Framing the Automated Vehicle Landscape

Toward a Safe, Equitable, Efficient, and Integrated Mobility Future

MaRS Solutions Lab

Executive Summary

An unprecedented revolution in mobility is happening, and automated vehicles (AVs) are part of it. This report explores key considerations for the deployment of AVs in the Greater Toronto and Hamilton Area, and articulates unifying design principles to guide cross-sector collaboration toward a safe, equitable, efficient, and integrated mobility future. The report identifies nine key challenges, and proposes near-term actions and prototypes for each challenge, to accelerate the transition to a mobility system that works for all.

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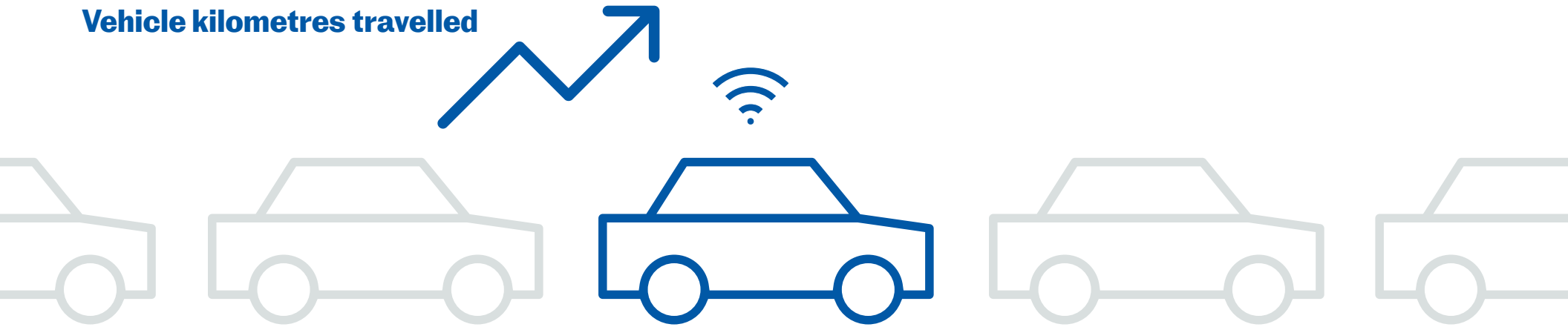
Why Regulate Automated Vehicles?

It's not just the tools we have that matter, but how we use them. Automated vehicles (AVs) could optimize the commuting experience, with benefits that include increased safety,[1] reduced commuting time, reduced costs, increased access to opportunities, increased comfort, improved air quality, and productivity gains.[2] Yet if deployment is managed poorly, AVs can exacerbate existing challenges around congestion, access and equity, pollution, and transit efficiency. The broader adoption of automated vehicles may substantially increase the volume of vehicle kilometres travelled, as personalized mobility becomes an attractive option[3] and we see a reduction in costs across labour, maintenance, and fuel. This, along with the rebound effect,[4] is what creates such a compelling case for proactive regulatory modernization. The issues raised by AVs aren't completely novel, but the pace and scale of change require policy-makers to be more proactive and agile.

"There is a need to integrate the policy and design that makes this useful and beneficial to cities. What Toronto and Ontario does on this topic can set precedents across the world."

Rohit Aggarwala, Sidewalk Labs

Vehicle kilometres travelled



“Preparing and integrating automated and autonomous vehicles into regional transportation systems is not something that can be done alone, but when all orders of government, and jurisdictions across the world, work together to advance the best possible future for urban mobility.”

City of Toronto Transportation Services, Divisional Workplan 2016–2018,
Preparing for Autonomous Vehicles

Why Regulate Automated Vehicles?

To be convinced of the need for proactive regulatory modernization, consider two possible futures for Toronto when AVs are adopted into the city's transportation network.

In 2050...

Single-rider automated vehicles have outcompeted most forms of public transportation because of their convenience and price competitiveness. Because of the preference for private door-to-door rides, we see an overall increase in congestion on the road, and time-to-location during rush hours continues to climb. Collisions have increased, as AVs and human-operated vehicles share the same roads but behave very differently. Single-rider self-driving cars are accessible for many Torontonians, but they remain too expensive for many others, who rely on public transportation. The public transportation experience continues to erode, due to strained infrastructure, overcrowding, and congestion. The in-vehicle experience of driverless cars is dominated by retail and social media experiences, filling the downtime of commuting with inconsequential and highly addictive consumer behaviours.

OR

Automated vehicles are leading the City of Toronto into a new age of sustainability and efficiency. The roads are safer than ever before, with an 80% reduction in casualties. In addition to private passenger vehicles, subways, buses, and streetcars have been automated, increasing the overall efficiency and integration of the public transit network. Some single-rider AVs are on the road, but they pick up and drop off riders in designated zones. The reduction in door-to-door ride-hailing services incentivized a higher investment in automated public shared mobility services and active mobility options. The in-vehicle experience of AVs is diverse, ranging from commercial experiences to social service delivery. Riders can perform a range of activities in transit—like repairing their computer or getting a health check-up—repurposing the downtime of transit into highly productive time for commuters.

AVs Are One Part of a Bigger Mobility Revolution

AVs Are One Part of a Bigger Mobility Revolution

An unprecedented revolution in mobility is happening, and robot drivers are going to be part of it, because they can really move the needle on safety. Algorithms never get tired, distracted, impaired, or angry. Crucially, they can learn from every mistake and instantly update globally. But this revolution in mobility is bigger than just replacing human drivers. It is the convergence of five additional and equally important trends.

1. Integrated

All modes of moving people and goods around and between our cities need to allow for seamless interconnectivity through an integrated system.

2. Connected

When vehicles start talking to one another and to transportation infrastructure, they can be safer and smarter, avoiding accidents and congestion. They can also generate network effects, like optimizing the allocation of shared vehicles against a dynamic demand signal.[5]

3. Electric

If we deploy automated vehicles with combustion engines, we may actually end up increasing greenhouse gas emissions. Electric vehicles can be powered by renewable energy. They also offer the potential to eliminate most of the noise pollution from traffic.

4. Shared

The majority of experts and participants in our study desired a much higher proportion of shared mobility than we have at present. Shared mobility (i.e., carpooling and mass transit) can radically reduce congestion, costs, and environmental impacts. Sharing doesn't require any new technology. It doesn't require us to build expensive infrastructure or buy new vehicles. If we do it right, it could even build community cohesion, inclusion, and belonging.

5. Active Mobility

For going long distances, carrying heavy loads, and universal accessibility, we need transportation powered by clean energy. For short trips and the first and last mile, active mobility should be the preferred option. Whether it is walking or using bicycles, kick scooters, skateboards, roller skates, skis, or snowshoes, active mobility improves health and well-being. Active mobility reduces the incidence of obesity, cardiovascular disease, Type 2 diabetes, cancer, and several mental illnesses, including depression, while also further reducing the environmental footprint of mobility.[6]

Time Horizons and Trends in AV Deployment

Today, two-thirds of vehicles operating in Canada have some connectivity through embedded telematics and similar features.[7] Automated vehicles available for consumer purchase include Level 1 (Driver Assistance) and Level 2 (Partial Automation). Level 3 (Conditional Automation) technologies are being tested on public roadways throughout North America, Europe, and Asia,[8] and some jurisdictions are beginning to explore Level 4 (High Automation) in restricted environments.[9]

By 2025, it is anticipated that every car sold — including automated vehicles — will be connected by multiple means. There are a variety of estimates as to when Level 4 and 5 automated vehicles will begin to operate on public roadways, ranging from the early- to mid-2020s to the mid-2030s and beyond. This transition period from human drivers to fully automated vehicles may present the most uncertainty and complexity.[10] [11] [12] [13] [14]

For the next 10- to 20-year period, personally owned and shared, partially and fully automated, and partially and fully connected vehicles will coexist, which poses significant social, technical, and regulatory challenges.[15] While a number of major manufacturers plan to launch autonomous passenger cars in the next year, the current consensus is that deployment of Level 4 and 5 vehicles on public roads will not be commonplace until the 2030s or 2040s.[16]

Considerations for AV Regulation

We are here

Near-Term (2019–2024)
Modernize safety standards
Protect privacy & security
Regulate for innovation
Increase AV literacy
Harmonize regulations

Medium-Term (2025–2029)
Modernize traffic laws
Modernize traffic law enforcement
Update insurance & liability
Manage the transition
Mitigate negative impacts

Long-Term (2030 and beyond)
Harmonize network mobility planning
Transition infrastructure

Note: It is probable that we won't undertake these activities in as neatly defined points in time as visualized above. More likely, we will continuously revise and redefine these points over a period of 10+ years. For example, distracted driving laws will be modified for Level 3 automated vehicles but will no longer be relevant for Level 5 AVs.

How might we create market and policy conditions that enable automated vehicles to support safe, equitable, and efficient transportation models for Toronto and Ontario?

Problem Frame

Our Research

Over a six-week period spanning November to December 2018, MaRS Solutions Lab, with the support of Sidewalk Labs, performed research and convened stakeholders to deliberate on automated vehicle (AV) deployment in Toronto, with a focus on safety and microeconomic considerations. The activity sought to explore the potential of AVs to improve mobility and to scope out regulatory changes that could manage negative externalities.

This document summarizes our high-level insights and guidance for automated vehicles based on our understanding of the literature and our stakeholder engagement to date. The work is a jumping-off point and complements ongoing AV activities under way by the City of Toronto and other organizations. We are primarily focused on scoping considerations for an ongoing deeper collaborative process, in which companies, government, civil society, and citizens can co-design and deploy (1) regulatory interventions to manage AV deployment, and (2) use cases for emerging transportation technologies that solve for both social need and commercial viability.

This brief is accompanied by a detailed report that documents the process, interview insights, research findings, and workshop outcomes in greater depth.

The work involved three activities:

1. A rapid research and horizon scan

2. Interviews with 13 national and international AV experts

3. Development and delivery of a co-design workshop with 26 participants from public, private, academic, and civil society organizations

Our Research

The scope and depth of the research was limited by a six-week time horizon. Research gaps should be sustainably filled, including co-design and user research with general citizens.

37
reports analyzed

13
interviewees

26
workshop participants

182
collective hours dedicated to co-design by workshop participants

28
organizations

04
municipalities

12
private companies

12
civil society organizations

21
hours of expert interviews

320
collective hours spent reviewing documents and processing findings

Design Principles to Guide AV Deployment

Over the six-week period, we were able to ideate and build consensus across our research participants for the following design principles to guide automated vehicle deployment. Design principles are a touchstone for all collaborators. They unify our diverse innovation agendas by reminding us of our shared goals.

Design principles are one part *proactive* (helping to set intentions) and one part *reflective* (helping to measure progress). You will find a detailed description and list of metrics for each principle in the detailed report. We intend to continue to develop and activate metrics for each design principle to measure Toronto and Ontario's progress over time.

1. Improve **safety** of passengers and non-passengers
2. Increase the overall **efficiency** of transportation and infrastructure
3. Minimize **environmental impacts** of the mobility system.
4. Reduce road **congestion** and infrastructure impact
5. Design for universal **access** and **equity** of service
6. Ensure **affordability** of transportation services
7. Protect **privacy**, **cybersecurity** and appropriate data **transparency**
8. Improve **quality of life** for all
9. Earn **public trust** and confidence in AV technology
10. Enable **citizen participation** and consultation across the full innovation arc

1. Make road safety king.
2. Form & function: Think beyond driverless cars.
3. Business models: Elevate social use cases and efficient transportation models.
4. Design streets with all forms of mobility in mind.
5. Prioritize public, active, and shared mobility.
6. Optimize technical data.
7. Protect personal information.
8. Use clean energy.
9. Activate a shared vision for the long game and strong leadership to drive immediate action.

Recommendations

1. Make road safety king.
The Challenge

There are many good reasons to want a radically different transportation system than the one we currently have. Eliminating congestion. Reducing environmental footprint. Accessible mobility for everyone. Cheaper rides. Massive productivity gains. As desirable as these are, we heard from experts and stakeholders: safety trumps them all. When we can get around without costing us the lives of our loved ones, we will have an immeasurably better society to live in.

Most industry analysts anticipate AVs will eventually be safer than standard vehicles.[17] [18] [19] In AVs, data underpins safety performance, as vehicle operation and technical evolution is continually refined by the data gathered in testing and deployment scenarios.[20] This poses a unique opportunity, in that driver data can be applied to rapidly evolving technology and thus effect step changes toward safety.

To date, however, the data generated (and the performance achieved) is highly influenced by the unique conditions of a particular testing environment. This implies that real-world operating performance is highly context driven and therefore not necessarily replicable across or in other regions, particularly when factoring in inclement weather and climate conditions. Also, and in many cases, the race to commercialize and capitalize on AV technology has generated keen private-sector interest to keep testing results exclusive. This poses complexity for planners and the private sector, as both share interest in consistently meeting safety objectives, yet each is driven by different motivations when it comes to data provision.

Moreover, experts have acknowledged that ensuring safety will be most challenging in the near-term transition period, when autonomous, semi-autonomous and traditional vehicles share the road, and the technology is still highly prototype in nature.[21] [22] [23] This complexity will be exacerbated by the associated need for the vehicle-to-infrastructure (or more broadly, vehicle-to-everything) connectivity required for optimal AV operation—an area that has lagged behind innovations in vehicle design.[24]

> "The difference between aviation and automotive is the scale of the complexity of the problem. [Aviation has] a very clear standard of the mechanical, electrical, and software reliability of an aircraft, and these are well-understood modules.
>
> Where that breaks on autonomous driving is that it's hard to know how much detail to detect—what is and isn't important to driving. Every individual human being has to be disambiguated from a crowd of 50 on the sidewalk. Or every duck that walks on the road has to be detected correctly, as well as every goose. How far do we have to go; how much do we have to understand about the environment in order to drive safely?"
>
> Steven Waslander, Director, Toronto Robotics and Artificial Intelligence Laboratory (TRAILab)
> Associate Professor, Institute for Aerospace Studies

1. Make road safety king.
What Can Be Prototyped?

Local Conditions for AV Deployment

1. Controlled regional pilot testing

Local decision-makers will need to enable varied and in situ deployment scenarios for industry to test and evolve technology[25] to the point where it is sufficiently de-risked to operate in the public realm, yet they will have to do so in a manner that will not put humans and infrastructure in harm's way. This prototype idea is simply a provocation to amplify existing efforts in this area.

2. Zero tolerance at all stages of discovery

On the part of industry, testing will need to consistently meet a zero-tolerance bar for serious human injury at all stages and variations of technical discovery, including in the most complex near-term transition period. This is in support of the City of Toronto's *Vision Zero* plan to reduce traffic-related fatalities and serious injuries.[26]

3. Enact a framework for technical data sharing that directly enables crash avoidance and optimizes supporting infrastructure

The sharing of critical, potentially proprietary technical data between (and within) the private sector and with the public sector would significantly contribute to the collective interest to evolve technological performance and infrastructure, and minimize safety risks. This would also help decision-makers plan and set performance measures, informed by and corresponding with the stage and results of regional deployment to date. However, currently in Ontario, the Autonomous Vehicle Innovation Network (AVIN) does *not* collect proprietary data from its members according to its *Data and Information Sharing Protocol*.[27] This and other restricted sharing protocols would need to change in order to enable the collective benefits from aggregated technical data.

> "Let's say there's an accident. If something goes wrong, how do we regulate? And how do we sort out the root cause and who's to blame for this? [...] What happens when an [AV] car hits a cyclist or a pedestrian? There are all sorts of ethical issues that need to be thought about. [...] Getting vehicles able to [drive autonomously] is one thing. But actually regulating in a safe, equitable, and fair way, that's the real challenge. And I think that's what's going to slow things down."
>
> Chris Sainsbury, KPMG LLP

2. Form and function: Think beyond driverless cars.
The Challenge

AV does not (just) mean driverless car. If you ask a citizen to picture an automated vehicle, they will likely think of a car without a driver because we've built our current transportation system around the form of a five-seat automobile. But if we build the future in the image of the past, we will surely miss the unique opportunity of this revolution to move people, goods, and services in fundamentally new ways that look nothing like today's cars.[28] We have yet to get truly creative when answering the question: *what is in the realm of AVs or robotics*?

AV deployment in market could either reinforce inefficient consumer and economic models for transportation or provide an opportunity for the transportation community to reset some historically problematic economic models and consumer behaviours around mobility.

Stakes are high in the near-term. The industry's choice of leading business models will set an expectation from consumers about how AVs will function in their lives, all while organizations will still be proving viability and profitability of the services.

Creative use cases for AV deployment will require a more concerted investment from both private and public sectors to accommodate the innovative technologies that optimize our roads with existing and future infrastructure.

Freight & Cargo
Vehicles that drive themselves will not necessarily transport people: they could also transport freight and cargo, deliveries, and supplies, and could move along sidewalks, underground, or inside buildings.[29]

Shuttles
Shuttles have a significantly less barrier to market, as there are constrained or routed operating zones in geo-fenced areas that imply predictability and thus facilitate mapping effort.[30] [31] [32]

Municipal Services
Boundaries may blur between vehicles that do not just drive themselves but also perform functions like trash collection[6] or snow clearing.[33] [34]

Passenger Experience
The current experiences of checking in at airport security, dining at restaurants, and attending health or financial appointments can be revolutionized by leveraging the interior of AVs.[35]

2. Form and function: Think beyond driverless cars.
What Can Be Prototyped?

Explore human-centred service delivery on the periphery of AV

- Personal use, mass transit, and freight are vastly different use cases for AVs and should be guided by leaders in each space to accelerate progress on all fronts. Promoting desirability of AVs for a broad consumer base requires a universal design lens, considering all types of citizens in the public realm, not just the few. We should design for extreme users now to achieve a better model for all in the near-, medium-, and long-term.

Get creative with emerging business models

- Take this opportunity to evaluate the pros and cons of our current economic model for transportation, de-emphasize inefficient models, incentivize environmentally sustainable behaviour, and introduce social business models.

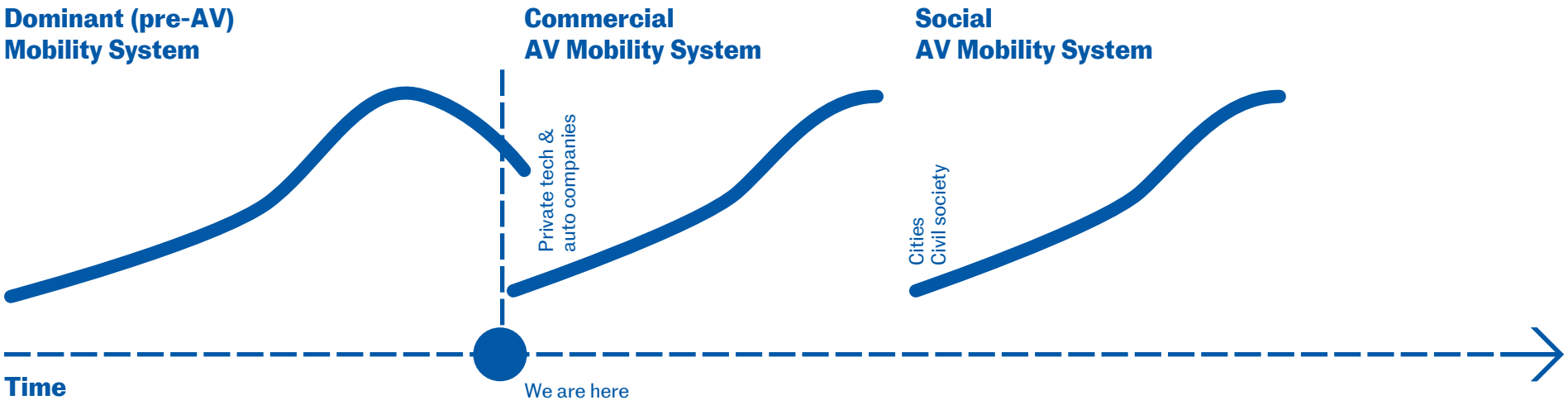
Collaborate across public and private sectors to plan, design, and deploy supporting infrastructure investments

- The face of our cities may stay relatively similar or change completely. Whether it's a small tweak to current infrastructure or a complete overhaul of the skin of our cities, multi-sectoral investment is needed to ensure interoperability, quality, and performance of space. In our excitement and focus around the technology, we can't forget about trees, cyclists, and people.

3. Business models: Elevate social use cases and efficient transportation models.

The Challenge

The dominant mobility system (pre-AV) is already starting to be disrupted by the AV mobility system. However, the first wave of AVs focuses primarily on commercial models like personal use and ride-hailing services. The commercial wave is led by private technology and automotive companies. Private companies have different interests than institutionalized public services, in that the latter are charged with ensuring public good, system operation, and urban form, while the private sector is beholden to driving shareholder value.[36] Champions of social use cases for automated vehicles, like cities and civil society organizations, are lagging behind in their investment, design, and deployment of automated vehicles.



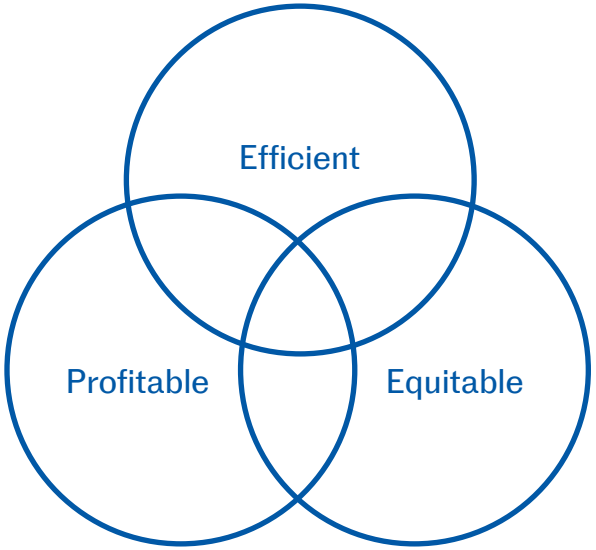
3. Business models: Elevate social use cases and efficient transportation models.

The Challenge

The tension among profitability, equity, and system efficiency proves challenging when seeding new technologies at the systems design level. Affordable, accessible, and equitable mobility is a fundamental design principle to guide AV adoption,[37] but the delivery of this promise is more difficult in practice.

Commercial ventures naturally prioritize revenue growth to remain viable in market. As a result, social benefit and efficiency gains for the transportation system overall are often deprioritized by companies against more attractive and competitive economic options for the company in the near-term. Conversely, the public sector seeks to prioritize public interest, sometimes at the expense of efficient solutions. In an automobile market driven by private sector interests and public interest regulations, it will be difficult to gain momentum for models that deliver on all three promises of profitable, efficient, and equitable services without public sector intervention.

A key insight that surfaced from our co-design workshop suggests that if we rely on commercial models to pioneer the delivery of AV services for all citizens, many segments of the population will get left behind and the cost to government will be high. For example, one fear for the future of mobility is that rural communities and vulnerable populations will not be served in the pursuit of profitable and efficient transportation models. In that future, we would lose the efficacy of mobility all together, creating a system for the wealthy, urban, and able.



3. Business models: Elevate social use cases and efficient transportation models.

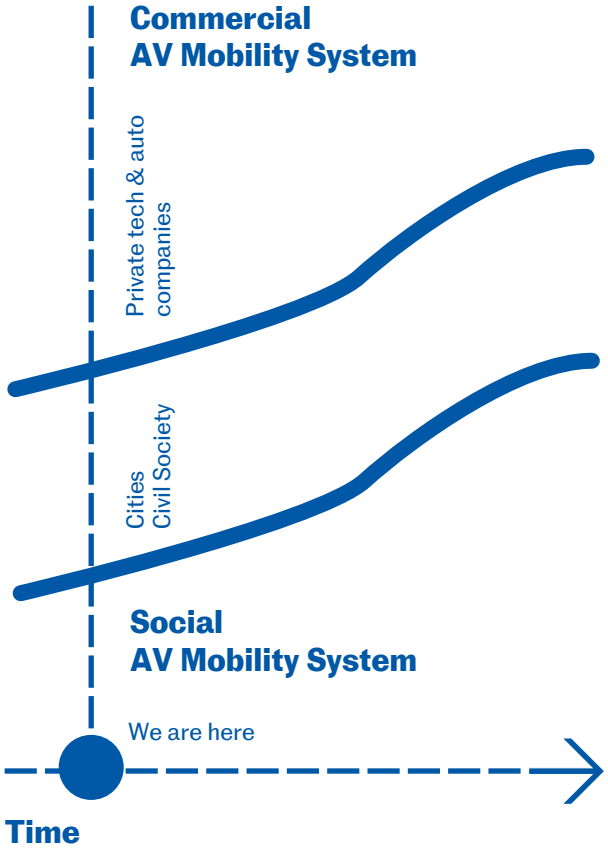
What Can Be Prototyped?

Accelerate the design and deployment of social use cases for AVs

- Develop incentives and creative partnership models to activate the social AV mobility system at an equal pace to the commercial AV mobility system. The social AV mobility system includes but is not limited to use cases that support public transportation, health, wellness, social service delivery, and education.
- Flex market power in support of social enterprise. Explore creative purchasing, consumer engagement, and network effects that elevate social businesses and expand their market share.
- Commit mixed public and private R&D investment to early pilots of social use cases for AVs.

Decelerate commercial use cases for AVs with strong negative externalities

- Scan and study commercial delivery models with a critical lens, understanding negative externalities with the following lenses: microeconomics, macroeconomics, consumer behaviour, environment, universal access, and health and wellness.
- Work across design and engineering communities to find and activate commercially viable alternatives to consumers behaviours and economic models producing negative externalities.

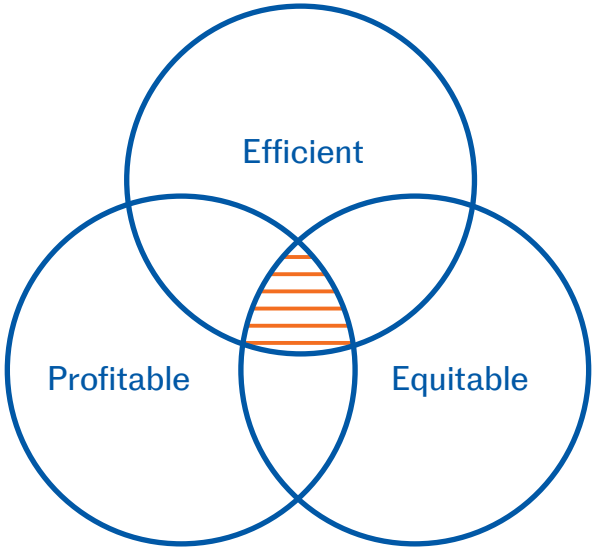


3. Business models: Elevate social use cases and efficient transportation models.

What Can Be Prototyped?

Prioritize profitable + efficient + equitable business models

- Innovation teams that want to bring AVs to market at scale should invest time in exploring business models that are profitable, equitable, and efficient. What modalities get people from point A to point B in the least amount of time with the least amount of waste?
- Identify and quantify positive and negative externalities of emerging business models and capture externalities through pricing structures that align private and public value creation, ensuring an efficient, equitable and fair market.



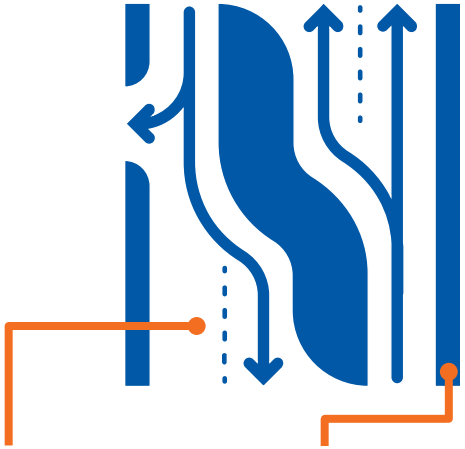
Case Study

IKEA is a great example of achieving revenue growth while balancing social benefit. In FY 2017, IKEA generated 2.5 billion euros in net profit, offering 9,500 products at various price points and accessible locations, all while internally working to eliminate waste across operations through the most efficient use of resources.[38]

4. Design streets with all forms of mobility in mind.
The Challenge

As the population in the Greater Toronto and Hamilton Area (GTHA) increases and the economy grows, there is an overall increase in travel demand (i.e., more cars on the road travelling further distances with the same infrastructure), leading to major congestion. Parking, stopping and construction demands, road capacity, non-optimized traffic signals, and collisions or unexpected traffic incidents all add to existing congestion.[39] If not deployed thoughtfully, AVs could add to the problem. Travelling in single-rider on-demand cars will be easier, more convenient, and potentially cheaper, adding more vehicles to the road and creating more pick-up and drop-off congestion from ride-hailing.

- Congestion costs the average household $125 according to the Toronto Region Board of Trade.[40]
- Cost of congestion to the regional economy is valued at over $6 billion per year and is projected to increase to $15 billion by 2031.[41]
- Extra travel time for the average commuter at peak hours is 34 minutes.[42]
- Several US cities have concluded that the demand of ride-hailing services has contributed to a substantial increase in vehicle kilometres travelled, leading to increased congestion in urban cores.[43]



The Street
Current street design proves difficult for AVs to navigate due to unpredictable movements across many modes of transit vying for lane space. AV street navigation is especially problematic during testing periods for both driver-assisted models and fully automated models. Read more about the City of Toronto's Complete Streets Plan.[44]

The Curb
The war over curbside real estate is a confounding factor for congestion. With rapidly increasing demands for this space created by emerging business models like Uber's door-to-door ride-hailing services, the curb will be highly contested even before automated vehicles are part of the picture. Read more about the City of Toronto's Curbside Management Strategy.[45]

4. Design streets with all forms of mobility in mind.

What Can Be Prototyped?

Support planners toward Toronto's 'blueprint for autonomous urbanism'

- In *Blueprint for Autonomous Urbanism*, the National Association of City Transportation Officials (NACTO) offers a general guide for city planners to optimize the automated mobility revolution toward safe, efficient, and inclusive transportation networks. If this is a guiding framework for cities, how will it be applied specifically for Toronto? Considering that street design is very complex and extremely sensitive to the local and network contexts, what are Toronto's special considerations and adaptations to the generalized model? [46]

The vision for the future is one in which streets of all sizes are designed for people, not vehicles. Autonomous vehicles will require less space than traditional vehicles, affording cities the opportunity to dedicate more space to public amenities. These streets could move traffic more efficiently and safely for all users. From major urban streets that allow seamless transit access to residential streets that become a place for neighbors to meet and children to play, the future street is a place for people.

Blueprint for Autonomous Urbanism, NACTO

5. Prioritize public, active, and shared mobility.
The Challenge

Public transportation is a key beneficiary of automation, but has significantly lower investment in automated technologies than its private tech and automotive counterparts. With little vested capital in R&D to date, how can public transportation use cases play catch-up and be part of the early deployments of AVs in Toronto and Ontario?

To deliver on the promise of reduced congestion, shared mobility is also a critical piece of the puzzle to integrate within the AV deployment framework.[47] However, customer preference for single-rider vehicles presents an obstacle for commercial and government designers alike. How can we design compelling shared mobility models and behaviourally nudge consumers away from single-rider models?

Active mobility is most easily forgotten in the conversation of automation because it is the alternative to vehicular travel. However, we want to elevate and encourage all forms of walking, biking, scooters, skates, and other forms of self-propelled travel. The benefits are not only a reduction in congestion but also significant increases in health and wellness. How can we ensure active mobility is prioritized as we design the supporting infrastructure for automated vehicles?

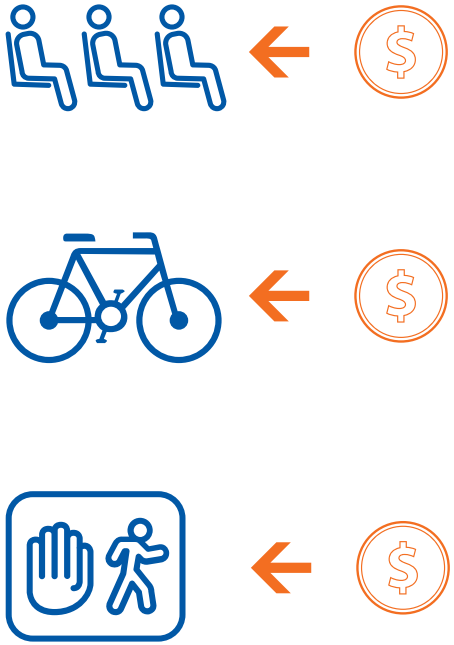
Just like drivers, commuters of public, active, and shared mobility behave irrationally and ignore the rules of the road. Great designs for collaborative streets will need to withstand the test of human behaviour.

5. Prioritize public, active, and shared mobility.
What Can Be Prototyped?

Incentivize automated solutions in the public transportation network
- Earmark municipal, provincial, and federal budgets to begin designing, testing, and deploying automated vehicle solutions for public transportation.
- Build and activate the necessary multidisciplinary innovation teams within public transportation organizations and through contracting.

Tax distance and/or emissions per AV ride to incentivize shared mobility as a congestion management tool
- Mitigate consumer taste for single-rider vehicles by taxing riders and service providers alike for distance travelled and emissions per rider. Distributing accountability across consumers and providers will motivate new business model and mobility designs more rapidly than taxing consumers alone. While consumers are responsible for personal behaviour changes, transportation organizations have a responsibility to offer desirable alternatives to single-rider options.

Incentivize business models and nudge consumption patterns that favour active and shared mobility
- Provide incentives to companies delivering high-quality shared mobility options.
- Create behavioural nudges and offer incentives to consumers to participate in shared and active mobility.
- Consider solutions that manage irrational and aggressive behaviours by commuters of all types.



"It is also important to consider what is currently being subsidized by the City and ask if this reflects and aligns with behaviours we want to encourage."

Kevin McLaughlin, Mobility Startup

6. Optimize technical data.
The Challenge

Fatalities caused by collisions occur once per 100 million miles driven in the US.[51] By that standard, AV companies will need to test hundreds of millions more miles to prove safety.[52] However, it is not only about the quantity of miles driven but also the quality, which makes testing in various geographic locations, terrains, and weather conditions imperative to achieving safety. Canada has an opportunity to generate test data for extreme winter conditions that most countries cannot.

Currently, the technical data generated from the testing and simulations run by the major players are proprietary and private. This data is also reflective of the geographical area and weather conditions present in the testing zones and does not include all potential scenarios, terrains, or conditions, and may hinder the operational effectiveness of an AV in certain geographic areas. Technical testing data is not being shared broadly because companies rely on the competitive advantage of their performance data when entering market.

Sharing technical data across jurisdictions for the common good—including simulation scenarios, weather, and road conditions—would result in the maximum positive safety outcomes of the performance of automated vehicles. Sharing can also improve potential commercial outcomes, allowing companies to reach market faster, accelerate consumer trust and confidence of the technology, and manage safety risks more efficiently. It is important that AV data is shared responsibly, meaning it's shared only in ways that advance passenger safety, privacy, and security. This includes putting active measures in place to protect against hacking, anonymize data at source, and prevent data breaches.

Has driven **16 million** kilometres on public roads and **11 billion** kilometres in simulation since inception.[48]

Uber

Drove **5 million** kilometres before halting its operations in March 2018.[49] Testing resumed December 2018.

cruise

Can conduct **150 simulations per minute** in a virtual world, and tests in complex geographies such as San Francisco.[50]

6. Optimize technical data.
What Can Be Prototyped?

- Undertake a consultative process to identify and guide what kind of technical testing data is shared to help both planners and industry. This process would be used to help set parameters on what constitutes an appropriate commodity layer of use to urban regions and of benefit to industry. The nature of and context for data collection and legal sharing agreements will also need to be specified.
- Different models for responsibly sharing AV data could be prototyped. These include data sharing agreements, data collaboratives, and data trusts. These models could be tested in conjunction with AV test areas, such as the AVIN Technology Demonstration Zone in Stratford, ON. It is important to engage public and private owners of AV data sets, as well as local residents, in deciding what data to share and for what uses.
- The European Union has commissioned a staff working document with guidance for sharing private-sector data in the European data economy. The document outlines the importance of data collected online and by objects. It suggests data should be accessible and shared to support the development of new products, services, and methods of production, and that data can act as a key enabler of growth and jobs in Europe. Similar guidelines could be tested here in Canada.

Has driven **16 million** kilometres on public roads and **11 billion** kilometres in simulation since inception.[48]

Uber

Drove **5 million** kilometres before halting its operations in March 2018.[49]
Testing resumed December 2018.

Can conduct **150 simulations per minute** in a virtual world, and tests in complex geographies such as San Francisco.[50]

Case Studies: Optimize technical data.

Together for Safer Roads[53]

Together for Safer Roads is a coalition of global private-sector companies collaborating to improve road safety across industries. The coalition uses the data, technology, and global networks of its members to:

- advance best practices for companies and their fleets;
- address strategic road-safety challenges;
- advance innovative solutions of road-safety tech; and
- deliver evidence-based solutions for Safer Companies and Fleets, Safer Cities, Safer Road Tech, and Safer Policies.

Estimating crash risk levels

In Atlanta, GA, information was collected and analyzed by combining both public and private data sets to create a dashboard with analytical indices to estimate crash risk levels based on weather, traffic, events, and other risk indicators.

City of Helsinki[54]

Policy-makers, startups, and large companies have proven to be willing to experiment with novel ideas in Greater Helsinki. Pilots contributed to the success of Helsinki's shared mobility landscape even when they proved unsuccessful. Kutsuplus improved the geographic data and provided road tests to enhance the accuracy and functionality of routing algorithms. The experiences learned and models built during the Kutsuplus project were useful in creating the SOHJOA pilot and the RobobusLine.

Leveraging tech talent

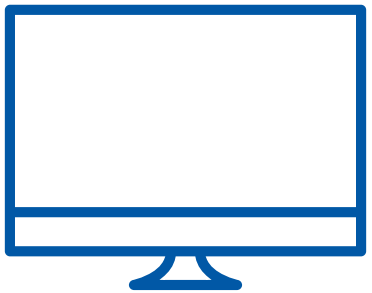
Whim was built by local talent using the research, insights, and routing algorithms derived from previous initiatives. Additionally, partnerships between large employers and tech startups have led to Vedia Ride and Vedia Share, which are creative microtransit commuting solutions. The StreetReboot and Future City competitions are both direct attempts to leverage this talent to solve urban challenges.

7. Protect personal information.
The Challenge

In order for AVs to be safe and effective, manufacturers will need to collect extraordinary amounts of consumer data, raising questions of data ownership, access and privacy, and specific ethical concerns. Consumer data such as daily routine, passenger information, and GPS location will be captured by these vehicles and could potentially be shared or sold to third parties.[55]

Commercializing personal data can result in subversive commercial models that trade on consumer identity, sell based on personal habits, and manipulate user emotions in the moment of consumption. Restricting user data collection, storage, and sharing is as much a privacy concern as it is a public health and wellness concern. At the same time, anonymized and aggregated personal data can help corporations and governments optimize transit efficiency, find gaps in service provision, and offer services that meet the needs of consumers and their interests.

The strong status quo for user data in current tech models makes the transition away from user data-based business models all the more complicated. A shift away from transactional data would challenge dominant business models and means users will need to pay for services in situations where freemium models may be the current standard.



"In the near-term, privacy and cybersecurity should be a focus."

Ontario Centres of Excellence

7. Protect personal information.
What Can Be Prototyped?

Force action on data privacy

- Automotive manufacturers and fleet operators must prioritize customer privacy. For example, members of Global Automakers adhere to the privacy principles outlined in Consumer Privacy Protection Principles for Vehicle Technologies and Services. Sharing technical data will rapidly improve technology performance, but sharing user data (such as accounts, movement, and social media) *must* be optional (even restricted) to avoid subversive commercial models that trade on consumer identity, sell based on personal habits, and manipulate user emotions in the moment of consumption.

Build meaningful alternatives to freemium models[56]

- What are alternative sales and service models that can replace access-for-data models? Employ designers, strategists, behaviourists, and engineers in the public and private sector alike to uncover the next dominant consumer model for a post-freemium consumer world.

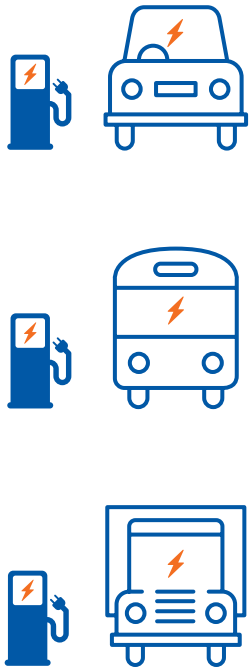
Explore alternative data that can maximize efficiency of transit networks

- Challenge the commonly held belief that individual user data is necessary to achieve network efficiencies. Explore alternative data collection models that focus on collecting data through sensors on inanimate objects rather than tracking human movement.

8. Use clean energy.
The Challenge

If we deploy automated vehicles with combustion engines, we may actually end up increasing greenhouse gas emissions. Without focused attention by the public and the private sector, clean energy vehicles and automated vehicles will not proceed in tandem. We run the risk of AVs adding to the poor air quality and climate impacts associated with hydrocarbon fuels. The sensing and computing systems associated with highly automated vehicles imply additional power draws due to added weight and increased energy consumption on a per vehicle basis.[57] Moreover, AV technical development to date has remained tied to traditional oil-based fuel sources, meaning vehicles have the potential to significantly magnify the drawbacks associated with hydrocarbon dependency (including but not limited to climate change and environmental degradation).

When planned well, AVs can minimize overall vehicular energy consumption by optimizing shared mobility options, platooning, and intersection connectivity. By connecting AV deployment to cleaner energy sources such as electricity and biofuels, we take a step toward cleaner and more equitable fuel sources and electricity grids.



"With an electric vehicle, you are reducing overall maintenance. Electric vehicles have approximately 30 moving parts. In a motor vehicle, there are approximately 2,000 moving parts. Those parts can require more maintenance."

Richard Gilbert, Author of Transportation Revolutions

8. Use clean energy.
What Can Be Prototyped?

Couple AV deployment with clean energy alternatives[58]

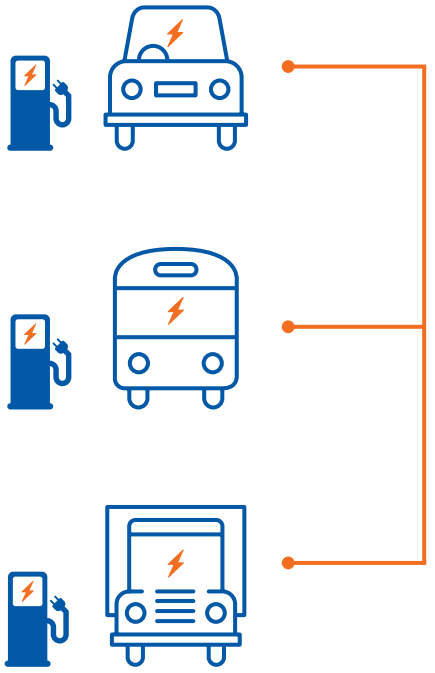
- Automated vehicles can be powered by renewable energy. By pinning AVs with clean energy and prioritizing development of the required vehicle technology and road infrastructure, we have the opportunity to link a 21st-century technology with—and thus simultaneously promote—the evolution of a cleaner electricity grid.
- Electrification is one alternative to carbon fuels, but it includes negative externalities linked to lithium production and battery disposal.[59]
- Hybrid electric vehicles and alternative fuels—such as ethanol, biodiesel and solid waste—provide another option for clean energy deployment of AVs. These bio-based fuels can be used in various blending ratios of up to 50%, depending on seasonality.

Focus on operating efficiency

- Consider optimizing vehicle power consumption. Prioritize vehicle light-weighting and bio-based materials. Optimize sensing and data to consider the efficiency and weight of the onboard computers, as well as the power draws associated with high-resolution imaging.
- On a system level, prioritize advancements in vehicle routing, including shared modes, platooning, backhauling, and overall optimization of traffic flow.

Highlight efficiency and lifestyle benefits to electrification

- For example, electric vehicles offer the additional value of removing significant noise pollution from traffic.
- Electric vehicles are at least twice as efficient as conventional vehicles, and as electricity grids transition to lower carbon alternative and renewable fuels, electric vehicles benefit immediately without requiring upgrades.[60]



9. Activate a shared vision for the long game and strong leadership to drive immediate action.

The Challenge

The mobility revolution won't happen overnight, but we need immediate action. It's going to take several decades to fully realize the potential of integrated, connected, electric shared AVs and active mobility networks. But if we don't start preparing today, we will be in for a very bumpy ride, as each wave of disruptive innovation catches us by surprise. If we respond to each of these major trends in isolation, we will end up with a patchwork of piecemeal fixes that perpetuates an increasingly strained legacy mobility system. This legacy system is too expensive to maintain: it needlessly robs us of lives, time, and resources every day.

As we move forward, we want to consistently take the long view. Decisions made today must consider the potential for unintended consequences and should be measured against not only immediate benefit but also long-term impacts. We didn't talk to any expert that doubted our mobility system is on the cusp of a major transition. It's not a question of if but how and when the transition occurs. Will Toronto and Ontario get ahead of the curve and plan for an orderly and just transition? Or will we end up trapped at either extreme of the risk versus caution spectrum? The former could result in a Wild West and a race to the bottom. The latter could mean we miss out on the social, economic, and environmental benefits that a new mobility system can deliver.

9. Activate a shared vision for the long game and strong leadership to drive immediate action.

What Can Be Prototyped?

Map a unified longitudinal plan

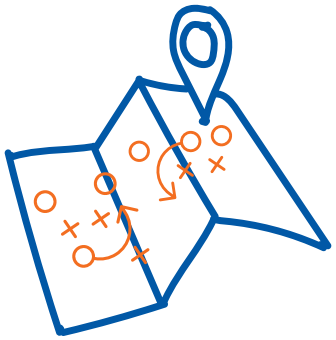
- We need to start preparing today. We can map a longitudinal view of the mobility system transformation in Toronto and Ontario: building dedicated lanes, testing and perfecting the performance of early AVs, educating the public, exploring social use cases, and designing alternative economic models. The longitudinal plan shows the 360-degree view of transitions in technology, infrastructure, and consumption patterns over time.

Assign actions and actors for each time horizon

- Across the longitudinal view, different actors will take the lead. Through a planning exercise based in convening and co-design, assign private, civil, and public organizations as lead or support players across the 360-degree view to articulate a playbook of how we work together over the coming 20 years.

Start with low-hanging fruit

- Identify and activate the obvious collaborations.



1. Policy Convening
2. Business Model Exploration

Next Steps

Our Solutions Lab Methodology

Our Policy Approach*

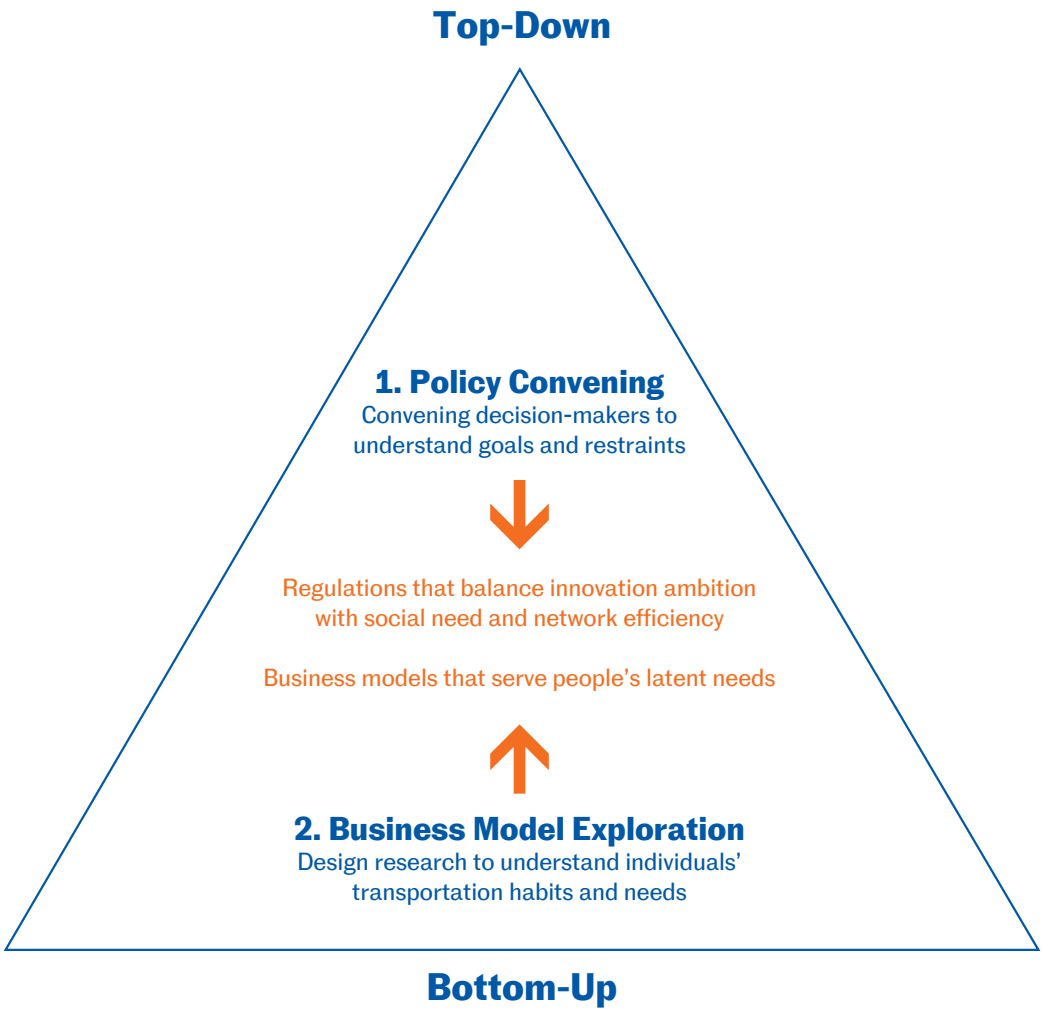
Bringing together stakeholders from across society, including government and industry partners, MaRS Solutions Lab acts as a neutral convener that helps design policies and strategies that support innovation. We specialize in designing and facilitating complex engagements, bringing in insights from different perspectives (user, institution, and system). This process of bringing people in the loop early on also facilitates scaling later on to generate the greatest impact.

We take a high-level approach to develop a **systemic frame** contextualizing the issue...

...balanced with a ground-up **ethnographic** approach to nuance our understanding with human storytelling, unmet needs, and latent opportunity areas.

*Excerpt from *MaRS' Periodic Table for Social Change*. See here for the full periodic table.

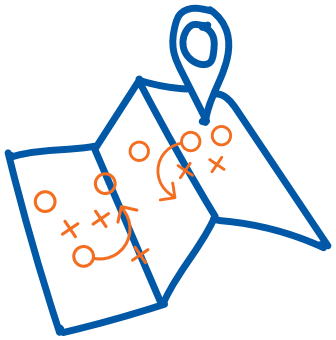
Approach


Top-Down
1. Policy Convening
Convening decision-makers to understand goals and restraints
Regulations that balance innovation ambition with social need and network efficiency
Business models that serve people's latent needs
2. Business Model Exploration
Design research to understand individuals' transportation habits and needs
Bottom-Up

Policy Convening

Summary

The mobility revolution won't happen overnight, but we need immediate action. It's going to take several decades to fully realize the potential of integrated, connected, electric shared AVs and active mobility networks. But if we don't start preparing today, we will be in for a very bumpy ride, as each wave of disruptive innovation catches us by surprise. If we respond to each of these major trends in isolation, we will end up with a patchwork of piecemeal fixes that perpetuates an increasingly strained legacy mobility system.



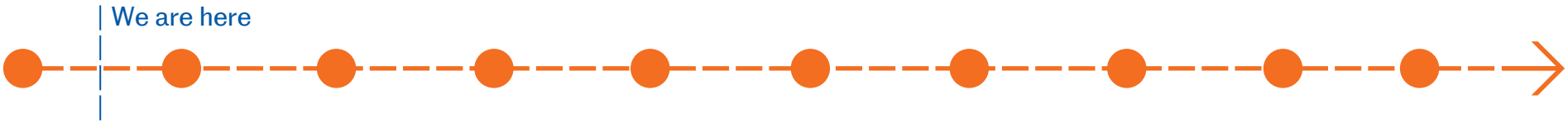
Approach

We will build on the momentum of policy convening conducted during Phase 1 of this work to continue bringing market leaders, city planners, civic organizers, and policy-makers into the same room to build consensus and solutions for the sticky problems of AV deployment. We will accomplish this with a monthly workshop approach that builds on the progress from previous sessions. The group will develop a long-term regulatory framework, build prototypes of specific regulatory interventions, and alpha test those regulatory interventions.

Deliverables

See next page

Policy Convening
Timeline



Frame & Vision
5 months

Hold workshops to surface tensions, develop consensus on design principles to deploy AVs, and articulate a high-level systemic frame for policy and regulation.

Deliverables
Detailed descriptions of specific regulatory interventions
Action plan with roles & responsibilities

Evidence
3 months

Hold workshops to develop detailed prototypes of policy and regulation. Test them with market leaders, policy-makers, and citizens.

Deliverables
Detailed descriptions of specific regulatory interventions
Action plan with roles & responsibilities

Policy Change
4 months

Hold workshops to pilot plan early adoption of regulatory frameworks across sectors. Hold meetings to track progress.

Deliverables
Launch plan to activate regulatory interventions
Alpha testing of early-stage regulatory interventions

Business Model Exploration

Summary

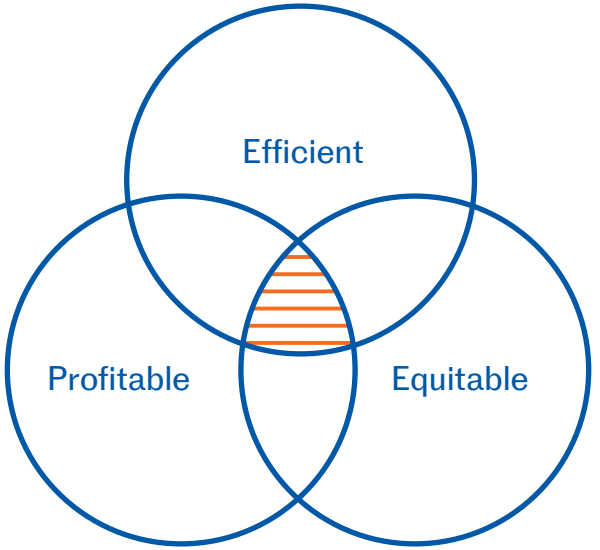
AV does not (just) mean driverless car. If you ask a citizen to picture an automated vehicle, they will likely think of a car without a driver, because we've built our current transportation system around the form of a five-seat automobile. But if we build the future in the image of the past, we will surely miss the unique opportunity of this revolution to move people, goods, and services in fundamentally new ways that look nothing like today's cars.[28] We have yet to get truly creative when answering the question: *what is in the realm of AVs or robotics*?

Approach

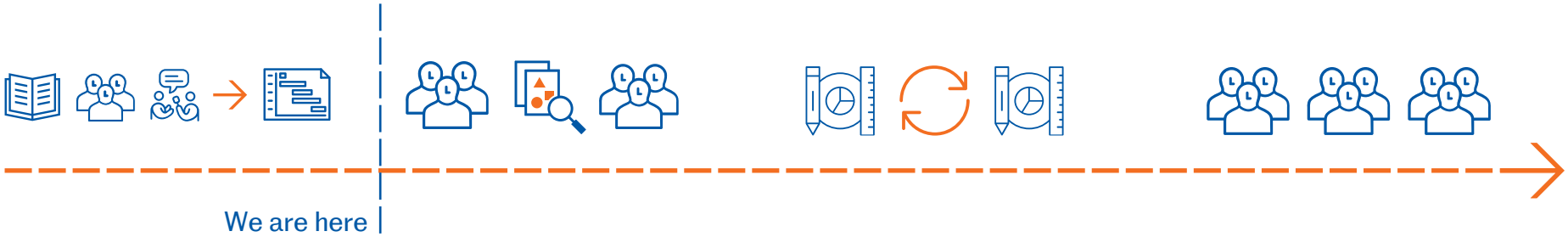
We will develop viable, desirable, and feasible business models that challenge the dominant thinking about how AVs are best deployed into the Toronto market. We will conduct ethnographic research with Toronto citizens to understand current state habits and behaviours surrounding mobility, and to identify challenges and latent needs. Using those in-depth insights, we will develop prototypes of business models that fulfill social need and elevate transportation network efficiencies, and are economically viable.

Deliverables

See next page



Business Model Exploration
Timeline



Framing
3 months

Perform contextual research, expert interviews, and expert workshops to determine key themes, establish shared goals, and identify gaps in current efforts.

Deliverables
AV trends one-pager
Workshop delivery
Public report of findings

Design Research
3 months

Conduct ethnographic research to understand citizens' transportation habits, identify their latent mobility needs, and organize into key opportunity areas of new business models for AV deployment.

Deliverables
Ethnographic insights report
Concept sketches
Prioritized prototype ideas

Prototyping
3 months

Rapidly prototype prioritized business models that serve citizens' mobility needs, achieve social good, and elevate transportation network efficiencies.

Deliverables
High-fidelity prototypes
Early test results

Testing
3 months

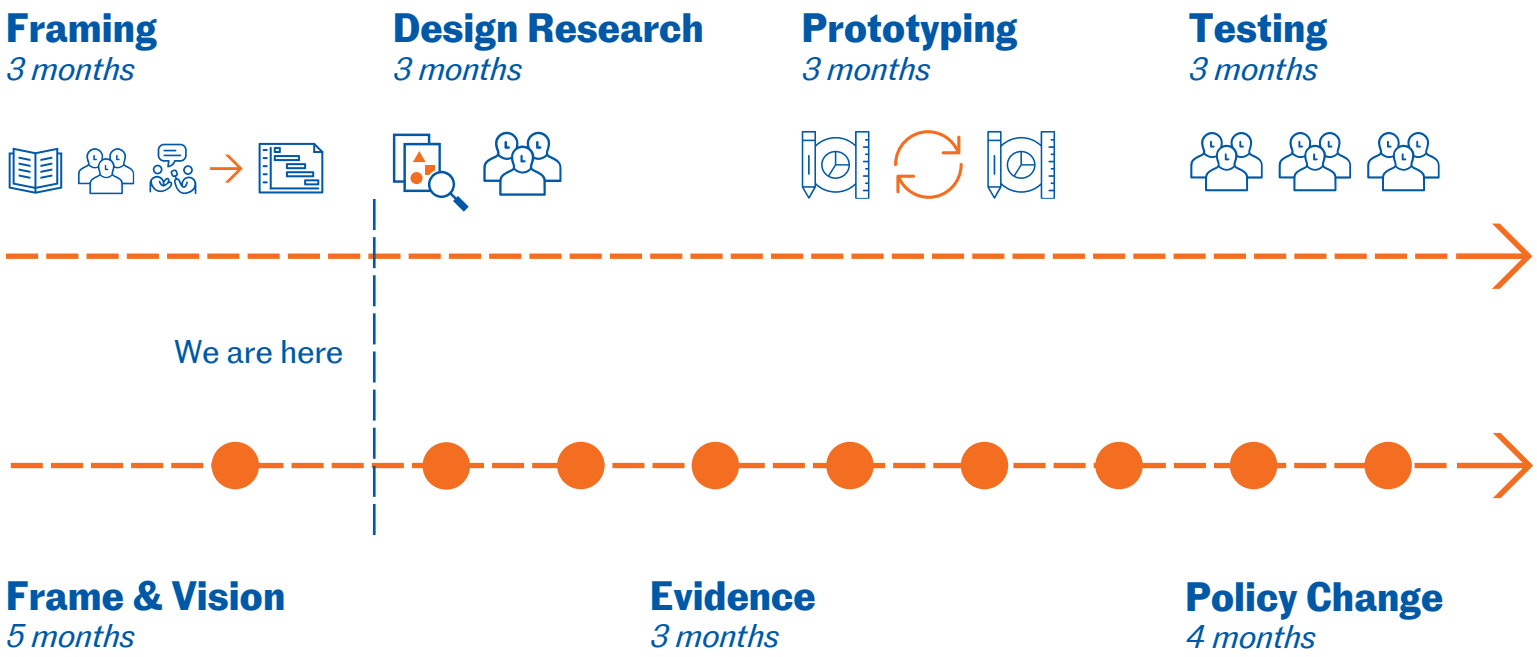
Validate value propositions, validate the growth hypothesis, reiterate prototypes, and plan pilot for alpha/beta launch of business models into market.

Deliverables
Market readiness report
Updated high-fidelity prototypes
Alpha/beta launch plan

Feedback across streams

We will consider policy approaches that create space for new business models to be brought to market.

Feedback loops across the policy convening and business modelling activity will elevate both efforts.



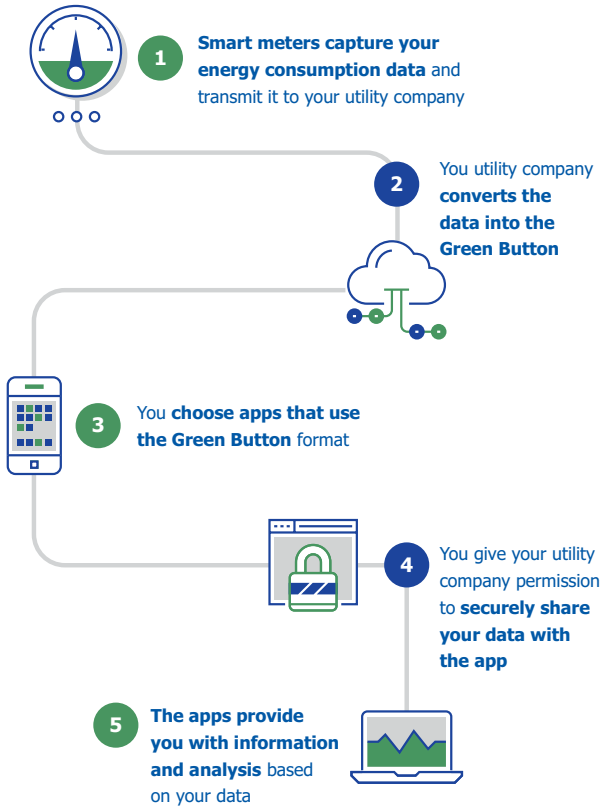
Case Study: Green Button
A 3.5-year policy transformation

Summary
In Ontario, smart meters monitor electricity use in 4.8 million homes and across thousands of commercial and industrial buildings. Those terabytes of data are the building blocks technology companies need to create customer-facing apps that engage users and nudge them toward saving energy. However, with each of the province's 70-plus utility companies collecting, storing, and sharing data in its own way, developers have no single data pool or method to access data and offer solutions to customers. MaRS identified this untapped market value and proposed the adoption of common data standards across the energy sector.

Approach
MaRS, along with the Ministry of Energy, led a cross-industry working group composed of private-sector companies, regulators, utilities, and the Ontario and Federal Privacy Commissioners' offices to collectively identify, evaluate, pilot, refine, and adopt the Green Button standard in Ontario.

Deliverables
MaRS led the technical review and produced adoption guides, represented Ontario on the Green Button Alliance, ran pilots with two utilities and 10 ventures, ran a Green Button energy data hackathon (11 solutions) and app challenge (27 apps), supported utility implementation across 60% of Ontario, and led use case definition and business case development that directly informed the stakeholder consultation and policy development process.

Today, the Green Button standard is mandated in Ontario across all energy utilities and, optionally, for water utilities.



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This report was created by the MaRS Solutions Lab.

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Footnotes

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