Smart Prosperity Institute

CLEAN ECONOMY WORKING PAPER SERIES

JANUARY 2022 / WP 22-2

GOVERNING THROUGH ELECTRIC VEHICLE UNCERTAINTY

A PASSENGER MOBILITY REGIME ANALYSIS

Nathan Lemphers

University of Ottawa

This research project was supported by Smart Prosperity Institute's Economics and Environmental Policy Research Network (EEPRN) and the Greening Growth Partnership

Ce projet a été réalisé avec l'appui financier de :
This project was undertaken with the financial support of:

Environnement et Changement climatique Canada | Environment and Climate Change Canada

This working paper draws on research supported by the Social Sciences and Humanities Research Council:

Social Sciences and Humanities Research Council of Canada | Conseil de recherches en sciences humaines du Canada

uOttawa
Institut de l'environnement
Institute of the Environment

Canada

Governing through electric vehicle uncertainty: a passenger mobility regime analysis

Nathan Lemphers [a,b,*]

[a] Institute of the Environment, University of Ottawa, 1 Stewart St, Ottawa, Ontario, Canada K1N 7M9

[b] Department of Political Science, University of Waterloo, 200 University Ave. West, Waterloo, Ontario, Canada N2L 3G1

The global trend of electrifying passenger transportation is accelerating and holds the potential to disrupt the status-quo and create new winners and losers. How can cities prepare for this transformation? By differentiating between sectoral and service regimes, this study assesses the present state of passenger transportation in three Canadian cities—Calgary, Toronto, and Montréal—and examines how electric vehicles may impact the city's passenger mobility system in 2040. In doing so, this research improves our understanding of how the various alignments within and among prevailing service regimes creates different place-based challenges and opportunities at the sectoral level for an electromobility transition. Crucially, it deepens our understanding of the broader risks and uncertainties associated with electromobility transitions and aids policymakers as they govern through these ambiguities.

KEYWORDS: Sustainable mobility, Service regimes, Sectoral regimes, Electric vehicles, Socio-technical regime, Geography of transitions

JEL CODES: L90, N70, O18, R14, R42

ACKNOWLEDGEMENTS: The author gratefully acknowledges the support of the Smart Prosperity Institute Research Network, Environment and Climate Change Canada's Economics and Environmental Policy Research Network (EEPRN), and the Social Sciences and Humanities Research Council of Canada (grant no. 895-2017-2018). The author would also like to thank Christine Desrochers for her assistance with interview transcription, Daniel Rosenbloom, Bernhard Truffer, and David Wolfe for their insightful comments and for feedback received at the 2021 Earth System Governance Conference.

[*] Corresponding author at: Department of Political Science, 200 University Ave. West, Waterloo, Ontario, Canada N2L 3G1. Email address: Nathan.lemphers@uwaterloo.ca

INTRODUCTION

Globally, transportation systems are under stress. Increasing amounts of goods and people are moving further distances on aging, underfunded infrastructure. Meanwhile, more sustainable transportation modes often struggle to compete with established, more polluting means of transport. Despite this struggle, new electrified forms of transport are taking hold in certain cities. In leading cities like Oslo, thanks to a highly-supportive policy environment, electric vehicles are outpacing sales of conventional fossil-fuelled cars and disrupting business-as-usual for the local transportation system (Joshi, 2020). More than 20 countries have legislated or proposed legislation for a ban on light-duty internal combustion engine vehicles (ICEVs) or a 100 percent electric vehicle (EV) sales target (Table 1). Globally, most major automakers see the growing bans on internal combustion engine vehicles and the growth opportunities for electric vehicles and have plans to produce over 400 battery electric vehicle models by 2025 (Gersdorf et al., 2020). Further, many automakers (e.g., Daimler, Volkswagen, Volvo) have announced they will no longer be making new internal combustion engine vehicles.

Table 1: Countries with an ICE ban or electrification target in law or proposed legislation

Norway	2025	Singapore	2030	China	2035
Denmark	2030	Slovenia	2030	Japan	2035
Iceland	2030	Sweden	2030	France	2040
Ireland	2030	United Kingdom	2030	Portugal	2040
Israel	2030	Cabo Verde	2035	Spain	2040
Netherlands	2030	Canada	2035	Sri Lanka	2040

Source: (International Energy Agency, 2021)

As increased production, global competition, and public policy drives down electric vehicle purchase costs and as charging networks are built out, these new vehicles may catalyze a transformation of passenger transportation, especially if combined with electrifying other forms of mass and micromobility, such as buses and bicycles. The disruptive potential further increases with the anticipated rise in connected and autonomous vehicles and new mobility-as-a-service business models (Sperling, 2018). Existing studies reveal the challenge for local policymakers to manage the potential impacts of these technologies (Booth et al., 2019; Rashidi et al., 2020; Staricco et al., 2019). As cities have discovered with transportation network companies (e.g., Uber, Lyft) and online short-term rental platforms (e.g., AirBnB), new technologies can carry negative social, environmental, and economic consequences, if policymakers are caught unprepared. For instance, transportation network companies have caused mode-shifting away from public transit and increased traffic congestion in some cities (Erhardt et al., 2019; Young et al., 2020).

The socio-technical transitions literature studies the social, political, economic, and technological factors involved in the evolution of socio-technical regimes. Socio-technical regimes embody the institutionalized set of rules in a particular organizational field as it pertains to the actors, artefacts, and markets that govern the delivery of societal services (Geels, 2004). These various elements of a socio-technical regime partially determine the pace and direction of transition processes. Following the multi-level perspective, meso-level socio-technical regimes are also dynamically shaped by and positioned between landscape-level developments and niche-level technological developments (Geels, 2004).

Historically, many empirical applications of socio-technical regimes have treated regimes as monolithic or homogenous (Fuenfschilling and Truffer, 2014; Smith et al., 2005). In reality, multiple regimes co-exist alongside one another and so analysts have reconceptualized socio-technical system analysis to internalize these inter-regime interactions (Konrad et al., 2008; Raven and Verbong, 2007). However, these earlier modifications still failed to account for the heterogeneity and unevenness within and between existing socio-technical regimes, and how regimes evolve over time.

More recent efforts have provided more nuance and complexity to the analysis of socio-technical regimes. These include the study of how infrastructure services are delivered unevenly based on socioeconomic, racial and gender divisions (Ramos-Mejía et al., 2018; Swilling, 2013) and on spatial configurations (Coenen et al., 2012; Munro, 2019; Murphy, 2015). Other scholars have re-conceptualized inter- and intra-regime interactions to account for some of these important variations over time (Papachristos et al., 2013; Rosenbloom, 2020), increasing the policy relevance of this socio-technical transitions research stream**.** Still other scholars have focussed on the fragmentation and misalignment within and among different regimes (van Welie et al., 2018).

I build on the framework provided by van Welie *et al.* (2018) — which differentiates between sectoral and service regimes and the misalignment and dysfunction that is created within a splintered sanitation regime in Nairobi — by applying it in a comparative setting and, as will be explained below, linking it to emerging research in risk management. A comparative approach also helps to identify the context specific factors, which can enrich the study of sustainability transitions (Binz et al., 2020). This hybridized research orientation also enhances the relevance of this research for policymakers. Despite the obvious differences between Kenya and Canada, van Welie et al.'s framework can be applied to in the Global North and in the transportation sector. It has already been used to better understand the role of mobility-as-a-service on transportation in New South Wales, Australia (Smith and Hensher, 2020). Schippl and Truffer (2020) have recently extended the framework to understand the divergent trajectories of autonomous and electric vehicle usage in prototypical urban and rural settlement patterns in Germany. They found that electromobility has greater potential to realign broader urban mobility systems towards sustainability compared to rural areas, where the simple substitution of private ICEVs with private EVs is more likely. Beyond this, current trends indicate that EV adoption has been significantly higher in urban centres than in rural areas (Wappelhorst, 2021). Arguably, it is in major urban areas where the transition to electromobility may be the swiftest and most profound thanks in part to the shorter driving distances, proximity to charging stations, financial resources, institutional capacity, and early technology adoption often found in these locations.

Broadly, this paper asks the following question: How can cities prepare for electromobility? This is linked to four other inter-related questions: What is the current alignment within a city's passenger mobility system? To what extent is electromobility currently integrated into a city's passenger mobility system? Looking forward to 2040, if these trends continue, how may additional electromobility alter this system? How can cities manage the potential risks associated with a shift to electromobility?

To answer these questions, we examine the preparedness for electrifying personal mobility in three Canadian cities: Calgary, Toronto, and Montréal. These cities were selected because of their considerable variation in regional political economy and urban form and because they are all important urban centres within a single country, facilitating comparison across these cities. Given these differences, the electromobility transition for these cities will not be uniform across such a large and decentralized federation with distinct regional political economies.

This paper makes several empirical and theoretical contributions. 1) It provides the first comparative test of van Welie et al.'s (2018) analytical framework. 2) Building on Schippl and Truffer (2020), this paper disaggregates an archetypal urban environment to empirically examine how different urban contexts shape electromobility transitions. 3) It integrates understandings of risk management into the sustainability transitions literature. The comparative insights gathered in this paper will have relevance for policymakers and advocates wanting to understand the potential risks and opportunities associated with electromobility in their particular region or learn from the experiences of other jurisdictions. These three case studies highlight the place-specific challenges and opportunities for electrifying intra-city passenger transportation.

This paper is organized in the following manner. Section Two outlines the analytical approach and details the paper's framework. Section Three applies the framework to the three case studies to analyze the current context of passenger mobility, describe the current preparedness for electromobility, and using forward reasoning, examine potential sectoral regime dynamics in 2040. Section Four discusses the findings and concludes with avenue for future research.

APPROACH

Following van Welie et al.'s (2018), this study differentiates between service and sectoral regime. This distinction is intended to position the everyday aspects of life—which are often neglected in the transitions literature—in the broader context of a sector. Additionally, this conceptualization enables multiple service regimes to be analyzed concurrently in a given sector, providing insights into the degree of alignment and connectivity across service —a crucial function since the transition to electromobility reshapes not only private vehicles, but also public transit, shared vehicles (e.g., taxis, ride hailing services, and car sharing), micromobility (e.g., bikes and scooters) and walking. Beyond the obvious linkages with the multi-level perspective, this framework is also grounded in social practice theory (Shove et al., 2012). As such, I use the everyday practices of users and providers to inform a more coherent and geographically limited analysis of transition pathways. Following Geels et al. (2015), the framework also aligns with the reconfiguration approach, where non-incremental change is approached through change in sociotechnical systems and practices as opposed to reform of technology and behaviour or a revolutionary upheaval of deep societal structures.

Taken together, this depiction of socio-technical regimes helps to generate more complex insights on the risks and opportunities from such a transition and helps policymakers to prepare for the global shift in the transportation sector. This paper also contrasts the current context dominated by fossil fuelled mobility with a potential highly electrified future. In doing so, this approach embraces a more complex and fluid understanding of regime interactions (Rosenbloom, 2020).

A service regime refers to "specific institutionalized combinations of technologies, user routines, and organizational forms for providing the service" (van Welie et al., 2018) Service regimes consist of several socio-technical dimensions that vary in their alignment with one another. I use the five elements advanced by Schippl and Truffer's (2020) that adapt the service regime elements in van Welie et al. (2018) to a passenger mobility application: 1) **Technologies and infrastructure** refers to the materiality of a service regime (e.g., hardware, physical infrastructure, urban design); 2) **Organizational mode** concerns the management of a mobility service and the design of user interfaces; 3) **User requirements and expectations** denotes, respectively, the skills, knowledge, or competencies needed to use a service and the interest of users to access a functioning, reliable, affordable, safe, clean and convenient mobility; 4) **Planning practices and public financing** encompass formal planning guidelines and regulations and also informal planning norms such as the car-euphoric planning prevalent during the 1950s and 1960s; 5) **Societal meaning** refers to the widely held norms and values of a service regime (e.g., health, low-cost, independence, environmentally-friendly). Crucially, the alignment or misalignment of these five dimensions condition the strength and stability of a service regime (Fuenfschilling and Truffer, 2014). For instance, a well-aligned public transportation service regime would have sufficient infrastructure (buses, rail stations) to move residents efficiently, and a viable funding model through some combination of fares, public funding, and private capital. It requires transit authorities meet user expectations on the coverage and frequency of service and align with societal norms regarding the importance of low-cost and convenient service. Further, users in a highly aligned public transportation system would have the skills and knowledge to access the system. Rather than avoiding or mitigating risks, a poorly aligned public transportation service regime creates additional risks for users and service providers as inefficient practices and unintended consequences compound uncertainties.

As socio-technical configurations become increasingly internally aligned, service regimes are said to become more mature. This process is found in many studies of niche maturation or historical accounts of regime emergence (Geels, 2005; Raven and Gregersen, 2007). Beyond alignment of these five dimensions, the degree of diffusion, social acceptance, longevity, and contestation are crucial determinants of regime strength and regime institutionalization (Fuenfschilling and Truffer, 2014). In other words, a strong service regime occurs when a significant portion of providers and users take a service regime for granted. At a more macro-level, an effective, stable, and strong service regime must be aligned with both local contexts and landscape forces, such as major social, geographical, and technological constraints (Bergek et al., 2015; Fuenfschilling and Truffer, 2014; Geels and Schot, 2007). Consequently, a service regime must be tailored to highly variable local practices, competences, beliefs, routines, and physical and material conditions.

A binary strong-weak classification of service regime strength masks the complexity within the various dimensions of a service regime. Partial alignment of these dimensions is highly likely. As a result, van Welie et al. (2018) proposes a gradient from thinly structured, emergent regimes to uncontested dominant service regimes. Schippl and Truffer (2020) extend this logic and create four classifications: a) poor alignment with conflicting institutional arrangements, b) partly aligned with clear deficits and conflicts, c) aligned with clear drawbacks remaining, and d) well-aligned.

A sectoral regime concerns the delivery of broad societal functions like transport, food, education, or electricity (van Welie et al., 2018). Sectoral regimes comprise the structures needed to coordinate multiple service regimes in a given place and time (Schippl and Truffer, 2020). The strength of sectoral regimes is a function of the alignment among its constituent service regimes. Poor alignment leads to friction among service regimes and ultimately a weak sectoral regime; whereas, well-aligned service regimes create complementarities, improving access and availability for sectoral regime users. Inter-service regime alignment manifests along three interfaces or interrelations, proposed by Schippl and Truffer (2020): a) **Technical/infrastructural**: these interfaces encompass competition for space and infrastructure that provide smooth and convenient connection between two transportation modes (e.g., park-and-ride or bike-and-ride facilities); b) **Organizational**: these interfaces refer to organizations that enable intermodal connections (e.g., single ticketing technology for regional trains and local buses); c) **Institutional**: these interfaces consider the presence of integrated transportation planning approaches, competition for resources among planning departments, or alignment with user expectations or broader social meanings (e.g., efficient, affordable, clean, safe transportation options). Following Schippl and Truffer (2020), I combine these three interfaces of inter-service regime dynamics within a single assessed degree of alignment (i.e., weak, moderate, and strong), which aligns with van Welie et al.'s (2018) understanding of regime strength existing on a continuum.

At the level of a sectoral regime, van Welie et al. (2018) propose four typologies to classify the varying degrees of intra-sectoral and intra-service regime alignment (Figure 1): 1) Monolithic regimes occur when one service regime is dominant and internally-aligned; 2) Polycentric regimes have multiple, internally-aligned service regimes that are well-aligned at the sectoral level; 3) Fragmented regimes also have multiple, internally-aligned service regimes but they are mis-aligned at the sectoral level; and, 4) Splintered regimes consist of multiple service regimes that are only partially aligned internally and externally. This ideal-typical conceptualization enables analysts to examine the degree of complementarity within and among a sector's constituent service regimes. These typologies also convey different manifestations of risk. Monolithic regimes lack redundancies or connections with other service regimes reducing overall resilience. Fragmented, and especially splintered regimes, lack many internal and external alignments among service regimes that could help policymakers to manage endogenous and exogenous risk.

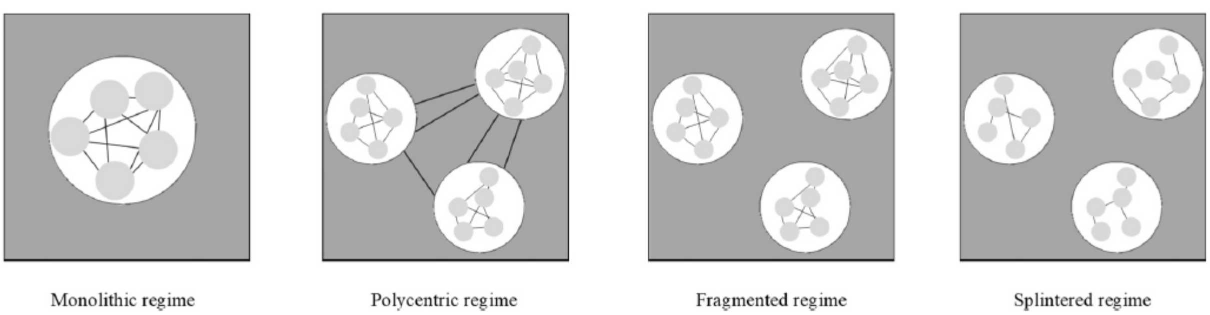

Fig. 1. Sectoral regime typologies: sectoral regime (grey square), service regimes (white circles), dimensions of service regimes (grey circles), alignments (lines). Source: van Welie et al. (2018).

To refine the scope of this analysis, I will study the intra-city passenger mobility system. While freight and inter-city passenger transport (via rail, plane, vehicle, bus, and boat) are critical pieces in the electromobility puzzle. Freight has a different group of users and service providers that are distinct from urban passenger mobility and inter-city transport necessarily involves consideration of other municipalities and orders of government (e.g., federally regulated rail and aviation).

Within the sectoral regime of intra-city passenger mobility, I will look at the dynamics among private vehicles as well as public transit (e.g., electric buses, trams), shared vehicles (e.g., taxis, ridesharing services, car-sharing companies), micromobility (e.g., bikes, scooters), and walking. It is the degree of alignment of these passenger mobility system components that is the focus of study. Preparedness for connected and autonomous vehicles and mobility-as-a-service business models are also important but excluded from the main analysis. However, they are brought into the discussion as additional factors for which policymakers must prepare.

Schippl and Truffer's (2020) framework allows me to ask the following questions that examine how cities can best prepare for electromobility: What is the current alignment within a city's passenger mobility system? To what extent is electromobility currently integrated into a city's passenger mobility system? Looking forward to 2040, if these trends continue, how may additional electromobility alter this system? How can cities manage the potential risks associated with a shift to electromobility?

Using these questions, I apply this analytical framework on data from three major urban centres in three different provinces of Canada: Calgary, Alberta; Toronto, Ontario; and Montréal, Québec. These cities were selected because of their significant variation on basic demographic, urban form, and transportation attributes (Table 1). Further, since they are located in the same country, it is possible to control for many national and international factors (e.g., national policies, position within global markets). In general, Calgary and Montréal are the most different with Toronto lying in-between. For instance, Calgary's population is far less dense than Montréal and Toronto and the Albertan city contains a much higher proportion of single detached homes. The median household income of Montréal is roughly half that of Calgary. Montréal has a relatively high proportion of residents that rent and live in multi-unit buildings. The commute modal split for Toronto and Montréal are similar while Calgary has a higher incidence of private vehicle commutes. These basic differences in urban form and demographics help chart distinct pathways to electromobility for each city. While electrification of transport is still in its early days in these cities, as detailed in this study, it is already possible to see the different approaches taken to the electrification of passenger transport. Together, these differences enable insights to be gathered on what regionally specific preparation for electromobility looks like.

While out of scope for this study, these cities are located in three major regional economies: Alberta, Ontario, and Québec. Alberta, highly dependent on fossil fuel production, remains largely bereft of any provincial electromobility policies. Ontario, home of Canada's fossil-powered auto industry, has lagged behind neighbouring Québec. Québec has long used its cheap and abundant hydroelectricity to promote economic development and diversification.

Table 1. 2016 Census subdivision data for Calgary, Montréal, and Toronto.

	Calgary	Montréal	Toronto
Population (million)	1.2	1.7	2.7
Population density (residents/km2)	1,501	4,662	4,344
% Single detached homes	56.3	7.3	24.2
% Renters	28.6	63.3	47.2
Median household income (2015 CAD)	97,334	50,227	65,829
Commute mode split (%)			
Private vehicle (driver or passenger)	76.1	50.1	50.6
Public transit	15.8	36.5	37
Walking	4.9	8.6	8.6
Biking	1.6	3.9	2.7

Source: (Statistics Canada, 2016)

Evidence for identifying the present and future state of electromobility in these three cities is drawn from 23 interviews (Table 2) with transportation service providers, transportation user groups, and observers of municipal electrification efforts, along with a range of secondary sources, largely government statistics and transportation plans.

Table 2. Interviewee Overview (n=23)

Calgary (8)		Montréal (7)		Toronto (8)	
Municipal government	3	Municipal government	2	Municipal government	2
Transportation user groups	3	Transportation user group	1	Transportation service provider	4
Transportation service provider	1	Transportation service provider	2	Transportation analyst	1
Economic development agency	1	Environmental group	1	Vehicle manufacturer	1
Transportation analyst	1	Transportation analyst	1		

Radical low carbon innovation, such as the widespread adoption of electromobility, creates sweeping uncertainty (Geels et al., 2018). This uncertainty is particularly pronounced at early stages of development, when incomplete information is pervasive (Walker et al., 2010). As more electromobility technologies are introduced—alongside the adoption of connected, autonomous, and shared mobility—the fragmentation of service and sectoral regimes may accelerate. This fragmentation or heightened misalignment carries additional risk or uncertainty for different transportation users and providers. Despite the omnipresence of risk, and it's extensive study within disciplines of complexity science, organizational sociology, planning, and science and technology studies (Li et al., 2018), the extant literature on risk within socio-technical transitions remains largely silent. When risk is examined by transitions scholars, the type of risk and how that risk influences transition pathways is far from clear (Osazuwa-Peters et al., 2020). Failure, despite creating learning opportunities for subsequent efforts, is similarly neglected in transitions scholarship (Turnheim and Sovacool, 2020). Instead, the transition literature skews towards scholarship on successful or well-underway transitions. In this context, this study helps to "rebalance the empirical base of transition studies" towards accounts that favour, at least historically, stability (Turnheim and Sovacool, 2020).

ANALYSIS

Current Context

To understand a city's pathway towards a more sustainable transportation system it is first necessary to begin in the present. Using data from Tables 1 and 2, which provide background statistics on Calgary, Montréal, and Toronto and their respective transportation systems, and from interviews from transportation experts in these cities, I assessed the internal alignment of the service regimes for private car, public transit, shared vehicles, micromobility, and walking (Table 4). Of course, there is variation within cities—from central business districts to suburban communities—but this analysis looks at the city-wide level of census subdivision. Toronto and Montreal share many similarities. Both cities suffer from a poorly aligned private car service regime, due to congestion, pollution, and wastage of valuable land. Meanwhile, Calgary's abundant parking and extensive commuter highway network enables shorter commute times and more aligned private car use, while still creating air pollution and preventing alternative land uses. Walking in Toronto and Montreal is partly aligned. Both cities have similar levels of residents that commute on foot (8.6per cent), nearly double the amount in Calgary (4.9per cent). Despite many walkable neighbourhoods in Toronto and Montreal, the safety for pedestrians remains compromised because of the volume and speed of vehicular traffic. Due to the low-density, highly car-oriented development, walking in Calgary is poorly aligned.

Table 3. Select passenger mobility statistics from Calgary, Montreal, and Toronto

	Calgary	**Montreal**	**Toronto**
Number of vehicles	1,015,104[1,*]	650,028[2,*]	1,033,000[3,+]
Number of vehicles per capita	0.82	0.38	0.38
Number of taxis	1,881[4,○]	2,790[2,*]	5,500[5,*]
Number of taxis per 1,000 residents	1.52	1.64	2.01
Number of shared bikes	0	9,175[6,@]	6,850[7,@]
Number of shared bikes per 1,000 residents	0.00	5.38	2.51
Kms of bike lanes/paths	1,290[8,@]	1,200[9,*]	973[10,*]
Kms of bike lanes/paths per 1,000 residents	1.04	0.70	0.36
Transit bus fleet size	1,048[11,*]	2,497[2,*]	2,294[12,○]
Transit fleet size per 1,000 residents	0.85	1.46	0.84
Annual transit ridership	51,100,000[11,*]	416,000,000[2,*]	525,000,000[12,○]
Average annual rides per resident	41	244	192

Car park and ride spaces	14,069[13,@]	n/a	13,090[14,@]
Bike parking at Transit stations	n/a	3,256[15,@]	2,500[16,@]

Legend: 2021:[@], 2020: *, 2019: °, 2018: [+], 2016: [‡]

Sources : [1] Ministry of Transportation, 2021; [2] Communauté métropolitaine de Montréal, 2021; [3] Baxter, 2019; [4] Dippel, 2019; [5] McGran, 2020; [6] Sandler, 2021; [7] Bike Share Toronto, 2021; [8] City of Calgary, 2021; [9] Ville de Montréal, 2020a; [10] City of Toronto, 2020a; [11] Calgary Transit, 2021b; [12] Toronto Transit Commission, 2020; [13] Calgary Transit, 2021a; [14] Toronto Transit Commission, 2021b; [15] STM, 2021b; [16] Toronto Transit Commission, 2021a.

The three cities share some similarities. They all have aligned shared vehicle regimes. While costly compared to public transit, service is frequently available throughout the cities. That said, the market for these services is much larger in Toronto, which boasts a third more taxis per capita than Calgary and ten times more ridesharing drivers than Calgary.

The micromobility regimes for Calgary, Toronto and Montreal are poorly aligned. In general, there is limited bike path connectivity and significant safety concerns when using paths that are not separated from vehicular traffic. All cities have similar amounts of bike lanes/paths. That said, when factoring in population, Calgary has nearly three times more bike paths per capita than Toronto and 35 per cent more than Montreal. Nevertheless, there are many more Toronto (2.7 per cent) and Montreal (3.9 per cent) residents that commute by bike compared to Calgary (1.6 per cent). While Calgary has an extensive recreational path network, its poor connection with residential and commercial areas limits alignment. Montreal has nearly 2.2 times more shared bikes per resident than Toronto but neither of these cities have a shared scooter program. Conversely, Calgary does not have a shared bike program but does have a shared scooter service, albeit with coverage limited to the communities surrounding downtown.

Table 4. Current internal alignment of five transportation modes in Calgary, Montreal, and Toronto.

Internal Alignment	Private Car	Public Transit	Shared Vehicles (e.g., taxi, ride/car-sharing)	Micromobility (e.g., bikes and scooters)	Walking
Toronto	**Poorly aligned**	**Partly aligned**	**Aligned**	**Poorly aligned**	**Partly aligned**
	Congestion, pollution, waste of space	High ridership, high congestion	Frequently available although costly relative to public transport	Limited bike path connectivity, safety concerns	Many walkable neighbourhoods
Calgary	**Aligned**	**Poorly aligned**	**Aligned**	**Poorly aligned**	**Poorly aligned**
	Abundant parking but pollution, waste of space	Low ridership, limited frequency away from major corridors	Frequently available although costly relative to public transport	Extensive recreational path network by limited connectivity with residential and	Extensive recreational path network but many activities not in walking distance

				commercial areas	
Montréal	**Poorly aligned**	**Aligned**	**Aligned**	**Poorly aligned**	**Partly aligned**
	Congestion, pollution, waste of space	High ridership, moderate congestion	Frequently available although costly relative to public transport	Limited bike path connectivity, safety concerns	Many walkable neighbourhoods

Legend:

Poorly aligned with conflicting institutional arrangements
Partly aligned with clear deficits and conflicts
Aligned with clear drawbacks remaining
Well-aligned

Public transport exhibited the most variation. Calgary's public transport service regime is poorly aligned, with low overall ridership and limited frequency away from major corridors. Montreal's public transit service regime is aligned, due to high ridership and only moderate congestion, compared to Toronto's more congested transit system. Montreal has 27 per cent higher ridership per person than Toronto and nearly 6 times greater than Calgary. Despite similar shares of commuters using public transit in Toronto and Montreal, the Québec metropolis has 75 per cent more buses per capita than Toronto's fleet of buses and streetcars, reducing congestion on buses.

Passenger mobility service regimes do not operate independently but rather in conjunction with other service regimes within a broader sectoral regime. Figure 2 shows the assessed degree of alignment between service regimes. All three cities have a polycentric-fragmented sectoral regime, where alignment within and between service regimes is uneven. No city has strong alignment among service regimes—a testament of the current inefficiencies in passenger mobility. That said, some minor variation exists across sectoral regime configuration. Montreal has a moderate alignment between cycling and walking because of the high levels of shared bikes throughout the city, compared to Calgary and Toronto. Due to the Calgary's low ridership of transit and low population density, the linkage between transit and walking is weak relative to Toronto and Montreal.

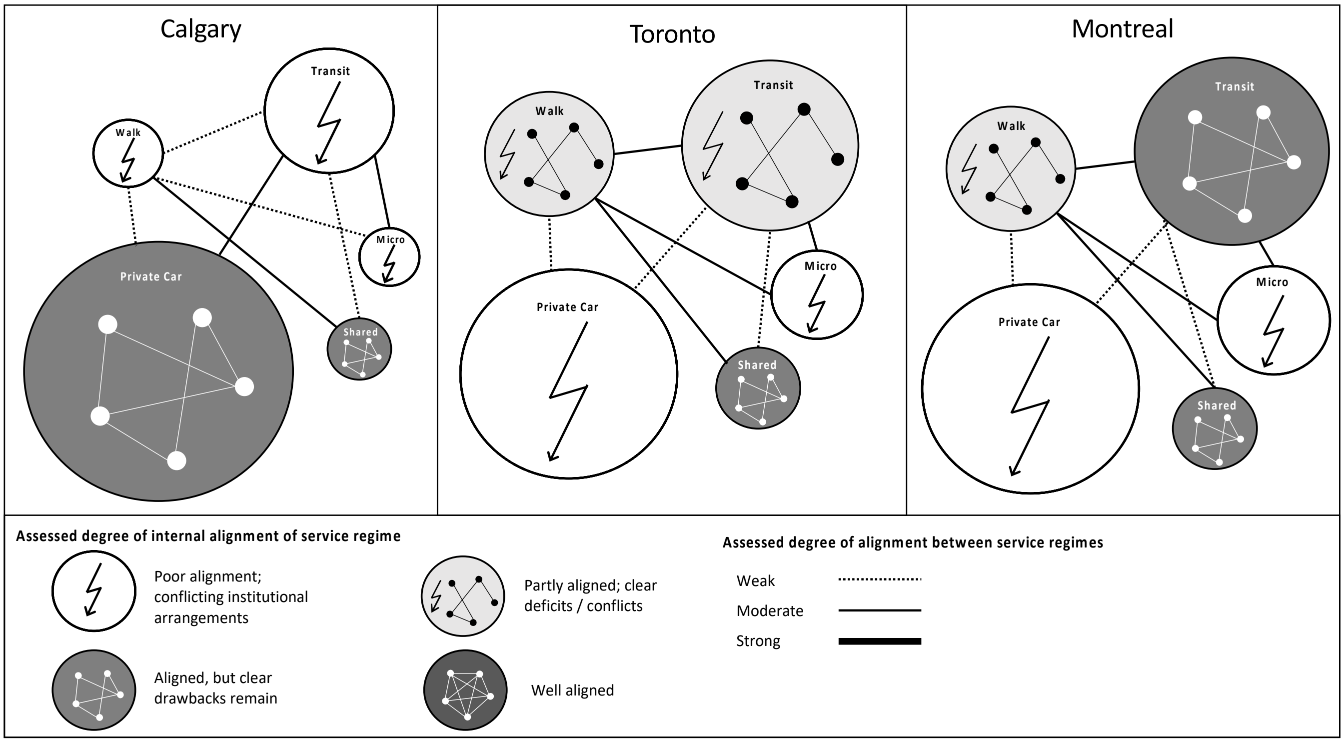

Fig. 2. Current passenger transportation sectoral regime configuration for Calgary, Toronto, and Montreal.

Preparing for electromobility

At present, outside of light rail and subways, electrified passenger transportation in all three cities remains niche (Table 5). Calgary has only 1100 EVs (as of 2019) comprising 0.1 per cent of all passenger vehicles. Toronto has 6200 EVs (as of 2018) comprising 0.6 per cent of all passenger vehicles and Montreal has 7763 EVs (as of 2020) comprising 1.2 per cent of all passenger vehicles. On a per capita basis, Montreal has five times as many EVs than Calgary and twice as many EVs than Toronto. Montreal has nearly five times more charging stations per capita than Calgary and 2.3 times more charging stations per capita than Toronto. However, for Montreal this equates to only 0.7 charging stations per thousand residents. Over 20 per cent of Montreal's shared bike fleet is currently electrified—compared to only 4 per cent in Toronto—while Calgary's shared scooter service is all-electric. Calgary has no e-buses and has made significant recent investment in buses powered by compressed natural gas. Only 1.4 per cent of Montreal's buses are electric, compared to 2.9 per cent in Toronto. Toronto has the highest number of EV transit buses in any North American city, nearly twice as many as Montreal, yet this represents less than 1.5 per cent of the Toronto Transit Commission's bus fleet. When Toronto's electric streetcars are included, Toronto's electric fleet increases to 11.2 per cent. Calgary has no electric buses and instead has made major investments in buses fuelled by compressed natural gas. Given the presently limited diffusion of electromobility technologies, a future of 100 per cent electrified passenger transport may be challenging to envision.

Table 5. Select electromobility statistics from Calgary, Montreal, and Toronto

	Calgary	**Montreal**	**Toronto**
Number of EVs (BEVs and PHEVS)	1100[1,°]	7763[2,*]	6200[1,+]
EV percentage of total passenger vehicles (%)	0.11	1.19	0.60
Number of EVs per 1,000 residents (BEVs and PHEVS)	0.89	4.55	2.27
Number of EV public charging stations	186[3,*]	1258[4,*]	864[5,*]
Number of public EV charging stations per 1,000 residents	0.15	0.74	0.32
Number of shared e-scooters	1500[6,@]	0	0
Number of shared e-bikes	0	1,905[7,@]	300[8,*]
Number of operating battery electric buses	0	7[9,*]	60[10,@]
% of e-buses and street cars	0.00	0.28	11.25

Legend: 2021:[@], 2020: *, 2019: °, 2018: [+], 2016: [‡]

Sources: [1] Thomas, 2019; [2] Communauté métropolitaine de Montréal, 2021; [3] ChargeHub, 2021a; [4] ChargeHub, 2021b; [5] ChargeHub, 2021c; [6] Villani, 2021; [7] Sandler, 2021; [8] Rider, 2020; [9] STM, 2021a; [10] Jarratt, 2021.

However, policymakers, advocates and automakers are making headway. Policy targets are strengthening as sustainable transportation coalitions gain influence and transformative climate action enters mainstream policy discourse. Deep decarbonization goals have been adopted by the three cities and major automakers. Calgary has set a 2050 GHG emission reduction target of 80 per cent below 2005 levels (City of Calgary, 2018). The 2020 Calgary Transportation Plan calls for the entire municipal fleet to be zero-emission by 2050 (City of Calgary, 2020). In 2019, Toronto adopted a net-zero by or sooner 2050 goal. Toronto's TransformTO plan (2017) and EV Strategy (2020) both advanced the goal of 100 per cent of zero-emission vehicles (City of Toronto, 2020b). The Toronto Transit Commission plans to be 100 per cent zero-emission by 2040. Like Toronto, Montreal also has a mid-century net-zero emission goal and an emission-free bus fleet by 2040 (Ville de Montréal, 2020b). However, Montréal also plans to ban ICEVs from the greater downtown core by 2030 and starting in 2025 only acquire fully electric buses (STM, 2021a). Major automakers have followed announcing the end of new ICEV models. In 2020, General Motors announced the goal selling only zero-emissions vehicles from 2035 onwards. Meanwhile, Volkswagen is investing nearly $42 billion US in EVs by 2025 (Home, 2021). Over the last five years, technological innovation, automaker, and municipal commitments have radically altered the likelihood of electrified passenger mobility.

Electromobility in 2040

Extending city-specific trends, using data from long-term municipal transportation plans and insights drawn from interviews, this section examines how the service and sectoral regimes of passenger transportation may compare within and across cases in 2040. This year was selected because, if electrification plans are realized, it would represent the middle to late stages of a transition for personal mobility. As in the past, the transition towards greater electromobility for each city will be different because of different policy approach and pre-existing place-specific factors (e.g., demographic, economic, political).

In 2040, the internal alignment of private cars, public transport, and micromobility improve for most of the cities (Table 6). All cities experience reduced overall pollution from private vehicles, however rapid population growth in Toronto's private vehicle-dependent suburbs worsens congestion. Public transportation alignment also rises in the three cities as more investment improves transit frequency and reliability and quiet, pollution-free buses improves user experience. Meanwhile, the extended range possible from electric bikes/scooters and improved bike path infrastructure increases its modal share and reduces congestion on roads and public transit. Electrifying personal transport does not significantly impact walking. Electrification does not substantially alter the taxi and ride/car-sharing regime, as these services remain more expensive relative to public transport.

Table 6. Potential 2040 alignment of transportation modes in Calgary, Montreal, and Toronto.

Internal Alignment	Private Car	Public Transport	Shared Vehicles (e.g., taxi, ride/car-sharing)	Micromobility (e.g., bikes and scooters)	Walking
Toronto	**Poorly aligned**	**Aligned**	**Aligned**	**Aligned**	**Partly aligned**
	Worsened congestion, waste of space	High ridership, improved service frequency and coverage, congestion remains	Frequently available although costly relative to public transport	Improved bike path connectivity, e-bikes extend range, safety concerns	Many walkable neighbourhoods
Calgary	**Well-aligned**	**Partly aligned**	**Aligned**	**Partly aligned**	**Poorly aligned**
	Waste of space - but city is low density	Moderate ridership, limited frequency away from major corridors	Frequently available although costly relative to public transport	Extensive recreational path network, e-bikes extend range for commuters, low-density residential and distant commercial centres unaligned with user needs	Extensive recreational path network but many activities not in walking distance
Montréal	**Partly-aligned**	**Well-aligned**	**Aligned**	**Aligned**	**Partly aligned**

	Congestion, waste of space	High ridership, improved service frequency and coverage	Frequently available although costly relative to public transport	Improved bike path connectivity, e-bikes extend range, safety concerns	Many walkable neighbourhoods

Legend:

Poorly aligned with conflicting institutional arrangements
Partly aligned with clear deficits and conflicts
Aligned with clear drawbacks remaining
Well-aligned

When assessed as an interlocking sectoral regime, the impact of electrifying personal transport takes on additional significance. Like Schippl and Truffer (2020), we classify the highly electrified 2040 sectoral regime as polycentric-semi-aligned for all three cities (Figure 3). Overall, the internal alignment of service regimes has improved and the alignment among service regimes has strengthened. However, the relative alignment between service regimes, much like their internal alignment, varies across the three cities. In Calgary, the alignment between private vehicles and public transit has improved as electrified light rail is extended and park and ride facilities expanded. Improved and electrified public transit also strengthens alignment with walking, shared vehicles, and micromobility. Of the three cities, Montreal boasts the strongest alignment across different service regimes. Influenced by consistent and ambitious municipal and provincial active mobility and transport electrification policies, Montreal sees strong alignment between cycling/scooters and walking with other transport modes, particularly public transit. While Toronto has the same ratio of strong/moderate/weak linkages among service regimes as Calgary, Toronto's strong connections rest not with private vehicles but primarily between public transit and cycling/scooters, and shared vehicles and walking. However, Toronto's link between micromobility and walking is moderate as the biking infrastructure is not as extensive as Calgary's or as integrated as Montreal's.

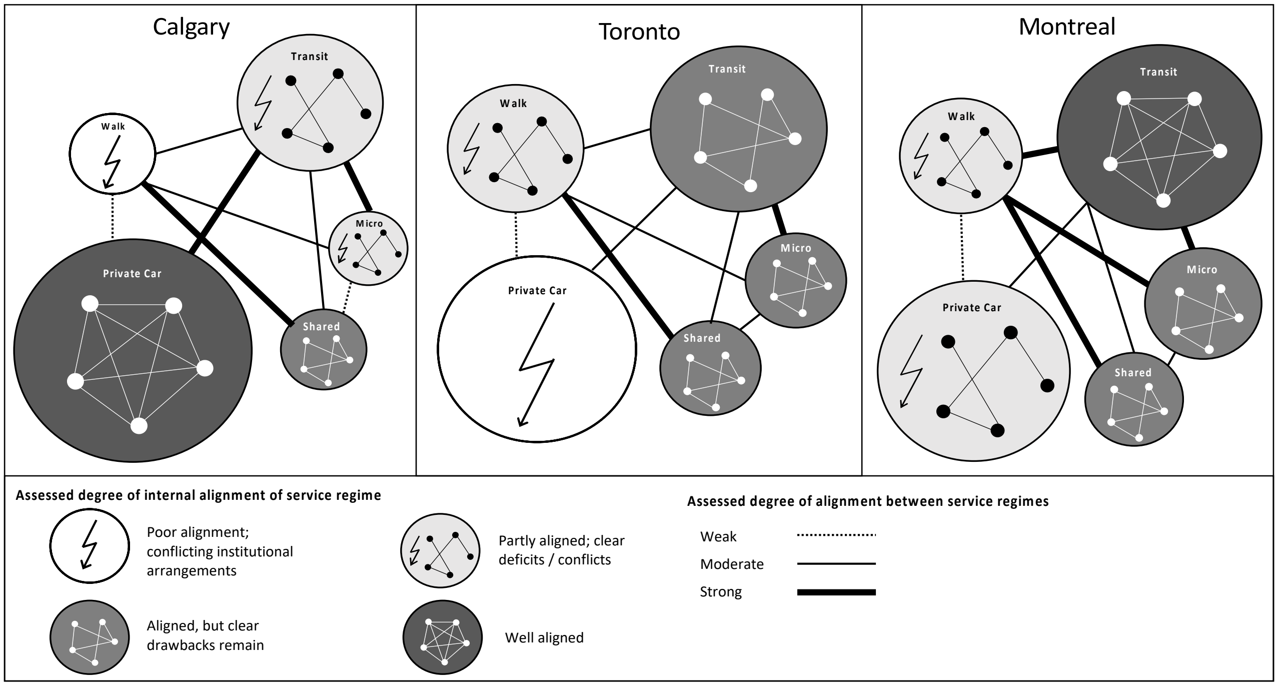

Fig. 3. Potential 2040 passenger transportation sectoral regime configuration for Calgary, Toronto, Montreal.

DISCUSSION AND CONCLUSION

The rise of electromobility holds the potential to transform how people move within cities. However, as is already being seen, electromobility will manifest differently across cities. The rate and degree of e-mobility integration is dependent on a host of factors. This analytical framework provides the analyst with a more complex understanding of how a new mobility technology may impact the function of a broader sectoral regime. They rightly underscore the influence of spatial forms in shaping transition trajectories. Low-density cities, like Calgary, present challenges and opportunities for transportation electrification. Suburban communities are not often faced with EV charging challenges associated with houses that lack off-street parking or multi-unit residential buildings. Yet, those same low-density neighbourhoods make frequent public transit service more challenging, regardless of fuel source. Adding to the challenge, the internal alignment of micromobility and walking regimes is often weakened in lower-density cities. In sprawling cities, single-use zoning and vast distances between commercial services and public amenities create persistent barriers for improving alignment within and among these service regimes.

The framework also operationalizes how service regimes interact. As stressed by Fuenfschilling and Truffer (2014), many previous applications of the regime concept within the socio-technical transitions literature have simplified the institutional relations within and among regimes. By contrast, this framework provides the analytical architecture to navigate the institutional complexities associated with socio-technical regime change. While this study focussed on electrification technologies, the framework could also examine the simultaneous impact from other technologies, such as integrated ticketing or first and last mile transportation services. In doing so, the framework could layer on additional complexities to help the analyst understand the impacts of simultaneous technological change on different service regimes and the broader sectoral regime.

Beyond simply applying the framework of van Welie et al. (2018) and Schippl and Truffer (2020), this study extends their work in two important ways. First, rather than relying on archetypes of urban and rural land use, I operationalize the framework using a diversity of urban contexts. Even among three major cities in a single country analytically useful variation exists. Second, using informed conjecture based on existing trends and expert interviews, I extrapolate how electrification can impact not only private cars and car-sharing/taxis—as considered in Schippl and Truffer (2020)—but also how this technology will impact public transit and micromobility. The rapid growth of electric bikes and scooters and the ambitious electrification plans of many public transit authorities suggest broader impacts than what Schippl and Truffer (2020) depicted.

As with other radical low carbon innovations, the adoption of zero-emission passenger transportation involves pervasive uncertainty for users and service providers. Governance challenges abound. For policymakers, several policy approaches can be taken to govern through this risky socio-technical environment: **resistance** (planning for the worst possible case), **resilience** (ensuring rapid recovery), and **adaptation** (modifying policies as the context evolves) (Geels et al., 2018; Walker et al., 2010). These approaches are not mutually exclusive and can be pursued at the same time. Van Welie et al.'s (2018) framework on service and sectoral regimes represents a useful tool for policy actors adopting these three approaches to understand and manage the risks associated with wide-scale deployment of electromobility.

1) Resistance. The framework can anticipate worst case scenarios by highlighting potential unintended regime interactions and misalignment of constituent elements within a given sector. For instance, poor integration of biking infrastructure with other transport modes can not only result in unsafe or disconnected biking infrastructure but impede private vehicles or public transit. More positively, the framework can also identify unforeseen synergies among service regimes which create unanticipated benefits.

2) Resilience. Rapid technological change, shifting consumer demand, or the collapse of important local industries can all destabilize passenger transportation systems. To survive or even thrive amidst change, Elinor Ostrom (2010) found that polycentric approaches to natural resource governance can lead to more sustainable outcomes. Similarly, although not tested here, a more connected and polycentric governance approach to the transportation sector may result in swifter recovery from exogenous or endogenous shocks compared to systems fragmented and siloed transportation systems. This framework provides insights on how to strengthen the linkages within and across service regimes to enable greater flexibility and system complementarity.

3) Adaptation. Flexible policies can be relatively responsive to changing and deeply uncertain conditions. By involving relevant policy actors in the regular update of these framework assessments, policymakers can be informed by an evolving knowledge base across an entire sectoral regime. Linked to resilience, adaptive policies that promote adaptive and integrated infrastructure can also improve the functioning of sectoral regimes. For instance, in 2021 the Calgary Parking Authority built a 503-vehicle and 99-bicycle parking garage that can be easily retrofitted to accommodate EV charging or additional residential or commercial space should the need exist in the future (Dippel, 2021).

How can cities best prepare for electromobility? In short, they can strengthen a diversity of mobility options and improve alignments within and across these options. In doing so, these preparative actions hedge the risks associated with an electromobility transition while creating important redundancies. For a historically private vehicle-centric passenger transportation system this may create "inefficiencies" such as limiting parking spaces, reducing road widths, or slowing posted speed limits. However, in light of the accelerating electromobility transition, these so-called inefficiencies enable cities to simultaneously pursue adaption, resilience, and adaptation strategies. Such an approach also encourages municipal policymakers to address the not insignificant number of inefficiencies associated with extreme dependence on private vehicle use (e.g., traffic congestion, air pollution, noise, safety, competition with other more productive land uses). Beyond this, policy preparedness for electromobility also means grounding policy responses in the local context. For instance, a shared e-scooter pilot program in Calgary has been largely successful however initial attempts to introduce e-scooters in Montreal and Toronto have faced strong concerns from community groups and city officials. These two, relatively more densely populated cities have higher pedestrian traffic than in Calgary and consequently scooter parking competes with other existing sidewalk uses and users, including the elderly and mobility impaired.

However helpful this framework may be, analytical gaps still remain and provide the basis for future lines of inquiry and framework improvements. **1) Multi-level governance.** Future research could better consider the constraints and opportunities associated with multi-level governance. In Canada, provincial and federal governments play crucial roles in regulating passenger mobility and funding infrastructure. The stability and directionality of this support (e.g., highway or public transit infrastructure, conventional or electric bus funding) can improve the preparedness of cities for the transition to electrified transportation. **2) Data disaggregation.** While this project provided more complexity to the rural-urban typologies of Schippl and Truffer (2020), further detail on urban forms could help identify alignment within and among service regimes at the level of neighbourhoods. This could generate more insights into, for example, the governance of electromobility in Montréal's 19 boroughs—which have permitting and planning authority that can shape electromobility adoption. **3) Intersectoral interactions.** Beyond the interplay between service regimes within the larger passenger mobility sectoral regime, other sectors inevitably impact how people get around. Of the cases examined here, interviewees confirmed that the electricity sector has had a profound impact on the uptake of electromobility in Quebec (Lemphers et al., 2021), Ontario's ICEV-dominated auto manufacturing sector has shaped Toronto's response, and Alberta's oil and gas industry has constrained the adoption of electromobility policies in Calgary (Wolfe and Lemphers, 2023). Subsequent research could extend the scope of this study to explore these intersectoral interactions through a multi-system perspective (Rosenbloom, 2020), and generate insights on Geels et al.'s call for system reconfiguration.

References

Baxter, J., 2019. Electric Vehicle Strategy, City of Toronto. https://www.toronto.ca/legdocs/mmis/2020/ie/bgrd/backgroundfile-141238.pdf (Accessed 21 July 2021).

Bergek, A., Hekkert, M., Jacobsson, S., Markard, J., Sandén, B., Truffer, B., 2015. Technological innovation systems in contexts: Conceptualizing contextual structures and interaction dynamics. Environmental Innovation and Societal Transitions 16 (2015) 51-64, http://dx.doi.org/10.1016/j.eist.2015.07.003

Bike Share Toronto, 2021. Experience Toronto in a whole new way, https://bikesharetoronto.com/. (Accessed 21 July 2021).

Binz, C., Coenen, L., Murphy, J.T., Truffer, B., 2020. Geographies of transition—From topical concerns to theoretical engagement: A comment on the transitions research agenda. Environmental Innovation and Societal Transitions 34 (2020) 1-3, http://dx.doi.org/10.1016/j.eist.2019.11.002

Booth, L., Norman, R., Pettigrew, S., 2019. The potential implications of autonomous vehicles for active transport. Journal of Transport & Health 15 (2019) 100623, http://dx.doi.org/10.1016/j.jth.2019.100623

Calgary Transit, 2021a. Park and Ride Locations, https://www.calgarytransit.com/content/transit/en/home/park-and-ride/locations.html. (Accessed 21 July 2021).

Calgary Transit, 2021b. Statistics for 2020, https://www.calgarytransit.com/content/transit/en/home/about-calgary-transit/facts-and-figures/statistics.html. (Accessed 21 July 2021).

ChargeHub, 2021a. Calgary, Alberta EV Charging Stations Info, https://chargehub.com/en/countries/canada/alberta/calgary.html. (Accessed 21 July 2021).

ChargeHub, 2021b. Montréal, Québec EV Charging Stations Info, https://chargehub.com/en/countries/canada/quebec/montreal.html. (Accessed 21 July 2021).

ChargeHub, 2021c. Toronto, Ontario EV Charging Stations Info, https://chargehub.com/en/countries/canada/ontario/toronto.html. (Accessed 21 July 2021).

City of Calgary, 2018. Climate Resilience Strategy: MItigation & Adaptation Action Plans. City of Calgary, Calgary.
City of Calgary, 2020. Calgary Transportation Plan, City of Calgary. https://www.calgary.ca/transportation/tp/planning/calgary-transportation-plan/calgary-transportation-plan-ctp.html (Accessed 21 July 2021).
City of Calgary, 2021. Pathways and Trails, https://www.calgary.ca/csps/parks/pathways/pathways-in-calgary.html#:~:text=In%20fact%2C%20Calgary%20has%20the,and%2096%20km%20of%20trails. (Accessed 21 July 2021).
City of Toronto, 2020a. Cycling & Pedestrian Projects: Network Status, https://www.toronto.ca/services-payments/streets-parking-transportation/cycling-in-toronto/cycle-track-projects/network-status/. (Accessed 21 July 2021).
City of Toronto, 2020b. Electric Vehicles, https://www.toronto.ca/services-payments/water-environment/environmentally-friendly-city-initiatives/reports-plans-policies-research/electric-vehicles/#:~:text=The%20Strategy%20identifies%20a%20range,carbon%20energy%20sources%20by%202050. (Accessed 5 May 2021).
Coenen, L., Benneworth, P., Truffer, B., 2012. Toward a spatial perspective on sustainability transitions. Research Policy 41(6) (2012) 968-979, http://dx.doi.org/10.1016/j.respol.2012.02.014
Communauté métropolitaine de Montréal, 2021, Grand Montréal en statistiques, http://observatoire.cmm.qc.ca/observatoire-grand-montreal/outils-statistiques-interactifs/grand-montreal-en-statistiques/ (Accessed 21 July 2021).
Dippel, S., 2019, Calgary taxis lose market share to ride-hailing companies, city data shows, CBC News, 4 February, https://www.cbc.ca/news/canada/calgary/city-taxi-uber-tnc-1.5003434#:~:text=There%20are%20approximately%204%2C500%20taxi,licensed%20to%20drive%20for%20TNCs. (Accessed 21 July 2021).
Dippel, S., 2021, Calgary's new $80M parkade with a twist opens for business, CBC News, https://www.cbc.ca/news/canada/calgary/east-village-parkade-cmlc-1.6041589. (Accessed 21 July 2021).
Erhardt, G.D., Roy, S., Cooper, D., Sana, B., Chen, M., Castiglione, J., 2019. Do transportation network companies decrease or increase congestion? Science Advances 5(5) (2019) eaau2670, http://dx.doi.org/10.1126/sciadv.aau2670
Fuenfschilling, L., Truffer, B., 2014. The structuration of socio-technical regimes—Conceptual foundations from institutional theory. Research Policy 43(4) (2014) 772-791, http://dx.doi.org/10.1016/j.respol.2013.10.010
Geels, F.W., 2004. From sectoral systems of innovation to socio-technical systems. Research Policy 33(6-7) (2004) 897-920, http://dx.doi.org/10.1016/j.respol.2004.01.015
Geels, F.W., 2005. The dynamics of transitions in socio-technical systems: A multi-level analysis of the transition pathway from horse-drawn carriages to automobiles (1860–1930). Technology Analysis & Strategic Management 17(4) (2005) 445-476, http://dx.doi.org/10.1080/09537320500357319
Geels, F.W., McMeekin, A., Mylan, J., Southerton, D., 2015. A critical appraisal of Sustainable Consumption and Production research: The reformist, revolutionary and reconfiguration positions. Global Environmental Change 34 (2015) 1-12, http://dx.doi.org/10.1016/j.gloenvcha.2015.04.013
Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. Research Policy 36(3) (2007) 399-417, http://dx.doi.org/10.1016/j.respol.2007.01.003
Geels, F.W., Schwanen, T., Sorrell, S., Jenkins, K., Sovacool, B.K., 2018. Reducing energy demand through low carbon innovation: A sociotechnical transitions perspective and thirteen research debates. Energy Research & Social Science 40 (2018) 23-35, http://dx.doi.org/10.1016/j.erss.2017.11.003

Gersdorf, T., Hensley, R., Hertzke, P., Schaufuss, P., Tschiesner, A., 2020. The road ahead for e-mobility, McKinsey & Company. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-road-ahead-for-e-mobility#.
Home, A., 2021. Volkswagen powers up for the electric vehicle revolution, https://www.reuters.com/article/us-volkswagen-electric-ahome-idUSKBN2BG2MN. (Accessed 11 May 2021).
International Energy Agency, 2021. Global EV Outlook 2021, International Energy Agency. https://iea.blob.core.windows.net/assets/ed5f4484-f556-4110-8c5c-4ede8bcba637/GlobalEVOutlook2021.pdf.
Jarratt, E., 2021, Electric Autonomy Canada, 16 April, https://electricautonomy.ca/2021/04/16/ttc-300-electric-buses/. (Accessed 21 July 2021).
Joshi, K., 2020, Oslo city hits new milestone - most electric vehicles per capita, The Driven, 7 July, https://thedriven.io/2020/07/07/oslo-city-hits-new-milestone-most-electric-vehicles-per-capita/. (Accessed 21 July 2021).
Konrad, K., Truffer, B., Voß, J.-P., 2008. Multi-regime dynamics in the analysis of sectoral transformation potentials: evidence from German utility sectors. Journal of Cleaner Production 16(11) (2008) 1190-1202, http://dx.doi.org/10.1016/j.jclepro.2007.08.014
Lemphers, N., Bernstein, S., Hoffmann, M., Wolfe, D.A., 2021. Electromobility as an Innovation and Decarbonization Catalyst in Norway, Québec, and California. Energy Research & Social Science forthcoming (2021)
Li, Y., Taeihagh, A., Jong, M.d., 2018. The Governance of Risks in Ridesharing: A Revelatory Case from Singapore. Energies 11(5) (2018) 1277, http://dx.doi.org/10.3390/en11051277
McGran, K., 2020, Amid COVID-19, Toronto taxi and Uber drivers say business is way down — and the risks are up, Toronto Star, 25 March, https://www.thestar.com/news/gta/2020/03/25/amid-covid-19-toronto-taxi-and-uber-drivers-say-business-is-way-down-and-the-risks-are-up.html#:~:text=There%20are%20about%205%2C500%20taxis,companies%20like%20Uber%20and%20Lyft. (Accessed 21 July 2021).
Ministry of Transportation, 2021. Motorized Vehicle Registrations (2016-2020), Government of Alberta. https://open.alberta.ca/dataset/d6205817-b04b-4360-8bb0-79eaaecb9df9/resource/4a06c219-03d1-4027-9c1f-a383629ab3bc/download/trans-motorized-vehicle-registrations-select-municipalities-2020.pdf (Accessed 21 July 2021).
Munro, F.R., 2019. The geography of socio-technical transitions: Transition–periphery dynamics. The Geographical Journal 185(4) (2019) 447-458, http://dx.doi.org/10.1111/geoj.12306
Murphy, J.T., 2015. Human geography and socio-technical transition studies: Promising intersections. Environmental Innovation and Societal Transitions 17 (2015) 73-91, http://dx.doi.org/10.1016/j.eist.2015.03.002
Osazuwa-Peters, M., Hurlbert, M., McNutt, K., Rayner, J., Gamtessa, S., 2020. Saskatchewan's energy future: Risk and pathways analysis. Environmental Innovation and Societal Transitions 34 (2020) 237-250, http://dx.doi.org/10.1016/j.eist.2020.01.010
Ostrom, E., 2010. Beyond Markets and States: Polycentric Governance of Complex Economic Systems. American Economic Review 100(3) (2010) 641-672, http://dx.doi.org/10.1257/aer.100.3.641
Papachristos, G., Sofianos, A., Adamides, E., 2013. System interactions in socio-technical transitions: Extending the multi-level perspective. Environmental Innovation and Societal Transitions 7 (2013) 53-69, http://dx.doi.org/10.1016/j.eist.2013.03.002
Ramos-Mejía, M., Franco-Garcia, M.-L., Jauregui-Becker, J.M., 2018. Sustainability transitions in the developing world: Challenges of socio-technical transformations unfolding in contexts of poverty. Environmental Science & Policy 84 (2018) 217-223, http://dx.doi.org/10.1016/j.envsci.2017.03.010

Rashidi, T.H., Najmi, A., Haider, A., Wang, C., Hosseinzadeh, F., 2020. What we know and do not know about connected and autonomous vehicles. Transportmetrica A: Transport Science 16(3) (2020) 987-1029, http://dx.doi.org/10.1080/23249935.2020.1720860

Raven, R., Verbong, G., 2007. Multi-Regime Interactions in the Dutch Energy Sector: The Case of Combined Heat and Power Technologies in the Netherlands 1970–2000. Technology Analysis & Strategic Management 19(4) (2007) 491-507, http://dx.doi.org/10.1080/09537320701403441

Raven, R.P.J.M., Gregersen, K.H., 2007. Biogas plants in Denmark: successes and setbacks. Renewable and Sustainable Energy Reviews 11(1) (2007) 116-132, http://dx.doi.org/10.1016/j.rser.2004.12.002

Rider, D., 2020, Toronto adds electric bicycles to bike-share fleet — at no extra cost to users, Toronto Star, 19 August, https://www.thestar.com/news/city_hall/2020/08/19/toronto-adds-electric-bicycles-to-bike-share-fleet-at-no-extra-cost-to-users.html. (Accessed 21 July 2021).

Rosenbloom, D., 2020. Engaging with multi-system interactions in sustainability transitions: A comment on the transitions research agenda. Environmental Innovation and Societal Transitions 34 (2020) 336-340, http://dx.doi.org/10.1016/j.eist.2019.10.003

Sandler, G., 2021, BIXI is Coming Back To Montreal In 2021 With New Bikes And New Pricing, MTL Blog, 25 February, https://www.mtlblog.com/montreal/montreal-bixi-is-coming-back-in-2021-with-new-bikes-new-pricing. (Accessed 21 July 2021).

Schippl, J., Truffer, B., 2020. Directionality of transitions in space: Diverging trajectories of electric mobility and autonomous driving in urban and rural settlement structures. Environmental Innovation and Societal Transitions 37 (2020) 345-360, http://dx.doi.org/10.1016/j.eist.2020.10.007

Shove, E., Pantzar, M., M, W., 2012. The Dynamics of Social Practice. Sage, London.

Smith, A., Stirling, A., Berkhout, F., 2005. The governance of sustainable socio-technical transitions. Research Policy 34(10) (2005) 1491-1510, http://dx.doi.org/10.1016/j.respol.2005.07.005

Smith, G., Hensher, D.A., 2020. Towards a framework for Mobility-as-a-Service policies. Transport Policy 89 (2020) 54-65, http://dx.doi.org/10.1016/j.tranpol.2020.02.004

Sperling, D., 2018. Three Revolutions: Steering automated, shared, and electric vehicles to a better future. Island Press, Washington, DC.

Staricco, L., Rappazzo, V., Scudellari, J., Vitale Brovarone, E., 2019. Toward Policies to Manage the Impacts of Autonomous Vehicles on the City: A Visioning Exercise. Sustainability 11(19) (2019), http://dx.doi.org/10.3390/su11195222

Statistics Canada, 2016, 2016 Census Data, Government of Canada, https://www12.statcan.gc.ca/census-recensement/2016/rt-td/population-eng.cfm (Accessed 21 July 2021).

STM, 2021a. Electrification underway… Toward a 100% electric network, http://www.stm.info/en/about/major_projects/major-bus-projects/bus-network-electrification/electric-bus. (Accessed 10 May 2021).

STM, 2021b. Park your bike next to a métro station!, https://www.stm.info/en/info/advice/bicycles/parking-space-bicycles. (Accessed 21 July 2021).

Swilling, M., 2013. Contesting inclusive urbanism in a divided city: The limits to the neoliberalisation of Cape Town's energy system. Urban Studies 51(15) (2013) 3180-3197, http://dx.doi.org/10.1177/0042098013505160

Thomas, B., 2019, Alberta's electric vehicle numbers still low, but growing exponentially, Calgary Herald, 2 September, https://calgaryherald.com/news/local-news/albertas-electric-vehicle-numbers-still-low-but-growing-exponentially. (Accessed 21 July 2021).

Toronto Transit Commission, 2020. 2019 Operating Statisitcs, https://www.ttc.ca/About_the_TTC/Operating_Statistics/2019/index.jsp. (Accessed 21 July 2021).

Toronto Transit Commission, 2021a. Bike-and-ride: Park-and-ride, https://www.ttc.ca/Riding_the_TTC/Bikes/Park-and-ride.jsp. (Accessed 21 July 2021).
Toronto Transit Commission, 2021b. Commuter Parking, https://www.ttc.ca/Riding_the_TTC/Parking/index.jsp#:~:text=Paid%20parking%20from%205%20a.m.,Daily%20rate%20is%20%247. 2021).
Turnheim, B., Sovacool, B.K., 2020. Exploring the role of failure in socio-technical transitions research. Environmental Innovation and Societal Transitions 37 (2020) 267-289, http://dx.doi.org/10.1016/j.eist.2020.09.005
van Welie, M.J., Cherunya, P.C., Truffer, B., Murphy, J.T., 2018. Analysing transition pathways in developing cities: The case of Nairobi's splintered sanitation regime. Technological Forecasting and Social Change 137 (2018) 259-271, http://dx.doi.org/10.1016/j.techfore.2018.07.059
Villani, M., 2021, Electric scooters have returned to Calgary sidewalks, pahtways, and bike lanes, CTV News, 28 May, https://calgary.ctvnews.ca/electric-scooters-have-returned-to-calgary-sidewalks-pathways-and-bike-lanes-1.5446448. (Accessed 21 July 2021).
Ville de Montréal, 2020a. COVID-19: La Ville de Montréal proposera cet été le circuit des Voies actives sécuritaires, http://ville.montreal.qc.ca/portal/page?_pageid=5798,42657625&_dad=portal&_schema=PORTAL&id=32659&ret=http://ville.montreal.qc.ca/pls/portal/url/page/prt_vdm_fr/rep_annonces_ville/rep_communiques/communiques. (Accessed 21 July 2021).
Ville de Montréal, 2020b. Plan climat 2020-2030, Ville de Montréal. https://res.cloudinary.com/villemontreal/image/upload/v1607536657/portail/ktpxrxvj5qxggayecchd.pdf (Accessed 21 July 2021).
Walker, W.E., Marchau, V.A.W.J., Swanson, D., 2010. Addressing deep uncertainty using adaptive policies: Introduction to section 2. Technological Forecasting and Social Change 77(6) (2010) 917-923, http://dx.doi.org/10.1016/j.techfore.2010.04.004
Wappelhorst, S., 2021. Beyond major cities: Analysis of electric passenger car uptake in European rural regions, International Council on Clean Transportation. https://theicct.org/sites/default/files/publications/Ev-europe-rural-mar2021.pdf (Accessed 21 July 2021).
Wolfe, D.A., Lemphers, N., 2023. The Political Economy of Energy Transitions in Canada: Implications for the Auto Industry, in: Anastakis, D., Mordue, G. (Eds.), North American Auto Industry Since NAFTA. University of Toronto Press, Toronto.
Young, M., Allen, J., Farber, S., 2020. Measuring when Uber behaves as a substitute or supplement to transit: An examination of travel-time differences in Toronto. Journal of Transport Geography 82 (2020), http://dx.doi.org/10.1016/j.jtrangeo.2019.102629