Carbon Pricing and its Effect on Mobility and Social Exclusion in Canada

by
Darcy Reynard

A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

Urban and Regional Planning
Department of Earth and Atmospheric Sciences
University of Alberta

Abstract

In Canada, federal and provincial governments have implemented carbon pricing to reduce carbon emissions. One effect of a price on carbon is increasing the cost of using private vehicles, which may reduce mobility and increase the risk of social exclusion, especially where car dependence is high. In this thesis, I examine how carbon pricing in Canada has affected mobility and social exclusion. Across three academic articles, I answer two questions. First, how have governments in Canada considered the effect of carbon pricing on mobility and social exclusion? Second, what effect has carbon pricing actually had on mobility and social exclusion in Canada?

Chapter 2 demonstrates a method that uses Natural Language Processing to identify text on mobility and social exclusion from over 400 Canadian government documents on carbon pricing. Topics relating to equity often receive little mention in government documents about carbon pricing, making them hard to find using manual techniques. Latent Dirichlet Allocation is employed to find text about mobility and social exclusion, and determine which documents are most likely to contain them. To find text that represents mobility and social exclusion, word vectors are used to score the Latent Dirichlet Allocation topics. The algorithms accurately find the topics of interest. This technique can be applied to large textual corpora to find specified concepts and topics. The returned documents make up the corpus for the framing analysis conducted in Chapter 3.

In Chapter 3, I analyze how municipal governments in Canada frame the challenges of climate change and examine whether they link these challenges to issues of mobility and social exclusion. Focusing on planning documents from four large, Canadian cities—Calgary, Edmonton, Winnipeg and Vancouver—I identify four main frames: “the Growing City”, “If You Build It, They Will Come”, “Better City for All”, and “the Resilient City”. The Growing City

frame, dominant in Calgary, Edmonton, and Winnipeg, is used to support status quo urban development, with climate mitigation options included for more concerned residents. Conversely, Vancouver uses the Resilient City frame to indicate that climate mitigation and adaption strategies are essential for all citizens. Social exclusion is *not* explicitly addressed in the frames, although it is presented as a reason to support building alternative transportation or more public spaces. Social exclusion receives little consideration as a potential consequence of climate mitigation policies.

In Chapter 4, a zero-inflated negative binomial model is used to determine how the price of carbon in Canada has affected the amount of time residents spend away from home in a social setting. Statistics Canada's General Social Survey – Time Use from 2005, 2010, and 2015 is used to model changes in individual behaviour. According to the model, the price of carbon in Canada has not had a significant effect on the number of minutes an individual spends away from home in a social setting. There are three possible explanations for this finding. First, the price on carbon has been too low to elicit a significant change. Second, individuals have changed car use behaviours so that time spent socializing was maintained. Third, alternative transportation in urban areas was sufficiently well developed that car use could be reduced without impacting social exclusion.

In the three articles, I show that: 1) there is a disconnect between the three levels of government in Canada with respect to carbon pricing policy. Federal and provincial governments enact carbon pricing policy but the provision of everyday services is left to municipal governments. 2) Carbon pricing had little effect on mobility or social exclusion in Canada up to 2015. To address these points, governments in Canada need to work together in providing alternative mobility options to residents or the ability to access more of their needs with less mobility. For instance,

higher levels of government must not only fund new transit infrastructure, but also provide long-term operating funding. All levels of government working together is critical because the price of carbon in Canada must continue to increase to help meet international obligations and mitigate the effects of climate change. An increasing price on carbon means individuals will have to make more difficult lifestyle changes. These changes mean individuals will require more support in order to avoid unintended, negative consequences, like social exclusion.

Preface

This thesis is an original work by Darcy Reynard under the supervision of Dr. Damian Collins and Dr. Manish Shirgaokar. This thesis is comprised of three papers:

1. How to Find Specific Topics in a Large Policy Corpus Using Machine Learning Techniques (Under review at Social Science Computer Review)
2. Growth Over Resilience: How Canadian Municipalities Frame the Challenge of Reducing Carbon Emissions
   (In publication at Local Environment)
3. The Effect of Carbon Pricing in Canada on Time Spent on Social Activities Away from Home (Reviewed by the TRB for the 2021 Annual Meeting)

Darcy Reynard is responsible for all work. Dr. Collins and Dr. Shirgaokar provided guidance and assistance with the theoretical background, research methods, and commenting on manuscripts.

Acknowledgements

It would not have been possible for me to complete this thesis without the support of my supervisors and my family.

My supervisors, Damian and Manish, provided excellent academic mentorship throughout my four and a half years. They provided the appropriate push when my work lagged. They also stood behind me and provided guidance whenever I ran into trouble. Around the department, they are considered the best reviewers of manuscripts due to their promptness and the quality of their critique. I was fortunate to have their supervision for this thesis and I enjoyed collaborating with them on other projects as well.

My mom, Elaine, was always interested to know what I was doing at university. She was also willing to provide financial support so that I could achieve my goal of receiving a PhD. Unfortunately, my dad, Herman, died a few years before I started my PhD but it is safe to assume he would have been proud of my accomplishment.

I would like to thank my girls, Julie and Shannon. The flexible schedule of a grad student was sometimes a benefit because I could be home with them on sick days, volunteer at school, or take them to appointments. Also, my girls could come with me to campus on days they did not have school. We would have a cookie break and fast food lunch on the same day! Other times, my schedule would not allow me to go with them to China during their Spring Break or it meant Daddy had to take his laptop on camping trips. Their support and their accepting the quirks of my grad school life helped me succeed in the past four and a half years.

如果不是我妻子的长久默默支持，我是无法这个博士学位的。无法用语言来表达她对我有多重要，只想告诉她不仅仅是读博这些几年，而是我们这十六年婚姻的每一天。

Table of Contents

List of Tables

List of Figures

List of Acronyms and Abbreviations

General Social Survey (GSS)

Greenhouse Gas (GHG)

Intergovernmental Panel on Climate Change (IPCC)

Latent Dirichlet Allocation (LDA)

Natural Language Processing (NLP)

Natural Language Toolkit (NLTK)

Public Use Microdata File (PUMF)

Survey of Household Spending (SHS)

Examining Committee

Damian Collins, Department of Earth and Atmospheric Sciences, University of Alberta

Manish Shirgaokar, Department of Urban and Regional Planning, College of Architecture and Planning, University of Colorado Denver

Robert Summers, Department of Earth and Atmospheric Sciences, University of Alberta

Amy Kim, Department of Civil and Environmental Engineering, University of Alberta

Feng Qiu, Department of Resource Economics and Environmental Sociology, University of Alberta

Antontio Páez, School of Earth, Environment and Society, McMaster University

1 The Effect of Carbon Pricing on Mobility and Social Exclusion in Canada

The Earth is currently in an epoch called the Anthropocene where human activity is overwhelming natural climate cycles (Steffen, 2006). If action is not taken, extreme weather and climate events will occur more frequently and exact a huge cost, in both lives and money (IPCC, 2012). Greenhouse gases (GHG), like carbon dioxide and methane, are responsible for anthropogenic climate change and, therefore, their emission into the atmosphere must be limited. International agreements, like the Paris Agreement (United Nations, 2015), have been created in order to reduce the emission of GHGs. Governments have many tools at their disposal to either penalize those who emit GHGs or offer alternatives to those who wish to reduce their GHG emissions. For example, if municipal governments increase urban density and public transit, private vehicle usage tends to decrease (Ewing et al., 2007; Hong et al., 2014; McIntosh et al., 2014). The most economically efficient mechanism to reduce GHG emissions is to put a price on them (Nordhaus, 2014). These policies are referred to as carbon pricing.

Carbon pricing can be difficult to understand as the individual paying to emit GHGs is not receiving a physical item or a service in return for the money spent. The individual is paying now to offset future damages their emitted GHGs will cause. It is also not always clear where the price on carbon is applied. Canada uses an output-based pricing system so the facility where a good is produced is charged for the carbon content of the good (Environment and Climate Change Canada, 2020). The additional cost to produce the good is then passed on to the consumer. In his book, Nordhaus (2014) demonstrates a set of econometric models he used to calculate the price on carbon required now to offset future economic damage under various scenarios. A price on carbon *is* required now to offset future damage. A low price now will incentivize making the easier changes to reduce emissions; the so-called low-hanging fruit. The price must increase over time as the required changes become more difficult, though still necessary, to mitigate climate change. Paying now for future damage is a price signal for individuals and can incentivize them to emit less GHG.

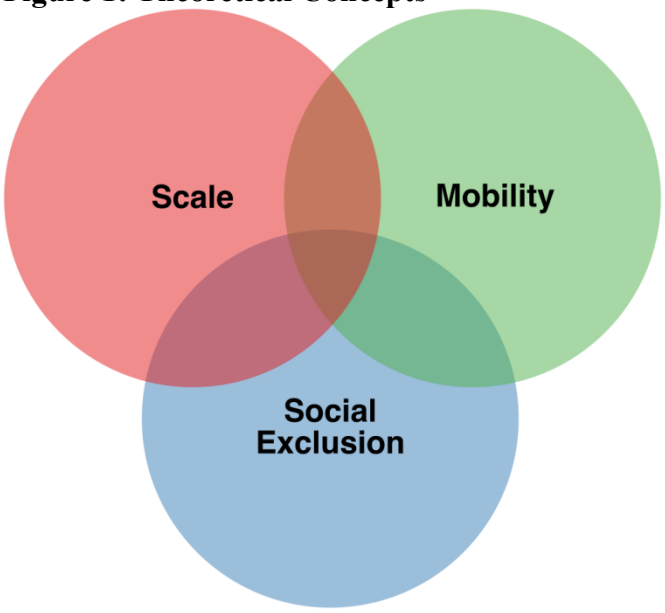
Private vehicles are a major source of GHG emissions. In Canada, 20% of GHG emissions come from cars and light trucks (Government of Canada, 2017). Increasing the cost of fuel with carbon pricing can reduce driving, increase transit use, and increase demand for denser housing options (Larson et al., 2012). However, increasing the cost of fuel when alternative transportation options are limited or do not exist either increases the cost to maintain existing mobility or lowers overall mobility. Decreased disposable income or low levels of mobility can prevent individuals from participating in society as much as they would like (Delbosc and Currie, 2011; Lucas et al., 2016b; Stanley et al., 2011). In this thesis, I will analyze how governments in Canada have considered the effect of carbon pricing on mobility and social exclusion. I will also analyze what effect carbon pricing has actually had on mobility and social exclusion in Canada.

The following sections in this introduction give an overview of the theoretical concepts upon which the research is based, the epistemology of the research, and the articles that make up the research in this thesis. Chapters two, three, and four are the three research articles, which have all been submitted and peer-reviewed for publication in academic journals or as conference presentations. The three articles are referred to in this thesis as the NLP paper, the framing paper, and the modelling paper. The conclusion is in chapter five. It contains a summary of how the findings of the three articles tie together and the overall contribution to academic knowledge and public policy made within this thesis.

1.1 Conceptual Framework Guiding this Research

Three theoretical concepts were chosen as the basis for this thesis: scale, mobility, and social exclusion. The research is conducted at the intersection of these ideas (see Figure 1).

Figure 1: Theoretical Concepts



1.1.1 Scale

The concept of scale is much more complex than simply the size of a map, the definition used by cartographers. In *The International Encyclopedia of Human Geography*, scale is presented as a concept made up of three interrelated aspects: size, level, and relation (Sayre and Di Vittorio, 2009). Size typically means geographical area or physical volume. Level often relates to hierarchies within an organization. National, provincial, and municipal governments are an example of a hierarchical scale. Relation is the comparison between something and for what it is intended. Sayre and Di Vittorio (2009) give an example of relation as weighing a truckload of waste at a landfill in grams instead of kilograms or tonnes. The truckload of waste would be reported in the millions of grams instead of thousands of kilograms or as a few tonnes. A few tonnes is easier for most people to comprehend than millions of grams. For geographers, the use of scale as a concept started in the 1970s as a way of debating how capital was altering space (Moore, 2008). Before that, scale was treated as the static area at which different processes occurred (Moore, 2008). Harvey (1968) treated scale as static though he proposed that scale was socially constructed by tension between individuals and groups and should therefore be a dynamic concept. Scale should be considered dynamic as individuals and organizations define the scale at which they operate but their scale continually changes due to conflict and power struggles (Miller, 1994; MacLeod and Goodwin, 1999; Marston, 2000; Brenner, 2001).

In 2005, Marston, Jones, and Woodward sparked "the debate that never seems to end" (Barnes, 2008: 655) when they published their article, *Human Geography Without Scale*. They argued that there had been little agreement in the debate over scale in human geography in the preceding 20 years. Marston et al. (2005) described many differences in opinion over vertical scale, and in particular, the nested hierarchies of governments. They gave three options for how scale should be thought about. First, hierarchical scale can be accepted but needs additional concepts to

account for the complex interactions of the various vertical levels of scale. Second, a hybrid model can be used to merge the horizontal and vertical concepts of scale. Third, and the option Marston et al. prefer, hierarchical scale should be abandoned. Their main argument for this position is that scholars are confusing horizontal and vertical scale. A horizontal scale looks at the size of things: a household, a city, a province, a country, or the entire world. At the same time, vertical scale is a nested set of hierarchies. For instance, families govern their own households, a municipal government represents a city, a provincial government represents a province, a national government represents a country, and many national governments come together to form organizations and treaties at a global scale, like the United Nations and the Paris Agreement. In this example, it may appear that horizontal and vertical scales are the same since a municipal government represents both a smaller horizontal area and a lower vertical scale position than a provincial government. Miller (1994) and Hoefle (2006) demonstrate that there are important differences between horizontal and vertical scale. They give examples of social movements and non-governmental organizations which attempt to have an influence at one horizontal scale but must interact with governments at various vertical scales.

Marston et al. also disagree with examining scale as fixed by political boundaries. They claim that accepting these fixed scales limits research and does not treat scale as an outcome of socio-spatial processes. Marston et al. (2005) give extensive evidence from Smith (1984, 1992), Swyngedouw (1997), and Brenner (1998, 2001) to argue that scale is a process and boundaries are forever changing in response to the flow of capital and political struggle. Yet Marston et al. (2005) argue that hierarchical scale should be abandoned simply because most researchers treat scale as fixed. Many of the responses to Marston et al. presented below also refute hierarchical scale as fixed. Rebuttals of Marston et al. (2005) came from Collinge (2006), Hoefle, (2006), Jonas (2006), Escobar (2007), and Leitner and Miller (2007) (Barnes, 2008) with Marston, Jones, and Woodward publishing at least three further articles together to answer their critics (Jones et al., 2007; Woodward et al., 2008, 2012). These three articles range from responding to specific critiques to further explaining what they meant by scale as a "flat ontology", their replacement for horizontal and vertical scale. Examining the critiques of Marston et al. (2005) will also help touch on some aspects of scale not mentioned previously.

Collinge's (2006) critique is based on his assertion that Marston et al. have misinterpreted the writings of Neil Smith, which Collinge argues is easy to do. Smith, according to Collinge, mixes spatial and social concepts and terms related to scale. Collinge also suggests there is a fourth alternative to the three options Marston et al. proposed: to consider scale as part of actor-network theory. The argument is that space is thought of as the area over which networks are formed and interact. In addition, Collinge claims hierarchical scales are inferior to networks since, even though jurisdictional or geographical boundaries of governments are fixed, the network connections within and between governments can vary over time. However, as I will briefly discuss later, Leitner and Miller (2007) argue that Marston et al. are not treating vertical scale properly and that the concept does indeed allow for changing power structures of governments, like Collinge's actor-network theory.

Hoefle (2006) directly critiques Marston et al.'s understanding of philosophy. Marston et al. had argued to replace scale with a concept of site with a flat ontology. Hoefle says ontology and epistemology are intertwined and cannot be separated. Hoefle suggests that Anglo-American intellectuals may not appreciate the epistemological value of scale, as their training tends to be empirical, in contrast to the more phenomenological training that French and German

intellectuals tend to have. Hoefle also sees the value of hierarchical scale, like those of different levels of government. He uses an example of a grassroots movement in the Amazon. This movement needed to understand the power structure of the various levels of government as it went about trying to effect change. At the same time, there were non-governmental organizations that needed to understand the various levels of government as they attempted to help communities. Understanding hierarchical scale was very important in this example and the grassroots and non-governmental organizations influenced the roles of the various hierarchies, making the power of the hierarchies dynamic. Finally, Hoefle argues that eliminating scale would effectively eliminate geography. The main thing that separates geography from the other social sciences is its application of spatialization. Eliminating scale would not differentiate geography from history or anthropology so geography, for all intents and purposes, would cease to exist, according to Hoefle.

Escobar's (2007) commentary seems to accept the flat ontology proposed by Marston et al., while adding assemblage theory. Escobar describes assemblages as wholes which are a sum of their parts. These assemblages can represent anything: interpersonal networks, markets, cities, or nations, for example. As the commentary goes on to explain assemblages, they appear analogous to hierarchical scale, although Escobar maintains they are more complex.

In one aspect, the critique by Leitner and Miller (2007) is the most interesting, as Marston et al. built their argument partly based on articles by Leitner (2004) and Miller (2000). Leitner and Miller's first problem with the Marston et al. article is its limited definition of vertical scale. Leitner and Miller argue that vertical scale can be top-down or bottom-up, or both, while Marston et al. only apply vertical scale to top-down systems. Leitner and Miller write that hierarchical scale is a particular form of top-down power relations. They go on to write that Marston et al. treat global scale as fixed and only local scale as mutable. According to Leitner and Miller, no scales are fixed and are constantly being altered due to the power struggles of different groups. One other important critique from Leitner and Miller is that Marston et al. miss the relationship between the production of space and the production of power - a central concept in Lefebvre's writing, which Marston et al. only mention dismissively once. Marston et al. analyze scale as size or level, but they do not touch on power, which Leitner and Miller argue is key.

1.1.2 Mobilities

Mobilities research is generally regarded to have been formalized by Hannam, Sheller, and Urry in 2006 when they wrote two editorials (Hannam et al., 2006; Sheller and Urry, 2006) and started the journal, *Mobilities* (Hannam et al., 2006; Faulconbridge and Hui, 2016). Up until that point, Sheller and Urry argue that "[s]ocial science has largely ignored or trivialized the importance of the systematic movements of people for work and family life, for leisure and pleasure, and for politics and protest" (2006, 208). Specifically, there was still a need for social sciences to examine how various technologies and objects help people move (Sheller and Urry, 2006). In the social sciences, particularly sociology according to Sheller and Urry, people were considered to either be sedentary or nomadic (Hannam et al., 2006; Sheller and Urry, 2006; Cresswell, 2010). The mobilities turn challenged this sedentary or nomadic concept in social sciences by adding new issues to the study of mobility and making research more interdisciplinary (Hannam et al., 2006).

Mobilities also came about as social scientists felt the work being done by transportation researchers was insufficient, as it tended to assume that demand for mobility was a given (Sheller and Urry, 2006). The 'mobilities turn' bridged the separation between social sciences and transportation research (Sheller and Urry, 2006). Social scientists also needed more than just how people moved: they wanted to know why people moved and what they felt while moving. Cresswell (2010) found that, previously, in transportation studies, experiences while travelling were not considered and time spent travelling was thought of as wasted time. Transportation studies do calculate a value of time (e.g., Koppelman and Bhat, 2006) but mobilities extends this concept. For social scientists, mobility is more than just moving, it is also the qualities and feelings created by being mobile (Cass and Faulconbridge, 2017). Mobility is made meaningful by the processes and experiences undertaken in order to be mobile (Cass and Faulconbridge, 2017). In transportation research, subjective well-being is still a minor component in understanding travel behaviour (Mokhtarian, 2019). For example, Zhu et al. (2017) found that, in China, longer commute times negatively affect subjective well-being as does walking or biking to work. Dissatisfaction with a longer commute is supported by research done in San Francisco by Ory and Mokhtarian (2005). Olsson et al., (2013) found that people who commute by walking or biking were happier, possibly due to these modes providing desired physical exercise or that commutes using these modes are generally shorter in Sweden than commutes using driving or transit. Mobility research has also found that using a private vehicle may have little impact on subjective well-being (Bergstad et al., 2010). Although, Paulssen et al. (2014) showed that individuals preferred convenience and comfort when choosing their mode of transportation, which private vehicles offer more than other modes. Respondents in their survey put a lot of emphasis on owning the mode of transportation. Studies on mobility should focus not just on external forces that make people move but also on the internal forces, like the desire to leave home for social activities (Mokhtarian et al., 2015).

Mobilities appears to contain a dichotomy that in order for something to be mobile, it needs to be compared to something that is fixed. As such, immobile things (also referred to as moorings), like borders, place, and territory, are important to the study of mobility (Cresswell, 2010). In addition, Adey (2006) stated that something that is mobile can be considered to be fixed if everything around it is moving in the same way. In his paper, he used the example of passengers in an airport moving as a collective group between a common origin and destination (Adey, 2006). They were all walking but, with respect to each other, they were in a fixed position.

This mobile/fixed dichotomy seems to have caused some confusion in the academic literature (Merriman, 2016). Some scholars argue that there is immobile infrastructure which support mobilities (Hannam et al., 2006; Sheller and Urry, 2006). Contrary to this, Adey (2006) claims that inanimate objects, such as airports, roads, or stores are mobile as they can be changed and they can facilitate mobility. Adey (2006) furthers this argument with his claim that inanimate objects can affect change, like a city will change due to goods, traffic, and tourists brought in through an airport. He is saying an immobile object is mobile due to the change it creates around it, at a scale greater than itself. Merriman (2016) seems to agree with Adey but argues that classifying things as either mobile or immobile overlooks less obvious characteristics of mobility. Humans tend to classify mobility at the scale they at which they most often consider objects. Yet, these objects may have a different mobility at less perceptible scales. Merriman calls this 'molecular mobilities' (Merriman, 2012). Merriman's 'molecular mobilities' concept is supported by Büscher et al. (2016) who state that mobilities and immobilities can vary at

different scales. Taken to the extreme, it has been argued that there is never any immobility, just differences in relative mobility (Adey, 2006).

In this thesis, a narrower definition of mobility is required. Mobilities started as a broad idea and has only expanded (Büscher et al., 2016), leaving it vulnerable to the criticism it is too broad to be functional (Sheller and Urry, 2006). Therefore, it is important to define limits. Mobilities can be seen as both horizontal and vertical. Horizontal mobilities are considered movement through space or across the land and vertical mobilities are generally considered as social mobility (Sheller and Urry, 2006). Kellerman (2011) defines four types of spatial movement: terrestrial, marine, aerial, and virtual. Of those four, I will only consider terrestrial mobility. One particular focus will be a smaller part of terrestrial mobility: automobility.

The concept of automobility refers to both mobility with the private automobile, and an individual being able to produce their own mobility (Urry, 2004). Since the private automobile produces more carbon per person per kilometre travelled than other forms of urban mobility (U.S. Department of Energy, 2016), its use and meanings are highly likely to be affected by carbon pricing. Mobility through the private automobile has been locked-in over the last century through the design of cities, the creation of infrastructure to support driving, and the culture of private vehicle ownership and use (Forstorp, 2006; Hagman, 2010; Miller and Ponto, 2016; Shirgaokar, 2016). The culture of the private vehicle includes the feelings people experience while using private vehicles and advertising by car manufacturers to strengthen those feelings (Lucas et al., 2011). Promotion of this culture has helped automobility become dominant in Western countries like Canada (Hagman, 2010; Goetzke and Rave, 2015; Kent, 2015). A situation has been created where it is expected that individuals will be dependent upon private vehicles and other forms of mobility have received little attention or infrastructure spending. As such, a tipping point is necessary to change behaviours away from the private vehicle (Urry, 2004) and reduce the amount of carbon per person put into the atmosphere. Breaking the dominance of the private vehicle will require not just technical and economic changes but also political, policy, and social changes (Urry 2004). Carbon pricing is an economic change that challenges the culture of the private vehicle. This challenge to the status quo, in part, is what makes carbon pricing so controversial.

There are new forms of automobility on the horizon as cars are being deprivatized through car-sharing and car-hire schemes (Urry, 2004). The ride hailing service Uber essentially allows anyone to use their private vehicle as a taxi. It is claimed that, through ‘sharing’ one’s own private vehicle and by using technology, Uber has made hailing a ride more efficient than traditional taxis (Dudley et al., 2017). An increase in the efficiency of hailing a ride, as well as car sharing, may be some of the changes necessary to weaken the dominance of the private automobile as people who use multiple modes for their mobility, such as public transit, cycling, or walking, may be less likely to purchase a private vehicle if hailing a ride is readily available. Krueger et al. (2016) found this preference to share rides amongst people who used multiple mobility modes in a study on autonomous vehicles, another new form of mobility with the potential to disrupt the dominance of the private vehicle. But, Krueger et al. (2016) and Haboucha et al. (2017) had similar findings that shared autonomous vehicles may increase the dominance of the private vehicle by increasing its convenience and result in less use of public transit. Chen et al. (2017) model a pessimistic case where individual vehicle fuel efficiency gains are more than offset by greater use of private vehicles due to automation, leading to an overall increase in carbon production. Automation is not the only area where technological gains in

efficiency are not resulting in an equal decrease in carbon emissions. Frondel and Vance (2017) found the fuel efficiency elasticity for current private vehicles to be 0.67, which means a 10 per cent increase in fuel efficiency results in a 6.7 per cent increase in fuel use for driving. These results suggest many households have a budget for private vehicle use, whether explicitly stated or not, and will drive a private vehicle to meet that budget, up to their maximum needed mobility. This means that governments are unlikely to reach greenhouse gas emission reduction targets through technological innovations like increased fuel efficiency alone.

Lastly, I consider the difference between "mobilities" and "mobility." Kellerman (2011) found that Urry and Adey, two of the main researchers in the field, seemed to be at odds over using the singular or plural term. They even published books where Urry (2007) used the title *Mobilities* while Adey (2017) used *Mobility*. It seems Urry prefers mobilities to cover the study of mobility in social sciences: "I use the term mobilities to refer to the broader project of establishing a movement-driven social science" (Urry, 2007: 18). Adey, on the other hand, states that looking at mobility always involves many forms of mobility. Therefore, the plural form of the word is unnecessary since mobility assumes multiple forms of movement. However, Kellerman goes on to suggest that Urry and Adey may only be referring to spatial, that is horizontal, mobility. If vertical mobility is examined along with horizontal mobility, Kellerman suggests mobilities may be the correct term. For my research, I will consistently use mobility to refer to how people move around the city but I will use the term mobilities to refer to the area of research centred on movement.

1.1.3 Social Exclusion

Social exclusion is a process in which various factors prevent individuals or groups from participating in the normal activities in which other people routinely engage (Kenyon et al., 2002; Rajé, 2003; Preston and Rajé, 2007). Some scholars state that social exclusion has been researched in sociology for a long time but under different names such as marginalization, segregation, deprivation, and inequality (Daly and Silver, 2008). Others attribute the origin of the term to Lenoir (1974) and Lefebvre (1974), who argued that capitalism required some individuals to be excluded from society (Preston and Rajé, 2007; Daly and Silver; 2008). Levitas (1996) and Buck (2001) describe the evolution of the term slightly differently. They say that, in the 1970s and 1980s, there was a shift in language and the static concept of deprivation became the concept of exclusion.

Interest in social exclusion increased in the 2000s due to both the UK Labour government's efforts to reduce it, and concerns over how neoliberal urban and transportation policies would increase it (Schwanen et al., 2015). This increase in interest was brought about by the 2002-2003 Social Exclusion Unit (SEU) study of transportation and social exclusion (Social Exclusion Unit, 2003; Lucas, 2012). In the early 2000s, there was also a shift to focus more on social inclusion, a more positive term and the opposite of social exclusion (Preston and Rajé, 2007). As seen with the UK report, social exclusion has been one of the main considerations in social policy change in Europe (Daly and Silver, 2008). This means that policy makers should take into account the abilities, skills, resources, and capacities of people when they create policy (Lucas, 2012). Despite the focus, reducing social exclusion has not been easy. One problem is that reducing social exclusion can run contrary to a government's environmental goals (Kenyon et al., 2002). In a country where most citizens rely on private vehicles, which emit more carbon than other forms of mobility, one way of reducing carbon emissions is by reducing use of private vehicles. Reducing the use of private vehicles, without supplying alternate forms of mobility, reduces a

resident's ability to access jobs, education, healthcare, or travel to social gatherings, which is the very definition of increased social exclusion. I will return to the connection between social exclusion and transportation in section 1.1.4.

Social exclusion is often seen as dichotomous; an individual or group is either excluded or not (Levitas, 1996; Schwanen et al., 2015). However, social exclusion should not be thought of as binary, but rather as a dynamic process with a continuum of effects brought about by a wide range of influences (Kenyon, 2003; Schwanen et al., 2015). The boundary between being considered excluded or not is unclear and varies between cites or countries, because social exclusion is, by definition, relative to local norms and levels of development. Yet another problem with social exclusion is that it can be considered derogatory in that it can become conflated with stereotypes of low socioeconomic status (Schwanen et al., 2015). Due to this derogatory nature, it becomes thought of in a spatial context; a localized problem in a large area of normality (Schwanen et al., 2015). Thinking of social exclusion in this way can miss the wider causes of the exclusion and result in communities being blamed for their situation (Cameron, 2006; Schwanen et al., 2015). Social sciences have been complicit in this blaming by defining social exclusion as a local, community, or neighbourhood problem while, at the same time, not putting such limits on the positive concept of social inclusion (Cameron, 2005, 2006). This allows risk and responsibility to be thrust upon the excluded (Cameron, 2006) and hides that there are larger, societal causes of social exclusion which an individual may be powerless to change. For example, the social safety net has been critical to address social exclusion. The social safety net helps keep individuals out of poverty which may help them engage more in society. Hence, removing the social safety net means exacerbating social exclusion and consequent issues being experienced by disadvantaged groups. Social exclusion affects individuals and groups experiencing other forms of exclusion the most (Kenyon et al., 2002). For example, low educational attainment can exclude an individual from higher paying jobs. Lower income can then limit the number of social outings such an individual can afford relative to others in their vicinity.

Despite that example, social exclusion is not synonymous with poverty although many researchers claim poverty causes social exclusion (Levitas, 1996). An individual can still experience social exclusion if they are not poor but live in an area of high crime, they lack skills, are not able to control their own life, or lack mobility (Kenyon, 2003). Being extremely mobile can also cause social exclusion (Kenyon, 2003). For example, an individual who is constantly away from home because of work may feel a detachment from their community due to their ever-changing location. Despite the other possible causes, much of the focus on social exclusion only looks at poverty. Employment or unemployment are often examined as causes of social exclusion when there should be a broader focus (Levitas, 1996; Schwanen et al., 2015). Social exclusion research should not just look at the experience of disadvantaged people but also the social and economic outcomes of being socially excluded (Lucas, 2012). Policies that reduce poverty will not necessarily reduce inequality or disadvantage whereas policies to reduce social exclusion are more likely to reduce inequality or disadvantage (Kenyon, 2003). Another problem with the focus on poverty is that social exclusion has become synonymous with poverty. Equating social exclusion with poverty tends to blame individuals or groups for falling behind the rising wealth of society (Levitas, 1996).

Social exclusion is not only about income; as hinted at above, transportation can also play a major role (Kenyon et al., 2002; Kenyon, 2003; Preston and Rajé, 2007; Lucas, 2012). A lack of

access to social opportunities for individuals or groups within a wider population that does have proper access to opportunities can be a major cause of social exclusion (Kenyon et al., 2002; Preston and Rajé, 2007). This lack of access does not just include the usual destinations in transportation research: work, shopping, and leisure activities. Social exclusion is also determined by lack of access to social activities like visiting family and friends (Kenyon, 2003; Rajé 2003; Preston and Rajé, 2007). One of the most important contributions of the SEU report was how it helped identify the connection between transportation and social policy issues (Lucas, 2012). Having social exclusion and transportation in such a large government report helped bring the two issues together for policy debates.

1.1.4 Intersection of Concepts

The theory for the articles in this thesis is situated at the intersection of scale, mobilities, and social exclusion (see Figure 1). Scale and mobilities are related by the movement of power and boundaries (Hannam et al., 2006). Miller and Ponto (2016) show that scale and mobility depend upon one another, as the movement of power can define the boundaries of scales of influence, and the uneven scale of power and resources can influence individual and group mobility. Some examples include countries imposing visa requirements on tourists from specific countries or workers being attracted from places with low employment to those with high employment. Also, mobility can vary at different scales from walking at the local scale to international flights at a global scale. These examples also show the concept of relational scale as there would be a mismatch in trying to use walking, which is probably best used at a neighbourhood scale, for travelling around the world.

I have already mentioned that scale and social exclusion are related in that social exclusion tends to be considered a localized problem (Cameron 2005; Schwanen et al., 2015). However, social exclusion is also multi-scalar: it can affect individuals, households, and neighbourhoods (Cameron, 2006; Schwanen et al., 2015); and can be caused, in part, by local, national, and global policies (Levitas, 1996; Kenyon, 2003; Cameron, 2006; Lucas, 2012). Researchers studying social exclusion analyze personal factors (age, sex, race), local area factors (public transportation, urban form), and national and global factors (labour markets, legislation, or migration) (Levitas, 1996; Kenyon, 2003; Cameron, 2006; Lucas, 2012). This multi-scalar aspect can make it difficult to address social exclusion through policy changes since social exclusion can result from factors at multiple scales.

There is also an intersection between mobility and social exclusion. Government policy directed at reducing exclusion typically assumes high levels of mobility (Kenyon, 2003). Mobility, especially car mobility, is expected in today's society—to the extent it has become accepted that individuals without the high mobility achieved through owning a private vehicle may be excluded from society (Kenyon, 2003). Accepting that non-drivers can be excluded from society means that people who are unable or unwilling to drive are treated as inferior to those who drive. The mobility problems experienced by the socially excluded reflect the values, processes, and actions of government transportation agencies (Lucas, 2012), and these agencies should not be accepting, even unintentionally, of certain segments of the population having low mobility.

1.1.5 Application of Concepts

Scale is an important concept to consider when discussing carbon pricing in Canada. The conflict in Canada over carbon pricing is hierarchical. There have been disagreements and legal challenges in Canada over whether or not carbon pricing is an effective tool to help the country

meet its international climate obligations and if the federal government has the authority to implement a country-wide carbon pricing policy (Martell, 2019; McCarthy, 2019; Stefanovich, 2020). Hierarchical scale is also demonstrated in the first two articles in this thesis, the NLP paper (Chapter 2) and the framing paper (Chapter 3), by the separation of services provided by different levels of government. Carbon pricing in Canada is being implemented at the federal and provincial levels of government while everyday mobility services and social support programs are mainly provided at the municipal level. The NLP paper shows that text concerning mobility and social exclusion primarily appear in municipal documents. The modelling paper (Chapter 4) demonstrates the importance of relative scale. A statistical model is created to measure the effect carbon pricing has had on the time spent by individuals away from home in a social setting. It is hypothesized that, if the increase in fuel price due to carbon pricing is not large enough relative to the total fuel price, individuals will not have a noticeable change in behaviour. Consequently, at least at low carbon pricing levels, social exclusion should not be evident.

The concepts of mobility and social exclusion are prominent in all three articles in this thesis. Carbon pricing incentivizes individuals to switch from private vehicles to alternative forms of mobility, like transit, cycling, or walking. The NLP paper (Chapter 2) contains a literature review of mobility and social exclusion. Words representing those two concepts are then used in a natural language processing algorithm to find text on those concepts in a large corpus of government documents. The framing paper (Chapter 3) uses framing analysis to show how municipal governments are presenting their future plans. Mobility is a prominent topic in the documents as residents tend to be concerned about an increasing population increasing traffic congestion on city streets. The main frame used by municipal governments shows if the government has a lower level of concern about climate change and is presenting a business-as-usual growth plan that proposes building more roads to address congestion or if the government is more concerned about climate change and is advocating for, and intending to provide, alternative forms of mobility. Governments also differ in how social exclusion is framed. Governments present either passive or active frames when discussing social exclusion. The passive frame presents public spaces that will be built, and it is assumed the space will be used while the active frame presents more concrete ideas on encouraging social interaction in public spaces. The third article, the modelling paper (Chapter 4), contains a statistical model to show the relationship between carbon pricing in Canada and time spent away from home for socializing. Variables representing mobility are included in the model to control for changes in time spent driving, using transit, cycling, or walking.

1.2 Carbon Pricing Literature

Carbon pricing policies can be examined through all three of the concepts identified above—scale, mobilities, and social exclusion. Carbon pricing policies have a hierarchical scale since they are federal and provincial policies that affect spending by households. These policies also have a horizontal scale because spending on carbon varies by household, these households vary spatially within a city, and the price on carbon varies between provinces. The effect on household mobility will also vary spatially across cities and between provinces. For example, a suburban—compared to an inner city—household with high dependence on private vehicles may have a reduction in mobility if carbon pricing rebates do not sufficiently offset the increased cost of driving and there are limited alternative means of mobility. Such a reduction in mobility due to carbon pricing could result in greater social exclusion for that household compared to an inner-city counterpart. Reviewing policies and debates on carbon pricing could reveal if the

spatially uneven effects of carbon pricing, and providing alternative forms of mobility for those likely to experience the greatest loss of mobility, have been properly considered.

As far as public perception of carbon pricing is concerned, the academic literature acknowledges that increasing the cost of driving is unpopular in Canada due to high dependence upon private vehicles, uncertainty about climate change, and political framing of taxes as a burden upon hard-working individuals (Rabe and Borick, 2012; Kim et al., 2013). An article by Beck et al. (2015) seems to indicate a gap in the academic literature looking at government policy being concerned about impacts on mobility and social exclusion. Previous studies of British Columbia's carbon tax have looked at the political process of implementing it, its environmental effectiveness, and its economic impact, but not its impact on mobility. Beck et al. (2015) also summarized other studies which examined the impact on household energy expenditures, finding that British Columbia's carbon pricing has reduced greenhouse gas emissions while not having a negative effect on the economy.

There are many academic papers on carbon pricing concerning whether or not it is a progressive or regressive tax. A tax is considered regressive when high income earners pay tax at a lower rate than low income earners. Wang et al. (2016) found that carbon pricing in developed countries is mostly regressive. This is because lower income households spend more for fuel as a proportion of their total income and tend to drive vehicles that pollute more than higher income households (West, 2005). In his study on carbon pricing in France, Bureau (2011) found that the top quintile of households by income paid more per household for fuel than the bottom quintile of households. However, as a percentage of total household expenditures, low income households paid more, which means carbon pricing in France is a regressive tax. Mathur and Morris (2014) had similar findings, stating that a carbon tax of about $\$19/tCO_2e$ would be regressive. In their assessment, Beck et al. (2015) found the British Columbia carbon tax to be progressive, even before tax reductions and other rebates to low income households were considered. There are also studies which show that carbon pricing is "U-shaped" depending on the actual price put on carbon. Dissou and Siddiqui (2014) describe such an effect when they found that carbon pricing is regressive at low prices and progressive at higher prices due to the cost of energy becoming more of a significant household expenditure at higher carbon prices. The finding that carbon pricing is progressive at higher prices means a higher price on carbon will make the top quintile of individuals that proportionally emit the most carbon (Brand et al., 2013) proportionally pay the most. For low income households that do not use or have very little dependence on private vehicles, the carbon pricing policies of Alberta and British Columbia may be beneficial, though Alberta's carbon pricing policy was revoked in 2019 (McCarthy, 2019). Low income households will see little increase in their household spending on mobility since they purchase very little, if any, gasoline or diesel, and these households will either receive a rebate (Government of Alberta, 2017) or pay a lower income tax rate (Government of British Columbia, 2017). In addition, money from carbon pricing may be invested in public transportation or cycling infrastructure which may increase mobility for everyone, particularly for low income households.

To meet international carbon emission commitments with carbon pricing alone would require a price of nearly $\$1300/tCO_2e$ (Waisman et al., 2013). However, if carbon pricing is combined with other changes to urban design and public transportation, about $\$750/tCO_2e$ could influence enough change in mobility behaviour for countries to meet their carbon emission commitments. To get a sense of scale of the proposed price by Waisman et al. (2013), the federal carbon pricing backstop put in place by the Government of Canada sets a price of $\$30/tCO_2e$ in 2020 which

increases the cost of gasoline by 6.98¢/L (Environment and Climate Change Canada, 2017). A price of about \$1300/tCO_2e would increase fuel prices by \$2.87/L which would approximately triple current gasoline prices in Canada. Such a high price on carbon is not necessary if changes are made to cities and, in fact, Waisman et al. (2013) state that to be effective, carbon pricing will need to be accompanied by changes to the urban environment and transit investments. Not including carbon pricing, Canadians currently pay between 16¢/L to 43¢/L in taxes on gasoline (Natural Resources Canada, 2017). As a comparison to what Canadians pay in extra taxes on gasoline, Germans paid a total of 167¢/L in taxes on gasoline in 2014 (GIZ, 2015). Frondel and Vance (2009, 2017) found that charging more for gasoline reduced vehicle kilometres traveled in Germany. Their model gave a fuel price elasticity of -0.39 for German data while Gillingham (2014) found fuel price elasticities between -0.12 and -0.30 depending upon income and household location using data from California. It seems the price of gasoline is important as, nearly a decade earlier, a study by Storchmann (2001) found that gasoline taxes in Germany had little effect on reducing vehicle kilometres travelled, possibly due to the total price of gasoline in Germany being about 96¢/L in 1995. Currently, the price of gasoline in Germany is around 215¢/L. An acceptance of taxes on gasoline as well as taxes based on vehicle fuel efficiency shows that Germans are aware of anthropogenic climate change and are willing to be incentivized to reduce their carbon emissions (Achtnicht, 2012).

Carbon pricing will likely have the most impact on mobility for lower socioeconomic households that are highly dependent upon private vehicles. But, which households are responsible for emitting the most carbon? Brand et al. (2013) examined the carbon emission distribution from transportation based on the income of individuals in the UK. They found that carbon emissions are skewed; that the bottom quintile of individuals is responsible for 0.8 per cent of road transportation carbon emissions while the top quintile is responsible for 63 per cent. One reason for this skewed distribution is the different levels of access to private vehicles: households with more than one private vehicle per adult emitted considerably more carbon, on average, than households with fewer than one car per adult and substantially more carbon than households without a private vehicle (Brand et al., 2013). These statistics suggest that if carbon pricing is a progressive tax, it will impact not only those who are most able to pay but those who are most responsible for carbon emissions. Brand et al. (2013) also found that 35 per cent of total carbon emissions from transportation were due to daily trips to/from work or school. This may mean carbon pricing, investment in public transportation (Storchmann, 2001), and changes to land-use planning (Glaeser and Khan, 2010; Zhong and Bushell, 2017) could greatly reduce carbon emissions from transportation. For example, carbon pricing can nudge people to choose public transit, especially for work or school trips (Storchmann, 2001). Brand et al. (2013) found that discretionary trips for socialization and leisure accounted for the second-largest share of carbon emissions from transportation at 24 per cent. It will be shown in this thesis whether or not carbon pricing in Canada has had a significant impact on socialization away from home.

1.3 Epistemology

There are two philosophies that serve as the epistemological basis for the research in this thesis: critical realism and positivism. The NLP paper (Chapter 2) proposes a new method for finding text on topics of interest in a large corpus, so it is not based on a particular philosophy. The framing paper (Chapter 3) falls under the epistemology of critical realism as the article will not be looking for cause and effect but to understand the development of government policy (Wikgren, 2005). The modelling paper (Chapter 4) uses the positivist epistemology (Sheppard,

2001). In the modelling paper, I make use of data collected by Statistics Canada and analyze the data under the assumption that they accurately represent household behaviour in Canada.

1.3.1 Critical Realism

Critical realism was proposed by Roy Bhaskar in the 1970s (Bhaskar, 2016). In critical realism, reality is separated into three domains: the real, the actual, and the empirical (Bygstad and Munkvold, 2011; Fletcher, 2017; Parr, 2015; Wikgren, 2005). The framing paper consists of an analysis of municipal government documents to determine how the future of the cities is framed. The real domain is where the causal mechanisms exist (Fletcher, 2017). This is the domain where real world events are occurring and influencing the thinking of those who will ultimately draft the municipal documents. It is difficult to explain what constitutes the actual domain. Events in the real domain trigger events in the actual domain but the events in the actual domain may not be observed (Bygstad and Munkvold, 2011). The final documents are examined in the empirical domain. The municipal documents are read and interpreted to gain understanding and to explain how events in the real domain shaped the final outcome of the documents.

An early critique of critical realism was that it does not have an agreed upon research method (Pratt, 1995; Yeung, 1997). This led Bygstad and Munkvold (2011) to propose six steps for critical realist data analysis:

1. Description of events
2. Identification of key components
3. Theoretical re-description (abduction)
4. Retroduction: Identification of candidate mechanisms
5. Analysis of selected mechanisms and outcomes
6. Validation of explanatory power

As recently as 2017, articles were still being published, acknowledging that critical realism as an analytical technique was still not well understood and demonstrating how to apply critical realism to qualitative research (Fletcher, 2017).

While the framing paper did not follow the six steps laid out by Bygstad and Munkvold (2011), it does rely heavily on the critical realist concept of abduction. The goal of abduction is to justify an observed outcome from a number of possible explanations (Poon, 2005). In the framing paper, four frames which are used by municipal governments are identified. These four frames are the observed outcome from all the possible explanations as to why municipal governments wrote their documents as they did. While the analysis of the frames stops short of proving causation, reasons are presented as to why different cities use different primary frames in their planning documents.

1.3.2 Positivism

Positivism is considered an opposing theory to critical realism (Bygstad and Munkvold, 2011; Cox, 2013; Fletcher, 2017; Huckle, 2004). In positivism, the investigator begins with a set of theories and assumptions and attempts to deduce their consequences (Poon, 2005); knowledge is created by quantification and applying the scientific method (Couclelis and Golledge, 1983). The modelling paper uses rigorous analytical procedures to test a hypothesis using quantitative data. This approach fits Kitchin's (2006) summary of positivism. It is typically assumed that any

analysis in quantitative geography is positivist (Sheppard, 2001) and that assumption is correct for the modelling paper. In this article, the hypothesis is that carbon pricing has negatively impacted the overall mobility of individuals and, therefore, individuals reduced the amount of time spent away from home in social settings. An econometric model is created using survey data from Statistics Canada to test the hypothesis. Geographical theories are used to select the independent and control variables in the model.

1.4 Overview of Three Papers constituting this Dissertation

The purpose of this research was to answer two questions. First, how have governments in Canada discussed the impact of carbon pricing on mobility and social exclusion? Second, how has carbon pricing in Canada affected the mobility and ability of individuals to engage in social activities away from home? In order to answer the first question, I needed to collect government documents on carbon pricing, find where in those documents the topics of mobility and social exclusion were being discussed, and analyze how those topics were being discussed. To answer the second question, I used survey data from Statistics Canada to model statistically the relationship between carbon pricing and the time spent away from home for social activities. The research for this thesis is contained in three academic articles:

1. How to Find Specific Topics in a Large Policy Corpus Using Machine Learning Techniques
2. Growth Over Resilience: How Canadian Municipalities Frame the Challenge of Reducing Carbon Emissions
3. The Effect of Carbon Pricing in Canada on Time Spent on Social Activities Away from Home

The first article, referred to as “the NLP paper”, presents a method to use two Natural Language Processing algorithms to find secondary topics in a large corpus of government documents on carbon pricing. The second article, “the framing paper”, uses the documents returned by the NLP paper. Framing analysis is used to determine how municipalities discuss climate change in planning documents. “The modelling paper” is the third article in this thesis. A statistical model is created to analyze how carbon pricing in Canada has affected the time spent away from home in a social setting.

There is a natural progression from the NLP paper to the framing paper. An explanation of how documents on carbon pricing and green infrastructure were collected from the three levels of government in Canada is presented in the NLP paper. Documents which are most likely to discuss mobility and social exclusion are identified using an NLP algorithm. These suggested documents are the corpus used in the framing paper to analyze how municipal governments present these two concepts to residents. Together, these two papers show how carbon pricing, mobility, and social exclusion are being discussed by governments in Canada. The real-life impact of carbon pricing on Canadians is examined in the modelling paper. This paper uses three cycles of Statistics Canada’s General Social Survey – Time Use. A statistical model is developed to determine if carbon pricing has had a significant impact on the amount of time respondents spent away from home in a social setting. The cycles of the General Social Survey were collected in the following years: in 2005, before any province in Canada had carbon pricing; in 2010, when just British Columbia had carbon pricing; and in 2015, when British Columbia and Québec had carbon pricing (McCarthy, 2019). There is the potential for future work using the

next cycle of the General Social Survey because, as of October 2020, all provinces in Canada either had their own carbon pricing policy or were under the federal carbon pricing backstop (Office of the Parliamentary Budget Officer, 2020). Together, the three papers will show how carbon pricing is being discussed in Canada and if carbon pricing has had an effect on the social lives of residents of Canada.

2 How to Find Specific Topics in a Large Policy Corpus Using Machine Learning Techniques

2.1 Textual Big Data in Social Sciences

Over the past decade, social scientists have entered the era of Big Data (Kitchin, 2013; Shearmur, 2015). Governments are publishing large datasets and releasing them as open data. There are greater possibilities to become involved in decision-making, yet big data brings its own challenges such as new and evolving research methods (Barns, 2016; Reynard, 2018). Much of the information going into decision-making, as well as the policy outcomes of government are textual, and may not be released in machine-readable formats (e.g., PDF). Traditionally investigators relied on manually reading and coding texts to uncover information within documents (McTavish and Pirro, 1990). Lately, Natural Language Processing (NLP) algorithms offer tools to analyze large textual corpora. Two common algorithms for analyzing textual data are Latent Dirichlet Allocation (LDA) and word vectors, also known as word embeddings. LDA is currently employed in fields such as archeology, classics, computer sciences, literature, and political science to determine the main topics being discussed in a corpus of documents (Gerrish and Blei, 2012; Goldstone and Underwood, 2012; Mimno, 2012a; Mimno, 2012b; Schofield et al., 2017). In these examples, LDA is used to find "topics" being discussed in a collection of text, but it is up to the researcher to determine what these topics represent. Using LDA in this way (as an unsupervised classification) does not assist researchers looking for specific topics in a vast corpus of textual data. That requires using an algorithm to score data against a known outcome (a supervised classification). Though researchers have used probabilistic methods to explore topics in textual corpora (Kinra et al., 2020; Kou et al., 2015; Tirunillai and Tellis, 2014), there has been little exploration of using pre-defined topics or concepts to identify text in a large corpus. Gerrish and Blei (2012) provide a rare example where they used a supervised LDA algorithm to study voting behavior by elected officials in the United States. Bills being debated in Congress are given tags based on their subject theme. These tags were used by Gerrish and Blei to score the topics output by LDA, run using the text of the bills. To the best of my knowledge, in the Urban Studies and Public Policy literatures, there has not been an exploration of how theoretical concepts can be used as anchors within a supervised classification, which in turn can identify and extract relevant text. This paper's objective is to demonstrate a method of performing such an analysis.

In this paper, I employ a method to find topics being discussed in a vast corpus of documents on carbon pricing and score the output LDA topics by how closely they match the two pre-specified topics, namely, mobility and social exclusion. The algorithm is also used to suggest which documents are more likely to contain text concerning these pre-specified topics. This article demonstrates this method by finding documents that are most likely to contain information about mobility and social exclusion in over 400 documents containing over 6.7 million words, which were returned in a search for carbon pricing on Canadian government and non-governmental organization websites. LDA is used to find the topics that are discussed in the data set. Then word vectors are used to score how closely the topics represent mobility or social exclusion. By using word vectors to score the LDA topics, I remove much of the researcher bias in selecting the topics that most represent mobility and social exclusion. This method is similar to Kou et al. (2015), who used word vectors to label LDA topics automatically. The main difference is that they used word vectors to determine topic labels, a process that is typically done qualitatively by

the individual running the LDA algorithm. I used word vectors to find an output topic that matches each of my pre-defined input topics of interest.

In the remainder of this section, I explain why using machine learning techniques is appropriate when researching a large textual corpus. In Section 2, NLP, LDA, and word vectors are explained in greater detail. The application of methods of using LDA and word vectors for supervised classification is presented in section 3. Section 4 presents the results, Section 5 discusses the performance of the supervised classification, and concluding remarks are presented in Section 6.

2.1.1 Why use machine learning to investigate carbon policy documents for deciphering text on mobility and social exclusion

Since federal and provincial governments in Canada have implemented carbon pricing policies, it is important to know if all three levels of government have anticipated the effects of carbon pricing policies on households, and if they will assist households in countervailing these effects. The expectation is that the extent and nature of governmental knowledge and concern for these effects is apparent in the government reports that formed the basis of carbon pricing policies. However, there are numerous policy documents generated at the various government levels, and it is inefficient to analyze such a large corpus using human-based analysis techniques. The limitation of traditional techniques of document analysis led me to develop the method presented in this article. To determine if mobility and social exclusion are discussed in the documents, two NLP techniques, namely, LDA and word vectors were applied. I had two methodological objectives: (a) to find the two topics of interest (mobility and social exclusion), which are *not* the main topics of the corpus, given that it focuses on climate change mitigation through carbon pricing; and (b) to identify a subset of documents that are most likely to contain text about mobility and social exclusion. This subset of documents will make up the corpus of documents which are analyzed in Chapter 3, the framing paper.

A large volume of studies and reports on carbon pricing in Canada exists due to the length of time some jurisdictions have had a carbon pricing policy, the political contentiousness of the topic, and the involvement of all levels of government (federal, provincial, and municipal). These government policy documents form the data set for this paper. Due to the sheer number and large size of these plans and reports, it is impractical to analyze every document; a challenge that likely also occurs in other areas of public policy research. Moreover, there are few resource-efficient research tools that can allow scholars to identify specific documents from large corpora, reduce analyst bias, and build thematic cohesion around key ideas contained in the text. The methodological contribution of this research is to demonstrate an effective, low-cost toolkit to identify specific topics and decipher topical areas within a large textual corpus.

The demonstration of leveraging NLP techniques is achieved through letting machine power wade through over 400 policy documents. I show that, by using NLP techniques, the initial corpus of over 6.7 million words is reduced to 0.5 million words. Further, these 0.5 million words are predicted to contain much more text about mobility and social exclusion than the 6.2 million words that is removed from the corpus. The method demonstrated in this paper can be used by researchers widely who need to query specific constructs in large bodies of textual information, including secondary topics.

2.2 Machine Learning Tools used in this Research

2.2.1 Natural Language Processing in Python

The main library for NLP in Python is the Natural Language Toolkit (NLTK Project, 2019). NLTK was originally developed at the University of Pennsylvania in 2001 and is now an open source project (Bird et al., 2009). The toolkit provides algorithms in Python to simplify common natural language processing procedures like part-of-speech tagging, syntactic parsing, and text classification. A second NLP Python library used in this analysis is gensim. The gensim library was developed to simplify some of the methods in the NLTK, predominately the unsupervised semantic modelling of plain text (Řehůřek and Sojka, 2010). Of specific interest for this analysis, gensim contains methods to perform a common unsupervised text classification algorithm, LDA, and algorithms to create and analyze word vectors. Gensim also contains algorithms to clean and prepare text for use in LDA or word vectors, and makes it easier to implement these algorithms than the NLTK library.

2.2.2 Latent Dirichlet Analysis

The main assumption of LDA is that a corpus is a collection of words that contains one or more topics (Blei et al., 2003; Girolami and Kabán, 2003). Topics are determined statistically by their co-occurrence. Put another way, groups of words that often appear close together throughout a corpus are considered to belong to the same topic (Müller and Guido, 2016). An important consideration is the text or reading window, i.e., looking within a document or across multiple documents. Care also needs to be taken that families of similar objects (policy documents) are used for the LDA rather than mixes of information types (policy documents, news transcripts, tweets).

The number of topics in a corpus is not known. It is up to the researcher to specify the number of topics returned by the LDA algorithm and test if the number of returned topics is appropriate (Chang et al., 2009). In order to find topics, LDA uses a maximum likelihood estimator that calculates the probability that certain words tend to cluster together and are therefore topics (Girolami and Kabán, 2003). LDA takes a collection of documents, the corpus, as input then uses statistical techniques to discover hidden topics within and across the documents (Blei, 2012). LDA is considered an unsupervised classification algorithm since topics are determined by the clustering of similar words in a corpus and not by comparison to a previously classified set of documents (Chang et al., 2009). The LDA algorithm returns a model with a specified number of topics and the probability that each word in the corpus belongs to that topic. It is up to the user to determine the subject of a topic by looking at the most likely words that belong to each topic and interpreting how those words might be related (Chang et al., 2009; Wallach et al., 2009). The LDA model created in gensim can also present the probability that, when one of the output topics is specified, a document contains that topic. A single document may contain multiple topics but the probability of each topic being contained in the document, as calculated by the gensim algorithm, likely varies.

2.2.3 Word vectors

Word vectors, also commonly known as word embedding, represent words as a distance and angle in a high-dimensional space (Maas et al., 2011). Words are converted to this vector space based on proximity to other words, so that words which are similar to one another, in context and meaning, are likely to have similar vectors (Mikolov et al., 2013). Not only do similar vectors

have similar positions in the vector space, but it is also possible to add and subtract the vectors to find related words. Adding and subtracting vectors is done in the same manner as using vectors in math or physics. The typical example is King – Man + Woman = Queen (Mikolov et al., 2013). Similarly, the difference between Cars and Car is the same as Apples and Apple since the first vector is the plural of the second vector, and the difference between plural and singular versions of a word should be approximately equal for all words (Mikolov et al., 2013).

There are two methods for creating the word vectors: they can be calculated from the corpus being used, as is done for this analysis, or pre-built models can be downloaded. An example of a pre-built model is GloVe, a word vector model built from two billion tweets that contains 1.2 million words (Pennington et al., 2014). In this analysis, I take advantage of word vectors to calculate the similarity between lists of words. As noted in Section 2.2.2, LDA returns topics but it is up to the researcher to determine the subject of each topic by reading the associated list of most representative words. Gensim provides a method to calculate the similarity between two lists of words using word vectors (Řehůřek and Sojka, 2010). By using this method to calculate the similarity between the most representative words for each LDA topic and a list of mobility or social exclusion words, I am able to select quantitatively the mobility and social exclusion topics.

2.3 Analytical Steps

2.3.1 Data collection

The documents in the corpus are from Canada's federal government, its ten provinces, and the cities of Calgary and Edmonton in Alberta; Vancouver, British Columbia; Winnipeg, Manitoba; Halifax, Nova Scotia; and Ottawa and Toronto in Ontario. These seven cities are among the 13 largest in Canada, with Toronto being the most populous urban centre, and Halifax the 13th (Statistics Canada, 2019). They were selected to achieve broad geographical coverage of major Canadian urban centres (located across six provinces), and because they predominately publish documents in English (Montréal and Québec City were excluded from the sample). Documents created in or after 2005 were retained. Carbon pricing was introduced in British Columbia in 2008 and was one of the main issues of the federal election in the same year, so government policy is less likely to be based upon documents created before 2005 (McCarthy, 2019).

Figure 1: Processing steps flow chart

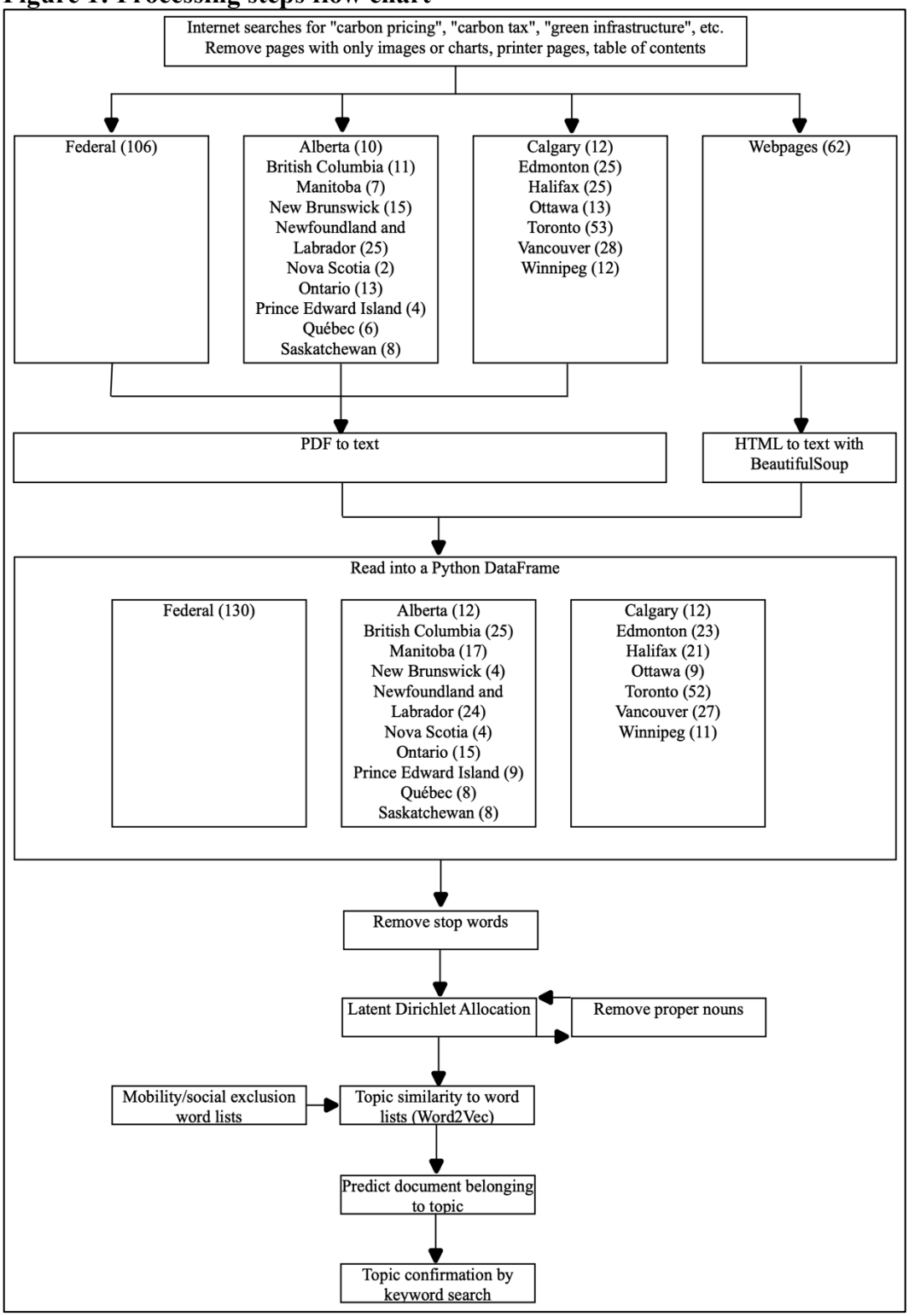


Figure 1 A flowchart of the text processing steps. Numbers of documents for each jurisdiction are in parentheses. Most documents are PDF with four documents being Microsoft Word files and 62 documents being government webpages.

Most of the documents focusing on carbon pricing were obtained from searching government websites, such as www.canada.ca, www.gov.bc.ca, and www.toronto.ca. The internal search tools on these websites were used to look for content such as carbon pricing, carbon tax, or green infrastructure. I also searched for these terms using a Google search with a search flag for a particular domain, e.g., site:gov.ab.ca. Similar searches on more specific government websites, such as www.publications.gc.ca, www.parl.ca, and LegisInfo, were also performed. Additional reports to government came from Environment Canada, the National Round Table on the Environment and the Economy (NRTEE), the Ecofiscal Commission, and the Pembina Institute. Nearly all documents returned were PDFs, but there were also 62 webpages and four Word documents. The number of documents collected for each jurisdiction is shown in parentheses after the jurisdiction name in Figure 1.

The next three sections will explain in detail how the corpus was cleaned and analyzed. As an overview, the processing sequence is: clean the data, run LDA to determine the topics in the corpus, score the topics using word vectors to find one LDA topic for each pre-determined topic, and use the LDA model to predict which input documents are most likely to contain text on the pre-determined topics. Parts of the processing sequence need to be rerun numerous times as the algorithm parameters are tested. For example, early runs of LDA returned topics with many proper nouns as representative words. Those proper nouns were added to the list of stop words and the processing sequence was rerun, starting at the point where stop words were removed.

2.3.2 Data cleaning

Cleaning the data entails converting all the PDF and Word documents and webpages into plain text and reading the text into Python. This step starts with manually reviewing each PDF document and removing pages with no useful information since such pages would affect the NLP results. Specifically, tables of contents, reference lists, chapter title pages with no other text, printer pages, lists of people within an organization, and acknowledgements were removed. All the PDFs were converted to plain text using Apple's Automator application as it returned better results than the Python PDF conversion libraries that I tested. Webpages were also converted to text and the main body of text extracted from the website using Python's Beautiful Soup library. Word documents were saved as text directly from Word. All the text documents were then read into Python and the first 200 characters printed to the screen in order to check for encoding errors. If a document was human readable, it and its encoding were written to a data frame. If the document was not human readable, the Python script would loop through alternate encodings until a human readable encoding was found. In total, 411 of the original 437 PDF documents and webpages were successfully converted to text and saved to the data frame. Thus, 94% of the original documents were retained. Document loss was mostly due to not being able to find the proper encoding of the text document. Some Ontario webpages were lost due to the construction of the website. Attempts to download the underlying text of the webpage yielded a text document which was simply an error message about web browser requirements.

The second step in cleaning the text data is to standardize it and remove superfluous words which will adversely affect the model. In order to process the text using NLTK and gensim, the text was cleaned by converting all words to lowercase, removing common stop words, removing punctuation, and removing special characters. Stop words are words like "and", "or", and "but" which are common in English and are not significant for this analysis. I did not apply stemming as there is evidence that it would harm the output model (Schofield et al., 2017). I added a field to the data frame to record which jurisdiction the document came from – e.g., Canada, Alberta,

British Columbia, or Halifax, etc. I also added a second field containing the level of government the document came from – Federal, Provincial, or Municipal.

Before running LDA, I reduced the number of words in the corpus, filtering out the most extreme occurrences of words. It is common practice to remove words that appear too seldom or too often in documents so that they do not dominate the analysis (Müller and Guido, 2016). In gensim, extreme words are filtered out by specifying the upper and lower bounds for the number of documents in which a word appears. The minimum, the second column in Tables 1A and 1B, is expressed as a count. Values between 0 and 20 documents were tested. The maximum, the second row in Tables 1A and 1B, is expressed as a percentage of the total number of documents. Values between 10% and 60% were tested and these values were the main benchmarks used to improve the output of the LDA model. For example, carbon would be filtered out as appearing too often. Since the documents were selected using searches that included carbon as a search word, carbon should appear in the vast majority of the documents and, therefore, was selected as a key word in most of the LDA topics in early tests of the algorithm. I then separated the texts into the three scales of interest, namely, Federal, Provincial, and Municipal. The data were now cleaned and ready for the LDA algorithm.

2.3.3 Latent Dirichlet Allocation (LDA) to find topics in the corpus

The cleaned text was inputted into the LDA algorithm in order to find the topics contained in the corpus. The main parameter for LDA is the number of topics returned by the algorithm. I set the LDA model to cluster the corpus into ten topics. A manual check indicated that creating more than ten topics tended to produce redundant themes. After each run of LDA, word vectors were used to measure the similarity between the pre-determined topic lists of words and each of the ten LDA topics. The maximum similarity scores for each model run during parameter testing are shown in Tables 1A and 1B, and these results were used to filter the input into LDA. For example, requiring a word to appear in at least five documents but in no more than 40% of all documents resulted in a maximum similarity score of 0.801 between the list of mobility words and the representative words returned for each LDA topic, when analyzing municipal documents. The goal was to compromise and find one set of parameters that could best find one LDA output topic for each of the input pre-determined topic word lists, even if it meant not using parameters that gave the highest similarity score for each topic. Filtering to words that appear in at least five documents and in fewer than 40% of all documents in the final LDA model gave the overall best results. Given the size of my corpus and the pre-determined topics, a manual review was sufficient to confirm topic definition using LDA. However, researchers may have to rely on other criteria and methods in large scale studies (Bickel, 2019; Röder et al., 2015). The quality of topics may need to be judged as well beyond a manual review (see Röder et al., 2015).

After running the first iteration of the LDA model, proper nouns, like Manitoba, Saskatchewan, Winnipeg, and NRTEE, were still appearing too often as they fell within the filtering parameters. In one topic, Calgary, Edmonton, Halifax, and Winnipeg were included as representative words because the document search returned reports from those cities discussing proposed bike lanes and transit expansion plans. For example, among Calgary's and Winnipeg's 12 documents each, three each were about specific transportation policies with the name of the city included. Since the names of the cities were used close to transportation-related words in their transportation planning documents, they appeared to be representative of a topic. Saskatchewan was included in the representative words in a topic that contained words which most represent social exclusion. I removed proper nouns which were appearing among the most likely words in the output topics.

This process was iterative as I would run LDA, check the output for proper nouns, add those proper nouns to a list of excluded terms, and then rerun LDA. Some proper nouns were not excluded because they referred to climate change documents and agreements, such as the Paris Agreement and IPCC. Removing proper nouns also seemed to increase the coherence of the representative words for each topic. While I did not formally calculate coherence scores (see Röder et al., 2015), manually assigning a label for each topic was easier once proper nouns were removed.

2.3.4 Similarity scoring

Based on the literature, two lists of words were created to determine which words best represented the concepts of mobility and social exclusion. Discussion amongst myself and my supervisors refined the list. The list of mobility words was: accessibility, bike, mobility, transit, transportation, and walk. The list of social exclusion words was: community, entertainment, family, friends, health, mental, social, and wellbeing. For the mobility word list, the emphasis was on alternative (sustainable) modes. One goal of carbon pricing is to reduce the use of private vehicles and encourage more use of public transit, walking, and cycling (Environment and Climate Change Canada, 2016; Paterson, 2014). The lists were created by discussing the words with my supervisors and reaching consensus on which should be included in each list. Word vectors were used to check the appropriateness of some of the words. For example, “arena” or “theatre” are locations where social activities occur but were not considered appropriate for the social exclusion word list as they are physical structures and may be used in other contexts. Using word vectors showed that they each are similar to other words relating to physical infrastructure. They are also similar to the word, “entertainment”, which I thought better represented the concept of social exclusion.

Gensim’s word vectors algorithm, Word2Vec, was used to measure the similarity between each list of words and each of the topics created by LDA. The two main parameters for filtering text before LDA are the minimum and maximum number of documents in which a word may appear. To test these two parameters, the words were filtered with various values for the minimum number of documents and maximum percentage of documents parameters before LDA was run. Tables 1A (mobility) and 1B (social exclusion) show the results of these sensitivity analyses. The maximum similarity score at each scale (Federal, Provincial, and Municipal) is in bold text. Both mobility and social exclusion have most of their largest values at the municipal level, when words appear in at least five documents, and when words appear in fewer than 40% of all documents. I used these parameters for the final LDA model.

Table 1A: Sensitivity analysis of LDA parameters for the concept of mobility

		Maximum Percentage of Document					
Scale	**Minimum Number of Documents**	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**
Federal	0	-0.005	0.035	0.242	0.084	0.020	0.149
Federal	1	-0.005	0.035	0.242	0.084	0.020	0.149
Federal	2	-0.005	0.035	0.242	0.084	0.020	0.149
Federal	5	0.091	0.095	0.128	**0.021**	-0.007	0.149
Federal	10	-0.024	0.038	0.012	0.006	-0.047	0.077
Federal	15	0.010	0.050	0.035	-0.022	0.013	0.087
Federal	20	0.025	0.106	0.152	0.075	0.001	0.079
Provincial	0	0.274	0.019	0.038	0.150	0.121	0.136
Provincial	1	0.274	0.019	0.038	0.150	0.121	0.136
Provincial	2	0.274	0.019	0.038	0.150	0.121	0.136
Provincial	5	0.206	0.102	0.095	**0.072**	0.018	0.136
Provincial	10	0.358	0.190	0.124	0.127	0.101	0.136
Provincial	15	0.245	0.145	0.132	0.265	0.118	0.263
Provincial	20	0.291	0.073	0.029	0.072	0.289	0.139
Municipal	0	0.644**	0.543*	0.803***	0.812***	0.693**	0.728**
Municipal	1	0.644**	0.543*	0.803***	0.812***	0.693**	0.728**
Municipal	2	0.644**	0.543*	0.803***	0.812***	0.693**	0.728**
Municipal	5	0.505*	0.615**	0.764**	**0.801*** **	0.756**	0.728**
Municipal	10	0.703**	0.632**	0.744**	0.790**	0.705**	0.840***
Municipal	15	0.528*	0.502*	0.728**	0.803***	0.698**	0.726**
Municipal	20	0.419*	0.622**	0.771**	0.816***	0.634**	0.725**

Note: Values in the table are word vector sensitivity scores comparing the most likely words for each LDA topic and the terms for the mobility concept. The maximum value of the ten topics is shown. Each cell represents one run of the LDA algorithm for the purposes of parameter testing. Values over 0.4 are indicated by *, values over 0.6 are indicated by **, and values over 0.8 and indicated by ***. The values for the final LDA parameters are shown in bold text.

Table 1B: Sensitivity analysis of LDA parameters for the concept of social exclusion

		Maximum Percentage of Document					
Scale	Minimum Number of Documents	10%	20%	30%	40%	50%	60%
Federal	0	0.194	0.312	0.304	0.414*	0.306	0.201
Federal	1	0.194	0.312	0.304	0.414*	0.306	0.201
Federal	2	0.194	0.312	0.304	0.414*	0.306	0.201
Federal	5	0.137	0.445*	0.392	**0.255**	0.186	0.201
Federal	10	0.029	0.302	0.223	0.282	0.359	0.265
Federal	15	0.192	0.309	0.193	0.279	0.303	0.299
Federal	20	0.098	0.336	0.391	0.353	0.295	0.211
Provincial	0	0.380	0.153	0.136	0.262	0.072	-0.010
Provincial	1	0.380	0.153	0.136	0.262	0.072	-0.010
Provincial	2	0.380	0.153	0.136	0.262	0.072	-0.010
Provincial	5	0.230	0.323	0.386	**0.255**	0.243	-0.010
Provincial	10	0.288	0.153	0.338	0.324	0.253	0.086
Provincial	15	0.423*	0.191	0.343	0.243	0.325	-0.014
Provincial	20	0.429*	0.235	0.190	0.255	0.221	0.189
Municipal	0	0.488*	0.413*	0.514*	0.447*	0.418*	0.341
Municipal	1	0.488*	0.413*	0.514*	0.447*	0.418*	0.341
Municipal	2	0.488*	0.413*	0.514*	0.447*	0.418*	0.341
Municipal	5	0.378	0.352	0.438*	**0.576***	0.540*	0.341
Municipal	10	0.439*	0.397	0.519*	0.452*	0.374	0.371
Municipal	15	0.395	0.595*	0.542*	0.500*	0.360	0.386
Municipal	20	0.369	0.548*	0.485*	0.463*	0.507*	0.312

Note: Values in the table are word vector sensitivity scores comparing the most likely words for each LDA topic and the terms for the social exclusion concept. The maximum value of the ten topics is shown. Each cell represents one run of the LDA algorithm for the purposes of parameter testing. Values over 0.4 are indicated by *, values over 0.6 are indicated by **, and values over 0.8 and indicated by ***. The values for the final LDA parameters are shown in bold text.

The topic with the highest similarity to the list of mobility words was chosen as the topic that most represented the concept of mobility. The topic for social exclusion was likewise chosen using the list of social exclusion words. I used the final trained LDA model to predict which of the original documents were most likely to belong to the mobility and social exclusion topics. The documents chosen by LDA were confirmed to indeed contain mobility or social exclusion topics by reading the documents and conducting a keyword search.

2.4 Results: From Topics to Specific Documents

The output of LDA for the municipal topics can be seen in Table 2. Federal and provincial results are similar but not shown since the most likely topics for *both* mobility and social exclusion are only in the municipal group. Each row of the table is a topic, as determined by LDA, and the columns are the most representative words from the topic. Most representative means that each word in the entire corpus is assigned a probability of belonging to a topic; the

top ten words are displayed in Table 2. For example, Topic 6 in Table 2 represents the mobility topic. Words like pedestrian, bicycle, walk, and street are likely to appear close together in the documents and, therefore, are considered to be a topic by the LDA algorithm. The number below each word is the likelihood that the word belongs to the topic. For the mobility topic, the likelihood of the top ten words range between 0.0056 to 0.0155, while the likelihood range is between 0.0039 to 0.0104 for the social exclusion topic.

The LDA results also contains the similarity scores (last two columns in Table 2), calculated using gensim's Word2Vec algorithms, between the most representative words for each topic (the ten words shown along the row) and the mobility and social exclusion terms presented in section 2.3.4. The two highlighted rows, Topic 6 and Topic 2, are the topics with the highest word vector similarity scores to the mobility and social exclusion word lists, respectively. The similarity scores of 0.801 for mobility and 0.576 for social exclusion match the numbers in Tables 1A and 1B for a minimum number of five documents and a maximum of 40% of the documents. The differences in the mobility and social exclusion similarity scores in both Tables 1 and 2 show that mobility is more of a concern for governments in Canada, and especially for municipal governments. These differences also suggest that social exclusion is more difficult to define because the maximum word vector score for mobility is consistently higher than the maximum social exclusion similarity score for each LDA iteration.

Table 2 Municipal topics from the LDA model

	Word 0	Word 1	Word 2	Word 3	Word 4	Word 5	Word 6	Word 7	Word 8	Word 9	mobility similarity	social similarity
Topic 0	recipient (0.0120)	fleet (0.0105)	safety (0.0082)	expenditures (0.0066)	request (0.0053)	delivery (0.0053)	communications (0.0053)	survey (0.0052)	contract (0.0045)	replacement (0.0045)	0.223	0.023
Topic 1	volume (0.0126)	satisfy (0.0086)	citizen (0.0061)	cities (0.0057)	measurements (0.0055)	soil (0.0053)	description (0.0051)	satisfaction (0.0049)	solar (0.0047)	statistics (0.0046)	0.048	0.217
Topic 2	**greenest (0.0104)**	**neighbourhood (0.0061)**	**safety (0.0052)**	**landscape (0.0044)**	**recreation (0.0043)**	**volume (0.0043)**	**cities (0.0040)**	**recycle (0.0040)**	**street (0.0039)**	**footprint (0.0039)**	**0.434**	**0.576**
Topic 3	survey (0.0270)	trip (0.0247)	panel (0.0229)	mode (0.0133)	walk (0.0091)	sample (0.0088)	zone (0.0082)	exhibit (0.0073)	bike (0.0068)	diary (0.0050)	0.548	0.015
Topic 4	bus (0.0197)	greenest (0.0074)	diesel (0.0068)	cent (0.0058)	tree (0.0050)	fleet (0.0041)	cities (0.0041)	customer (0.0038)	battery (0.0035)	walk (0.0031)	0.541	-0.098
Topic 5	word (0.0162)	delete (0.0075)	amend (0.0069)	adaptation (0.0063)	wastewater (0.0050)	master (0.0047)	amendment (0.0043)	cities (0.0042)	flood (0.0040)	zone (0.0040)	0.095	-0.043
Topic 6	**pedestrian (0.0155)**	**bicycle (0.0148)**	**walk (0.0126)**	**street (0.0116)**	**streets (0.0086)**	**traffic (0.0074)**	**safety (0.0069)**	**trip (0.0065)**	**neighbourhood (0.0061)**	**rout (0.0056)**	**0.801**	**0.260**
Topic 7	greenest (0.0114)	downtown (0.0110)	neighbourhood (0.0049)	safety (0.0047)	street (0.0046)	cent (0.0042)	survey (0.0041)	reserve (0.0040)	pedestrian (0.0040)	metro (0.0038)	0.654	0.300
Topic 8	downtown (0.0108)	landscape (0.0049)	recreation (0.0049)	street (0.0046)	cultural (0.0045)	river (0.0039)	neighbourhoods (0.0037)	cities (0.0037)	healthy (0.0035)	neighbourhood (0.0034)	0.392	0.523
Topic 9	request (0.0049)	cent (0.0048)	estate (0.0047)	neighbourhoods (0.0047)	lease (0.0045)	solar (0.0045)	reserve (0.0040)	recreation (0.0037)	healthy (0.0036)	safety (0.0036)	0.366	0.458

Note: Each row represents a topic as returned by LDA. The words in each row are the most representative of that topic. Topic 6 represents the topic of mobility and Topic 2 represents the topic of social exclusion.

Documents predicted to be most representative of the mobility topic can be seen in Table 3A. A document was considered to belong to a topic if it received a likelihood score of belonging to a topic greater that 50% from the LDA model. I used the 50% cut off because there is a split in the probability that a document is likely to contain a topic at 50% likelihood. The LDA model mostly found that municipal documents were likely to belong to the mobility topic. Only one federal and two provincial documents received a likelihood score greater than 50%. This result was expected since *municipal* Topic 6 was used to predict which documents were most likely to contain text about mobility issues. In addition, during the sensitivity stage, LDA analysis of municipal documents produced topics that were, in general, more similar to the list of mobility words than federal or provincial documents. These higher similarity scores are consistent with cities being more involved in providing day-to-day services, like transit, to their citizens than provincial or federal governments.

Table 3A Documents suggested by LDA that contain the mobility topic

	Document Title	Location	Scale	Mobility Word Vector Score
Municipal				
	Winnipeg Pedestrian and Cycling Strategies (2014)	Cities	Municipal	0.9999
	City of Vancouver, Transportation 2040 - plan as adopted by Vancouver city council on October 31, 2012 (2012)	Cities	Municipal	0.9999
	City of Calgary, Calgary transportation plan (2012)	Cities	Municipal	0.9998
	City of Edmonton, The way we move - transportation master plan September 2009 (2009)	Cities	Municipal	0.9998
	City of Winnipeg, Winnipeg - transportation master plan (2011)	Cities	Municipal	0.9998
	City of Winnipeg, Winnipeg pedestrian and cycling strategies final report - part 5 implementation and monitoring (2014)	Cities	Municipal	0.9995
	City of Winnipeg, Sustainable transportation - an our Winnipeg direction strategy (2011)	Cities	Municipal	0.9993
	City of Winnipeg, Winnipeg pedestrian and cycling strategies final report - part 3 strategic framework (2014)	Cities	Municipal	0.9942
	City of Calgary, The city of Calgary - municipal development plan (2017)	Cities	Municipal	0.9796
	City of Edmonton, Building a brighter 101 avenue - what we heard summary (2016)	Cities	Municipal	0.9229
	City of Toronto, Ward 17 let's TransformTO brainstorm for a sustainable city - community consultation report (2016)	Cities	Municipal	0.7044
	City of Calgary, Branch — Transportation Planning (n.d.)	Cities	Municipal	0.6375
	City of Toronto, Ward 18 talks: the environment – TransformTO (2016)	Cities	Municipal	0.6285
	City of Calgary, Transportation action plan 2015-2018 approved (2018)	Cities	Municipal	0.6106
	City of Calgary, Green Line LRT long term vision: 160 Avenue N to Seton executive summary (2017)	Cities	Municipal	0.5566
Provincial				
	Climate action - Province of British Columbia (2015)	BC	Provincial	0.8868
	Green Infrastructure & Other Actions - Province of British Columbia (2015)	BC	Provincial	0.5676
Federal				
	Government of Canada, Turning the corner - regulatory framework for industrial greenhouse gas emissions (2008)	Canada	Federal	0.6998

Note: The likelihood was calculated using the Word2Vec algorithms.

The results of the documents selected for the social exclusion topic from LDA can be seen in Table 3B. As with the mobility topic, municipal documents were scored as most likely to belong to this topic with only one provincial and no federal documents receiving a score greater than 50%. The provincial document is a one-page brochure from Manitoba. Thirteen of the 14 municipal documents are part of Vancouver's Greenest City initiative, and the other municipal document is from Toronto.

Table 3B Documents suggested by LDA that contain the social exclusion topic

	Document Title	Location	Scale	Social Word Vector Score
Municipal				
	City of Vancouver, Draft greenest city 2020 action plan (2011)	Cities	Municipal	0.9992
	City of Vancouver, Greenest city action plan implementation update (2010)	Cities	Municipal	0.9975
	City of Vancouver, Greenest city 2020 action plan brochure (n.d.)	Cities	Municipal	0.9961
	City of Vancouver, Greenest city priorities (n.d.)	Cities	Municipal	0.9938
	City of Vancouver, Greenest city 2020 action plan (2012)	Cities	Municipal	0.9625
	City of Vancouver, Greenest city 2020 action plan 2012-2013 implementation update (2013)	Cities	Municipal	0.9101
	City of Vancouver, Greenest city 2020 action plan (gcap) (2012)	Cities	Municipal	0.8910
	City of Vancouver, Greenest city 2020 implementation plan (2010)	Cities	Municipal	0.7174
	City of Vancouver, Greenest city action plan 2016-2017 update (2017)	Cities	Municipal	0.6793
	City of Vancouver, Greenest city 2020 action plan 2016-2017 implementation update (2017)	Cities	Municipal	0.6362
	City of Vancouver, Greenest city 2020 action plan 2011-2012 implementation update (2012)	Cities	Municipal	0.6123
	City of Toronto, Let's TransformTO! brainstorming session in ward 19 (2016)	Cities	Municipal	0.5575
	City of Vancouver, Greenest city 2020 action plan 2013-2014 implementation update (2014)	Cities	Municipal	0.5055
	City of Vancouver, Greenest city 2020 action plan 2014-2015 implementation update (2014)	Cities	Municipal	0.5009
Provincial				
	Manitoba, made-in-Manitoba climate and green plan - what it means for carbon revenue recycling (n.d.)	MB	Provincial	0.9726

Note: The likelihood was calculated using the Word2Vec algorithms.

To check if the suggested documents did contain text about mobility, I conducted a keyword search of the most frequent words appearing in the mobility documents (Table 3A). The five most common words were city, service, plan, transportation, and transit. These words appeared between 3,433 and 6,147 times each. Cycling was the 18th most common word and street was 22nd. The query included stemmed words, so, for example, cycle, cycled, cycles, and cycling were counted together. In the social exclusion documents, city, green, plan, action, and build were the five most common words, appearing between 899 and 2,324 times each. Of the words in the social exclusion word list, community appeared 636 times, family 95 times, health 102 times, and social 111 times. Entertainment, friends, mental, and wellbeing did not appear in the 1,000 most frequent words. The entire corpus of documents contained over 6.7 million words. The suggested documents for mobility contained 382,792 words and the suggested documents for social exclusion contained 151,731 words.

All the municipal documents selected discussed transportation. To check if transportation occurred in the entire corpus, I searched for this topic within a sample of documents that the model *did not* score highly for mobility or social exclusion issues. This sample showed that mobility was a very common theme in municipal document. Of the sampled documents that did not score highly for mobility, only a budget summary for Toronto did not discuss mobility at all.

A transportation panel survey report from Vancouver actually focussed on mobility yet had not scored highly for mobility.

2.5 Primary findings with reference to level of government

2.5.1 Primary findings and ways forward for replication

Using gensim's algorithms for LDA and word vectors was efficient for identifying documents containing text related to mobility or social exclusion issues. Upon reading the documents, it was apparent why the word vector scores were consistently higher for the mobility topic than the social exclusion topic. All of the municipal documents reviewed contained extensive text about mobility. Thirteen of the 16 suggested mobility municipal documents were transportation master plans, studies about sustainable transportation, or a study on a specific road. Comparing the topic with the highest mobility score, Topic 6, with the second highest, Topic 7, showed that Topic 6 was better able to find the appropriate documents. Topic 6 returned documents like transportation master plans and cycling strategies. Topic 7 returned just five documents, none of which were the same as the documents returned by Topic 6. The most representative word in Topic 7 was "greenest" so three of the five documents were from Vancouver's Greenest City Action Plan. The other two documents were from Transform TO, Toronto's plan to lower GHG emissions.

The social exclusion topics had lower word vector similarity scores and, as expected given these scores, all the documents tended to discuss social exclusion much less than mobility issues. This is likely due to the words chosen which were supposed to represent mobility or social exclusion issues. It was easier to choose the mobility words, especially since a key goal of carbon pricing is to encourage use of more sustainable forms of mobility, like public transit, cycling, and walking (Environment and Climate Change Canada, 2016; Paterson, 2014). It was more challenging to choose words which are representative of social exclusion; as mentioned in Section 2.3.4, the Word2Vec algorithm was used to help make this selection. For instance, a destination for social activities – like arena, restaurant, or theatre – could be tested using Word2Vec to show similar words, like entertainment. Word2Vec was not used when creating the mobility list of words for this study.

It is not a surprise that nearly all municipal documents discuss mobility. Two main services provided by municipal governments in Canada are roads and public transportation. Transportation issues were even discussed in the sample of documents which the algorithm did not suggest as containing the mobility topic. These documents tended to be about cars and roads, while the mobility word list was intended to find alternative transportation.

2.5.2 Strengths of current analysis and future studies

A strength of this analysis is that it reduces researcher bias. Manually interpreting LDA topics is subjective and automated approaches to labelling topics is an active area of research (Chang et al., 2009; Kou et al., 2015). Selecting the lists of mobility and social exclusion words was subjective. However, once those lists are created, they are used to evaluate all of the LDA results. In addition, word vectors are superior to a keyword search to find the mobility and social exclusion topics. Word vectors calculate the similarity between two lists of words, whereas each keyword search only returns instances of an exact match for a single word.

Using word vectors to score the topics could have been improved by further refining the words that represented mobility or social exclusion issues. Those two lists of words captured the larger

ideas from the literature but were subjectively chosen. However, as mentioned in the previous paragraph, the lists are used to calculate similarity scores for all the LDA models, so the method is standardized. Overall, this method has less subjectivity than if a human were to classify all of the output LDA topics. This is the key strength of my approach. Only looking at the five, 10, or 20 most representative words for each topic, it is difficult for a human to quantify by how much more one LDA output topic represents social exclusion compared to another LDA output topic. By using word vectors, this method was able to quantify which LDA topic was most similar to each of the pre-determined topics. The word vector scoring approach was especially helpful when testing parameters for the algorithm. Tables 1A and 1B show clear patterns which were used to select the final parameters. This method would also be useful if a new, completely different corpus was analyzed. In such a case, it would be possible to determine quantitatively if the new corpus contained documents that contained text about mobility or social exclusion issues.

One weakness of this analysis was the possibility that a set of similar documents could skew the results. The social documents were dominated by one word that was the most representative of the social exclusion topic: greenest. This is because 13 of the 14 social exclusion documents were from Vancouver's Greenest City 2020 Action Plan. The topic still selected documents that discussed social issues; nine of those 13 contain text that was coded as representing equity or social exclusion. All of the Greenest City Action Plan documents discuss topics like community hubs, neighbours, public space, and the sharing economy which are other words that represent the social exclusion topic. The Greenest City documents also used a template to standardize the documents, which may have influenced the LDA results, especially since there were six very similar implementation updates.

The combination of LDA and word vectors successfully identified government carbon pricing documents that were likely to discuss mobility and social exclusion issues. The topic that represented mobility scored higher than the topic which represented social exclusion, likely due to mobility being operationalized in more concrete terms through investments in transit, cycling, and pedestrian infrastructure. Municipal governments tend to provide the infrastructure used daily by households, particularly roads and transit. The LDA analysis confirmed that mobility and social exclusion topics were more likely at the municipal level. Importantly, the LDA model accurately found provincial and federal documents which mentioned mobility and social exclusion issues. The technique used to find mobility and social exclusion issues in government documents is important for the wider academic community. The technique presented in this chapter can be applied to any large corpus of text in order to find specific, yet secondary, topics of interest. This ability to sort through vast amounts of text and find the most relevant documents quickly is a necessity in the era of big data.

3 Growth Over Resilience: How Canadian municipalities frame the challenge of reducing carbon emissions

3.1 Introduction

In response to anthropogenic climate change (IPCC, 2012), governments have entered into agreements, such as the Paris Agreement (United Nations, 2015), to reduce carbon emissions and limit the effects and magnitude of climate change. The most efficient way to reduce carbon emissions is by putting a price on carbon emitted into the atmosphere (Nordhaus, 2014). Carbon pricing has been a contentious issue in Canada over the past decade. The province of British Columbia introduced the first economy-wide carbon price in 2008 and Alberta, Quebec, and Ontario introduced their own policies for pricing carbon over the past five years (McCarthy, 2019). In 2019, a federal carbon pricing program came into effect for any province that did not have a comparable carbon pricing system in place (McCarthy, 2019). Canada's federal carbon pricing backstop is currently $30/tonne and is scheduled to rise to $50/tonne in 2022, although a price of $210/tonne may be required for the country to reach its Paris Agreement commitments (Canada's Ecofiscal Commission, 2019; Environment and Climate Change Canada, 2017). As of this writing (October 2020), four provinces are challenging the federal government's authority to impose a nation-wide price on carbon (Government of Ontario, 2018; Martell, 2019; McCarthy, 2019).

In the NLP paper (Chapter 2), machine learning techniques were used to analyse policy documents addressing climate change from all three levels of government in Canada, and to identify those that were more likely to discuss mobility and social exclusion. For this study, I use framing analysis (Entman, 1993) to examine a subset of those documents in order to address my research questions: (1) How are municipal governments in Canada framing the challenges of climate change and reducing carbon emissions?; and (2) Do they link these challenges to the topics of mobility and social exclusion, and if so, how? The use of framing analysis with municipal government documents and climate change is uncommon. Over a decade ago, Van Gorp (2005) observed that most framing research is concerned with news, economics, or conflict. This remains true today, as the vast majority of articles that employ framing analysis examine news articles, especially stories about conflict and immigration. This article adds to the academic literature in two ways. First, framing analysis is used on a novel corpus and topic, i.e., municipal planning documents and their vision for the future of the city. Second, this article shows how municipal governments present the future of their cities in light of the climate emergency.

3.2 Literature Review

While federal and provincial governments in Canada fight over carbon pricing (Martell, 2019), municipal governments must deal with the day-to-day impacts of this policy on residents. Residents' carbon emissions are greatly influenced by dependence upon private vehicles, availability of transit, convenience and safety of cycling and walking, and land-use patterns (Glaeser, 2012; Glaeser and Khan, 2010; Newman and Kenworthy, 2015). All of these factors are strongly shaped by the decisions of municipal governments. In response to the climate emergency, municipal governments need to make changes to mobility and land-use in order to help residents reduce their carbon emissions. These changes should in turn help reduce the costs residents pay to emit carbon and help Canada meet its international commitments. Yet making

these changes may require major lifestyle changes by residents. These changes may be unpopular since they disrupt long-held cultural norms and personal behaviours (Sheller, 2004; Urry, 2004).

Since the early twentieth century, Canadian cities have been designed for mobility almost exclusively by private vehicle, from the physical infrastructure to the predominating culture (Forstorp, 2006; Hagman, 2010; Miller and Ponto, 2016). A condition has been created where it is expected that individuals will be dependent upon private vehicles. Other forms of mobility have received less attention and infrastructure spending. As such, a tipping point is necessary to change behaviours away from the private vehicle (Urry, 2004) and reduce the amount of carbon per person emitted into the atmosphere. The climate crisis and the use of carbon pricing to internalize the cost of emitting carbon may become that tipping point. How municipal governments present their vision for their city is likely to strongly influence how much residents are willing to change behaviours.

If municipal governments do not provide ways to reduce dependence upon private vehicles, residents may be at increased risk for social exclusion (Lucas et al., 2016b). Social exclusion is a process in which individuals or groups are prevented from participating in the normal activities in which other people routinely engage (Kenyon et al., 2002; Rajé, 2003; Preston and Rajé, 2007). Government policy on reducing social exclusion typically assumes high levels of overall mobility (Kenyon, 2003). Yet, carbon pricing increases the cost of using private vehicles, so mobility may be reduced, especially where other mobility options are poor (Farber and Páez, 2011b). Due to the climate emergency, municipal governments need to be planning for a low-carbon future and helping their residents to reduce carbon emissions. When carbon pricing increases the cost of private vehicle use, not providing alternative mobility can lead to social inequity. Research has shown that municipal governments tend to not consider social equity in their climate mitigation plans (Meerow et al., 2019). Making cities less dependent upon private vehicles, whether in response to the climate crisis or not, increases equity by making major destinations more accessible for all (Farber and Páez, 2011b). In Canada, where federal and provincial governments are implementing carbon pricing, it is necessary to investigate how municipal governments are presenting their climate adaptation and mitigation plans, and whether they are supporting residents' willingness to change mobility behaviours without becoming vulnerable to social exclusion.

3.3 Methods

3.3.1 Framing Analysis

In 1993, Entman wrote that communications was a fractured discipline lacking core knowledge. He proposed formalizing the research field by collecting the various theories from other disciplines that fit within communications. He used the example of framing as a theory being employed across the social sciences and humanities which could be formalized by communications scholarship. Entman (1993) stated there are four aspects to frames: they define problems, diagnose causes, make moral judgements, and suggest remedies. In addition, frames have four locations: the communicator, the text, the receiver, and the culture (Entman, 1993). This article focuses mainly on the text since, as will be explained in Section 3.3.2, my sampling procedure predominantly returned documents from municipal governments (similar communicator), the documents are intended for residents of the municipality (similar receivers), and these municipalities are predominantly in Western Canada (similar cultures).

The main goal of framing is to influence the receiver of the information to think about a topic and come to the conclusions desired by the communicator (Pan and Kosicki, 1993). The communicator has already decided upon policy and is leading the receiver to support those decisions (Mah et al., 2014). Put another way, the solution criteria can be framed such that solutions which are already in place seem like the only possible or appropriate solutions (Mah et al., 2014). However, frames can also be used to break down complex political, social, cultural or economic issues so that they may be more easily understood by the receiver (Winslow, 2017).

Framing analysis can be used to examine how the communicator leads the receiver to the desired response (Pan and Kosicki, 1993; Reese, 2007). The communicator uses an organized message and cultural significance when framing an issue so that the desired message resonates with the receiver (Pan and Kosicki, 1993). For the frame to be credible, the communicator must make it consistent and empirical, and the communicator must also be credible (Benford and Snow, 2000). Two approaches are commonly employed: diagnostic framing and prognostic framing (Benford and Snow, 2000; Cress and Snow, 2000). In diagnostic framing, the communicator identifies a problem and advocates for changes based on the problem while prognostic framing identifies a solution and encourages the receiver to work towards that solution (Cress and Snow, 2000). An example of a diagnostic frame is the War on Terror, where countries and groups are blamed for terrorist activities (Winslow, 2017), while an example of a prognostic frame is climate change as an economic opportunity where jobs and prosperity are the end goals that could be achieved if certain actions are taken (Fletcher, 2009). While diagnostic framing focuses on defining problems and diagnosing causes, prognostic framing emphasizes suggesting remedies. Moral judgements as to the cause of a problem (Entman, 1993) are used in nearly all frames as they work forward from problem to solution, as in diagnostic frames, or backwards from solution to problem, as in prognostic frames.

3.3.2 Analytical Steps

The documents for this analysis were collected by searching Canadian federal, provincial, and municipal government websites for terms such as “carbon pricing”, “carbon tax” and “green infrastructure”. Websites of the federal government, all ten provinces, and seven of Canada’s 13 largest cities were searched. Four of the largest 13 cities were not included because they are in southern Ontario, close to Toronto. Montréal and Québec City were also excluded as their municipal planning documents are primarily published in French. I also conducted a Google search for particular domains, such as “site: gov.ab.ca”. In order to capture documents that may have informed British Columbia’s implementation of a price on carbon in 2008 and the discussion of carbon pricing in the 2008 federal election campaign, documents created in 2005 or later were retained (McCarthy, 2019). The initial corpus was 437 documents. Natural Language Processing techniques were then used to select documents that were most likely to contain text about mobility or social exclusion. These methods were explained in greater detail in the NLP paper (Chapter 2).

The NLP analysis identified two separate sets of documents: one group of 17 documents that was predicted to contain text about mobility, and one group of 15 documents that was predicted to contain text about social exclusion. Of these 32 documents, the 23 municipal planning documents—from Calgary, Edmonton, Vancouver and Winnipeg—are retained for this study, which is focused on municipal responses to climate change and the framing of that issue. The other nine documents were omitted because they were either from other levels of government, were from non-governmental organizations, or were short reports that did not contain frames.

The Greenest City Action Plan documents from the City of Vancouver are grouped together, and analysed as a single policy, as the framing and text in those documents are very similar to each other.

The documents were coded using NVivo 12. Coding was done by reading all the documents and selecting text that represented concepts within the two, more general concepts of mobility and social exclusion. The NLP paper (Chapter 2) describes how key words for each concept were used to identify relevant text - such as “bike”, “transit”, and “walk” (for mobility), and “community”, “family”, and “health” (for social exclusion). The text on the concept of social exclusion was divided more specifically into equity and housing, two major categories identified in the documents.

To analyse this dataset, I used an interpretive policy approach, as described by Goodwin (2011). This approach looks to find the meanings, values, and beliefs expressed in policies and how these meanings are expressed to the receiver. A hermeneutic technique (Matthes and Kohring, 2008) was used to identify four frames in the documents. This technique is performed by the researchers reading the documents and drawing their own conclusions as to how the information is presented. In most uses of the hermeneutic approach, the final frames are not verified through the use of statistical analysis (Matthes and Kohring, 2008). Keyword searches in NVivo were used to check the context in which the keywords were used, extract quotes, and verify the frames.

3.4 Results

After reading and coding the documents, I identified four main frames: one centred on mobility alone, and three that included both mobility and social exclusion. Many transportation documents used “the Growing City” frame and were mainly concerned with improving transportation infrastructure to handle a population that is expected to increase significantly in the future. This frame did not mention social exclusion. Mobility and social exclusion were very prominent in the other three frames: “If You Build It, They Will Come”, “Better City for All”, and “the Resilient City”. A summary of which frames appear in the municipal documents is presented in Table 1. More than one frame can occur in a document. However, only one primary frame is identified for each document.

Table 1: Summary of Frames

Document	Municipality	Growing City	"If You Build It, They Will Come"	Better City for All	Resilient City
Calgary Transportation Plan	Calgary		*	**	
Green Line LRT Long Term Vision: 160 Avenue to Seton	Calgary	**		*	*
Municipal Development Plan	Calgary	**	*	*	*
The Way We Move – Transportation Master Plan	Edmonton	**	*	*	
Building a Brighter 101 Avenue - What We Heard Summary	Edmonton		**		
Greenest City 2020 Action Plans (13 documents)	Vancouver	*	*	*	**
Transportation 2040	Vancouver		*	*	**
Sustainable Transportation - An OurWinnipeg Direction Strategy	Winnipeg			**	
Winnipeg Transportation Master Plan	Winnipeg	**	*	*	
Winnipeg Pedestrian and Cycling Strategies	Winnipeg	**		*	
Frame Type		**Diagnostic**	**Prognostic**	**Prognostic**	**Diagnostic**

Table 1: A summary of the different frames used in the municipal documents. ** indicated the primary frame used in a document and * indicates a secondary frame in a document.

3.4.1 The Growing City

The Growing City frame is usually found in the introduction to documents as the municipality lays out the overall context of the document. Calgary, Edmonton, and Winnipeg are framed as welcoming new residents and needing to grow to accommodate them:

> *Over one million new residents will be welcomed to Calgary and over 500,000 new jobs will be created by 2076. Providing fast, frequent and reliable transit for Calgarians as the city grows, is essential to keep Calgarians moving. (City of Calgary 2017a, 9)*
>
> *Edmonton is the fifth largest of Canada's municipalities with a population of approximately 750,000 people in 2009. It is at the heart of a thriving region which currently includes over one million people in the Census Metropolitan Area (CMA). Over the next 30 years, the City of Edmonton's population is expected to exceed one million people, while the CMA will exceed 1.6 million people. This growth will bring about enormous levels of change and challenge as the City delivers services to many new people, businesses and industries. (City of Edmonton 2009, 13)*
>
> *Winnipeg is a vibrant and growing community in the heart of the Canadian prairies. As the provincial capital and the largest city in Manitoba, the 660,000 residents who currently call Winnipeg home represent 60% of Manitoba's total population. Winnipeg and the Manitoba Capital Region are growing at a pace we have not seen in several decades. Our economy is booming as businesses takes advantage of Winnipeg's unique trade position in North America. (Urban Systems 2014, vi)*

Vancouver is also experiencing growth, and this frame is used in its Greenest Cities 2020 Action Plan, but does not receive as much emphasis, appearing later in the document, and only briefly. For instance, the following quote is found on page 19 of a 48-page document:

> *The plan affirms the GCAP Green Transportation targets for 2020 and sets a 2040 target: at least two-thirds of all trips in the city will be on foot, bike, or transit. Achieving these targets will make walking and cycling safer, and expanded transit capacity will accommodate a growing city. (City of Vancouver 2013, 19)*

The focus of the Growing City frame is that additional infrastructure is necessary to meet the needs of new residents expected to move to the city over coming decades. To meet their mobility needs, emphasis is put on continuing to fund and build transportation infrastructure. This frame is not solely about expanding the road network; environmental concerns can appear as part of the frame. Public transit, active transportation, and complete communities are proposed as the solutions by municipal governments to these concerns. However, the main emphasis is on continued or increased investment in transportation infrastructure to support mobility in private vehicles. Alternative forms of transportation are framed as being provided to increase mobility options for more environmentally concerned residents:

> *Objective [–] Maintain automobile, commercial goods and emergency vehicle mobility in Calgary while placing increased emphasis on sustainable modes of transportation (walking, cycling and transit). (City of Calgary 2012, 3-2)*
> *As Edmonton continues to grow, the efficient operation of the city's transportation system will require additional roadway infrastructure despite improvements in traffic and roadway management. […] the Province has committed to the continued construction of Anthony Henday Drive. (City of Edmonton 2009, 70)*

Despite using environmental concerns to justify mobility options, the Growing City frame assumes the continued dominance of private vehicle use:

> *As a city grows outward, reliance on automobiles increases. Edmontonians living in suburban style developments are the least likely to take public transportation, as shown by City studies. This reliance on automobiles, combined with outward expansion of the city, means that people's automobile trip lengths will become longer. The resulting cycle of increased kilometres traveled, road congestion, and the perceived need to build more roadways requires ever more taxpayer dollars for operation and maintenance, and is fiscally and environmentally unsustainable. (City of Edmonton 2009, 33)*

The frame includes warnings of coming negative experiences. For instance, in its Transportation Master Plan, Edmonton tempers expectations on continued, congestion-free, private vehicle use:

> *As Edmonton evolves from a mid-size prairie city to a large metropolitan area, it is inevitable that congestion levels will increase, particularly during peak periods. Physical, financial and community constraints in many areas make it unfeasible or even undesirable to build or expand roads to alleviate congestion.*

> *As such, the City of Edmonton will need to place greater emphasis on strategies to optimize the use of the existing road system. (City of Edmonton 2009, 8)*

Winnipeg uses the Growing City frame in the same manner as Edmonton to temper expectations of future, congestion-free, private vehicle use:

> *Increased population and employment will also result in increased auto trips and increased congestion on Winnipeg streets. An increase of 50% in vehicle-kilometres traveled in the morning peak hour is anticipated. Although in general, the planned road network can accommodate trip growth without significant congestion, there will be choke points where travel demand will exceed capacity, particularly at limited access locations such as river and railway corridor crossings. (City of Winnipeg 2011b, 21)*

The Growing City frame is a diagnostic frame. An expected influx of population is presented as a problem for the municipality to overcome, primarily through more transportation infrastructure, but also through other steps, such as expanding its borders. Implicit in this frame is the cultural norm that 'everyone' wants detached, single-family housing; as such, accommodating a larger population requires building out:

> *Map 5, Jurisdictional Areas, identifies future growth areas for The City of Calgary. Identified future growth areas may be subject to change corresponding to the originating IDPs [Intermunicipal Development Plans] from which they are derived. These growth areas are intended to only signal the starting point for future annexation discussions with adjacent municipalities. (City of Calgary 2017b, 1-5)*

Densification is presented as an alternative to single-family housing and the continued outward growth of the city. However, densification seems to require justification, linking it to environmental concerns or supporting public transit, and it is not presented as the first choice of residents:

> *The MDP [Municipal Development Plan] proposes a more compact urban form for Calgary by locating a portion of new housing and jobs within higher intensity, mixed-use areas that are well-connected to the Primary Transit Network. Such areas define the strategic locations where high-quality transit and a diversity of commercial, residential and service uses currently exist, or where they could be developed over the long term. (City of Calgary 2017b, 2-9)*
>
> *It is recognized that a large proportion of Winnipeg's growth will still take place in new communities beyond the existing built-up area. The goal for OurWinnipeg is to ensure new communities are developed in a sustainable manner, which includes both urban form and transportation choice. (City of Winnipeg 2011b, 30)*

3.4.2 "If You Build It, They Will Come"

The "If You Build It, They Will Come" frame connects specific infrastructure to social inclusion. The argument is that by building parks, plazas, bike lanes, denser housing, walkable streets, and such socially-inclined infrastructure, municipalities encourage residents to use these facilities and engage with one another:

> *The MDP promotes a city where new growth is leveraged to build more complete communities. This means supporting "completeness" in planning for communities, as well as the timely "completion" or buildout of those communities. Complete communities are vibrant, green and safe places, where people of varying ages, incomes, interests and lifestyles feel comfortable and can choose between a variety of building types and locations in which to live, and where daily needs can be met. (City of Calgary 2017b, 2-14)*
> *We are planning our neighbourhoods to be quieter, greener, and more walkable—where the grocery store is a few blocks from your house and you meet your neighbour more often than you sit in a traffic jam. (City of Vancouver 2012b, 17)*

Generally, no details are provided as to why people will use infrastructure or socialize more if new public spaces or active transportation infrastructure are provided. This frame is a prognostic frame. It tends to emphasize the predetermined steps to reach the solution, rather than the solution itself. It seems the steps are more concrete concepts, i.e. build a public plaza, whereas the solution is more abstract, i.e. social exclusion will be reduced. This emphasis may also be due to this frame often being used to build support for alternative forms of mobility, which runs counter to the cultural norm of private vehicle use:

> *Walking — Make walking safe, convenient, comfortable, and delightful. Ensure streets and sidewalks support a vibrant public life and encourage a walking culture, healthy lifestyles, and social connectedness. (City of Vancouver 2012d, 15)*

The main point that separates this frame from the next frame, Better City for All, is that it focusses on specific actions. Actions such as building plazas or bike lanes are presented as tools for promoting social interaction, whereas the next frame has a much more general focus.

3.4.3 Better City for All

This frame uses the general notion about building a better city that will bring a vibrant economy and a better quality of life for residents. It promotes general infrastructure changes, like better active transportation or more public spaces, applied throughout the city, to create a better quality of life for all:

> *By reducing barriers that exclude individuals from participating in the community, all Calgarians will be able to move freely and engage in economic, social and cultural life. (City of Calgary 2012, 3-45)*

In the documents, municipalities state they will increase transit, affordable housing, and the number of jobs within their borders. These general actions will increase equality/equity and make the city better for all. In addition, this frame includes actions such as increasing jobs or economic opportunities as ways to encourage residents to be more socially active. General actions in order to combat climate change are also included as part of this frame:

> *There is a need for investment in transit service that draws on diverse energy sources and reduces carbon emissions. Continued reliance on personal vehicles will increase greenhouse gas emissions. In order to meet environmental targets*

> *there is a need to invest in making transit a convenient alternative to the car that contributes to a lower carbon footprint. (City of Calgary 2017a, 17)*
> *Promoting walking and cycling as attractive and convenient transportation choices can help reduce automobile dependence, increase physical activity levels, improve public health, reduce infrastructure demands, and create more livable and vibrant communities. (Urban Systems 2014, 3)*

Similar to "If You Build It, They Will Come", this is a prognostic frame, which emphasizes the benefits of alternative modes of mobility. This frame is offering solutions and optimism for a better city. It does not matter what the current state of the city is, the city is framed as having the opportunity to be better:

> *The transportation system should offer choices for all people, regardless of their income, age, literacy, mental and physical ability or cultural background. An accessible transportation system that incorporates walking, cycling, transit, carpooling, private vehicle use and other options offers all citizens the opportunity to participate in the economic and social activities of the city. (City of Calgary 2012, 3-45)*

3.4.4 The Resilient City

The Resilient City frame directly acknowledges climate change and its implications, something that the others do not do. This frame is used to promote the city as being prepared, or acknowledging it needs to be prepared, for the upcoming challenges related to climate change. A city is framed as being able to respond to climate change if its residents are given opportunities to reduce carbon emissions or can be insulated from energy price spikes. The frame is typically presented in the introduction of the document and sets the scene for the municipality to present the climate-related actions it is proposing. Environmental resilience is the most common meaning, but economic resilience is also used:

> *The Greenest City 2020 Action Plan (GCAP) aims to prepare Vancouver for the potential impacts of climate change, while building a vibrant community, a thriving green economy, and a greener, healthier city. Hundreds of projects across the city are reducing energy use, supporting alternative modes of transport, decreasing waste and water use, and improving access to nature and local food. Often these projects support multiple Greenest City goals at once. For example, energy audits for rental buildings help move towards achieving the Green Buildings, Green Economy, Clean Water, and Lighter Footprint goals. (City of Vancouver 2014a, 4)*

This diagnostic frame starts with the problem of growing environmental and economic threats and then proposes solutions:

> *Over half of all the carbon pollution in Vancouver comes from buildings—more than transportation and waste combined. In July 2016, Vancouver became the first major city in North America to set specific targets and actions to eliminate greenhouse gas emissions from new buildings by 2030, through the Zero Emissions Building Plan. (City of Vancouver 2017a, 14)*

The Resilient City frame is unique in that it emphasizes the changes required by all citizens to mitigate and adapt to climate change. The other frames, especially the Growing City, mention environmental concerns, but proposed solutions are presented as merely behaviour change options for those residents who are actually concerned about the climate crisis, but change is not presented as necessary.

> *This plan sets the course toward realizing a healthy, prosperous, and resilient future for our city. It calls on us all to rise to the challenge of transforming our community to create a better life for future generations. (City of Vancouver 2012b, 4)*

The Resilient City frame is in some respects the opposite of the Growing City frame: the former states that everyone must change behaviours in order to mitigate climate change but concedes cities will still experience some growth; the latter presents growth as good and adapting behaviours due to the climate crisis as an option for some. Despite being contrary frames, they sometimes appear within a single document, but the frame that is emphasized appears to depend on cultural and political factors. For instance, the Resilient City frame is utilized less than the Growing City frame in the City of Calgary's Green line LRT Long Term Vision and its MDP, but the emphasis of the two frames is reversed in Vancouver's Greenest City 2020 Action Plans. Climate change mitigation has been more accepted in British Columbia as evidenced by the province having Canada's first economy-wide carbon price in 2008, while it remains considerably more contentious in Alberta (Martell, 2019; McCarthy, 2019).

3.5 Discussion

3.5.1 Prioritizing Growth over Resilience

The search for government documents on carbon pricing yielded a corpus of 437 documents from which 23 municipal documents containing text about mobility and social exclusion were retained for this analysis. The municipal level of government is most likely to deal with the day-to-day needs of residents, and I used framing analysis to reveal how they represented issues of mobility and social exclusion in this era of rapid climate change, in which mitigation and adaptation are becoming policy imperatives.

The frame used in cities willing to do the least about climate change is the Growing City frame. This conservative frame presents a singular goal of accommodating future population growth through status quo planning; no fundamental changes to transportation or land use are presented. This frame was a dominant frame for Calgary, Edmonton, and Winnipeg, and merely presented how more of the same infrastructure should be built to accommodate the expected growth in population. This frame is not completely devoid of text about climate change, but adaptation is used only as an extra reason for building alternative transportation, such as LRT or bike lanes. No reasons (beyond accommodating population growth) are required to justify more roads or single-family housing. Most residents are not expected to make any changes to their lifestyle, but alternative transportation infrastructure, as well as higher density housing, are presented as options for residents. The frame also tempers expectations by warning residents that they may experience more traffic congestion due to the additional car journeys generated by population and economic growth.

The two frames used by all four cities to present some of the changes required for climate adaptation are "If You Build It, They Will Come" and "Better City for All". These progressive

frames are used to promote sustainable urbanism, with a focus on transportation and land use. Building "alternative" infrastructure will improve both environmental resilience and social inclusion, according to these frames. Both include social inclusion as an ideal. Unlike the Growing City, these frames are used to shift the thinking of residents away from the status quo. However, they use language that presents the changes required for more sustainable cities as suggestions, hopes and dreams, and are often secondary to the Growing City frame. The effect is to present alternatives to car-dependence and urban sprawl not as imperatives but as 'options' for a few residents, which might become more necessary in the future.

The Resilient City is the only frame that genuinely addresses climate mitigation. This transformative frame presents climate change as a real threat, necessitating changes to transportation and land use patterns. Vancouver is the only city that uses this as the primary frame in documents. As with the other frames, options for behaviour change are presented, although in this case they are not 'options for some', but rather 'imperatives for most'. It requires much more than tinkering with current approaches to planning cities; this frame is used to propose new systems. However, this new systems approach may be over-stating the ability of cities and residents to change given the path dependencies within some current systems.

The Growing City and Resilient City frames are diagnostic. While they do not lay blame per se, they identify growth and climate change as challenges and present solutions. The "If You Build It, They Will Come" and Better City for All frames are prognostic. They begin with the desired goals of social interaction, health, and vibrancy, and present building active transportation infrastructure and public spaces as the way to achieve these. There was a high degree of consistency within each of the frames; for example, all of municipalities employing the Growing City frame utilized the same idea: population is increasing, continued or increasing economic growth is desired, roads will become congested, and money needs to be invested in infrastructure in response.

Most of the municipal documents are "talking the talk" on how to create sustainable cities and showing concern for the forecasted impacts of climate change. However, outside of Vancouver, the dominant frame in municipal planning documents is a Growing City – a narrative that prioritizes accommodating growth above all else. Calgary, Edmonton, and Winnipeg do not have major geographical constraints to continued outward, greenfield expansion. The City of Vancouver, on the other hand, is geographically constrained by waterways and adjacent municipalities. These limits on expansion mean the City of Vancouver cannot make full use of the Growing City frame, which is referred to only occasionally, in the context of anticipating some population growth. It is already Canada's densest municipality with three more of its neighbouring municipalities in the top ten (Statistics Canada, 2017a). Proposing more people, more roads, and more congestion may not be politically feasible in this context. Vancouver is the only city considered here that prioritizes the major changes required for municipalities to combat climate change, using the Resilient City as a dominant frame. Vancouver's coastal location is likely one factor contributing to this, as sea level rise is a concern for the City of Vancouver and not for the mid-continental cities of Calgary, Edmonton, and Winnipeg.

3.5.2 The intention of Municipal Plans in the Climate Change Era

It is outside the primary scope of this paper to examine to what extent governments have been "walking the walk" and making changes to reduce carbon emissions and combat climate change, although intent can be inferred in a limited manner. For example, Vancouver's Greenest City

2020 Action Plans have specific goals and performance measures about reducing private vehicle use and increasing other forms of transportation. The performance measures for Vancouver have been trending in the correct direction and it appears Vancouver could meet many of its 2020 targets. The other municipalities do not appear to be taking climate change seriously as demonstrated by their transportation master plans presenting more sustainable forms of mobility as options, not as the expected norm. Those documents claim alternative forms of mobility should be encouraged but contain few, if any, goals for reducing private vehicle use. Alternate forms of mobility are typically presented as a choice for more environmentally concerned residents or as an ethereal way of making residents happier, as in the "If You Build It, They Will Come" and Better City for All frames. This approach is likely strategic, in that stronger and more direct promotion of sustainable transport in cities (i.e. via improved public transportation, bike lanes or pedestrian amenities) is contentious in Canada and is often met with the "war on the car" frame (Walks, 2015). Emphasizing mode choice and the health and social connectedness benefits of sustainable transport appears to reduce the potential for adversarial responses, in part by posing less of a challenge to the status quo. This is also the only way that municipalities seem to be connecting climate mitigation and mobility with social exclusion.

For the frames to be successful, the communicator must use ideas that are culturally significant (Pan and Kosicki, 1993). For example, the Growing City frame uses anticipated population increases as a threat of future overcrowding. This fear goes back at least to the 1700s in London, England and the birth of suburbia (Fishman, 2008). As Mah et al. (2014) argued, the threat of overcrowded cities and streets leads the reader to what seems to be a municipality's desired outcome: more building outwards.

One limitation to this analysis is the corpus of documents selected by the machine learning algorithm. The initial search returned 437 documents from the federal government, ten provinces, and seven municipalities from across Canada. The algorithm favoured municipal documents and, in particular, documents from four of the seven municipalities included in the initial search. This study has identified, described, and analysed common frames used by these four large western Canadian cities; further work is required to determine if these frames appear in policies produced by other cities, or at other levels of government.

3.6 Conclusions

My analysis of four municipalities' policies addressing climate change found they used four frames when presenting their vision: the Growing City, "If You Build It, They Will Come", Better City for All, and the Resilient City. Calgary, Edmonton, and Winnipeg primarily used the Growing City frame to convey a message that, for the most part, status quo planning (including sprawl and car dependence) is all that is necessary to accommodate anticipated population growth. Vancouver was the only city to use the Resilient City as its dominant frame, indicating an awareness that climate change mitigation necessitates substantive change. The "If You Build It, They Will Come" and Better City for All frames were generally secondary frames in documents advocating for alternative transportation infrastructure or improvements to public space. They are progressive frames, but they only suggest these alternatives as nice to have, not as necessary for climate adaptation and mitigation. They are also the only frames which use social inclusion as a justification for these alternatives to car-dependence or urban sprawl.

Canada has committed to reducing its carbon emissions through the use of carbon pricing. These policies are implemented at the federal and provincial levels. However, municipal governments

in Canada are generally responsible for providing the day-to-day services that affect mobility and social inclusion within cities. This analysis of municipal planning documents shows how municipalities are presenting their futures in light of the climate emergency. Three of the four do not propose major changes to their urban planning and, as such, offer their residents' limited opportunities to reduce carbon emissions. It follows that their residents may be exposed to higher costs of mobility and an increased chance of social exclusion in the era of carbon pricing. Notably, the "If You Build It, They Will Come" and Better City for All frames make social inclusion a central goal, but are predominantly secondary frames, used as extra justification for active transportation or public spaces infrastructure.

All frames present the current municipal planning situation and the goals for the future. Moreover, in all documents analysed here, the dominant frame appears early. Thus, it can quickly be determined if a city is using the Growing City frame and not taking climate change seriously by just tinkering with the status quo, or if a city is using the Resilient City frame and is trying to make some real changes. If Canada is to meet its international climate agreements, more of its cities will need to use the Resilient City as their dominant frame.

4 The Effect of Carbon Pricing in Canada on Time Spent on Social Activities Away from Home

4.1 Introduction

Canada is a country dependent upon cars. Nearly 80% of residents commute to work as either a driver or a passenger in a car (Statistics Canada, 2017d). When comparing Canada to the United States, European G20 countries, and select other European countries, Canada has the highest number of vehicles owned per capita and, on average, Canadians drive the second-most kilometres per year, behind just the United States (United Nations Economic Commission for Europe, 2017). This car dependence means that 20% of Canada's GHG emissions come from cars and light trucks (Government of Canada, 2017). Canada has a mixed record when it comes to environmental policy. Canada was a leader in banning ozone-depleting chlorofluorocarbons (Benedick, 1996), is a signatory on the Paris Agreement to fight climate change (Environment and Climate Change Canada, 2017), and has a nation-wide price on carbon (McCarthy, 2019). Conversely, Canada was the only country to withdraw from the Kyoto Climate Accord (CBC News, 2011) and its environmental policies earned it many Fossil Awards during the United Nation's annual Conference of the Parties (Climate Action Network, 2013).

Carbon pricing is a nudge to reduce GHG emissions, but it pits two goals of government against one another. One the one hand, governments implement carbon pricing to reduce the use of private vehicles. On the other hand, if alternative forms of travel are not available, overall mobility may be reduced. This threatens to undermine other government policies directed at reducing social exclusion, which typically assumes high levels of mobility (Kenyon, 2003). Due to these conflicting goals of governments, it is necessary to examine how different levels of government implement carbon pricing, and its effects on mobility and social exclusion. The NLP paper (Chapter 2) showed that there is a disconnect between federal, provincial, and municipal policy. The framing paper (Chapter 3) showed that cities in Canada are addressing the seriousness of the climate crisis to varying degrees in their planning documents. This disconnect between levels of government is concerning. Carbon pricing, implemented at the federal and provincial levels, is supposed to be uniform across Canada (Environment and Climate Change Canada, 2017). It will make driving a car more expensive, nudging residents to drive less. However, daily transportation is a municipal matter and policies to reduce car dependence vary from city to city (Buehler et al., 2017; Gerber and Gibson, 2009; Newman and Kenworthy, 2011). Policies aimed at reducing car dependence without providing alternatives may increase the cost of using a car for mobility or lower an individual's overall mobility. This increased cost of mobility or lower overall mobility may then decrease an individual's ability to participate in society as much as they would like, a phenomenon known as social exclusion (Kenyon et al., 2002; Lucas, 2012; Preston and Rajé, 2007; Rajé, 2003).

This chapter makes a contribution to the academic literature by answering: what effect has carbon pricing in Canada had on the amount of time individuals spent away from their home in a social setting? I expect that carbon pricing had an effect on increasing social exclusion in Canada, assuming the price of carbon was sufficiently high enough to encourage behaviour change. If carbon pricing is putting more individuals at risk of social exclusion, more coordination is required between federal, provincial, and municipal governments to reduce GHG while not increasing social exclusion.

The statistical model developed in this chapter will show that carbon pricing has had no significant impact on time spend away from home in a social setting. Either carbon pricing has been too low in Canada to reduce car dependence or residents have been able to make the switch to alternative mobility options. All three levels of government should work in conjunction to ensure Canada can meet its global climate change commitments without adversely affecting the quality of life for residents.

4.2 Understanding Mobility and Social Exclusion: A Review

4.2.1 Mobility: city form and car dependence

In this article, consideration of mobility is limited in scope to how household members move within an urban environment. The mobilities literature is vast (see Adey, 2006; Hannam et al., 2006; Merriman, 2014; Sheller and Urry, 2006) but the focus here is solely on mobility using private vehicles or other sustainable forms of transportation, namely, public transit, cycling, and walking. Mobility using a private vehicle is known as automobility.

Mobility scholars like Sheller and Urry have been writing since the 2000s about the negative consequences of automobility. In 2000, they identified the need for a nudge to reduce energy consumption by private vehicle use and redirect investment into public transit, cycling, and walking (Sheller and Urry, 2000). Governments in Canada have implemented carbon pricing as part of that nudge. Disincentives alone will likely not be enough because dependence upon private vehicles is ingrained in society; from “car culture” (Goetzke and Rave, 2015; Hagman, 2010; Kent, 2015; Sheller, 2004) to how cities are designed (Merriman, 2014; Newman and Kenworthy, 2015; Wu et al., 2015). Stated differently, automobility has been locked-in over the last century through the design of cities and the creation of infrastructure that supports driving (Forstorp, 2006; Hagman, 2010; Miller and Ponto, 2016). If carbon pricing is a disincentive to using private vehicles, it is an incentive to switch to more sustainable forms of mobility. In order to reduce GHG emissions and combat climate change, cities need to offer mobility options other than just private vehicles and change their urban form (Newman et al., 2009). If cities only reduce private vehicle use without increasing the availability of other options or changing land-use, overall mobility may be noticeably reduced, which, in turn, may lead to social exclusion.

4.2.2 Consumer behaviour: the effect of gasoline price changes on driving

Carbon pricing will make driving private vehicles more expensive, thus likely diminishing automobility. Carbon pricing makes gasoline more expensive and there are many academic articles on the effect of gasoline prices on the behaviours of individuals. Studies on gas price elasticity, the change in consumption of gasoline in the response to a change in its price, all found a decrease in consumption with an increase in price. Depending on the location of the study and reason for the change in price, the elasticity was found to vary between -0.22 and -0.76, which means driving fell 2.2% - 7.6% if the price of gasoline increased by 10% (Gillingham, 2014; Goodwin et al., 2004; Puller and Greening, 1999). Carbon pricing may be more effective in reducing automobility than the studies on gasoline prices predict. Lin and Prince (2013) found that automobility is reduced less when the price of gasoline is most volatile. It may be that individuals attempt to refill their gas tank when gasoline prices are lowest and this is easier to do when there is a shorter period of time between increases and decreases in the gasoline prices. Carbon pricing adds a long-term cost to the price of gasoline so would increase price without increasing the volatility of the price of gasoline. In addition, Lin and Prince (2013) found there was a greater reduction to automobility when prices were high, given an equal

amount of volatility. However, the effect of carbon pricing may diminish over time as consumption tends to revert back more and more to the level of consumption before a price shock (Puller and Greening, 1999). One other change to automobility that can be induced by carbon pricing is a switch to more fuel-efficient vehicles or more efficient driving to reduce fuel consumption (Goodwin et al., 2004). These efficiencies are not directly translated to GHG emissions reductions due to the rebound effect. Overall driving in the United States increased up to 22% between 1966 and 2001 due to improvements in fuel efficiency (Small and Van Dender, 2007).

4.2.3 Social exclusion: socializing and time use

Social exclusion is a process in which various factors prevent individuals or groups from participating in the normal activities in which other people routinely engage (Kenyon et al., 2002; Preston and Rajé, 2007; Rajé, 2003). There is a clear link in the literature between mobility and social exclusion (Goetzke and Rave, 2015; Lucas, 2012; Stanley and Lucas, 2008; Stanley et al., 2011). In car-dependent locations, reducing mobility by private vehicle reduces access to economic and social activities for individuals (Delbosc and Currie, 2011).

In their work with seniors (individuals over 60 years old), Scharf and colleagues (Scharf et al., 2005) identified five forms of social exclusion: 1) exclusion from material resources, 2) exclusion from social relations, 3) exclusion from civic activities, 4) exclusion from basic services, and 5) neighbourhood exclusion. From the perspective of reduced mobility due to carbon pricing, the first four of Scharf et al.'s (2005) forms of social exclusion are applicable to individuals dependent upon private vehicles. In order to lessen what they pay to emit GHG, households will be required to make decisions. Households can decide to reduce other expenditures or switch to transit, bicycling, or walking which typically take more time than car-based travel for single trips. A reduction in the time or money available to households may cause a form of social exclusion as argued by Scharf et al. (2005). Reducing trips for social purposes is more likely than reducing essential trips, like commuting to work or getting groceries. More time spent travelling for mandatory trips reduces the likelihood of participating in discretionary activities (Farber and Páez, 2011a).

4.3 Methods

4.3.1 Data Assembly

Data for this analysis comes from three cycles of Statistics Canada's General Social Survey – Time Use (GSS) (2005, 2010, and 2015). The GSS is designed to gather data on social trends so that Statistics Canada may assess changes to Canadians' living conditions and well-being, and to collect information on current or emerging social issues (Statistics Canada, 2017b). Respondents must be over the age of 15 and living in one of Canada's ten provinces – the three northern territories are excluded (Statistics Canada, 2017b). For this analysis, I am interested in changes to mobility and social patterns due to carbon pricing. A Public Use Microdata File (PUMF) version of the GSS was used, obtained through licence from odesi (Ontario Council of University Libraries, 2020). Due to confidentiality, age and income variables were categorized into 10 year and $10 000 bins, respectively. In addition, only the province of residence and whether the respondent lived in an urban or rural setting was available. For this analysis, residents living in a rural setting were excluded as well as respondents who reported more than 180 minutes in a car. Urban dwellers are more likely to have access to alternative transportation so the resulting model may reveal more nuanced behaviour changes. Respondents who spent

more that 180 minutes in a car were likely dependent upon their vehicle as part of their job and unlikely to be able to make changes based on carbon pricing. The resulting data had 13,793 observations for 2005, 10,596 for 2010, and 12,233 for 2015.

The price on carbon in Canada for the three survey years was added manually to the data from various government documents. In 2005, no province in Canada had set a price on carbon so the 2005 carbon price was set to \$0. In 2010, only British Columbia had an economy-wide price on carbon. The price on carbon was \$15/tCO_2e to begin the year and was raised to \$20/tCO_2e on 1 July 2010 (Government of British Columbia, 2008). Since the month that a respondent completed the GSS questionnaire was not available in the PUMF GSS, an average price of \$17.50/tCO_2e was used for British Columbia in 2010. In 2013, Québec and California created a cap and trade carbon market (McCarthy, 2019). The average price on carbon in Québec was \$15.90/tCO_2e in 2015 (International Carbon Action Partnership, 2020). British Columbia's carbon price was \$30/tCO_2e in 2015 (Government of British Columbia, 2008). In addition to the price on carbon, the yearly average retail price for gasoline for each province was added to the data. These prices were obtained from Statistics Canada (Statistics Canada, 2018b). Both the carbon price and gasoline prices were adjusted to 2015 dollars (Bank of Canada, 2020).

4.3.2 Zero-inflated Negative Binomial Model

My research question is "what effect has carbon pricing in Canada had on the amount of time individuals spend away from their home in a social setting?" Consequently, the dependent variable for the model is the amount of time, in minutes, spent away from home. This variable was created by summing together six duration variables from the GSS: "at the grocery store, other stores, or mall", "at a library, museum, or theatre", "at a sports centre, field or arena", "at a restaurant, bar or club", "at a place of worship", and "at a medical, dental or other clinic" (Statistics Canada, 2017c). The dependent variable has an excess number of zeros as 16,889 of the 36,582 total observations recorded zero minutes for the away from home variable. Since the number of minutes spent away from home for possible social activities is a count and there is an excess number of zeros for individuals who did not engage in these types of activities during their surveyed day, a zero-inflated negative binomial model is therefore suitable for this analysis (Garay, 2011; Mullahy, 1986; Ohi and Kim, 2020).

$$\Pr(Y_i = y_i) = \begin{cases} p_i + (1-p_i)\left(\frac{\phi}{\mu_i+\phi}\right)^{\phi}, & y_i = 0, \\ (1-p_i)\frac{\Gamma(\phi+y_i)}{\Gamma(y_i+1)\Gamma(\phi)}\left(\frac{\mu_i}{\mu_i+\phi}\right)^{y_i}\left(\frac{\phi}{\mu_i+\phi}\right)^{\phi}, & y_i = 1,2,\dots, \end{cases} \quad \text{(Garay, 2011)}$$

A zero-inflated negative binomial model uses a maximum-likelihood estimator to solve two phenomena found in the data: a distribution of count data, which is truncated at zero, and a component which is a point mass at zero. A binary model estimates the probability of a zero and a negative binomial model estimates the count component (Zeileis, 2008). The time spent away from home could also be considered a continuous variable, which would make a left-censored Tobit model appropriate. A Tobit model was tested but the zero-inflated negative binomial model outperformed it according to both the pseudo-R^2 and the Akaike Information Criterion. For this analysis, I used the zeroinfl algorithm from the R library, pscl (Zeileis, 2008; R Core Team, 2019). The distribution of the away from home variable, by year, is shown in Figure 1. In Table 1 are the summary statistics for all variables in the model.

Figure 1: Time Spent Away from Home

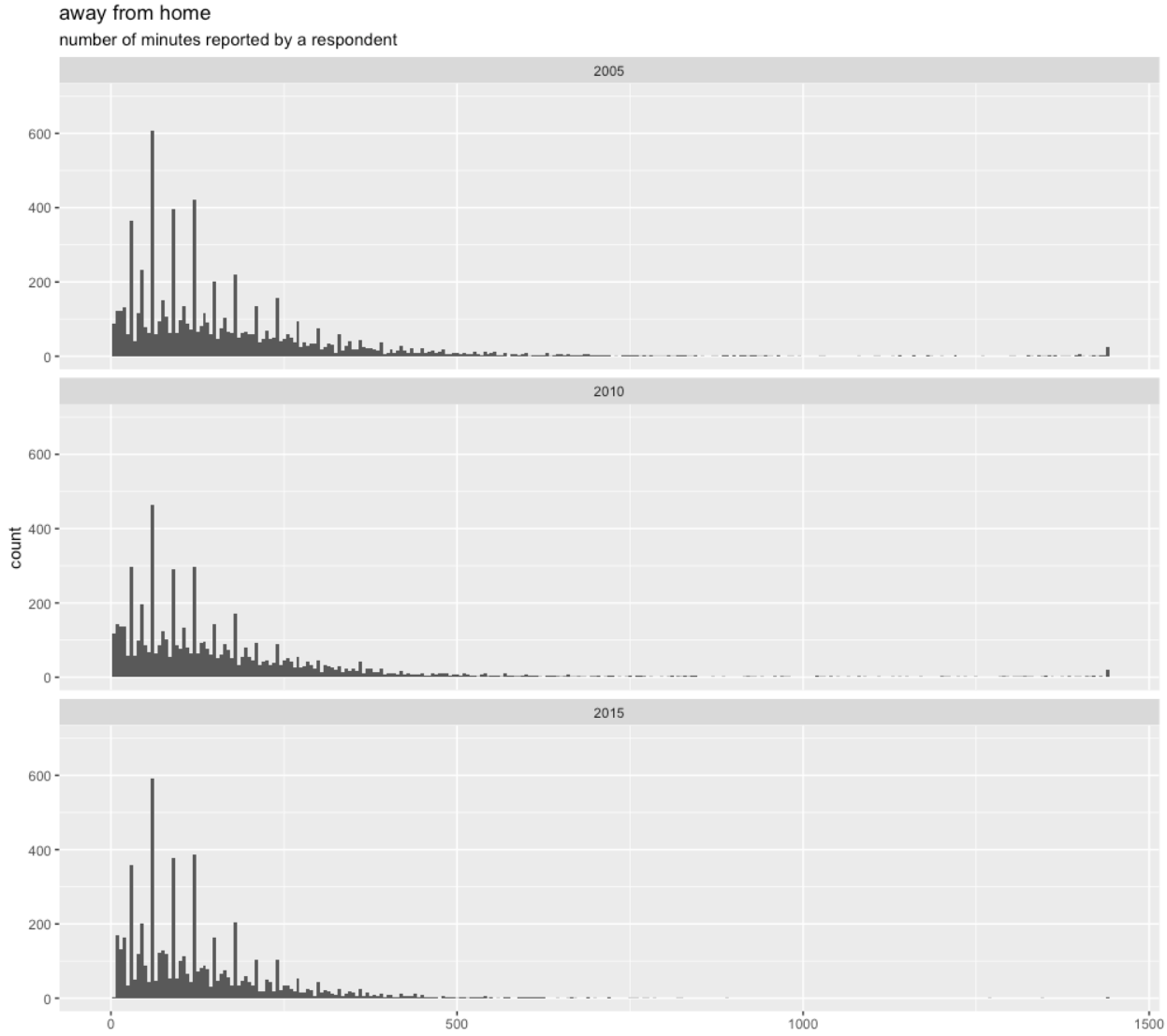


Figure 1: Histogram of the away from home variable showing the number of minutes a respondent spent away from home, at a place such as a grocery store, library, sports centre, or restaurant. Note that plots are limited to a maximum count of 1000 so the bars at zero minutes have not been plotted. The counts of individuals spending zero minutes away from home are 6281 in 2005, 4242 in 2010, and 6366 in 2015.

Table 1: Summary of Variables

	2005 (N=13780)	2010 (N=10569)	2015 (N=12233)	Total (N=36582)
away from home				
Mean (SD)	98.716 (168.637)	101.786 (167.294)	63.343 (103.789)	87.774 (150.668)
Range	0 - 1440	0 - 1440	0 - 1440	0 - 1440
carbon price in 2015 dollars				
Mean (SD)	0.000 (0.000)	3.215 (7.102)	7.267 (10.807)	3.359 (7.936)
Range	0.000 - 0.000	0.000 - 18.900	0.000 - 30.000	0.000 - 30.000
mean provincial gas price in 2015 dollars				
Mean (SD)	111.567 (5.357)	112.781 (6.117)	108.554 (6.804)	110.910 (6.335)
Range	101.730 - 121.549	98.870 - 121.199	95.550 - 120.129	95.550 - 121.549
in car				
Mean (SD)	44.570 (43.461)	47.357 (45.163)	43.197 (43.545)	44.916 (44.018)
Range	0 - 178	0 - 178	0 - 175	0 - 178
in transit				
Mean (SD)	8.032 (32.547)	7.210 (30.086)	6.592 (27.164)	7.313 (30.127)
Range	0 - 1005	0 - 600	0 - 430	0 - 1005
walking				
Mean (SD)	5.456 (18.025)	6.188 (20.475)	4.879 (21.028)	5.475 (19.789)
Range	0 - 310	0 - 405	0 - 900	0 - 900
biking				
Mean (SD)	0.507 (6.313)	0.488 (6.484)	0.565 (6.857)	0.521 (6.548)
Range	0 - 210	0 - 255	0 - 300	0 - 300
age group (10 year bins)				
Mean (SD)	3.649 (1.780)	4.048 (1.785)	4.201 (1.782)	3.949 (1.798)
Range	1 - 7	1 - 7	1 - 7	1 - 7
sex				
Male	5951 (43.2%)	4497 (42.5%)	5364 (43.8%)	15812 (43.2%)
Female	7829 (56.8%)	6072 (57.5%)	6869 (56.2%)	20770 (56.8%)
children in house				
Mean (SD)	0.380 (0.779)	0.361 (0.763)	0.350 (0.752)	0.364 (0.766)
Range	0 - 3	0 - 3	0 - 3	0 - 3

adults in house				
Mean (SD)	2.047 (1.026)	2.107 (1.040)	1.956 (0.907)	2.034 (0.994)
Range	1 - 6	1 - 6	1 - 6	1 - 6
education years				
N-Miss	73	94	141	308
Mean (SD)	13.467 (2.392)	13.747 (2.378)	14.098 (2.359)	13.758 (2.392)
Range	10 - 18	10 - 18	10 - 18	10 - 18
income in 2015 dollars ($10,000 bins)				
N-Miss	3482	3071	0	6553
Mean (SD)	71.572 (41.756)	69.383 (37.887)	76.680 (37.643)	73.106 (39.281)
Range	17.850 - 142.800	16.200 - 129.600	15.000 - 120.000	15.000 - 142.800
live alone				
N-Miss	0	41	0	41
Partner in household	6873 (49.9%)	5738 (54.5%)	6523 (53.3%)	19134 (52.4%)
No partner in household	6907 (50.1%)	4790 (45.5%)	5710 (46.7%)	17407 (47.6%)
at home				
Mean (SD)	1017.210 (312.205)	1035.110 (308.952)	1048.678 (316.298)	1032.904 (312.922)
Range	0 - 1440	0 - 1440	0 - 1440	0 - 1440
at work				
Mean (SD)	207.425 (266.506)	180.326 (253.149)	176.947 (255.939)	189.404 (259.554)
Range	0 - 1440	0 - 1440	0 - 1440	0 - 1440

Table 1: Summary of variables used in the zero-inflated negative binomial model. Note: the income variables are in thousands of dollars. The income variables have also been adjusted for inflation to 2015 dollars.

The dependent variable in the model is “away from home”, which was described in the first paragraph of this section. The independent variable is the price on carbon in each province in Canada in 2015 dollars. The variables “at home” and “at work” are the number of minutes an individual spent at home and at work, respectively, during the day they were surveyed. These two variables explain the excess zeros in the “away from home” variable.

4.4 Results

The output from the zero-inflated negative binomial model is shown in Table 2. The significant variables, at the 5% level, are the time spent in a car as a driver or passenger; the time spent travelling by transit; the time spent walking; the time spent biking; the age of the individual, binned into 10 year increments; household income; the squared household income; the year the individual was surveyed, with 2005 being the reference year; and the amount of time spent at home or at work. The time spent at home or at work were also significant in predicting if an individual spent zero minutes away from home. It is important to note that the independent variable, the price of carbon, was not significant in the model, even with the price of fuel included to control for the variation in the price paid at gas stations in different provinces and

years. The signs of most of the coefficients are as expected. More time performing another activity, like driving, walking, or biking, results in less time spent away from home. A VIF test was performed on a linear version of the model to test for multicollinearity. The time spent at home and at work had the largest values, 2.28 and 1.91 respectively, but were not a concern for multicollinearity. The interpretation of the sign of other significant variables in the zero-inflated negative binomial model is more nuanced. For instance, older individuals spent more time away from home. Individuals also spent less time away from home in 2010 and 2015 than in 2005. The coefficients for household income and household income squared are interpreted as time spent away from home decreases as income increases. However, the behaviour reaches a minimum at around $64,000, at which point the time spent away from home begins to increase. The entire model is significant, at the 5% level.

Table 2: Summary of Zero-Inflated Negative Binomial Model

	Estimate	Std..Error	IRR	z.value	Pr...z..
(Intercept)	**8.1410**	**0.1358**	**3432.4**	**59.9270**	**0.0000**
mean provincial gas price in 2015 dollars	-0.0004	0.0011	0.9996	-0.3210	0.7482
carbon price in 2015 dollars	-0.0002	0.0009	0.9998	-0.1919	0.8478
in car	**-0.0016**	**0.0001**	**0.9984**	**-11.7751**	**0.0000**
in transit	**-0.0015**	**0.0002**	**0.9985**	**-7.3186**	**0.0000**
walking	**-0.0022**	**0.0003**	**0.9978**	**-8.5396**	**0.0000**
biking	**-0.0028**	**0.0008**	**0.9972**	**-3.6519**	**0.0003**
age group (10 year bins)	**0.0104**	**0.0037**	**1.0105**	**2.8175**	**0.0048**
Female	-0.0178	0.0107	0.9824	-1.6622	0.0965
children in house	0.0002	0.0075	1.0002	0.0275	0.9781
adults in house	0.0021	0.0069	1.0021	0.2962	0.7671
education years	0.0021	0.0024	1.0021	0.8682	0.3853
income in 2015 dollars ($10,000 bins)	**-0.0010**	**0.0002**	**0.9990**	**-5.9675**	**0.0000**
income squared	**0.0000**	**0.0000**	**1.0000**	**53.6318**	**0.0000**
No partner in household	-0.0009	0.0127	0.9991	-0.0692	0.9449
Year 2010	**-0.0516**	**0.0134**	**0.9497**	**-3.8495**	**0.0001**
Year 2015	**-0.1490**	**0.0156**	**0.8616**	**-9.5272**	**0.0000**
at home	**-0.0027**	**0.0000**	**0.9973**	**-129.4053**	**0.0000**
at work	**-0.0031**	**0.0000**	**0.9969**	**-114.7514**	**0.0000**
			Odds Ratio		
(Intercept)	**-7.2130**	**0.1524**	**0.0007**	**-47.3245**	**0.0000**
at home	**0.0055**	**0.0001**	**1.0055**	**43.8925**	**0.0000**
at work	**0.0064**	**0.0001**	**1.0064**	**53.7557**	**0.0000**

N = 29795
Theta = 2.3606
Number of iterations in BFGS optimization: 1
Log-likelihood: -1.089e+05 on 23 Df
AIC = 217800.452
Pseudo-R^2 = 0.249
McFadden's pseudo-R^2 = 0.072
Maximum likelihood R^2 = 0.435
Table 2: results from the zero-inflated negative binomial model

4.5 Discussion

According to the model, the answer to the research question is that carbon pricing has not had a significant impact on time spent away from home in a social setting. Also of note, a change in gasoline prices did not significantly change the amount of time an individual spent away from

home. The incident risk ratio (IRR) column shows the expected change in the time spent away from home for a one unit change in one of the variables. For the variables that also represent a count in minutes, time in car, time in transit, time walking, time biking, time at home, and time at work, the IRR values are all just under one so, while significant, spending one more minute doing one of those activities reduced the time spent away from home by just a few seconds. For the categorical variables, like Year, the IRR represents the difference between the variable shown and the reference case. For example, the median individual spent 30 minutes away from home in 2005. According to the model, the same individual would have spent just under 26 minutes away from home in 2015. The interpretation for the zero-inflated part of the model is that an individual would almost certainly spend time away from home if they spent zero minutes at home or at work. For each minute an individual spends at home or at work, their chances of spending zero minutes away from home decreases.

There are three possible explanations which may be the most likely reasons for carbon pricing not being significant in the model. First, carbon pricing in Canada, up until 2015, has been too low to elicit significant behavioural changes in residents for time spent away from home. In 2010, only British Columbia had a price on carbon and was joined by only Québec in 2015 (McCarthy, 2019). The added cost to gasoline rose from 3.49¢/L to 4.65¢/L in British Columbia during 2010 and was 6.98¢/L in 2015. For Québec in 2015, the added cost to gasoline would have averaged around 3.5¢/L. During 2010 and 2015, the total cost of gasoline was between 112¢/L and 120¢/L in British Columbia and Québec. This means the cost of operating a private vehicle increased less than 6% for just fuel alone in British Columbia in 2015. As discussed in Section 4.2.2, this increase would decrease automobility around 2% - 4% in the short term and automobility would return close to pre-carbon pricing levels in the long term. From the statistical model, it appears this small reduction in automobility did not significantly reduce the respondents' social time away from home.

Second, auto dependency is high in Canada, but residents are making behavioural changes so that social time away from home is not greatly affected. Spinney et al. (2020) found that driving status for seniors did not significantly change socializing away from home. This was possibly due to fewer episodes of socializing but extending the duration of each episode. Car-dependent households may try to save money on fuel by reducing their total number of trips but lengthening the duration of trips they do make. Alternatively, the behavioural change could be that increases in gasoline prices were offset by increases in fuel efficiency. Frondel and Vance (2017) have shown that increasing prices does reduce driving, but not as much as increasing fuel efficiency increases driving. On average, carbon pricing in Canada may have had no effect as the increased cost was offset by using less gasoline due to increased vehicle efficiency. Overall, Canadians driving as much as they did before carbon pricing but driving more efficient vehicles would be good for Canada's environmental commitments as less gasoline would be used to drive the same distance.

Third, urban areas provide adequate access to alternative transportation modes. In the model, the amount of time spent using a mode of transportation was significant and all coefficients indicated an individual spent less time socializing for an increase in transportation time. Unfortunately, the data are not cross-sectional so it cannot be determined if individuals, on average, changed their travel mode of choice due to carbon pricing. The data were restricted to only individuals living in urban areas so it is more likely they have transportation choices other than private vehicles yet,

the model cannot answer if individuals chose other modes of transportation due to an increased cost in using private vehicles.

Two other significant variables merit more discussion as to how they affect the time spent away from home. First is income. The model contains income as both a linear and squared variable. The coefficient of the linear term is negative while the coefficient of the squared term is positive. These coefficients indicate that the amount of time spent away from home decreases as income increases, for very low incomes. Once household income is approximately $64,000/a, the amount of time spent away from home begins to increase. There is a weak correlation in the data between household income and household size. It is possible the lower income households are more likely to be young, single adults who spend more time away from home. It is safe to assume that wealthier households have more disposable income which may be spent on socializing. It has been shown that higher income households consume more and emit a disproportionate amount of carbon, compared to lower income households (Brand et al., 2013). The second significant variable that will be discussed is Year. Compared to 2005, individuals spent significantly less time away from home in a social setting in 2010 and 2015. This may be a continuation of a trend seen by Farber and Páez (2011a). They showed a decreasing amount of time spent socializing out of the home from 1992 to 2005 using the GSS. The time period studied by Farber and Páez (2011a) is before more widespread use of the Internet for socialization so their conclusion is that increased distance, hence more time driving, is the reason for less time socializing. That conclusion may also hold for this analysis. An increase in socializing via the Internet may also apply for this research since 2010 and 2015 are being compared to 2005. In addition, time spent shopping is included in the dependent variable. On-line shopping has increased since 2005 and may explain less time spent away from home in a social setting (Schultz and Block, 2015). Economic factors may have also affected an individual's ability to socialize away from home. The recession following the 2008 financial crisis was still occurring in Canada in 2010 (Gordon, 2017), so individuals may have had less disposable income or more economic uncertainty, which led to less time for discretionary activities.

There are some limitations to the explanatory power of the model. First and foremost is that the model was created using the public-use microdata file. To maintain confidentiality, variables like age and household income were categorized by Statistics Canada. However, most importantly for this model, an individual's location was limited to the province in which they lived and if they lived in an urban or rural area. Future work is planned using the confidential GSS from Statistics Canada. This work was not completed as of writing as Statistics Canada's Research Data Centres were closed due to the COVID-19 pandemic. The confidential GSS contains the individual's location down to the Dissemination Area level of geography, an area that consists of about 400-700 individuals (Statistics Canada, 2018a). This level of spatial accuracy will allow additional variables to be used to control for car dependence and land-use factors. A second limitation is the number of provinces in Canada that had carbon pricing policies in effect when the GSS was collected; only British Columbia in 2010 and British Columbia and Québec in 2015 (McCarthy, 2019). The GSS – Time Use was scheduled to be collected again in 2020. At that point, every province in Canada had a carbon pricing policy in place, either their own or the Federal Carbon Pricing Backstop (Environment and Climate Change Canada, 2017; McCarthy, 2019). However, the COVID-19 pandemic has either stopped the collection of the GSS in 2020 and/or affected behaviours so that the 2020 dataset could not be analyzed in conjunction with previous GSS collections.

4.6 Conclusions

This analysis shows that carbon pricing in Canada has not significantly affected the amount of time individuals spent away from home in a social setting. However, due to the limitations of the data and model, it can only be assumed why carbon pricing has had no significant effect. The low number of provinces with a carbon pricing policy at the time the data were collected and the low price on carbon were likely contributing factors. It was assumed that Canada is a very car dependent country, but it could not be determined by the model how individuals coped with increased gasoline prices without impacting time spent socializing. It is hoped future work will better be able to better answer the research question.

5 Conclusion

The goal of this research was to answer two questions. First, how have governments in Canada discussed the impact of carbon pricing on mobility and social exclusion? Second, how has carbon pricing in Canada affected the mobility of individuals and their ability to engage in social activities away from home? The three academic articles in this thesis answer these two questions. The first two papers, the NLP paper and the framing paper, both show a policy disconnect between the federal, provincial, and municipal governments. The first two levels of government are setting carbon prices across Canada while the latter is left to deal with the everyday needs of residents. The everyday needs which are the focus of this thesis are mobility and social exclusion.

The remained of this chapter will discuss how the three theoretical concepts informed the research in the three academic articles, the contribution to academic research made by the three academic articles, their policy implications, and proposed future work to continue this area of research.

5.1 Use of concepts

5.1.1 Scale

Despite being a broad and complex concept, in the three articles in this thesis, scale was limited to hierarchical scale and relative scale.

Hierarchical scale is represented by the power dynamics between different levels of government in Canada, where carbon pricing is a contentious issue. There is an ongoing power struggle between federal and provincial governments on who has the authority to set carbon pricing. The federal government has implemented a carbon pricing backstop so the entire country meets a minimum price on carbon. Three provinces contend the federal government has overstepped its authority and have brought court cases against the backstop (McCarthy, 2019; Office of the Parliamentary Budget Officer, 2020; Stefanovich, 2020). There is also a struggle between municipal governments for federal and provincial investment in green infrastructure projects. Municipalities have a wish list of projects and must request and then wait for higher levels of government to provide funding. This dependency on higher levels of government, which must pick and choose projects from all over the country or province, is a zero-sum game when it comes to providing for residents' everyday mobility and reducing social exclusion. Increasing federal or provincial funding for one project means less funding, or no funding, for another project (Federation of Canadian Municipalities, 2020; Infrastructure Canada, 2020).

Relative scale was a factor in carbon pricing not having a significant effect on social exclusion. The additional cost of carbon pricing was relatively small compared to the total cost of fuel. In the modelling paper, the maximum price on carbon was \$30/tCO_2e. This price adds 6.98¢/L to the cost of gasoline. The cost of gasoline in Canada in the years covered in the modelling paper was between 95¢/L and 122¢/L (Statistics Canada, 2018b). This means that the carbon price added about six or seven per cent to the total cost of gasoline. Using the coefficients from Gillingham (2014), the lowest quartile of households would decrease their driving by two per cent while the highest quartile of households would decrease driving by just one per cent due to carbon pricing increasing the cost of gasoline. Gillingham's (2014) modeling may over-estimate the effect of the carbon price since the lowest quartiles of households receive a carbon pricing rebate that exceeds the increase in their total household expenditures due to the carbon pricing

backstop (Office of the Parliamentary Budget Officer, 2020). If governments wish to reduce driving by only using carbon pricing as a disincentive, the concept of relative scale suggests the added cost due to carbon pricing needs to be larger, relative to the total cost of gasoline although this could affect lower socio-economic households more depending on the rebate structure.

5.1.2 Mobility

Providing mobility for residents is a prime concern for municipal governments. The NLP and framing analyses showed most municipal documents contain text about mobility, but priorities differ between business-as-usual automobility and a switch to alternative forms of mobility. The framing analysis in particular revealed that car culture still dominates municipal planning. Three of the four cities analyzed used The Growing City frame to convince residents that they could expect more of the same; more roads to alleviate more congestion from more people and more expansion of the city. Changing car culture has been difficult, even as the negative externalities of private vehicle use on cities and the environment become more and more well-known. Attitudes about car culture may be changing, especially amongst younger generations, and Western countries may be seeing less use of private automobiles. That is to say, they may be past "peak car" (Bastian et al., 2016; Newman and Kenworthy, 2011; Stapleton et al., 2017). Economic inequity may be a factor behind declining use of private automobiles (Manville et al., 2017) as well as the changing attitudes of Millennials (McDonald, 2015). Yet, despite some Millennials seeing private vehicles as wasteful and environmentally unfriendly, car culture means they are still obtaining their driver's licences due to feelings of needing to drive to access opportunities (Hopkins, 2016).

Urry (2004) stated that breaking the culture of private vehicle dependence would require political, policy, and social change. The framing paper showed that these political and policy changes may be occurring. All of the frames, except The Growing City frame, were used by municipal governments to influence their residents' thinking on alternative mobility. If You Build It, They Will Come and Better City for All are prognostic frames. They present a solution and encourage the reader/recipient to work towards that solution (Cress and Snow, 2000). These frames are used by municipalities to present the benefits of alternative mobility in an attempt to lead residents to reduce use of private vehicles. The Resilient City frame has the same goal but an opposite approach. It is a diagnostic frame in that it presents a problem and then leads the recipient to the desired solution (Cress and Snow, 2000). By using The Resilient City, political and policy decisions are framed as a response to climate change and the solution is decreased dependency on private vehicles.

Another key contribution of the mobility literature was in selecting independent variables for the econometric model. Particularly, if the GSS with the geographic location of the survey respondents had been available in 2020, variables could have been used to control for dependence on private vehicles due to location. There is a clear link in the academic literature between mobility and social exclusion (Delbosc and Currie, 2011; Lucas et al., 2016a; Mattioli et al., 2017; Stanley et al., 2011). A location variable in the data would have enabled the model to account for the availability of alternative mobility choices where the respondents lived. Control variables would have been chosen with the 3Ds – density, diversity, and design – as a starting point (Cervero and Kockelman, 1997). This was not possible due to the physical closure of Statistics Canada's Research Data Centre during the COVID-19 pandemic (see section 5.5.2).

5.1.3 Social Exclusion

The results from the NLP and framing papers show that governments in Canada pay little attention to social exclusion beyond stating it is a problem and using hopeful, non-specific text that it will be reduced. Word vectors consistently returned lower similarity scores when trying to find text on social exclusion compared to text on mobility. This means that, amongst the topics returned by each run of the LDA algorithm, one topic always represented mobility more than another topic represented social exclusion. Stated another way, the highest similarity scores between the representative words for each topic and either the mobility or social exclusion word lists was always greater for the mobility word list. The framing paper showed that the two main frames used in municipal documents, The Growing City and The Resilient City, did not focus on social exclusion. Text about social exclusion was contained in the other two frames – If You Build It, They Will Come and Better City for All. These frames used by municipalities contain wishful thinking that simply providing more public space and active transportation infrastructure will reduce social exclusion. There is some support in the academic literature that providing public space and alternative mobility infrastructure will reduce social exclusion (e.g., Ma et al., 2018), but the Canadian cities in the framing paper do not include specific goals in this area.

The modelling paper suggests no impact from carbon pricing on social exclusion. As discussed in Section 5.1.1, this may be due to the low price on carbon and households prioritizing spending on mobility. Section 5.4 contains future research directions in order to further determine if, or how, carbon pricing may be impacting social exclusion in Canada.

5.2 Research contribution

One of the chief research contributions in this thesis is the NLP process for finding secondary topics in a large corpus. As stated in the NLP paper, content analysis is traditionally done by reading and manually coding text (e.g., McTavish and Pirro, 1990). If specific topics are being sought within the corpus, either the entire corpus must be read, or sections selected based on titles or quick skimming of the text. Even skimming over the text in a large corpus can be time consuming and there is no economy of scale as a corpus becomes larger or new documents are introduced. Social scientists have begun using NLP methods over the past decade (Gerrish and Blei, 2012; Goldstone and Underwood, 2012; Mimno, 2012a; Mimno, 2012b; Schofield et al. 2017). However, NLP, and specifically LDA, are applied as an unsupervised classification. An unsupervised classification is when an algorithm groups similar items together but does not label the output. An example of unsupervised classification from traditional statistical techniques is k-means clustering, where the analyst labels groups that emerge from data. The use of LDA has advanced to where users are applying algorithms in an attempt to automatically label the topics returned by the LDA algorithm (Kinra et al. 2020; Kou et al. 2015; Tirunillai and Tellis 2014). These applications of LDA are still unsupervised and will not find specific, secondary topics in a large corpus. The NLP paper proposes a new method for determining which topic returned by the LDA algorithm is most similar to a pre-determined topic. The algorithm can then suggest which documents in the entire corpus are more likely to contain text on the pre-determined topic.

The second research contribution are the frames found in the municipal planning documents. Two of the frames, The Growing City and The Resilient City, indicate whether a municipal government is concerned with climate change or not. It was shown, in the framing paper, that one of these two frames is typically used early in the document and so quickly indicates if the municipality intends to keep expanding or if it intends to adapt to and/or mitigate the effects of

climate change. References to the Growing City frame suggest business as usual, whereas references to the Resilient City frame indicate a commitment responding to climate change. These frames can be used to analyze future municipal plans. For example, the City of Edmonton released a draft of its new city plan in September 2020. Like the 2009 Transportation Master Plan, which is included in the framing paper, it begins by using The Growing City frame, suggesting the City of Edmonton is still not serious about climate change.

5.3 Findings, problems with current policies, and future direction for policy

The results of the three academic papers in this thesis indicate that governments in Canada are not doing enough to reduce GHG emissions and lack a coherent policy approach. The NLP paper showed a policy disconnect between the three levels of government, the framing paper showed a focus on continued growth with little consideration for climate change, and the modelling paper showed little to no behaviour change due to carbon pricing up to 2015.

The policy disconnect was between governments applying a carbon price and those responsible for daily mobility and social exclusion. The federal and provincial governments are implementing carbon pricing policies and attempting to make them progressive policies by lowering taxes or giving rebates. The federal government's pan-Canadian framework on clean growth states that federal, provincial, and territorial governments will work together to incentivize a shift to less carbon intensive forms of mobility (Environment and Climate Change Canada, 2016). However, the framework only states that mobility investment will be in public transit upgrades and expansions. Of note is the use of the word, "infrastructure", when discussing public transit. It appears increased funding for *operating* public transit is not considered. At the provincial level, the Government of British Columbia (2008) made its carbon price revenue neutral by reducing income taxes on the lowest two tax brackets, as well as cutting corporate taxes. Under Alberta's initial, economy-wide provincial carbon pricing policy, households received rebates and those rebates were phased out as household income increased (Winter and Dobson, 2013). The federal and provincial carbon pricing policies reviewed lack specific details on how those two levels of government will work with municipal governments in providing and maintaining alternative mobility for residents, beyond building more light rail.

Looking at Canada's price on carbon, it seems to be appropriate to elicit the desired change. In 2022, Canada's carbon price will be \$50/tCO_2e and it will rise to \$170/tCO_2e by 2030 (Environment and Climate Change Canada, 2017; Environment and Climate Change Canada, 2020). This price is approximately in line with the price on carbon required to limit warming to 2°C, according to Nordhaus (2014). It appears carbon pricing up to \$30/tCO_2e in British Columbia and Québec did not elicit behavioural changes up to 2015, according to the results of the modelling paper, so further increases are necessary to encourage change.

In Canada, the carbon price needs to continue increasing, as economic models like Nordhaus' (2014) suggest. But this disincentive to emit GHG should not be the only policy and rebates should not be the only instrument to ensure the carbon pricing policy is progressive. Currently, 90% of revenue raised by the federal backstop is returned to households as a rebate (Office of the Parliamentary Budget Officer, 2020). The rebate distribution means that most households receive more money in rebates than they pay to emit carbon. The households that pay more than they receive are in the top two income quintiles. If alternate forms of mobility are not incentivized, the rebate may not change driving behaviours, or may make them worse, as households tend to prioritize driving costs (Mattioli, 2017). Without improved mobility alternatives, households in

the lowest income quintiles could reduce their carbon footprint in other areas and use their rebate to maintain or increase private vehicle use. Households in the top income quintiles should have enough discretionary spending to cover the increased cost of fuel due to carbon pricing, although high socioeconomic households have been shown to decrease private vehicle use when gasoline prices increase (Gillingham, 2014). Since households do not necessarily maximize their utility as economic textbooks predict, carbon pricing needs to be supplemented with other policies, like stricter fuel economy standards (Boyce, 2018; Klenert et al., 2018). But, most importantly, all levels of government need to make coordinated investments in transit and other alternative forms of mobility (Boyce, 2018). A unified approach from all levels of government is required to incentivize change and reduce GHG emissions.

All levels of government need to commit the money raised through carbon pricing to being spent on alternative mobility and densification of cities. Cities should be designed around the concepts of the compact city, also known as the 15-minute city (O'Sullivan, 2020); the woonerf; or the "city of short distances" (see Handy, 2020). Governments using these planning philosophies are attempting to make cities more accessible. By designing cities such that work, shopping, and leisure destinations are within 15 minutes of walking, biking, or public transit, cities could increase accessibility, lower GHG emissions, and decrease social exclusion (Stanley et al., 2011). All levels of government would need to be involved. Federal and provincial governments would need to commit to not just funding light rail transit projects but also provide funding for the day-to-day operation of public transit. Currently, funding of public transit in cities varies considerably from province to province (Canadian Urban Transit Association, 2013). For example, 40% of transit funding in Alberta comes from municipal governments and 25% comes from the provincial government. In Ontario, transit funding is 23% from municipal governments and 42% from the provincial government (Canadian Urban Transit Association, 2013). Infrastructure projects that increase car dependence, like ring roads and freeway interchange expansions, would need to have reduced funding. Provincial laws govern the ability of municipalities to annex land (Meligrana, 2013). This means provinces can restrict greenfield expansion and create policies in unison with municipal governments to encourage densification. Incentives to reduce GHG emissions do not need to be universal. Mapping the carbon consumption required to live in various areas of a city can help show where action is required to reduce GHG emissions (Kinigadner et al., 2020). In Canada, particular attention needs to be paid to how to maintain alternative mobility for all and the ability to access social destinations in the winter (Stout et al., 2018).

5.4 Study Limitations

The framing paper had two main limitations. First, as mentioned in the paper, the only suitable documents for the framing analysis which were suggested by the NLP algorithm were from four Canadian cities: Calgary, Edmonton, Vancouver, and Winnipeg. While documents from these four did reveal one frame that did not seriously address climate change, the Growing City, and one frame that did address climate change, the Resilient City, those four cities may not be representative of cities in Canada. The four cities are located in the four western-most provinces in Canada and two of the cities, Calgary and Edmonton, are both in the province of Alberta. No documents from the two most populous provinces in Canada, Québec and Ontario, are represented in the corpus. The NLP algorithm only suggested one document from Ontario but it was a short summary of a council meeting and did not contain a frame. Documents from Québec were excluded due to the research being conducted only on English-language documents.

The second limitation was the slight mismatch between how the documents were selected and how they were ultimately analyzed. The NLP algorithm was programmed to find documents which contained text on mobility and social exclusion, and it successfully found 22 documents for the framing analysis. However, the framing analysis ended up focussing more on frames that were generally related to climate change. The Growing City and Resilient City frames were predominantly used to frame mobility issues while the If You Built It, They Will Come and Better City for All frames tended to frame issues of social exclusion. Both limitations could have been mitigated by changing the selection criteria for the municipal documents. The framing analysis would have likely had similar results if municipal master plans from cities across Canada had been selected though the focus on carbon pricing, mobility, and social exclusion would have been lacking.

5.5 Future Work

Each of the three academic articles that make up this thesis contain suggestions on directions for further research, but these suggestions are limited to the topic of the article. Some of the future research based upon the work in this thesis spans more than one of the articles or was not suggested in an article at the time it was submitted for publication. The two main directions for future research are attitudes about, and effects of, carbon pricing in Canada.

5.5.1 Attitudes Towards Climate Change Adaptation and Carbon Pricing

In the framing paper, how municipal governments framed the future growth of cities was analyzed. Some of the municipal documents used in the framing analysis are about a decade old. The oldest document was the Transportation Master Plan from the City of Edmonton which was published in 2009 (see Appendix 1 for a complete list of the municipal documents used in the framing paper). The City of Edmonton is reviewing the next iteration of its municipal plan document as of September 2020 (City of Edmonton, 2020). Future research should be conducted, comparing the framing used in updated municipal documents with the framing used in the documents analyzed in the framing paper. In Edmonton's case, over ten years has passed between the analyzed document and an updated document. In 2009, the City of Edmonton predominantly used the Growing City frame which emphasizes continued, business as usual growth with climate change mitigation or adaptation receiving little mention. Awareness of anthropogenic climate change has increased in those ten years (Environics Institute and David Suzuki Foundation, 2014). Examining updated municipal documents would consider if the frames used in municipal planning documents changed along with public awareness.

A limitation of the framing paper was that only what municipal governments were writing in planning documents was being analyzed. The City of Vancouver was the only city analyzed that was "talking the talk" about climate change. The other three cities examined in the framing paper only gave passing mention to mitigation or adaptation. Analysis as to whether or not the four studied cities are "walking the walk" should be done. The City of Vancouver's Greenest City Action Plan 2020 contained targets and performance measures. An analysis could be undertaken on whether cities implement their plans with respect to the main frame they use in their planning documents. City planner and urbanist, Brent Toderian, is quoted as saying, "the truth about a city's aspirations isn't found in its vision. It's found in its budget." Future research should examine if cities that use the Growing City and Resilient City frames meet or exceed planned infrastructure spending. My initial hypothesis would be that cities that use the Growing City frame would exceed planned spending for infrastructure projects that increase car dependency.

A third area of research is the change in public perception of needed municipal infrastructure spending due to climate change. This area of research would require applying NLP methods to historical documents to analyze the change over time. The corpus could be comprised of documents like newspaper opinion pieces or letters to the editor, citizen submissions to municipal governments, or blog posts. The frames from the framing paper could be used to examine if public perception differs from how the municipal government has framed the issue or if the use of a particular frame has influenced public perception.

5.5.2 The Effect of Carbon Pricing on Mobility and Social Exclusion

The first step to better answer how has carbon pricing affected mobility and social exclusion in Canada would be to update the statistical model in this thesis using the confidential GSS. As stated in both the introduction and as a limitation in the modelling paper, the confidential GSS was not available because Statistics Canada's Research Data Centre at the University of Alberta was closed due to the COVID-19 pandemic. When the confidential GSS can be used, the statistical model can be improved with variables that better control for the respondents' demographics, socioeconomic status, and the physical characteristics of their neighbourhood. The PUMF only contains two variables to locate the respondents: their province and if they live in an urban or rural location. The confidential GSS contains their geographic location at the dissemination area level. The dissemination area can be combined with census data to calculate additional control variables based on Cervero and Kockelman's (1997) three Ds of travel demand: density, diversity, and design. Population density and housing stock are two variables which fit under the three Ds. The three Ds have been expanded to at least six Ds by including destination accessibility, distance to transit, and demographics (Ewing and Cervero, 2001; Ewing et al, 2015). The Canadian census contains data on commute time and mode, household size, and income which fall under the six Ds. Adding extra variables to better control for local area effects around the respondents would likely improve the explanatory power of the statistical model. This is because an individual's response to increased automobility costs due to carbon pricing is likely influenced by their fuel consumption habits and the availability of alternative forms of mobility.

The effect of carbon pricing on mobility and social exclusion could also be answered in a different way using the GSS. For example, the time spent driving could be the dependent variable while the price on carbon in Canada is the independent variable. This model would be similar to the one used in the modelling paper with time spent driving and time spent away from home in a social setting switching places. The variables used to explain the excess number of zeros in the time spent driving would also need to change. The same improvements to the model mentioned in the previous paragraph would also be necessary.

Similar models could also be built using the Survey of Household Spending (SHS) instead of the GSS. In academia, using the GSS is more common than using the SHS. A Google Scholar search for "statistics canada", "general social survey", and "time use" returns 1310 results while a search for "statistics canada" and "survey of household spending" returns 951 results, The Time Use survey is just one version of the GSS and is collected once every five years. Despite being more popular in academic research, the five year collection cycle was a limitation in the modelling paper because only data from 2005, 2010, and 2015 were available. By 2015, only two provinces had economy-wide carbon pricing and the federal government's carbon pricing backstop did not come in to effect until 2019 (Environment and Climate Change Canada, 2017; McCarthy, 2019). In contrast to the GSS, the SHS is collected annually (Statistics Canada, 2017e). Instead of answering how *time* spent on mobility and social exclusion changed due to carbon pricing, the

SHS could answer how *money* was spent differently on mobility and social activities. The SHS would likely have more explanatory power because the more frequently and recently collected data may have better measured changes in behaviour due to changes in carbon pricing. Building a statistical model using the SHS should be a priority for future work.

5.6 Closing remarks

Anthropogenic climate change is occurring and GHG emissions need to be reduced. Carbon pricing is an effective tool to nudge individuals to change behaviours. There is an opportunity for those who live in cities to reduce their GHG emissions by driving less and increasing the density of the communities in which they live. This thesis has shown that, while Canada is on the right track with its federal carbon pricing backstop, there is still more that can be done. An integrated approach by all three levels of government in Canada can reduce GHG emissions, provide adequate mobility, and decrease social exclusion. It is possible to make Canadian cities healthier and happier.

References

1. Achtnicht, M. (2012). German car buyers' willingness to pay to reduce CO2 emissions. *Climatic Change*, *113*(3–4), 679–697. https://doi.org/10.1007/s10584-011-0362-8
2. Adey, P. (2006). If Mobility is Everything Then it is Nothing: Towards a Relational Politics of (Im)mobilities. *Mobilities*, *1*(1), 75–94. https://doi.org/10.1080/17450100500489080
3. Adey, P. (2017). *Mobility*. Taylor & Francis.
4. Bank of Canada. (2020, April 1). *Inflation Calculator*. https://www.bankofcanada.ca/rates/related/inflation-calculator/
5. Barnes, T. J. (2008). History and philosophy of geography: Life and death 2005—2007. *Progress in Human Geography*, *32*(5), 650–658. https://doi.org/10.1177/0309132507086883
6. Barns, S. (2016). Mine your data: Open data, digital strategies and entrepreneurial governance by code. *Urban Geography*, *37*(4), 554–571. https://doi.org/10.1080/02723638.2016.1139876
7. Bastian, A., Börjesson, M., & Eliasson, J. (2016). Explaining "peak car" with economic variables. *Transportation Research Part A: Policy and Practice*, *88*, 236–250. https://doi.org/10.1016/j.tra.2016.04.005
8. Beck, M., Rivers, N., Wigle, R., & Yonezawa, H. (2015). Carbon tax and revenue recycling: Impacts on households in British Columbia. *Resource and Energy Economics*, *41*, 40–69. https://doi.org/10.1016/j.reseneeco.2015.04.005
9. Benedick. (1996). Montreal Protocol on Substances that Deplete the Ozone Layer. *International Negotiation*, *1*(2), 231–246. https://doi.org/10.1163/15718069620847781
10. Benford, R. D., & Snow, D. A. (2000). Framing Processes and Social Movements: An Overview and Assessment. *Annual Review of Sociology*, *26*(1), 611–639. https://doi.org/10.1146/annurev.soc.26.1.611
11. Bergstad, C. J., Gamble, A., Gärling, T., Hagman, O., Polk, M., Ettema, D., Friman, M., & Olsson, L. E. (2011). Subjective well-being related to satisfaction with daily travel. *Transportation*, *38*(1), 1–15. https://doi.org/10.1007/s11116-010-9283-z
12. Bhaskar, R. (2016). Enlightened common sense: The philosophy of critical realism. Routledge.
13. Bickel, M. W. (2019). Reflecting trends in the academic landscape of sustainable energy using probabilistic topic modeling. *Energy, Sustainability and Society*, *9*(1), 1–23.
14. Bird, S., Klein, E., & Loper, E. (2009). Natural language processing with Python: Analyzing text with the natural language toolkit. O'Reilly Media, Inc.
15. Blei, D. M. (2012). Probabilistic topic models. *Communications of the ACM*, *55*(4), 77–84.
16. Blei, D. M., Ng, A. Y., & Jordan, M. I. (2003). Latent Dirichlet Allocation. *Journal of Machine Learning Research*, *3*(Jan), 993–1022.
17. Boyce, J. K. (2018). Carbon Pricing: Effectiveness and Equity. *Ecological Economics*, *150*, 52–61. https://doi.org/10.1016/j.ecolecon.2018.03.030
18. Brand, C., Goodman, A., Rutter, H., Song, Y., & Ogilvie, D. (2013). Associations of individual, household and environmental characteristics with carbon dioxide emissions from motorised passenger travel. *Applied Energy*, *104*, 158–169. https://doi.org/10.1016/j.apenergy.2012.11.001
19. Brenner, N. (1998). Between fixity and motion: Accumulation, territorial organization and the historical geography of spatial scales. *Environment and Planning D: Society and Space*, *16*(4), 459–481.

20. Brenner, N. (2001). The limits to scale? Methodological reflections on scalar structuration. *Progress in Human Geography*, *25*(4), 591–614.
21. Buck, N. (2001). Identifying neighbourhood effects on social exclusion. *Urban Studies*, *38*(12), 2251–2275.
22. Buehler, R., Pucher, J., Gerike, R., & Götschi, T. (2017). Reducing car dependence in the heart of Europe: Lessons from Germany, Austria, and Switzerland. *Transport Reviews*, *37*(1), 4–28. https://doi.org/10.1080/01441647.2016.1177799
23. Bureau, B. (2011). Distributional effects of a carbon tax on car fuels in France. *Energy Economics*, *33*(1), 121–130. https://doi.org/10.1016/j.eneco.2010.07.011
24. Büscher, M., Sheller, M., & Tyfield, D. (2016). Mobility intersections: Social research, social futures. *Mobilities*, *11*(4), 485–497. https://doi.org/10.1080/17450101.2016.1211818
25. Bygstad, B., & Munkvold, B. E. (2011). In search of mechanisms. Conducting a critical realist data analysis.
26. Cameron, A. (2005). Geographies of welfare and exclusion: Initial report. *Progress in Human Geography*, *29*(2), 194–203. https://doi.org/10.1191/0309132505ph542pr
27. Cameron, A. (2006). Geographies of welfare and exclusion: Social inclusion and exception. *Progress in Human Geography*, *30*(3), 396–404.
28. Canada's Ecofiscal Commission. (2019). *Bridging the Gap: Real Options for Meeting Canada's 2030 GHG Target*. https://ecofiscal.ca/wp-content/uploads/2019/11/Ecofiscal-Commission-Bridging-the-Gap-November-27-2019-FINAL.pdf
29. Canadian Urban Transit Association. (2013). *Federal, Provincial and Territorial Public Transit Funding Programs in Canada*. https://cutaactu.ca/sites/default/files/cuta-federal_provincial_territorial_funding_report-2012.pdf
30. Cass, N., & Faulconbridge, J. (2017). Satisfying Everyday Mobility. *Mobilities*, *12*(1), 97–115. https://doi.org/10.1080/17450101.2015.1096083
31. CBC News. (2011, December 13). *Canada pulls out of Kyoto Protocol*. https://www.cbc.ca/news/politics/canada-pulls-out-of-kyoto-protocol-1.999072
32. Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research Part D: Transport and Environment*, *2*(3), 199–219. https://doi.org/10.1016/S1361-9209(97)00009-6
33. Chang, J., Gerrish, S., Wang, C., Boyd-Graber, J. L., & Blei, D. M. (2009). Reading tea leaves: How humans interpret topic models. *Advances in Neural Information Processing Systems*, 288–296.
34. Chen, Y., Gonder, J., Young, S., & Wood, E. (2017). Quantifying autonomous vehicles national fuel consumption impacts: A data-rich approach. *Transportation Research Part A: Policy and Practice*. https://doi.org/10.1016/j.tra.2017.10.012
35. City of Edmonton. (2020). *Edmonton City Plan*. https://www.edmonton.ca/city_government/documents/PDF/Draft_City_Plan_FINAL.pdf
36. Climate Action Network. (2013, November 22). *Canada wins 'Lifetime Unachievement' Fossil award at Warsaw climate talks*. https://climateactionnetwork.ca/2013/11/22/canada-wins-lifetime-unachievement-fossil-award-at-warsaw-climate-talks/
37. Collinge, C. (2006). *Flat ontology and the deconstruction of scale: A response to Marston, Jones*. http://www.jstor.org/stable/pdf/3804385.pdf
38. Couclelis, H., & Golledge, R. (1983). Analytic Research, Positivism, and Behavioral Geography. *Annals of the Association of American Geographers*, *73*(3), 331–339. https://doi.org/10.1111/j.1467-8306.1983.tb01420.x

39. Cox, K. R. (2013). Notes on a brief encounter: Critical realism, historical materialism and human geography. *Dialogues in Human Geography*, *3*(1), 3–21. https://doi.org/10.1177/2043820613485041
40. Cress, D. M., & Snow, D. A. (2000). The Outcomes of Homeless Mobilization: The Influence of Organization, Disruption, Political Mediation, and Framing. *American Journal of Sociology*, *105*(4), 1063–1104. https://doi.org/10.1086/210399
41. Cresswell, T. (2010). Towards a Politics of Mobility. *Environment and Planning D: Society and Space*, *28*(1), 17–31. https://doi.org/10.1068/d11407
42. Daly, M., & Silver, H. (2008). Social exclusion and social capital: A comparison and critique. *Theory and Society*, *37*(6), 537–566. https://doi.org/10.1007/s11186-008-9062-4
43. Delbosc, A., & Currie, G. (2011). The spatial context of transport disadvantage, social exclusion and well-being. *Journal of Transport Geography*, *19*(6), 1130–1137. https://doi.org/10.1016/j.jtrangeo.2011.04.005
44. Dissou, Y., & Siddiqui, M. S. (2014). Can carbon taxes be progressive? *Energy Economics*, *42*, 88–100. https://doi.org/10.1016/j.eneco.2013.11.010
45. Dudley, G., Banister, D., & Schwanen, T. (2017). The Rise of Uber and Regulating the Disruptive Innovator. *The Political Quarterly*. http://onlinelibrary.wiley.com/doi/10.1111/1467-923X.12373/full
46. Entman, R. M. (1993). Framing: Toward Clarification of a Fractured Paradigm. *Journal of Communication*, *43*(4), 51–58. https://doi.org/10.1111/j.1460-2466.1993.tb01304.x
47. Environics Institute & David Suzuki Foundation. (2014). *Canadian public opinion about climate change*. https://davidsuzuki.org/wp-content/uploads/2017/09/focus-canada-2014-canadian-public-opinion-climate-change.pdf
48. Environment and Climate Change Canada. (2016). *Pan-Canadian framework on clean growth and climate change: Canada's plan to address climate change and grow the economy.* http://www.deslibris.ca/ID/10065393
49. Environment and Climate Change Canada. (2017). *Technical paper on the federal carbon pricing backstop.* http://publications.gc.ca/collections/collection_2017/eccc/En4-306-2017-eng.pdf
50. Environment and Climate Change Canada. (2020a). *A Healthy Environment and a Healthy Economy*. https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/climate-plan/healthy_environment_healthy_economy_plan.pdf
51. Environment and Climate Change Canada. (2020b). *Quantification Guidance for the Output-Based Pricing System Regulations*. https://www.canada.ca/content/dam/eccc/documents/pdf/obps/OBPS_Quantification_Guidance_EN.pdf
52. Escobar, A. (2007). The 'ontological turn'in social theory. A commentary on 'Human geography without scale', by Sallie Marston, John Paul Jones II and Keith Woodward. *Transactions of the Institute of British Geographers*, *32*(1), 106–111.
53. Ewing, R., Bartholomew, K., Winkelman, S., Walters, J., & Chen, D. (2007). Growing Cooler: The Evidence on Urban Development and Climate Change. *Urban Land Institute*, *814*, 158.
54. Ewing, R., & Cervero, R. (2001). Travel and the Built Environment: A Synthesis. *Transportation Research Record: Journal of the Transportation Research Board*, *1780*(1), 87–114. https://doi.org/10.3141/1780-10

55. Ewing, R., Tian, G., Goates, J., Zhang, M., Greenwald, M. J., Joyce, A., Kircher, J., & Greene, W. (2015). Varying influences of the built environment on household travel in 15 diverse regions of the United States. *Urban Studies*, *52*(13), 2330–2348. https://doi.org/10.1177/0042098014560991
56. Farber, S., & Páez, A. (2011a). Mobility without accessibility: The case of car use and discretionary activities. In *Auto Motives: Understanding Car Use Behaviours* (pp. 89–105). Emerald Group Publishing Limited.
57. Farber, S., & Páez, A. (2011b). Running to stay in place: The time-use implications of automobile oriented land-use and travel. *Journal of Transport Geography*, *19*(4), 782–793. https://doi.org/10.1016/j.jtrangeo.2010.09.008
58. Faulconbridge, J., & Hui, A. (2016). Traces of a Mobile Field: Ten Years of Mobilities Research. *Mobilities*, *11*(1), 1–14. https://doi.org/10.1080/17450101.2015.1103534
59. Federation of Canadian Municipalities. (2020). *Green Municipal Fund*. https://fcm.ca/en/programs/green-municipal-fund
60. Fishman, R. (2008). Bourgeois utopias: The rise and fall of suburbia. Basic books.
61. Fletcher, A. J. (2017). Applying critical realism in qualitative research: Methodology meets method. *International Journal of Social Research Methodology*, *20*(2), 181–194. https://doi.org/10.1080/13645579.2016.1144401
62. Fletcher, A. L. (2009). Clearing the air: The contribution of frame analysis to understanding climate policy in the United States. *Environmental Politics*, *18*(5), 800–816. https://doi.org/10.1080/09644010903157123
63. Forstorp, P.-A. (2006). Quantifying automobility: Speed,'Zero Tolerance'and democracy. *The Sociological Review*, *54*(1_suppl), 93–112.
64. Frondel, M., & Vance, C. (2009). Do High Oil Prices Matter? Evidence on the Mobility Behavior of German Households. *Environmental and Resource Economics*, *43*(1), 81–94. https://doi.org/10.1007/s10640-008-9246-4
65. Frondel, M., & Vance, C. (2017). Drivers' response to fuel taxes and efficiency standards: Evidence from Germany. *Transportation*. https://doi.org/10.1007/s11116-017-9759-1
66. Garay, A. M., Hashimoto, E. M., Ortega, E. M., & Lachos, V. H. (2011). On estimation and influence diagnostics for zero-inflated negative binomial regression models. *Computational Statistics & Data Analysis*, *55*(3), 1304–1318.
67. Gerber, E. R., & Gibson, C. C. (2009). Balancing Regionalism and Localism: How Institutions and Incentives Shape American Transportation Policy. *American Journal of Political Science*, *53*(3), 633–648. https://doi.org/10.1111/j.1540-5907.2009.00391.x
68. Gerrish, S., & Blei, D. M. (2012). How they vote: Issue-adjusted models of legislative behavior. *Advances in Neural Information Processing Systems*, 2753–2761.
69. Gillingham, K. (2014). Identifying the elasticity of driving: Evidence from a gasoline price shock in California. *Regional Science and Urban Economics*, *47*, 13–24. https://doi.org/10.1016/j.regsciurbeco.2013.08.004
70. Girolami, M., & Kabán, A. (2003). On an equivalence between PLSI and LDA. *SIGIR*, *3*, 433–434.
71. Glaeser, Edward L., & Kahn, M. E. (2010). The greenness of cities: Carbon dioxide emissions and urban development. *Journal of Urban Economics*, *67*(3), 404–418. https://doi.org/10.1016/j.jue.2009.11.006
72. Glaeser, Edward Ludwig. (2012). Triumph of the city: How our greatest invention makes us richer, smarter, greener, healthier, and happier. Penguin.

73. Goetzke, F., & Rave, T. (2015). Automobile access, peer effects and happiness. *Transportation*, *42*(5), 791–805. https://doi.org/10.1007/s11116-015-9647-5
74. Goldstone, A., & Underwood, T. (2012). What can topic models of PMLA teach us about the history of literary scholarship. *Journal of Digital Humanities*, *2*(1), 39–48.
75. Goodwin, P., Dargay, J., & Hanly, M. (2004). Elasticities of Road Traffic and Fuel Consumption with Respect to Price and Income: A Review. *Transport Reviews*, *24*(3), 275–292. https://doi.org/10.1080/0144164042000181725
76. Goodwin, S. (2011). Analysing policy as discourse: Methodological advances in policy analysis. In *Methodological choice and design* (pp. 167–180). Springer.
77. Gordon, S. (2017). Recession of 2008–09 in Canada. In *The Canadian Encyclopedia*. https://thecanadianencyclopedia.ca/en/article/recession-of-200809-in-canada
78. Government of Alberta. (2017). *Carbon levy and rebate*. https://www.alberta.ca/climate-carbon-pricing.aspx
79. Government of British Columbia. (2008). *British Columbia Carbon Tax*. 8.
80. Government of British Columbia. (2017). *British Columbia's Revenue-Neutral Carbon Tax*. http://www2.gov.bc.ca/gov/content/environment/climate-change/planning-and-action/carbon-tax
81. Government of Canada. (2017). *Greenhouse gas sources and sinks: Executive summary*. https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/sources-sinks-executive-summary.html
82. Government of Ontario. (2018, August 2). *Ontario Announces Constitutional Challenge to Federal Government's Punishing Carbon Tax Scheme*. https://news.ontario.ca/mag/en/2018/08/ontario-announces-constitutional-challenge-to-federal-governments-punishing-carbon-tax-scheme.html
83. Haboucha, C. J., Ishaq, R., & Shiftan, Y. (2017). User preferences regarding autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, *78*, 37–49. https://doi.org/10.1016/j.trc.2017.01.010
84. Hagman, O. (2010). Driving Pleasure: A Key Concept in Swedish Car Culture. *Mobilities*, *5*(1), 25–39. https://doi.org/10.1080/17450100903435037
85. Handy, S. (2020). Is accessibility an idea whose time has finally come? *Transportation Research Part D: Transport and Environment*, *83*, 102319. https://doi.org/10.1016/j.trd.2020.102319
86. Hannam, K., Sheller, M., & Urry, J. (2006). Editorial: Mobilities, Immobilities and Moorings. *Mobilities*, *1*(1), 1–22. https://doi.org/10.1080/17450100500489189
87. Harvey, D. W. (1968). Pattern, Process, and the Scale Problem in Geographical Research. *Transactions of the Institute of British Geographers*, *45*, 71. https://doi.org/10.2307/621393
88. Hoefle, S. W. (2006). Eliminating scale and killing the goose that laid the golden egg? *Transactions of the Institute of British Geographers*, *31*(2), 238–243.
89. Hong, J., Shen, Q., & Zhang, L. (2014). How do built-environment factors affect travel behavior? A spatial analysis at different geographic scales. *Transportation*, *41*(3), 419–440. https://doi.org/10.1007/s11116-013-9462-9
90. Hopkins, D. (2016). Can environmental awareness explain declining preference for car-based mobility amongst generation Y? A qualitative examination of learn to drive behaviours. 15.
91. Huckle, J. (2004). Critical Realism: A Philosophical Framework for Higher Education for Sustainability. In P. B. Corcoran & A. E. J. Wals (Eds.), *Higher Education and the*

Challenge of Sustainability (pp. 33–47). Kluwer Academic Publishers. https://doi.org/10.1007/0-306-48515-X_4
92. Infrastructure Canada. (2020, March 13). *Green Infrastructure: Investing in Green Infrastructure*. https://www.infrastructure.gc.ca/plan/gi-iv-eng.html
93. International Carbon Action Partnership. (2020, June 30). *Allowance Price Explorer*. https://icapcarbonaction.com/en/ets-prices
94. IPCC. (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation: Special Report of the Intergovernmental Panel on Climate Change (C. B. Field, V. Barros, T. F. Stocker, & Q. Dahe, Eds.). Cambridge University Press. https://doi.org/10.1017/CBO9781139177245
95. Jonas, A. E. (2006). Pro scale: Further reflections on the 'scale debate'in human geography. *Transactions of the Institute of British Geographers*, *31*(3), 399–406.
96. Jones, J. P., Woodward, K., & Marston, S. A. (2007). Situating flatness. *Transactions of the Institute of British Geographers*, *32*(2), 264–276.
97. Kellerman, A. (2011). Mobility or mobilities: Terrestrial, virtual and aerial categories or entities? *Journal of Transport Geography*, *19*(4), 729–737. https://doi.org/10.1016/j.jtrangeo.2010.08.015
98. Kent, J. L. (2015). Still Feeling the Car? The Role of Comfort in Sustaining Private Car Use. *Mobilities*, *10*(5), 726–747. https://doi.org/10.1080/17450101.2014.944400
99. Kenyon, S. (2003). Understanding social exclusion and social inclusion. *Proceedings of the Institution of Civil Engineers-Municipal Engineer*, *156*, 97–104.
100. Kenyon, S., Lyons, G., & Rafferty, J. (2002). Transport and social exclusion: Investigating the possibility of promoting inclusion through virtual mobility. *Journal of Transport Geography*, *10*(3), 207–219. https://doi.org/10.1016/S0966-6923(02)00012-1
101. Kim, J., Schmöcker, J.-D., Fujii, S., & Noland, R. B. (2013). Attitudes towards road pricing and environmental taxation among US and UK students. *Transportation Research Part A: Policy and Practice*, *48*, 50–62. https://doi.org/10.1016/j.tra.2012.10.005
102. Kinigadner, J., Büttner, B., Wulfhorst, G., & Vale, D. (2020). Planning for low carbon mobility: Impacts of transport interventions and location on carbon-based accessibility. *Journal of Transport Geography*, *87*, 102797. https://doi.org/10.1016/j.jtrangeo.2020.102797
103. Kinra, A., Beheshti-Kashi, S., Buch, R., Nielsen, T. A. S., & Pereira, F. (2020). Examining the potential of textual big data analytics for public policy decision-making: A case study with driverless cars in Denmark. *Transport Policy*, S0967070X20303590. https://doi.org/10.1016/j.tranpol.2020.05.026
104. Kitchin, R. (2006). Positivistic geography and spatial science. *Approaches to Human Geography*, 20–29.
105. Kitchin, R. (2013). Big data and human geography: Opportunities, challenges and risks. *Dialogues in Human Geography*, *3*(3), 262–267. https://doi.org/10.1177/2043820613513388
106. Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., & Stern, N. (2018). Making carbon pricing work for citizens. *Nature Climate Change*, *8*(8), 669–677. https://doi.org/10.1038/s41558-018-0201-2
107. Koppelman, F. S., & Bhat, C. (2006). *A self instructing course in mode choice modeling: Multinomial and nested logit models*. http://caee.utexas.edu/prof/bhat/COURSES/LM_Draft_060131Final-060630.pdf
108. Kou, W., Li, F., & Baldwin, T. (2015). Automatic Labelling of Topic Models Using Word Vectors and Letter Trigram Vectors. In G. Zuccon, S. Geva, H. Joho, F. Scholer, A.

Sun, & P. Zhang (Eds.), *Information Retrieval Technology* (Vol. 9460, pp. 253–264). Springer International Publishing. https://doi.org/10.1007/978-3-319-28940-3_20

109. Krueger, R., Rashidi, T. H., & Rose, J. M. (2016). Preferences for shared autonomous vehicles. *Transportation Research Part C: Emerging Technologies*, *69*, 343–355. https://doi.org/10.1016/j.trc.2016.06.015
110. Larson, W., Liu, F., & Yezer, A. (2012). Energy footprint of the city: Effects of urban land use and transportation policies. *Journal of Urban Economics*, *72*(2–3), 147–159. https://doi.org/10.1016/j.jue.2012.05.001
111. Lefebvre, H. (1974). La production de l'espace, Paris. *Anthropos*, *420*.
112. Leitner, H., & Miller, B. (2007). *Scale and the limitations of ontological debate*. http://www.jstor.org/stable/pdf/4640005.pdf
113. Lenoir, R. (1974). *Les exclus: Un Français sur dix* (Vol. 13). Seuil.
114. Levitas, R. (1996). The concept of social exclusion and the new Durkheimian hegemony. *Critical Social Policy*, *16*(46), 5–20.
115. Lin, C.-Y. C., & Prince, L. (2013). Gasoline price volatility and the elasticity of demand for gasoline. *Energy Economics*, *38*, 111–117. https://doi.org/10.1016/j.eneco.2013.03.001
116. Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport Policy*, *20*, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013
117. Lucas, K., Bates, J., Moore, J., & Carrasco, J. A. (2016). Modelling the relationship between travel behaviours and social disadvantage. *Transportation Research Part A: Policy and Practice*, *85*, 157–173. https://doi.org/10.1016/j.tra.2016.01.008
118. Lucas, K., Blumenberg, E., & Weinberger, R. (2011). *Auto motives: Understanding car use behaviours*. Emerald Group Publishing.
119. Lucas, K., Mattioli, G., Verlinghieri, E., & Guzman, A. (2016). Transport poverty and its adverse social consequences. *Proceedings of the Institution of Civil Engineers - Transport*, *169*(6), 353–365. https://doi.org/10.1680/jtran.15.00073
120. Ma, L., Kent, J., & Mulley, C. (2018). Transport disadvantage, social exclusion, and subjective wellbeing: The role of the neighborhood environment—evidence from Sydney, Australia. *Journal of Transport and Land Use*, *11*(1). https://doi.org/10.5198/jtlu.2018.1008
121. Maas, A. L., Daly, R. E., Pham, P. T., Huang, D., Ng, A. Y., & Potts, C. (2011). Learning word vectors for sentiment analysis. *Proceedings of the 49th Annual Meeting of the Association for Computational Linguistics: Human Language Technologies*, *1*, 9.
122. MacLeod, G., & Goodwin, M. (1999). Space, scale and state strategy: Rethinking urban and regional governance. *Progress in Human Geography*, *23*(4), 503–527.
123. Mah, C. L., Hamill, C., Rondeau, K., & McIntyre, L. (2014). A frame-critical policy analysis of Canada's response to the World Food Summit 1998–2008. *Archives of Public Health*, *72*(1), 41. https://doi.org/10.1186/2049-3258-72-41
124. Manville, M., King, D. A., & Smart, M. J. (2017). The Driving Downturn: A Preliminary Assessment. *Journal of the American Planning Association*, *83*(1), 42–55. https://doi.org/10.1080/01944363.2016.1247653
125. Marston, S. A. (2000). The social construction of scale. *Progress in Human Geography*, *24*(2), 219–242.
126. Marston, S. A., Jones, J. P., & Woodward, K. (2005). Human geography without scale. *Transactions of the Institute of British Geographers*, *30*(4), 416–432.

127. Martell, C. (2019, May 3). Saskatchewan premier plans to appeal carbon tax decision to Supreme Court. *CBC News*. https://www.cbc.ca/news/canada/saskatchewan/the-carbon-tax-is-constitutional-sask-court-of-appeal-1.5121414
128. Mathur, A., & Morris, A. C. (2014). Distributional effects of a carbon tax in broader U.S. fiscal reform. *Energy Policy*, *66*, 326–334. https://doi.org/10.1016/j.enpol.2013.11.047
129. Matthes, J., & Kohring, M. (2008). The Content Analysis of Media Frames: Toward Improving Reliability and Validity. *Journal of Communication*, *58*(2), 258–279. https://doi.org/10.1111/j.1460-2466.2008.00384.x
130. Mattioli, G., Lucas, K., & Marsden, G. (2017). Transport poverty and fuel poverty in the UK: From analogy to comparison. *Transport Policy*, *59*, 93–105. https://doi.org/10.1016/j.tranpol.2017.07.007
131. McCarthy, S. (2019). Carbon Pricing in Canada. In *The Canadian Encyclopedia*. https://www.thecanadianencyclopedia.ca/en/article/carbon-pricing-in-canada
132. McDonald, N. C. (2015). Are Millennials Really the "Go-Nowhere" Generation? *Journal of the American Planning Association*, *81*(2), 90–103. https://doi.org/10.1080/01944363.2015.1057196
133. McIntosh, J., Trubka, R., Kenworthy, J., & Newman, P. (2014). The role of urban form and transit in city car dependence: Analysis of 26 global cities from 1960 to 2000. *Transportation Research Part D: Transport and Environment*, *33*, 95–110. https://doi.org/10.1016/j.trd.2014.08.013
134. McTavish, D. G., & Pirro, E. B. (1990). Contextual content analysis. *Quality and Quantity*, *24*(3), 245–265. https://doi.org/10.1007/BF00139259
135. Meerow, S., Pajouhesh, P., & Miller, T. R. (2019). Social equity in urban resilience planning. *Local Environment*, *24*(9), 793–808. https://doi.org/10.1080/13549839.2019.1645103
136. Meligrana, J. F. (2013). The Politics of Municipal Annexation: The Case of the City of London's Territorial Ambitions during the 1950s and 1960s. *Urban History Review*, *29*(1), 3–20. https://doi.org/10.7202/1016421ar
137. Merriman, P. (2012). *Mobility, space and culture*. Routledge.
138. Merriman, P. (2014). Rethinking Mobile Methods. *Mobilities*, *9*(2), 167–187. https://doi.org/10.1080/17450101.2013.784540
139. Merriman, P. (2016). Mobility Infrastructures: Modern Visions, Affective Environments and the Problem of Car Parking. *Mobilities*, *11*(1), 83–98. https://doi.org/10.1080/17450101.2015.1097036
140. Mikolov, T., Yih, W., & Zweig, G. (2013). Linguistic regularities in continuous space word representations. Proceedings of the 2013 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, 746–751.
141. Miller, B. (1994). Political empowerment, local—central state relations, and geographically shifting political opportunity structures: Strategies of the Cambridge, Massachusetts, Peace Movement. *Political Geography*, *13*(5), 393–406.
142. Miller, B., & Ponto, J. (2016). Mobility among the Spatialities. *Annals of the American Association of Geographers*, *106*(2), 266–273.
143. Mimno, D. (2012a). Reconstructing pompeian households. *ArXiv Preprint ArXiv:1202.3747*.

144. Mimno, D. (2012b). Computational historiography: Data mining in a century of classics journals. *Journal on Computing and Cultural Heritage*, *5*(1), 1–19. https://doi.org/10.1145/2160165.2160168
145. Mokhtarian, P. L. (2019). Subjective well-being and travel: Retrospect and prospect. *Transportation*, *46*(2), 493–513. https://doi.org/10.1007/s11116-018-9935-y
146. Mokhtarian, P. L., Salomon, I., & Singer, M. E. (2015). What Moves Us? An Interdisciplinary Exploration of Reasons for Traveling. *Transport Reviews*, *35*(3), 250–274. https://doi.org/10.1080/01441647.2015.1013076
147. Moore, A. (2008). Rethinking scale as a geographical category: From analysis to practice. *Progress in Human Geography*, *32*(2), 203–225. https://doi.org/10.1177/0309132507087647
148. Mullahy, J. (1986). Specification and testing of some modified count data models. *Journal of Econometrics*, *33*(3), 341–365. https://doi.org/10.1016/0304-4076(86)90002-3
149. Müller, A. C., & Guido, S. (2016). Introduction to machine learning with Python: A guide for data scientists. O'Reilly Media, Inc.
150. Natural Resources Canada. (2017). *Fuel Consumption Taxes in Canada*.
151. Newman, P., Beatley, T., & Boyer, H. (2009). *Resilient cities: Responding to peak oil and climate change*. Island Press.
152. Newman, P., & Kenworthy, J. (2011). 'Peak car use': Understanding the demise of automobile dependence. *World Transport Policy & Practice*, *17*(2), 31–42.
153. Newman, P., & Kenworthy, J. (2015). The end of automobile dependence. In *The End of Automobile Dependence* (pp. 201–226). Springer. http://link.springer.com/chapter/10.5822/978-1-61091-613-4_7
154. NLTK Project. (2019, April 17). *Natural Language Toolkit*. https://www.nltk.org
155. Nordhaus, W. D. (2014). A question of balance: Weighing the options on global warming policies. Yale University Press.
156. Office of the Parliamentary Budget Officer. (2020). Reviewing the Fiscal and Distributional Analysis of the Federal Carbon Pricing System (RP-1920-024-S_e).
157. Ohi, S. J., & Kim, A. M. (2020). Count Models to Represent the Impacts of Weather and Infrastructure on Flight Disruptions. *Transportation Research Record: Journal of the Transportation Research Board*, *2674*(5), 510–521. https://doi.org/10.1177/0361198120916731
158. Olsson, L. E., Gärling, T., Ettema, D., Friman, M., & Fujii, S. (2013). Happiness and Satisfaction with Work Commute. *Social Indicators Research*, *111*(1), 255–263. https://doi.org/10.1007/s11205-012-0003-2
159. Ontario Council of University Libraries. (2020, May 14). <*odesi*>. https://search2.odesi.ca/#/
160. Ory, D. T., & Mokhtarian, P. L. (2005). When is getting there half the fun? Modeling the liking for travel. *Transportation Research Part A: Policy and Practice*, *39*(2–3), 97–123. https://doi.org/10.1016/j.tra.2004.09.006
161. O'Sullivan, F. (2020, February 18). Paris Mayor: It's Time for a "15-Minute City." *CityLab*. https://www.citylab.com/environment/2020/02/paris-electionanne-hidalgo-city-planning-walks-stores-parks/606325/
162. Pan, Z., & Kosicki, G. (1993). Framing analysis: An approach to news discourse. *Political Communication*, *10*(1), 55–75. https://doi.org/10.1080/10584609.1993.9962963

163. Parr, S. (2015). Integrating critical realist and feminist methodologies: Ethical and analytical dilemmas. *International Journal of Social Research Methodology*, *18*(2), 193–207. https://doi.org/10.1080/13645579.2013.868572
164. Paterson, M. (2014). Governing Mobilities, Mobilising Carbon. *Mobilities*, *9*(4), 570–584. https://doi.org/10.1080/17450101.2014.961260
165. Paulssen, M., Temme, D., Vij, A., & Walker, J. L. (2014). Values, attitudes and travel behavior: A hierarchical latent variable mixed logit model of travel mode choice. *Transportation*, *41*(4), 873–888. https://doi.org/10.1007/s11116-013-9504-3
166. Pennington, J., Socher, R., & Manning, C. (2014). Glove: Global Vectors for Word Representation. *Proceedings of the 2014 Conference on Empirical Methods in Natural Language Processing (EMNLP)*, 1532–1543. https://doi.org/10.3115/v1/D14-1162
167. Poon, J. P. H. (2005). Quantitative methods: Not positively positivist. *Progress in Human Geography*, *29*(6), 766–772. https://doi.org/10.1191/0309132505ph583pr
168. Pratt, A. C. (1995). Putting critical realism to work: The practical implications for geographical research. *Progress in Human Geography*, *19*(1), 61–74. https://doi.org/10.1177/030913259501900104
169. Preston, J., & Rajé, F. (2007). Accessibility, mobility and transport-related social exclusion. *Journal of Transport Geography*, *15*(3), 151–160. https://doi.org/10.1016/j.jtrangeo.2006.05.002
170. Puller, S. L., & Greening, L. A. (1999). Household adjustment to gasoline price change: An analysis using 9 years of US survey data. *Energy Economics*, *21*(1), 37–52. https://doi.org/10.1016/S0140-9883(98)00006-1
171. R Core Team. (2019). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing. https://www.R-project.org/
172. Rabe, B. G., & Borick, C. P. (2012). Carbon Taxation and Policy Labeling: Experience from American States and Canadian Provinces: Carbon Taxation and Policy Labeling. *Review of Policy Research*, *29*(3), 358–382. https://doi.org/10.1111/j.1541-1338.2012.00564.x
173. Rajé, F. (2003). The impact of transport on social exclusion processes with specific emphasis on road user charging. *Transport Policy*, *10*(4), 321–338. https://doi.org/10.1016/S0967-070X(03)00038-6
174. Reese, S. D. (2007). The Framing Project: A Bridging Model for Media Research Revisited. *Journal of Communication*, *57*(1), 148–154. https://doi.org/10.1111/j.1460-2466.2006.00334.x
175. Řehůřek, R., & Sojka, P. (2010). Software Framework for Topic Modelling with Large Corpora. *Proceedings of the LREC 2010 Workshop on New Challenges for NLP Frameworks*, 45–50.
176. Reynard, D. (2018). Five classes of geospatial data and the barriers to using them. *Geography Compass*, e12364. https://doi.org/10.1111/gec3.12364
177. Reynard, D., & Shirgaokar, M. (2019). Harnessing the power of machine learning: Can Twitter data be useful in guiding resource allocation decisions during a natural disaster? *Transportation Research Part D: Transport and Environment*, S1361920918308113. https://doi.org/10.1016/j.trd.2019.03.002
178. Richardson, L. (2020). *Beautiful Soup Documentation*. https://www.crummy.com/software/BeautifulSoup/bs4/doc/

179. Röder, M., Both, A., & Hinneburg, A. (2015). Exploring the Space of Topic Coherence Measures. *Proceedings of the Eighth ACM International Conference on Web Search and Data Mining - WSDM '15*, 399–408. https://doi.org/10.1145/2684822.2685324
180. Sayre, N., & Di Vittorio, A. (2009). Scale. In *International Encyclopedia of Human Geography*. Elsevier.
181. Scharf, T., Phillipson, C., & Smith, A. E. (2005). Social exclusion of older people in deprived urban communities of England. *European Journal of Ageing*, *2*(2), 76–87. https://doi.org/10.1007/s10433-005-0025-6
182. Schofield, A., Magnusson, M., Thompson, L., & Mimno, D. (2017). Understanding text pre-processing for latent Dirichlet allocation. *Proceedings of the 15th Conference of the European Chapter of the Association for Computational Linguistics*, *2*, 432–436.
183. Schultz, D. E., & Block, M. P. (2015). US online shopping: Facts, fiction, hopes and dreams. *Journal of Retailing and Consumer Services*, *23*, 99–106.
184. Schwanen, T., Lucas, K., Akyelken, N., Cisternas Solsona, D., Carrasco, J.-A., & Neutens, T. (2015). Rethinking the links between social exclusion and transport disadvantage through the lens of social capital. *Transportation Research Part A: Policy and Practice*, *74*, 123–135. https://doi.org/10.1016/j.tra.2015.02.012
185. Shearmur, R. (2015). Dazzled by data: Big Data, the census and urban geography. *Urban Geography*, *36*(7), 965–968. https://doi.org/10.1080/02723638.2015.1050922
186. Sheller, M. (2004). Automotive Emotions: Feeling the Car. *Theory, Culture & Society*, *21*(4–5), 221–242. https://doi.org/10.1177/0263276404046068
187. Sheller, M., & Urry, J. (2000). The city and the car. *International Journal of Urban and Regional Research*, *24*(4), 737–757.
188. Sheller, M., & Urry, J. (2006). The New Mobilities Paradigm. *Environment and Planning A*, *38*(2), 207–226. https://doi.org/10.1068/a37268
189. Sheppard, E. (2001). Quantitative Geography: Representations, Practices, and Possibilities. *Environment and Planning D: Society and Space*, *19*(5), 535–554. https://doi.org/10.1068/d307
190. Shirgaokar, M. (2016). Expanding cities and vehicle use in India: Differing impacts of built environment factors on scooter and car use in Mumbai. *Urban Studies*, *53*(15), 3296–3316. https://doi.org/10.1177/0042098015608050
191. Small, K. A., & Van Dender, K. (2007). Fuel efficiency and motor vehicle travel: The declining rebound effect. *The Energy Journal*, *28*(1).
192. Smith, N. (1984). Uneven development: Nature, capital, and the production of space. University of Georgia Press.
193. Smith, N. (1992). Contours of a spatialized politics: Homeless vehicles and the production of geographical scale. *Social Text*, *33*, 55–81.
194. Social Exclusion Unit. (2003). Making the Connections: Final Report on Transport and Social Exclusion, 2003. *Government of the United Kingdom*, 147.
195. Spinney, J. E. L., Newbold, K. B., Scott, D. M., Vrkljan, B., & Grenier, A. (2020). The impact of driving status on out-of-home and social activity engagement among older Canadians. *Journal of Transport Geography*, *85*, 102698. https://doi.org/10.1016/j.jtrangeo.2020.102698
196. Stanley, J. K., Hensher, D. A., Stanley, J. R., & Vella-Brodrick, D. (2011). Mobility, social exclusion and well-being: Exploring the links. *Transportation Research Part A: Policy and Practice*, *45*(8), 789–801. https://doi.org/10.1016/j.tra.2011.06.007

197. Stanley, J., & Lucas, K. (2008). Social exclusion: What can public transport offer? *Research in Transportation Economics*, *22*(1), 36–40. https://doi.org/10.1016/j.retrec.2008.05.009
198. Stapleton, L., Sorrell, S., & Schwanen, T. (2017). Peak car and increasing rebound: A closer look at car travel trends in Great Britain. *Transportation Research Part D: Transport and Environment*, *53*, 217–233. https://doi.org/10.1016/j.trd.2017.03.025
199. Statistics Canada. (2017a). *The 10 highest population densities among municipalities (census subdivisions) with 5,000 residents or more, Canada, 2016*. https://www150.statcan.gc.ca/n1/daily-quotidien/170208/t001a-eng.htm
200. Statistics Canada. (2017b). *General Social Survey—Time Use (GSS)*. http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=4503
201. Statistics Canada. (2017c). General Social Survey (Time Use) 2015.
202. Statistics Canada. (2017d). *Journey to work: Key results from the 2016 Census*. https://www.statcan.gc.ca/daily-quotidien/171129/dq171129c-eng.pdf
203. Statistics Canada. (2017e). *Survey of Household Spending*. http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&lang=en&db=imdb&adm=8&dis=2&SDDS=3508
204. Statistics Canada. (2018a, September 17). *Dissemination area: Detailed definition*. https://www150.statcan.gc.ca/n1/pub/92-195-x/2011001/geo/da-ad/def-eng.htm
205. Statistics Canada. (2018b). *Table 18-10-0001-01 Monthly average retail prices for gasoline and fuel oil, by geography*. https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000101
206. Statistics Canada. (2019). *Population and Dwelling Count Highlight Tables, 2016 Census*. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/hlt-fst/pd-pl/Table.cfm?Lang=Eng&T=801&SR=1&S=3&O=D&RPP=25&PR=0&CMA=0#tPopDwell
207. Stefanovich, O. (2020, September 22). Federal government's climate policy hangs in the balance as Supreme Court considers carbon tax. *CBC News*. https://www.cbc.ca/news/politics/stefanovich-carbon-tax-supreme-court-of-canada-set-up-1.5729473
208. Steffen, W. (2006). The Anthropocene, global change and sleeping giants: Where on Earth are we going? *Carbon Balance and Management*, *1*(1), 3. https://doi.org/10.1186/1750-0680-1-3
209. Storchmann, K.-H. (2001). The impact of fuel taxes on public transport—An empirical assessment for Germany. *Transport Policy*, *8*(1), 19–28.
210. Stout, M., Collins, D., Stadler, S. L., Soans, R., Sanborn, E., & Summers, R. J. (2018). "Celebrated, not just endured:" Rethinking Winter Cities. *Geography Compass*, *12*(8), e12379. https://doi.org/10.1111/gec3.12379
211. Swyngedouw, E. (1997). Neither global nor local:'Glocalization'and the politics of scale. *Space of Globalization: Reasserting the Power of the Local*, 115–136.
212. Tirunillai, S., & Tellis, G. J. (2014). Mining Marketing Meaning from Online Chatter: Strategic Brand Analysis of Big Data Using Latent Dirichlet Allocation. *Journal of Marketing Research*, *51*(4), 463–479. https://doi.org/10.1509/jmr.12.0106
213. United Nations. (2015). Paris Agreement. *International Legal Materials*, *55*(4), 740–755.

214. United Nations Economic Commission for Europe. (2017). *2018 Transport Statistics Infocards*. https://www.unece.org/fileadmin/DAM/trans/doc/2018/wp6/_Infocards_REV_7Dec2017.pdf
215. Urry, J. (2004). The "System" of Automobility. *Theory, Culture & Society*, *21*(4–5), 25–39. https://doi.org/10.1177/0263276404046059
216. Urry, J. (2007). *Mobilities*. Polity.
217. U.S. Department of Energy. (2016). *Average Per-Passenger Fuel Economy of Various Travel Modes*. https://www.afdc.energy.gov/data/
218. Van Gorp, B. (2005). Where is the Frame?: Victims and Intruders in the Belgian Press Coverage of the Asylum Issue. *European Journal of Communication*, *20*(4), 484–507. https://doi.org/10.1177/0267323105058253
219. Waisman, H.-D., Guivarch, C., & Lecocq, F. (2013). The transportation sector and low-carbon growth pathways: Modelling urban, infrastructure, and spatial determinants of mobility. *Climate Policy*, *13*(sup01), 106–129. https://doi.org/10.1080/14693062.2012.735916
220. Walks, A. (2015). Stopping the "War on the Car": Neoliberalism, Fordism, and the Politics of Automobility in Toronto. *Mobilities*, *10*(3), 402–422. https://doi.org/10.1080/17450101.2014.880563
221. Wallach, H. M., Murray, I., Salakhutdinov, R., & Mimno, D. (2009). Evaluation methods for topic models. *Proceedings of the 26th Annual International Conference on Machine Learning - ICML '09*, 1–8. https://doi.org/10.1145/1553374.1553515
222. Wang, Q., Hubacek, K., Feng, K., Wei, Y.-M., & Liang, Q.-M. (2016). Distributional effects of carbon taxation. *Applied Energy*, *184*, 1123–1131. https://doi.org/10.1016/j.apenergy.2016.06.083
223. West, S. E. (2005). Equity Implications of Vehicle Emissions Taxes. *Journal of Transport Economics and Policy*, *39*, 24.
224. Wikgren, M. (2005). Critical realism as a philosophy and social theory in information science? *Journal of Documentation*, *61*(1), 11–22. https://doi.org/10.1108/00220410510577989
225. Winslow, L. (2017). Frame Analysis. In M. Allen (Ed.), *The SAGE Encyclopedia of Communication Research Methods*. SAGE Publications, Inc. https://doi.org/10.4135/9781483381411
226. Winter, J., & Dobson, S. (2013). *Who is getting a carbon tax rebate?* 8.
227. Woodward, K., Jones, J. P., & Marston, S. A. (2008). Downsizing Wal-Mart: A Reply to Prytherch. *Urban Geography*, *29*(1), 78–84. https://doi.org/10.2747/0272-3638.29.1.78
228. Woodward, K., Jones, J. P., & Marston, S. A. (2012). The politics of autonomous space. *Progress in Human Geography*, *36*(2), 204–224. https://doi.org/10.1177/0309132511432083
229. Wu, Y.-F., Xu, H.-G., & Lew, A. A. (2015). Consumption-led mobilized urbanism: Socio-spatial separation in the second-home city of Sanya. *Mobilities*, *10*(1), 136–154. https://doi.org/10.1080/17450101.2013.853952
230. Yeung, H. W. (1997). Critical realism and realist research in human geography: A method or a philosophy in search of a method? *Progress in Human Geography*, *21*(1), 51–74. https://doi.org/10.1191/030913297668207944
231. Zeileis, A., Kleiber, C., & Jackman, S. (2008). Regression Models for Count Data in R. *Journal of Statistical Software*, *27*(8). http://www.jstatsoft.org/v27/i08/

232. Zhong, S., & Bushell, M. (2017). Impact of the built environment on the vehicle emission effects of road pricing policies: A simulation case study. *Transportation Research Part A: Policy and Practice*, *103*, 235–249. https://doi.org/10.1016/j.tra.2017.06.007

233. Zhu, Z., Li, Z., Chen, H., Liu, Y., & Zeng, J. (2017). Subjective well-being in China: How much does commuting matter? *Transportation*. https://doi.org/10.1007/s11116-017-9848-1

Appendix I: Planning Documents

1. City of Calgary. (2012). Calgary Transportation Plan. www.calgary.ca/transportation/
2. City of Calgary. (2017a). Green Line LRT Long Term Vision: 160 Avenue to Seton.
3. City of Calgary. (2017b). Municipal Development Plan.
4. City of Edmonton. (2009). The Way We Move – Transportation Master Plan.
5. City of Edmonton. (2016). Building a Brighter 101 Avenue – What We Heard Summary.
6. City of Vancouver. (n.d.). Greenest City 2020 Priorities.
7. City of Vancouver. (2010). Greenest City 2020 Implementation Plan 2010-01-26.
8. City of Vancouver. (2011a). Draft Greenest City 2020 Action Plan 2011-01-05.
9. City of Vancouver. (2011b). Greenest City 202 Action Plan 2011-07-05.
10. City of Vancouver. (2012a). Greenest City 2020 Action Plan.
11. City of Vancouver. (2012b). Greenest City 2020 Action Plan.
12. City of Vancouver. (2012c). Greenest City 2020 Action Plan – 2011-2012 Implementation Update.
13. City of Vancouver. (2012d). Transportation 2040.
14. City of Vancouver. (2013). Greenest City 2020 Action Plan – 2012-2013 Implementation Update.
15. City of Vancouver. (2014a). Greenest City 2020 Action Plan – 2013-2014 Implementation Update.
16. City of Vancouver. (2014b). Greenest City 2020 Action Plan – 2014-2015 Implementation Update.
17. City of Vancouver. (2014c, July 9). Greenest City Action Plan Implementation Update.
18. City of Vancouver. (2017a). Greenest City 2020 Action Plan – 2016-2017 Implementation Update.
19. City of Vancouver. (2017b). Greenest City 2020 Action Plan – 2016-2017 Update.
20. City of Winnipeg. (2011a). Sustainable Transportation – An Ourwinnipeg Direction Strategy.
21. City of Winnipeg. (2011b). Winnipeg Transportation Master Plan.
22. Urban Systems. (2014). Winnipeg Pedestrian and Cycling Strategies.