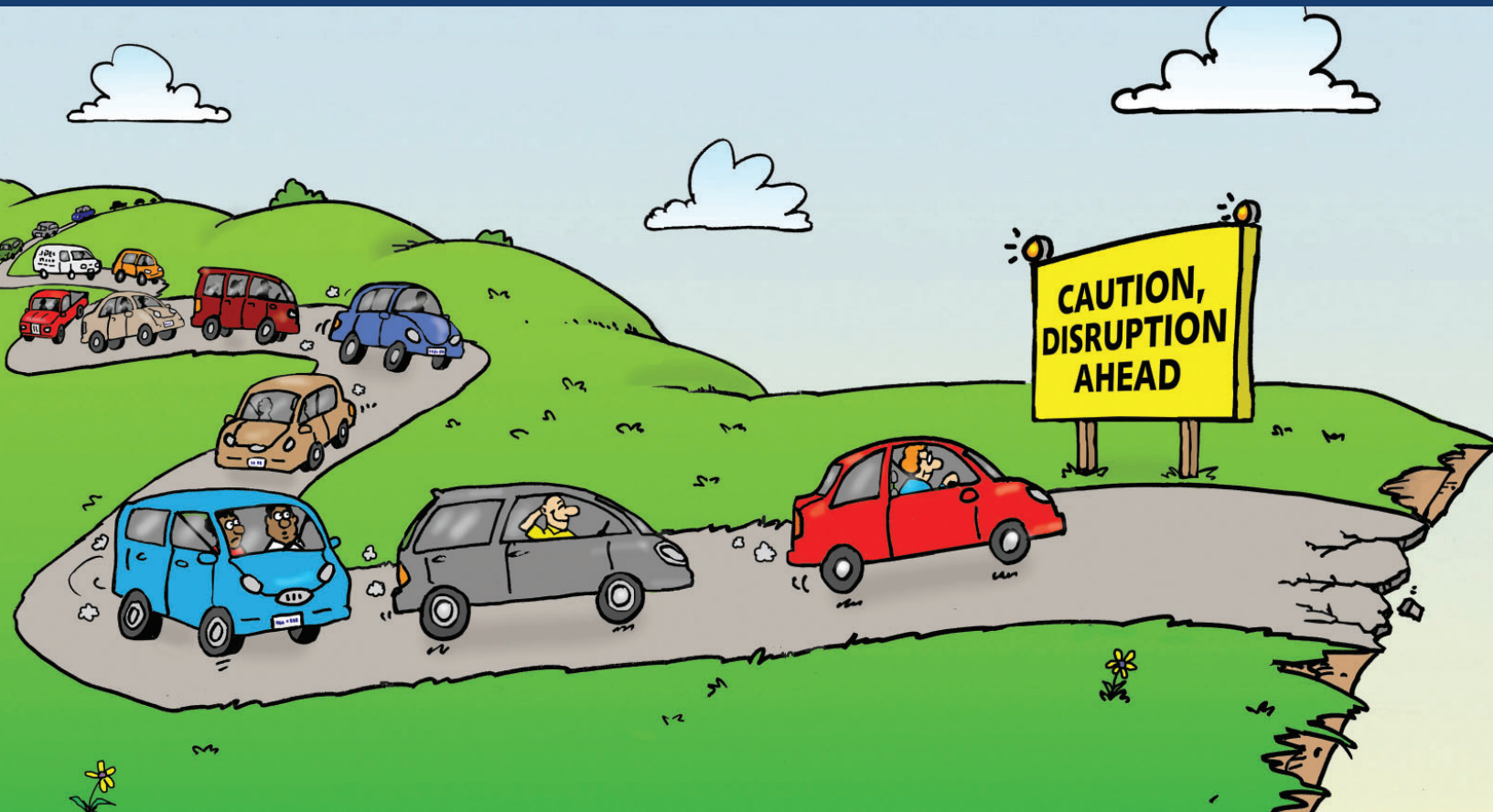


IMPROVED TRANSPORTATION IN THE TORONTO REGION



A SUMMARY REPORT BY THE

 **UNIVERSITY
OF ONTARIO**
INSTITUTE OF TECHNOLOGY

IMPROVED TRANSPORTATION IN THE TORONTO REGION

A summary report¹ by the
University of Ontario Institute of Technology

2018

¹ This report summarizes 'Assessment of Electric Vehicles and Ridesharing in Ontario' prepared by the University of Ontario Institute of Technology (available at <https://sites.uoit.ca/sustainabilitytoday/>) supported through the Metcalf Foundation, Mitacs, Waterfront Toronto, and Veridian Connections and municipalities of Clarington and Pickering.

INTRODUCTION

Transportation is the lifeblood of our communities. People need to get to work, deliver goods, and provide services to customers. People need to transport their kids to school, to dance class or to hockey practice, and people need transportation to take vacations, visit relatives, and attend the concert or the big game. Adequate transportation services are key to other community objectives such as affordable housing and provision of experiential learning opportunities for students.

The challenge is that transportation is changing fast.

Traffic congestion affects business success and people's quality of life, forcing people to adapt their schedules or change their jobs to be closer to home. Gasoline prices pressure people's budgets. The digital revolution that disrupted entertainment and shopping now disrupts cars and trucks. Look at Ontario's largest urban area, for example. Transportation in the Toronto Region² is shifting dramatically, partly due to the convergence of many new technologies, including:

- Decentralized electricity grids and local generation
- Vehicle design (electric, EVs, and autonomous, AVs)
- Information and Communication Technologies (vehicle automation and smart phone apps e.g. Uber and Lyft, GPS, 5G)

Changes taking place in transportation go beyond worsening congestion; they include a revolution in vehicle design and operation. Transportation plays a role in urban sprawl, which challenges the environment, agriculture and peoples' health. Poverty worsens from a lack of mobility. And transportation itself, thanks in part to smart phones with broad data access, is moving from something people do, into a service they buy—whether that means having groceries purchased online and delivered, sharing a neighbourhood vehicle or parking space, or engaging Uber or Lyft to take you to work.

Transportation is changing in Ontario and the pace and complexity invites chaos. Rather than being daunted by the change, Ontario can encourage the convergence of technologies to maximize potential benefits, even as we prepare for what we know will be the challenges of disruption.

With a new government aimed at helping people improve their lives, the province is well-placed to manage the changes taking place to create more opportunities for families and for businesses. In that regard, this report suggests there is much we can do in Ontario to improve transportation starting now, with a special focus on transportation improvements in the Toronto Region and Southern Ontario (and key communities in Northern Ontario).

² The 'Toronto Region' (TR), or Toronto Urban Region (TUR), is used consistently here with the 'Greater Golden Horseshoe', as defined under the Province of Ontario's Places to Grow Act to include two broad areas: the inner core made up of the City of Toronto and Regions of Durham, Halton, Peel, Wentworth (Hamilton), and York (GTHA – about 8 million population); and the outer ring of (about 2 million population) Waterloo, Niagara Falls, St. Catherine Barrie, Brantford, and Guelph.

Specifically, this report offers several system-based transportation initiatives:

- 1** To seamlessly move more people, reduce the numbers of vehicles on highways, and better connect the inner and outer parts of the Toronto Region by efficiently linking transit nodes, such as college and university campuses (e.g. 'Learn on the GO').
- 2** To encourage ride-sharing. To enhance social mobility and community cohesion by making it easier, safer, and more common, to travel with others.
- 3** To show how the adoption of low-carbon (electric and fuel cell) vehicles could improve Ontario's overall transportation system, without expensive subsidies.
- 4** To establish a common community-based transportation platform combining transit and ride-sharing, ride-hailing services, e.g. expanded SmartCommute and BlancRide.
- 5** To strive for a minimum 50% reduction in carbon emissions associated with road transportation in Ontario (while increasing overall travel).
- 6** To ensure that transportation systems are fully and consistently aligned with local and regional land use plans.

The report also includes a transportation index and a dynamic compilation of information culled from hundreds of new studies. A detailed analysis accompanies this report and is available online³.

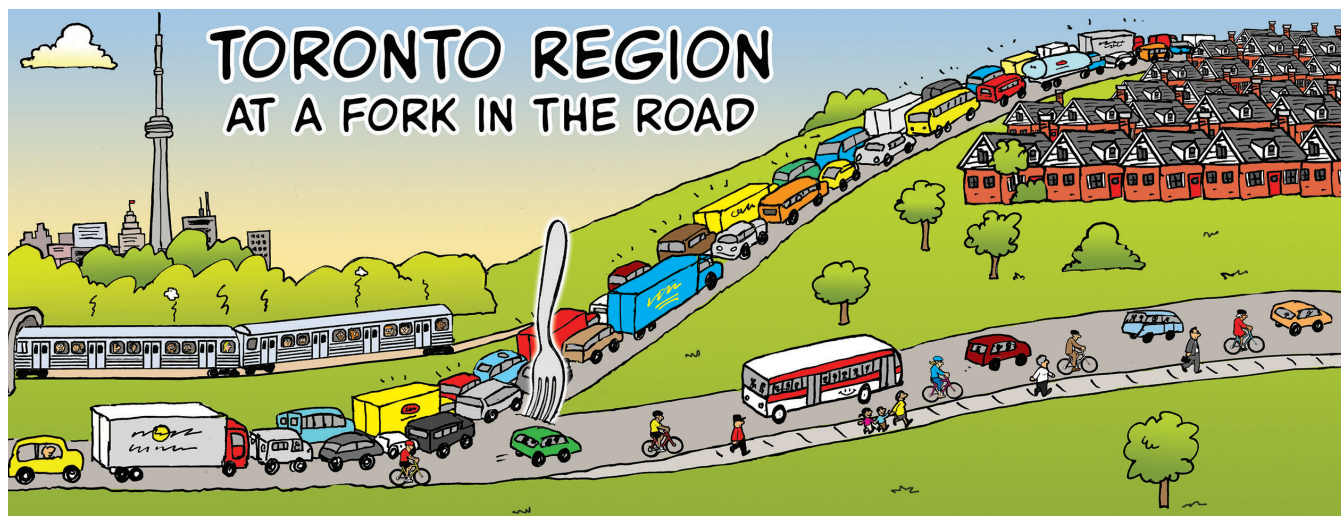
³ Five key reports underpin the background of this review: (i) RethinkX "Rethinking Transportation 2020 - 2030". 2017. Arbib and Seba; (ii) An Integrated Perspective on the Future of Mobility. 2016. McKinsey&Company and Bloomberg New Energy Finance; (iii) Draft 2041 Regional Transportation Plan. 2017. METROLINX; (iv) Making the Move: Choices and Consequences. 2013. Transit Panel report to the Government of Ontario; (v) Canada's Electric Vehicle Policy Report Card. 2016. J. Aksen, S. Goldberg, N. Melton. Full referencing available in main report.

TORONTO AT A CROSSROADS

The Toronto Region and Ontario are highly car-dependent. Our culture, community planning, building design, and entrenched economic interests are largely driven by the automobile. Changing these policies and habits will be difficult.

For example, the province of Ontario receives more than \$3 billion per year in sales tax alone for vehicle purchases. Communities and houses are designed around the automobile. Vehicles and auto-parts remain Ontario's and Canada's largest export item, and represent more than 101,000 jobs in Southern Ontario. About 15% of the Toronto Airport Authority's revenues come from parking and ground transportation fees, and the Region of Durham alone is planning to build more than 100,000 single family homes in the next 15 years (most of which today can only be reasonably accessed by personal vehicles).

Toronto Region is at a crossroad. In one direction: congestion, health impacts, GHG emissions, and sprawl grow. The other direction represents the largest structural and social change the Region has ever undertaken. The transportation initiative outlined in this report aligns transportation with land use planning, and represents the Region's (and Ontario's, and probably Canada's) largest effort toward sustainable development.



THE ROLE OF, AND DISRUPTION TO, TRANSPORTATION

Transportation is the life-blood of Ontario's economy. If people and goods cannot move freely, the economy and personal wellbeing stagnate. Congestion, the inability to move around easily, and atrophying local economies: these are the most common complaints voters and taxpayers raise with their representatives.

In Ontario, a few arterial routes are critical:

The 400-series highways, especially Highway 401 linking Detroit to Montreal; The heavily congested CP and CN rail lines doing double duty transporting freight and rail commuters; Subway lines in Toronto, and; Pearson International Airport, connecting the province to the world.

Similar to how clogged arteries are a major health threat to humans, Ontario is now experiencing dangerous congestion along key highways. Frustrations, damage to the economy, and bypasses, are common.

The scale of impending technological disruption through better arterial travel, greater embrace of autonomous and electric vehicles, and greater use of ride-sharing, involves shifts of more than \$140 billion per year (with potential savings of \$45 Bn – or about \$8,000 per Ontario household). This change could also reduce carbon emissions by some 25 Mt per year (more than that achieved through closing Ontario's coal-fired power plants). The largest potential benefit however, may be the chance to strengthen the province's economy.

New technologies such as autonomous and connected (and electric) vehicles, integrated mobility platforms, GPS vehicle tracking, smart (and localized) electricity distribution grids, lower carbon trains and buses (electric, fuel cell, natural gas), and advances in freight delivery (e.g. drones, freight consolidation), are evolving quickly and will demand practical ways to integrate and regulate the new technologies and business approaches.

Improved transportation systems linking technology centers from Kitchener-Waterloo to Toronto (and further east) could drive the region's economy. Through frequent and reliable surface arterial routes (rapid buses and vans) along with ride-sharing, research centers, businesses, communities, health centers and academia can be readily connected within a few years without the need for major new infrastructure.

These strategies are capable of reducing costs (by about \$8,000 per household) while improving transportation service across most of the Province.

THE NEED FOR A SYSTEM-WIDE APPROACH IN ONTARIO AND THE TORONTO REGION

People know that urban services are important: things like solid waste management, water supply, electricity, broadband Internet access, and roads. Providing those services, however, is often complicated by jurisdictional overlaps, the need for regulation, and lack of clarity on the roles of private versus public sector service providers. Energy is a good example. In Ontario electricity is largely owned and managed by the Province, while natural gas and petroleum are provided by the private sector with heavy regulatory oversight for natural gas (e.g. the Ontario Energy Board oversees prices) and modest oversight for petroleum (prices tend to follow global trends).

The same is true for transportation. There are more than 20 transit operators in the Toronto Region, Metrolinx and TTC being the two largest. Individually, a transit operator like the Toronto Transit Commission can make some important and useful changes; introducing free-rides for children 12-and-under, and a two-hour transfer option, are among the most cost-effective and environmentally sound actions (compared to several global cities – see main report). But despite those individual successes, it is hard to coordinate changes among various operators; e.g. the creation of a common Presto payment system.

Ontario roads and highways are divided among more than 450 local governments and provincial and national agencies. Tolls, or congestion charges, are contentious in Ontario, even though this kind of ‘differential pricing’ represents one of the most powerful ways to optimize transportation systems. New road tolls in Southern Ontario are more difficult to enact because of the relatively high toll rates on the 407 ETR.

Cost savings in urban services usually accrue through greater competition in the private sector. However, this can be elusive. For example, Canadians pay among the highest costs for cellphone and internet services in the world, while the largely private sector companies provide an important example of potential market capture. The introduction of Uber ride-hailing, and the combative reaction from existing taxi operators, represents another example of the challenges of providing more efficient urban services.

There is considerable uncertainty about what Ontario’s transportation system will look like beyond 2030. Technologies, business models, and community and regulatory demands are evolving quickly. During this time, however there is high demand for new transportation infrastructure. For example the Relief Line, Smart Track, and new highways. Regardless of design and alignments, new large-scale transportation infrastructure will likely not be in place before 2035. Interim measures that can provide congestion relief are critically needed.

Transportation in Toronto: A tale of two cities

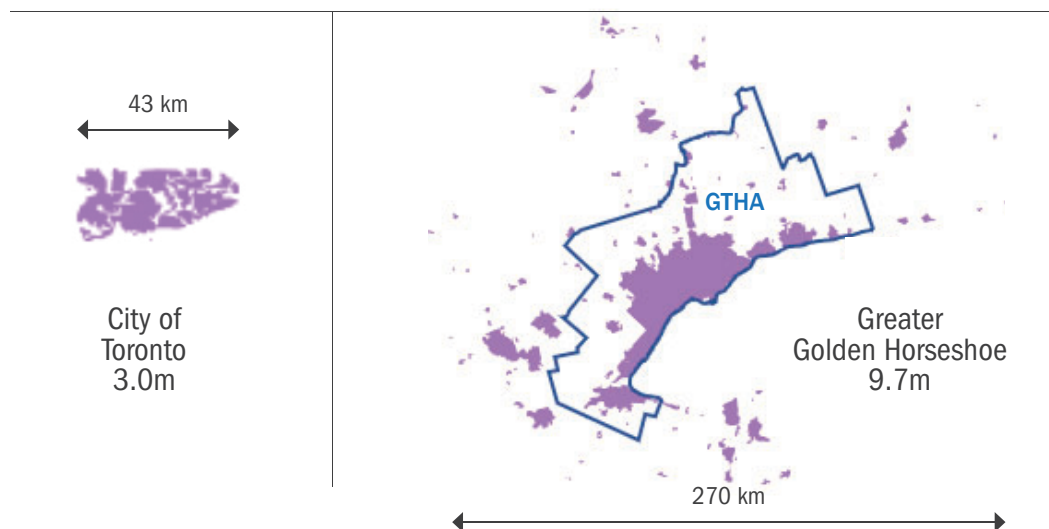
Relative to other global cities, Figure 1 illustrates the spatial footprint of City of Toronto (population 3 million) and Toronto Region (Golden Horseshoe, population 9.7 million). The City of Toronto (population density, 4150 people/km²) is a compact city, relatively easy to serve with mass transit, while Toronto Region (population density, 307 people/km²) is one of the world's most sprawling large cities. These two cities are inextricably linked and need to act as one coordinated city. Every day about 600,000 people commute into the City of Toronto (most by car) while about 400,000 travel out of the City to work in neighboring regions. Typical commute times now exceed 50 minutes (among the longest commutes in North America). In the Kitchener-Waterloo Region, 10,000 more commuters travel into the region every day, rather than those who exit to work in the GTA⁴ (about a third of the tech-workers commute into the Waterloo Region).

A priority for transportation systems in Toronto Region is to provide a means to connect the inner and outer parts of the overall region. Densities and distances dictate that this 'bridge' will need to be mainly surface transit, and ideally using existing alignments and corridors (as any new alignment or transit system would likely take a minimum of ten years and congestion is already severe today, leave alone another decade or more).

On a typical day in a Toronto residential community, some 20-30 delivery vehicles pass by every home. Canada Post, morning newspapers, FedEx and UPS, bicycle couriers, and increasingly food delivery (groceries and prepared) all consume road capacity, often generate emissions and typically operate at a fraction of their space capacity.

The rate at which the Toronto Region shifts from the current transportation system to a 'transportation as a service' approach will largely be determined by local governments.

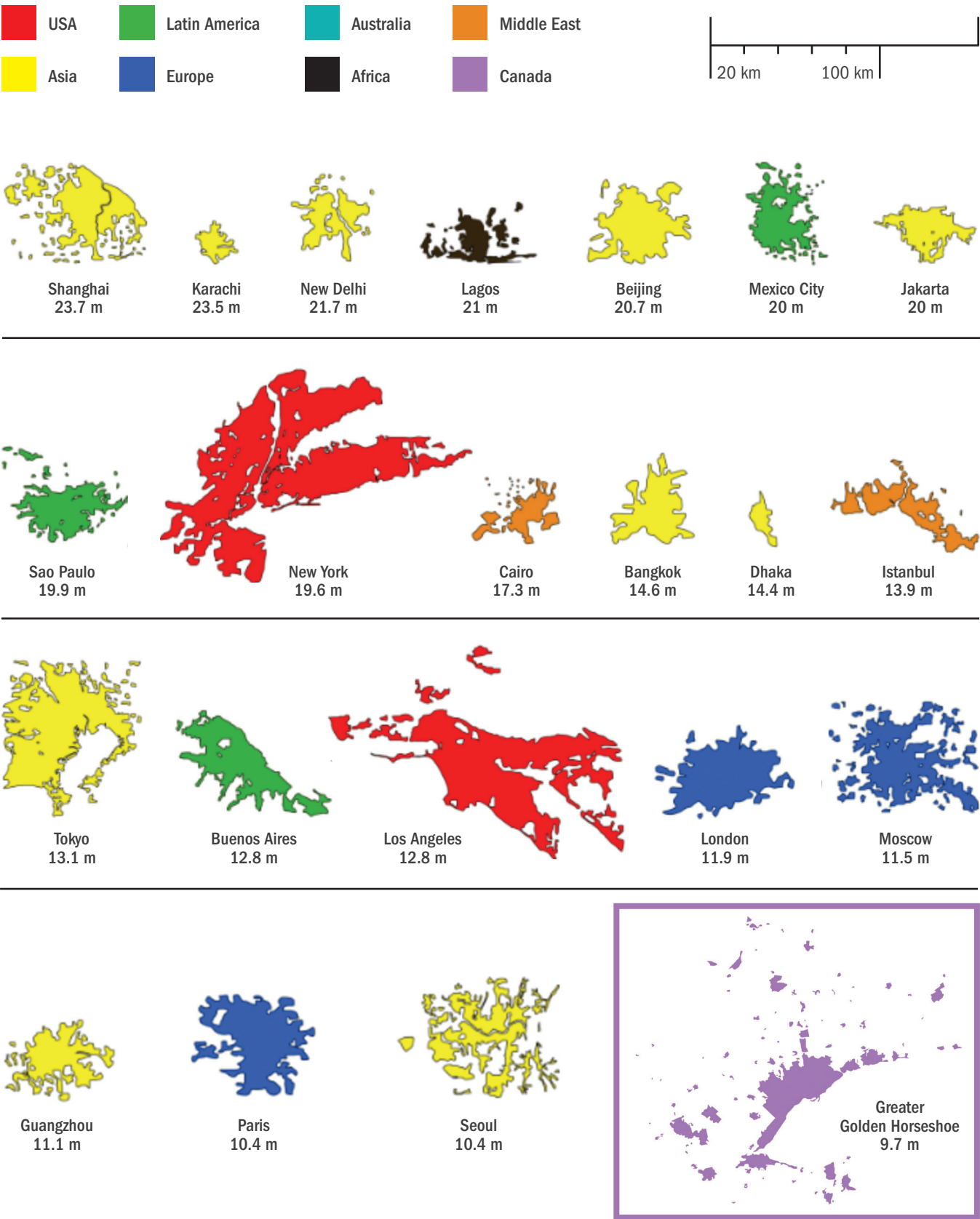
Figure 1: Toronto Region's Urban Footprint

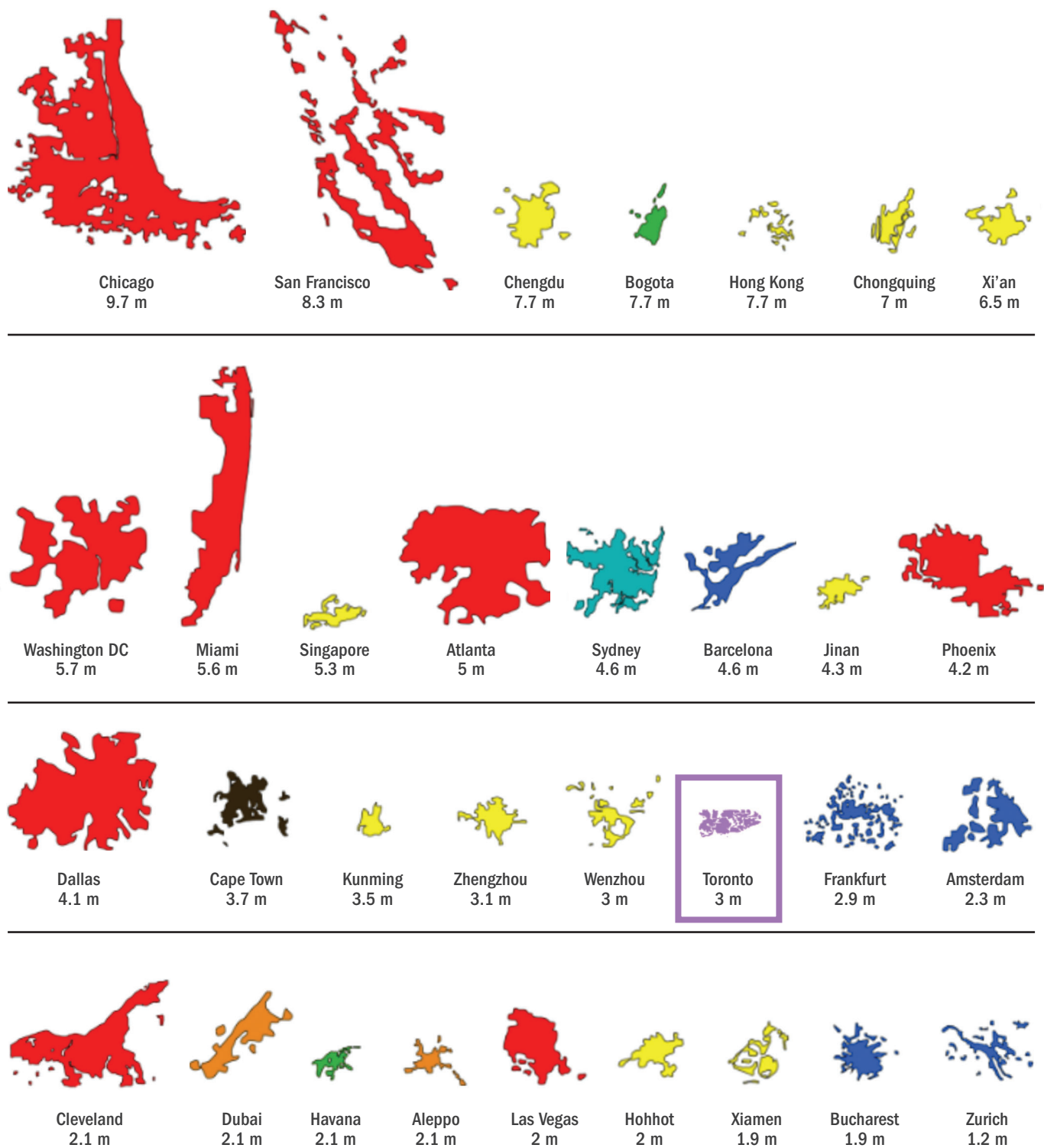


⁴ <https://kitchener.ctvnews.ca/more-than-one-third-of-local-tech-workers-commute-from-toronto-city-1.2588732>
Accessed 1 August, 2018

COMPARISON OF GLOBAL URBAN FOOTPRINTS

Cities arranged by population. Spatial extent of cities varies considerably across regions.





Adapted From: M. Hartzell, 2013.

CATALYSTS FOR CHANGE

EVs alone are not sufficient to bring about the enormous benefits that could accrue from changes to the Toronto Region transportation system, but this report suggests how EVs might catalyze this change and create widespread benefits in Ontario. This report suggests that efforts to encourage electric and autonomous vehicles in Southern Ontario will in turn provide broader improvements in personal mobility and freight delivery. To that end, the report analyzes the barriers to more widespread adoption of electric vehicles (EV) in the Toronto Region. The assessment focuses on three regional neighborhoods: The West Don Lands (WDL - a new neighbourhood east of downtown Toronto), Seaton (Pickering) and Clarington⁵.

A shift from internal-combustion engine (ICE) vehicles to EVs in the Toronto Region alone could eventually reduce carbon emissions by 25 Mt tonnes, about 2 tonnes per person. However, a shift from ICE to EVs alone will not address congestion in the Toronto Region. 'Transportation as a service' is likely the most important technical and social trend facing Ontario today. That is why this report emphasizes that Toronto needs an integrated approach that includes a 'one-two punch' of EVs *plus* ridesharing (along with improvements to arterial transit corridors).

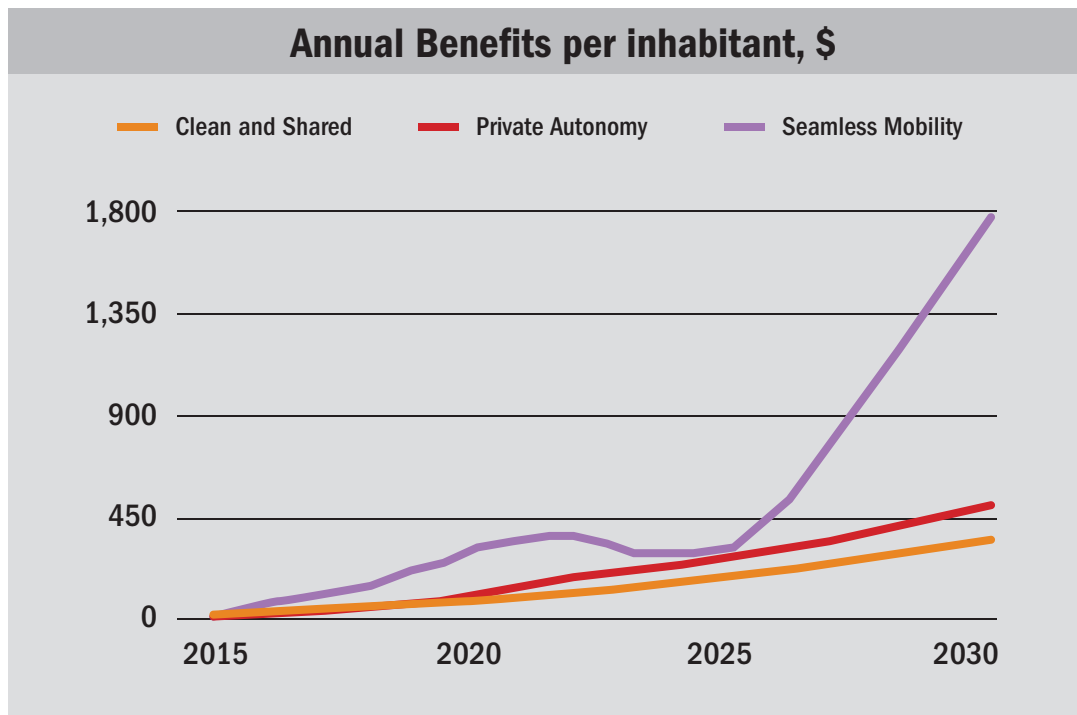
This combined EV/ride-sharing with arterial transit approach would reduce carbon emissions and traffic congestion while also providing significant economic and social benefits. Specifically, the report suggests that new transportation systems could provide economic benefits of some \$45 billion and reductions in CO₂ emissions by more than 25 Mt per year. This is a preliminary assessment, and detailed studies are still needed, however it is clear that opportunities of this scale are exceedingly rare.

This report states that:

- Based on anecdotal discussions, residents in West Don Lands, Toronto (and presumably other dense urban centers) prefer lifestyles requiring low vehicle ownership (regardless of EV or ICE); integrated multi-modal systems are key.
- In Durham Region, new communities in Seaton and Newcastle prioritize near-by connectivity, i.e. 'first-mile, last-mile' links, particularly to existing and proposed GO stations.
- In typical southern Ontario communities preliminary work shows that a 10% EV penetration rate leads to overloading of about 12.5% of local electrical transformers. A 30% EV penetration rate will lead to significant overloading of transformers (grid revisions will be necessary).

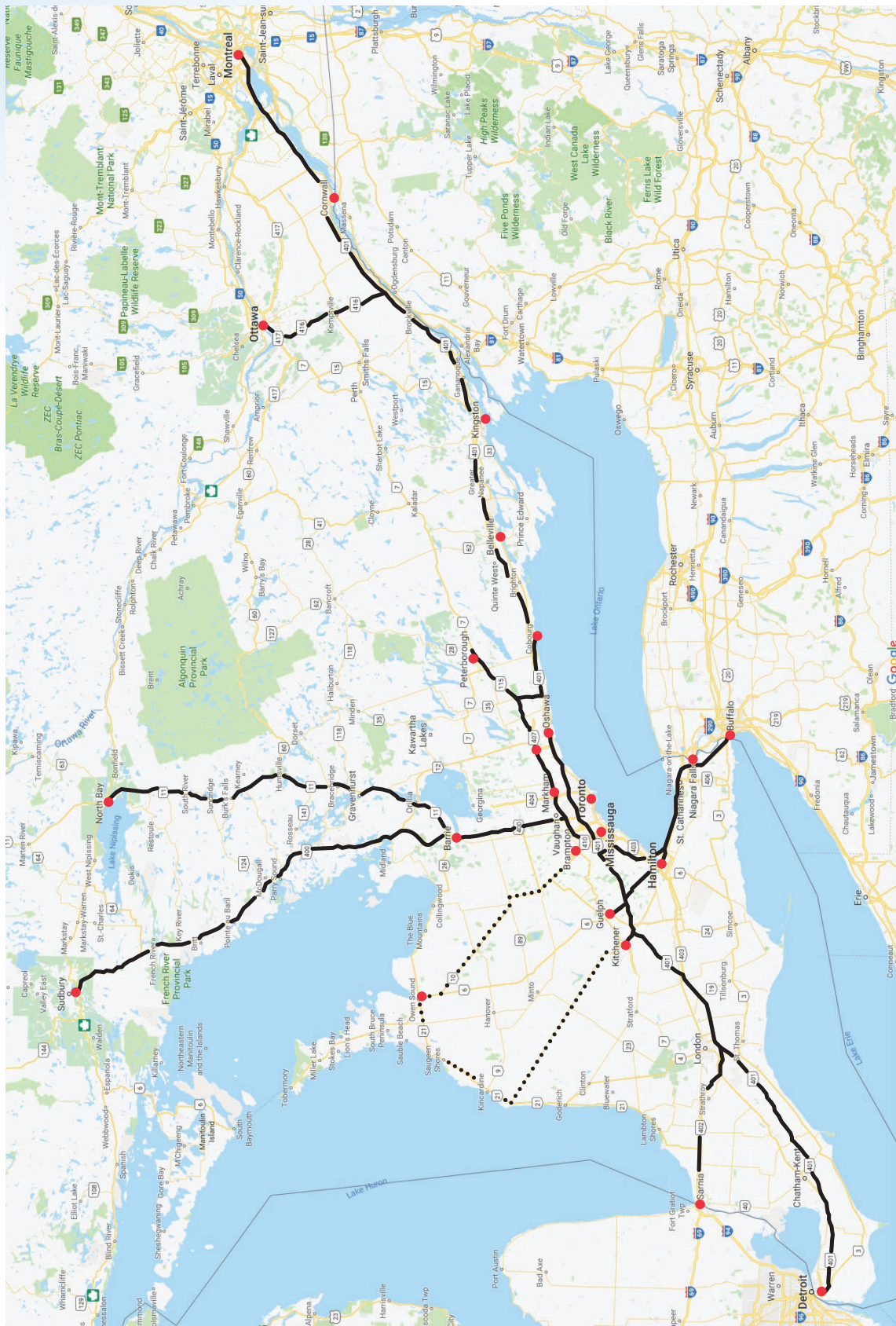
⁵ This analysis began as a project funded by the Metcalf Foundation to review EV barriers in three representative GTA communities. The study quickly broadened in order to maximize enormous potential benefits from improved transportation (economic, social and environmental).

- In dense cities, e.g. Changsha, China and likely the City of Toronto, ridesharing has the potential to reduce total kilometers driven by more than 20% and vehicle trips by 40% (assuming a maximum distance between trips less than 10 km, and schedule time less than 60 minutes).
- In the Toronto Region (Greater Golden Horseshoe), ridesharing has the potential to reduce total kilometers driven by 11% and vehicle trips by 16% (assuming a maximum increased distance between trips 20% of total trip length, and schedule time less than 60 minutes).
- One of the most significant barriers to increased ridesharing in Toronto Region (and most other jurisdictions) is lack of social trust. Like most of the world, social trust is declining in Toronto Region, likely due to decreases in social capital, which is directly linked to the levels of civic engagement and social connectedness. Social trust (or lack of) is linked to income inequality. Immigrant populations in Canada have significantly lower social trust than other Canadians. Ridesharing may well have even greater benefits in increasing social capital than reducing congestion, accidents, and emissions.



Projected benefits under 'Seamless Mobility' (fully intergtaed), 'Private Autonomy' and 'Clean and Shared' (EVs and ride-sharing). From: S. Bouton, E. Hannon, S. Knupfer and S. Ramkumar, The future(s) of mobility: How cities can benefit, McKinsey&Company, 2017. [USD]

Strengthening Ontario's surface arterial routes; connecting transit nodes



A PROPOSAL FOR TRANSPORTATION SUCCESS: 'LEARN ON THE GO'

When it comes to transportation, the Toronto Region benefits from two things.

First, much of Toronto Region is well-served by transportation infrastructure. Every year governments spend more than \$10 billion on building and \$20 billion on operating Ontario's roads. The road maintenance budget of the City of Toronto alone, for example, exceeds \$5 billion per year. Typically, roads (and transit systems) operate at over capacity, hence serious congestion. Linking key transit nodes through an efficient system could facilitate the movement of more people (while reducing the number of vehicles on highways and using existing infrastructure).

Second, Southern Ontario has one of the highest concentrations of post-secondary students, and institutions. With 13 colleges and universities (20+ campuses) and 600,000 students in the GTHA and an additional 24 colleges and universities and 450,000 students stretching from Windsor to Brockville and north to Sudbury. Within a 90-minute commute of the Toronto Region, some 30 colleges and universities with more than 1 million students and faculty can easily be linked. This is the world's highest concentration of educators, students, and start-up agencies like MaRS and Communitel.

'Learn on the GO' proposes to 'stitch together the fabric of Ontario' while reducing carbon emissions on a large scale (even greater than previous efforts to phase out coal-fired electricity generation) and significantly improve Ontario's economy. Post-secondary institutions would act as key transit nodes, and post-secondary students would help police the service ensuring security and efficiency (helping to build social trust).

Transportation services on arterial routes would occur at 15-to-30 minute intervals from 6:00 am to 11:00 pm daily with less frequent service evenings and weekends (vehicle size and number could be dictated by demand). Post-secondary students, and possibly faculty and staff, would have fares covered as part of fees and salaries. Larger employers could also access the service and obtain bulk discounts on fees. Key employers like Ontario Power Generation, Bruce Power (with large civil works projects in Durham Region and Bruce County), the Royal Bank and Thomson Reuters and major shopping destinations such as Oxford Properties (Square One, Yorkdale, Scarborough Town Center) could help catalyze the system. The system would integrate existing transit systems and newly emerging private sector components.

Time-of-use benefits, truck by-pass, and dedicated lanes and rights-of-way on 400-series highways and 407 ETR (where the Province of Ontario maintains ownership of a transit corridor) could be provided for the arterial surface transit system, ensuring faster travel times.

This ‘Learn on the GO’ proposal has roots in the StudentMoveTO program that began in 2015 with Universities of Ryerson, OCAD, York and Toronto, and through a 2017 proposal by University of Ontario Institute of Technology (UOIT) to the Ministry of Environment and Climate Change. UOIT (with one of the highest rates of commuting, and a relatively low carbon emissions inventory) offered to offset all remaining carbon emissions through a rideshare and surface transit program (buses and vans). This initiative brings together ridesharing applications such as Blencride and SmartCommute, large-scale transit corridors, and low(er) carbon buses and vans.

Universities could cover all or a portion of Learn on the GO fares for students and staff, provided the rider has an active Presto card (or equivalent). Riders entitled to reduced travel fares could perhaps be required to take an online course on security issues, similar to Ontario’s ‘SmartServe’ training for wait-staff in establishments serving alcohol. All students and staff could be requested to install a simple app on their smart phones to connect campus security personnel with local police departments and Metrolinx safety constables.

Expanding an Ontario Solution

The Places to Grow Act (2017) defines and locates 25 ‘growth nodes’ in Toronto Region (see Figure 2). Many of these growth nodes are near, or part of, post-secondary establishments (and key employer locations, e.g. Pearson Airport). Combining the growth nodes and post-secondary campuses for transit routing can help quickly develop an integrated transit network.

Smaller scale but equally vital, ‘service nodes’, should also be promoted. These facilities could provide the following services in an integrated manner: mobility connections (rapid transit, rideshare, parking); vehicle fueling (EV, petrol, and possibly hydrogen); shared workspace (possibly including training centers and telepresence facilities); shelter-in-place resilience centers; parcel delivery; food basics.

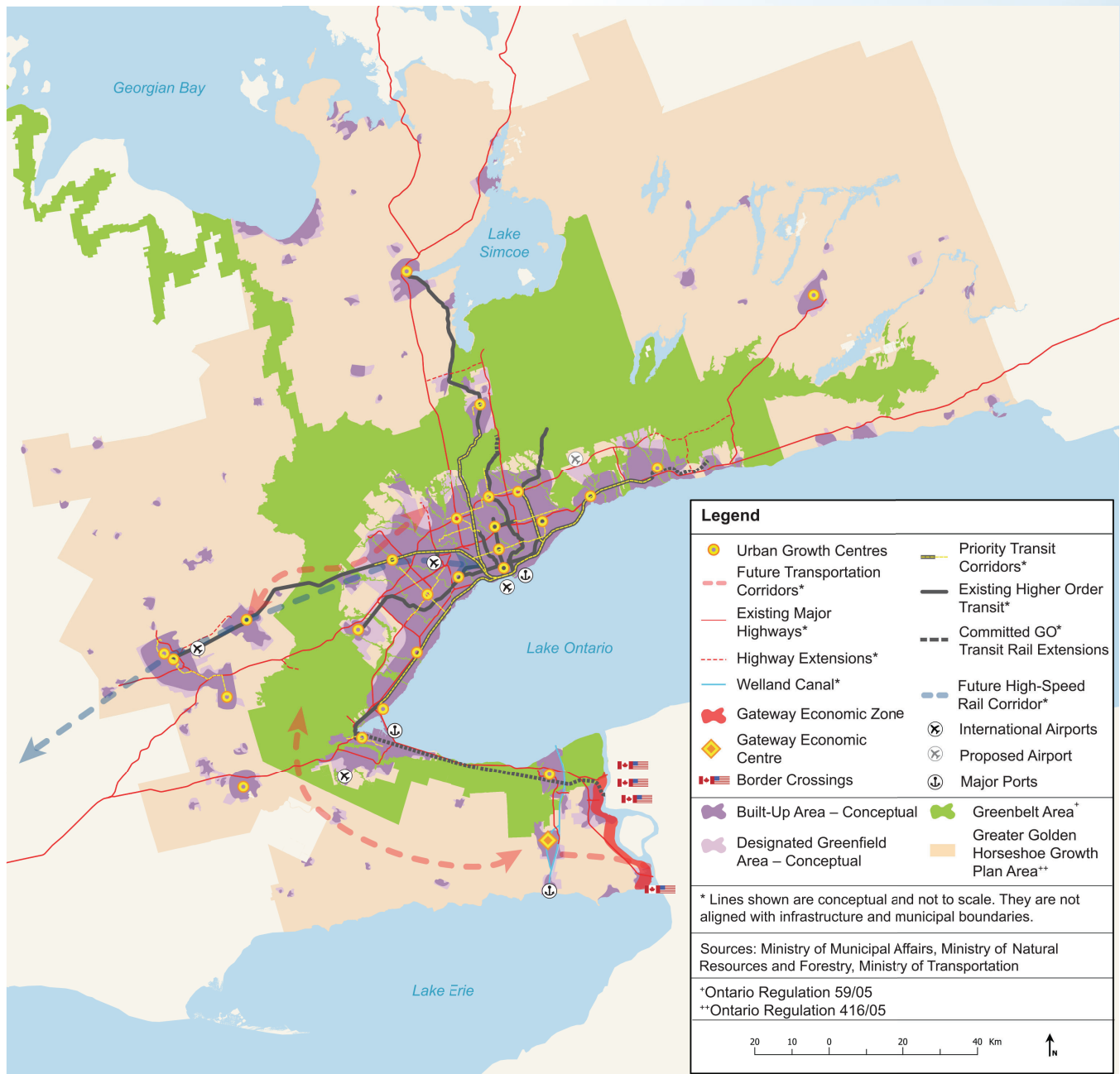
Much of the attention on ridesharing is with today’s millennials and connected city-residents. Uber, Uber-pool, Lyft and other mobility services are largely an urban phenomenon, and mainly serve customers that are more affluent. This will change.

Often the number one barrier to employment, for example in Prince Edward County, is access to transportation (usually defined as ‘must have valid Driver’s License and access to own vehicle’)⁶. Similarly, lack of mobility, is often a key barrier for the urban poor, e.g. in the Durham Region.

Ridesharing programs will likely evolve first to serve younger, richer urban customers (and post-secondary students through Learn on the GO); however with minor ‘tweaking’ ridesharing can provide an important service for communities that are more rural and the urban poor.

⁶ Personal communication – local builders and trades people.

Figure 2: Toronto Region 'Growth Nodes'



INNISFIL LEADS IN PILOTING WITH UBER

On a cold winter evening, on his way home from work, Jason Reynar, Innisfil's Chief Administration Officer, saw Joanne walking alongside the highway laden with grocery bags. He stopped to offer her a ride. The two struck up a conversation on the challenges of getting around Innisfil without a car. This eventually led to the Town of Innisfil entering into a pilot project with Uber.

The Town of 36,500 had just received a major transit study suggesting either a one- or a two-bus system (\$231,000 or \$330,000 plus \$439,000 or \$541,000 capital and operating costs respectively). Bus service would have limited hours and only serve areas within walking distance to the route. An alternative idea was piloted with Uber. Beginning May-2017 Innisfil residents have flat fare rides to-and-from popular destinations like the train station and commuter parking lots, and all rides originating, or ending in Town are discounted by \$5. An independent evaluation is not yet available, but so far, the service has a 70%+ satisfaction level and is saving the Town as much as \$5 million per year⁷.

A second pilot stage is now underway in Innisfil. A similar innovative pilot started recently in Belleville. In evenings, bus riders are able to book their bus online, reducing wait-times and increasing reliability. Early results show ridership increasing by as much as forty percent.

One of the most pressing questions facing transportation planners today is the future role of the automobile. The exact date is unknown, but planners are reasonably certain that soon, the transportation system will fundamentally shift. Disruption to the sector and layout of communities will be widespread and irreversible.

How will these new cars and services operate, who will regulate them, how much will they cost to operate, how will they use existing roads, and what new infrastructure do they need?

These questions are more complex in regions like Ontario where car culture is deeply entrenched. Few economies and lifestyles are more reliant on the automobile than Ontario. Large-scale manufacturing of cars in Ontario dates back to 1907 when the McLaughlin Motor Car Company started building cars in Oshawa.

Weaning the province from the automobile and developing new transportation systems will be difficult and some things are likely to stay the same. For example, arguments over who gets priority use of roads will continue. Road space will always be scarce, especially in urban centers. Freight delivery will fight for space, and personal AVs may challenge fleet vehicles providing shared services.

⁷ Details from Uber website <https://www.uber.com/cities/innisfil/ride/>

HIGHWAY 400: MORE VALUE FOR MONEY?

In 2003 Premier Ernie Eves, committed the Province of Ontario to twin 173 km of Highway 69 from Parry Sound to Sudbury. Costs of this undertaking are likely around \$2 billion, with completion expected between 2025 and 2030. This cost excludes the half billion dollars allocated for ongoing improvements to 30 km of Highway 400 south of Barrie between Highways 89 and 11, and the \$500 million for the now completed twinning from Port Severn to Parry Sound.

The initiative to fully provide four-lanes from Barrie to Sudbury (and re-name to Hwy 400) was partially catalyzed following the tragic August 2002 accident near the Killarney turn-off that took the lives of Kelly Anderson and her twin 12-year-old sons. Lobbying for improvements to Highway 69 dates back more than 30 years. All three political parties supported twinning of the Highway.

With the challenging alignment through marsh and granite of the Canadian Shield, a relatively short construction season, and numerous river crossings, Highway 400 to Sudbury is one of the most costly highways in the world. This cost-to-potential-benefit is especially high considering typical traffic counts on the section of highway from Parry Sound to Sudbury rarely exceeds an average annual daily traffic (AADT) volume of 8,000 (compare this to 420,000 AADT on Highway 401 in North York; MTO, 2016).

An option to increase the benefits of the high cost of Highway 400 to Sudbury is to increase the number of people travelling the route. Typically, this would be accomplished through increased traffic volumes (e.g. MTO measures vehicles travelling not people). Another alternative is to designate the route a 'surface arterial' with increased bus and rideshare options. Linking key transit nodes such as Barrie, Innisfil (see Uber-pilot discussion), Port Severn, and Parry Sound would provide another transportation option. Provided that the requisite rideshare and intermodal platforms are linked, many new travelers could use the Highway 400 corridor to access cottages, smaller communities, and Sudbury. Sudbury is proposed to be included in the 'Learn on the GO' program. Similar surface arterial routes could be developed to Sault Ste. Marie, North Bay, London-Windsor, Belleville-Kingston-Montreal. These would complement existing bus routes (e.g. the Northland currently connects Toronto to Sudbury with three-times-per-day bus routes).

The arterial routes would have frequent travel (transit and ride-sharing) linked to ride-sharing and ride-hailing services at key transportation nodes. A service target would be that travel on 400-series highways would be as fast through 'transportation-as-a-service' means as through personal automobiles.

SUMMARY RECOMMENDATIONS TO SUPPORT THE TRANSITION TO TRANSPORTATION AS A SERVICE (ONTARIO)

NB: many of these recommendations are adopted from other studies, e.g. Metrolinx regional transportation plan.

Local Governments (municipalities)

- In new communities (in the Toronto Region), encourage new home design to facilitate easy conversion of garages and driveways to other uses (flexible building design and zoning).
- In new communities designate locations for parcel drop-off and commuter collection nodes.
- Identify and encourage establishment of work (transit) nodes; include designation in land-use plans.
- Work together to develop 'open source' mobility platform(s) for integrated travel across modes and contiguous communities.
- Serve as key interlocutor with residents on the need for transportation pricing to drive efficiencies, e.g. parking fees and tolls (advocate for municipal share of road revenues).
- Support the segregation of vehicle types, e.g. restricted hours for heavy-duty trucks, and identified zones for AVs, bike lanes, and pedestrian walkways.
- Encourage a fee for distance travelled for all autonomous vehicles (AVs) – differentiate the fee for single occupancy versus ride-sharing and ride-hailing.
- As part of land-use plans, publish population density goals by neighborhood – update progress annually. As AVs become widespread enact property tax policies that recognize deviations from density targets, i.e. act now to ensure that AVs do not bring about more urban sprawl.
- Differentiate parking fees by vehicle size, pollution levels, and typical occupancy levels.
- Lead on 'first- and last-mile' transportation service provision.
- Lead on data collection and security aspects of vehicles operating on local roads.
- As likely termini, the cities of Sudbury, North Bay, Kingston, Ottawa, Sarnia, London and Windsor have a unique role to play in supporting (and establishing) the proposed arterial transit system.
- Corporate influence will be intense, and the provincial and federal government are responsible for much of the funding and regulatory aspects of the system, however, municipalities need to lead in developing Ontario's new transportation system.
- Apply 'safety by design' in new TaaS infrastructure and services, e.g. licensing, training and vehicle monitoring.

Government of Ontario

- Re-visit the long-term energy plan for a possible increase of 5,000 MW in electricity demand as the transportation fleet electrifies. Ensure that the carbon intensity of Ontario's grid-supplied electricity stays below 75 g CO₂/kWh.
- Prioritize arterial (surface) routes and transit servicing (signal likely routes, modes and timing).
- Fully integrate TTC and Metrolinx transit offerings (consistent with TTC long-range planning and 2018 Metrolinx Transportation Plan); include regional transit companies as well.
- Re-visit fees as a way to enhance efficiencies, e.g. parking fees and tolls.
- Signal that by a given date, say 2030, vehicles (especially AVs) will be levied a fee for distance travelled – differentiate the fee for single occupancy versus ride-sharing.
- Assess ways that 400-series highways can provide disaggregated travel lanes and times, e.g. separate lanes for vehicles below 1600 Kg (base curb weight); differentiated travel speeds (reduced for heavy-duty trucks, increased for rapid transit buses).
- Assess ways that heavy-duty trucks could by-pass Highway 401 through Hwy 407 ETR (with possible integrated bus rapid transit and heavy-duty truck lanes).
- Ensure that new transportation systems evolve with services for seniors, children, and persons with disabilities.
- Expand transportation services to link key system nodes such as post-secondary institutions, health care facilities, and tourist destinations.
- Prioritize the movement of people and goods (vis a vis manufacturing and local area development).
- Dictate a response time target for first-responders to return-to-service of roads after an accident, e.g. the USA FHWA 90 minute target for return-to-service after a major incident.
- Set a total annual upper-limit for the province's electricity sector, with individual CO₂e emissions below 2T per person (with an aspirational goal of 1T per person by 2050).
- Support launch of 'Learn on the GO' for Ontario's post-secondary institutions.

Government of Canada

- Establish a transportation transition program – with training and possibly financial support to key areas such as Alberta’s oil patch, automobile manufacturers, truck drivers, and auto servicing business operators.
- Provide an active website and regular publications on disruption of the transportation sector; benchmark Canada’s relative progress; designate several ‘pilot communities’ and service providers to develop aspects of the TaaS system.
- Ensure that oversight and regulation of Canada’s communication services is consistent with data systems requirements for transportation as a service objectives.

Boards of Education

- Encourage ‘walk (or bike) to school’ options for students and staff.
- Assess ways to open student bussing to local residents (security clearances and payment plans possible – provide real-time GPS of bus routes and stops).
- Encourage schools to locate next to, or support development of other key transportation nodes (pursue integrated use options for facilities).
- By 2025 provide draft policy for student transportation through AVs.

Local Distribution Companies (electricity utilities)

- Consider business opportunities to provide servicing to, or complete provision of, EV and AV fleets. For example, support battery-swap EV fleet servicing.
- Advise homebuilders and homeowners on ways to integrate vehicle charging with battery storage and increased resilience (off grid capacities).

Post-Secondary Institutions

- Work together to establish a Toronto Region arterial transit system to connect all institutions, i.e. develop ‘Learn on the GO’.
- Work with partners to provide low cost transit options for students – with support for others to use the system.
- Collaborate with local governments to establish transit nodes near facilities (employment, freight & delivery, and logistical support).
- Assess practicality of making residences available on short-term basis to non-student occupants (possibly expanding facilities).

Private Sector

- All employers in the Toronto Region with more than 1000 employees (direct and/or contracted) should consider joining the smart commute program (as expanded with Learn on the GO).

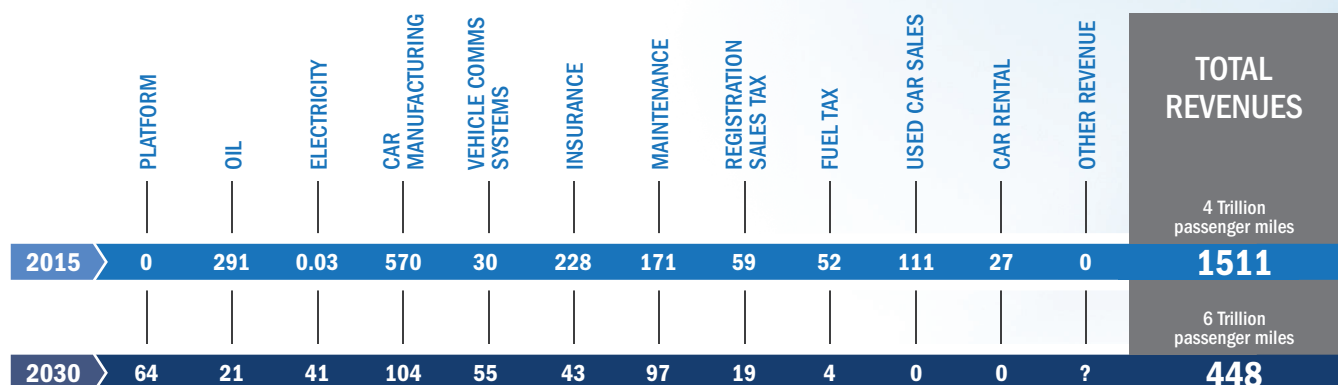
TRANSPORTATION INDEX: ONTARIO AND CANADA

Annual motor vehicle license sales and renewal revenue in Ontario:	\$1.1 billion
Annual number of visits to drive-through establishments in Canada:	1.3 billion
Number of retail gas stations in Ontario:	3,601
Annual insurance premiums for Ontario drivers:	\$10 billion
Sales of diesel fuel in Ontario:	5,427,217,000 liters (14.7 million tonnes CO ₂) per year
Sales of gasoline in Ontario:	16,261,678,000 liters (37.4 million tonnes CO ₂) per year
Gasoline and motive fuel tax revenue in Ontario:	\$3.1 billion per year
Canada's annual vehicle export revenue:	\$84.3 billion (94% from Ontario)
Average monthly payment on new vehicles:	\$570 for loan and \$490 for lease
Value of vehicles and parts produced in Ontario:	\$201 million per day
Number of automotive manufacturing industry employees in Ontario:	101,000
Canada's retail sales in the automotive aftermarket:	\$19.3 billion per year
Number of employees and service technicians in Canada's aftermarket:	490,000
Annual revenue:	METROLINX, \$1.2 billion; Passenger rail (VIA), \$271 million
Annual freight rail (CP, CN) revenues:	\$6.2 billion, \$12.8 billion respectively
Number of Canada's 20 worst highway bottlenecks located in Toronto:	10
Extra time behind the wheel, per year, that Canada's bottlenecks cost drivers:	11.5 million hours
Extra fuel used for the extended drive times at Canada's bottlenecks:	22 million liters
Minimum annual Highway 407 toll revenue:	\$373 million
Annual number of convictions through vehicle related incidences in Ontario:	1,323,774
Police officer's shift time spent in their vehicle:	49%
Annual motor vehicle related Emergency room visits in Ontario:	62,562
Minimum costs associated with injury from transportation incidences in Ontario:	\$1.23 billion
Average gross payment of automobile accident settlements:	\$120,000 per claimant
Number of taxi and limousine companies and self-employed drivers in Ontario:	17,276
Annual revenue for taxi and limousine services in Ontario:	\$807 million
Vehicles manufactured in Canada in 1999: 3 Mn.	Last year: 2.2 Mn
Ontario's imports of petroleum and natural gas:	\$11 billion per year

TRANSPORTATION INDEX: TORONTO REGION

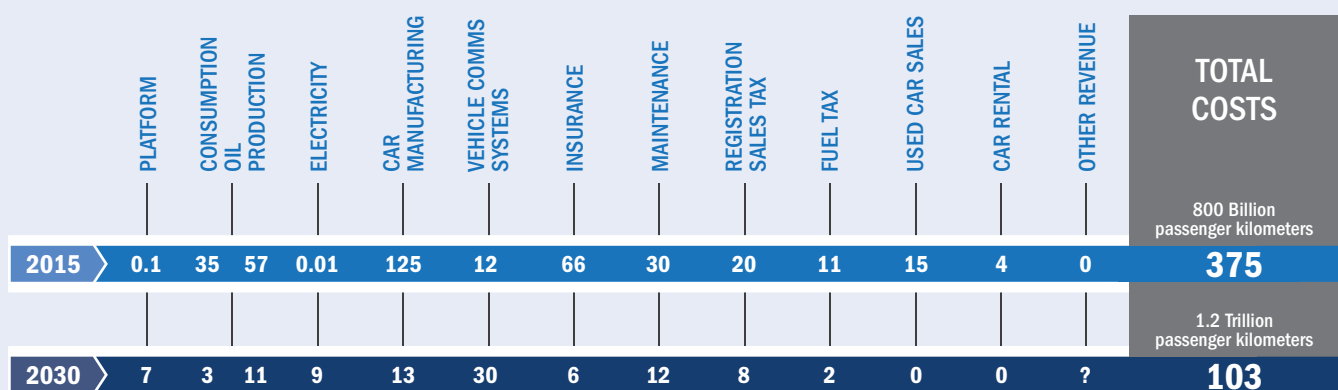
Number of vehicles registered:	6,123,926
Minimum annual operating cost of personal vehicles:	\$67 billion
Annual license plate renewal revenue:	\$734,871,120
Minimum number of parking spaces:	6,771,165
Number of drive through establishments:	1,142
GHG emissions from gasoline and diesel vehicles:	32 million tonnes CO ₂ per year
Number of trucks carrying goods travelling in the Region:	65,000 per day
Minimum value of goods coming into the Region by truck:	\$1.44 billion per day
Total transit operating budgets:	\$16 billion per year
Minimum annual car parking & ground transportation fees Pearson Airport:	\$160 million
Congestion costs to drivers on Hwy 401 between Hwy 427 and Yonge St:	3 million hours per year
Minimum number of vehicles on highways:	2 million per day
Trips per day at Highway 401 and Islington:	403,000 vehicles
Ratio of motor vehicles to pedestrian trips in Toronto:	10:1
Number of police officers:	13,983
Vehicle ticket violations revenue:	\$252 million per year
People transported by ambulance after an automobile accident:	37,311 per year
Minimum cost for these transports:	\$30,706,953
Minimum annual hospital parking revenues:	\$60 million
Minimum annual firetruck dispatches to motor vehicle fire or accidents:	99,824
Minimum annual number of vehicle accidents resulting in injury or death:	45,216
Minimum number of pedestrians and cyclists killed in City of Toronto in 2017:	48
Number of driving schools:	604
Number of car wash stations:	1,260
Annual car wash revenues:	\$109,029,060
Estimated minimum number of City of Toronto police officers that live outside of Toronto:	80%

Figure 3: Annual Transportation Costs for USA in Billions Dollars, USD



Adapted from RethinkX 2017, 'Vehicle communication systems' estimated by authors; includes share of smart-phone and subscription fees.

Figure 4: Estimated Annual Transportation Costs for Canada in Billions of Dollars (\$CDN)



National projection based on Figure 1 (RethinkX 2017 - values applied to Canada).

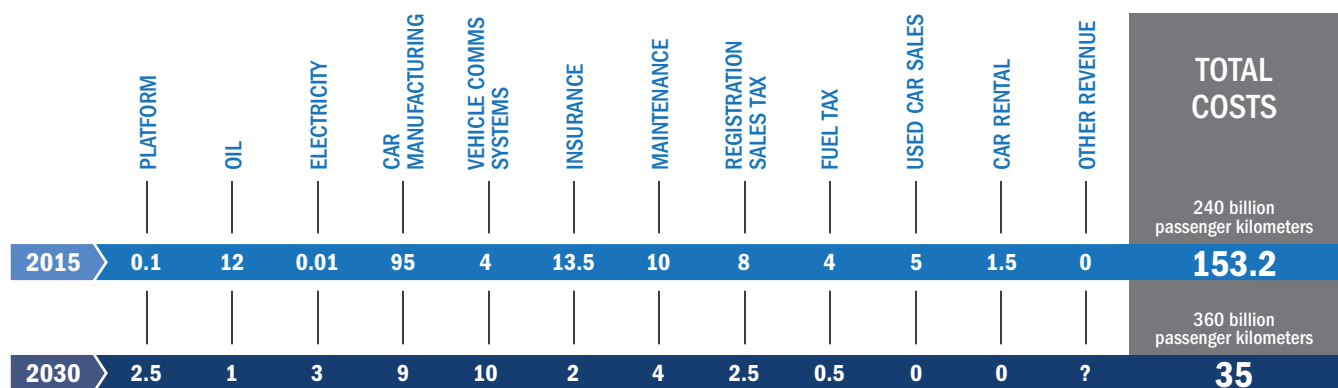
Oil production based on 2015 oil production levels of 621,610 m3/day (3.9 Mbbl/d@\$40 net/bbl and an estimated 80% production decline).

Economic comparison based on Canada's \$US 45,032 per person GDP and USA \$US 59,532 per person (World Bank, 2017) and populations of Canada - 36.7 million and US - 326 million (Canadian worker productivity 82% of US counterpart).

'Car manufacturing' presented as fraction of economy rather than share of transportation cost (share of personal costs likely 50% less).

'Other revenues' likely to include road-usage charges and mobile data fees.

Figure 5: Estimated Transportation Costs for Ontario (Toronto Region) in Billions of Dollars (\$CDN)



Based on Figures 3 and 4. Oil production negligible. Travel and economic values about 30% of Canada's overall. Other revenues' likely to include road-usage charges and mobile data fees. Values consistent with RethinkX, 2017. Suggested date of 2030 likely represents earliest possible transition.

This report summarizes a study completed by
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