenial vs aged)
    - e.g. redesign wheeltrans > on phone 1hr to book ride
        accessible bldgs > routes of travel currently not great
        predictable
- where does owning vs sharing/using fit on the map?
  ↳ e.g. repurpose garages for other things

Activity 2

- run red light > do it risk hitting something?
  will there be stoplights > if no one there - does it stop?
  jaywalking > can this be programmed? walk it safe
  regular conditions vs non-regular > safety
  e.g. lights go out + becomes 4-way stop
- asimov's laws > code in it someone needs help > maybe if vehicle empty
- cash (@ line) - question of public policy > conversion to cards / digital vs paper
  - many places going this direction to no cash > how do you accept + move cash, validate it
- help + need > this is complex - needs to be broken down
  e.g. AAA / CAA vs medical emergency
  vehicle stops > does it address problem or call someone who will
  e.g. dispatch a person
  think this is a good thing
  e.g. cold weather warning > currently can call 311 to send someone to talk to them
  e.g. person on a ledge / bridge > how do you get them down
- speed up? parameters on what can speed up > would it not operate @ optimum speed anyway if we can program?
  e.g. emergency vehicles, car pool
  ↳ feel like it's going faster - e.g. rev. engine
- travel @ posted speed limits > doesn't allow for optimization b/c still human drivers
  e.g. good for travel in res. neigh-hoods w kids to allow for human reaction times
- consider extreme weather
- chauffer children >
- food instantaneously > gratification > is this good?
  - grocery shopping - like gets me out of the house
    - ↓ wasted food
    - hate lines, people - want to look @ ingredients
    - hate waiting
- do they have to drive around to get rides vs being programmed
- more expensive to purchase
  e.g. becomes investment vehicle for individual
  takes away motivation to purchase personally if more $
  ↳ more tech so more $
  ↳ economies of scale > production lines to ↓ cost

Chris Notes

Movies

- Demolition Man
  - Not too far Off from teslas now
  - No traffic!
  - Similar to An airplane when caution/crisis is present.
  - Interesting to see other cars react to another car thats in manual mode.
- Minority Report
  - Communal car networks
  - Both models
    - Sterring wheel
    - No steering - fully Autonomous
  - Affinity to current infrastructure systems
    - ie pavement, wheels etc.
    - Above ground
- I, Robot
  -

Level Setting

- [x] Terms - ie EV, AV, Platooning ADAS LIDAR,
- [x] AV Levels
- [x]

Activity 1

- Urban Sprawl
  - Paradigm Shift
- Needs for a car
- Lift / Uber
  - Supposed to close Gaps in Commuting/transit
    - ↳ Causing more traffic!
  - Uber is inefficient
    - ↳ As many driven km to pick up people vs drivingthem
  - Last mile / Transit options in suburban cities
- Connectivity is the utopia

- "Ignorance of space"
  - People vs. Car space
  - ↓space ↑space

▶ Speed up or down ~~?~~ if in a hurry?
- Safety systems
- All ready at max speeds ← should already be @ max.

Save most lives or Save my life

▶ Drive Angry / cut you off?

▶ Compete w Public Transit

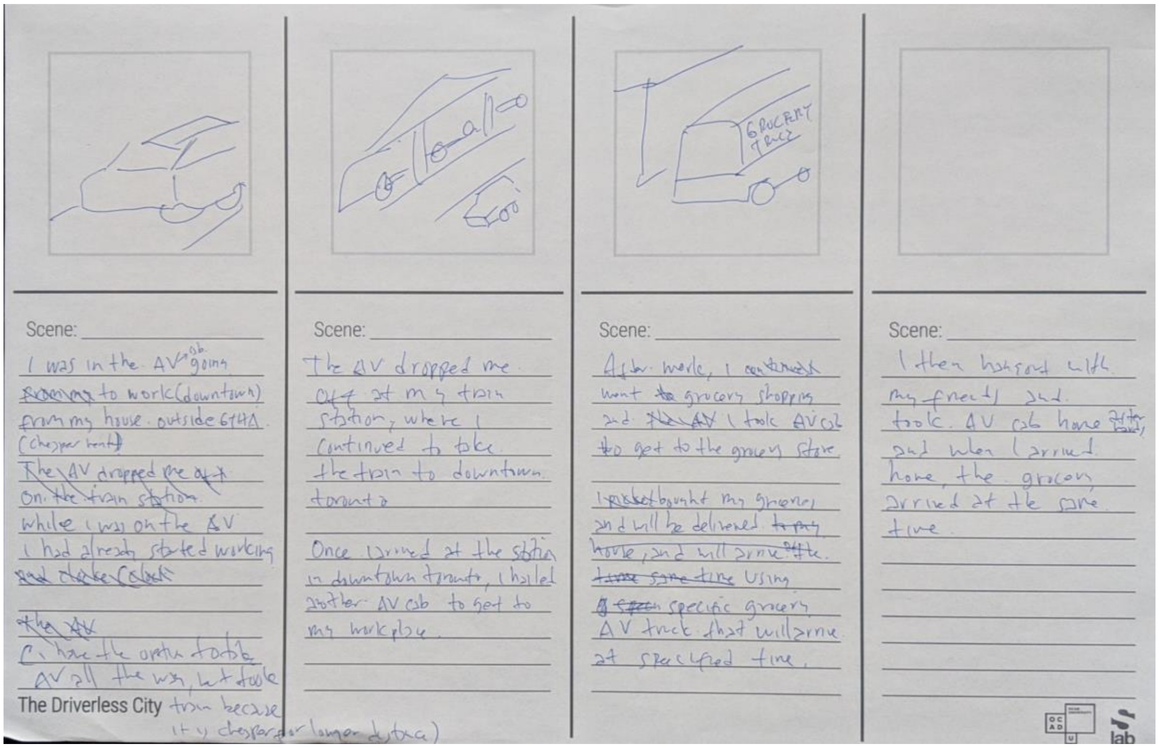
Good: User options to Commute

Bad: Congestion issues
Tax dollars to compensate Public Transit

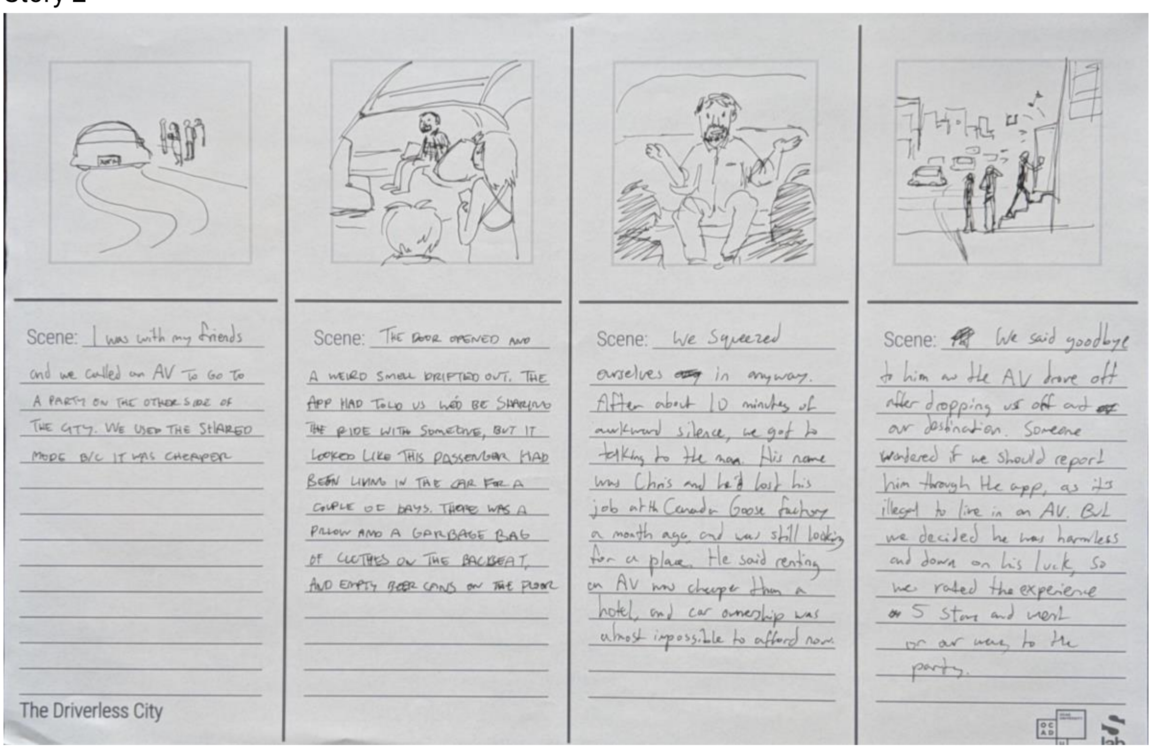
▶ Private AVs Stopping for help
Unsure b/c of user choice of car's action

Appendix D: Futures Workshop Story Writing

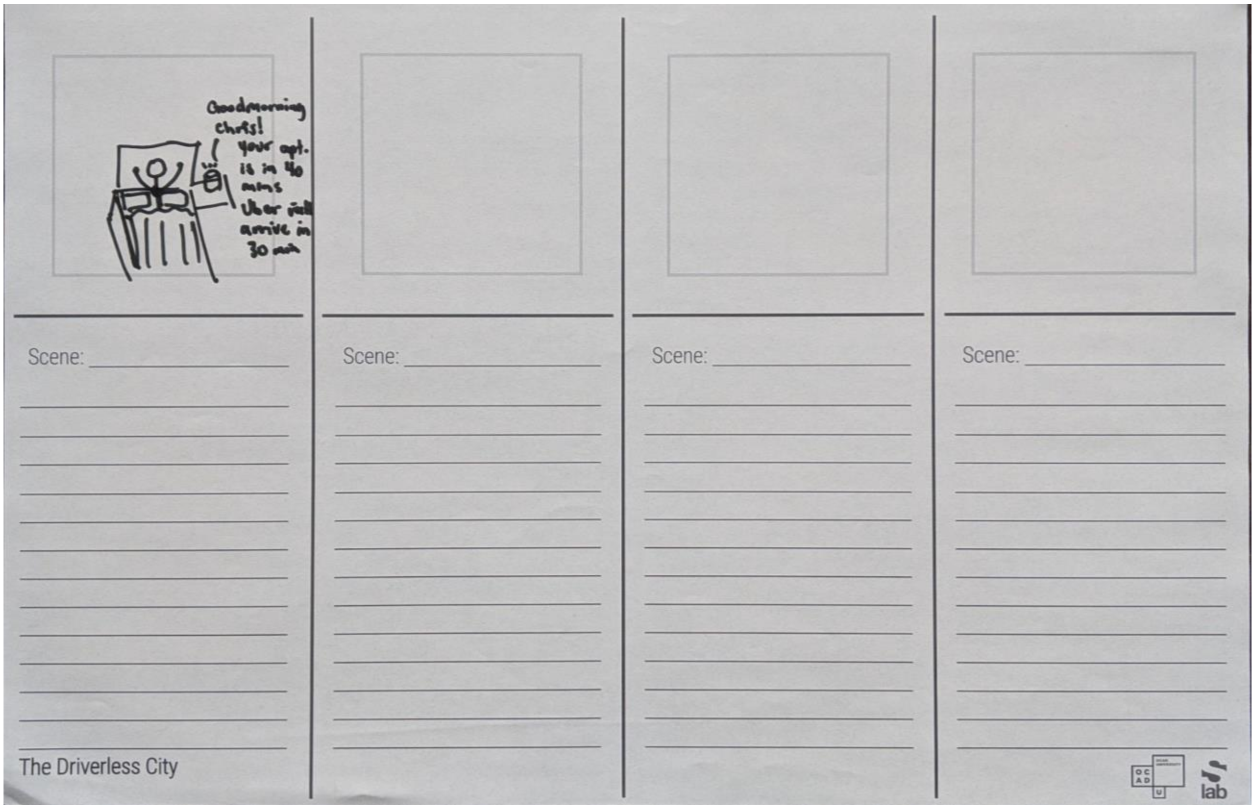
Story 1



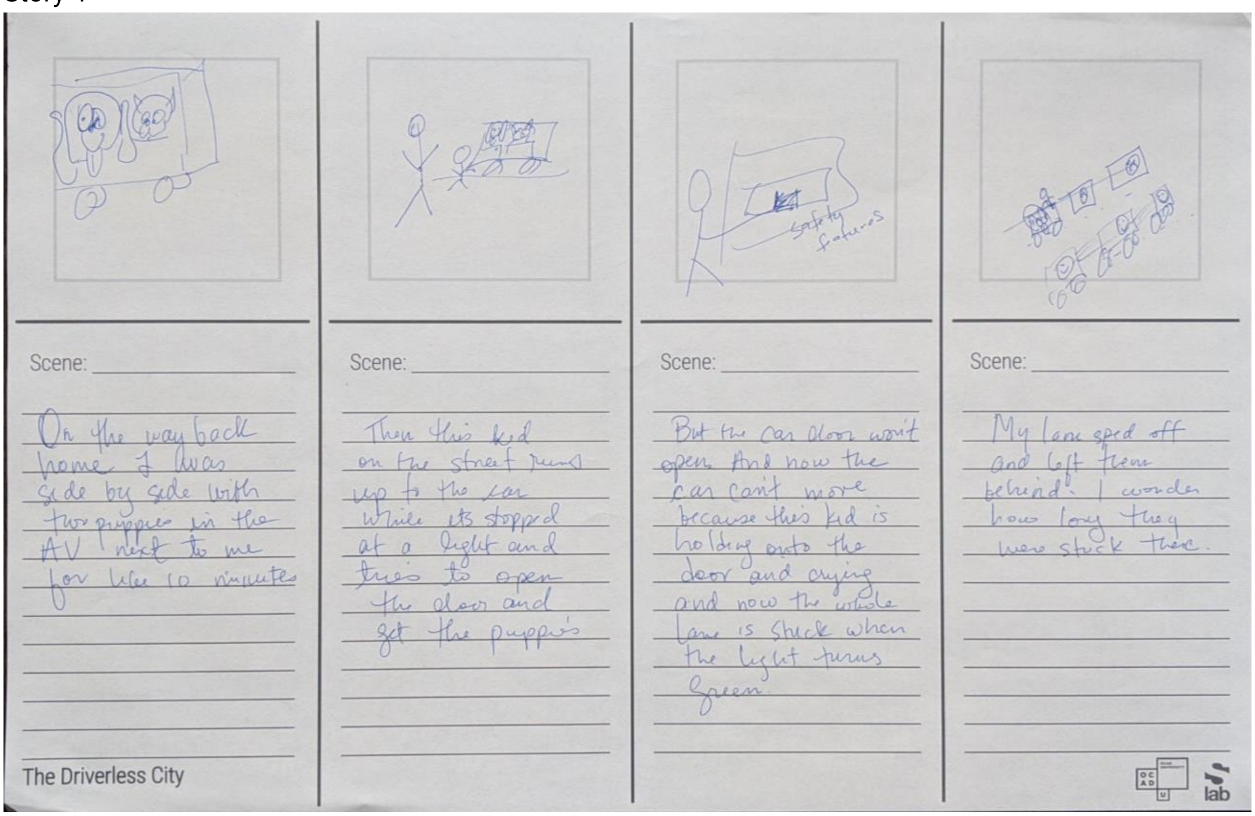
Story 2



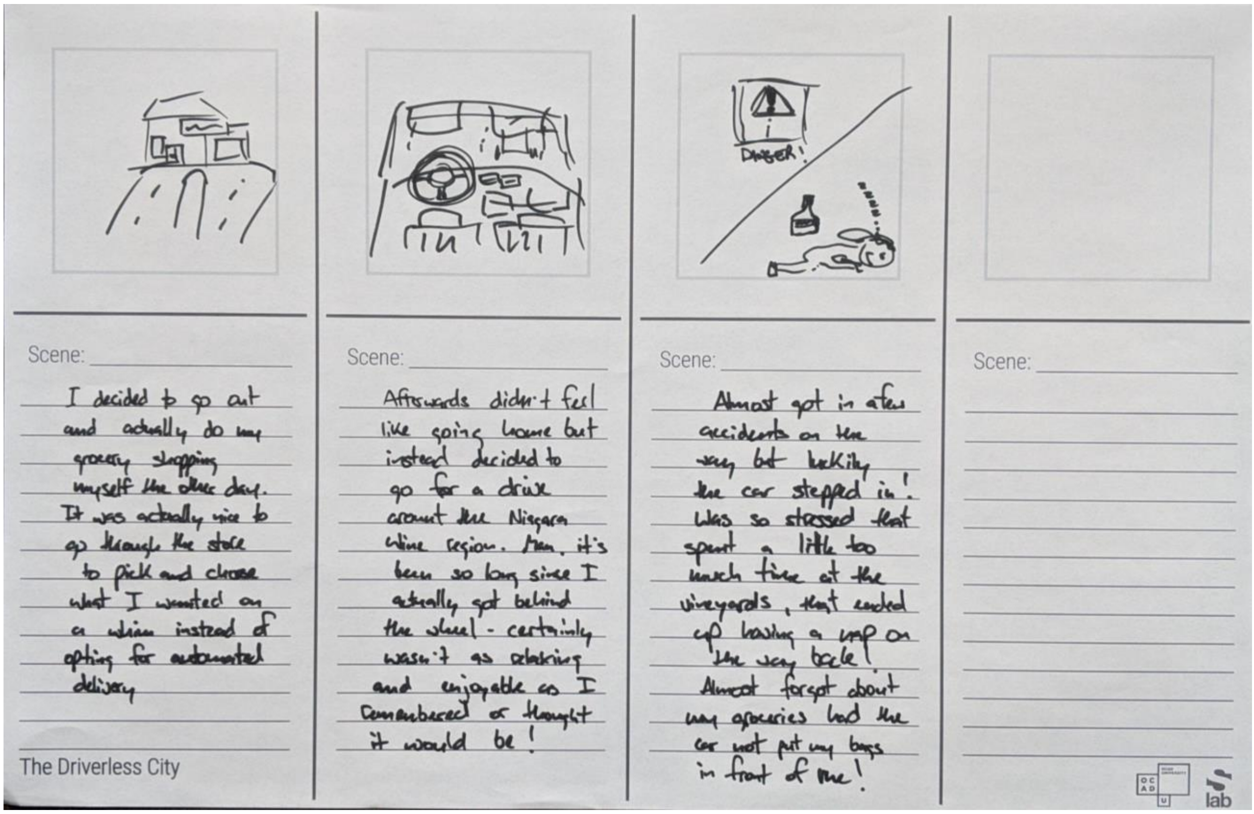
Story 3



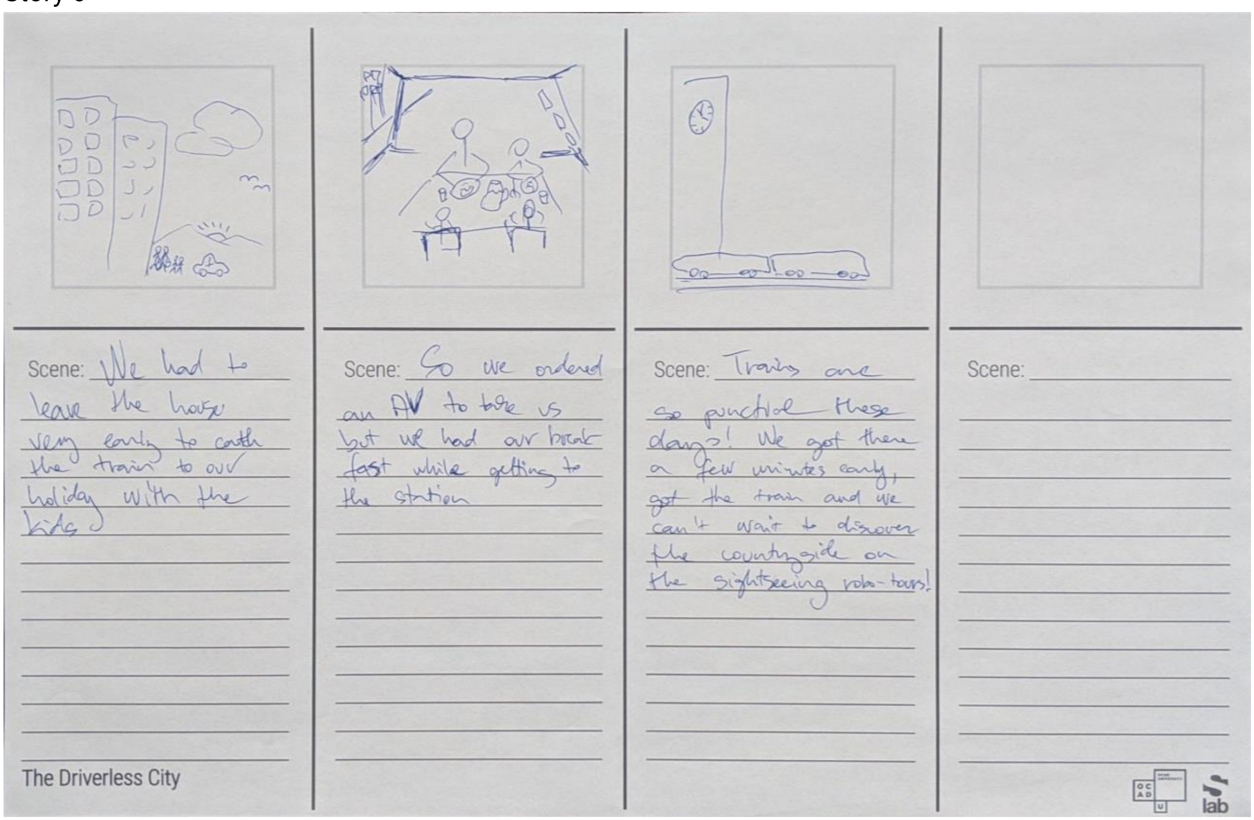
Story 4



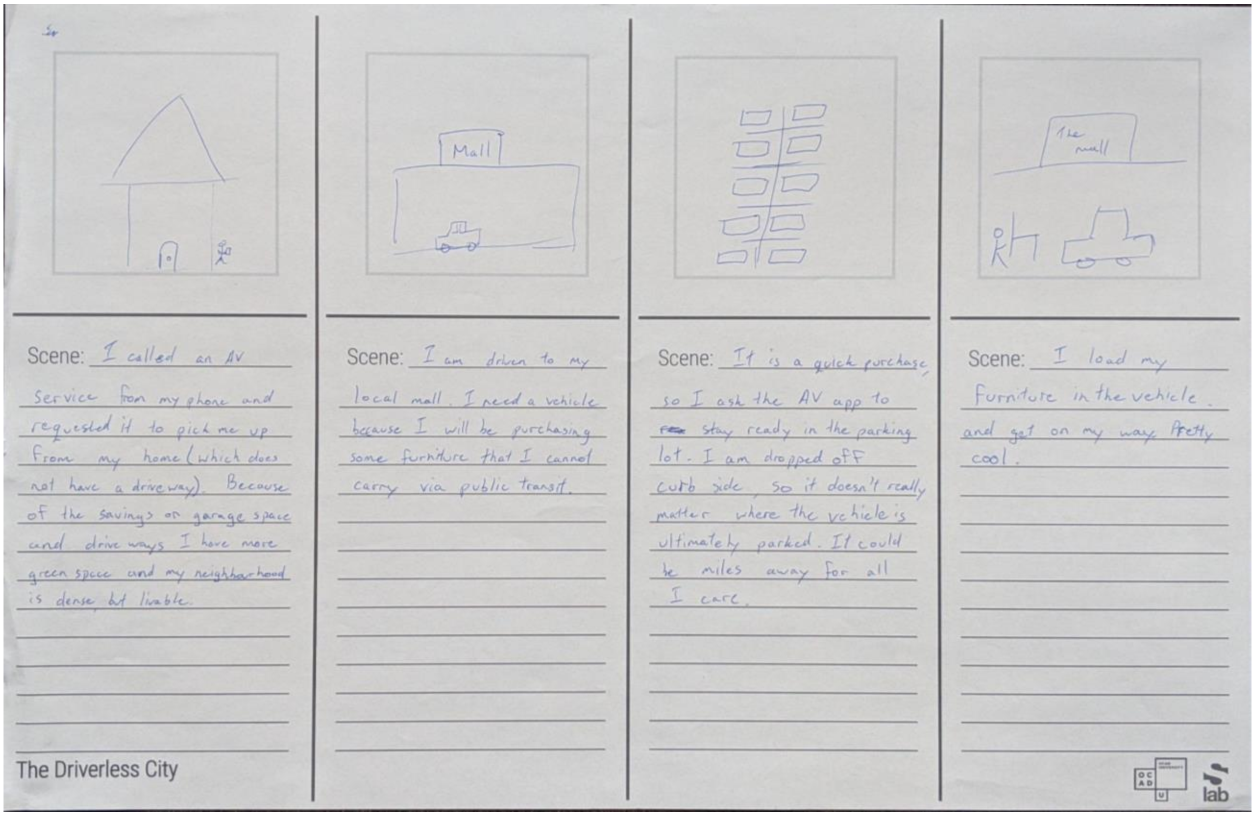
Story 5


DANGER!
Scene:
I decided to go out and actually do my grocery shopping myself the other day. It was actually nice to go through the store to pick and choose what I wanted on a whim instead of opting for automated delivery
Scene:
Afterwards didn't feel like going home but instead decided to go for a drive around the Niagara wine region. Man, it's been so long since I actually got behind the wheel - certainly wasn't as relaxing and enjoyable as I remembered or thought it would be!
Scene:
Almost got in a few accidents on the way but luckily the car stepped in!. Was so stressed that spent a little too much time at the vineyards, that ended up having a nap on the way back! Almost forgot about my groceries had the car not put my bags in front of me!
Scene:
The Driverless City
lab

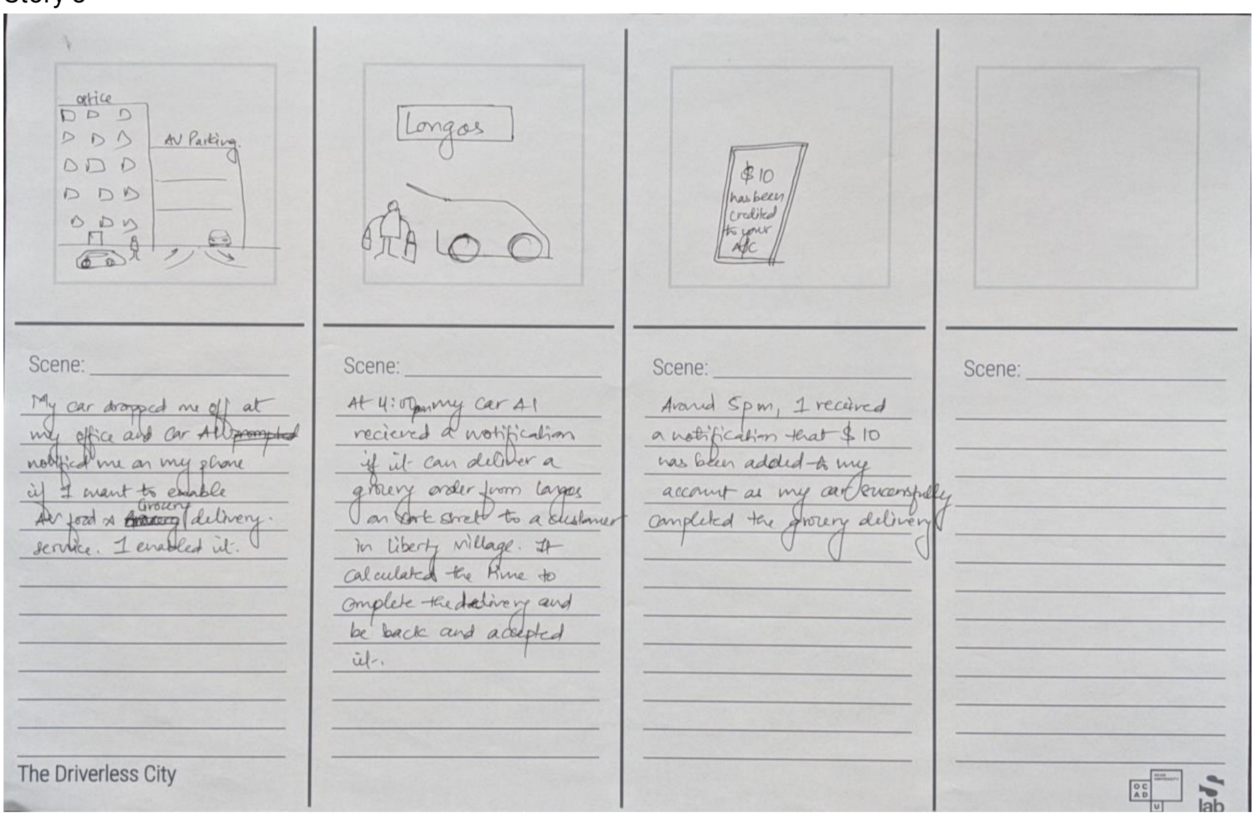
Story 6


Scene: We had to leave the house very early to catch the train to our holiday with the kids
Scene: So we ordered an AV to take us but we had our breakfast while getting to the station
Scene: Trains are so punctual these days! We got there a few minutes early, got the train and we can't wait to discover the countryside on the sightseeing robo-tours!
Scene:
The Driverless City
lab

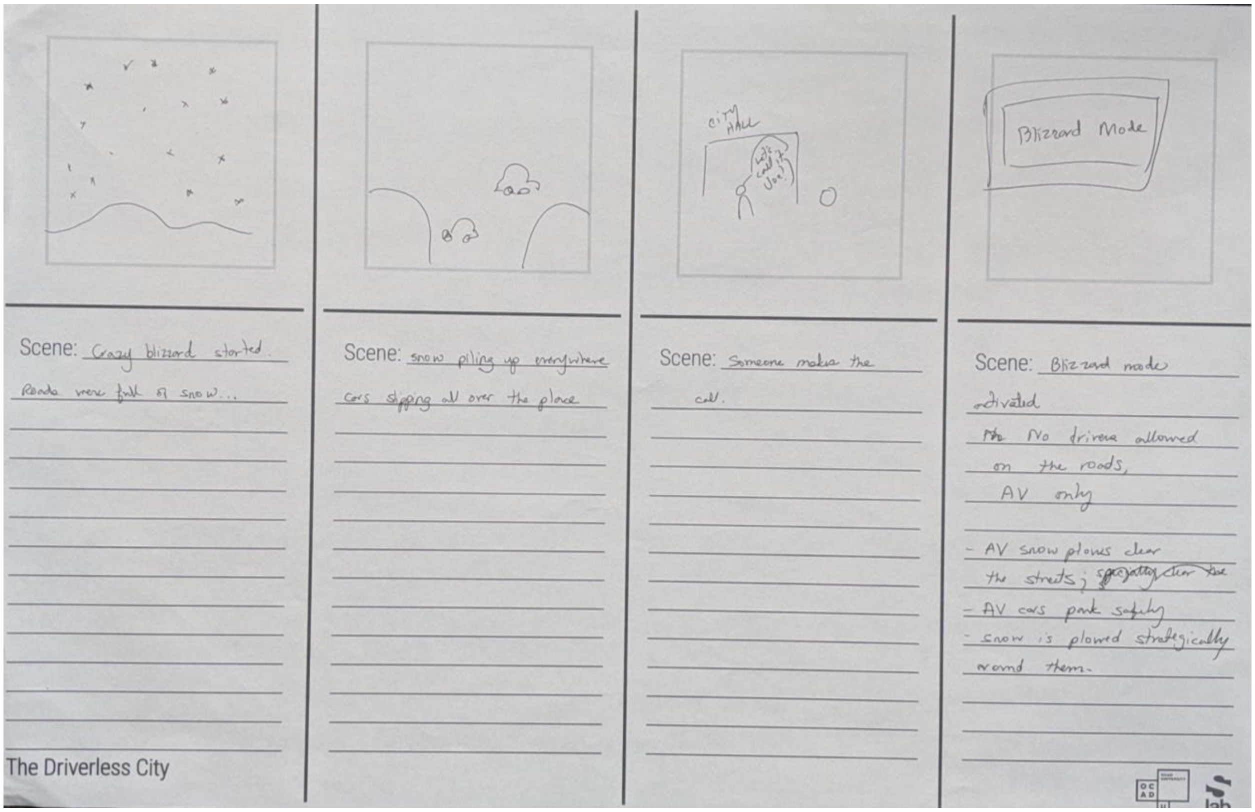
Story 7



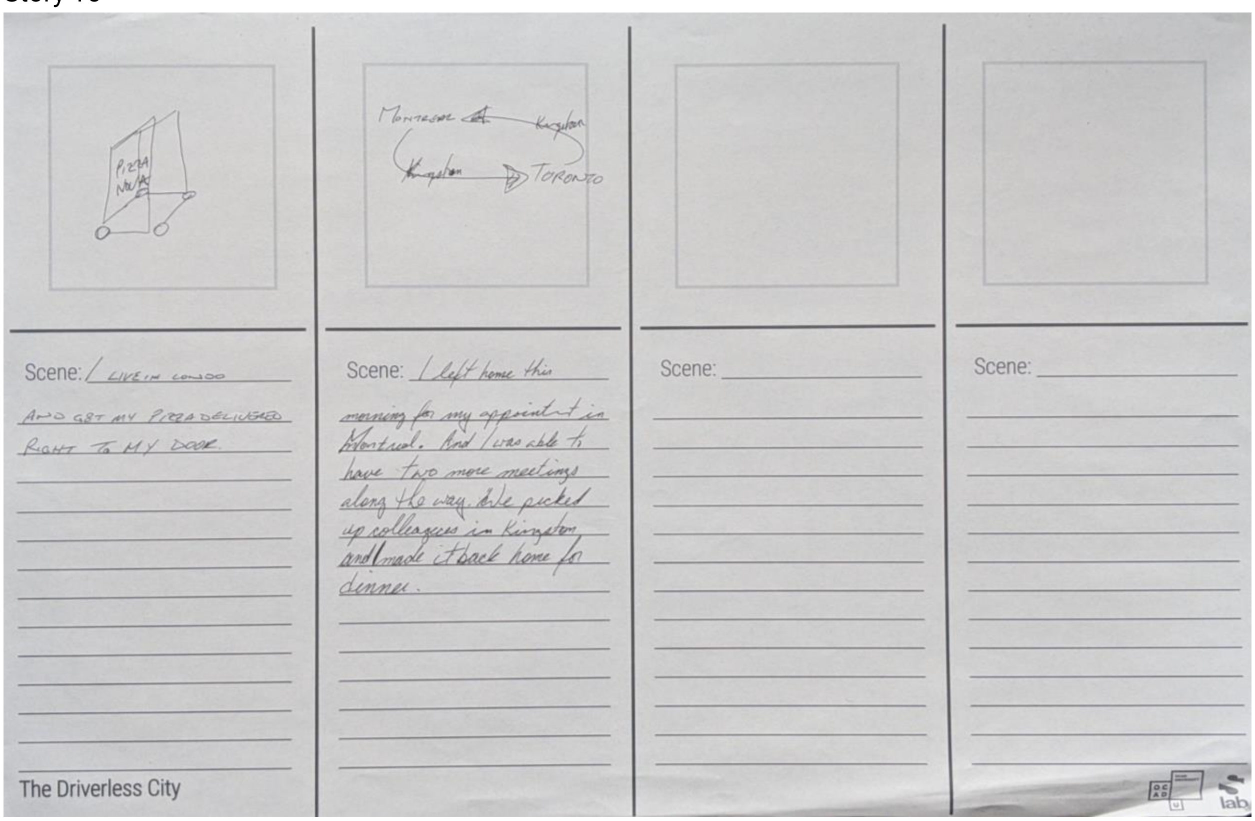
Story 8



Story 9


CITY HALL
Blizzard Mode
Scene: Crazy blizzard started. Roads were full of snow...
Scene: snow piling up everywhere cars slipping all over the place
Scene: Someone makes the call.
Scene: Blizzard mode activated
No drivers allowed on the roads, AV only
- AV snow plows clear the streets;
- AV cars park safely
- snow is plowed strategically around them.
The Driverless City

Story 10


PIZZA NOVA
MONTREAL
Kingston
Kingston
TORONTO
Scene: I LIVE IN CONDO AND GET MY PIZZA DELIVERED RIGHT TO MY DOOR.
Scene: I left home this morning for my appointment in Montreal. And I was able to have two more meetings along the way. We picked up colleagues in Kingston and made it back home for dinner.
Scene:
Scene:
The Driverless City

Appendix E: Delphi Survey

The Driverless City

Level Setting

Thank you for agreeing to participate in this Research Study.

The purpose of this study is to help narrow down some potential ways Automated Vehicles (AVs) may affect the way cities are designed and built in the future.

Please refrain from discussing the questions in this survey with your colleagues for the duration of the study. They may also be participants and doing so may skew the results.

This survey has 2 sections, and there are 10 questions in total. Please respond to the questions by providing your professional estimate/forecast on specific impacts of AV technology. Make sure to enter the most likely outcome. Instead of a positive or negative outlook, enter the most realistic one.

For purposes of this survey, consider the following:

- AV (Driverless vehicle) refers to SAE levels 4 & 5
- The geographic scope is North America (Canada and the U.S., only)

The further you project into the future, the harder it is to forecast. Responses are set initially for each year, then every 2.5 years, then every 5, then every decade.
The symbols before each year indicate:

• 10 years (Decade)
◦ 5 years
-- Individual year

You will be able to scroll back and adjust the sliders on previous questions if subsequent questions make you reconsider what you entered on the first pass.

Please provide any supporting evidence in the comments box after the question if relevant.
If there are any articles, research or statistics that are key to your forecast, please provide a link or bibliographical reference. These will be anonymously shared in the next round.

You can reference your own publications. Other participants will receive the details of the publication, but *not who* is citing it.

1. Name *

2. email *

Please do not hesitate to contact the Principal Investigator if you have any questions:

Sergio De Lara
MDes candidate, Strategic Foresight and Innovation
OCAD University

Next

0%

The Driverless City

Not if, but when

This section of the survey deals with circumstances that are certain to occur, but retain high uncertainty regarding when and to what degree they will occur.

Provide your forecast by moving the slider on each year. The further you project into the future, the harder it is to forecast. Responses are set initially for each year, then every 2.5 years, then 5, then every decade.
The symbols before each year indicate:

• 10 years (Decade)
◦ 5 years
-- Individual year

You will be able to scroll back and adjust the sliders on previous questions if subsequent questions make you reconsider what you entered on the first pass.

Please provide any supporting evidence in the comments box after the question if relevant.
If there are any articles, studies or statistics that are key to your forecast, please provide a link or bibliographical reference. These will be anonymously shared in the next round.
You can reference your own publications. Other participants will receive the details of the publication, but *not who* is citing it.

For this survey, keep the following in mind:

- AV (Driverless vehicle) refer to SAE levels 4 & 5
- The geographic scope is North America (Canada and the U.S., only)

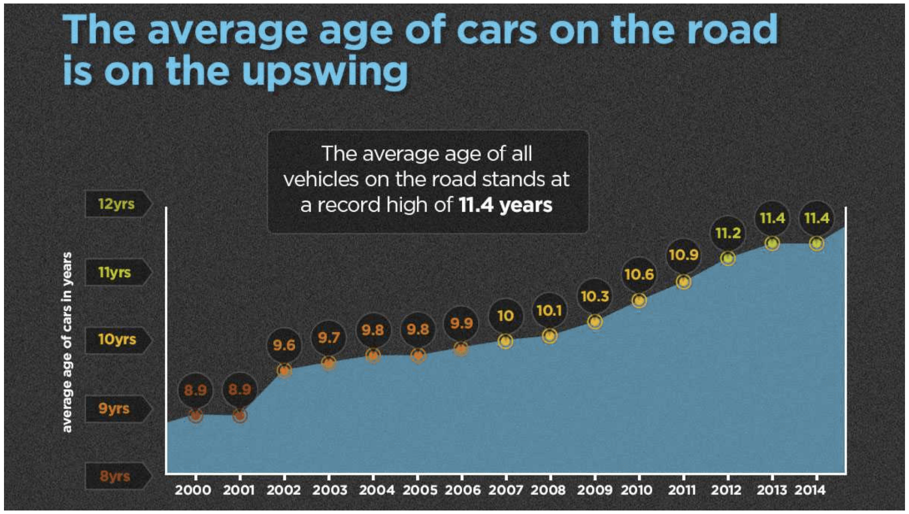
---

3. **AV PENETRATION**
What percentage of vehicles on the road will be *human-driven* and what percent will be *driverless (AVs)*?

If you don't have data that differs, consider the following:

- Average life expectancy of a vehicle in the U.S is 15.36 years

- Average life expectancy of a vehicle in Canada is 12.88 years
  - In 2000, 33.7 % of vehicles in Canada lasted at least 15 years
  - In 2017, 54 % of vehicles in Canada lasted at least 15 years



Sources: Nationwide Mutual Insurance Company, DesRosiers Automotive Consultants, Consumer Reports, Inc.

For each year, slide the marker to the percent of vehicles you forecast will be **driverless (AV)**:
*

0% AV (all human-driven) 50% Mix 100% AV (all driverless)

0 10 20 30 40 50 60 70 80 90 100

- 2020
-- 2021
-- 2022
-- 2023
-- 2024
◦ 2025
-- 2027
- 2030

◦ 2035

•2040

◦ 2045

• 2050

• 2060

• 2070

Comments

4. **AV MODALITY**

What percentage of vehicles on the road will be *private* and what percentage will be *shared*?

These percentages are **independent** of the number or percent of AV's on the road.
(i.e.: You could have 1% of vehicles be AVs and be 100% shared, or 90% of vehicles be AV and be 10% shared)

Private vehicles include:

- Status quo: individual or family ownership
- Used exclusively by family and friends, but not open to the broader public.

"Shared" vehicles include:

- Owned and managed as part of a fleet by an organization (e.g. a fleet of AV's owned and managed by Uber/Lyft/Zipcar/Flex).
- Micro-fleets managed by a larger, city-wide platform (Privately owned, but used by the broader public. e.g. Turo)
- Public transit vehicles (including shuttles and buses **but excluding** trains, subways and other vehicles on tracks and rails)

For each year, slide the marker to the percent of vehicles you forecast will be **shared**:
*

0% SHARED (all private) 50% Mix 100% SHARED (none private)

	0	10	20	30	40	50	60	70	80	90	100	
• 2020												☐ Not Applicable
-- 2021												☐ Not Applicable
-- 2022												☐ Not Applicable
-- 2023												☐ Not Applicable
-- 2024												☐ Not Applicable
◦ 2025												☐ Not Applicable
-- 2027												☐ Not Applicable
• 2030												
◦ 2035												
• 2040												
◦ 2045												
• 2050												
• 2060												
• 2070												

Comments

5. **AV FUNCTION**

What percentage of AV's on the road will transport *cargo* and what percentage will transport *human passengers*?

These percentages are **independent** of the number or percent of AV's on the road.

Cargo vehicles include:

- Mobile vending machines
- Food and product delivery rovers.
- Freight trucks that may tether or link to human drivers, but can't themselves hold one.

Human passenger AV's are ***designed and meant*** to carry people, regardless of whether they can also carry cargo or move empty. These include:

- Privately or publicly owned vehicles transporting people (including robo-taxis and family cars)
- Service and Delivery AV's that require a human operator or service person (such as driverless garbage truck with human collectors, or an ambulance with a paramedic and patient)

For each year, slide the marker to the percent of vehicles you forecast will transport **human passengers**:
*

0% Human Passengers (all cargo) | 50% Mix | 100% Human Passengers (zero cargo)

0 10 20 30 40 50 60 70 80 90 100

•2020 ☐ Not Applicable

-- 2021 ☐ Not Applicable

-- 2022 ☐ Not Applicable

-- 2023 ☐ Not Applicable

-- 2024 ☐ Not Applicable

◦ 2025 ☐ Not Applicable

-- 2027 ☐ Not Applicable

- 2030
- 2035
- 2040
- 2045
- 2050
- 2060
- 2070

Comments

6. **PARKING**

What percentage of current parking space will *remain as parking space* and what percentage will be *repurposed*?

Different cities across Canada and the U.S. have different amounts of space dedicated to vehicle parking. They vary in how they are measured (total square meters/feet, density, total number of spaces, spaces per capita/household, etc.) and in what gets measured (public vs private, on street vs off). More importantly, the quantity itself varies greatly from city to city, as different laws, policies, and densities ask for different amounts of parking (this also includes the availability of options such as public transit and active mobility).

For this question, consider an *average change* in the amount of parking across all cities.

As AV's roll out and require less parking, this question intends to forecast how much of this land will be opened up for redevelopment or repurposing, and how much of it will need to remain as parking.

For each year, slide the marker to the *percent of parking* that will be **repurposed**:
Consider 2019 as a starting point at 0% (current state is 100% of existing parking - none has been transformed)
*

0% Repurposed (100% parking)	50% - Half of existing	100% Repurposed (zero parking)

	0	10	20	30	40	50	60	70	80	90	100
• 2020											
-- 2021											
-- 2022											
-- 2023											
-- 2024											
◦ 2025											
-- 2027											
• 2030											
◦ 2035											
• 2040											
◦ 2045											
• 2050											
• 2060											
• 2070											

Comments

Please do not hesitate to contact the Principal Investigator if you have any questions:

Sergio De Lara
MDes candidate, Strategic Foresight and Innovation

OCAD University

Note: The "percent complete" tracker below is inaccurate
You are more than halfway through the survey.

Back Next

25%

The Driverless City

Not if, but how much

This section of the survey deals with circumstances that are very unlikely to remain the same and continue as they have. However, they beget uncertainty regarding how they will shift; which direction the trend will follow.
They are more contentious because there is high uncertainty regarding when and how much these issues will either accelerate or decelerate.

Provide your forecast by moving the slider on each year. The further you project into the future, the harder it is to forecast. Responses are set initially for each year, then every 2.5 years, then every 5, then every decade.
The symbols before each year indicate:

• 10 years (Decade)
◦ 5 years
-- Individual year

You will be able to scroll back and adjust the sliders on previous questions if subsequent questions make you reconsider what you entered on the first pass.

Please provide any supporting evidence in the comments box after the question if relevant.
If there are any articles, studies or statistics that are key to your forecast, please provide a link or bibliographical reference. These will be anonymously shared in the next round.
You can reference your own publications. Other participants will receive the details of the publication, but *not who* is citing it.

Continue keeping the following in mind:

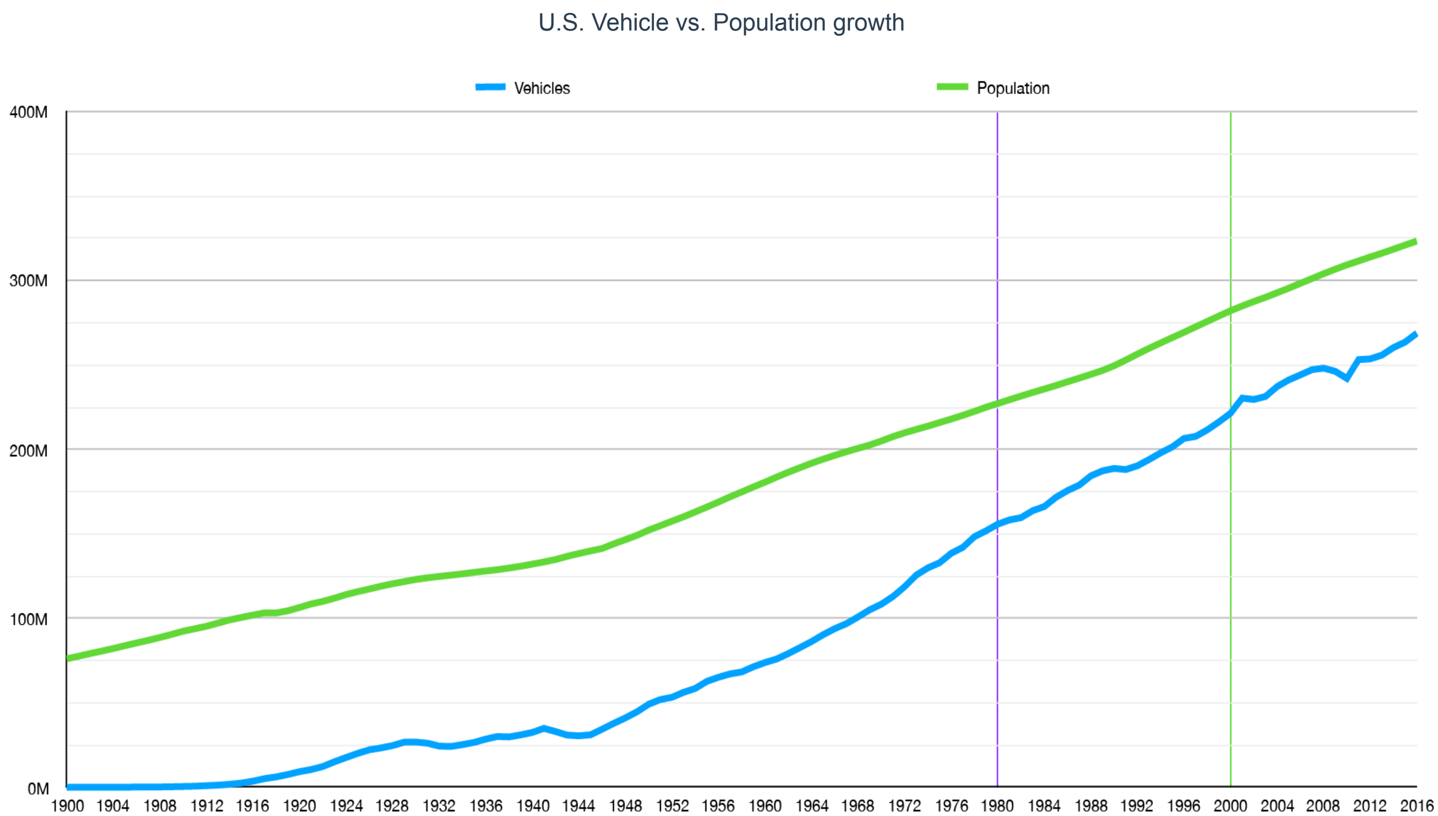
- AV (Driverless vehicle) refer to SAE levels 4 & 5
- The geographic scope is North America (Canada and the U.S., only)

If you don't have data that differs, consider the following:

- Average life expectancy of a vehicle in the U.S is 15.36 years
- Average life expectancy of a vehicle in Canada is 12.88 years

---

VEHICLES ON THE ROAD
Will AV's increase or decrease the number of vehicles on the road?



Source: U.S. Department of Transportation's Federal Highway Administration, US Census Bureau

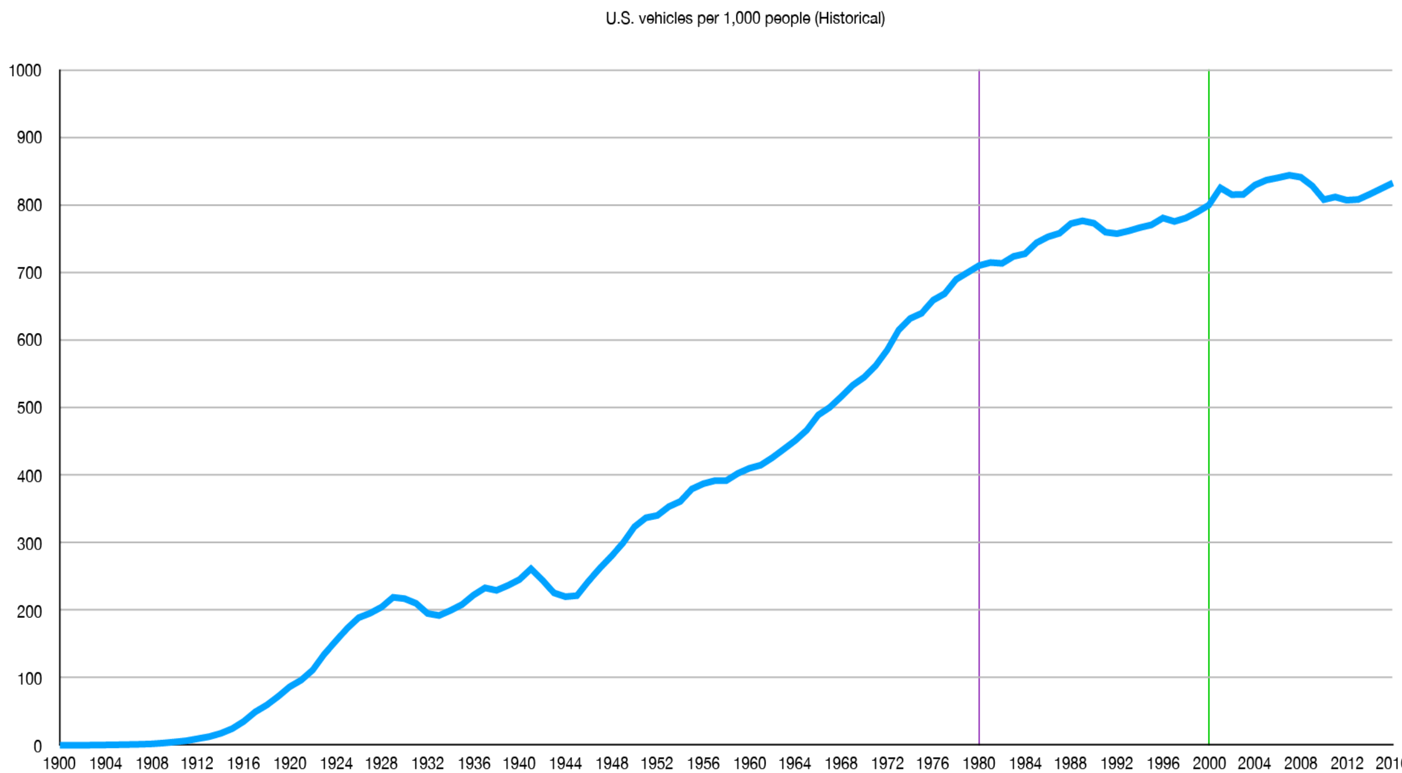
Total number of vehicles in circulation is too abstract and unrelatable a concept for most people to work with. A more pragmatic approach would be to use a percent or ratio: "Road Motor Vehicles per Thousand People". This ratio can very easily be converted to percentiles or palatable ratios. (e.g. Canada's latest 652 vehicles per 1000 people can be expressed as "0.65 vehicles per capita", "almost 2 cars for every 3 persons" or "there are 35% less cars than there are people"

NOTE: These counts include cars, vans, buses, and freight and other trucks; but excludes trailers, off-road, construction, farming, motorcycles and other two-wheelers.

The following graph demonstrates the historical Vehicles per 1000 people in the United States from 1900–2016 as a reference to North American trends and patterns (Canadian data was not found going this far back).

- The green line marks the starting point for the subsequent two graphs.

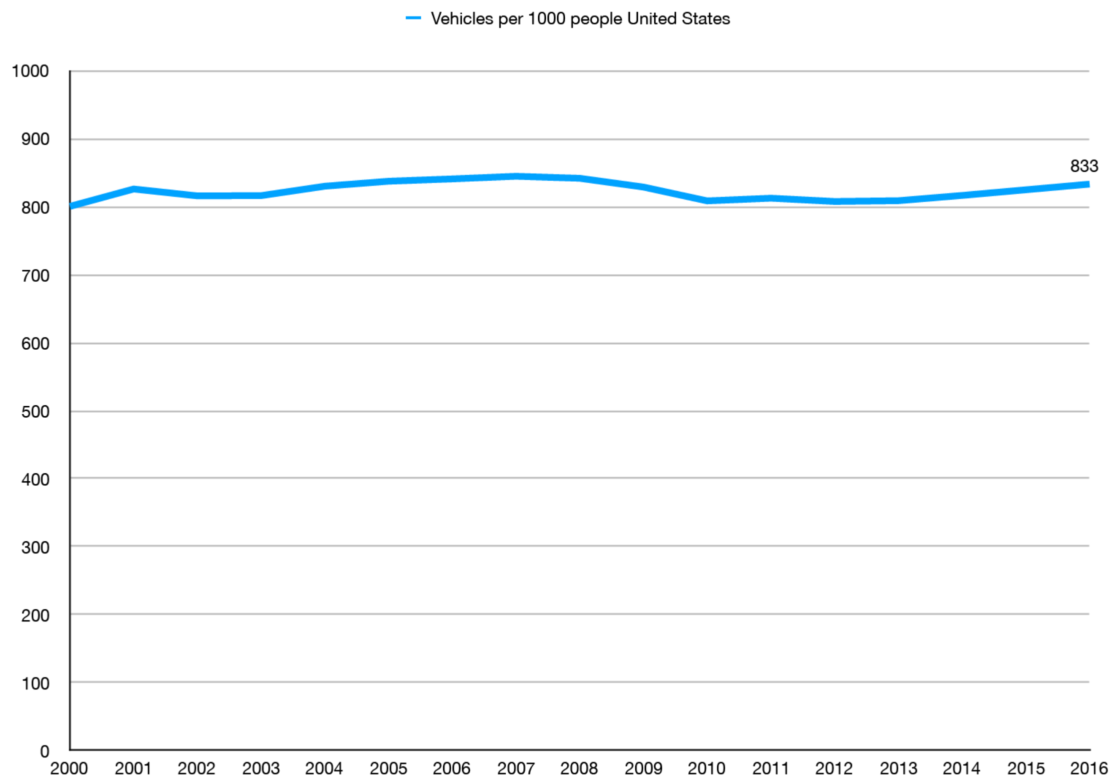
- The purple line marks 50 years into the past for reference.
  (Comparatively, the survey you are completing now asks for a forecast 50 years into the future)



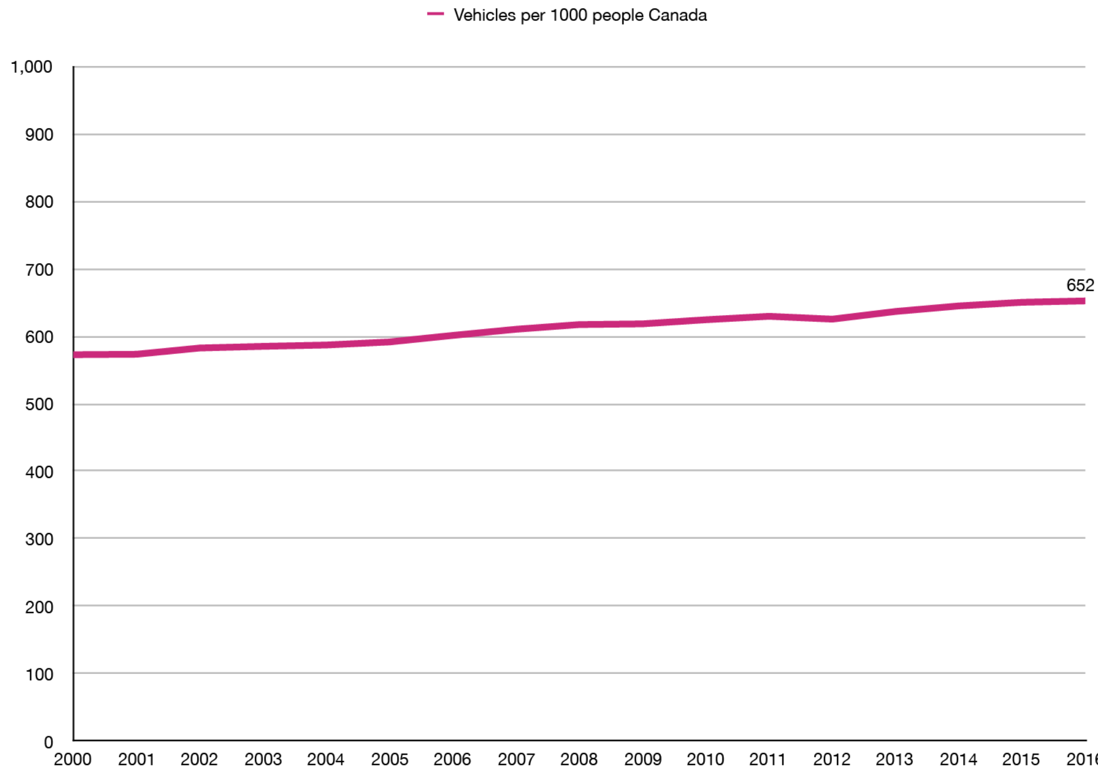
Source: Oak Ridge National Laboratory, *[Transportation Energy Data Book: Edition 35]*, ORNL-6990, Oak Ridge, TN, September 2016, Tables 3.5 and 3.6.

The following two graphs show the most complete data available for both Canada and the United States. Use these as your starting baseline for your corresponding forecast.

Data for 2017 and 2018 is incomplete and was not included for these reasons.



Source: Oak Ridge National Laboratory, *Transportation Energy Data Book: Edition 35*, ORNL-6990, Oak Ridge, TN, September 2016, Tables 3.5 and 3.6.



Sources: Statistics Canada. [Table 23-10-0067-01 Road motor vehicle registrations, by type of vehicle]

Statistics Canada. [Table 17-10-0005-01 Population estimates on July 1st, by age and sex]

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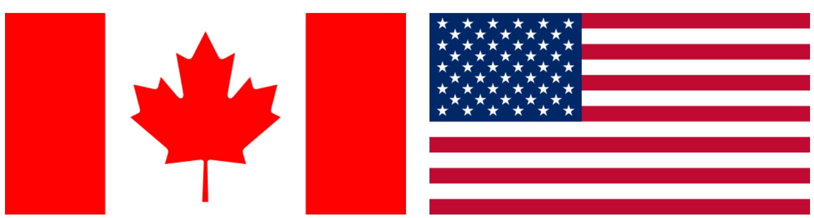
7. For the following question, please select your home/base country, i.e. the one your expertise is based on.



Which country are you providing a forecast for question 8 (AV Population)?
*

-- Please Select --

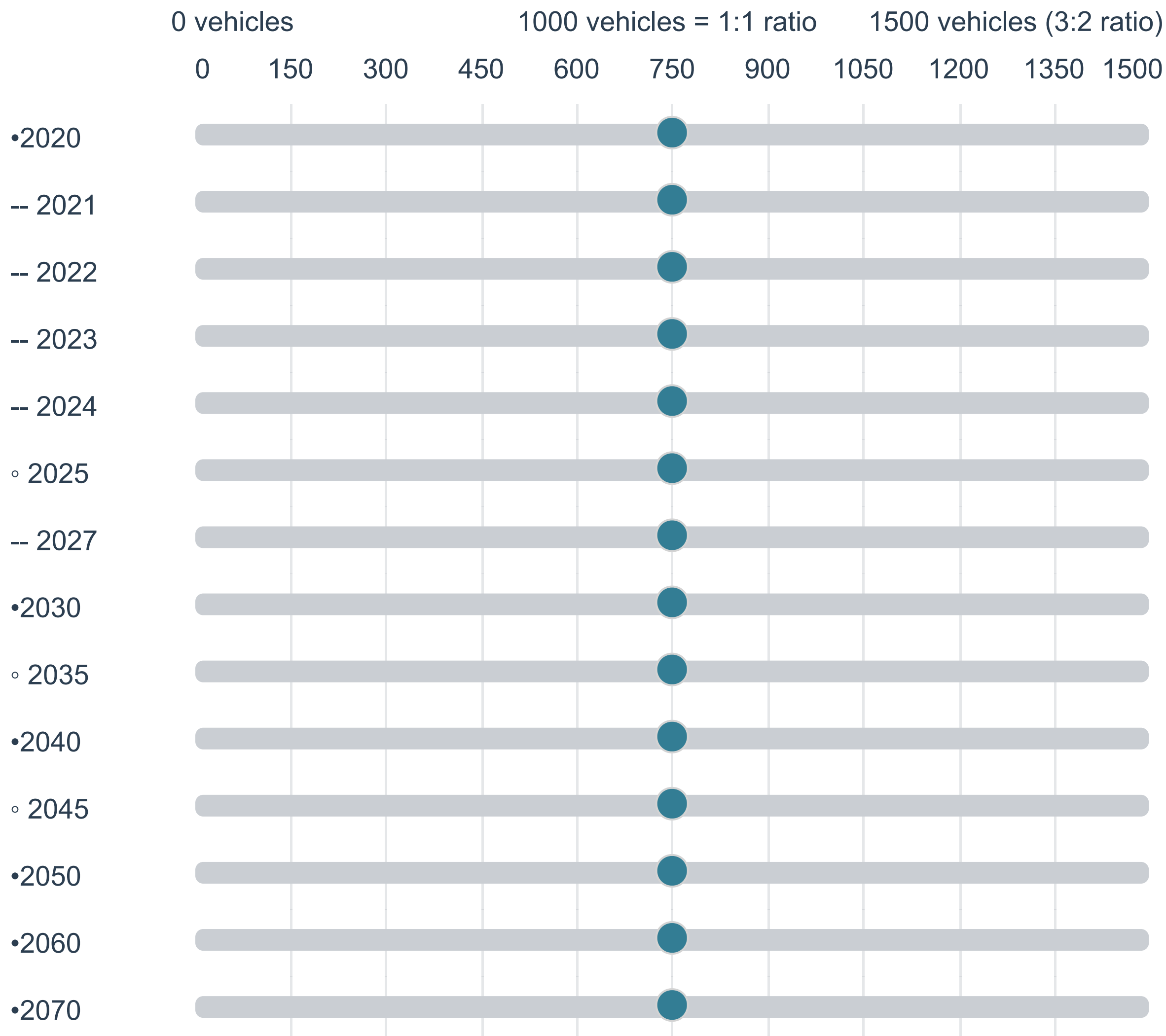
8. **AV POPULATION**

How many road motor vehicles per 1,000 inhabitants will there be?

2016 Starting points (previous marker as per charts and question above) are:

- Canada: 652
- United States: 833

*



Comments

9. **URBAN SPRAWL**

As AV's replace the conventional vehicles, will they induce *more sprawl* or will cities become more *compact and connected*?

Although there is no universal, agreed-upon way to measure Urban Sprawl, one of the most cited is the index created by Smart Growth America. Their report is based on research published by the Metropolitan Research Center at the University of Utah, prepared for the National Cancer Institute at the National Institutes of Health, and the Ford Foundation.

Metropolitan Statistical Areas and metropolitan counties were evaluated using four main factors:

1) development density
2) land use mix
3) activity centering
4) street accessibility

These factors are combined in equal weight and controlled for population to calculate each area's Sprawl Index score. The average index is 100, meaning areas with scores higher than 100 tend to be more compact and connected and areas with scores lower than 100 are more sprawling. You can see a list of highest and lowest scoring U.S. cities in their report, as well as the score of 221 metropolitan areas and 994 counties.

Whether you are familiar with the SGA index or not, the scale for this question is 100 points in either direction, which you can also consider percentile points.
Given the average city score is 100, keep in mind that a positive shift of 100 points would make that city as compact and connected as New York (which scored 203) and a (negative) shift of -50 would mean as sprawling as Nashville or Atlanta currently are.

For each year, slide the marker to the *average shift* of *all North American cities* towards either greater **sprawl** or more connected and **compact**:
Consider 2019 as a starting point of 0 (current state - no shift yet)
*

More SPRAWL					No shift				More COMPACT	
-100	-80	-60	-40	-20	0	20	40	60	80	100

• 2020

-- 2021

-- 2022

-- 2023

-- 2024

◦ 2025

-- 2027

• 2030

◦ 2035

• 2040

◦ 2045

• 2050

• 2060

• 2070

Comments

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10. **ROAD SPACE**

Will an AV future require *less* or *more* road space?

Cities across Canada and the United States have different amounts of their total land area dedicated to road space. These percentages vary depending on whether measurements are made for the entire Right of Way, paved surfaces, or whether they exclude parking and

other automobile related land uses. Example percentages include:
Vancouver with 26.5% used for roads, streets and alleys.
New York has 22%

For this question, consider the *average change* across cities in the amount of road space they will have because of AV technology
Make sure to consider other factors and technologies - effects could be negated and net shift equal 0 or move in the opposite direction.
Please be sure to clarify considerations in the comments section.

For each year, slide the marker to **<u>change in the percent</u>** of land that is *used for roads*:
Consider 2019 as a starting point of 0% (current state - no change yet)
*

LESS Roads | No change | MORE Roads

-50 -40 -30 -20 -10 0 10 20 30 40 50

- 2020
-- 2021
-- 2022
-- 2023
-- 2024
◦ 2025
-- 2027
- 2030
◦ 2035
- 2040
◦ 2045
- 2050
- 2060
- 2070

Comments

Please do not hesitate to contact the Principal Investigator if you have any questions:

Sergio De Lara
MDes candidate, Strategic Foresight and Innovation
OCAD University

Note: The "percent complete" tracker below is inaccurate
This is the end of the survey.

Back Next

50%