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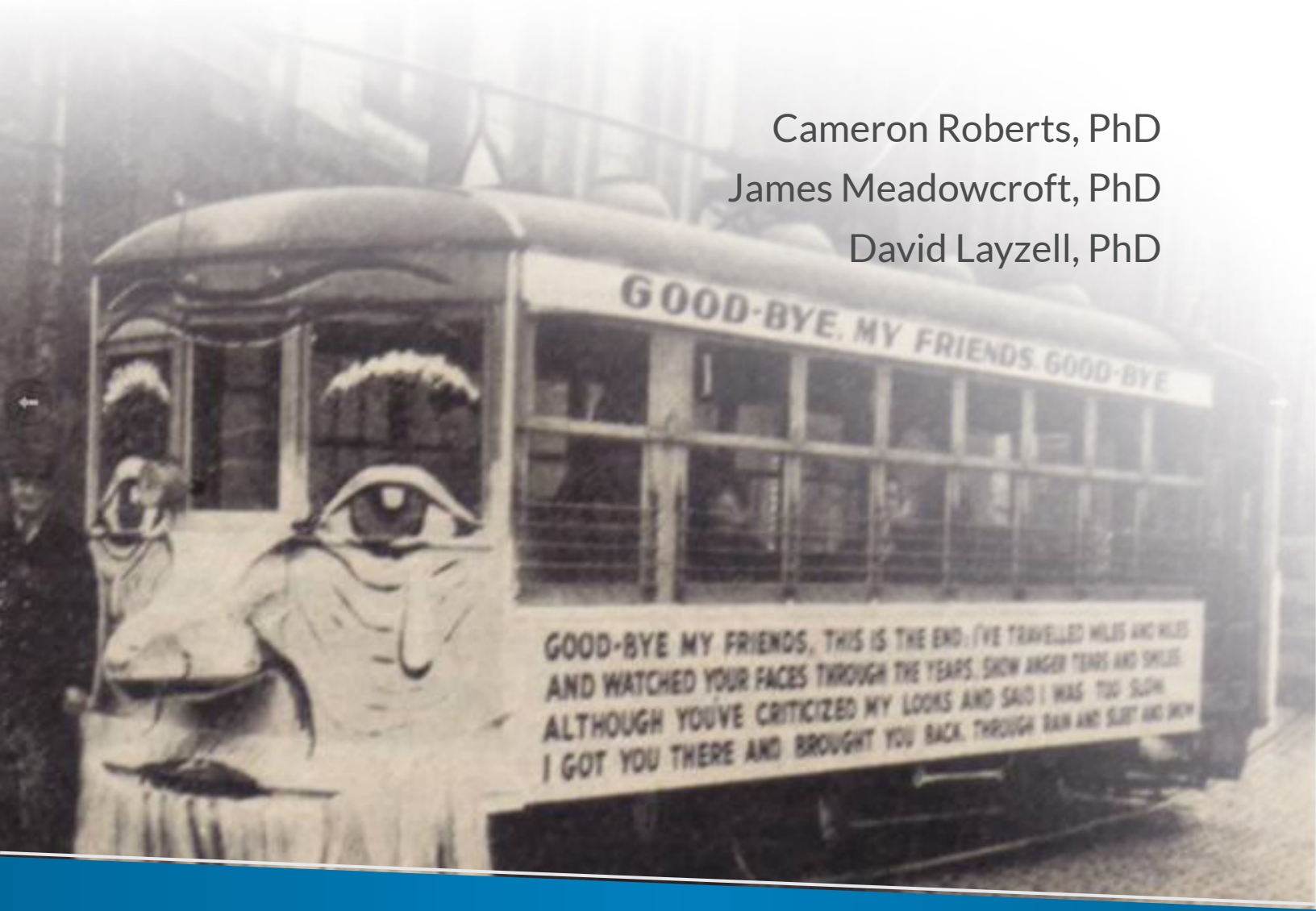

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About the Transition Accelerator (TA)

The Transition Accelerator is a national not-for-profit organization, established in 2019, which works to bring together industry, government, academics and social groups to co-develop credible, compelling visions and pathways for systems change to create a better Canada, including – but not limited to – meeting climate change targets.

For information on the Transition Accelerator see: www.transitionaccelerator.ca.

About the Authors

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Executive Summary

This paper examines the experience of an earlier transition in land transport that saw the rapid adoption of the automobile. It focuses on three important questions:

- WHY did Canadian mobility change during the first half of the twentieth century?
- HOW did cars emerge relatively quickly as the dominant mode of transportation?
- WHAT lessons can we learn from this history to inform future sustainability transitions?

The transition to a car-based transportation system in Canada proceeded with startling speed. In 1908, railways and streetcars dominated passenger mobility in Canada, and there were just 3003 registered cars in the country: considerably less than can now be accommodated in a large parking lot. By the 1930s, however, cars had become commonplace. Roads, traffic laws, and personal habits were being reshaped around them, while the car industry had become a major employer, and the railway and streetcar systems were in a death spiral. If change at this rate were to sweep the Canadian personal mobility system today, then by the middle of this century we could be using completely different transportation systems — potentially with far lower carbon emissions.

"In large scale transitions, people are as important as technology. While technological innovation is an important ingredient, many of the most profound causes of change result from cultural, political, social, and economic developments taking place far from the design labs or assembly lines."

Examination of the process of the historical transition in Canadian automobility reveals that it reached far beyond the cars themselves. In the first place, cars had to be integrated into the everyday lives of Canadians: something which required an active process of innovation on the part of the

car's users, as well as on the part of businesses and policymakers who developed things like new urban traffic laws, and the motel industry. Second, the success of the automobile was facilitated by the fact that by the start of the twenty-first century, the railway and streetcar barons who owned the incumbent transportation system had become politically toxic in a way that made them vulnerable to challenges from new forms of transportation. Finally, there was a process of increasing returns attached to the development of car infrastructure such as highways, as the people who oversaw this process had a vested interest in seeing it continue. Each of these historical observations can be linked to a theoretical concept from the sociology of technology: 'domestication', 'incumbency', and 'technological momentum'.

The final section of the paper distils six lessons that can be taken from this case study:

1. **Persistent unsolved problems with the status quo can open the door to change.** Current problems with the car-based transportation system (such as congestion, pollution, and accidents) could play a similar role in destabilizing the system today that overcrowding, lateness, and high fares played in destabilizing the railway system in the early twentieth century.

2. **Established systems have momentum, but challengers can also exploit positive feedback loops.** The early automobile benefited from a virtuous cycle, as more cars meant more roads and more people lobbying for roads. Similar dynamics might help boost a new system to prominence.

3. **Users matter.** Many of the user practices that enable a new mobility system to replace the private gasoline-powered automobile will be the result of innovation by users, as was the case with the automobile itself prior to the Second World War.

4. **Visions shape processes of change.** The modern system of divided highways was motivated in large part by futuristic and ambitious speculation during the 1920s and 1930s. Similar visioning will be necessary to develop the structures of a new transportation system.

5. **Early decisions influence subsequent choices.** Choices made early in the adoption of the gasoline-powered automobile had a disproportionate influence on subsequent developments. So as we introduce new technologies (for example electric or autonomous vehicles) we should think ahead about their potential social consequences.

6. **Innovation in one system can open the door to transformative change in other sectors.** Road transportation changed virtually every aspect of Canadian society, and we should anticipate a similar scale of changes to occur as we confront transitions to sustainable mobility.

Taken together, these boil down to the larger point that in large scale transitions, people are as important as technology. While technological innovation is an important ingredient, many of the most profound causes of change result from cultural, political, social, and economic developments taking place far from the design labs or assembly lines. This highlights the importance of connecting technical innovation in low-carbon mobility with its broader social context — something that the Transition Accelerator places at the core of its mission.

1. Introduction

During the first half of the twentieth century, Canada's transport system changed with startling speed. In 1900 city streets were dominated by pedestrians, bicycles, streetcars, and horse-drawn vehicles. By the end of the Second World War in 1945, they had become thoroughfares for buses, trucks, and private automobiles. The statistics of this transformation are described in some detail in a companion Transition Accelerator paper [1].

The rise of motorized transport brought many benefits — allowing people and goods to move more quickly, more conveniently, and over longer distances. It dramatically increased productivity in agriculture and industry, enabling people to travel further to seek jobs and amenities, and it facilitated the introduction of novel goods and services. Over time the personal automobile became an anchor of modern consumer society and a symbol of affluence and autonomy.

The triumph of the car, however, also brought problems to Canada's highways and cities: air pollution, deaths from collisions, urban sprawl, and carbon emissions. Today, road collisions and air pollution cause over ten thousand premature deaths per year [2], [3], while passenger transportation accounts for 13 percent of Canadian greenhouse gas emissions [4]. This poses an important question: Can the carbon-intensive, car-based transportation system be changed into something more sustainable quickly enough to address the challenge of climate change. With this in mind, the precedent of the rapid transition to automobility is encouraging: It might bode well for a rapid twenty-first century transition to a new, more sustainable transportation system dominated by low-carbon transportation technologies including electric vehicles, public transit, and active transportation (walking and cycling).

"The precedent of the rapid transition to automobility is encouraging: It might bode well for a rapid twenty-first century transition to a new, more sustainable transportation system."

This suggests that to understand how Canadian transportation might change in the future, it is useful to look at how it changed in the past. History allows us to appreciate the fine details of large-scale technological change [5] and to reflect on the challenges associated with a rapid change in the technologies and practices of personal mobility. Many of the difficulties faced by the early car-based transportation system also confront contemporary efforts: for example, how best to shape novel technologies and emerging social practices to meet societal needs; how to deal with resistance from

'incumbents' who control existing systems; and how to build momentum to accelerate change.

While the companion paper in this series presents a quantitative summary of the growth of car travel in Canada, this paper adopts a more qualitative approach. It draws from historical journal articles and books covering the transition to a car-based transportation system in Canada and beyond, and presenting the lessons from this research in a way that is informed by social science theories describing how technologies interact with society during periods of large-scale technological change [1].

Following this introduction, section 2 provides a brief overview of the history of the Canadian automobile. It describes the rapid pace of the transition and the massive changes that accompanied the rise of motorized transport. Sections 3 discusses factors that shaped this transformation in more detail, introducing some theoretical concepts to help understand this process. Based on this analysis, section 4 suggests six lessons that can be drawn from history. Finally, the conclusion draws out one broad learning — that in any large-scale transition, people are as important as machines.

2. A Brief History of Automobility in Canada

To put the scale and speed of the transition to automobility in Canada in perspective, it is useful to consider how things looked at the start of the twentieth century, when the Canadian automobile was in its infancy. At that time, the transportation system was dominated by railways and streetcars, which had seen several construction booms during the latter part of the nineteenth century [6]. Interest in building cars at this point was tepid at best, with Canadian manufacturers producing "only a few small, barely functional vehicles" [7, p. 1]. Even as the industry grew, the market remained limited: by 1908, there were only 3003 registered motor vehicles in the country [7], and two-thirds of vehicles on Canadian roads were owned by foreigners, most of whom were tourists from the United States [8]. For those early drivers, there were not very many places to actually use their cars. The previous century's enthusiasm for rail-based transportation had subjected roads to decades of neglect. Apart from a handful of macadam (and even fewer asphalt [9]) roads built at the behest of cyclists, most roads in Canada were rough dirt roads that became near-impassable in wet or snowy weather [9]. The first trans-Canada car trip did not happen until 1913: It took 59 days, and the car had to be fitted flanged wheels so that it could travel on railways in areas where roads did not exist [8].

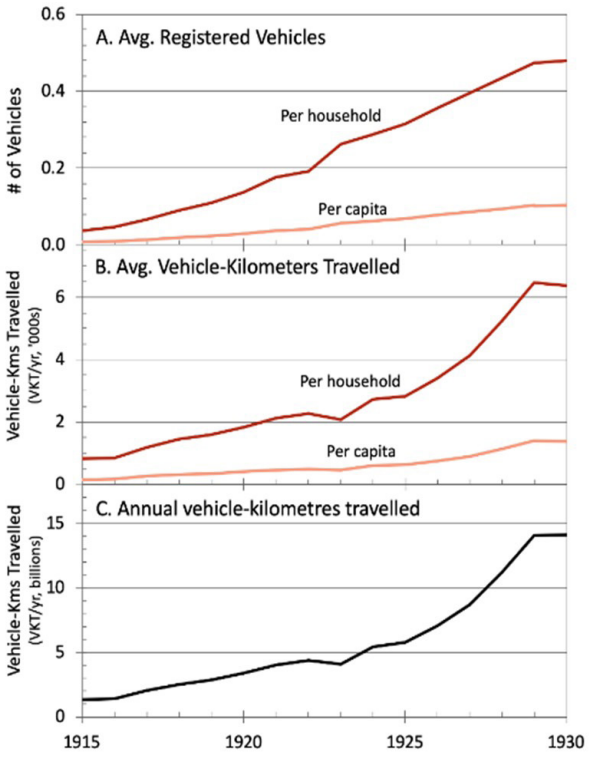

Figure 2.1
The rapid growth in the Canadian automobile system throughout the twentieth century. From Torrie, forthcoming.

Despite these challenges, there was interest in expanding the car industry. The 90,000 visitors who attended the 1913 Toronto Motor Show were an early sign of the explosive growth to come (Figure 2.1). By then, Canada was host to a competent, powerful, and confident car industry, which in 1914 produced 24,000 "practical, reasonably reliable vehicles — all powered by gasoline engines" [7, p. 1]. As cars became more affordable, more people bought them. The rate of adoption was startling. In 1912, traffic monitors at an intersection near Toronto counted 382 automobiles in one hour — a huge increase from the 6 they had counted at the same place in 1908 [7]. By 1914, Canada had 69,598 registered motor vehicles, and by 1918 this number had increased to

275,745 [7]. All three levels of government began to take a greater interest in road improvements to cope with the additional traffic [8]. In 1919, Ottawa passed the Canada Highways Act, which provided employment by assisting provinces with road building using federal money [8].

By the 1920s, cars had "truly entered the life of the masses" [7, p. 21], swelling provincial treasuries with motor vehicle revenues, and populating cities and rural areas with car clubs, service stations, dealerships, parking lots, and traffic jams [7], [8]. Motor vehicles began to make inroads into railway traffic around this time, particularly toward the end of the decade, as the railways were hit by the impacts of the Great Depression [9]. The car industry continued to grow, amassing capital and employees, and increasing the number of vehicles it produced, until by the end of the decade Canada emerged as the world's second-largest car producer. By this time, Ford Canada's plants in Montreal, Toronto, and Winnipeg could produce 800 cars in an 8-hour shift [7]. The car industry also started to diversify into different kinds of commercial vehicles during this decade, including the first purpose-built buses and trucks [8].

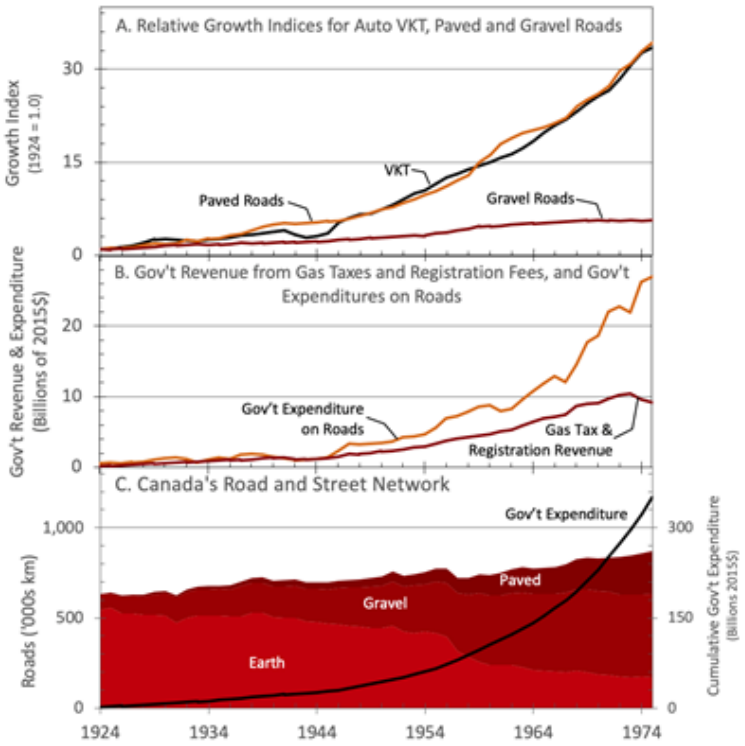

Figure 2.2
The growth of the Canadian street network.
From Torrie, 2019.

In 1925, the second attempt at a trans-Canada driving trip took only 39 days, thanks to improved roads, although the car still had to take railways in some places [8]. But progress on road construction was evident in the fact that by 1928, 88 percent of Canadian roads were macadam [9]. As the Great Depression took an ever-increasing toll on the railways and streetcars, the automobile cemented itself as the central element of a viable transportation system. By 1930, there were over one million passenger car registrations in Canada — one for every 9.5 Canadians [7]. The cars themselves had matured by this point, with the main thrust of innovation during the 1930s being in the area of styling [7]. Buses and trucks also saw a major boom — by 1937 their numbers on Canadian roads had increased 41-fold since 1916 [8]. Greyhound was getting established in Alberta and

BC [7], and by the end of the decade, the railways were abandoning routes so quickly that the government had to regulate the process to ensure that communities did not become completely stranded [9].

At the outbreak of the Second World War, revenue from cars accounted for between 20 and 30 percent of taxation in most provinces. This was primarily allocated to road construction, causing standards to improve rapidly to keep pace with increasing traffic intensity [7], [8]. The Second World War brought a pause to this rapid growth. The federal government banned the sale of private automobiles, and the industry shifted towards war production, becoming a major supplier of vehicles to the war effort [7]. But by the time the industry emerged from war production and began once again building cars, the automobile transportation system had reached a state largely recognizable today. By 1953, close to 80 percent of all Canadian passenger travel was by automobile. The cars were predominantly of the comfortable, reliable, closed-body designs familiar today, thanks to improvements in materials such as sheet metal and glass [7]. And the industry — now dominated by the familiar oligopoly of the "big 3" — was producing hundreds of thousands of vehicles per year. An ever-growing road network was rolled out by a "small army" of highway engineers and other professionals [8]. This was the time when Toronto's 401, the Queen Elizabeth Way, the Calgary-Edmonton Highway, and, ultimately, the Trans-Canada highway, were paved [8]. Passenger rail, meanwhile, entered a terminal decline that was only arrested by the formation of Via Rail in 1977.

In short, the automobile went from a niche product built by a nascent industry, used by a handful of hobbyists, and driven on rough, bumpy, washed-out roads, to the keystone technology of the dominant transportation system familiar in Canada today. This process took approximately forty years, with the most rapid period of change spanning the two decades between the First and Second World Wars. If our current transportation system changes as rapidly over the next two decades as the system did in the two decades following 1919, then we will have experienced a revolution in personal mobility by the 2040s. If such a revolution occurs, it could go two ways. On the one hand, it could result in a radically sustainable transportation system. On the other hand, it could result in something whose environmental harms are even worse than those of the current system. To encourage the development of more sustainable transportation systems, therefore, it is important to understand how transportation transitions happen. This paper discusses this, using the transition to car-based mobility in Canada as a case study in radical socio-technological change.

3. Processes of Change in the Canadian Transportation System

The previous section provided a brief overview of the rapid adoption of the automobile in Canada, and the profound societal changes to which it was connected. This section covers the history in more detail, focusing on how this rapid and profound change in Canadian personal mobility took place. It investigates three mechanisms, each of which played a key role at a different stage in the process. First, it discusses the developments among communities of users that transformed the automobile from a rich-people's plaything into a serious form of transportation. This was an active process in which much of the value of the automobile as a transportation system was created by its users. Next, it discusses the status of the rail-based transportation systems and the powerful industrial interests associated with them that pre-dated the passenger automobile. Around the turn of the twentieth century, the power of these incumbents was eroding, which weakened their ability to resist competition from road vehicles. Finally, this section discusses the development of a broader system of Canadian automobility. As cars became more popular, public infrastructure had to change to accommodate them. This change occurred as part of a self-reinforcing political process in which a new set of incumbent interests came to dominate the conversation about transportation infrastructure in Canada.

3.1. Technological and social innovation: Building new practices of mobility

The early history of the automobile is full of stories of tinkering and experimentation. Many of the most famous experiments with self-propelled road vehicles, such as Karl and Bertha Benz's Patent Motorwagen, took place in Europe. But similar experiments were going on all over the world, including in Canada. Inventors and entrepreneurs built cars in Toronto in 1897, in Vancouver in 1899, and in Sherbrooke in 1903 [7]. Attempts at commercialization were not far behind. Investors established the ill-fated Canadian Cycle and Motor Company in 1899, and Russell Motors, the first and only all-Canadian car company, was founded by CCM, a bicycle manufacturing company, in Toronto in 1906. By 1907, there was a stable and growing Canadian car industry — mostly located in Ontario, and mostly copying American designs under license [7]. It was also supported by a large industry of parts suppliers and material distributors.

While this technological and industrial innovation established the automobile as a physical artifact, more work was required to make cars into a practical transportation system. The first cars built in Canada were upper-class toys. This was not only because their price placed them outside

the reach of any but the rich, but also because they were noisy, unsafe, uncomfortable, unreliable and largely impractical as a serious mode of transportation. Recreational use by the wealthy turned these bugs into features: Bouncing along on an uncomfortable wooden seat as you fought your way down poor-quality roads only to have to stop to make repairs several times along the way was not an appealing way to commute to work. It was, however, a great way to live up to late nineteenth-century social imperative for upper-class men to demonstrate self-reliance, mechanical skill, and an affinity for adventure [10].

This first model of car travel created some of the cultural and legal preconditions for the more utilitarian form of car use we see today. Wealthy recreational drivers created a set of social discourses portraying cars as "adventure machines" that played into later practices of long-distance car travel that are still used in car advertising. They also founded organizations, such as the Canadian Automobile Association (founded in 1915) to advance their interests, most notably by lobbying for traffic laws that accommodated their right to drive the way they wanted to, despite considerable hostility to cars that existed among the much larger proportion of the population who could not afford them.[1]

1 Prince Edward Island, for example, banned cars entirely between 1908 and 1914. [7]

Box 3.1 Domestication

The word "domestication" is most commonly associated with animals or plants, and the process by which humans modify them to be useful to us. This has always been a two-way process: In domesticating dogs, grains, horses, and even micro-organisms such as yeast, humans changed the genetics of these organisms. But these domestications also had profound impacts on human societies, enabling entirely new modes of living.

In the context of science and technology studies, domestication theory (whose foundational work is Knut Sørensen's Making Technology our Own: Domesticating Technology into Everyday Life [13]) is about the integration of new technologies into our lives: a process that changes both the technologies, and the lives of the people who use them.

This process requires creative work. It is also unpredictable. The literature in science and technology studies produces several interesting examples of this. The minimoog synthesiser, for example, was not originally intended as a rock and roll instrument, but was made into one by the efforts of one interprising salesman and a few pioneering musicians [14]. The telephone was originally developed with an eye to simple, quick, utilitarian phone calls, with its early developers expressing concern that social calls would clog up the networks. Nineteenth-century users had different ideas, however, and quickly turned telephones into a social device [15], [16]. This is a core aspect of creating the value proposition of any new technology, because every technology at the outset is at least somewhat indeterminate in terms of the functions it can actually perform in people's normal lives. The domestication process occurs both in the private sphere, as users find uses for a new technology and adapt their lives and routines around those uses, and in the public sphere, as new social habits involving the technology and its users are contested and legitimised [49], [50].

So a technology's value proposition is not "finished" when it is first developed and marketed by engineers, entrepreneurs, or other professionals. While those people can try to push for it to be used in a certain way, and can suggest exciting uses in their marketing efforts, they can also respond to the ways users domesticate the technology by making appropriate modifications to subsequent models. Domestication is an iterative process of feedback to and from manufacturers and users. Sometimes it even involves conflict between these groups. Ultimately, however, the application of a new technology to everyday life is an important part of the innovation process, and is as critical to creating the value proposition of a new technology as anything that happens in research and development labs or on assembly lines.

In 1907, Ford Motor Company developed the Model T and the first assembly line, which radically brought down the price of cars. While this technical development was of American origin, it was quickly transplanted to Canada, resulting in cars being available to the middle classes for the first time. The cars themselves had also become considerably more comfortable and reliable. To make cars useful, however, the middle class that was now able to buy their own cars for the first time had to adapt their

lifestyle to the new form of mobility they permitted. One important group in this process was middle-class professionals, particularly those such as doctors and salesmen who integrated cars into their profession as a faster, easier, and more efficient way to conduct house calls. Another group that enthusiastically adopted the automobile was farmers [8]. Rural areas, especially Saskatchewan, were one of the fastest areas for the growth of private automobile ownership, as farmers used them to address rural isolation and increase their access to the services in nearby towns. Other new uses for the cars were more creative: Some farmers began using cars as a stationary power source to drive farm equipment and home appliances. Third-party companies quickly took advantage of this tendency, developing special kits to prop up a Model T on its rear axle and attach its wheels to stationary equipment [11]. This last point illustrates the unpredictability of how technologies are domesticated. Car companies did not originally intend their product to be used to power farmers' washing machines or threshers (Henry Ford himself denounced the practice), but the people who purchased the cars had the final say. As this was going on, the falling price of motor vehicles allowed a larger and larger demographic to start driving them, while even those who could not afford a car of their own were able to enjoy the novelty of motor transportation by riding on a motor bus [12].

The end of the First World War saw a major boom in car use in Canada, and the broad appeal of cars at this time is made clear by the dramatic increase in car ownership. The owners of all these new cars used them to increase the total distance they travelled: they moved to suburbs and began taking long driving holidays, rather than simply using cars to go through their old routines faster and more efficiently. The rapid diffusion of cars did not correspond to a change in the time spent travelling, and it actually increased the proportion of people's income that they spent on mobility. This suggests that the car's early users were actively choosing to devote more personal resources to a new form of travel, which enabled new lifestyle choices, such as suburban living, rather than simply slotting a new machine into their old lifestyles.

"The owners of all these new cars used them to increase the total distance they travelled: they moved to suburbs and began taking long driving holidays, rather than simply using cars to go through their old routines faster and more efficiently."

This process was a product of individual decisions, but also of wider social trends. One such development was the cultural value that was ascribed to cars as symbols of progress, modernity, success, or masculinity [13]–[15].

These attributes were constructed through complex social interactions, but also deliberately cultivated in the marketing strategies employed by car manufacturers, such as the much-discussed "Sloanism"[2] employed by General Motors, which saw new features trickle down from the most expensive brands to the least expensive, enshrining cars as a status symbol [16].

Long-distance trips also required their own set of new social practices. They depended not only on reliable cars, high-quality intercity roads (discussed below), and gas stations, but also on sleeping and eating accommodations to facilitate multi-day trips. First came the early twentieth-century practice of "auto-camping", developed by car tourists as a free, unregulated form of travel that involved sleeping in a tent pitched on the road-side. These car-campers were not only responding to the new independent mobility afforded by the development of the private automobile, but also to new cultural trends in the early twentieth century prioritizing self-reliance, engagement with nature, and touring one's own country rather than travelling abroad. The popularity of auto-camping led to the establishment of dedicated auto-camping sites outside of cities, which were eventually privatized and equipped with indoor facilities. Soon, they became the first motels, which were a critical part of long-distance road travel infrastructure, especially when cars and highways were not yet up to the task of facilitating long-distance travel in a single day [17].

3.2. Incumbency: The fall of the railways and streetcars

At the time the first cars were invented, streetcars and railways were strong incumbent transportation systems in urban and intercity travel respectively, with a lot of power to shut down challengers. Historical literature on late nineteenth-century Canadian history describes "railway barons" having a massive influence on the national government [6], [18]–[20]. Streetcar firms also had a long history across North America of manipulating politics in their favour, and of behaving aggressively towards any rivals or challengers to their dominant position [12], [21].

The potential threat that these companies could pose was illustrated by the streetcars' ruthless crushing of the jitney. Jitneys were a type of informal taxi. Their drivers operated private cars along semi-fixed routes where they picked up multiple passengers. This was a successful mode of urban transportation in Canada during a brief period around the time of the First World War, but it typically did not produce enough revenue to attract the corporate capital that had built the urban streetcar systems. The streetcar companies, therefore, focused on removing the competitive threat. They

2 Sloanism was named after General Motors CEO Alfred P. Sloan, who introduced a system of flexible mass production, enabling different kinds of features to be rolled out to a range of different models selling at different price points.

launched a media campaign, using their professional journals and association meetings to define jitneys in the public eye as an inefficient and inferior technology that needed to be regulated in the name of fairness. They also played up safety and moral concerns, especially among women. They then lobbied city halls to impose strict regulations on jitneys, including licensing requirements, anti-crowding rules, bond requirements, and accident insurance.[3] Often, streetcar companies would offer concessions to city hall, such as new lines to underserved areas, in exchange for anti-jitney regulations. In extreme cases, they were able to secure veto power for themselves over any new jitney licenses, or even outright bans on jitneys. By the 1930s, the jitney had all-but disappeared from Canadian streets [29].

The case of the jitney shows that the incumbent transportation systems were willing to suppress any innovation that posed a competitive threat, and were able to call on a wide range of political, social, financial, and legal resources to do so. This could have been a potent obstacle to the growth of the emerging car-based transportation system. Ultimately, however, this trenchant resistance never materialized. The opposition that streetcar and railway companies did offer was half-hearted, poorly thought-out, and largely ineffective. Railway companies made a few attempts to introduce new kinds of engines and carriages to compete with buses and cars, but these were invariably too little; too late [25]. Streetcar companies ran their own motor buses for a time, but were not able to integrate them into their networks effectively enough to avert their collapse just after the Second World War.

To understand why this was the case, it is necessary to go back several decades before cars were even a factor in the Canadian transportation system, to look at where the power of these incumbents came from, and why this power began to deteriorate in the early twentieth century. Railways had a long history of political influence in Canada. Antoine-Aimé Dorion, a former Canadian co-premier, even named the railways as one of the key political movers behind Canadian confederation, recounting at one point that "the Confederation of all the British North American provinces naturally suggested itself as the surest means of bringing with it the construction of the intercolonial railway. Such was the origin of this confederation scheme" [18, p. 14][4]. After Confederation, the federal government generously supported railway construction, offering land grants or direct financing to railway builders [6], [18], [19]. Both federal and provincial governments granted railways exclusive service contracts as a further enticement, which the railways in turn enforced ruthlessly. As the railways amalgamated into

3 Accident insurance was a particularly damaging requirement, because few insurers were willing to insure such a new and untested business model, and when they did, they charged very high premiums.

4 Dorion was one of the most prominent political opponents of Confederation, and so had his own reasons for portraying it as a scheme primarily intended to benefit industrial interests. Undoubtedly Confederation's supporters would present a different narrative. The fact that this idea was plausible enough to be voiced by a prominent politician, however, says a lot about the power of the railways at this time.

larger and larger monopolies competing for territory, disputes over these service contracts became ruthless contests that could spill over from the legal and political realm into direct physical confrontation. Railways would build track designed to physically occupy space, thereby excluding their rivals, which could turn the construction of individual lengths of track into high-stakes confrontations. On one notable occasion, when the province of Manitoba approved a North-South railway through its territory, the Canadian Pacific Railway parked an old engine at the point where the Manitoba railway was supposed to cross its own line, to block the construction. The result was a multi-day standoff in which track was repeatedly torn up and re-built, and workers nearly came to blows. Established railway lines would also counter new lines by building new track of their own, strategically placed to starve the competitor of passengers and freight, and would also aggressively buy each out, or strategically deny service to areas where passengers or freight might transfer onto competing rail or water routes [18], [23].

"... the Confederation of all the British North American provinces naturally suggested itself as the surest means of bringing with it the construction of the intercolonial railway. Such was the origin of this confederation scheme."

Antoine-Aimé Dorion

Streetcar companies played similar games at the urban level, using a combination of legal and political influence, and physical obstruction, to protect their franchises. One common tactic was to build unprofitable lines of track as "moats" around cities, to deny competitors access to territory. Aggressive conflict often erupted over these kinds of area-denial strategies. The battle between two streetcar lines in the Montreal suburb of Mile End included widespread accusations of bribery, reports of kidnapping, manipulation of council minutes, and threats of physical violence. It culminated with the mayor of Mile End tearing up half a mile of the Montreal Street Railway's track, to support the competing Park & Island Railway [28].

Box 3.2 Incumbency

The word 'incumbents' refers to the people and institutions associated with an existing socio-technological system. Because most dominant technological systems do not face competition from technologically-mature alternatives — cars are a particularly good example of this — incumbents tend to enjoy significant commercial, cultural, and political power, and commonly wield that power in defense of the system's continued existence. They are supported in this by the material aspects of the system itself, because large infrastructures and production facilities tend to require a major effort to change. Considered together, these factors mean that incumbents are usually be a major obstacle to socio-technological change.

The theory of incumbency has a long history in transitions studies, and has gone through major iterations. Thomas Hughes first developed the concept of a large technical system: an assemblage of complementary technologies that fulfill a larger function [5]. Hughes examined the early growth of British, American, and German electricity systems, and the title of his book, *Networks of Power,* includes a pun that highlights the centrality of politics and influence in the growth of these systems. The notion of incumbent powers supporting pre-existing technological systems was further elaborated by René Kemp's [6] framework for strategic niche management which describes the role of an incumbent "regime" standing in the way of new technologies. In 2002, Geels [8] made regimes a critical part of the 'multi-level perspective' on socio-technical transitions. According to this framework, which has become dominant in transition theory and in the academic discussions of sustainability transitions, a regime is a complex assemblage of technologies, policies, financial arrangements, user practices, cultures, and financial arrangements which lock in an established technological system and the social institutions connected to it. Attempt to change one of the elements of the regime leads to push-back from all the others. Typically, transitions occur when a regime is destabilized by external "landscape" forces, or by its own internal tensions. This conceptualization of a regime has been the focus of most research on incumbency for the last two decades, [9], [10], [11], [12].

Figure 3.1 A jitney in Vancouver. [22]

Rather than being a way for the streetcars and railways to shut out automobile competition, however, these kinds of tactics actually reduced their ability to fight this competitive threat. Aggressive moves against competitors, including rank political corruption and physical violence, had a lasting impact on the reputation of these incumbents, which had come to be seen as abusive monopolists by the close of the nineteenth century. This had political implications. Railways were frequently the subject of bitter debates, especially in Western Canada, where they had a long history of charging shippers and passengers more than they charged their Eastern counterparts [6]. The federal government made various attempts to mitigate this by encouraging competition in the industry, but this tended to decrease the railways' long-term ability to compete against challengers. When the government gave generous support to new transcontinental railway lines — which they did twice in an effort to increase competition and thus reduce transportation costs in the West — they created an over-built system that could never earn enough revenue to pay for its infrastructure. When they imposed regulations on passenger fares and freight rates, explicitly following the example of earlier regulatory efforts in the United States and the United Kingdom [25]–[28][5], they made railway pricing slow to respond

5 These efforts in other countries are well-documented to have arisen from political hostility against the railways, and so it is likely that the Canadian laws inspired by the American Interstate Commerce Commission, or the British Railway Rates Tribunal, had at least some similar sentiments behind them.

to new competitive threats [18]. This process is well documented in historical work on other countries [27]–[29], and most of the research on Canada suggests that something broadly similar happened here [6], [23].

Streetcars were also frequently the subject of resentment by travellers, politicians, and media figures, who accused them of price gouging and Machiavellian scheming at city hall [30]. Historical research on American cities shows that these resentments contributed to the downfall of some streetcar companies [31]. Because streetcar companies tended to depend on franchise agreements with the local city hall, they couldn't survive very long in an atmosphere of political hostility. In Toronto, popular frustrations at the streetcar companies led to them being bought out by the city at the end of their contract in 1923, to create the early Toronto Transit Commission [21].

The network structure of these incumbents was also uniquely vulnerable to disruption. This was particularly the case with passenger railways, who depended financially not just on a large network of lines and stations to draw in as many passengers as possible, but also on freight railways, whose revenue was critical to maintaining that infrastructure. Chipping away at even a small aspect of this, (such as high-value low-volume freight, which road transportation excelled at [6], [26], [29]) posed a serious threat to the railways. Trucks, buses, and private cars were able to create a death spiral on the railways, forcing them to either close branch lines that had become unprofitable, (thereby reducing the territory they could provide access to), or to cross-subsidize these lines with revenues from more profitable lines, (which in many cases would necessitate price increases that would also drive traffic onto the roads). In Canada, as in many other countries, this unique vulnerability made it even harder for trains to compete with road transportation.

"The network structure of these incumbents was also uniquely vulnerable to disruption. This was particularly the case with passenger railways, who depended financially not just on a large network of lines and stations to draw in as many passengers as possible, but also on freight railways, whose revenue was critical to maintaining that infrastructure."

The effect was subtler with streetcars, which initially adopted motor buses as a supplement to their networks, taking advantage of motor buses' progressive associations to sell tickets for a premium price compared with the normal streetcar fares [30]. But this attempt to control the technology was short-lived. Buses took away the streetcar companies' advantage of owning dedicated infrastructure (rails and wires), so it was easy for new bus companies to undercut them. Streetcar systems in cities across the country began to collapse, as the additional competition meant that they could no longer earn enough money to pay for their infrastructure [12], [30], [32]. By the start of the 1950s, there were almost no streetcar systems left in Canada (Figures 3.2 and 3.3).

The result of this was that both streetcars and railways were facing several compounding liabilities just at the time when they might have had an opportunity to push back against road competition, or co-opt road vehicles into their own networks. This left them unable to act decisively. The result was that by the 1930s, the kind of commercial and political power that had enabled the streetcars to so aggressively shut down jitney networks no longer existed. Today, alternatives to the private gasoline-powered automobile face a car industry every bit as entrenched as the railways and streetcars were in 1900. A similar destabilization of the power of incumbents might be necessary for the next revolution in Canadian transportation.

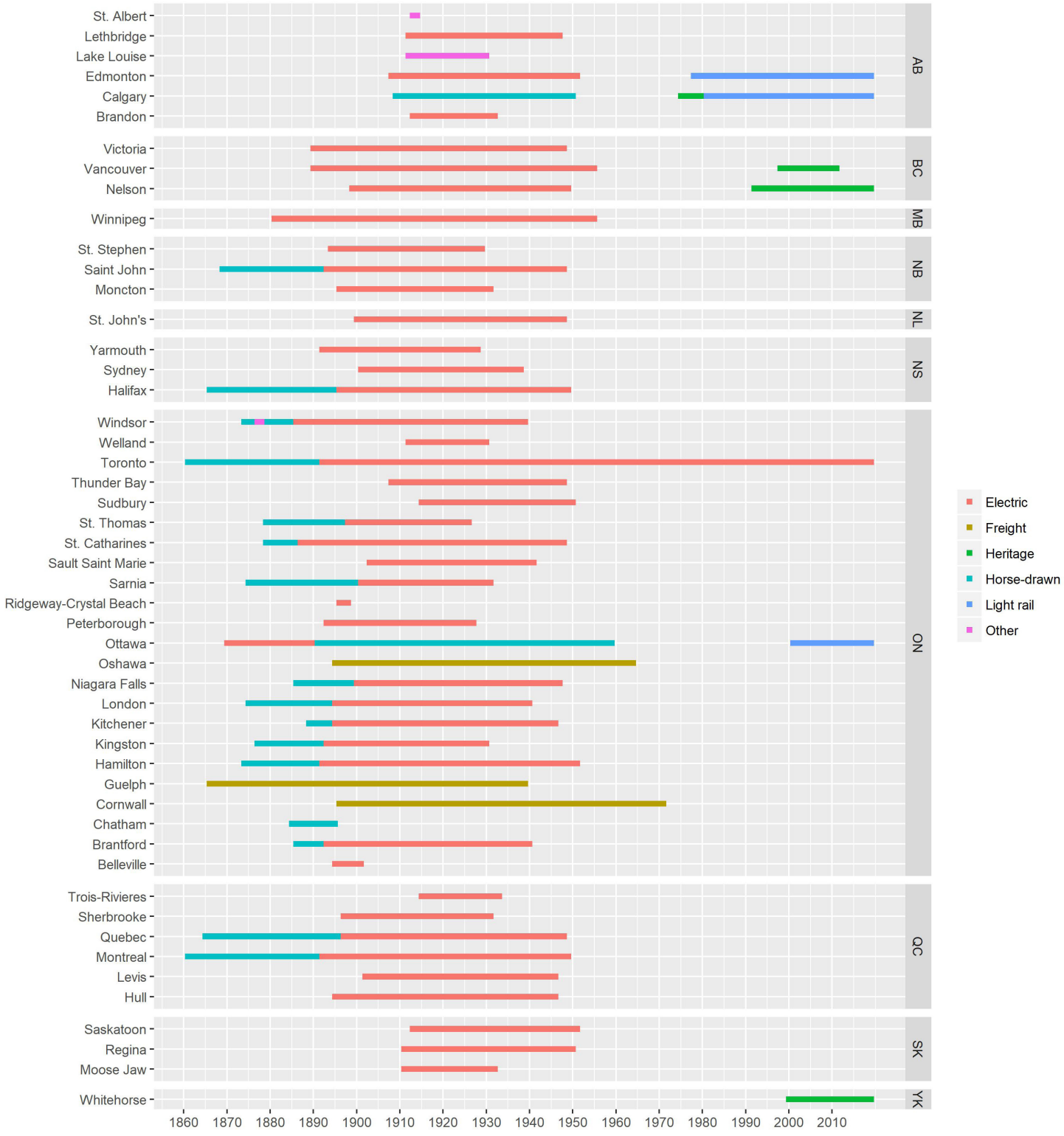

Figure 3.2 Canadian streetcar networks, 1860 to present. Data from Wyatt [33]

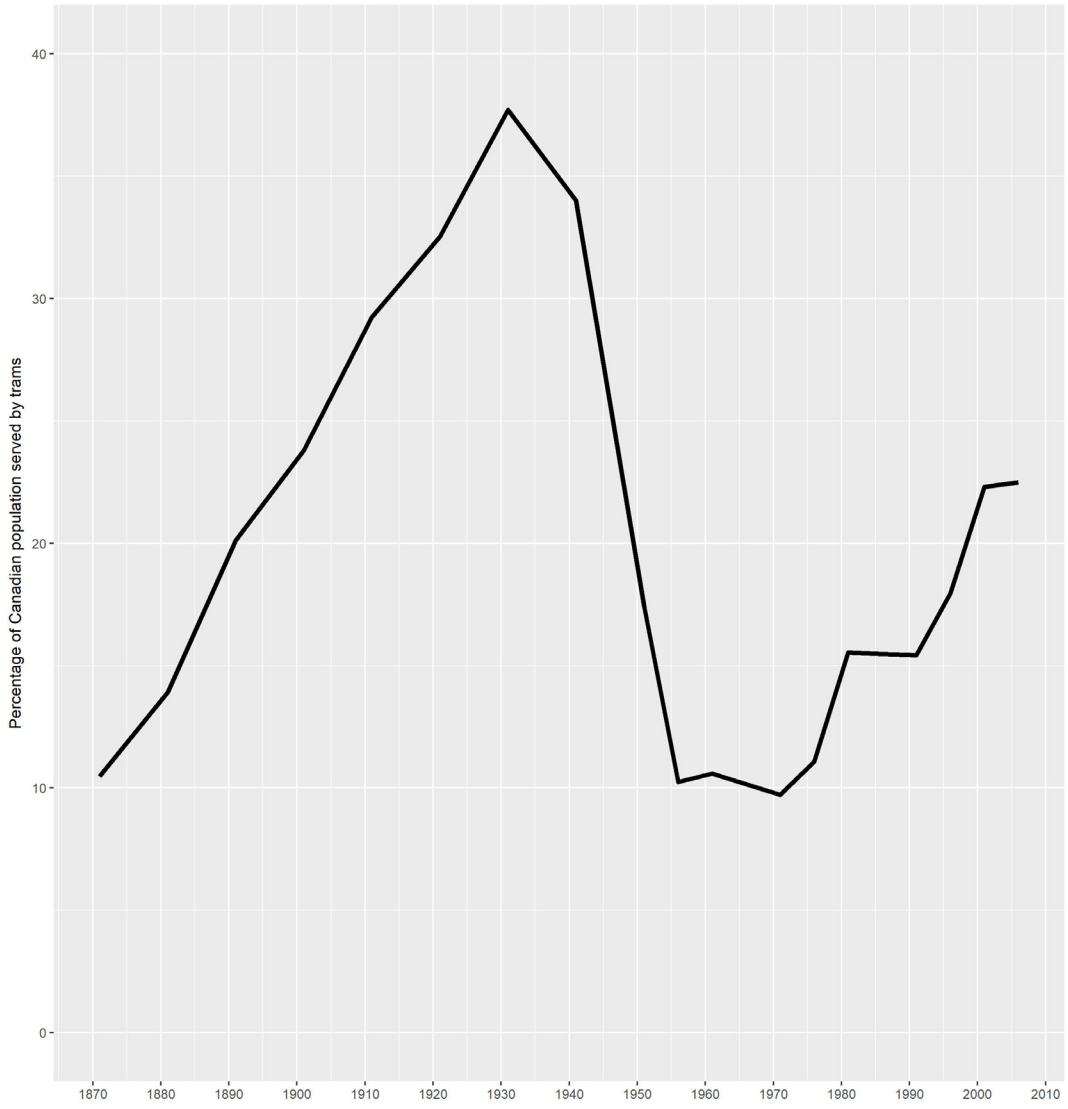

Figure 3.3 The proportion of Canadians living in cities that were served by light rail [33]

3.3. Technological momentum in transitions

The combination of a stable use pattern and limited competition from incumbent transportation systems caused car ownership to rapidly become more common, as more and more Canadians drove further and further every year. The growing number of vehicles on the roads had to be accommodated, through new traffic laws, road infrastructure, and social norms.

"The growing number of vehicles on the roads had to be accommodated, through new traffic laws, road infrastructure, and social norms."

The growth of these critical supporting elements in the Canadian automobile system shows how a new transportation technology can rise from a marginal practice to a massive system whose use is all-but mandatory.

This is easiest to track by looking at the construction of roads, and the impact this had on other forms of transportation infrastructure. While Canada had a large number of roads since at least the time of Confederation in 1867, many of these remained in poor shape at the onset of the twentieth century [6], [9]. Some roads were impassable in the winter. Others were only passable in the winter, by horse-drawn sleighs. Nearly all were intended more as supportive infrastructure to transport people and goods to and from the railroads, rather than as a national transportation network in their own right [9].

The gradual improvement of roads to a state that was useful for motorists pre-dates the automobile. The bicycle craze of the late nineteenth century created a constituency of wealthy young men who were interested in having smooth riding surfaces, and who created the "Good Roads Movement" to agitate for many road improvements. Many of the first roads that cars drove on were thus built initially to facilitate travel by bicycle [9]. As more people started to drive cars, they formed new constituencies that could agitate for further road improvements. The Canadian Automobile Association was lobbying for roads back in the earliest days of the automobile as an upper-class toy [8]. Once cars became cheap and reliable enough to become appealing to farmers, farming organizations got involved, arguing for the expansion and improvement of farm-to-market roads [8].

"In downtown environments, an alliance of car manufacturers, motorist organisations, and other related interests redefined traffic and urban social norms, through measures such as creating the new crime of 'jaywalking' to help get pedestrians out of the way of motorists."

Peter Norton's work on American cities shows that in downtown environments, an alliance of car manufacturers, motorist organizations, and other related interests redefined traffic and urban social norms, through measures such as creating the new crime of "jaywalking" to help get pedestrians out of the way of motorists [34]. As roads and vehicles improved to the point that large industries, such as the bus and trucking industries, were able to profit from them, they too got in on the action, as did the construction firms that profited directly from road building [8], [35]. This process was boosted further by the Great Depression (where road construction was

Box 3.3 Technological Momentum

Technological systems develop momentum as finances, research and development efforts, and managerial priorities focus on a particular type of technology, regardless of what other alternatives might exist. Like the physical phenomenon of momentum, this characteristic of large technical systems increases as the systems get bigger, and their development gets faster. At the early stages in the development of a new technology, this momentum can be slowed or modified by policy, business strategy, or even the actions of wealthy or well-connected individuals. But as a system becomes bigger and more complex, its trajectory becomes harder and harder for any one party to influence.

This phenomenon was documented by Thomas Hughes [20], who has identified several causes. As a technological system matures, the people working on it develop standard methods and approaches to problem-solving, which are then taught to the next generation of engineers, managers, and technologists who will be running the system. This is related to, but separate from, the power of incumbents discussed earlier. While incumbency is characterized by the deliberate exercise of power, technological momentum develops through unconscious assumptions and standardised approaches to running the system that become institutionalised and go unquestioned.

Hughes used a military metaphor: the development of a technological system is like an advancing front line, with engineers, entrepreneurs, and managers "fighting" to solve different aspects of the problem. Particularly persistent problems form "reverse salients" (Figure 3.4), and attract lots of attention. This typically leads to a breakthrough solution at some point, which advances the overall system, but then creates further problems in other areas, which then become reverse salients in the next iteration of the system's development. Hughes uses the example of metering alternating current, which was a major disadvantage it faced compared with direct current until a viable meter was developed in 1888, leading to a rapid expansion of alternating current systems.

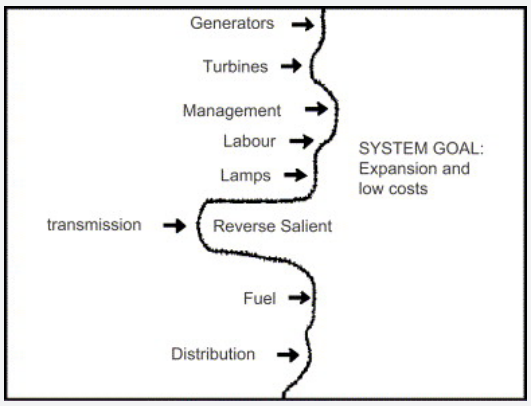

Figure 3.4 A reverse salient. From Hughes [5].

Technological momentum involves the various experts involved in technological development, including inventors, entrepreneurs, managers, and policymakers. What it typically means is that the solution to a problem with the system is to grow and complexify it. This, however, only creates further unsolved problems, which perpetuate the system's growth, and eventually contribute to locking it in as a dominant regime.

a way to get the unemployed back to work), as well as by the growing economic ambitions of many Canadian provinces

This process was boosted by a series of high-profile visioning efforts, which portrayed road expansion as a critical element of a modern, efficient, and progressive society. The most famous attempt to envision the utopian car-oriented society of the future was the Futurama exhibit put on by General Motors at the New York World's Fair in 1939. Its massive, intricate dioramas allowed visitors to "fly" over a vision of the United States in the year 1960 — a country crisscrossed by efficient, clean, fast highways that had made congestion a thing of the past and allowed convenient mobility for everybody. The exhibit was by far the most popular at the exhibition, with another exhibit by Ford, with a similar message, coming in second [15]. Similar efforts could be found around the world. In the United Kingdom, the London Society and architect Geoffrey Jellicoe were instrumental in imagining a motorized England of the future, in which a network of highways played a similar role [36], [37]. And highway construction was made a core element of nation-building in Nazi Germany and Fascist Italy [38], [39]. These projects had an important impact on transportation projects in democratic countries, who were eager to send delegations to see the new roads. In Canada, with the end of the Second World War, both federal and provincial governments embarked on a series of major road-building projects, including Toronto's 401 and Queen Elizabeth Way, and the Calgary-Edmonton Highway. In many cases, these were positioned as province-building exercises, just as the Canadian Pacific Railway had been an exercise in nation-building [8].

By the 1960s, motorists themselves had become a major political constituency, demanding more and better roads to ease traffic congestion [8]. This created a political feedback loop: more motorists, and more money going towards road transportation industries, meant increased political pressure for roads. When these roads were built, there was further growth in the numbers of private motorists and additional revenue for the road transportation industries. The Canadian automobile system also acquired technological momentum by building a network of technical specialists involved with road construction, who tended to see it as the natural and obvious solution to transportation problems. Recent scholarship on efforts to re-design urban environments in Toronto has highlighted the continuing importance of some forms of expert knowledge in locking in the automobile system. Despite municipal planning priorities shifting to the creation of liveable, walkable environments, the design of the roads is still the province of traffic engineers, who see urban streets primarily as thoroughfares for cars [40].

The feedback contributing to increased road-building in Canada was also produced by the physical impact of the infrastructure — as city planners' focus on cars as the dominant means of transportation created urban

environments that were difficult, and often unsafe, to navigate without a car. Large boulevards, parking lots, and a de-emphasizing of pedestrian, cyclist, or public transit infrastructure all contributed to this process. It only accelerated after the Second World War as urban freeways became a major new kind of transportation infrastructure. The impact of this was noticeable to the people who lived through this period, so much so that some Canadians were enthusiastic participants in a series of 1970s "freeway revolts" which saw urban residents pushing back against the construction of major highway projects, such as Toronto's proposed Spadina expressway [41]–[43]. Meanwhile, the collapse of streetcars and intercity railways, as discussed above, made road transportation mandatory for many people, who had lost access to all other forms of transportation.

The effects of technological momentum are double-edged. In the early stages of a transition, they can create an important obstacle to emerging transport technologies, as their advocates struggle against prevailing institutions to secure appropriate infrastructure adaptations. This may require taking advantage of infrastructure and institutions that were originally created for another purpose. Once momentum starts to accumulate, however, system transformation can become unstoppable: its expansion becomes self-justifying, and every new addition to the system creates new users who agitate for it to be expanded even further.

4. Lessons

The previous section explored the rapid transition in Canadian mobility that took place at the start of the last century. This section draws on that analysis to suggest six lessons to be kept in mind as we work toward sustainable mobility transitions in Canada.

Lesson 1: Persistent unsolved problems can open the door to change

The status quo in complex socio-technical systems, such as established transportation systems in Canada, is not just about technologies, but also about companies, policies, user habits, infrastructures, and cultures. Many of the people involved with these things can wield power, which they can use to resist challengers to the established way of doing things. Jitneys in Canadian cities in the 1920s found this out the hard way, when they were ruthlessly crushed by the streetcar industry.

Complex systems, however, tend to generate complex problems, ranging from solvable technical glitches to trenchant political, economic, and environmental issues. Often, as a system becomes more complex and more locked-in to a settled way of doing things, some of these problems get worse rather than better. This was the case with the status quo in Canadian transportation prior to about 1907: as in many other countries, Canadian railways had become unassailable monopolies which had resisted policy-makers' attempts to regulate them or encourage more competition. They also faced the uniquely Canadian problem of having to cover vast and often unpopulated distances, which made it difficult to pay for the infrastructure without charging very high rates to shippers and passengers. Streetcars had similar issues: like railways, they were often run monopolistically, and they could not always access as much of a city as its citizens would like. When these problems could not be solved by innovation or legislation, they created resentment. When motorized road vehicles appeared as a viable challenger to rail-based transportation, that resentment against incumbent transportation systems helped to fuel the growth of a new transportation system based on cars.

Something similar might be going on with the current transportation system based on the private automobile. There is some evidence that the enthusiasm for cars that existed in previous generations is wearing thin [44-45], and there is increasing awareness of persistent problems with cars, such as congestion, parking shortages, traffic collisions, air pollution, and climate change. These frustrations could generate support for sufficiently compelling alternatives, and many groups (from everyday travellers to municipal governments and tech companies) are currently looking for a better way to organize transportation, particularly in cities.

Lesson 2: Established systems have momentum, but challengers can also exploit positive feedback

History shows that technological momentum can influence both sides of a transportation transition. Incumbent systems benefit from years of standardized equipment, procedures, regulations, and business models. Infrastructure was a particularly important part of the story in the Canadian case. Because rail-based transportation had become the default, especially for intercity travel, there was a shortage of good roads that could enable any alternative form of travel. Initially, this was a barrier to the development of motorized road transportation in Canada. But as cars became cheaper, more reliable, and more popular, and as provinces and cities expanded and improved their road networks, it began to create a feedback effect. Better roads meant more cars, trucks, and buses, which in turn meant more road users who could advocate for even more good roads. Eventually, this led to whole new engineering and planning disciplines, new road designs, and a revolution in traffic legislation, as lawmakers tried to better accommodate cars. While this process did not only occur in infrastructure, it was here that it was most visible — as paved strips of roadway increasingly crisscrossing the country.

Any future mobility transition in Canada will have to take advantage of similar dynamics to scale up from small experiments to a nationwide system. This means encouraging self-reinforcing interactions between new vehicles, new infrastructures, new business models, new policies, and new user practices. We have already seen this in practice with some forms of sustainable mobility gaining in popularity today. Electric vehicles, for example, have benefited from a virtuous cycle between consumer interest, technological development, and build-out of charging infrastructure. Growing numbers of bike commuters, meanwhile, have had greater rates of success lobbying for new bicycle infrastructure, which in turn attracts more cyclists onto the road.

Lesson 3: Users matter

It is tempting to imagine innovation as a process that happens mostly in research and development facilities, or on the factory floor. But this study shows that this is only half the story. Innovation happens on the consumption side as well as on the production side. While the producers of the automobile were developing self-starters, all-steel bodies, and assembly lines, its users were finding new uses and defining new practices, and in the process they helped change the automobile from a luxury recreational machine, to a piece of crucial equipment for farmers, and to the basis of an entire transportation system.

Everybody's life involves technological interactions: we use a collection of devices, ranging from houses to refrigerators, from cars to mobile phones,

to keep ourselves alive, healthy, and as happy as we can manage. Bringing new technology into that picture requires innovation in everyday practices that feeds back to the further development of these technologies, as well as to wider infrastructural and policy systems. In the case of the automobile, its domestication by users led to new types of cars, new types of roads, and new kinds of traffic laws.

Today we see countless small-scale experiments around different approaches to more sustainable mobility, that are helping define the patterns of technical and social innovation that offer the most promising options for the future. For a ride-share program to successfully challenge the mass use of private cars, for example, new user practices would have to emerge around summoning a vehicle whenever a passenger wants to travel, rather than relying on one parked in a driveway.

Lesson 4: Visions can galvanize processes of change

Narratives and images of the future played a major role in the construction of a new, road-based transportation system not just in Canada, but all over the world. Ford's vision of mass production — where automobiles were so cheap that the factory workers could afford to buy them — opened up vistas of a world transformed by the automobile. Exhibitions, art, and media coverage from the early twentieth century depicting the motorized future might seem like simple public relations efforts, but it is no coincidence that the highways built in the 1950s bore such a close resemblance to General Motors' 1939 Futurama exhibition at the World's Fair.

This international and transnational dimension was particularly pronounced here. Modern highways were developed in a process that hopped from one country to the next, with the Canadian highways taking inspiration and engineering advice from the American interstates, which were themselves connected to the German Autobahnen and Italian Autostrada. All of these developments were, in turn, influenced by earlier public depictions of what a motorized future might look like. These were often utopian, blurring the line between art, science fiction, and technological forecasting. But they were effective. The media coverage they attracted caught the attention of engineers, politicians, and travellers alike, to obvious effect just a few decades later.

Today, developing inspiring shared visions of improved social mobility, together with the capable and compelling pathways that show how such transformed systems could be built out in practice is a critical step to help accelerate processes of change. Charismatic tech-billionaires like Elon Musk and Jeff Bezos articulate inspiring visions that can alter people's perceptions of the future in a single half-hour speech. But these visions need to be collectively determined - with inputs from a diversity of societal groups,

and analysis of the implications for society as a whole — if they are to articulate a public interest perspective on the future of transportation.

Lesson 5: Early decisions influence subsequent choices

The history of the automobile also shows that early choices can have a disproportional influence on the further development of an emerging technical system. The most obvious example is that cars are powered by gasoline. While gasoline cars had obvious advantages in terms of range and speed, electric cars also had advantages: they were cleaner, more reliable, and easier to start. Because social factors led to more rapid adoption of gasoline cars, however, particularly after the invention of the self-starter, they became the pattern for future car development going forward. And electric cars received little attention until the energy crises of the 1970s.

This was not the only early choice about automobiles that had important impacts going forward. Cars could have been used as communal, flexible, jitney transportation; as railway-owned shuttles to get to-and-from stations; or as predominantly rural vehicles that would have to give way to other road users in cities. The fact that none of these scenarios ever actually materialized, and that other alternative use models for road transportation remain elusive today, is related to choices that were made in the 1920s and 1930s.

This suggests the importance of policymakers, city planners, public interest groups and researchers to engage with emerging mobility alternatives at the earliest stage. By bringing system-level analysis and a public interest lens to bear at an early point it is possible to influence the foundational elements of new mobility systems to ensure they evolve along lines that maximize collective benefits before they become rigid. This is particularly important for autonomous vehicles, which could either be massively beneficial or massively harmful to the climate, depending on the details of how they are used; much of which will be decided early in their commercial development.

Lesson 6: Innovation in one system can open the door to transformative change in other sectors

The automobile was an innovation in one area of transport. But its ultimate impacts on Canadian society have been profound. The basic technology was applied to trucks and busses, and later to dedicated machinery used for farming, logging, excavation and construction. The transformation of public transit and freight movement created further support for the infrastructure that supports cars, by extending the use of road transportation to other people besides just private motorists.

The changes were more dramatic than that, however. Easy, flexible, on-demand mobility led to completely new patterns of living and travel. While "streetcar suburbs" already existed before the automobile, the urban sprawl that followed mass motorization was a change of a different magnitude. And as private cars allowed people to travel long distances without having to worry about the routes or schedules of the railways, railway tourist resorts were replaced by a constellation of motels, national parks, and out-of-the-way tourist attractions. These changes had further knock-on effects in other industries and people's everyday lives. Today, drive-through restaurants selling meals designed to fit in cup holders have become a staple of the restaurant industry, while houses and even ships have been re-designed to accommodate cars.

Looking forward, the transformation of existing mobility systems will draw on digital and communications technologies, have implications for electricity production, consumption and storage, and will be linked to shifting patterns of industrial production. It will involve the transformation of cities and patterns of work and leisure. Indeed, any transportation transition that has sufficient scope to achieve the levels of carbon reduction required to stabilize the global climate is going to have far-reaching knock-on effects, particularly if it involves new path-breaking technologies such as autonomous vehicles. This is a further argument for a careful process of vision development, forecasting, and modelling to determine the actual long-term impacts of the transition now getting underway. Many versions of sustainable mobility in cities (such as that promoted by the recently cancelled Sidewalk Labs project in Toronto) involve complete re-designs of urban environments. This will have far-reaching effects on people's daily lives and will therefore require a careful process of consultation and vision development.

5. Conclusion

Exploring the options for the transition to more sustainable systems of mobility suited to the twenty-first century lies outside the scope of the present paper. It is safe to say, however, that these options will include revitalized forms of public transit, a greater place for active mobility (walking and cycling), and the possibility that electrified, autonomous and shared vehicles may displace the individually owned, self-driven, internal combustion engine automobiles that are the norm today. This is bound to have consequences for the organization of cities and patterns of everyday work and recreation.

In the near future, it is possible that the critique of the multiple failures of existing transportation systems (cost, convenience, safety, pollution, etc) and not just their fossil fuel dependence will drive change (lesson 1). Whichever combination of alternatives ultimately emerges will confront resistance from incumbents, but at some point, momentum will shift from old systems to the new (lesson 2). Options that users actively embrace — that make sense within the framework of their values, needs and aspirations — are those that will succeed (lesson 3). Inspiring visions can cement the reform alliances required to drive change, encouraging investment and mobilizing innovators (lesson 4). Paying attention today to the costs and benefits of alternative pathways can help steer this change in socially beneficial directions and avoid the 'lock-in' of early undesirable configurations (lesson 5). And the transformation of personal mobility can be a catalyst for broader changes to societal systems to improve quality of life and reduce environmental burdens (lesson 6).

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