CURBING THE CAR

Structural Determinants of Driving Mode Choice in Montreal and Sociopsychological and Cultural Barriers to Sustainable Mode Choice

Supervised Research Project Report
Submitted in partial fulfillment of the Masters of Urban Planning degree

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Executive Summary

Context

The excessive use of private vehicles in urban areas contributes to daunting environmental, social, and public health challenges cities face. Cars—regardless of their fuel—cause deaths and injuries from crashes; produce particulate matter that damages cardiovascular, respiratory and neurological health; contribute to sedentarism and obesity; and dampen street life essential to promoting active lifestyles. Harm-reduction approaches can blunt some of the costs separately, but to simultaneously and completely address cars' most pernicious effects cities must keep people out of cars whenever possible and reduce the distance traveled when it is not.

Some of the factors that shape driving behavior, including the built-form, land-use patterns and transport systems, fall squarely within cities' traditional regulatory competencies, such as zoning, taxing and spending. Other factors, which are sociopsychological and cultural, will require a more creative or expansive role in coordination with other levels of government and the private sector.

Research and Policy Recommendations

This research explored aspects of both the structural or objective factors and the sociocultural ones with an aim of providing policymakers with evidence-based options for curbing car use using a mix of statistical analysis and literature review. Key findings include:

- Transit accessibility (measured here by the number of jobs a person can reach in 45 minutes by transit) is strongly associated with reductions in the odds of driving and distance traveled. Planners should therefore focus on improving the ease of reaching desired opportunities rather than simply on moving people faster. This means focusing on improving transit service, especially frequency, and on improving the mix of land uses locally so people don't have to travel as far.
- When expanding transit options and adjusting land uses, planners must take a nuanced approach. The impacts of local and regional accessibility show different relative impacts depending on travel purpose and driving behavior varies based on household income and life stage. In particular, people from lower-income households are more likely to drive for work than people from wealthy households, all else being equal. To address this, planners should ensure that the public transit system provides equitable access by linking lower-income workers to the jobs that are available to them.
- Planners and city officials should work to reduce private vehicle ownership, particularly second and third cars, by ensuring that ownership and use bear their true costs. By ending free on-street parking and imposing road-usage fees, officials may be able to chip away at the perverse incentives that exist to own additional cars, which are strongly linked with driving mode choice and distance.
- Cities must work with other levels of government to aggressively target the prevailing car culture that influences the psychological and cultural factors that shape driving behavior. Among other things, cities may wish to engage in sustained public awareness/education campaigns, including incorporating transit and active transport training into school curricula. In conjunction with other levels of government, cities should also consider ways to limit public-space messages that reinforce driving culture. This could include banning car commercials on city owned property, especially on public transit, for example.

Conclusion

City officials have a wide range of tools at their disposal to encourage people to adopt more sustainable modes of transportation. Officials, however, will not likely be able to drive down driving without a comprehensive approach that integrates initiatives aimed at structural determinants, such as land use and transport systems, with those aimed at addressing culture and habit. They must therefore extend their efforts beyond traditional planning competencies and engage with other levels of government to generate a modal shift.

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Introduction

Canadian cities—like vast swathes of the developed and developing worlds—have a car problem. Once heralded as a transformative technology that greatly expanded individual mobility and access to social and economic opportunities, the private automobile has become as much bane as boon, particularly in urban and suburban areas. Starting in the second half of the 20th Century, cities and their residents—inside and outside of cars—became prisoners of the two-ton, four-wheeled boxes around which land use, urban spaces, transportation systems and even cultural identities have been formed. [1]. "The rise of the automobile industry and the socioeconomic impact of the road and the car are central to the history of the advanced capitalist countries in the twentieth century, and explain an especially large part of the history of the American people [1]," JJ Flink observes in the preface to The Automobile Age. The same, of course, can be said of the United States' neighbor to the north.

Our societal car addiction fuels some of the most significant challenges we face collectively. Human-induced climate change, for example, represents one of the largest threats to cities and their residents over the short-, medium- and long-term [2]. In the United States, transport-related greenhouse gas emissions (GHGs) constituted 29% of total GHGs in 2017 [3]. In Canada, transport GHGs have steadily increased since 1990 [4]. Indeed, transport was responsible for nearly 25 percent of Canada's global warming emissions in 2017, ranking as the second-largest source by economic sector [4]. Although heavy vehicles and light-duty trucks accounted for much of the increase, personal automobile travel continues to produce a significant portion of the transportation-related total [4]. Reducing emissions from personal vehicle-travel therefore represents a key challenge for combating climate change at the local and national levels.

The other consequences of private cars' centrality and ubiquity are manifold: High-speed through traffic on city streets-turned-roads dampens public life and hinders social interactions [5]. Auto-dominated transportation systems and lifestyles have facilitated a more general transition to sedentarism with serious public-health consequences, such as obesity, diabetes and cardiovascular diseases [6,7]. These indirect health impacts are no less real for being—perhaps—less visible than the lives and livelihoods lost to vehicle crashes. Around the world, roadways claim more than 1.25 million lives a year [8]. In 2017 alone, Canada recorded more than 1,800 roadway fatalities, nearly 20% of whom were people walking or biking [9,10]. The fatality statistics do not even begin to paint a complete picture of cars' carnage because they ignore the multitude of life-altering injuries and impacts on direct and indirect victims of crashes. Automobiles and supporting infrastructure also generate significant environmental harms, such as noise, air [11,12] and water pollution [13], which either cause or exacerbate many of the social and public health impacts already mentioned. So pervasive and pernicious are private automobiles' ecological and public health impacts, that some scholars and policymakers have, quite correctly, asked: "Are cars the new tobacco [14]?"

To respond to the intense social, public health and environmental challenges posed by excessive automobile dependence, policymakers can adopt two principal approaches. The first is harm reduction, which means reducing the problems caused by driving through interventions targeting specific harms, such as traffic-safety regulations to cut driver deaths or transitioning to lower-

carbon fuels to limit GHG emissions [15,16]. The second is wholesale behavior change, shifting people away from their cars entirely [17].

In many respects, the first approach is significantly easier because it does not ask people to radically alter their habits or to re-examine elements of their identity. Here, Canadian jurisdictions have achieved modest—though piecemeal—success from different permutations of the harm-reduction approach, including reducing roadway fatalities through engineering and design interventions and slowly encouraging the adoption of hybrid and electric vehicles. For example, thanks, in part, to hefty government subsidies and an expanding charging network, some 50,000 electric vehicles are reportedly on the roads in Quebec, halfway to the province's goal of 100,000 [18].

Meaningful and sustained behavior change, on the other hand, is more challenging because it requires addressing both instrumental and objective attributes of the transport system as well as deeply ingrained patterns of behavior. Behavior change is nevertheless worth pursuing because it represents the only approach with the possibility of simultaneously addressing all the many harms caused by excessive private-car use. In this regard, Canadian jurisdictions have made little progress. For example, the number of registered passenger vehicles on Quebec roads rose nearly 10 percent from 2011 to 2017 [19]. (Trends in vehicle kilometers traveled (VKT) in Canada are more difficult to obtain because of limited data. The federal government discontinued the Canadian Vehicle Survey in 2009)[20].

This supervised research project, prepared in partial satisfaction of the M.U.P. degree from the McGill University School of Urban Planning, explores two complementary bodies of research. The first chapter aims to reveal the land use and transportation-system determinants of driving mode share and distance driven using Montreal as an example. It applies advanced statistical analysis to individual-level disaggregrate data from the 2013 regional origin-destination suvey to identify the correlation between different land use, built-environment and transport-system characteristics, such as destination accessibility, and driving behavior. Interventions related to these city-system attributes sit squarely within the compentancy of urban planners and officials and have been the focus of sustained research [21–23]. Still, as this research demontrates, these structural considerations explain a relatively small – through nonetheless important – proportion of driving behavior. For that reason, the second chapter of this project mines the existing literature to explore the psychosocial aspects of the prevailing driving culture which researchers increasingly agree may offer new avenues to help nudge driving mode choice in more sustainable directions.

This SRP argues that a sustained public campaign, similar to broad-reaching health initiatives targeting smoking or drunk driving, must accompany efforts to reform existing transportation systems in order to achieve lasting behavioral change. Neither structural interventions (systemic change) to bolster alternatives to driving nor "softer" campaigns targeting human behavior and choices will be sufficient in isolation to shift travel mode choice toward more sustainable options. Instead, interventions targeting personal behavior and more systemic changes in transport provision must accompany and reinforce one another. To address personal behavior, policymakers must have a comprehensive understanding of both the more traditional instrumental, econometric constraints on mode choice behavior, such as time and money, and the psychosocial and cultural motivations that are equally, if not more, important in shaping human

action [17]. To date, it appears that policymakers have failed to adequately grapple with the cultural and psychological barriers to transitioning away from private-car dependence.

Chapter One

Motive Matters: How Travel Purpose Interacts with Predictors of Individual Driving Behavior in Greater Montreal[1]

The built environment, land use patterns and the transport system can help shape inviduals' travel choices and behavior. Through regulations such as zoning, taxing and spending, cities can directly and indirectly shape many elements of the urban form and systems, dubbed the 5Ds: density, diversity, design, distance to transit and destination accessibility [24]. Accessibility sits at the intersection of these factors and remains an area of sustained interest for researchers. [25,26]. In its simplest form, accessibility measures the ease of reaching opportunities [27]. But the unassuming definition belies the conceptual power it boasts as a composite measure that unifies two important, but frequently siloed, considerations in transport planning: mobility and proximity [28]. It also represents the cumulative interaction of four discrete factors: land-use, transport, individual characteristics and time [25]. In effect, the modern concept of accessibility directly connects land-use patterns and transport-system characteristics. For city decisionmakers, then, accessibility is an especially valuable metric because it offers a wholistic and simultaneous assessment of these characteristics.

Using disaggregate travel data from Montreal, Quebec's 2013 origin-destination survey, this chapter explores accessibility's relationship with driving behavior at two spatial scales: (a) local accessibility – the availability of walking-distance amenities as represented by neighborhood-level Walk Score assessments and (b) regional transit accessibility, defined here as the number of jobs that can be reached by public transit in a given time from the respondent's home census tract.

Travel choices and behavior are highly idiosyncratic and influenced by a constellation of factors, including personal characteristics and the purposes for which trips are made [29]. To address some of this variety and to support more nuanced policy recommendations, this research takes the additional step of considering how local and regional accessibility may influence travel for different purposes: (a) overall travel, (b) work, (c) education, (d) healthcare, and (e) "discretionary" travel, consisting of leisure, socialization, shopping or errands. Conceptually the travel purposes considered represent varying degrees of individual discretion regarding time and mode and are thus expected to respond differently to planning interventions aimed at promoting different types of accessibility.

Literature Review

The impact of the built form on travel behavior is among the most researched and, at times, contentious topics among planners and transport researchers. Overall, it is safe to state that the preponderance of published articles suggests that varying combinations of the 5Ds display statistically significant relationships with reductions in different measures of vehicle distance traveled [23,30,31]. Yet, despite sustained scholarly interest, the exact nature of the relationship

[1] This chapter has been accepted for publication in the Transport Research Record.

between the urban form and travel preferences and behavior, its causal direction, and the intensity of its impact, remains opaque and, in some cases, disputed [16,23,32,33].

As a subcomponent of the 5Ds, destination accessibility represents a major line of inquiry in part because it serves as a valuable composite indicator, linking elements of the land use and transport systems [34]. For planners and city policymakers, it is a particularly useful concept because, depending on its application, it can help achieve broader environmental and socioeconomic outcomes [35]. Location-based accessibility measures, which calculate opportunity tallies for specific zones, are by far the most commonly applied. Within these, two more frequently applied measures exist: cumulative opportunities and gravity [25,36]. Cumulative opportunities measures are those that tally the number of opportunities that can be reached from a given origin without exceeding a specified travel-cost threshold, commonly time, distance or cost.

Of the researchers whose studies have examined the impact of accessibility, most have identified a statistically significant, though sometimes moderate, relationship [16,37,38]. In the study that most directly influenced this analysis, Ewing et al. [38] find that both car and transit accessibility measured by jobs reachable within different times are associated with decreases in household VMT. In an earlier study, Cervero & Duncan (2006) find that the relative impact of accessibility on vehicle distance traveled, as measured by elasticities, can even outweigh that of individual and household characteristics [39]. Indeed, they find that accessibility—as measured by jobs and housing balance—reduces total travel distance more than retail balance [39].

Two key issues arise when looking across these studies and these issues have implications for the direction of this and future research. First, considerable variance in household or individual vehicle distance traveled often remains unexplained in even the most robust models [16,33,38], as reflected by the r-scores obtained. Second, there is considerable variation in vehicle distance traveled outcomes across urban and individual contexts, making further research into different environments and under different conditions particularly important, as demonstrated by the broad range of explanatory variables, results and elasticities obtained by different studies [23,40].

This chapter aims to contribute to this line of research using Montreal as an example. Ultimately the goal is to provide a sound evidentiary basis for the development of additional policies and interventions aimed at reducing regional dependene on private automobiles.

Data and Statistical Analysis

Trip-level mode and destination data were obtained from the 2013 edition of Montreal's origin-destination survey, the most recent publicly available version [41]. Conducted every five years since 1970, this survey collects information from a random sample of tens of thousands of Montreal-area households regarding travel habits over the preceding 24-hour weekday period. This analysis draws on a subset of these data representing people who made trips fully within the local and regional public transit-service areas. The use of disaggregate, person-level data allows researchers to model individual choices and behavior, potentially allowing policymakers to develop more precisely targeted interventions than might be possible with models based on aggregate mode choice at the census tract or other level.

To streamline calculations, the analysis is restricted to people whose trips consisted of origin-destination pairs located within 100 kilometers of the Montreal Island center as measured by road-network travel distance. Because I sought to identify the influence of individual, household and neighborhood characteristics on driving behavior for different reasons, I discarded records with missing data regarding destinations, trip purpose, mode or household characteristics. Finally, I focused exclusively on those people who could be reasonably classified as "potential drivers." For purposes of this analysis, a potential driver means a licensed driver from a household with at least one car [41].

For each of the trip segments recorded in the survey, I classified the mode as primary driver or other. Because the primary research question focuses on built-environment and transport- system determinants of (a) the decision to drive for travel at any point throughout the day and (b) the distance driven once that decision is made, a distinction between alternative modes was not considered important. To calculate driving distance, I relied on the ArcGIS Network Analyst toolbox applied to a road network downloaded using OSMnx [42]. (This road network was downloaded in April 2019 and may therefore reflect changes not present when the 2013 O-D survey was completed. Although historical road network data were unavailable, the study-area network was already well established at the time of the O-D survey, suggesting that differences in on-network road distances are not especially significant).

Before assigning purposes to travel, I grouped individual trip segments into home-based loops, a common definition for a trip chain. I then assigned a primary purpose to each loop from one of four categories [43]. Trip-purpose categories included work, school, healthcare and "discretionary," which encompasses leisure, recreation, social calls and shopping. Based on the assumption that work, school and, to a certain extent, healthcare have schedules and locations that are not defined wholly by the traveler, they were considered to be primary purposes in descending order of priority for any loop for which they were present. See Figure 1.

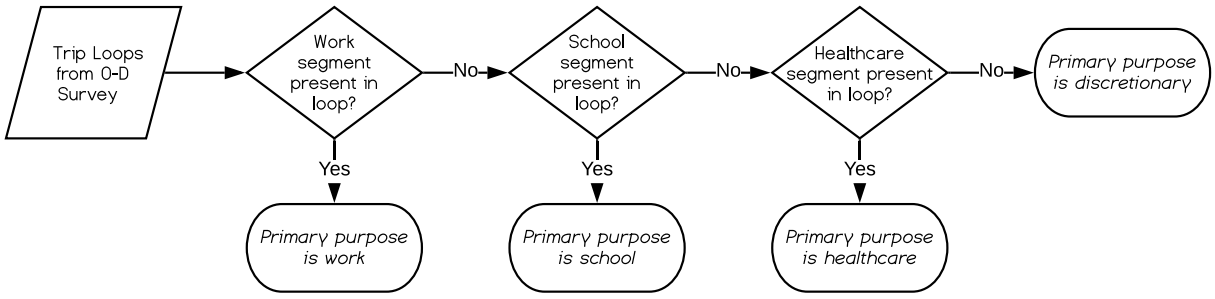

Figure 1 Assignment of primary travel loop purposes

All loops lacking segments for these "mandatory" activities were classified as "discretionary." Creating loops beforehand ensured that all reported vehicle travel, including returns home, could be classified according to the trip purposes of interest. We then aggregated loop-level trip distance calculations for each individual person in the retained dataset.

For measures of local accessibility, I relied on Walk Scores for home neighborhoods [44]. For regional accessibility, I employed a transit-based cumulative-opportunities measurement with a 45-minute threshold. For the transit network, I assembled GTFS data for all transit agencies

providing service in the study area. To more closely align with conditions at the time of the O-D survey, I used archived General Transit Feed Specification (GTFS) data from November 2013, the oldest data for which data were consistently available from all the agencies. I then calculated travel times between all Census Tract centroids using the ArcGIS Network Analyst Extension for Transportation Analysis developed by Melinda Morang. I derived Census tract jobs figures from Census Work Flows [45]. When calculating jobs accessibility, I established the 45-minute threshold because it most closely aligns with the average transit commuting time in Montreal [46]. To enable direct comparison of the impacts of local and regional accessibility, I normalized both using z-scores.

Modeling

Modeling individual VKT from the data set presented two interrelated challenges: The data are generally not normally distributed, requiring a log transformation, but also contain many zero values, which cannot be directly log transformed. To address this, I employed a two-step "hurdle process" as described by Ewing et al. 2015 [38]. In the first step, we construct multilevel logistic regressions to explain the binary decision to drive or not using our complete dataset, including all travelers whether they drove or not. Under this approach, the decision to drive for any of the studied purposes is the initial "hurdle," or criterion, for inclusion in the subsequent analysis of the determinants of driving distance. For this second step, I construct a series of multi-level linear regression models to explain total weekday driving distance for each of the studied travel purposes together and separately. By using only the subset of observations with non-zero driving distances in this second step, I are able to directly log transform our distance-driven dependent variable. This two-step approach also maps well with the sequential policy objectives I aim to support through the identification of correlations between land use and transport systems and driving behavior that policy makers may potentially leverage to reduce VKT: First keep people out of cars and, when that is unlikely or impossible, figure out how to get them to drive less.

For both the logistic and linear models I first used a nested, multi-level mixed effects approach using the R statistical programming language. I placed individuals within households and households within census tracts. This approach aims to address the fact that people within the same households, and households within the same neighborhood, are likely to share certain characteristics that are not otherwise accounted for within the model [38,47]. The household level did not prove statistically significant for the binary logistic regressions and was removed in the final modeling.

I included the following independent variables for individual characteristics: age, gender, employment and/or student status and possession of a driver's license. For purposes of modeling, I organized employment status into three bins reflecting the assumed differences in the associated need to travel routinely outside the home (full-time; part-time and/or student; homemaker, retired and not employed). For household characteristics, I included household income, the number of preschoolers, the number of school age children, the number of adults and the number of vehicles in a household.

For our neighborhood and regional characteristics, I included two measures of accessibility, which reflect different geographic scales and types of destinations. For local accessibility, I relied on a

2010 database of neighborhood-level walkability scores from Walk Score, a private company that prepares a publicly available gravity-based assessment of amenities within 1 mile of locations. For regional accessibility, I used transit-based jobs accessibility defined as the number of jobs reachable within 45 minutes from the centroid of each home census tract. Initially, I sought to include vehicle-based jobs accessibility and a transit-to-car accessibility ratio, but the variables were found to be too closely correlated with transit accessibility.

When evaluating mode and distance by segregated trip purpose, I also included travel for other purposes as independent variables to account for possible time competition and fatigue from other travel. For example, when analyzing work-related driving travel and VKT as dependent variables, I included VKT for school, healthcare and discretionary travel as explanatory variables.

Our modeling does not directly consider the effects of self-selection, a key component of the causal relationship between built-form and other related determinants of VKT. The use of multi-level modeling and the inclusion of socio-economic control variables, however, can help account for some of this phenomenon's impact. Also, I assume consistent accessibility throughout the day, which has been demonstrated to serve as a reliable measure [48,49]. Many trips, however, took place at different times, introducing unexplained variance into the model.

Results

Descriptive Statistics

The total number of potential drivers who traveled outside the home during the survey period numbered 59,761 for any purpose. Of these potential drivers, more than 75% reported driving at least once during the survey period, see Table 1. Among the 37,104 people who reported work travel and the 22,341 who reported discretionary travel, similar percentages reported driving for these purposes. Of the 2,453 people who traveled for healthcare, 71% drove. At the other end of the spectrum, only 38% of 4,695 school travelers drove.

Table 1 Summary of potential and actual drivers segmented by trip purpose

Travel Type	All Travelers	Drivers	Percent Drivers
All types (combined)	59,761	45,011	75
Work	37,104	28,580	77
School/Education	4,695	1,783	38
Healthcare	2,453	1,737	71
Discretionary (recreation, shopping, socialization, pick-ups)	22,341	16,759	75

Within the sample subset, households on average contained 2.9 people – 2.3 adults and 0.7 children. On average 61% of adults in each household in the retained dataset reported being a full-time employee. Households averaged a car-to-driver's license ratio of nearly 1 to 1.

Table 2 Summary Statistics for Travel, Individual, Household, Neighborhood and Regional Variables (Based on subset of people having a driver's license coming from a household with at least one car (n = 59,761)).

Statistic	Mean	St. Dev.	Min	Max	Source
Individual travel (km)					
All VKT	19.6	20.2	0.0	81.2	Calculated
Work VKT	13.8	19.5	0.0	81.2	Calculated
School VKT	0.822	5.6	0.0	80.8	Calculated
Healthcare VKT	0.6	4.5	0.0	81.0	Calculated
Discretionary VKT	4.3	10.7	0.0	81.2	Calculated
Individual characteristics					
Age	47.4	15.8	16.0	98.0	2013 O-D Survey
Age (squared)	2,498.0	1,534.8	256.0	9,604.0	2013 O-D Survey
Female	0.50	0.5	0.0	1.0	2013 O-D Survey
Student	0.09	0.28	0.0	1.0	2013 O-D Survey
Full-time	0.61	0.49	0.0	1.0	2013 O-D Survey
Part-time	0.06	0.24	0.0	1.0	2013 O-D Survey
Homemaker	0.02	0.14	0.0	1.0	2013 O-D Survey
Retired	0.19	0.39	0.0	1.0	2013 O-D Survey
Not employed	0.03	0.17	0.0	1.0	2013 O-D Survey
Household characteristics					
Cars per household	1.81	0.89	1.0	14.0	2013 O-D Survey
Adults per household	2.26	0.85	0.0	13.0	2013 O-D Survey
School-age children per household	0.49	0.84	0.0	6.0	2013 O-D Survey
Preschoolers per household	0.17	0.47	0.0	5.0	2013 O-D Survey
Neighborhood and regional characteristics					

Statistic	Mean	St. Dev.	Min	Max	Source
Neighborhood Walk Score (Local accessibility)	56.9	22.0	0.0	100.0	Walk Score
Local accessibility (z-score)	0.0	1.0	-2.37	1.86	Walk Score
Transit-accessible jobs by census tract (Regional accessibility)	228,001.20	273,827.0	0.0	1,584,390.0	STM, RTL, EXO, STL GTFS, Statistics Canada
Regional accessibility (z-score)	0.0	1.0	-0.83	4.95	STM, RTL, EXO, STL GTFS, Statistics Canada
Percent of car jobs accessible by transit in 45 minutes	27.3	28.5	0.0	117.6	STM, RTL, EXO, STL GTFS, Statistics Canada

The average distance driven for respondents in the survey for all purposes combined was 19.6 kilometers, including return trips. Among the disaggregated travel purposes, people who traveled for work had the highest average daily VKT at 13.8 km. School and healthcare travel had significant lower average distances driven of less than a kilometer, while automobile travel for discretionary purposes averaged 4.3 kilometers. Differences in driving distances by work status and sex also appear. See Figure 2. For all purposes combined, women who worked full-time or part-time or were homemakers or retirees had lower median driving distances than men for all purposes combined. Women who were students or unemployed recorded higher overall median distances driven. Generally speaking, individual driving distances were more flatly dispersed for full-time workers and students. Homemakers and retirees showed less variation in distance driven, clustering more tightly at the lower end of the spectrum.

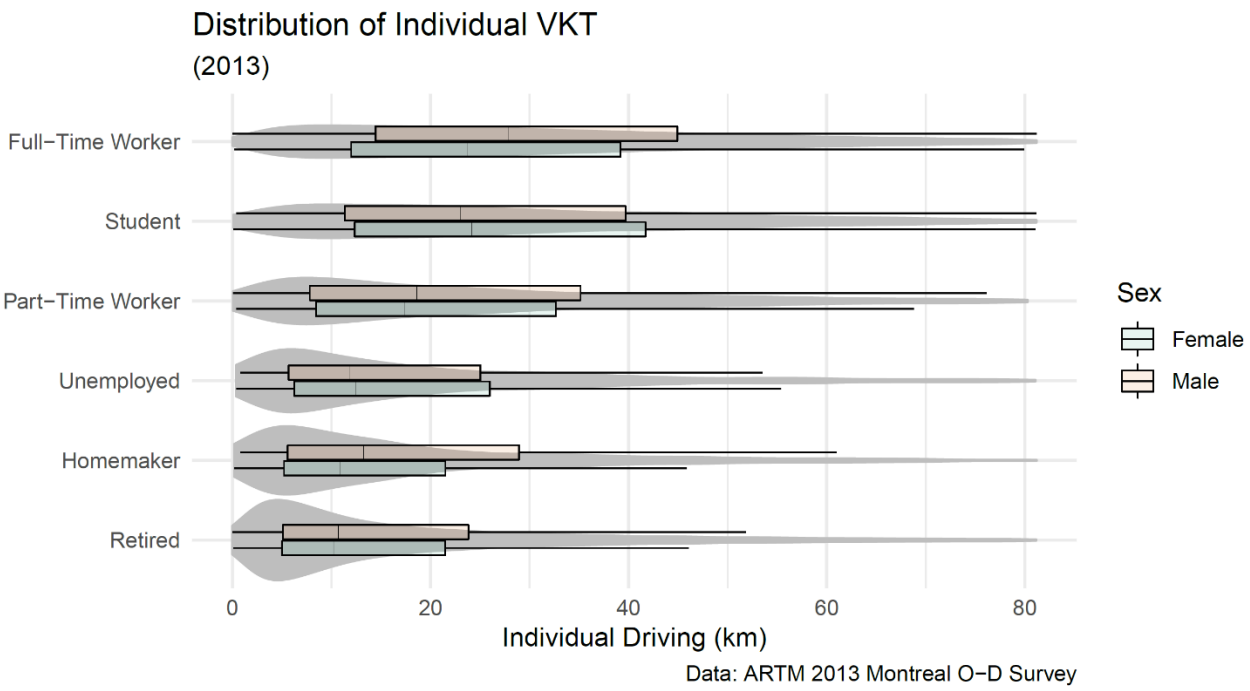

Figure 2 Distribution of individual VKT by employment status and sex.

Study Area Description

This study analyzes travel occurring within 100 kilometers of the center of the Island of Montreal, which is located at the heart of the Montreal Census Metropolitan Area in southern Quebec. The region, home to more than 4 million [50], is characterized by a largely monocentric development pattern with the highest concentration of jobs located in the Ville Marie Borough, Montreal's central business core adjacent to the St. Lawrence river. *See Figure 3.* The area's regional and metro rail service is principally designed to funnel travelers into this central core from surrounding Montreal boroughs and independent municipalities. These surrounding jurisdictions display widely varying urban forms and land-use patterns, ranging from the densely populated areas of mixed residential and commercial properties in boroughs such as the Plateau Mont-Royal to predominantly single-family residential areas, such as Hempstead, Westmount and the West Island suburbs.

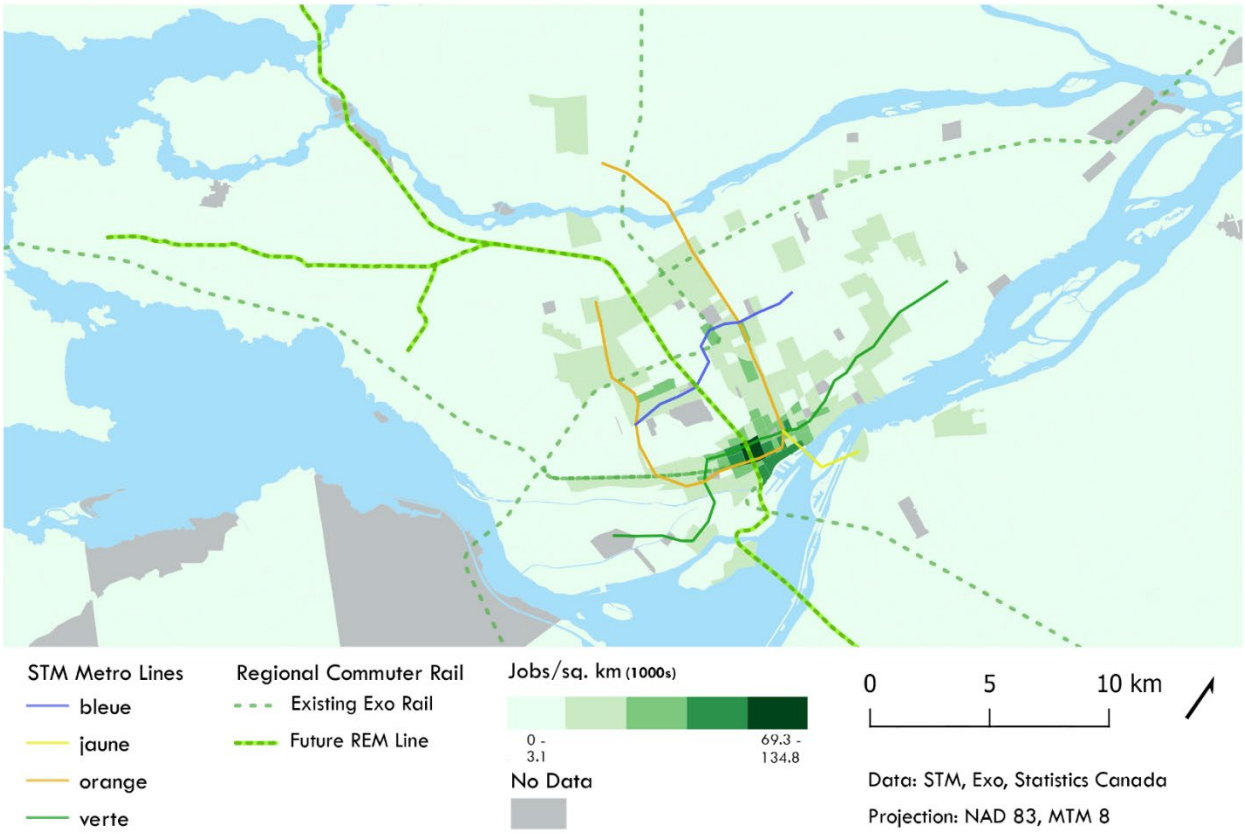

Figure 3 Montreal's major rail transit network in relation to job density.

Spatial Patterns in Average Individual VKT

As seen in Figure 4 our driving-behavior data presents clear spatial patterns that largely conformed to our expectations at the study's outset: As one moves further from Montreal's downtown, VKT increases. The greatest average individual driving distances for all purposes are concentrated in suburban and exurban areas forming a ring around the Island of Montreal. By contrast, the denser inner-city areas tend to generate lower VKTs. The distribution also highlights several outlying areas that defy this general pattern, potentially underscoring the value of commuter transit infrastructure and polycentric development as possible means to reduce individual VKT.

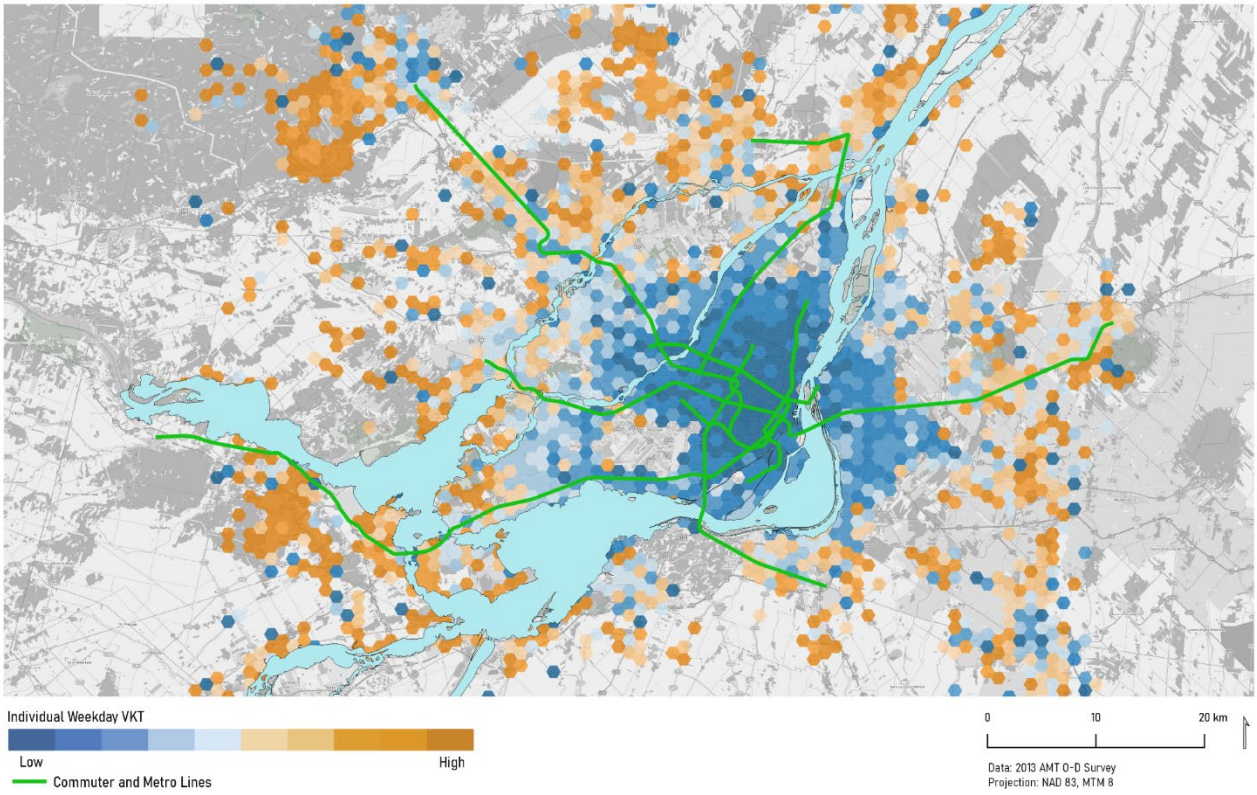

Figure 4 Average individual VKT by deciles for all trip purposes combined.

To Drive or Not to Drive: That is the Regression

As a first step in our analysis, I sought to determine when potential drivers—those who have a driver's license and come from a household with at least one car—become actual drivers. To that end, I explored two principal questions (a) which of the selected factors has an influence on the binary decision to drive or not to drive at some point during the survey day and (b) whether that influence is consistent across travel purposes. For this analysis, I relied on a multilevel mixed-effects logistic regression for all people within our data subset who reported any travel for the categories I considered. The findings from the statistical models are reported in Table 3.

Table 3 Results table for multilevel logistic regressions for odds of driving for various travel purposes.

	Drove for …				
	Any purpose	Work	School	Healthcare	Discretionary purposes
Predictors	Odds Ratios	Odds Ratios	Odds Ratios	Odds Ratios	Odds Ratios
Age (years)	1.055 ***	1.037 ***	1.278 ***	1.039 ***	1.035 ***
Age (sq)	1.000 ***	1.000 ***	0.997 ***	1.000 ***	1.000 ***

	Drove for …				
	Any purpose	Work	School	Healthcare	Discretionary purposes
Predictors	Odds Ratios	Odds Ratios	Odds Ratios	Odds Ratios	Odds Ratios
Female (y)	0.559 ***	0.618 ***	0.783 ***	0.618 ***	0.457 ***
Part-time worker (vs. full-time employed)	0.281 ***	0.475 ***	0.935	0.62	0.546 ***
Unemployed, student or homemaker (vs. full-time employed)	0.812 ***	1.281	2.314 *	0.86	0.963
Additional cars in household	2.597 ***	3.286 ***	2.703 ***	1.445 ***	1.465 ***
Adults in household	0.605 ***	0.570 ***	0.649 ***	0.591 ***	0.716 ***
Preschoolers in the household	1.213 ***	1.169 ***	1.204	1.054	1.245 ***
School-age children in the household	1.019	1.041 *	0.778 ***	1.119	1.141 ***
Lower-income household (<60K CAD/yr) (vs. higher-income)	1.339 ***	1.648 ***	1.524 ***	1.076	0.974
Medium-income household (60K CAD to 120 CAD/yr) (vs. higher income)	1.044	1.109 **	1.083	0.929	0.926
Transit-accessible jobs within 45 minutes (10,000s) (z-score)	0.731 ***	0.708 ***	0.670 ***	0.798 ***	0.745 ***
Home neighborhood	0.885 ***	0.852 ***	0.810 ***	0.831 *	0.884 ***

	Drove for …				
	Any purpose	Work	School	Healthcare	Discretionary purposes
Predictors	Odds Ratios	Odds Ratios	Odds Ratios	Odds Ratios	Odds Ratios
Walk Score (z-score)					
Drove for work (y)			3.043 ***	1.746 *	1.202 ***
Drove for school (y)		4.843 ***		6.048 *	3.087 ***
Drove for health purposes (y)		1.649 *	6.538 **		1.746 ***
Drove for discretionary purposes (y)		1.258 ***	1.997 ***	2.283 ***	
(Intercept)	0.658 ***	0.626 **	0.003 ***	2.32	1.809 ***
Random Effects					
ICC	0.01	0.02	0.05	NA	0.02
N	811 ct	748 ct	559 ct	510 ct	716 ct
Observations	59761	37104	4695	2453	22341
Marginal R^2 / Conditional R^2	0.268 / 0.275	0.299 / 0.311	0.372 / 0.402	0.143 / NA	0.136 / 0.156

* p<0.05 ** p<0.01 *** p<0.001

For all travel purposes combined, car ownership in the household appears to exert the strongest positive influence on the likelihood of driving. For each additional car, the odds of driving increase 2.6 times, all else being equal. By contrast, the presence of additional adults in the household appears to possess a moderating influence, perhaps due to increased competition for cars. To a point, increasing age is significantly correlated with a higher likelihood of driving for all purposes combined and for the disaggregated travel purposes. Both regional accessibility to jobs by public transport and local accessibility (Walk Score) are statistically significant with a negative impact on the likelihood of driving for all trip purposes combined and, to varying degrees, for the disaggregated travel purposes, when holding all other variables constant. Interestingly, incremental improvements in regional accessibility by transit (as measured by z-scores) appear to be correlated with more significant declines in the propensity to drive than local accessibility

across all purposes, with all other variables held constant. Overall, women are statistically far less likely to drive than men, all else being equal. This holds true across all travel purposes.

Relative to people from high-income households, people from lower-income households are more likely to travel by car for all purposes combined and for work and school travel, with all other variables held constant. If I did not control for regional and local accessibility in the models, I might hypothesize that these somewhat surprising results derived from different residential patterns, perhaps with lower-income households occupying less accessible areas. Here, however, the models control for both public-transit and walking accessibility from a traveler's home census tract, indicating that this counterintuitive finding cannot be explained by uniformly applied measures of accessibility at the point of departure. One possible explanation that merits additional investigation is that lower-income people may travel to destination areas that are less directly served by alternative transport. That is to say, transit may currently be structured to provide access to job and education destinations that are more desirable or relevant to wealthier people than to people from lower-income households. Though beyond the scope of this paper, one way to test this hypothesis would be to determine whether there is a statistically significant difference in the travel-time penalty (difference between car and transit times) incurred by individuals within the survey.

Having preschoolers, as opposed to school-age children, is correlated with a much higher likelihood of driving for all reasons combined, possibly owing to the perceived need to carry accoutrements such as strollers or supplies.

Multi-Level Linear Regressions for VKT

In the second step of this analysis, I modeled the relationship between the same set of explanatory variables and log transformed individual vehicle distance traveled by the subset of respondents who drove. Similar patterns of statistical significance emerge as with the logistic regression for positive VKT, though the direction of the relationship is not always the same. Table 4 shows the findings from the multilevel regression models.

Total VKT

Regarding driving for all purposes combined, all variables except being a part-time rather than full-time employee showed statistical significance and the presence of preschoolers in the home, all else being equal. The number of cars per household has a positive and statistically significant impact on VKT. When holding other variables constant, each additional car in the household is associated with a nearly 5% increase in total individual VKT, perhaps as a result of reduced competition for vehicles within a household. Meanwhile, the number of adults represents a drag on individual VKT, while keeping all other variables constant, potentially as a result of increased competition.

Being from a lower-income household rather than a higher- income household is associated with driving 17.4% percent less total distance; being from a middle-income household is associated with driving 4% less than a high-income household, while keeping all other variables equal at their means. These relationships could be explained by financial limitations imposed by lower incomes; a broader geographic dispersion of lower-income jobs, placing them in closer proximity to more

people than higher-income jobs, which tend to be concentrated in central business districts; or a combination of both.

For all categories except healthcare, the model indicates that as people grow older, they drive more. This trend reverses at a certain point as illustrated by the statistical significance of the age-squared variable.

Both local and regional accessibility present a statistically significant negative correlation with individual VKT for all purposes of travel combined, all else being equal. Local accessibility is associated with slightly greater declines in overall VKT than regional accessibility for all driving travel. Each point increase in the z-score of the home census tract Walk Score is associated with an approximately 10% decrease in VKT, all other variables held constant. Each increment in the z-score for transit-accessible jobs corresponds to a decline of about 9.5%, all else being equal.

Table 4 Results table for multilevel linear regressions for individual VKT for various travel purposes.

	log(total vkt)	log(work vkt)	log(school)	log(health vkt)	log(discretionary vkt)
Predictors	Estimates	Estimates	Estimates	Estimates	Estimates
Age (years)	0.0141 ***	0.0287 ***	0.0390 ***	0.0081	0.0080 *
Age (sq.)	-0.0002 ***	-0.0003 ***	-0.0006 ***	-0.0001	-0.0001 ***
Female (y)	-0.1540 ***	-0.1955 ***	0.0716 *	-0.0809	-0.0385 *
Part-time worker (vs. full-time employed)	-0.0351	-0.2145 ***	0.141	-0.2744	0.0991
Unemployed or homemaker (vs. full-time employed)	-0.5182 ***	-0.1002 *	-0.041	-0.0461	0.0037
Additional cars in household	0.0490 ***	0.0249 ***	0.0650 **	-0.0388	0.0406 ***
Adults in household	-0.0655 ***	-0.0494 ***	0.0003	-0.0204	-0.0799 ***
Preschoolers in the household	0.0049	0.0257 *	-0.1142 *	0.0158	-0.0089
School-age children in the household	-0.0115 *	-0.0123 *	-0.0454 *	-0.0694 *	-0.0370 **
Lower-income household (<60K CAD/yr)	-0.1744 ***	-0.1871 ***	-0.0261	-0.0927	-0.1316 ***

	log(total vkt)	log(work vkt)	log(school)	log(health vkt)	log(discretionary vkt)
Predictors	Estimates	Estimates	Estimates	Estimates	Estimates
Medium-income household (60K CAD to 120 CAD/yr)	-0.0422 ***	-0.0585 ***	-0.0585	0.0079	-0.0058
Transit-accessible jobs within 45 minutes (10,000s) (z-score)	-0.0951 ***	-0.1228 ***	-0.2382 ***	-0.1335 ***	0.0025
Home neighborhood Walk Score (z-score)	-0.1024 ***	-0.0752 ***	-0.0669 *	-0.1700 ***	-0.1678 ***
Work VKT			-0.0105 **	-0.0163 ***	-0.0108 ***
School VKT		-0.0179 ***		-0.0027	-0.0126 ***
Healthcare VKT		-0.0119 ***	-0.0148		-0.0099 ***
Discretionary VKT		-0.0098 ***	-0.0095 ***	-0.0022	
(Intercept)	2.9569 ***	2.6977 ***	2.1362 ***	2.8243 ***	2.4266 ***
Random Effects					
ICC	0.11	0.16	0.23	0.21	0.17
N	32281 $_{h\_id}$	21657 $_{h\_id}$	1678 $_{h\_id}$	1700 $_{h\_id}$	15101 $_{h\_id}$
	798 $_{ct}$	733 $_{ct}$	399 $_{ct}$	462 $_{ct}$	703 $_{ct}$
Observations	45011	28580	1783	1737	16759
Marginal R^2 / Conditional R^2	0.140 / 0.233	0.080 / 0.226	0.166 / 0.359	0.093 / 0.284	0.046 / 0.205

* p<0.1 ** p<0.05 *** p<0.01

Work-Related VKT

Work-related VKT displays a similar pattern of statistical significance to overall VKT with two notable exceptions: Part-time versus full-time employment and the number of preschoolers in the household both prove statistically significant; they did not in the overall model. Part-time versus full-time employment is associated with 21% fewer kilometers driven for work purposes, suggesting that part-time employment opportunities may be more geographically dispersed and therefore closer to residences.

Additional household cars tend to be associated with increases in driving distance (+2.5%), while each additional adult in the household is correlated with a decline of 5% in personal VKT to work, keeping all other variables constant at their mean.

Being a woman is associated with driving about 19% less, as is being from a lower-, rather than, higher-income household, all else equal. The age of children in the household influences work-related travel. Work travel distance increases 2.6% for each preschooler in the household but declines 1.2% for each school-age child in the household, all else equal.

Local and regional accessibility are strongly correlated with decreases in work-related driving. As expected, regional transit accessibility as measured by reachable jobs corresponds to greater reductions in work-related VKT. For each increase in the z-score for regional accessibility, work-related driving distance is expected to drop about 12%, all else being equal. Meanwhile, each increase in the z-score for Walk Score for a home neighborhood is associated with an approximately 7.5% decline in work VKT.

The impact of travel for other purposes appears to be small but generally in the same direction. Each additional kilometer traveled for school, healthcare or discretionary purpose corresponds with increases of between 1% and 1.7% in work-travel distance, while keeping all other variables constant at their means.

School VKT

An increase in the number of cars in the household by one drives up distance traveled by 6.5%. but unlike work travel, additional adults in the household do not represent a moderating influence on school-related VKT, keeping all other variables constant at their means. For each additional year in age, expected VKT increases by 4%, but then begins to decline, all else equal. Rather surprisingly, household income was not statistically significant for school-related VKT.

Again, both local and regional accessibility demonstrate a negative correlation with VKT. Regional accessibility displays a strong influence than local accessibility. For each additional increase in the z-score for transit-accessible jobs, school driving distance falls by about 24%, all else being equal; each increase in Walk Score z-score relates to a 7% decline in school driving distance.

The presence of preschoolers and school-age children in the household has a statistically significant negative relationship with individual school-related VKT, with a decline of 11% for each preschooler in the household and 4.5% distance for each additional school-age child in the household, all else equal. For each added kilometer of work-related or discretionary driving, there is an approximately 1% decline in school driving distance.

Healthcare VKT

Few variables in the model show statistical significance with respect to healthcare distance driven, suggesting other factors more strongly influence driving distance for healthcare purposes. Indeed, local and regional accessibility, work driving and the presence of school-age children in the household appear to be significant at at least the 95% confidence level. Here, local accessibility is associated with greater decreases in individual healthcare VKT than regional accessibility. Each point increase in the z-score for the home neighborhood Walk Score corresponds to a decrease of 17% in healthcare VKT, all other variables held constant. Meanwhile, each additional increment in the z-score for regional accessibility relates to a 13% decline in health driving distance.

Work driving distances were negatively correlated with health-care distance traveled with each additional kilometer associated with a decline of 1.6% in health-care driving, while keeping other variables constant at their means.

Discretionary VKT

The number of cars within a household has a significantly significant positive impact on distance traveled by car for discretionary purposes, each additional car corresponds to a 4% increase in VKT for discretionary purpose. As the number of adults increases, distance driven declines by 8%. Each year of age corresponds to a 0.8% increase in discretionary distance traveled, up to a point, all else equal.

Being a woman is associated with driving 4% less discretionary distance compared to men. Hailing from a lower-income household is associated with 13% less discretionary driving distance; coming from a medium-income household corresponds to 4% fewer VKT compared to those from higher income household, while keeping all other variables constant at their mean.

Here, only local, rather than regional, accessibility has a statistically significant correlation with declines in driving distance for discretionary purposes. Each additional increment in the z-score for the home neighborhood Walk Score point corresponds to 17% less discretionary VKT. This result is perhaps unsurprising, but it does underscore the notion central to this research that travel decisions made for different purposes are subject to different considerations. It is conceivable—even likely—that people are obliged to travel further from home for less discretionary purposes, such as work. But for discretionary purposes, they may have both the ability and desire to opt for destinations closer at hand, meaning that the capability to travel regionally by transit is of less importance in this context.

School, healthcare, and work distance driven are all significant, highlighting the notion that discretionary travel is, in fact, discretionary and therefore subject to the constraints imposed by other travel demands. Each additional kilometer driven for each of those categories is associated with approximately a 1% decline in discretionary driving distance, all else equal.

Discussion

These results suggest a range of policy options for reducing individual VKT. The varying patterns of significance across travel purposes also suggest that policy responses must be conceived and targeted in different ways. Given the statistical significance of many of the socio-economic variables, it is also clear that not all these policies will relate directly to the built environment and transport system, although changes to both may serve as essential prerequisites or supports.

First and foremost, our findings suggest that addressing car ownership must be a much greater portion of the policy puzzle when it comes to reducing transport-related VKT. Among all the variables studied, the presence of additional cars in the household represents one of the only two variables that showed consistently statistically significant relationships across all categories of travel for both the binary decision to drive and the distance driven once that decision is made. (The other is local accessibility). Policies in this regard might include incentives for eschewing a car altogether, such as free or discounted transit passes. These polices might also include using pricing mechanisms, such as sales and property taxes, congestion charging and registration and parking fees, to dissuade travelers from having or using a car when possible [51]. In many places, however, car ownership remains essential for basic day-to-day activities such as work and shopping. To avoid unduly burdening car-dependent residents, policymakers may wish to consider progressive approaches to pricing that make each additional car incrementally more expensive. Currently, among all households retained our analysis the ratio of cars to adults in each household is approximately 0.8; among drivers the ratio is higher at 0.88.

Second, local and regional accessibility show consistent impacts on driving and driving distance across most travel purposes considered. In the aggregate—and in combination with other initiatives—accessibility-focused planning efforts may therefore prove influential both directly and as support for other initiatives [31]. For example, enhancing accessibility by transit and other modes may reduce the perceived need to purchase additional cars.

Third, patterns in the role played by demographic and socio-economic characteristics render equity a vital consideration. The data show, for example, that people from lower-income households are far more likely to drive than people from wealthier households. But in many cases, these same people are likely to drive shorter total distances for both work and discretionary purposes than people from higher-income households. This finding suggests different spatial patterns of employment in the Montreal region as lower-income jobs may be more broadly dispersed. Policymakers could potentially take advantage of the differential in driving distances by income group to soften the financial impact of future road pricing mechanisms [52]. They could for example, apply charges over a certain annual or monthly threshold of driving. These particular results may also indicate that people from wealthier households are better served by transport alternatives, affording them greater opportunity to select their mode of transport to their preferred destinations, especially for work purposes, which is consistent with the findings of other studies exploring inequity in transport systems that find the wealthy generally travel faster and further than the lower income groups [53].

Conclusions

Understanding the conditions policymakers can adjust to reduce the impact of rising individual car travel represents a fundamental and enduring challenge. The stakes are high as communities across the world confront an unfolding climate crisis. Transport emissions represent a large and growing fraction of total emissions in both Canada and the United States. Reducing them will require a wide range of options and tools, one of which may be to further refine approaches for urban planning with an eye towards at least allowing people to comfortably, conveniently, and safely make the choice not to travel by car [54].

Much remains to be explored when considering the highly idiosyncratic and context-specific nature of travel behavior and driving decisions. Yet the research to date and this chapter of the study clearly indicate that many factors with a demonstrable influence fall squarely within planners' and city officials' control. As other researchers have noted, "residents do tend to drive less and use other modes more often when they live in compact areas, all else being equal" [54] p. 26. When combined, the 5Ds—of which the destination accessibility studied here is an essential element—may yield large reductions in total vehicle distance traveled. Though important from the standpoint of cutting GHG emissions, reductions in mobile travel will certainly provide other additional benefits, including decreases in other air- and water-borne pollution, less costly travel, fewer roadway deaths and injuries, and more lively streetscapes.

In many respects, accessibility and the other Ds merely enable more responsible and sustainable transport choices. The rest remains up to people and their individual and collective choices. This strongly suggests the need to pursue these policies in conjunction with a broader range of supportive tools, such as road pricing. In the meantime, promising areas of additional research remain to eventually put Montreal drivers and others on the "short" road instead of the long one.

Chapter Two

Driven: Culture and Psychosocial Barriers to Reducing Auto Dependence[2]

Although structural considerations, including the built form, land-use configuration and the transport system clearly play an important role in explaining indvidual driving mode choice, much remains to explain. At their best, the models described above describe no more than 35% of driving behavior in the Montreal region. Indeed, much of the decision depends on psychosocial factors, including cultural and indvidual beliefs and habit. This chapter aims to bolster policymakers' consideration of these factors, which must be targeted in addition to structural elements of urban and transport systems.

This chapter first briefly discusses the types of efforts municipalities and other jurisdictions have made to reduce private vehicle driving. The chapter then describes a theory of change for inducing changes in travel behavior and discusses the cultural and psychological barriers to reducing auto-dependence. Based on these barriers and related theories, this chapter then proposes an integrated framework to unify structural and sociocultural-psychological considerations in mode-choice policymaking. Next, this chapter paper discusses other situations in which policymakers have successfully engaged with psychology and culture to address public health or environmental problems and explores the relevance of these examples as pathways to reducing car usage. Finally, the chapter briefly discusses potential policy recommendations directed at different elements of the integrated model.

Efforts to Date

In attempting to reduce private vehicle travel, planners and policymakers have largely focused on transport infrastructure, built form and economic attributes through incentives and penalties. In Montreal, the larger Metropolitan Community has placed significant emphasis on concepts such as transit-oriented development (TOD) to provide residents with easier access to sustainable modes [55]. TODs, in essence, promote compact development in areas adjacent to transit to bolster the availability of driving alternatives. The City of Montreal also has invested in the development of an extensive biking network, particularly in the Plateau, Rose-Mont and Ville-Marie boroughs. And the regional and local transit authorities have worked on improvements to existing bus and metro service, including dedicated lanes for surface transit [56] and enhancements in frequency for both [57]. We know that these types of interventions are correlated with improvements in sustainable mode share. [23,32,40]. Elsewhere in North America, municipalities have begun to experiment with road pricing to reduce private-vehicle travel and its associated harms [58,59]. But evidence also suggests that initiatives such as these are insufficient to bring about the necessary level of change. To truly effect behavioral change, a more consistent

[2] This chapter was first prepared for URBP 506, Environmental Policy and Planning, taught by Prof. Madhav Badami.

and sustained public campaign directly targeting the sociocultural-psychological aspects of mode choice may be necessary [60].

Theory of Change

Faced with the social and environmental challenges posed by an auto-dominated society, policymakers have at their disposal interventions that fall into the two broad categories described above: harm-reduction achieved through the application of approaches that target specific ills or behavior change. Given the scope of the challenges, harm reduction is and will remain insufficient. For example, transitioning to battery-electric passenger cars will curtail tailpipe emissions and potentially reduce overall GHG pollution, particularly if electricity is derived from a clean grid [61]. But this will do nothing to address the social and environmental impacts of mineral extraction for battery production or even reduce the particulate pollution from brakes and tires that comprises 90 percent of the total particulate pollution from automobiles [62]. Reducing the average weight of passenger vehicles also will result in efficiency increases and lower GHG emissions and other pollution such as particulate matter from braking [63]. But doing so will do little to reduce economic loss associated with congestion, the health impacts linked to sedentary behavior or the street-life-dampening effects of high-speed or high-volume vehicle traffic [15].

Instead, policymakers must begin to consider how to generate shifts in travel behavior and mode choice. This is by no means easy. As numerous researchers have revealed, transport mode choice does not rest entirely on utility-maximizing, cost-minimizing instrumental choices. Rather, it derives from a complex interaction of these and other more deeply rooted psychological and socio-cultural factors. Changing behavior, in turn, rests on two, interrelated pillars: One, changing individual travel intentions and behavior and, two, restructuring transport provision through larger systemic change. As Higham et al. (2013) noted , neither is sufficient in and of itself. [64]. This paper posits that these twin pillars will exert influence between one another, assuming that alterations in individual behavior will facilitate a shift in contextual norms and enhance political appetite for broader systemic change in the areas of transport provision and land use. Meanwhile, broader systemic changes will facilitate changes in individual behavior.

Cultural and Psychological Barriers to Mode Change

Cars are ubiquitous and car culture is deeply ingrained, rendering a transition to more sustainable modes all the more difficult. In some cases, this is reflected in the reflexive use of automobiles, even for trips that could easily be completed on foot or bike. In the European context, for instance, it has been estimated that up to half of car trips are less than 3 to 5 kilometers in length and could, therefore, be replaced by walking or cycling [65]. The unexamined pervasiveness of automobiles is evident in an advertisement for a Vancouver car-rental company that only half-jokingly—and rather flippantly—suggests using a car as a wheeled metal umbrella. (See Figure 5). For some elements of North American society, vehicle use and, in particular, use of vehicles with internal-combustion engines, underpins almost tribal constructions of (toxic) masculinity. Nowhere is this more evident than in phenomena such as the brand rivalry between Ford and Chevrolet owners,

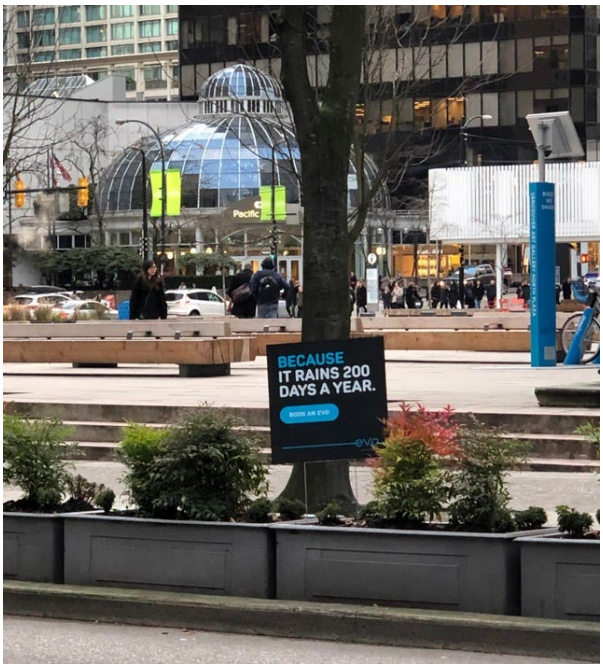

Figure 5 An advertisement for Vancouver car-rental company Evo suggests that people should drive because it rains frequently. (Source: Reddit/misterkrashkart)

which has given rise to countless memes and jibes predicated on sexualized, heteronormative or outright homophobic notions. See, for example, Figure 6. In the context of electric vehicles, similar cultural perceptions are evidenced by the phenomenon of "ICE-ing" in which drivers of traditional fossil-fuel cars purposefully block electric charging stations [66].

Media further entrenches car culture. Car ads on television, in newspapers and even on public transportation peddle a false notion of freedom, masculinity and control. Newspapers dedicate entire sections to automobiles and driving. For example, Canada's Post Media publishes "Driving," which the company says reaches more than two million readers per week. And elements of popular culture, from Herbie to Knight Rider's KIT, even anthropomorphize cars.

Policymakers must take seriously the barriers posed by both culture and psychology, which will require a coordinated and sustained effort. Doing so will both guide individual actions and help establish the necessary political preconditions and will to pursue additional necessary policies, including road-pricing, taxing and spending plans, land-use changes and outright restrictions on auto use in some areas and under certain conditions. Transport policymakers ignore this cultural context at our peril.

Figure 6 Sexualized or homophobic anti-Ford or anti-Chevy memes are commonly circulated on the Internet as part of a brand-based rivalry that reflects the broader cultural implications of vehicle ownership. (Source: Ranker and Reddit).

Growing Awareness Among Researchers and in the Literature

There is rising awareness among researchers in a range of social sciences fields that travel mode choice depends on far more than reasoned considerations of time and cost.[3] Anable 2005 observed: "[R]ational, instrumental arguments are insufficient to explain why measures to restrict car use generate strong emotions and negative reactance to change [67]." Although researchers have developed a broad range of different theoretical and explanatory models, there appears to be widespread agreement that psychological and cultural considerations play a deeply important role in travel behavior and mode choice [17,64]. In fact, some studies have suggested that psycho-social or symbolic-affective attachment to cars may explain commuter mode choice to a greater degree than instrumental considerations. In a survey-based study of Netherlands commuters, Steg (2005) found that symbolic-affective factors, including family expectations, played a more significant role in determining the percentage of work trips completed by car than considerations such as time and cost-savings [17].

By far, the most common psycho-social models of transport behavior and mode choice derive from Azjen's 1991 "Theory of Planned Behavior [67,68]." The theory posits that human behavior or action originates with intention, which is an outcome of the amalgam of: (a) attitudes toward the act behavior, which consists of a person's belief or feelings about whether it makes a positive or negative contribution to their life or wellbeing; (b) subjective norms, which consist of a person's cultural context, including social networks, cultural norms and group behaviors and beliefs; and (c) perceived behavior control, which is a person's subjective belief about how easy or difficult it might be to carry out a particular act or behavior [68]. The contents of someone's perceived behavioral control is effectively a person's subjective understanding of their ability to do something and may or may not align with their "actual behavioral control," which reflects the true constraints on someone's ability to do something, such as the availability of time, resources or services [68]. In this context, an individual's habits and history of action influence these three principal factors indirectly.

The basic Theory of Planned Behavior has been expanded to include other concepts related to travel mode choice. Central among these are concepts that more directly include the notion of habit, which may override reasoned decision making, particularly in frequently repeated actions such as daily commuting [69]. More recently, more comprehensive, integrated models based on these theories have been proposed to capture different elements of the underlying psychological and social considerations Higham et al. (2013) describes two in an article that focuses on sustainable tourism but with implications for travel behavior more generally. The first model is Gehlert, Dziekan and Garling (2013), which suggests "linear relationships" between the various aspects. This approach suggests, in the context of ecological sustainability that providing information on sustainability will change norms and perceptions and then individual behavior will be negotiated relative to "psychological costs [64]". The second is Schwanen and Lucas (2011), which explicitly looks at social norms deriving from peers, cultural norms deriving from society at large, and an individual's past experiences. According to Higham et al. (2013), "[s]pecifically, they

[3] Transportation Research Part F: Traffic Psychology and Behavior – even dedicated an entire journal to this dimension. Been around since 1998.

acknowledge that lifestyles and identities arise out of complex interrelationships of early cognitions, perceptions, moral motivations, values, personal norms, attitudes and beliefs, personal intentions and habits [64]." The notion of "early cognitions" ought to be of particular interest to transport planners and policymakers because it suggests that early interventions to shape individual perceptions and behavior may have lasting effects. This is, at least partially, confirmed by work such as Grimsrud & El-Geneidy (2013), which found that early transit ridership and delays in obtaining drivers' licenses generated sustained patterns over time and led to an earlier plateau of typical age-related declines in transit ridership among certain age cohorts [70]. Higham et al. (2013)'s model, adapted from Schwanen & Lucas (2011).

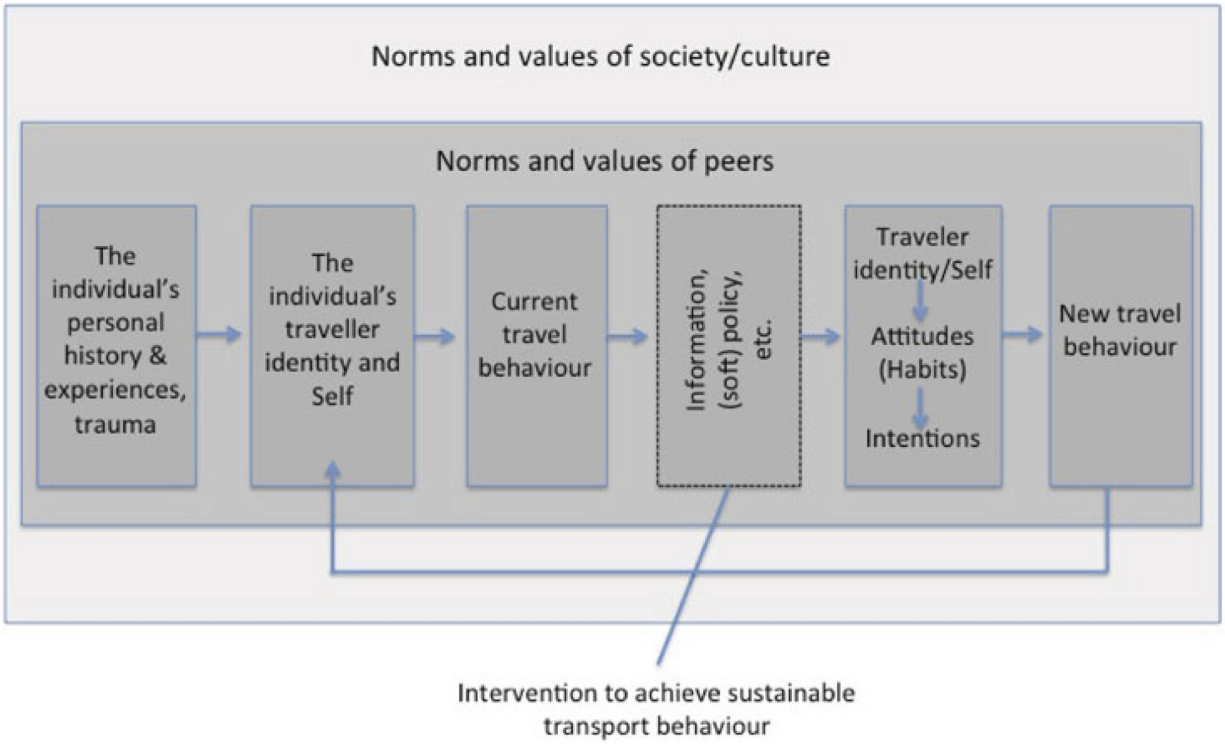

Figure 7 Higham et al. (2013)'s sociocultural-psychological model of transport behavior, adapted from Schwanen & Lucas (2011) [64].

An Integrated Model of Structural and Sociocultural-Psychological Factors for Transport Policymakers

For purposes of transport policymaking aimed at shifting people from private cars, this paper proposes a further expansion of Higham et al. (2013)'s model for two reasons. First, the authors of that paper acknowledge that the model accounts only for the "sociocultural and psychological dimensions of travel behavior [64]." Real limitations and instrumental considerations indirectly influence elements of the socio-cultural-psychological model and directly influence the range of transport-behavior choices actually available to travelers. In response, this paper proposes incorporating real constraints related to the systemic provision of transportation.

Second, this paper suggests that influencing the psycho-social inputs to these broader models of human behavior requires that policymakers develop interventions that take advantage of a more fine-grained understanding of the mental processes that affect how each of these larger psychological concepts play out. The principal addition is an explicit consideration of the role played by cognitive heuristics and biases. Innocenti et al. (2013) confirmed that these biases are present in mode choice determinations [71]. "[The] key experimental result is that travel mode is significantly affected by heuristics and biases leading to robust deviations from rational behavior [71]." In a lab experiment involving Italian undergraduate students, Innocenti et al. (2013) asked participants to choose between car and metro and bus and car trips after providing information regarding money and time costs for various trips. The participants' choices reflected something other than a rationally motivated minimization of cost. Instead, the participants displayed a consistent bias toward cars, which reflected what the authors considered to be "label bias" based on an affective association of cars with notions of freedom and status [71]. This occurred despite the fact that publicity surrounding the recent launch of Firenze's metro could have been expected to engender more positive feelings toward this mode of transit [71]. The participants also demonstrated a cognitive bias toward their first choice. In practical terms, the study's authors suggest that a preference for cars may be highly resistant to economic incentives alone and that policymakers interested in shifting mode choices should focus on individual awareness.

Policymakers' success at addressing and influencing different elements of the sociocultural-psychological model will depend on addressing the biases Innocenti et al. (2013) identified and numerous others. Among the key cognitive heuristics and biases for policymakers to consider—many of which directly relate to the element of "perceived behavioral control"—are:

- Variable perceptions of time based on contextual clues and level of engagement with surroundings [72,73]. Researchers have noted that, in some cases, travelers perceive waiting time as longer and active time as shorter, which could have implications for people's subjective enjoyment of different modes and even their perceived behavioral control.
- People's relationship with so-called "sunk costs," which is shaped by other biases such as loss aversion and framing effects [74–76]. In essence, people often fail to adequately weigh costs that they have already incurred or that they do not otherwise perceive simultaneously with use [71]. This may have the effect of making driving, where the lease or purchase cost is incurred at a different time, appear to be less costly than other modes whose costs are more explicit.
- People's tendency to "loss aversion", which results in an exaggerated valuation of losses relative to gains, even when they are objectively equal. [77]. This concept may have implications for how people and drivers respond to the different framing of policies aimed at reducing automobile travel such as removing parking to install a bus lane.
- People's natural tendency toward overconfidence in the assessment of their skill and ability to control outcomes. This could encourage people to drive and assume they will be able to "beat" traffic based on their control over their own car's route.

- The closely related, "optimism" bias, under which people tend to place greater weight or faith in positive outcomes [78]. Such a bias could easily cause a would-be driver to discount the likelihood of encountering traffic delays which are beyond their control.
- The "representativeness" bias, according to which people tend to judge the probability of an event based on their own experience rather than information that is provided to them. Innocenti et al. (2013) note this tendency to substitute one's own judgment when faced with outside information may make people's preference to the car resistant things like real-time information on delays.
- Perhaps most importantly, habit, which triggers a failure to reason through decisions at all. [71] Relying on Daniel Kahneman's notion of fast (heuristic and habit-driven) and slow (rational and reasoned) systems for human decisionmaking, Innocenti et al. observe that travel choices in repeated may effectively cease to be rational or deliberative. This suggests that policymakers must pursue interventions that force travelers to pause and deliberate before deciding on a course of action. Such an approach might include mandating distance based use charges for automobiles and requiring that they be displayed in-vehicle or even before trips commence. It further suggests, that policymakers may need to employ command-and-control approaches that simply eliminate driving as a choice for some areas and destinations [71].

It is worth noting that these psychological considerations combine in different ways in different people to yield a range of sometimes unexpected behavioral differences or similarities across groups. Everyone is different and attitudes toward different mode choices play out in different ways based on unique interactions and idiosyncratic constraints on choices. According to Anable (2005), "[t]he evidence clearly shows that the same behavior can take place for different reasons and that the same attitudes can take place for different reasons [67]." In her study of leisure visitors to heritage sites in the UK, Anable sought to cluster travelers not according to objective sociodemographic characteristics but rather in accordance with sociocultural attitudes and psychological leanings to identify their role in mode choice. In all, she identified six distinct clusters: four whose members drove and two whose members employed more sustainable modes. She discovered that sociodemographics attributes were not significantly different across the groups, suggesting that attitudinal factors played a greater role. Of even more relevance to policymakers and planners, the research suggested that different combinations of factors had played out differently among these groups suggesting the need for specially tailored interventions for each [67].

With these considerations in mind, this paper proposes an expanded, integrated version of the Higham et al. (2013) model with a series of adjustments to expressly incorporate "real" or "structural" constraints on individual behavior and to address various cognitive biases which may have an impact on elements of the higher-order psycho-social decisionmaking model. These considerations are captured in Figure 4.

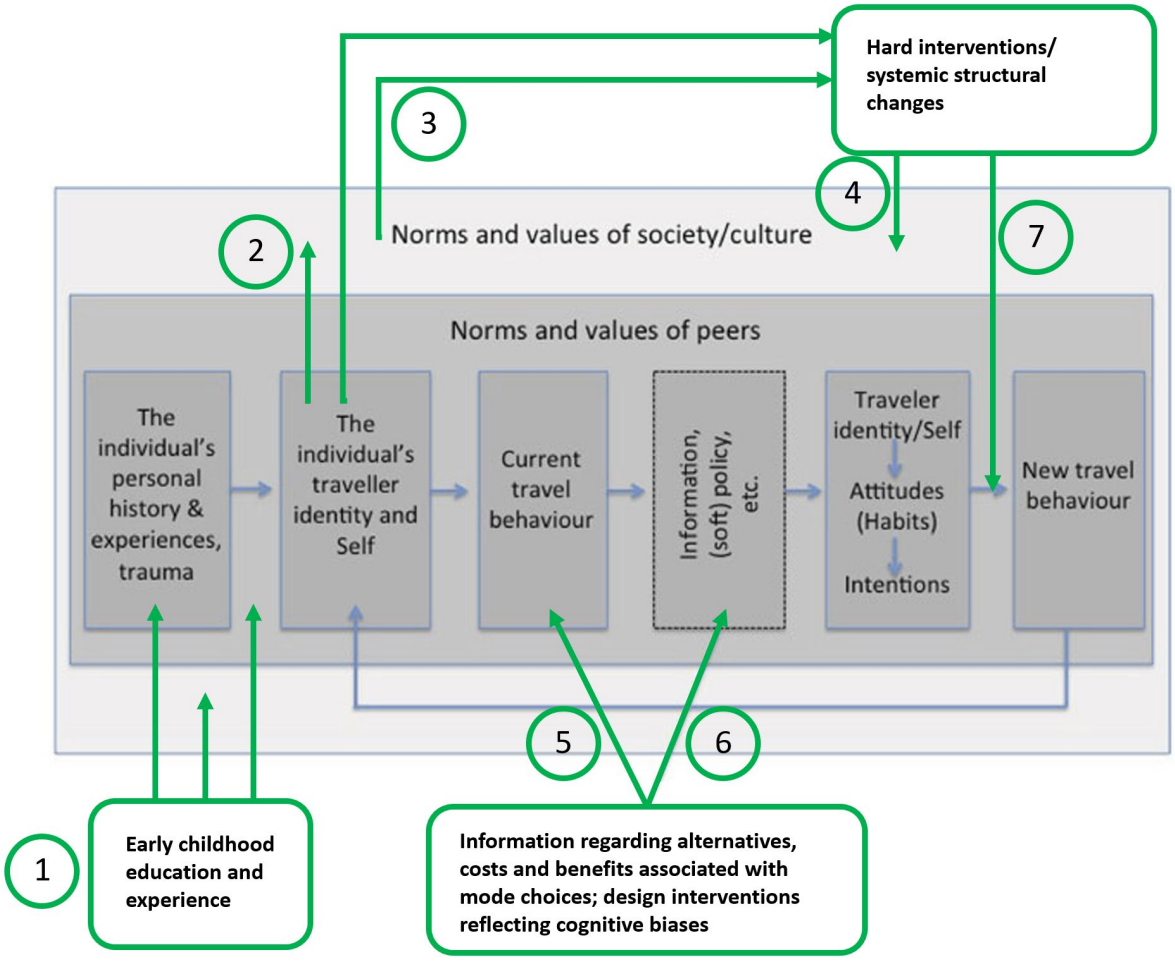

Figure 8 Proposed model for transport-mode-shift interventions integrating psycho-social and instrumental/structural considerations and approaches. (Amending Higham et al. 2013).

The integrated model proposed seeks to integrate instrumental and systemic structural interventions with psycho-social and cultural interventions to suggest a more comprehensive framework for shifting individual and collective travel behavior toward more sustainable modes. Systemic, structural interventions reflect those interventions that might have a bearing on attributes of "actual behavioral control [68]. That is to say, these reflect the objective constraints on an individual's ability to carry out intended behaviors. See No. 7 in Figure 4. They would include so-called hard interventions, such as restrictions on automobile use for certain times, areas or destinations or new public transit infrastructure, fare structures or subsidies. All of these would bear on increasingly familiar transport concepts such as accessibility, which measures the actual ease of reaching desired destinations [27,79]. Interestingly, increased "hard" interventions, such as regulation, may also create a positive feedback loop, enabling additional hard or regulatory interventions. Research in the context of anti-smoking regulations shows that these regulations may actually stimulate additional interest in further regulation and alter perceptions of social acceptability [80].

The sociocultural-psychological interventions, meanwhile, recognize that human decisionmaking and behavior is influenced by a host of factors that do not necessarily align with rational utility

maximization. Rather, they depend on, among other things, psychological and social constructs and evolutionarily derived cognitive heuristics and biases. Social practices are also important. "A good starting point for understanding how different stakeholders are networked together in the social production of energy-intensive transport behavior has been work focusing on social practices … These studies point to how actors, societal structures and norms and technologies co-mingle to produce habituated routines that are difficult to disembed [64]." This helps explain why behavioral outcomes, particularly with respect to transport, may appear dissonant or irrational. One example is the fact that elements of actual behavioral control reflect the conditions necessary to enable a particular behavior but they by no means guarantee a particular behavioral choice. People's perceptions of the availability and relative ease of certain options are more likely to determine whether they pursue a particular course of action or behavior. In the simplest terms, the notion of perceived behavioral control acknowledges that if someone is unaware of a bus stop near her home, its existence will have no bearing on whether she takes public transit. The perceptions and misconceptions about particular travel behaviors can also be more subtle and nuanced. For example, a potential transit rider may perceive bus travel to be too difficult because of long-held beliefs regarding personal safety or because he is unaware that the bus now accepts credit card payments rather than just cash. In each case, different interventions may be deployed at different stages of the behavior-making process reflected in the model described in Figure 4.

The following paragraph describes some of the salient feature of the proposed integrated model. Cited numbers refer to the numbers in green circles within the figure.

1- Policymakers may seek to influence "early cognitions," personal history, experience and trauma through childhood education programs designed to familiarize children with the use of alternatives to automobiles such as buses and to educate them regarding the risks and harms of automobile usage. These interventions would also, in the aggregate, contribute to the development of norms and values among peers and society as a whole.
2- In the aggregrate, individual perceptions of automobile and alternative travel modes influence peer and social norms and values.
3- Social norms and values directly influence the political acceptability of hard interventions to bring about mode shifts.
4- The existence of hard interventions and regulations may influence social values and norms, creating a positive feedback loop for additional regulation.
5- Information regarding alternatives, costs and benefits during the practice of a particular behavior or act may help address the persistent misestimation of costs that occurs because they are not perceived at the same time as they are incurred.
6- Information regarding more sustainable choices and outcomes, as well as information designed to enhance perceived behavioral control, may shape an individual's perceptions and beliefs.
7- Hard interventions regulatory interventions to reduce driving can directly constrain a person's actual behavioral control, eliminating certain types of behavior.

Implications for Policymakers

The proposed model suggests one possible framework for integrating the instrumental and structural elements of travel mode choice with the sociocultural-psychological elements of human behavior. Ultimately, to effectively shift people to more sustainable modes of transport, policymakers must be able to slay what Robert Giffford refers to in the context of climate change as the "dragons of inaction [60]". Gifford notes that most agree that climate change constitutes an existential threat but that psychological barriers prevent action. These include: "limited cognition about the problem, ideological worldviews that tend to preclude pro-environmental attitudes and behavior, comparisons with key other people, sunk costs and behavioral momentum, discredence toward experts and authorities, perceived risks of change, and positive but inadequate behavior change [60]." He notes that [s]tructural barriers must be removed wherever possible, but this is unlikely to be sufficient. Psychologists must work with other scientists, technical experts, and policymakers to help citizens overcome these psychological barriers [60]."

Examples of Broader Campaigns that Have Played on Different Elements of the Model

There are myriad examples in the past where policymakers have engaged in public campaigns aimed at altering behavior by targeting different elements of the psycho-social model this paper adopts. These examples include public-health efforts to curb smoking and campaigns to reduce particularly dangerous aspects of automotive travel, such as drunk driving. This section describes at a high level how these campaigns operated, the relative success they achieved and how similar approaches might be adopted in the context of altering behavior to shift drivers to more sustainable modes of transport.

Smoking

In many respects, the popularity of the personal automobile has followed a similar arc to smoking, which during its rise subject to myth-building, culture-shaping advertisements designed to generate certain attitudes and promote tobacco as a lifestyle. Prizes and promotions accompanied cigarette advertising, in much the same way that enhanced credit-card bonuses, loyalty rewards and weekly discounts accompany the sale of gasoline today [81]. But for tobacco, a sustained anti-smoking campaign unfolded in the United States beginning in the mid-20th Century. What began as a public-education movements that was largely the province of non-profit groups transformed into a government-backed public-health agenda with the publication of a landmark Surgeon General's report in 1964 linking smoking to negative health effects [82]. The campaign operated on many fronts that fit within the conceptual framework for behavior modification outlined above. The campaign relied on soft, information interventions that targeted individual smokers while also seeking to shift social values and norms [82]. Some advertisements, for example, made moral appeals to pregnant women encouraging them to quit smoking for the good of their fetuses. Government officials also worked to restrict youth access to cigarettes through regulations and education campaigns, thus reducing the likelihood of early habit formation [81]. Eventually the U.S. government also restricted tobacco advertising, which researchers have concluded worked to reduce smoking and its social acceptability. Over time,

governments also restricted where and when smokers could light up, constraining opportunities to engage in unhealthy behavior and further strengthening anti-tobacco social values and beliefs [80]. Although it has taken more than 60 years, smoking rates in the United States are now at their lowest level since tracking began. As of 2018, only about 13.7 percent of U.S. adults smoked [83]. In 1965, more than 42 percent of U.S. adults smoked.

Drunk Driving

Drunk driving in the United States and many other places has experienced a similar progression from social acceptability to social rejection, although it remains to be seen the extent to which such a shift has actually translated into true behavioral changes. In the United States, the absolute incidence of self-reported drunk driving declined between 1993 and 2014, while the number of drivers and vehicle miles has increased, suggesting at least a modest improvement [84]. Part of this may be attributable to shifting social mores and values influencing individual behaviors. Mothers Against Drunk Driving (MADD), a non-profit organization founded by the mother of a girl killed by a drunk driver, has waged a major public-relations campaign since the 1970s [85]. In addition to consistent messaging aimed at adjusting social norms and individual perceptions of drunk driving, the organization also successfully advocated for the passage of laws to restrict impaired driving and enhance penalties [85]. One researcher indicated that MADD's activities in Ontario between 1982 and 1996 could be associated with a 19% to 23% decline in drunk-driving fatalities [85]. The same researcher observed a shift in cultural norms, noting that "Drunk-driving 'accidents' become 'crashes caused by criminal negligence', altering a collective moral mentality [85]." A similar process may be underway with regard to the victims of automobiles more generally, as pedestrian safety advocates urge the media to discuss "crashes" rather than "accidents," which suggests a lack of agency or responsibility or agency on the part of drivers [86].

Potential Policy Approaches to Address Private-Vehicle Driving

This section suggests some particular policy interventions aimed at shifting travelers from private cars to more sustainable modes of transport by taking advantage of elements of the integrated model of instrumental and sociocultural-psychological interventions.

As a threshold matter, policymakers must lay the necessary groundwork by making systemic structural changes to the manner in which transport services are provided. No amount of nudging or cajoling toward more desirable transport behaviors will be successful if alternative options do not exist. These may include investing in new and revitalized sustainable transport infrastructure to enhance accessibility and enabling denser land uses in central areas while ensuring residential affordability.

At the same time, structural changes will fail to bring about desired changes in travel behavior without interventions that properly consider complex human psychology. Potential interventions should start with developing a solid understanding of the underlying sociocultural-psychological context. Information gathering tools, such as Montreal's origin-destination survey, gather critical information about people's travel behaviors but fail to capture any data regarding participants' underlying motivations and perceptions. Among other things, policymakers could ensure the O-

D survey is more useful by including attitudinal questions that shed light on important psychological attributes that shape behaviors [67]. Anable (2005) demonstrated that clustering and segmentation purely based on sociodemographics and without consideration of attitudinal characteristics could elide important differences between groups, making targeted campaigns less effective.

Policymakers may also wish to explore opportunities to shape travelers' perceptions and values regarding sustainable mode choices from an early age. This could take the form of curricula that exposes children to biking and public transit early while educating them about the environmental, social and public health consequences of private cars. This would also help substitute sustainable habits for less desirable ones. Legislators could also further delay the issuance of drivers' licenses to the age of 21 and create more comprehensive licensing education programs that are more reflective of depth of the responsibility that should attend driving. This might include education regarding the social, health and environmental harms of driving as well as discussions of the full costs of driving.

Policymakers should consider a combination of public-outreach campaigns to sensitize the public to the harms that accompany driving. As was the case with anti-smoking and anti-drunk-driving campaigns, these campaigns would be aimed at individual drivers to influence their decisionmaking process while also mobilizing and strengthening broader social norms and values in support of more sustainable choices. At the same time, policymakers should seek to reinforce sustainable social norms and values regarding transport mode choice by banning advertising for private automobiles [87]. One newspaper columnist recently suggested such a ban to "suck the glamour from the car industry [87]." Research suggests that similar restrictions on tobacco advertisements were at least marginally successful at influencing smoking behavior [88].

Policymakers may also consider altering the driving experience itself. Rather than facilitating the process, it should in effect be made every bit as nervewracking and psychologically demanding as befits an action that confers significant benefits, mostly for its users, but also generates major social harms. Relatedly, policymakers must ensure that driving does not remain a reflexive habit. Among other possibilities, policymakers should seek options that require travelers to consider the full costs of driving as close to the time of use as possible to reduce underestimates of sunk and other costs. This could be accomplished by, for example, charging a per-mile road fee with a visual counter installed or by requiring that all automobile leases be calculated on a per-mile basis, again with in-vehicle, prominently displayed counters. Similarly, policymakers could consider eliminating monthly parking passes and requiring payment—in cash—on a daily basis. These approaches would help address cost miscalculations and could also work to erode reflexive habit by requiring a level of contemplation, similar to calorie counts on restaurant menus .

Conclusions

Extreme use of the private automobile engenders significant social, health and environmental harms that policymakers must address by shifting people to more sustainable transport modes where possible. While cars remain useful—or even essential—under certain limited circumstances and in limited locations, there is simply little justification for auto-dependence in

densely populated urban areas. To begin this transition toward more sustainable modes, policymakers must necessarily adjust the systemic provision of transportation alternatives. But these sorts of structural or instrumental changes cannot, in and of themselves, guarantee individual behavioral change or generate the necessary political will for outright restrictions on the use of private cars for certain times, locations and destinations without adequately considering the sociocultural-psychological aspects of transport mode choice. Policymakers would, therefore, be well served by considering both the instrumental psychological components of mode choice. This paper has proposed an integrated model of behavioral outcomes around which policymakers can structure and target their interventions. Properly conceived and implemented, policies addressing these elements may lead to social and cultural changes similar to those observed in other public-health and -education campaigns to reduce tobacco use and drunk driving. The health and welfare of Canadian cities' residents depends on it.

Summary

Driving contributes disproportionately to the most significant environmental and public health challenges Montreal and other Canadian urban areas face today. In recent years, cities have tentatively begun to apply the tools offered by their traditional planning, zoning and spending authorities to shape the built environment, land use and transport systems in more sustainable ways. The research contained in this SRP further underscores the strong correlation between these attributes and driving mode choice and behavior in the Montreal area. The impacts vary across travel purposes, suggesting a nuanced and multifaceted approach is necessary as cities explore different interventions to shift drivers to public and other active transport.

At the same time, these structural considerations do not come close to explaining the full range of travel outcomes observed in Montreal's O-D survey. A growing body of research highlights the notion that mode choice is far from objectively utilitarian. (Indeed, there is some doubt that It could ever be wholly objectively utilitarian because people's perceptions and the limits of their own awareness of true structural conditions would mediate their assessment.) Instead, mode choice is influenced by sociopsyhological attributes and cultural contexts. The second chapter of this research project summarized some of the most conceptually powerful mode-choice models in the psychosocial and cultural research realms and proposed an expanded model integrating both sociocultural-psychological and instrumental considerations.

Ultimately, the statistical analysis and literature-based conceptual model proposed here suggest that city policymakers will need to take their interventions to promote more sustainable travel mode choices in new directions. This may take them out of their traditional competencies and comfort zone. Among other things, these may encompass aggressive regulation, price-setting and broad public awareness campaigns, including childhood education, to promote a culture of sustainable mode choice. In many cases, this will involve close collaboration with other levels of government. Education, for example, is under provincial jurisdiction in Quebec.

In the end, only through a coordinated and comprehensive approach may cities bend the curve on driving and reverse the historical tendency of transport technology to shape cities so that cities and their polices can shape the technologies we use.

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