Edmonton

IMPACT OF AUTONOMOUS VEHICLES ON GHG EMISSIONS

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SSG SUSTAINABILITY SOLUTIONS GROUP

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GLOSSARY

AVs: Autonomous vehicles

GHG: Greenhouse gas emissions

MaaS: Mobility-as-a-service

VKT: Vehicle kilometres travelled

INTRODUCTION

Private automobiles are parked 95% of the time, and are increasingly slowed down by traffic congestion during the 5% of the time they are actually being used.

The mass-produced, gasoline-powered, private automobile has proven to be one of the most compelling innovations of all time, and triggered widespread disruption and transformation throughout society. The cost of owning and maintaining private automobiles is a larger share of household spending than food, clothing or any other household expense except shelter, even without including the share of income tax that goes to building and maintaining the transportation infrastructure.[1] Canadians spend over 200 hours per year in their cars as either passengers or drivers, moving at an average speed of about 40 km/hour.[2] In addition to the actual travel time, if the time it takes to earn the money to pay for the cars is included with the fuel, the road infrastructure and all the other expenses associated with the private car system, the effective speed (sometimes called the social speed) of private vehicles can be reduced to less than 20 km/hour.[3] Notwithstanding all this expense and economic activity, private automobiles are parked 95% of the time, and are increasingly slowed down by traffic congestion during the 5% of the time they are actually being used.[4] This most disruptive of systems is itself ripe for transformative disruption, with a number of concurrent technological and business model innovations poised to transform the century-old car-centred system.

[1] Statistics Canada. Table 11-10-0222-01, Household spending, Canada, regions and provinces. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1110022201

[2] Transport Canada, "Transportation in Canada 2017 -- Statistical Addendum", Table R05 - Canadian Vehicle Use Study Light Vehicle Statistics, Averages per Trip, 2015.

[3] Litman, Todd. "Transportation cost and benefit analysis II–travel time costs." Victoria Transport Policy Institute, Victoria, Canada (2009).

[4] For example, see calculations here: https://www.reinventingparking.org/2013/02/cars-are-parked-95-of-time-lets-check.html

KEY TRENDS

1. The electric car is poised to accelerate up the "S" curve of new technology adoption, propelled by falling battery costs, expanding charging infrastructure, improved vehicle performance, and a growing variety of cars on the market covering a wide range of sizes, styles and price points.

2. Vehicle automation continues to advance, with many automated driver-assistance and safety features becoming standard equipment. Fully automated cars that can drive themselves are a technological *fait accompli*, but their deployment will depend on the rate at which both the hard and soft infrastructure can be put in place to support their safe and widespread use in urban environments. Nearly fully automated operation of some vehicles on limited access highways is already occurring. Powerful, on-board computers, machine intelligence and the high speed, low latency interconnectivity made possible by 5G networks will facilitate the realization of the full potential of vehicle automation.

3. Mobility-as-a-service (MaaS) business models, currently in their nascent stage of development with ride-sharing and car-sharing companies, combined with changing attitudes toward car ownership, will have transformative and far-reaching impacts as their share of the personal mobility market grows.

The above three trends are each disruptive in different ways, but taken together they represent a potential transformation of the personal mobility system with far-reaching implications for many aspects of daily life.

GHG EMISSIONS FROM TRANSPORTATION

The following factors drives GHG emissions resulting from transportation:

- the number of trips;
- the length of the trips;
- the number of people per vehicle;
- the energy efficiency of the vehicles; and

- the emission factors of the fuels (or electricity) consumed.

Automated vehicles will impact each of these factors.

Over a range of scenarios for how the autonomous vehicles will be deployed, total vehicle-kilometres of travel (VKT) will likely increase, but the net impact of autonomous vehicles on transportation, land use and settlement patterns will depend largely on whether they are primarily privately owned, personal vehicles or part of a MaaS system.

Over a range of scenarios for how the autonomous vehicles will be deployed, total vehicle-kilometres of travel (VKT) will likely increase.

The amount of time people will be willing to spend on their daily travel could increase as they no longer need to be driving the vehicle during that time and can therefore do other things, rest, or be more productive; the result is increased trip length. In this case, the vehicle stock would continue to grow, as would annual kilometres travelled per vehicle, leading to “more of the same” -- more congestion, more sprawl, and more vehicles.

In the other direction, in which the autonomous cars are part of a MaaS system, there would be truly transformative and disruptive impacts. The utilization of cars would increase several-fold, cutting the cost of mobility by more than 50% while reducing the size of the on-road vehicle fleet. Vast amounts of land currently set aside for parking would become available for re-allocation to higher value uses, and over the long term the pattern of urban land use would change in response to the new mobility system. While total automobile VKT would increase, this would be more than offset by the reduced number of vehicles on the road. Sophisticated routing and vehicle assignment software and control systems would relieve congestion around major destinations, and vehicle platooning and traffic management systems would optimize routing and travel times throughout the urban area. The low cost and convenience of AVs would result in the cannibalisation of public transit

In a MaaS scenario, parking requirements will decline, freeing up land for intensive, mixed use urban neighbourhoods and lively workplaces. This is an example of positive feedback that can foster a transformation of urban form and spatial structure that facilitates fewer and shorter trips and a larger modal share for walking and cycling.

If the autonomous vehicle is developed as part of a transition to a MaaS model, the high value and shorter lifetimes of the shared vehicles will help accelerate electrification of the fleet, reducing the emissions factor of the fuel, assuming clean sources of electricity.

Table 1: Summary of the potential impact of AVs on factors influencing GHG emissions in transportation

Factor	Impact of AVs
Number of trips	Increase
Length of trips	Increase
Number of people per vehicle	Variable
Energy efficiency of the vehicle	Increase
Emissions factor of the fuel	Decrease

IMPACT ON EDMONTON'S CARBON BUDGET

In order to evaluate the impact of AVs on future GHG emissions in Edmonton, a relatively conservative MaaS was evaluated in the energy and emissions model used to develop City of Edmonton's Community Energy Transition Strategy Update.[5]

In this scenario, vehicle ownership declines by 50% by 2050 but personal VKT increases by 20%.[6][7] The increase in VKT results as new cohorts of the population (young and elderly, for example) have access to vehicles. The convenience of AVs, and the decreased cost of travel[8] will cannibalize public transit and stimulate additional travel.

[5] See City Council Minutes of August 27, 2019: http://sirepub.edmonton.ca/sirepub/mtgviewer.aspx?meetid=2313&doctype=MINUTES

[6] Johnson, C., & Walker, J. (2016). Peak Car Ownership: The Market Opportunity of Electricity Automated Mobility Services. Rocky Mountain Institute. https://rmi.org/Content/Files/CWRRMI_POVdefection_FullReport_L12.pdf

[7] Many studies project significantly higher increases in VKT; see: Pernestå, A., & Kristoffersson, I. (2019). Effects of driverless vehicles-Comparing simulations to get a broader picture. European Journal of Transport & Infrastructure Research, 19(1).

[8] Ticoll, D. (2015). Driving changes: Automated vehicles in Toronto. https://www1.toronto.ca/City%20Of%20Toronto/Transportation%20Services/TS%20Publication

An additional assumption is made that each AV which is added is also electric and that the introduction of AVs to the community fleet occurs at the same rate as electric vehicles in the scenario which does not include AVs.

Table 2: Parameters adjusted to evaluate the impact of AVs on GHG emissions

Variable	Low Carbon- No AVs	Low Carbon + AVs
Low carbon actions	Aligned with Energy Transition Strategy Update	Aligned with Energy Transition Strategy Update
Vehicle technology	Electric vehicles	Autonomous electric vehicles
VKT	Current patterns of travel	Travel increases by 20%
Vehicle ownership	Current ownership rate	Vehicle ownership declines by 50%

Total VKT increases as AVs are added to the community fleet, including a 6% increase by 2030, a 13% increase by 2040 and a 19% increase by 2050. The cumulative increase in VKT over the period from 2022 to 2050 is 68 billion kilometres.

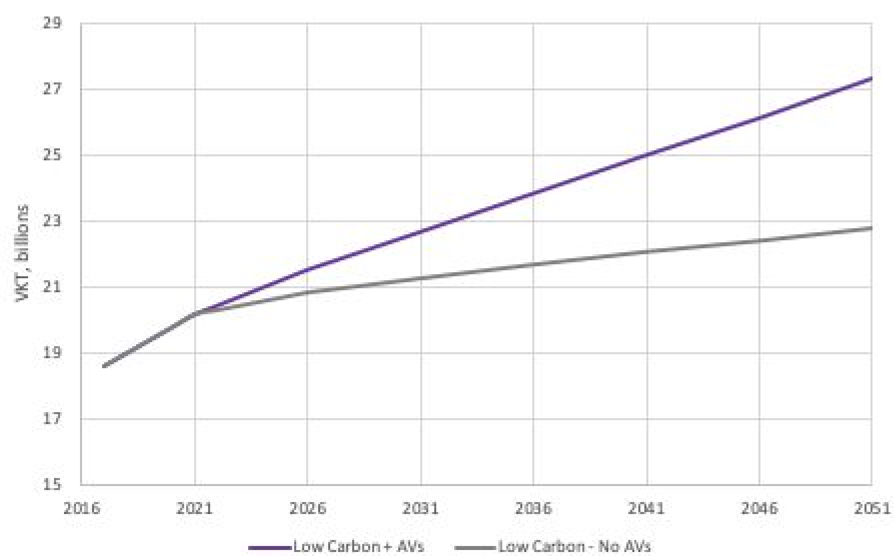

Figure 1: Impact of AVs on VKT in Edmonton's Energy Transition Scenario[9]

[9] Note that this analysis is based on earlier version of the low carbon scenarios developed for the City of Edmonton. Subsequent modelling changes, however. do not significantly influence the results.

This increase in VKT has implications for energy demand and supply, operations costs and transportation infrastructure.

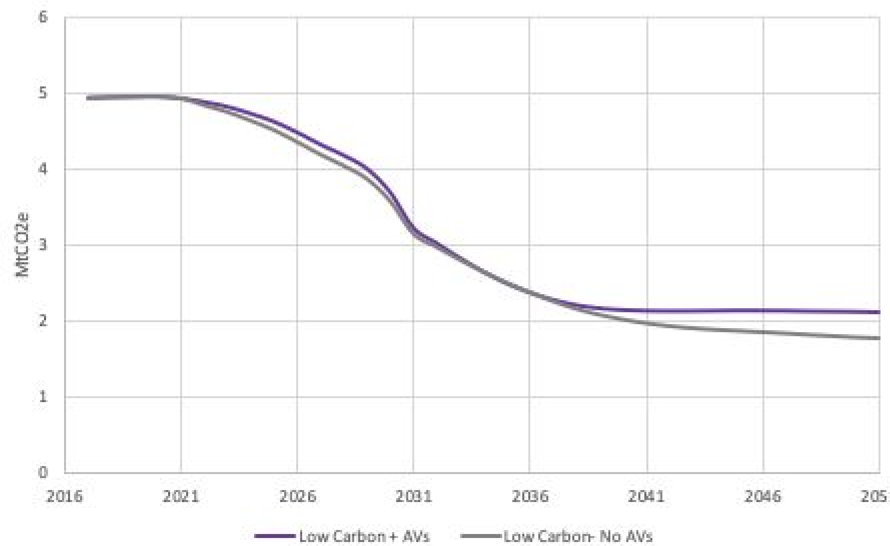

Figure 2: Impact of AVs on VKT in Edmonton's Energy Transition Scenario[10]

Figure 2 illustrates the impact of the AVs on total GHG emissions, a finding similar to other studies.[11] Electric vehicles are being introduced in both scenarios, so the increase in GHG emissions is the result of increased VKT. While the annual increase in GHG emissions is relatively small, the cumulative increase between 2022 and 2050 totals 4 MtCO2e. Note that if electricity was 100% renewable by 2050, GHG emissions would be the same in both scenarios by 2050. Even in this case, the cost of generating and purchasing renewable electricity would be higher in the AV scenario because of the energy demand arising from the additional VKT. Further, this additional electricity demand represents a further strain on the electricity grid. If, on the other hand, the emissions factor of the electricity grid becomes dirtier, or in the less likely case that the AVs are not electric, AVs would drive much greater increases in GHG emissions.

There are significant avoided capital costs in an AV scenario, due to the efficiency of utilisation of vehicles. In many cities, vehicles represent one of

[10] Note that this analysis is based on earlier version of the low carbon scenarios developed for the City of Edmonton. Subsequent modelling changes, however. do not significantly influence the results.

[11] Fox-Penner, P., Gorman, W., & Hatch, J. (2018). Long-term US transportation electricity use considering the effect of autonomous-vehicles: Estimates & policy observations. *Energy policy*, *122*, 203-213

the largest, if not the largest, annual energy-related capital expenditure.[12] At the household level, the MaaS model transforms what is typically a household capital cost to a service or operating cost correlated to use. The capital cost is shifted to a single or a few private or public entities, and is reduced overall, as fewer vehicles are purchased. Because vehicle utilisation increases, the lifetime of an AV is shorter than a private vehicle. Given appropriate public policy, a MaaS AV scenario could liberate capital to finance the energy transition in other sectors.

POLICY IMPLICATIONS

Ensuring that AVs reduce or limit increases in GHG emissions involves the following considerations:

- Reducing vehicular trips remains the highest priority through the provision of non-vehicular or transit infrastructure.
- AVs must be electric.
- The source of electricity for the AVs needs to be from renewable energy.
- Mechanisms to require or incentivise carsharing in AVs will reduce or limit the stimulation of additional vehicular trips.[13]
- The space liberated from parking is transformed to mixed-use developments which stimulate non-vehicular mobility.
- Policies designed to redirect avoided capital expenditures to support the energy transition will be developed.
- MaaS deployment models, including public or transit ownership, should be considered which are designed to maximise public benefits (i.e. GHG reductions, equity considerations) as opposed to maximising profit, which could stimulate more vehicular trips.
- Equity needs to be at the forefront of policy related to AVs.[14]

A review of leading cities found twenty specific measures that cities can undertake to ensure that AVs contribute to sustainable mobility more

[12] Based on analysis of multiple Canadian cities completed by SSG.
[13] Merlin, L. A. (2019). Transportation Sustainability Follows From More People in Fewer Vehicles, Not Necessarily Automation. Journal of the American Planning Association, 1-10.
[14] Cohen, S., & Sahar, S. (2017). Can We Advance Social Equity with Shared, Autonomous and Electric Vehicles?. Institute of Transportation Studies at the University of California, Davis.

broadly, such as dedicated AV zones, high occupancy lanes, dedicated parking, dividers for AVs and other road users, vehicle to grid integration and removal of on-street parking.[15]

CONCLUSION

The impact of AVs on the existing transportation system, and mobility in general is unknown, but the technology has the potential to revolutionize cities. Many assessments, including the modelling described in this paper, indicate that AVs have the potential to increase GHG emissions. Proactive public policy is critical to ensuring that AVs contribute to efforts to mitigate GHG emissions, as well as other societal objectives.

[15] Clausen, C. (2017). Niche management of Autonomous Vehicles for positive environmental outcomes in Copenhagen. *IIIEE Masters Thesis*.