Short-Term Impacts Of Autonomous Vehicles On Canadian Government Finances

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Introduction

Canadian transportation infrastructure has seen few major changes in the past half-century. While vehicles have become more fuel-efficient and aerodynamic, the system has remained the same: trips mostly made through private gas-powered low-occupancy vehicles, with a higher mode share of public transit in major urban centres (McKeown, 1997; Statistics Canada, 2017e). In the last decade, advancing technology, lagging regulations, and increasingly dense cities have made the future of transportation infrastructure uncertain. Ride-sharing through transportation network companies has introduced a less-regulated and convenient alternative to existing transportation modes, primarily disrupting taxis (Waheed et al., 2015). Rapid advancement in autonomous vehicle (AV) technology has raised the question of changes in travel patterns and potential secondary impacts from eliminating drivers in personal and commercial vehicles.

The shift to truly driverless personal vehicles may lead to decision-making and indirect impacts that are currently unclear and lightly examined by existing research, which has focused on the technical challenges and societal acceptance of AVs. Research that incorporates fiscal analysis tends to focus on the end-user impact or industry (Milakis, van Arem, & van Wee, 2017), but government finances may change with the introduction of AVs. This research connects projected autonomous vehicle adoption scenarios to government revenues and identifies potential risks to funding models, with quantitative estimates of the change in revenue for various governments and qualitative discussion of how other areas of public policy may be affected.

Literature Review

Adoption Rates

Table 1 lists estimates for the market share of AVs in two study years based on those found in literature, and their average. The three estimates vary in their forecasting models but resulted in a similar conclusion that AVs will be the dominant vehicles sold in North America by 2040-2050. The estimate taken from Bansal & Kockelman (2017) is an average of 8 individual scenarios tested in the study, which varied depending on the willingness of the consumer to pay, change in the price of technology, and the regulatory system surrounding AVs. The frequently cited rate from Litman (2018) and the Bass diffusion model from Lavasani, Jin, & Du (2016) are derived from historical adoption rates for previous technology shifts.

Table 1: Adoption rate averages and estimates from literature

Year	Average	Litman	Bansal & Kockelman	Lavasani et al.
2023	3.77%	3.69%	7.61%	0.00%
2028	8.13%	7.54%	15.95%	0.90%

Forecast Variables

Speculative discussion concerning AVs tends to provide qualitative predictions of how different aspects of society and transportation infrastructure may change. The changes AVs are expected to bring are termed

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here as forecast variables. Some common predictions in public discourse include increases in vehicle kilometres travelled (VKT), less parking and gas use, less traffic violations, less people registered as drivers, and inevitable adoption with varying optimism (Chase, 2016; Hawkins, 2018). Table 2 identifies forecast variable predictions found in academic literature.

Table 2: Predictions of change in forecast variables

Forecast Variable	Predicted Change	Supporting Literature
Vehicle kilometres travelled (VKT)	20% increase per AV at 10% share	(Fagnant & Kockelman, 2015)
	10-29% increase per shared AV (SAV) at 100% share	(Dia & Javanshour, 2017)
	10% increase in VKT for SAV vs. conventional AV	(Fagnant & Kockelman, 2014)
Total vehicles	75% decrease, 100% share	(Schoettle & Sivak, 2015)
	43-88% reduction, 100% SAV share	(Dia & Javanshour, 2017)
Parking	53-88% reduction, 100% SAV share	(Dia & Javanshour, 2017)
Shared vehicles	10% of AVs will be shared ownership	(Fagnant & Kockelman, 2015)
	1 SAV replaces 11 conventional vehicles (91% reduction at 100% SAV share, 9.1% at 10% SAV share)	(Fagnant & Kockelman, 2014)
	1 carshare replaces 9-13 vehicles (89-92% reduction at 100% SAV share, 8.9-9.2% at 10% SAV share)	(Martin, Shaheen, & Lidicker, 2010)

Impact Studies and Similar Analyses

Some research has attempted to quantify the fiscal and economic impacts of autonomous vehicles. Woudsma & Braun (2017), Litman (2018), and Milakis et al. (2017) indicate that most studies focus on quantifying the AV per unit cost, travel costs and congestion costs. Most relevant to this analysis was one study that quantified the total cost of transitioning Australia to electric vehicles using a low and high-cost boundary (Riesz, Sotiriadis, Ambach, & Donovan, 2016), comparing against a base case with internal combustion engines. However, the direct impact on a government's finances, outside of qualitative directional predictions, do not seem to appear in existing academic studies.

Methods

This analysis uses existing autonomous vehicle adoption rate forecasts and predictions of how they will impact government finances. The predictions are derived from existing academic research and public discourse and are used in combination with the forecasts in a comparative static analysis to predict the changes in Canadian government revenues in the short-term.

Financial Data

Eight sample governments were used in this analysis: the federal government of Canada; the four provincial governments of Ontario, Quebec, British Columbia, Alberta; the Regional Municipality of Waterloo, referred to as Waterloo Region; and the local governments of the City of Toronto and the City of Waterloo. The four provinces were specifically selected since they are the four most populous, representing 86% of the population of Canada.

While the analysis is framed from the perspective of 2018, revenues from 2016 were used as they were the most recent consistent data available. For the federal and provincial governments, annual reports and Public Accounts documents were used for the fiscal year 2016-2017 (Alberta Treasury Board and Finance, 2017; British Columbia Ministry of Finance & British Columbia Office of the Comptroller General, 2017; Finances Québec, 2017; Ontario Treasury Board Secretariat, 2017). For the regional and local governments, audited annual financial reports (AFRs) (KPMG, 2017a; 2017b; St Amant, Rossini, Wallace, PricewaterhouseCoopers LLP, 2017) were used as the primary source of revenue data. Since each of the municipalities fall under the jurisdiction of Ontario, supplemental revenue data were gathered from Financial Information Returns (FIRs) (Ontario Ministry of Municipal Affairs and Housing, 2017a; 2017b; 2018), which are annual filings submitted to the Ontario government from each regional and local government.

Correspondence between Forecast Variables and Government Revenue Line Items
Table 3 lists the forecast variables used in the analysis and their linked government revenue line items. Five forecast variables were selected from literature to model the impact of AVs on government budgets: VKT for vehicles with fuel engines, total vehicles, licenced drivers, parking levels, and mode share of AVs. Mode share values in each year of study were set to the average of the adoption rate curves in that year in existing literature (cited in Table 1). The remaining four forecast variables were used as the main variables of the analysis. For comparison, two variations of the VKT impact were provided: one where the change in VKT is assumed to include larger trucks and buses, which consumed over 95% of road diesel in 2008 (Barla, Gilbert-Gonthier, & Kuelah, 2014), and one where it does not.

Table 3: Forecast variables and their associated government revenue line items

Forecast Variable	**Government Revenue Line Item**
VKT (fuel engine)	Gas tax (gasoline and diesel components)
-- VKT (excluding diesel vehicles)	Gas tax (gasoline component)
Total vehicles	Driver’s licence and vehicle registration fees (vehicle component)
Licenced drivers	Driver’s licence and vehicle registration fees (driver component)
Parking levels	Parking fees

Because driver’s licence and vehicle registration revenues were often reported together in provincial data, the share of how much each component contributes to the overall line item was estimated using vehicle registration service fee tables from each province and vehicle registration data from Statistics Canada. Road vehicles and trailers constituted the majority of vehicles in each province, and of the road vehicles, 85% or more were those under 4500 kg (Statistics Canada, 2017b), so trailer registration fees and personal light vehicle registration fees were assumed to be representative of the cost of registering trailers and road vehicles, respectively. Personal light vehicle registration fees were multiplied by the number of road vehicles to provide an estimate of vehicle registration revenue due to road vehicles, since in each province these vehicles must be registered annually. Trailers followed a similar procedure in British Columbia, where annual registration fees were provided (*Motor Vehicle Fees Regulation*, 2018), but in the other three provinces, one-time fees were listed for trailers (*Registry Agent Product Catalogue*, 2017; ServiceOntario, 2016; Société de l'assurance automobile Québec, n.d.). The one-time fees were amortized over an assumed ownership of 25 years before multiplying by the number of trailers registered to estimate the revenue from trailers being registered in one year. Vehicle registration revenue due to road vehicles and trailers were added together and, as a proportion of the total driver’s licence and vehicle registration fee revenue, was found to be around 60% in British Columbia, Ontario, and Alberta, and around 67% in Quebec. Driver’s licence revenue was assumed to be the remainder: 40% in British Columbia, Ontario and Alberta, and 33% in Quebec. Each component was then used for the total vehicle and licenced driver impact analyses.

Similarly, gas tax revenues were reported inconsistently between provinces, so a method of separating aviation and diesel fuels from gasoline was required. Aviation fuel was separated because it is not used in road vehicles, and diesel was separated to compare the diesel and non-diesel scenarios of VKT change. The results of these separations are listed in Table 4. Aviation fuel consumed was estimated by using fuel consumption by Canadian airlines in 2016 (Statistics Canada, 2017a) to represent Canada-wide consumption, then allocating the volume proportionally to each province based on the province’s share of passenger (Statistics Canada, 2017b) and cargo (Statistics Canada, 2017c) flights. Aviation fuel tax rates were taken from government websites (Alberta Treasury Board and Finance, Tax and Revenue Administration, 2017; British Columbia Ministry of Finance, 2017; Ontario Ministry of Finance, 2018; Revenu Québec, 2018), and multiplied by the estimated volume of fuel consumed to find the estimated aviation fuel tax revenues. Diesel fuel consumption volumes were taken from CANSIM tables (Statistics Canada, 2017d), and tax rates were taken from the same sources as aviation fuels. Canada and Ontario did not undergo this separation, because Ontario's diesel fuel taxes are already separated, and once aviation taxes were removed from Canada's non-gasoline line item, the remaining fuel tax was from diesel. Diesel fuel consumption volumes and tax rates were multiplied together to estimate the diesel fuel tax contribution. In the three remaining provinces, aviation and diesel fuel taxes were removed from the general gasoline tax to estimate the contribution of general gasoline to the provincial gas tax. The aviation fuel tax contribution was then discarded, and the diesel and gasoline taxes were used for the VKT impact analysis.

Table 4: Estimated aviation, diesel and gasoline fuel tax revenues in 2016

Government	Aviation Fuel Tax ($)	Diesel Fuel Tax ($)	Gasoline Tax ($)
Canada	279 785 640	858 214 360	4 496 000 000
Ontario	123 933 740	742 234 805	2 501 688 486
Quebec	27 923 726	561 579 594	1 746 496 680
British Columbia	31 884 421	144 175 268	793 940 311
Alberta	14 380 509	458 263 000	870 356 491

Comparative Static Analysis

The forecast variables and government revenue line items were used in a comparative static analysis, which predicts the impact of autonomous vehicles on the current budget assuming the forecast characteristics of 2023 and 2028, or 5 and 10 years from now. Table 5 presents the low and high boundaries of the forecast variable changes used in the study, based on applying the trends from literature in Table 2 to the averaged market share in each year from Table 1. Because it is unclear how AVs will impact driver's licences if they have no "driver", they were assumed to range from the full share of AVs to no change.

Table 5: Low and high boundaries of forecast variable changes

Forecast Variable	Low Boundary		High Boundary	
	2023	2028	2023	2028
VKT (with and without diesel)	-3.77%	-8.13%	1.09%	2.36%
Total vehicles	-3.31%	-7.15%	-0.34%	-0.72%
Licenced drivers	-3.77%	-8.13%	0.00%	0.00%
Parking levels	-3.13%	-6.75%	-2.18%	-4.72%

Results

Before introducing the comparative static analysis, it is useful to know what the hypothetical limit of revenue change is to provide a sense of scale to the impact brought by autonomous vehicles. Table 6 shows the hypothetical loss limit for each government, and the forecasted worst-case scenario assuming each variable reaches its low boundary. The hypothetical loss limit was calculated by *completely* eliminating all linked government revenue line items (i.e., 100% reduction). The forecasted worst-case scenario was calculated by summing the budget changes of the low boundary for each variable to indicate the highest expected loss given the literature boundaries. The Region of Waterloo had no loss limit, since its revenue was not meaningfully impacted in the short term by changes in the gas tax, parking, driver's licences, or vehicle registrations. While Ontario municipalities receive money from the federal and provincial gas taxes, these are fixed annual amounts (Association of Municipalities Ontario, 2017; Infrastructure Canada, 2018), so it was assumed that gas tax loss would deplete the upper-level government first. Due to the lack of change, the Region of Waterloo is not depicted in any further results. Other municipalities are not expected to have meaningful changes, since parking revenue contributes minimally to their overall revenues.

Table 6: Hypothetical revenue loss limits and forecasted worst case scenarios

Government	**Hypothetical Revenue Loss Limit**		**Forecasted Worst Case Scenario**			
	%	**$**	**2023, %**	**2023, $**	**2028, %**	**2028 ($)**
Canada	-1.97	-5 354 214 360	-0.14	-370 982 487	-0.30	-800 867 111
Ontario	-3.53	-4 970 564 279	-0.18	-257,165,043	-0.39	-555 161 045
Quebec	-3.46	-3 560 076 274	-0.18	-180,735,732	-0.38	-390 167 484
British Columbia	-2.85	-1 467 115 579	-0.15	-76,069,732	-0.32	-164 217 311
Alberta	-4.32	-1 830 619 491	-0.23	-99,494,164	-0.51	-214 785 352
Region of Waterloo	0.00	0	0	0	0	0
City of Toronto	-0.01	-1 779 788	-0.00	-55 636	-0.00	-120 105
City of Waterloo	-0.10	-173 564	-0.00	-5 426	-0.01	-11 713

Figure 1 shows the comparative static analysis for 2028. The graphs for Toronto and Waterloo are depicted at a smaller scale due to the lower magnitude of their revenues, and the graph for Canada is at a slightly larger scale due to its higher magnitude of revenue. The reference value with no change in forecast variables or revenue is given by the crosshairs of the two reference lines. Each line is associated with a forecast variable, which shows the possible net budget change values given the boundaries provided in literature (Table 2). In 5 years (not shown), the impact of the individual variables is expected to be highest in Alberta, ranging from a change of -0.119% to 0.034% in total revenue due to a change in fuel engine VKT, and lowest in the cities, where it results in statistically negligible change for Toronto and around -0.003% for the City of Waterloo. The 10-year outlook (Figure 1) gives similar trends at a larger magnitude, as expected. Alberta has the highest projected impact, ranging from -0.255% to 0.074% in total revenue due to a change in fuel engine VKT. The cities again have the lowest impact with a maximum change of -0.001% for Toronto and between -0.007% and -0.005% for the City of Waterloo.

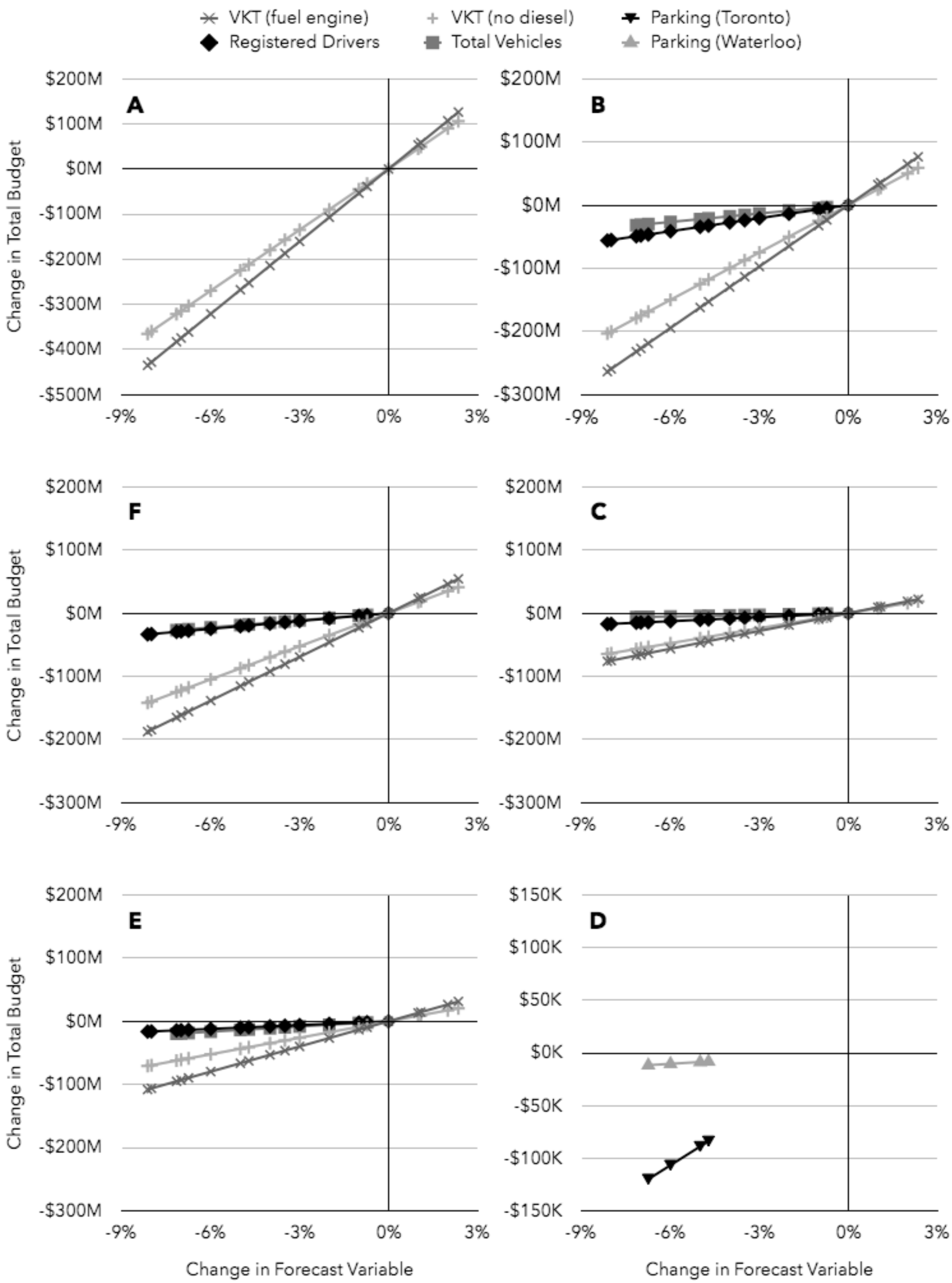
Discussion

Changes in the gas tax revenue were found to have a greater impact than changes in driver's licences and vehicle registrations in all provinces. Diesel vehicles, most of which are commercial in nature, did not appear to make a large impact on the budget when they were included in the initial conversion to AVs, but result in over $60 million lost in gas tax revenue for Canada and Ontario after 10 years. Overall, Canada and each province except for British Columbia, in a worst-case scenario given the boundaries in literature, could lose hundreds of millions of dollars in revenue. Moreover, roads would require more maintenance in the scenarios proposed in literature, and the general trend that gas tax revenues would fall in combination with increased driving would amplify the effect of revenue loss.

Limitations and Future Work

Government revenue line items were assumed to be directly proportional to their forecast variables. In reality, these relationships are more complicated, and prices would likely change as a result of the decreases in revenue from parking lots, driver's licences, vehicle registrations and gas taxes. Extensions of this work could try to incorporate how these taxes and fees change with the forecast variables, to provide a more realistic representation of the impact on the economy. For simplicity, this analysis assumed no change in revenue or demographics, with the purpose of demonstrating how changing only the forecast variables in today's environment would modify the revenue levels.

Figure 1: Comparative static analysis for 2028
(A. Canada, B. Ontario, C. British Columbia, D. Waterloo/Toronto, E. Alberta, F. Quebec)



Conclusion

Once AVs require no drivers, there is potential for them to change travel patterns and passenger behaviour, impacting governments fiscally. This study investigated how government revenues would be impacted in the short-term, assuming changes in four forecast variables for eight sample governments. Over a 5-10-year period, no government was expected to lose or gain over 0.3% in revenue from a shift in a single forecast variable, and no more than 0.51% assuming a worst-case scenario. Unless AVs are mainly powered through fuel, revenue is expected to decrease. This suggests that policy proposals could be suggested to mitigate these effects or take advantage of the loss in asset utility. Future analyses that consider changes in expenses and from elasticities would be useful in exploring the AV impact on governments.

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