

TITLE

by

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University of Toronto

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## **Abstract**

Title

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# Preface

This dissertation can be read as a complete and coherent document, however Chapters 2, 3, & 4 were originally written as separate articles to be published in peer-reviewed academic journals. As such, there is some redundancy in the introductory material, literature reviews, and methods sections of each.

At the time of writing, Chapter 2 has been published in the Annals of the AAG (Allen & Farber, 2021); Chapter 3 is under review at Environment and Planning A; and Chapter 4 is under review at the Journal of Transport and Land Use. I am first author on each of these publications and take full responsibility for omissions or errors in the analysis.

As each of the chapters provides some of its own context, the goal of Chapter 1 of this dissertation is to frame the issues motivating this research as a coherent body of work. Similarly, Chapter 5 serves to tie together the results of each article into broader implications and to suggest future lines of research.

# Chapter 1

## Introduction

This is a dissertation about cities and how they change over time. Their urban form, transportation networks, and social geographies. And the implications of such changes on residents' well being.

Contemporary human history is one of urbanization. More than 50% of the world's population lives within urban regions. This tops 80% in many developed nations, including Canada. Urbanization is associated with overall levels of poverty reduction, economic growth, increases in life expectancy, and improvements in a number of other social indicators; while concurrently, modern urban development exerts a great toll on the natural environments and can exacerbate social inequalities (Whitmee et al., 2015). These negative outcomes can partly be attributed to the qualities of urban development, particularly the suburban auto-oriented environments built over the past century. While offering quality of life improvements for many, suburbanization has consumed thousands of hectares of natural land as well as increased per capita energy use and GHG emissions (Ewing & Hamidi, 2015). It is also well founded that auto-oriented suburban built environments are detrimental to individual health and well-being relative to traditional, more compact, neighbourhoods (Ewing et al., 2003). This has led many researchers to design and advocate for policy and planning strategies that aim to curb urban sprawl and promote more compact development.

Under their veneer of homogeneity, the suburbs also exasperate inequalities and risks of social exclusion. These risks are less studied relative to the environmental and health impacts of suburbanization. Well functioning urban systems provide people the ability for people to participate in daily activities and access destinations necessary for individual health and well-being. However, millions suffer from transport poverty, where transport disadvantage (e.g. insufficient public transit options) compounds with other forms of social disadvantage (e.g. low-income or poor health) resulting in barriers to daily travel and thus dissuasion or inability to participate in daily activities, increasing the risks of social exclusion (Lucas, 2012). Social exclusion refers to when people are prevented from participating in society and activities necessary for their well-being (Levitas et al., 2007). Risks of transport poverty are greatest in suburban environments where cars are costly yet necessary for many (Allen & Farber, 2019). In Canada, transport poverty is evident via transport disadvantage being associated with low activity participation rates, particularly for those of lower socio-economic status living in areas of low transit accessibility (Paez et al., 2009; Roorda et al., 2010; Allen & Farber, 2020b).

Moreover, the demographic and socio-economic patterns of cities are dynamic. Historically, the development of early industrializing cities was quite monocentric, based on manufacturing, industry, and jobs in the core, and successions of wealth moving out to the suburbs along major transport corridors. Urban segregation and inequalities were thus usually visible via core-periphery gradients (Burgess, 1925; Alonso, 1964; Glaeser & Kahn, 2004). In the later half of the 20th century, there have been substantial population dynamics, which has been framed under post-Fordist restructuring (Walks, 2001), polycentric development (Anas, Arnott, & Small, 1998), and demographic inversions (Ehrenhalt, 2012) such as gentrification (Vigdor, Massey, & Rivlin, 2002) and suburbanization of poverty (Ades, Apparicio, & Seguin, 2012). Many contemporary cities, including several in Canada, have evolved into forms where poverty is most prevalent within the inner-suburban ring, located between wealthier older neighbourhoods and outer more recently built suburbs.

These recent demographic inversions are worrisome from a transport geography perspective as they likely are increasing travel barriers and abetting the scale of transport poverty due to an increased propensity of lower-SES households living in inaccessible neighbourhoods. Despite these concerning trends, there is limited research on the relation between changing urban socio-economic patterns like suburbanization of poverty, differential patterns of urban form and transit (in)accessibility, and risks of transport-related social exclusion. How and where are trends of suburbanization of poverty increasing risks of transport poverty?—Who are the suburban poor? Where do they come from?—Are lower-income residents disproportionately moving away from adequate transit service? These questions have implications for both theory on how the structure and patterns of cities evolve and change over time, as well as for providing evidence to inform policy aimed at poverty reduction and making cities more sustainable.

First, it is important to define and state higher-level research objectives. Research is the practice of finding and communicating knowledge and evidence. Indeed, a long noted goal of science is to try to explain nature, based on empirical observation—deciphering how and why things occur, and in geography, the how and why of where. Evidence regarding human environments in particular will almost always have normative interpretations as we collectively are embodied and reproduce our environments. Evidence in this domain does not only explain, but is also used as justification for policy, planning, and design aimed at re-shaping our environments. As such, for each of the empirical chapters of my dissertation, the concluding sections include discussion on the implications of findings both in terms of academic theory and policy recommendations concerning progressive options for promoting social inclusion, environmental sustainability, and planetary health, where applicable.

Second, a note on scope. The focus of my research is on human environments at a meso-scale, the scale of socio-spatial interactions, daily travel and activity participation, from the neighbourhood to the region. This consists of a combination of the built environment, transport networks, the demographic and socio-economic characteristics of

residents, and their daily activity patterns. My research is theoretically broad, but empirically focused on urban regions Canada. Methods are quantitative in nature, based on survey and administrative data from Statistics Canada, regional travel studies, as well as land use and transport network data from a variety of sources. From a temporal perspective, research will be primarily retrospective. Historical data will provide the ability to examine trends back to the latter 20th century.

# Chapter 2

## A Brief History of Changing Cities

### 2.1 A Century of Suburbanization

The social and physical patterns of urban spatial structure can be considered as a result of competition for desirable space (demand), available land and property (supply), and the development of transportation technologies and networks (Alonso, 1964; Anas et al., 1998). It is the interplay between these, and their dynamics, that has shaped the suburbs and manifested their negative environmental and social impacts.

Cities are often dichotomized between their centre and peripheries. Indeed the suburbs are not a modern phenomena, if we consider the suburbs as simply the transition zone between the urban and rural. Indeed the term originates from the Latin *suburbium* pertaining to what is below the city walls. In some ancient cities, these suburban lands housed people that were too poor to live in the city walls, or provided space for the rich and their leisure activities. Being poor and outside the city walls (sub-urban) meant foregoing the protection and utilities because they could not afford it. Historical cities were also often dense places rife with inequality. The elite had space, while the poor were crammed into poor housing. High density cities were necessary given lack of fast transport (limits of accessibility) and often needing to defend behind walls (Bruegmann, 2008).

The industrial revolution had several major consequences on the pathway towards today's form of (sub)urbanization. Factories and industry tended to locate in the city centre, near major transport hubs. This lead to urban migration, people locating near the available jobs that industry offered. These facilities also worsened the livability of the central city because of their noise and pollution. The industrial revolution also lead to the development of new transportation technologies, such as trains and streetcars. This allowed for the wealthy to live at further distances from the city centre, but still within commuting distance. These trends continued during the early 20th century (e.g. in the interwar years, London's population increased by 10%, but its land area increased by 20%). This urban growth was seen as combinations of *aggregations* of urban populations and *expansion* of urbanized land (i.e. expansion and intensification, concentration and decentralization), that manifested itself in decreasing density and increasing wealth as one moves away from the city centre (Burgess, 1925). People were seen to move up the social hierarchy by moving out away from the city via processes of succession and filtering, while the inner-city was the locus for in-migration and the working class (Burgess, 1925).

The private car was a catalyst that took these ongoing trends, and put them into over-drive. With the Model T, Henry Ford and his company initially developed a machine that was only affordable for the wealthy, but throughout the early decades of the 20th century, it became increasingly affordable relative to the yearly incomes for many households (Kunstler, 1994). The benefits of having a car were clear, it increased people's mobility and accessibility. They could travel to destinations more quickly, and it increased the number of possible destinations that could be reached in a reasonable travel time. Despite economic downturns, like the great depression or the oil crisis in the 70s, auto production and use continued to grow throughout the 20th century. Practically all of the developed world, and an increasing part of the developing world has become integrated into a system of auto-mobility. By the end of the 20th century, it was estimated that one billion cars were manufactured during the past century (Urry, 2004). It is now only the densest cities and the poorest rural areas in which cars are not a necessity for daily life. Auto-mobility

is also inherently linked with many other industries such as parts manufacturers, civil engineering, retail environments, urban planning, oil and gas sectors, and the wealth of nations generally (particularly oil producing nations). If driving declined, it would have a number of effects in the economy and the aforementioned industries would have to close down or pivot. Such economic changes could have various ripple effects in the social geographies of some cities, similar to de-industrialization of what is now called the rust belt of the USA.

Cars provided a form of unfettered mobility that provided residents the ability to live at further destinations from their daily activities. This was a much greater land area, or catchment area, than what could be reached by trains or streetcars, which were confined to very specific rail corridors and by walking distances from stations. Indeed, many scholars have discussed theoretically, as well as shown empirically that cars are a major driver of low-density suburban development (Baum-Snow, 2007; Glaeser & Kahn, 2004). The models by Baum-Snow (2007) implied that across a sample of metro areas in the USA, central city populations would have grown by about 8 percent on average had the entire interstate highway system not been built, instead of declining by 17 percent overall. Suburban development increased rampantly during the post-war period, as modern suburban development became affordable for the growing middle-class (particularly the large Baby Boom generation), who had a desire for suburban living, as well as higher incomes allowing them to get such space (Anas et al., 1998). Particularly in the North American context, many local governments were happy to open up such land to private development as well as offered mortgage subsidies (e.g. via tax credits) for home-buyers to spur the process (Blais, 2011; Ewing & Hamidi, 2015; Bruegmann, 2008). Overall, these factors resulted in a more homogeneous sprawl that was often only confined by strict topography such as a water body or mountain range.

Causes of suburbanization cannot be summed up by a simple linear equation. There are lots of linked effects (e.g. home owner credits, highway development policy, increasing crime in cities as people leave pushing more to want to move, socio-cultural opinions

of what consists the "good life", etc.). Many of these causes are related and have feedback effects. For example, from a transport perspective, we can argue that cars and highways led to urban sprawl by allowing development in formerly inaccessible lands (e.g. Glaeser & Kahn, 2004), but then this suburban development led to more cars since it made transit less efficient and accessible. This then focused further development patterns on highways as well as low-density housing and retail, further making the car more desirable, *ad infinitum*. Transportation planners, despite being complacent in suburban sprawl, have long understood that urban development is based on feedbacks between transportation and land-use (Wegener & Fuerst, 2004). Furthermore, there is often path dependency and mutual interests (Blais, 2011; Kunstler, 1994) such as the highway industrial complex.

The massive growth in suburban development over the past 100 years indicates an overwhelming preference and demand for suburban living. These preferences include greater volumes of interior living space, private yards, and high accessibility to both the city and the countryside (given that a household has a car). There are also socio-cultural pushes towards suburban living evident in media outlets, and the size of one's home and car are status symbols in many communities (Kunstler, 1994). Some of these ideas stemmed from utopian visions of cities such as Howard's "garden city", which was a balanced spatial pattern of residences and other human uses (work, retail, services), surrounded by greenbelts and connected by rail lines. Another example is Frank Lloyd Wright "Broadacre city" which was a grid of single detached homes based on the idea that people were not meant to live as "degraded machines" in high density urban environments (Wegener & Fuerst, 2004). These were based on concepts that human societies should be more connected to nature and away from the negative effects of cities such as density, noise, and pollution (indeed there is much more recent evidence on how access to green space positively effects well-being). Some suburban developments are able to provide this access and opportunity. These aforementioned benefits of living space and access to nature (and away from hyper-density of human activity) are why many prefer to live in the suburbs today. Certainly, many households make a trade-off between loca-

tion (i.e. accessibility) and housing quality when deciding where to live (Lee, Oropesa, & Kanan, 1994; Alonso, 1964)

The negative effects of modern suburbanization can be grouped into two; environmental and social. The environmental effects are clear. Suburban environments are directly associated with increased driving (Ewing & Cervero, 2010; Moos & Mendez, 2015) and with this, comes increased congestion, pollution, and emissions that impact local population health and contribute to climate change. Auto-based transportation is the single most important cause of environmental resource-use (Urry, 2004). This is a combination of the scale of material, space, and power used in the manufacture of cars and car-focused built environments. Transport accounted for 1/3 of CO<sub>2</sub> emissions during 20th century (Urry, 2004). The life-cycle environmental costs of auto production span the globe across various parts and assembly chains. There are also ample negative environmental effects associated with modern auto-oriented landscapes that cars have enabled, such as larger homes on larger parcels of land relative to the city. The relatively larger housing found in typical suburbs requires more energy use, both in terms of space for heating and cooling, as well as more material goods being produced to fill said space, resulting in larger carbon footprints than smaller urban homes. Moreover, modern suburbanization also takes up more land per person than older urban environments. Much of this was former green space and agricultural land, land uses that are now located further from city centres, meaning food has to be shipped a greater distance. This increased space also requires more money and material devoted to utilities to serve these neighbourhoods (e.g. stormwater sewers and retention ponds, waste water sewers, water transmission lines, roads and highways, etc.). A number of researchers have noted that these environmental costs are not properly incorporated into the costs of driving and land development (Blais, 2011; Ewing & Hamidi, 2015; Kunstler, 1994). In other words, society has been subsidizing this regressive development, instead of designing healthier, more sustainable, and more affordable communities.

The negative social impacts of suburbanization are more varied and nuanced. The

first of these relate to human health. For example, as more people drive, there has been a substantial increase in traffic fatalities (e.g. more Americans have died in car crashes since 2000 than American soldiers who died during WW2) as well as longer emergency response times (Ewing & Hamidi, 2015). As well, suburban auto-oriented environments quell other, more active, modes of travel such as walking, cycling, and transit (this typically includes walking to and from stops). There is a large body of research that has shown that suburban auto-oriented environments are linked with less physical activity and also with higher rates of obesity, heart disease, and cancer prevalence (Ewing & Hamidi, 2015; Ewing et al., 2003). There is also increasing concern that, because of their auto-dependency and low density attributes, suburban environments can cause transport disadvantage, inaccessibility, and barriers to daily travel—particularly for those who do not have regular access to a private vehicle (Roorda et al., 2010; Lucas, 2012; Allen & Farber, 2020b). Similarly, others have argued that reliance on a car and the banality of suburban environments can limit social interactions and creates a barrier to building social capital by creating an overly individualized atmosphere (Jacobs, 1961; Kunstler, 1994). My dissertation research focuses on the transport-related impacts of suburbanization, and how these have developed over time.

## 2.2 The Changing Social Geography of Cities

Alongside built environment changes, the demographic and socio-economic patterns of regions change over time as well. These regional changes can be dependent on external economic forces. A globalization of the world economy has shaped the economy of cities. This is arguably increasing a wage-gap. In the developed world, particularly in North America, there has been a decline in industrial and manufacturing jobs due to a global re-distribution of manufacturing sites. These jobs were predominantly blue collar and middle class, and during much of the 20th century, most households in North American cities were working, middle-class families. In some cities, such as Toronto, this has been

somewhat offset by an increase in knowledge, office-based, professional work (Walks, 2001). Many of these workers have a preference for inner-city living. The result is a polarization of the labour market in terms of occupation and income. Many low-income jobs are in retail or food industries, which have low wages and low employment benefits, particularly for temporary workers.

In some cases, this polarization of the labour market has resulted in divisions of urban space (Walks, 2013, 2001). Higher-income households can always outbid lower-income households for housing quality and preferred locations. If a lower-income neighbourhood has characteristics that a higher-income group finds desirable, gentrification can occur and the original residents may be forced to move due to costs of living increases. The opposite can also occur. Some neighbourhoods, once popular among middle- or higher-income households, can fall out of favour and property values fail to keep up with other neighbourhoods. Over time, lower-income households replace middle- and higher-income households in these neighbourhoods, via what can be broadly be termed as a filtering process (Hulchanski, 2010; Ades et al., 2012). Housing is also constrained by zoning. Social housing and aging rentals are clustered in certain parts of cities, which is filtered down to lower SES groups (Hulchanski, 2010). In Toronto, social housing is relatively dispersed. Many low-income rentals are in the form of Corbusian apartment towers built in the mid-20th century (August & Walks, 2018). These are mixed throughout the city as well. Those in the inner-suburbs are typically at the bottom of the housing ladder (Hulchanski, 2010; Ehrenhalt, 2012). Generally, there are very few apartments and lower-income housing in wealthier single-detached neighbourhoods mainly due to NIMBYism and zoning constraining intensification (Scally & Tighe, 2015). In the case of Toronto, zoning restrictions have focused brownfield development into a small portion of the city's land area, and the most profitable form of development are condominiums or offices.

Changes in regional socio-economic structure can also be due to demographic transitions, such as aging populations, families having fewer children, and more women in the

workforce (Bourne & Rose, 2001; Bourne, 1989). These can result in changes in income inequalities. For example, increased education rates leave a minority behind with a greater gap in wages. Aging populations can also increase the percent with no yearly income, due to income being the primary measure of inequality (Bolton & Breau, 2012). Immigration is also a factor (Bourne & Rose, 2001). Most immigrants are typically of relatively lower SES than current residents and settle in the most affordable parts of cities, but often where there are still some socio-cultural connections, either through social networks or settlement services (this can be thought of as a form of self-selected segregation).

Suburban housing and lifestyles appear to provide levels of comfort for many that were not achievable generations prior. This upward mobility to better housing was only achievable for those of certain levels of household income. In many cities during the 20th century, this resulted a hollowing out of the inner-cities, leaving only the poor behind. In this US, this has been termed "white-flight" given the racial correlates with income, or more systematic forms of racism (e.g. exclusionary zoning to limit low-income, often black, households to settle in a community). This concentration of poverty can have further feedback effects, such as increase in crime and urban decay, barriers to social mobility (e.g. Chetty, Hendren, & Katz, 2016), and limited resources due to a declining tax-base (Wilson, 2012). Jobs and other resources also became harder to obtain because of greater spatial distances. This has been termed as a "buffer" effect (Wilson, 2012) or as spatial mismatch (Holzer, 1991), which is when the movement of people and firms from central city areas to the suburbs causes growing employment problems for people who live in inner-cities (especially, low income, and in the US, black residents).

Some of these formally deprived inner-city areas have undergone gentrification. Gentrification can be defined as the replacement of the existing population in an area by one enjoying a higher socioeconomic position (Bruegmann, 2008). It also typically includes the retrofitting of physical urban space (e.g. buildings, the public realm), while maintaining a certain historical character. Generally a neighbourhood is thought of as gentrifying if its SES increases at a faster rate than the rest of the city on average. It usually involves

the transition of inner-city neighbourhoods from a status of relative poverty and limited urban investment into an area of greater commodification, reinvestment, and less relative poverty. Gentrification is thus a combination of social change, economic change (e.g. businesses, housing markets), and physical change of the built environment (Rose, 1984; Ley, 1986; Hammel & Wyly, 1996; Hamnett, 1991).

The modern, back-to-the-city, form of gentrification began in the 1960s and was soon discussed in depth by researchers in the 1970s (Sumka, 1979). Gentrification represents part of a demographic inversion (Ehrenhalt, 2012). Previously, city structure was adequately explained with urban theories from the Chicago school's concentric circles (Burgess, 1925), as well as theories of land rent (Alonso, 1964). With the onset of gentrification, city centres were becoming wealthy, going against this core-periphery gradient model of the city.

Early explanations of gentrification can generally be divided into production and consumption theories.

The production side argument focuses on supply (Hamnett, 1991), and in particular capitalist land markets (Smith, 1987). The supply side actors include builders, developers, landlords, mortgage lenders, government agencies, and real estate agents - many of whom are trying to maximize their profit. Smith (1987) frames gentrification using a Marxist perspective of uneven development, which can be defined as how societal and economic development does not take place everywhere at the same speed or in the same direction. Smith (1987) argues that much of this is due to capitalism, that will result in development where costs are lower and the potential for profit is greater. This is termed a *rent gap* in the context of gentrification, which is the difference between the potential profit of re-development and its current use. When the gap is great enough, redevelopment will likely occur given the probability of profit. Throughout the mid-20th century, the movement of capital into the suburbs led to less investment of the inner city, and as the rent gap grew, inner-city investment began to occur. In other words, gentrification can be thought of as a process of creative destruction.

However, several authors have argued that Smith's Marxist explanation is too deterministic and parochial (Rose, 1984; Ley, 1986; Hamnett, 1991). For example, Rose (1984) argues that Marxist theories are overly "structural" in the role of capitalism in producing gentrification, and does not consider other components. Indeed supply and demand are symbiotic, production of supply (or production of gentrification) won't occur without the demand. In the words of Hamnett (1991), "the rent gap may provide the means, but not the motive for gentrification" (Hamnett, 1991). This leads to the demand, the consumption side argument of gentrification.

The consumption theories consider a number of factors that are reduced to increased demand for inner city living. The first of these pertain to demographic change. In the 70s, there was an increase in the population of 20-30 year olds due to baby boom generation, who were entering the housing market. These new families were typically decreasing in size (e.g. number of children per parent), and there were also more women entering the labour market. These changing household structures (more smaller households, more women in the work force), meant there was a greater demand for smaller housing units such as condos, which are generally located in more central areas, areas that are often discussed as gentrifying. As well, there are more gay couples living together, couples without kids, non-related people living with each other (roommates), singles, single parents, elderly, all not desiring traditional suburban homes (Ley, 1986; Bourne & Rose, 2001). Much of the supply for non-traditional homes are in so-called gentrifying neighbourhoods (this is arguably a failure of land use planning and shortsighted development).

The preferences and constraints of these new adults were different than their predecessor cohort. In general, there were increased value in urban amenities among younger generations, compared to previous generations who valued greater living space (Ley, 1986; Bourne, 1989). These urban amenities included access to non-work activities such as cultural, commodities/retail, community. Or in other words, access to diversity in a broad sense, many of the positives of urban living that have been discussed by Jacobs

(1961). Early stages of gentrification were often attributed with counter-cultural lifestyles (e.g. artists, gay communities, activist organizations). There were also preferences for aesthetically pleasing landscape, that could partly be a backlash of the banality of suburbia that many gentrifiers grew up in (Hamnett, 1991; Kunstler, 1994). There was also an important role of individuality and growth of a more sensuous and aesthetic philosophy among the newer middle class (a new leisure class in pursuit of self-actualization, rather than a stable life with a house and a car) (Hamnett, 1991). Similarly, some people had preferences for active travel, or car-free lifestyles (Schwanen & Mokhtarian, 2005), that have been shown to impact residential location choices in more central areas (Cao & Chatman, 2016).

There are also two other macro-level factors worth noting. One is that the retrofitting of city centres is spurred by governments (e.g. re-designing streets, public parks, plazas, etc.) that increases desirability and demand for these areas (C. E. Jones & Ley, 2016; Zuk, Bierbaum, Chapple, Gorska, & Loukaitou-Sideris, 2018). For example, improved or new transit infrastructure can increase accessibility and desirability, and thus demand and competition for space (Higgins & Kanaroglou, 2016). In some cases, this has been cited as a catalyst for gentrification (C. E. Jones & Ley, 2016; Padeiro, Louro, & da Costa, 2019; Grube-Cavers & Patterson, 2015). Second, over the past several decades, there have been increases in commuting costs (both in terms of distance because of sprawl, travel times because of congestion, as well as increased fuel costs), that discourage living in distant suburbs.

In sum, gentrification should not be thought of as having a single cause (none of the aforementioned alone), but a combination of the above, that likely interact and feedback to produce the construct that's called gentrification. In general, gentrification is not a simple cause and effect process. Gentrification, and urban change more generally, is a symbiotic process of supply and demand, and of mutual causality.

Putting the complexity of the causes aside, the effects of gentrification are both substantial and controversial. First, gentrification makes real changes to the physical envi-

ronments of cities. Shops and storefronts change to cater to new populations. Streets are upgraded. Buildings are retrofitted. New buildings are built. In some cases, decaying remnants of industry have been converted into office, retail, and residential spaces (e.g. the Distillery District is a prime example of converting former industry land into a bastion of haute commerce in Toronto). As well, in general, living in gentrifying neighbourhoods promotes a more sustainable lifestyle compared to suburbia, it highlights desire for urban living, and pride people have for their non-suburban neighbourhood (before, during, and/or after the gentrification process). Daily behaviour in urban gentrified neighbourhoods have a lower carbon footprint compared to more suburban locales of similar SES (Ewing & Hamidi, 2015). However, gentrifying neighbourhoods may also be increasing commutes for low-income workers who cannot afford to live in these neighbourhoods, and are thus commuting greater distances.

The reciprocal to inner-city gentrification is socio-economic decline in suburbs. For example, in large cities in Canada, the most affordable parts of cities are now found in the inner-suburbs, particularly where has been substantial city-centre gentrification and increased demand for older neighbourhoods near the core. This is evident by an increase in low-income residents and recent immigrant settlement in the suburbs in Canada (Bourne & Rose, 2001; Ades et al., 2012). Similar trends are occurring as in US cities (Ehrenhalt, 2012; Delmelle, 2017).

Decline in middle-income jobs and increases in wage and income inequality have also resulted in a greater range between the costs of housing, and what lower-income households can afford, particularly within central parts of cities that have greater demand (Walks, 2001). This has resulted in some lower-income households being priced out of central parts of these cities, and subsequently re-locating to less dense, but more affordable neighbourhoods. Spatial patterns of recent immigrant settlement have also witnessed shifts from central areas towards relatively more affordable suburban environments (Ley & Smith, 2000). New, recently built, suburban housing stock remain predominately designed for middle to upper income households, typically for traditional (i.e. nuclear)

families. But low-income residents are not primarily located in typical suburban housing stock (e.g. single detached homes), but instead, are often clustered in apartment buildings in more suburban locations (Cooke & Denton, 2015; Skaburskis & Nelson, 2014). In Canadian cities, many of these were designed in an auto-oriented, Corbusian "Tower in the Park" style in the mid- to late-20th century. There are concerns that these buildings have few on-site services and amenities, lack rent controls, and many consist of decaying building structures; problems that are exasperated by an increased financialization of ownership that focuses on extracting value rather than the well-being of tenants (August & Walks, 2018). Despite these concerns, they are now the most abundant form of available lower-income housing in many cities due to increased demand, low supply, and high costs of housing in central areas.

From a research perspective, empirical evidence on suburbanization of poverty is usually based on longitudinal analysis of census data or specific panel surveys analyzing changes in the spatial distribution of low-income households or other SES variables over time. Recent research has highlighted trends of suburbanization of poverty in early-industrializing cities in nations such as the United States (Kneebone & Garr, 2010; Howell & Timberlake, 2014; Cooke & Denton, 2015), the Netherlands (Hochstenbach & Musterd, 2018), Sweden (Hedin et al., 2012), Scotland (Kavanagh, Lee, & Pryce, 2016), and Australia (Randolph & Tice, 2014).

Within the Canadian context, there is evidence of increasing income inequalities both within and between regions (MacLachlan & Sawada, 1997; Walks, 2013; Bolton & Breau, 2012; Breau, 2015; Chen, Myles, & Picot, 2012), as well as concentrations of low-income households forming in some inner-suburban neighbourhoods (Ades et al., 2012; Pavlic & Qian, 2014; Ades, Apparicio, & Séguin, 2016; Breau, Shin, & Burkhart, 2018). For example, Pavlic and Qian (2014) found that there has been decline or stagnation in prosperity in inner-suburban areas relative to central areas and newer outer-ring suburbs. Research by Ross et al. (2004) and Ades et al. (2012) included spatial segregation indices for low-income households and households in poverty in Canadian cities, finding that economic

segregation is increasing at a neighbourhood level and that low-income households are becoming increasingly concentrated and isolated within their spatial units. Statistical mapping exercises have also highlighted that neighbourhoods with higher concentrations of low-income households have been drifting further from the downtown core over the past several decades (Ades et al., 2012; Breau et al., 2018).

Overall, these trends of suburbanization of poverty have raised concerns regarding the increasing polarization and segregation of urban space by class and income (Hulchanski, 2010; Walks, 2013; Ades et al., 2012), as well as negative impacts caused by eviction and displacement on individual well-being and disrupting community cohesion (August, 2014, 2016). As such it is important, yet understudied how households end up to be poor and live in the suburbs. Chapter 3 of this dissertation directly examines the propensities of different pathways to suburban poverty, specifically to what extent is suburban poverty a product of moving from city centres, immigration, or becoming and remaining poor in-place.

## 2.3 Neighbourhood Effects & Daily Activity Behaviour

Studying neighbourhoods and how they change over time is important because of the beneficial or adverse effects living in certain neighbourhoods (i.e. neighbourhood characteristics) can have on individual outcomes. This is often termed as "neighbourhood effects" (Sampson, Morenoff, & Gannon-Rowley, 2002). In a literature review, Sampson et al. (2002) argues that there are four classes of neighbourhood mechanisms that can impact social outcomes: 1) Social ties / interactions. i.e. the level of social capital, which is generally conceptualized as a resource that is realized through social relationships. 2) Norms and collective efficacy, which is that the willingness of residents to intervene on behalf of children may depend on conditions of mutual trust and shared expectations among residents. i.e. can be considered as mutual trust and social cohesion 3) Institutional resources, particularly in terms of quality, quantity, and diversity of such that meet

the needs of the community (e.g. libraries, day car, schools, health, etc.). This can be measured by accessibility (opportunity) and by participation (outcomes) 4) Daily activity patterns and exposure to different components of society and the built environment. To this final point, I would also add accessibility and relation to the city as a whole (which is not mentioned by Sampson). My dissertation will explicitly contribute to and build upon the third and fourth point highlighted by Sampson et al. (2002).

Importantly, it is well observed that decreases in neighbourhood social indicators (e.g. crime, poverty, etc.) result in negative impacts for residents (Sampson et al., 2002). Poverty concentration can also have feedback effects (Wilson, 2012), that can be termed concentration effects and buffer effects. Concentration effects refer to the constraints and impacts associated with living in a neighbourhood in which the population is overwhelmingly socially disadvantaged. Buffer effects, or lack thereof, refers to whether there are a sufficient number of working- and middle-class professional families in a neighbourhood to absorb the shock or cushion the effect of uneven economic growth and periodic recessions on poor neighbourhoods. For example, if the poor become increasingly segregated, it often becomes more difficult to plan and provide needed services due to declining tax base, meaning less services to alleviate poverty. As well, poverty concentration can lead to limited economic development in poor areas - e.g. grocery stores or other services may not want to locate in a poor area as it might be less profitable (Ades et al., 2012). The aforementioned has partly motivated research on spatial segregation (Massey & Denton, 1988), in order to highlight areas that are more likely to be at risk.

Where you live can also impact long-term social mobility. One example is the Moving to Opportunities study, that provides excellent evidence that a child's exposure to better environments impacts their long term social mobility. In this study, 4,604 families in low-income neighbourhoods were randomly assigned into 3 groups: 1) Received subsidized housing voucher if they moved to a census tract with a poverty rate below 10 percent. 2) Received subsidized housing voucher without any additional contingencies. 3) A control group without a voucher. Then the authors estimated "intent-to-treat" effects based

on long-run tax records. These effects are essentially differences between treatment and control means (i.e. a difference-in-difference model). These are estimated as dummy variables in an OLS modelling effects on income and educational attainment, and the models include both individual and neighbourhood controls, and clusters errors at the household level (Chetty et al., 2016). Their main finding is that children (under 13) who moved to higher SES neighbourhoods have better long-term outcomes in terms of education and income.

Another important neighbourhood effect, only touched upon above, is how one's built environment can facilitate or act as a barrier to daily travel and activity participation. Indeed, travel is a derived demand, derived from wanting to participate in daily activities (P. Jones, 1979; Buliung & Kanaroglou, 2007). From a rational point of view, someone takes a trip when the utility (or value) of an activity outweighs the costs of travel (where costs can be considered as a generalized combination of monetary, temporal, and other factors). The characteristics of daily travel can be described in a number of dimensions: These include the number of trips per day, the activities participated at the destinations of these trips, the time and distance travelled on each of the trip legs as well as in aggregate, the mode of travel utilized, and which route people take on their journey. Daily travel has two primary predictors, individual factors and environmental factors (Hanson, 1982).

An individual's travel pattern is based on how they chose to participate in certain activities at certain places at certain times of day. Travel can thus be understood as the movement required to participate in daily activities (Hanson, 1982). Different people have different preferences for or constraints on the activities in which they participate (e.g. school, work, shopping, health care, etc.) that are related to their demographics and socio-economic status. For example, the elderly are less likely to travel during morning commuting periods than the middle aged. Indeed, the majority of quantitative travel behaviour studies include variables on age, employment status, and gender (Hanson, 1982). They also include variables pertaining to mobility tools and ownership, that vary by person and household. Examples include car ownership or whether or not someone

has at transit pass. These tools if available can facilitate travel. Income is thus a factor as well. For example, limited income can then create barriers to travel due to unwillingness or inability to afford a car, bicycle, or pay for regular transit trips.

Travel behaviour is also based on personal preferences. For instance, research by (Schwanen & Mokhtarian, 2005) shows that people who have a preference for living in walkable environments and who also live in walkable environments are more likely to walk than people who have a preference for suburban environments but live in walkable environments. Preferences for other life choices can also have an indirect effect on travel. For example, residential self-selection can be a confounding factor in travel behaviour studies - i.e. endogenous to the behaviour (Cao & Chatman, 2016).

The built environment also plays an important role in facilitating travel and activity behaviour. The built environment can be conceptualized into two scales; urban form and urban structure. Urban form is usually discussed in terms of local contexts—what is in the nearby (walkable) vicinity of a household. Components of urban form include streets, buildings, parks; architecture and urban design at a more general level. Indeed, there is ample research showing how “good” built environments can result in more sustainable outcomes such as increased transit use and lower vehicle kilometres travelled (Ewing & Cervero, 2010; Ewing & Hamidi, 2015). “good” in this case often refers to the 3Ds; *density* of activity, population, employment, etc. *diversity* of land uses, often measured in terms of entropy, and the *design* of street networks, size of blocks, and available sidewalks (Cervero & Kockelman, 1997).

Urban structure pertains to how a location is situated within the context of an urban region, and how characteristics of locations are related to each other through networks (Anas et al., 1998). Urban structure is often framed in terms of accessibility, which can be summarized as the ease of reaching activity destinations (Hansen, 1959; Geurs & Van Wee, 2004). There are a number of different flavours of accessibility pertaining to different destination activity types, times of day, modes of travel, or spatiotemporal constraints (Geurs & Van Wee, 2004; Levinson & Wu, 2020). A meta-review by Ewing and Cervero

(2010) found that destination accessibility is strongly related to VKT, roughly the same as first three Ds combined.

Accessibility measures can be used to predict a number of forms of travel behaviour. Indeed it has long been observed that "the frequency of human interactions such as messages, trips or migrations between two locations (cities or regions) is proportional to their size, but inversely proportional to their distance" (Wegener & Fuerst, 2004). This is analogous to the gravitational understanding of accessibility, and more practically, as a basis for spatial interaction modelling, which can be used to predict travel flows within a region. As well, accessibility can be used to predict a variety of travel behaviour outcomes such as mode choice, activity rates, travel times, and travel distances (Ewing & Cervero, 2010; Koenig, 1980; Badoe & Miller, 2000).

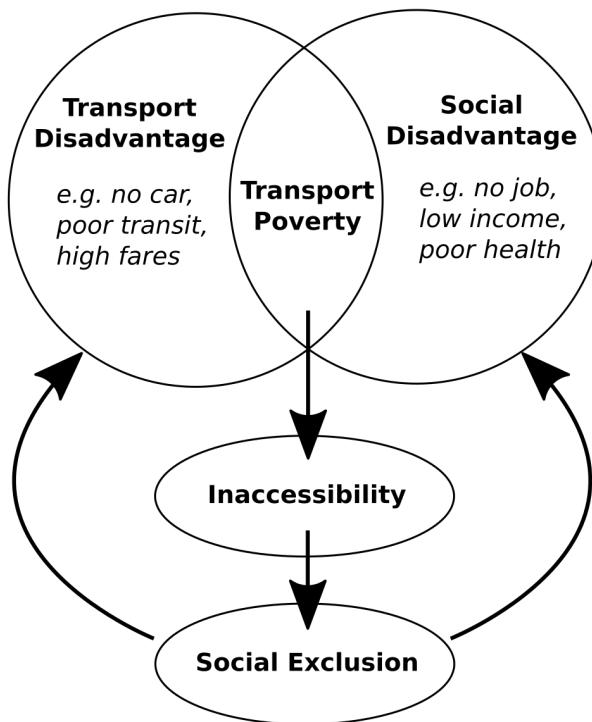
Notable as well is that environmental and socioeconomic factors can have varying effects depending on the travel behaviour outcome being studied. Research by Hanson (1982) finds that SES and land use impact all forms of travel behaviour measured. But, SES is main driver of trip rates and participation in certain types of activities, while the built environment is found to be the main driver of travel distances. There can be varying and interactive effects. For example, lower income and zero-car households were much more sensitive to having transit accessibility increasing trip rates than not being part of this overlapping set (Allen & Farber, 2020b).

These matters of travel behaviour are quite important for transport planning as they allow planners to examine and predict how different interventions would fare when it comes to improving these outcomes. These are often framed in terms of economic or environmental benefits. For example, greater levels transit accessibility are correlated with higher levels of transit ridership, lower VKT, and reduced travel times (Badoe & Miller, 2000; Ewing & Cervero, 2010). As such, many transport planners have called for improving levels of accessibility, and further including accessibility measurement into transport planning, in order to achieve outcomes across these dimensions (Handy & Niemeier, 1997).

There is also an increasing concern that neighbourhoods with limited accessibility to daily activities (e.g. grocery stores, health services, employment, etc.) can have negative effects for residents. In the worse cases, this can result in social isolation and social exclusion (Ades et al., 2012; Lucas, 2012). Travel requires costs (e.g. money to buy a car, time spent travelling). Travel costs are generally felt to a greater degree by lower-income households (e.g. owning or leasing a private car is a luxury that many lower-income households cannot afford). In the worst cases, transport disadvantage (e.g. such as not having access to a car, low levels of public transit service, etc.) can admix with other forms of social disadvantage (e.g. unemployment, low income, etc.), an effect termed as transport poverty (Lucas, 2012). This can result in adverse outcomes such as reduced accessibility, lengthy commutes, and lower levels of daily activity participation. In the worst cases, this can result in social exclusion, and then feedback to abet transport and social disadvantage. For example, being unemployed and not having a car while also living in an area poorly served by public transit can limit one's ability to travel to employment opportunities, prolonging unemployment. This prolonged unemployment can result in further levels of social and/or transport disadvantage. This is often worse in poor neighbourhoods that are far from employment opportunities. This has been termed spatial mismatch (Holzer, 1991). For example, this can occur if jobs in city decline, but poor population does not, many will have to try to find work in the suburbs. This then increases commuting costs. As well, finding employment in suburban areas is more difficult since search costs are greater, particularly if using more informal search networks (e.g. word of mouth, etc.). Moreover, if suburban population has grown, then wages may decline at suburban job locations since there are more people competing for nearby jobs. If wages are not able to supersede commuting costs, then people will not take these jobs. This can also be compounded with other components of social disadvantage experienced by poor inner-city residents (lack of education, lack of social networks, single parenting, etc.) (Holzer, 1991). It is arguable that this spatial mismatch is becoming inverted, with poverty concentrated in the inner-suburbs but jobs being concentrated in the city centre

or dispersed in auto-oriented business parks.

**Figure 2.1: Simplification of transport poverty**



Despite this knowledge and theoretical framework, there is very little research on the effect of transport disadvantage on long term earnings and poverty alleviation. This will be the topic of my fourth dissertation chapter.

## 2.4 Transportation Planning & Demographic Change

A primary goal of urban transport is to provide people the ability to travel to daily activities in a reasonable amount of time (Martens, 2016), and especially to try to reduce the prevalence of transport poverty (as outlined in the above paragraph and figure). If people are not able to travel to activity destinations necessary for their well being it indicates that the transportation network is not fulfilling one of its intended purposes.

Despite these basic objectives, it has been argued that the traditional paradigm of transport planning is socially regressive (Martens, 2016). Transport planning practice was historically based on the observation that aggregate patterns of travel behaviour are the product of supply (of activities) and demand (population) who are limited by constraints (money, mobility, nearby available opportunities) (Hanson, 1982; Wegener & Fuerst, 2004). This historically took the form of four-step travel demand modelling, and in some regions, has evolved into more detailed activity-based micro-simulations (Wegener & Fuerst, 2004). A result of traditional transport planning models is an egalitarian form focused on the network (and usually road and highway networks) rather than individuals. Travel demand models are most often built on revealed preference survey data, and are thus biased towards those groups and individuals who travel more often and further distances. Those who travel less are not considered as much due to the summation on links. Wealthier people tend to drive further distances by car than the poor, and are part of more links on the network model. Therefore, this type of transport planning benefits the rich more than the poor, and thus prioritizing investments in such a way creates further inequalities (Martens, 2016).

As such, several researchers have argued for transport planning to be based on philosophical arguments and theories of social justice (Banister, 2018; Pereira, Schwanen, & Banister, 2017; Martens, 2016). Development of a theory of justice for transportation has been thought of as a two-step process. First it involves setting the good of transportation as separate from all other goods (Martens (2016) argues this via Walzer's Spheres of Justice), and second this involves the systematic development of principles of justice that can define and distribute this good. Recent discussion on distributive justice of transport has drawn upon primarily from two philosophical ideas. The first is *Rawls' egalitarianism* (Rawls, 1971), that argues that people should have as much freedom as possible, as long as it does not impact other people's freedom (e.g. cars should not limit people's ability to walk in a city). In other words, inequality is only fair if people have equality of opportunity and if policy benefits the least advantaged members of society. i.e. inequality

is okay if they stem from preferences, not arbitrary circumstance. Since inequality is inevitable, policy should be based on a *maximin* criterion, that policy should maximize the minimum level of primary goods of the people in the worst-off position (Martens, 2016). The Rawlsian approach focuses on goods, such as income. The second, and expanding on the Rawlsian approach, are *Capability Approaches* where the focus should not be on goods, as Rawls' suggests, but on human capabilities. i.e. a focus on the ends (e.g. activity participation), not the means (e.g. income, owning a car) (Sen, 2005). Reducing capability inequalities will thus increase equality of opportunities. Martens (2016) and Pereira et al. (2017) use this for setting an agenda for transport justice, that we should not be trying to fairly distribute a good (such as income or cars) but instead fairly distribute a capability, and in the context of transport, this capability is accessibility, the ease of reaching activity destinations. They argue that this should be based on setting minimum standards of accessibility to destinations, minimizing inequalities in accessibility, and mitigating transport externalities.

Many researchers have argued that accessibility benchmarks should be specifically defined in transport planning documents (Manaugh, Badami, & El-Geneidy, 2015). In general, accessibility should not be so low that it infringes upon peoples rights, nor should accessibility levels be improved for some if they worsen it for others who already have less. However, it is still an open question of what is an acceptable minimum level of accessibility (or even how to measure it), and how this varies for different people with varying constraints and capabilities. Accessibility is indeed a combined capability, based on these individual components (physical, income) and the transport-land-use system. Defining sufficient accessibility is difficult, as it requires knowledge of the distribution of existing levels of accessibility and consequences for real people. Martens (2016) argues this should be based on the relationship between accessibility and activity participation, that likely has a non-linear shape (Allen & Farber, 2020b).

Then the question becomes, what is a fair level of activity participation? Activity participation captures outcomes (what people do), while accessibility captures capability

(what people can do). This should be based on the benefits, not just the quantity of activity participation (which is more of a proxy for the quality, but can indicate possible social exclusion). However, current methods of such are limited to econometric models and travel survey data, and simply counting activity participation by types of activities (Fransen, Farber, Deruyter, & De Maeyer, 2018; Allen & Farber, 2020b). There is a dearth of research on analyzing how accessibility enabled activity participation can have long-term social outcomes such as income mobility, employment, and poverty reduction. The fifth chapter of my dissertation will examine in-depth the links between accessibility and these social outcome.

One area to be particular concerned about is how the social geographies in cities are changing over time. As I noted in a previous section, the distribution of the low-SES households has shifted from city centres to more suburban locales (Ehrenhalt, 2012; Ades et al., 2012). Given these trends of suburbanization of poverty, there are now more low-income households in more suburban areas than in previous decades (Ades et al., 2012, 2016; Breau et al., 2018). This is potentially increasing the risks of transport poverty, and further exasperating urban inequalities more generally. However, it remains unknown how the risks of transport poverty are increasing in cities alongside trends of suburbanization of poverty. Research on neighbourhood socio-economic change has typically not included transport variables like transit accessibility, car ownership, commute times, and activity participation rates - key indicators of transport poverty and its outcomes. There have been a few studies that descriptively examine changes in public transit accessibility over time alongside changes in neighbourhood level socio-economic status (Foth et al., 2013; Farber & Grandez, 2017; Deboosere et al., 2019). However, these have been predominantly focused on public transit infrastructure, and did not consider car-ownership, an important component of transport (dis)advantage, nor have they considered outcomes such as activity participation. They are also only focused on a short time period or only consider the impacts of specific transit lines, rather than examining region wide changes over periods longer than a decade. There is some research by transportation engineers

on analyzing changes in trip and activity rates over longer periods time (e.g. Roorda et al., 2008; Kasraian et al., 2020; Ozonder & Miller, 2020). These studies tend to focus on aggregate trends at a regional level or improving the predictive capability of travel demand models, but they provide little insight on the links between travel behaviour with neighbourhood-level demographic changes, increasing income inequalities, and geographies of transport disadvantage. These gaps the literature will motivate both the second and third chapters of my dissertation in terms of examining historical trends, as well as the sixth chapter, which will explore how spatial distributions of transit accessibility may or may not manifest themselves in the near future.

## Chapter 3

# Suburbanization of Transport Poverty

### **Abstract:**

Many cities have undergone spatial re-distributions of low-income populations from central to suburban neighborhoods over the past several decades. A potential negative impact of these trends is that low-income populations are concentrating in more automobile oriented areas and thus resulting in increased barriers to daily travel and activity participation, particularly for those who are unable to afford a private vehicle. Accordingly, the objective of this paper is to analyze the links between increasing socio-spatial inequalities, transport disadvantage, and adverse travel behaviour outcomes. This is examined first from a theoretical perspective, and second via a spatio-temporal analysis for the Toronto region from 1991 to 2016. Findings show that many suburban areas in Toronto are not only declining in socioeconomic status, but are also suffering from increased barriers to daily travel evidenced by longer commute times and decreasing activity participation rates, relative to central neighborhoods. Because of these adverse effects, this evidence further supports the need for progressive planning and policy aimed at curbing continuing trends of suburbanization of poverty while also improving levels of transport accessibility in the suburbs.

## **Keywords:**

transportation, neighborhood change, poverty, daily travel, suburbs

### **3.1 Introduction**

In most early industrializing cities, poverty was traditionally clustered within central areas, while the more affluent lived in peripheral parts of cities away from heavy industry and pollution. During the mid-20th century, many cities have de-industrialized, resulting in increased demand for inner-city living and investment in housing stock in central areas. One effect of this in some cities is that the costs of housing in central areas has increased substantially, causing the spatial distribution of lower-income households to shift to less central, but more affordable, peripheral neighborhoods (Kneebone & Garr, 2010; Ehrenhalt, 2012; Howell & Timberlake, 2014; Pavlic & Qian, 2014; Cooke & Denton, 2015; Ades et al., 2016).

A potential negative impact of these trends is that low-income households are relocating to areas that are more auto-oriented, less walkable, and have relatively lower levels of public transit service than central areas. This could be resulting in longer commutes and increased barriers to daily activity participation, especially for those who are unable to afford a private vehicle. The ability to travel to important activity destinations is vital for economic independence (e.g. finding and retaining employment), health, and well-being - and at a greater scale, it can contribute to robust urban economies and healthier societies as a whole. In the worst cases, dissuasion or inability to travel to important destinations can limit activity participation, result in social exclusion, and negatively impact the vitality of urban environments (Lucas, 2012; Martens, 2016).

Accordingly, the objective of this paper is to describe the links between increasing socio-spatial inequalities (e.g. de-centralization of low-income households), transport disadvantage (e.g. spatial distribution of zero-car households, low levels of transit accessibility), and adverse travel behaviour outcomes (e.g. lengthier commute times and

lower activity participation rates). This is discussed first from a theoretical standpoint with reference to existing research, then a neighborhood level empirical investigation is conducted for the Toronto region, a city that is experiencing growing income inequalities and concentrations of poverty in more suburban areas (e.g. Hulchanski, 2010; Walks, 2001; Ades et al., 2012; Breau et al., 2018). This exploratory investigation is informed through six periods of the quinquennial Canadian census and a regional travel survey (from 1991 to 2016) in order to describe neighborhood-level changes in socio-economic status (SES) *vis-à-vis* changes in transport disadvantage and travel behaviour outcomes. Our methods include computing transit accessibility metrics that are comparable over time, statistical mapping, modelling changes in travel behaviour over time, and visualizing neighborhood change with respect to levels of suburbanization. While focused on Toronto, these methods can be transferable to other regions.

The key finding of our analysis is that social and transport disadvantage are increasing more in the suburbs relative to central areas, leading to adverse travel behaviour outcomes such as increasing commute times and lowering activity participation rates. Policy and planning strategies to reduce these negative outcomes should thus focus both on curbing trends of suburbanization of poverty as well as reducing levels of transport disadvantage in suburban neighborhoods.

## 3.2 Background

Suburbanization of poverty refers to the spatial re-distributions of low-SES households from central to suburban neighborhoods, usually in reference to changes occurring during the latter half of the 20th century and early 21st century. Recent research has highlighted trends of suburbanization of poverty in early-industrializing cities in nations such as the United States (Kneebone & Garr, 2010; Howell & Timberlake, 2014; Cooke & Denton, 2015), the Netherlands (Hochstenbach & Musterd, 2018), Sweden (Hedin et al., 2012), Scotland (Kavanagh et al., 2016), and Australia (Randolph & Tice, 2014).

In Canada, there is evidence of increasing income inequalities both within and between regions (Walks, 2013; Bolton & Breau, 2012; Breau, 2015; Chen et al., 2012), as well as concentrations of low-income households forming in some inner-suburban neighborhoods (Ades et al., 2012; Pavlic & Qian, 2014; Ades et al., 2016; Breau et al., 2018). For example, Pavlic and Qian (2014) classified census tracts by density, age of housing stock, and distance to downtown and found that there has been decline or stagnation in prosperity in inner-suburban areas relative to central areas and newer outer-ring suburbs. Research by Ross et al. (2004) and Ades et al. (2012) computed spatial segregation indices on low-income households and households in poverty in Canadian cities, each finding that economic segregation is increasing at a neighborhood level and that low-income households are becoming increasingly concentrated and isolated within cities' spatial units. Statistical mapping exercises have also highlighted that neighborhoods with higher concentrations of low-income households are located further from the downtown core over the past several decades (Ades et al., 2012; Breau et al., 2018).

These trends of suburbanization of poverty have raised concerns regarding the increasing polarization and segregation of urban space by class and income (Hulchanski, 2010; Walks, 2013; Ades et al., 2012), as well as negative impacts caused by eviction and displacement on individual well-being and disrupted community cohesion (August, 2014, 2016). There are also increasing concerns that low-income households now have greater levels of transport disadvantage than in previous decades due to being located further from major employment centres and living in neighborhoods with less walkable environments and lower levels transit service, limiting their ability to travel to and participate in daily activities, particularly for those who are unable to afford a private car (Skaburskis & Nelson, 2014; Ades et al., 2012). However, the transport-related impacts of suburbanization of poverty remain largely understudied.

A primary goal of urban transport is to provide people the ability to travel to daily activities in a reasonable amount of time (Martens, 2016). If people are not able to do so it indicates that the transportation network is not fulfilling its intended purpose. Travel

costs are generally felt to a greater degree by lower-income households (e.g. owning or leasing a private car is a luxury that many lower-income households cannot afford). Transport disadvantage (e.g. such as not having access to a car, living in a neighbourhood with low levels of public transit service, etc.) can admix with other forms of social disadvantage (e.g. unemployment, low income, etc.) resulting in negative outcomes like lengthy commutes and barriers to participating in daily activities (Lucas, 2012; Lucas et al., 2018). This combined effect is often called transport poverty. This is more likely to occur for lower-SES residents who live in suburban environments as these environments typically have lower levels of transit service and often require the use of private cars, which for many low-income households, are not affordable.

Several research projects have empirically analyzed how transport disadvantage can negatively impact activity participation for more at-risk groups like low-income households (e.g. Farber & Páez, 2009; Roorda et al., 2010; Lucas et al., 2016; Allen & Farber, 2020b). Auto-oriented environments can also dissuade active transportation like walking or cycling, for example, due to limited or unsafe pedestrian and cycling infrastructure or simply because destinations are too far away (Cervero & Kockelman, 1997; Ewing & Cervero, 2010). While some low-income households that live in suburban environments may be able to afford a car, they are often at greater risk of going into debt because of needing high-interest loans (Walks, 2018), being more susceptible to feeling the effects of rising fuel costs (Mattioli et al., 2019), and are more likely to drive cars that are used and unreliable, and therefore riskier purchases, despite their lower upfront costs (Klein, Tran, & Riley, 2020). These financial costs of private car access for lower-income households can increase financial stress and cause households to limit spending on other important areas (e.g. housing, healthy food, etc.).

Accordingly, there have been several recent studies that have analyzed how and where transport disadvantage aligns with socio-economic groups who are more vulnerable to experiencing transport poverty, both in Canada (e.g. Foth et al., 2013; Allen & Farber, 2019) and elsewhere (e.g. Currie, 2010; Fan, Guthrie, & Levinson, 2012; DeJohn, 2019).

These studies have either looked at the overall equity of transit systems, for example analyzing whether transit is adequately serving low-SES areas relative to other areas, or have focused on highlighting areas that have high risk of transport poverty; neighborhoods where low-SES households have inadequate public transit service. Generally, transit service is found to be equitable in most cities in the sense that transit is serving neighborhoods with low-SES households relatively more than overall populations. This is unsurprising since lower-income households live in smaller units with higher levels of population density and are more likely to want to live in areas with good transit service due to lack of car ownership. Also, more affluent households generally have less of a preference to live near transit due to being able to afford a car (Glaeser, Kahn, & Rappaport, 2008).

However, given existing trends of suburbanization of poverty, there are now more low-income households in suburban areas than in previous decades in many cities (Ades et al., 2012, 2016; Breau et al., 2018). This is potentially increasing the risks of transport poverty, and further exasperating urban inequalities more generally. However, it remains unknown how the risks of transport poverty are increasing in cities alongside trends of suburbanization of poverty. Research on neighborhood socio-economic change has typically not included transport variables like transit accessibility, car ownership, commute times, and activity participation rates - key indicators of transport poverty and its outcomes. There have been a few studies that descriptively examine changes in public transit accessibility over time alongside changes in neighborhood level socio-economic status (Foth et al., 2013; Farber & Grandez, 2017; Deboosere et al., 2019). However, these have been predominantly focused on public transit infrastructure, and did not consider car-ownership, an important component of transport (dis)advantage, nor have they considered outcomes such as activity participation. They are also only focused on a short time period or only consider the impacts of specific transit lines, rather than examining region wide changes over periods longer than a decade. There is some research by transportation engineers on analyzing changes in trip and activity rates over longer periods

time (e.g. Roorda et al., 2008; Kasraian et al., 2020; Ozonder & Miller, 2020). These studies tend to focus on aggregate trends at a regional level or improving the predictive capability of travel demand models, but they provide little insight on the links between travel behaviour with neighborhood-level demographic changes, increasing income inequalities, and geographies of transport disadvantage. Accordingly, the goal of the following analysis is to develop deeper understanding of where and to what extent suburbanization of poverty is potentially increasing the risks of barriers to daily travel, in order to better inform policy and planning aimed at reducing these risks.

### 3.3 Study Area and Data

The study area for this paper is the Toronto Census Metropolitan Area (CMA). CMAs are agglomerations of municipalities where at least 50% of the labour force works within the region's core. While not a perfect definition of what counts as an urban region, it is consistent with what has been used in previous research on the Toronto area regarding neighborhood change, socio-spatial polarization, and suburbanization of poverty (e.g. Walks, 2001; Ross et al., 2004; Ades et al., 2012, 2016). Table 3.1 indicates how the region has grown from 1991 to 2016, both in terms of population and built-up area.

**Table 3.1:** Summary statistics of the Toronto CMA from 1991 to 2016

	1991	1996	2001	2006	2011	2016
Population (millions)	3.84	4.19	4.50	5.02	5.49	5.82
Dwellings (millions)	1.35	1.46	1.60	1.77	1.96	2.10
Jobs (millions)	1.87	1.96	2.22	2.28	2.50	2.60
Built Up Area (km <sup>2</sup> )	1,700	1,900	2,100	2,200	2,200	2,300

#### 3.3.1 Data Sources

Data for this study draws from the long-form Canadian census and the Transportation Tomorrow Survey (TTS), the largest household travel survey in the region. Both of these

surveys are conducted quinquennially, within a few months of each other (the census in May and the TTS in September). This allows for them to be analyzed in concordance with little temporal uncertainty.

The Canadian census is divided into short-form and long-form versions. The short-form only asks questions regarding basic demographic information, while the long-form asks a wider range of questions including, but not limited to, education, housing characteristics, employment, and immigration. The long-form census is administered to 20% of households in Canada. However, the mandatory long-form census was not conducted in 2011, when it was replaced by the voluntary National Household Survey (NHS). The NHS has been criticized for its geographically varying response rate, which in some cases is correlated with different socio-economic variables. For completeness, we decide to use the NHS data for our analysis, but results for 2011 should be treated with caution and greater uncertainty than other years used in this study.

The TTS is a 5% sample of households in the Toronto region (Ashby, 2016). Its focus has primarily been on collecting data for regional travel demand models. We use the TTS for variables pertaining to car ownership, commuting behaviour, and activity participation rates. A limitation of this survey and derived data is that it only pertains to a single weekday. As well, like many travel surveys, there are concerns regarding under-reporting due to proxy responses per household, as well as under-reporting of short trips, trips without a specific destination like short recreational trips, or trips undertaken by active modes such as walking and cycling (Wolf et al., 2003). Despite these limitations, the TTS is the largest sample travel survey of its kind in Canada, and has been used as the basis for a number of transport planning studies, including longitudinal analyses (Miller & Shalaby, 2003; Roorda et al., 2008; Kasraian et al., 2020; Ozonder & Miller, 2020).

Census and TTS data were acquired as aggregate summaries pertaining to neighborhood sized spatial boundaries. TTS data are linked to Traffic Analysis Zones (TAZ) while census data are linked to census tracts. Some of these boundaries were re-delineated over time because of demographic change. To expedite part of our longitudinal analy-

sis, data from each year and each survey are joined to 2016 census tract boundaries via a population-weighted areal interpolation procedure that minimizes error when boundaries change over time (see Allen and Taylor (2018) for a description of this process). This data harmonization allows for analysis over a 25 year period from 1991 to 2016 at a consistent set of neighborhood-level geographic units ( $n = 1,133$  census tracts)

### 3.3.2 Measuring Social Disadvantage

Table 3.2 displays the variables from the Canadian census that are used to form our understanding of neighborhood level socio-economic status. This table provides regional context that is important to note prior to examining intra-regional trends. Variables were selected based on two criteria: 1) they have been used in previous studies that have examined social deprivation in Canada (Pampalon et al., 2009) as well as their relation to transport disadvantage (Foth et al., 2013; A. El-Geneidy et al., 2016; Allen & Farber, 2019), and 2) variable consistency across multiple census years.

**Table 3.2:** Summary of Statistics Canada census SES data for the Toronto CMA from 1991 to 2016

	1991	1996	2001	2006	2011	2016
Population (millions)	3.84	4.19	4.50	5.02	5.49	5.82
Average household income (in 2016 CAD)	\$92k	\$87k	\$100k	\$104k	\$102k	\$112k
% who live in low-income households	15%	21%	17%	19%	15%	18%
% who have housing cost 30% or more of their income	23%	37%	29%	33%	32%	34%
% of dwellings that need major repairs	7%	8%	7%	6%	6%	5%
% of families that are single-parent families	14%	16%	17%	17%	18%	18%
% who immigrated internationally in the past 5 years	9%	8%	8%	8%	7%	7%
% who do not have a high school diploma	33%	31%	23%	20%	17%	16%
% who are unemployed	9%	9%	6%	7%	9%	8%

The regional trends presented in Table 3.2 indicate relative stability in SES over time at an aggregate level, with some exceptions for specific variables. Looking at income, we

see that the average income in the region has increased, but there also has been a slight increase in percent of population in low-income households. This deviation aligns with research showing an increase in income polarization in the Toronto region (Hulchanski, 2010). Education rates have improved substantially in the region over time, from 33% of adults not having a high school education to only 16%. Other less pronounced trends over time include relative decreases in dwellings that need major repairs, immigration, and unemployment while there has been a slight increase in percent of single-parent families. Important to note is that relatively stable proportions over time however indicate growing overall counts of people in each group since the overall population of the region is steadily increasing over time (e.g. the total number of people in low income households in 1991 compared to 2016 nearly doubled). The most notable temporal deviation is for 1996, when a recession in the early 1990s explains worse SES indicators for this year (e.g. higher poverty rate, lower average income, greater percent of income devoted to housing).

We also generate a single indicator of neighborhood level socio-economic status using a Principal Components Analysis (PCA) on the variables presented in Table 3.2. PCAs are commonly used to develop composite indices (OECD, 2008), including neighborhood-level measures of socio-economic status (Pampalon et al., 2009; Cabrera-Barona, Wei, & Hagenlocher, 2016). A PCA reduces these correlated observed variables into independent composite variables. Specifically, the results of a PCA are the eigenvectors of the covariance matrix, ranked by how much variance they explain. We considered having more than one indicator of SES, but we found that the first component of the PCA explained 53% percent of the variance of the eight variables, while the second component only explained 15% percent. We term this output first principal component as  $SES_{i,\gamma}$ . It can be represented as a linear combination of the standard score,  $Z_{x,i,\gamma}$ , of each input variable,  $x$ , where  $i$  pertains to a census tract and  $\gamma$  is the year. All variables from all years were normalized prior to the PCA.

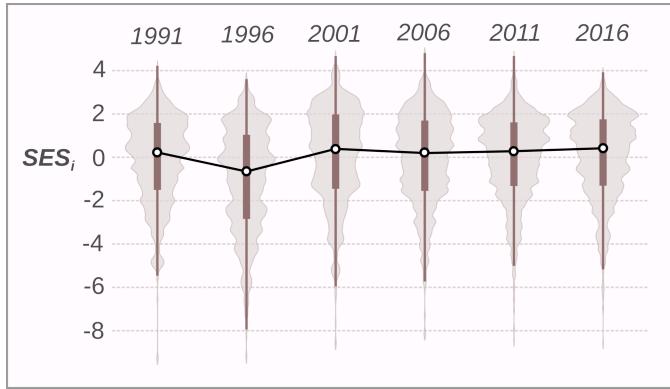
$$SES_{i,\gamma} = \sum_x w_x Z_{x,i,\gamma} \quad (3.1)$$

The factor weights,  $w_x$ , for each variable,  $x$ , are displayed in Table 3.3. Also displayed is the correlation coefficient between  $SES_{i,\gamma}$  and  $Z_{x,i,\gamma}$ .

**Table 3.3:** Results of a PCA of neighbourhood level socio-economic status for the Toronto CMA

	$w_x$	$\text{corr}(SES_{i,\gamma}, Z_{x,i,\gamma})$
Logged average household income (in 2016 CAD)	0.43	0.87
% who live in low income households	-0.45	-0.92
% who have housing cost 30% or more of their income	-0.33	-0.67
% of dwellings that need major repairs	-0.28	-0.57
% of families that are single-parent families	-0.38	-0.77
% who immigrated internationally in the past 5 years	-0.30	-0.62
% who do not have a high school diploma	-0.21	-0.43
% who are unemployed	-0.39	-0.79

The resulting values of  $SES_i$  have a mean of zero and a standard deviation equal to two. Also to note is that it has a negative skew ( $\bar{\mu}_3 = -0.75$ ), meaning that wealthier neighborhoods are more similar to each other in terms of SES, while poorer neighborhoods have greater dispersion. This highlights how the poorest neighborhoods are relatively further from the mean than affluent neighborhoods. Plots of the distribution of  $SES_i$  for each year are shown in Figure 3.1. Overall, there is stability in the average levels of SES over time. The notable exception is 1996 where there is a substantial decline in SES, likely due to the early 1990s recession. The relative consistency in distributions of SES by year is contrary to some previous research highlighting increased polarization over time (Hulchanski, 2010). This is likely because this previous research has focused solely on income inequalities, rather than a composite index of SES. Summary plots like these also mask spatial variations and changes in spatial patterns over time.



**Figure 3.1:** Population weighted distribution in  $SES_i$  by year

### 3.3.3 Measuring Transport Disadvantage

Transport disadvantage can be considered both in terms of opportunity and outcomes (Banister, 2018).

For outcomes, we use two travel behaviour variables: activity participation and commute times. Commute times for our analysis are based on historical travel time matrices linked to origin-destination survey data. These travel times were extracted from historical travel demand models of the region for the morning commute period (6:30am to 9:30am) (TMG, 2016). Commute times were averaged by neighborhood. Activity participation is defined as the neighborhood average of the number out-of-home activities people travel to over the course of a day, based on the TTS. At an individual level, the extent of daily activity participation could be a result of preferences or constraints. For example, low levels of activity participation could either be due to not wanting to travel to a destination or due to transport disadvantage (e.g. lack of car access) impeding travel. Moreover, high levels of activity participation may not always be based on choice, but could also be due to the time pressures of working more than one job and balancing household activities. Overall, though, previous research has highlighted how low levels of activity participation predominantly indicates that residents are experiencing barriers to daily travel, and furthermore, has been used as evidence of increased risks of transport-related social exclusion (Martens, 2016; Lucas et al., 2018). For instance, mapping neighbourhood-level

"participation deserts" have been used as a transport planning tool to assess which neighbourhoods within a region are suffering the most from transport disadvantage (Allen & Farber, 2020b).

For opportunity, we consider this in two dimensions as well: transit accessibility and auto availability. For the latter, we compute the percent of households without cars in each neighborhood from the TTS. While it is true that just because a household has a car, it does necessarily mean that it provides an adequate form of mobility for all members of a household (e.g. there may be competition for its use, and the car itself may not be reliable). However, lack of auto availability has been shown to be a substantial barrier for daily travel within North American urban contexts (Blumenberg, Brown, & Schouten, 2018; Allen & Farber, 2020b), and in the long-term, it is negatively associated with social outcomes such as income and employment (Blumenberg & Pierce, 2014; Smart & Klein, 2020).

Alongside auto availability, we also use the TTS combined with historical travel times to derive place-based measures of transit accessibility in order to describe the quality of public transit service across different neighborhoods. Accessibility is generally understood by transport geographers as how easy or difficult it is for people to reach activity destinations in a reasonable amount of time (Hansen, 1959; Geurs & Van Wee, 2004; A. M. El-Geneidy & Levinson, 2006). Transit accessibility is also a good proxy for measuring how centralized or suburban a neighborhood is since the greater the level of transit accessibility, the more connected it is to major activity hubs, and the less likely people in a neighborhood are dependent on private cars for daily travel. Relating accessibility to the distributions of populations (e.g. low-income households) can thus also tell us how centralized or suburbanized they are relative to the overall population, and how this may be changing over time. For our study, we compute measures of access to daily non-work activity destinations and access to employment. The first measure can be considered as a general measure of access to activity participation and social interaction in the region. This is calculated as follows:

$$A_{i,D,\lambda} = \sum_{j \in J} D_j f(t_{i,j,\lambda}) \quad (3.2)$$

$A_{i,D,\lambda}$  is the measure of access to destinations for zone  $i$  and travel mode  $\lambda$ . It can be interpreted simply as the travel-time weighted number of activity destinations reachable from  $i$ . In the calculation,  $D_j$  is the total number of non-work travel destinations in a zone,  $j$ ,  $t_{i,j,\lambda}$  is the travel time by mode  $\lambda$  from zone  $i$  to zone  $j$ , and  $f(t_{i,j,\lambda})$  is an impedance function that weights nearby locations more than those that are further away. We use the same negative exponential impedance function across all study years to allow for comparison over time.

$$f(t_{i,j,\lambda}) = e^{\beta t_{i,j,\lambda}} \quad (3.3)$$

$\beta$  is selected such that the median trip time returns a value of 0.5 with a maximum value of 1 at  $t_{i,j,\lambda} = 0$ . This selection of an impedance function is based on previous research showing how it can adequately approximate origin-destination trip flows in spatial interaction modelling as well as for its ease of interpretation (Östh, Lyhagen, & Reggiani, 2016). Spatial interaction models, specifically doubly-constrained models, include balancing factors which are akin to measures of accessibility. The median non-commute trip duration across all waves of the TTS used in this study (1991-2016) was 15 minutes, resulting in  $\beta = -0.0462$ . Values of  $\beta$  derived for travel demand models in the Toronto region have consistently been within the range of -0.02 to -0.06 (Kasraian et al., 2020).

A measure of access to employment is derived similarly, but it is expanded to also account for the size of the labour force in the region that is competing for employment opportunities. Therefore, this accounts for both job growth and growth of the labour force over time. For example, there are more jobs in the region in 2016 that people can access than in 1991, but there are also more workers in the region competing for these jobs. Measures of accessibility that account for this competition have a basis in doubly constrained spatial interaction modelling, and have been used to analyze accessibility

across different spatial contexts (Horner, 2004; Allen & Farber, 2020a). This is computed as follows.

$$A_{i,E,\lambda} = \sum_{j \in J} \frac{E_j f(t_{i,j,\lambda})}{L_{j,P}} \quad (3.4)$$

$$L_{j,P} = \sum_{\lambda \in \Lambda} \sum_{i \in I} \frac{\alpha_{\lambda,i} P_i f(t_{i,j,\lambda})}{A_{i,E,\lambda}} \quad (3.5)$$

$A_{i,E,\lambda}$  is the access to employment measure for zone  $i$  and mode  $\lambda$  and  $L_{j,P}$  is a measure of access to the labour force.  $A_{i,E,\lambda}$  can be interpreted as the number of jobs per worker.  $E_j$  is the total number of jobs in zone,  $j$ , and  $P_i$  is the number of workers in zone  $i$ .  $\alpha_{\lambda,i}$  is the mode share for travel mode  $\lambda$  such that  $\sum_{\lambda \in \Lambda} \alpha_{\lambda,i} = 1$ . Since  $A_{i,E,\lambda}$  and  $L_{j,P}$  are dependent on each other, they are estimated in an iterative fashion until they reach convergence. We use the same impedance function,  $f(t_{i,j,\lambda})$ , described in equation (3), but with a different decay parameter ( $\beta = -0.0277$ ) that corresponds to a value of 0.5 for a 25 minute commuting trip (the median commute time across all waves of the TTS).

The two accessibility measures are then combined into a single index, scaled between 0 (lowest) and 1 (highest). This is partly due to the high correlation between them ( $r = 0.98$ ), and to streamline the subsequent analysis. Given that both forms of activity participation are theoretically important, we also thought it would be best to combine them, even though just using one would only have a slight variation in terms of any subsequent results.

$$A_{i,\lambda} = \frac{0.5 A_{i,E,\lambda}}{\max(A_{i,E,\lambda})} + \frac{0.5 A_{i,D,\lambda}}{\max(A_{i,D,\lambda})} \quad (3.6)$$

Table 3.4 shows summary statistics of the TTS and the accessibility measures. The percent of zero-car households has remained relatively consistent over time, with a mild peak in 1996 corresponding to the recession. But again, because the population has grown, so has the overall number of zero-car households. Transit accessibility has increased slightly over time. This is indicative that transit service has kept pace with outward expansion,

and that inner-city development has occurred in more accessible areas.

**Table 3.4:** Summary statistics of transportation metrics from 1991 to 2016 for the Toronto CMA

	1991	1996	2001	2006	2011	2016
% of households without cars	15.0%	18.0%	16.7%	16.6%	14.1%	17.3%
Mean transit accessibility ( $A_{i,\lambda}$ )	0.33	0.35	0.37	0.37	0.39	0.37
Mean one-way commute duration (min)	31.0	29.8	31.4	32.0	32.3	33.2
Mean activities per day	1.39	1.32	1.37	1.31	1.30	1.20

In terms of travel behaviour, commute times have remained stable over time, with a slight increase in later years. This aligns with theory that travel time budgets remain relatively stable over time (Zahavi, 1974; Marchetti, 1994). Activities per day have decreased over time. This could be due to a number of factors such as changing demographics and preferences (e.g. aging populations travel less, millennials travel less than previous generations, information technology reduces desire for out-of-home activities) (Newbold & Scott, 2018; Xu, 2018). However, travel barriers could be a factor as well, particularly for the poor who live in auto-dependent neighborhoods.

## 3.4 Analysis and Results

### 3.4.1 Spatio-temporal Analysis

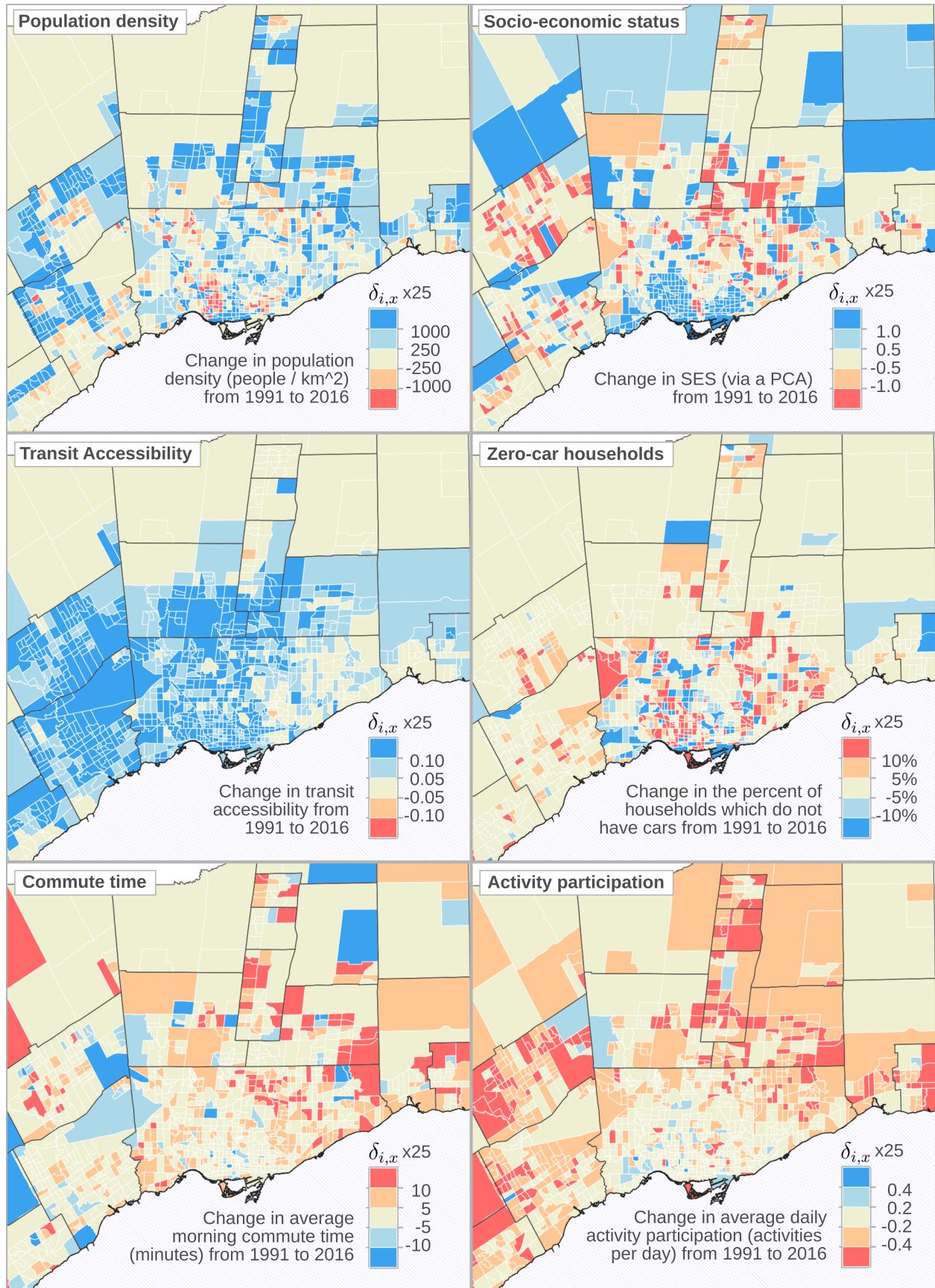
Regional statistics like those noted in the previous section do not allow us to examine nuanced spatial changes over time. Accordingly, we map the rate of change of different social and transport variables by neighborhood in order to visually examine where there are growing clusters of change. Specifically, for each variable  $x$  we estimate neighborhood-specific linear models as follows:

$$x_i = \alpha_{i,x} + \delta_{i,x}\gamma + \epsilon_{i,x} \quad (3.7)$$

Where  $i$  specifies a census tract,  $\gamma$  is the year, and  $\alpha_{i,x}$ ,  $\delta_{i,x}$ , and  $\epsilon_{i,x}$  are estimated by ordinary least squares regression. The slope of the line,  $\delta_{i,x}$ , can be interpreted as the average rate of change of the variable in each neighborhood per year from 1991 to 2006. Such an approach is limited since it does not consider non-linear effects of change over time, but we believe that this is an improvement over simply mapping differentials between two years, which has been common practice in previous Canadian neighborhood change studies (e.g. Ades et al., 2012; Hulchanski, 2010; Walks, 2001).

Maps of neighborhood change ( $\delta_{i,x}$ ) are displayed in Figure 3.2, and correlations between these rates of change are displayed in Figure 3.3.

The top-left panel in Figure 3.2 indicates where population growth and decline has occurred, with the majority of growth occurring in the suburbs as well as a few pockets of intensification in older urban areas. Areas of population loss have primarily occurred in older, pre-war, neighborhoods just east and west of the downtown core. These neighborhoods have also witnessed the greatest increase in SES, as evidenced in the top-right panel (the correlation between change in population density and change in SES is -0.09). These older centrally located neighborhoods are also often described as those that have undergone gentrification. On the other hand, neighborhoods that have witnessed substantial declines in SES are primarily located in more suburban areas. There is also some growth in low-SES households directly in the city centre. This could be due to a number of factors; increases in post-secondary students, rising housing costs relative to income, or deprivation within social housing and older apartment buildings. Overall, these spatial patterns of changing SES corroborate results of neighborhood change analyses in other research papers (Ades et al., 2012; Breau et al., 2018; Hulchanski, 2010; Pavlic & Qian, 2014).



**Figure 3.2:** Neighbourhood change in SES and transport disadvantage in Toronto from 1991 to 2016

For car ownership, we observe pockets of zero-car households growing within central and inner-suburban areas. This could be due to high costs of living limiting people's ability to purchase a car, or it could be due to increased preferences to live a car-free lifestyle (Habib, 2014; Papaioannou et al., 2020). Within central areas there are adequate levels of transit accessibility and walkable environments such that having a car is not a necessity. However, it is concerning that carlessness is growing in the inner-suburbs since this could be evidence of a reduction in people's capabilities for daily travel.

Looking at the map of transit accessibility, we see that very few neighborhoods have witnessed a decline in transit accessibility. Most neighborhoods have witnessed no change or achieved increases in transit accessibility. Gains are clearly greatest in the western half of the region. These are areas that have seen some increases in transit service, but also importantly, have witnessed high levels of job growth (Blais, 2018), which in tandem has increased accessibility over time. The eastern part of Toronto, known as Scarborough, has not experienced the same levels of job growth nor has it received significant transit investments over the past 25 years, causing a stagnation in transit accessibility over time.

Changes in commute times are less clustered overall but are found more in the periphery. Commute times have increased more in the east, corresponding with transit access stagnation. Activity participation rates also show the greatest declines away from the centre and in areas with decreasing SES. This aligns with both theory on transport poverty (e.g. Lucas, 2012), as well as empirical research (Roorda et al., 2010; Allen & Farber, 2020b), that low activity participation rates are related both to transport disadvantage and SES.

Population	SES	Transit accessibility	% zero-car hhlds	Commute time	Activity participation	$\delta_{i,x}$
1.00***	-0.09**	0.09**	-0.10***	0.04	-0.29***	Population (1000s)
	1.00***	0.05	-0.06*	-0.07*	0.22***	SES
		1.00***	0.07*	-0.20***	0.10***	Transit accessibility
			1.00***	0.04	-0.06*	% zero-car hhlds
				1.00***	-0.02	Commute time
					1.00***	Activity participation

\* 0.01 <  $p \leq 0.05$   
\*\* 0.001 <  $p \leq 0.01$   
\*\*\*  $p \leq 0.001$

**Figure 3.3:** Correlation coefficients between neighborhood change variables

To further explore these relationships, we generate two models to examine the multi-variate effects of social and transport disadvantage on adverse travel behaviour outcomes: increasing commute times and declining activity participation rates. These are modelled as follows.

$$Y = \rho W Y + \Theta X + \epsilon \quad (3.8)$$

Where  $Y$  is the vector of dependent variables (change in neighborhood averages of commute times and activity participation rates, respectively),  $X$  is a matrix of independent variables,  $\Theta$  is a vector of coefficients, and  $\epsilon$  are the error terms. The models were originally specified using ordinary least squares regression, but we found significant positive spatial auto-correlation among the residuals, leading to specifying a model that incorporates spatial effects (Anselin, 1988). A Lagrange multiplier test was used to decide on using a spatial lag model rather than a spatial error model (Anselin, 2005). This is incorporated via a spatial auto-regressive component,  $\rho W Y$ , where  $\rho$  is a spatial lag parameter and  $W$  is a row normalized Queen connectivity spatial weights matrix. Results are displayed in Table 3.5. In addition to the variables included in the map in Figure 3.2, we also included an independent variable representing change in the percent elderly population in each neighborhood since previous research has noted that the elderly travel

less than the non-elderly population (Newbold et al., 2005; Xu, 2018).

**Table 3.5:** Model results showing how neighborhood change in social and transport disadvantage effects changes in travel behaviour

	Change in activity participation		Change in commute time	
	Coefficient	p-value	Coefficient	p-value
n	1133		1133	
pseudo-R2	0.26		0.16	
$\alpha$	-0.004	0.000	0.145	0.000
$\rho$	0.400	0.000	0.388	0.000
Change in population (1000s)	-0.019	0.000	0.091	0.142
Change in $SES_i$	0.019	0.000	-0.159	0.235
Change in $A_{i,\lambda}$	0.281	0.003	-16.250	0.000
Change in % zero-car households	-0.002	0.002	0.044	0.013
Change in % elderly (65+)	-0.003	0.003	-0.111	0.000

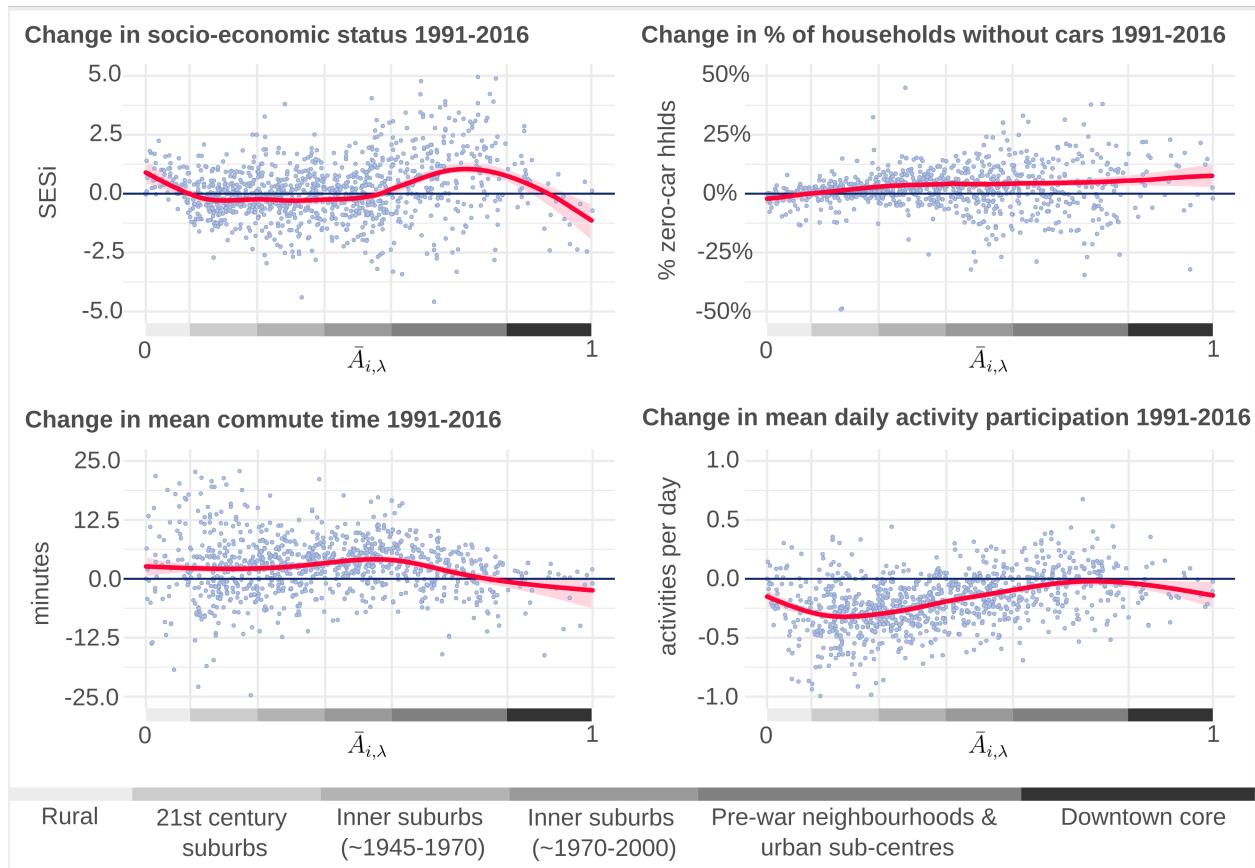
The commute time model indicates that increases in transit accessibility and car ownership are linked to reduced commute times, indicating a strong relation to transport disadvantage, overall. Change in SES over time, however, is not found to have a significant association with changing commute times, after controlling for other variables.

For the activity participation models, we find that growing social and transport disadvantages are both related to declining participation rates. This shows that the fewer resources people have, transport and socio-economic, the less likely they are able to travel to and participate in daily activities. This corroborates previous theoretical and cross-sectional findings on how social and transport disadvantage limit the ability to travel and participate in daily activities, a key indicator of transport poverty (Roorda et al., 2010; Lucas, 2012; Lucas et al., 2018; Allen & Farber, 2020b). The findings in Table 3.5 show that these trends are also true when examining changes in transport and social disadvantage over time, and lend a somewhat more causal explanation to the observed changes.

### 3.4.2 Suburbanization of Transport Poverty

In this section, we further examine whether neighborhoods with increasing social and transport disadvantage are occurring more in suburban areas compared to central neighborhoods. To do so, we first need to consider what counts as "suburban". Previous research has used metrics like distance to the urban centre, age of housing stock, and population or housing density, and often result in binary definitions of city versus suburb to describe how centralized or suburbanized a neighborhood is (Massey & Denton, 1988; Cooke & Denton, 2015). Instead, we use our transit accessibility measure to quantify suburbanization, as it is a combination of land-use patterns and connectivity. Transit accessibility is also a predictor of auto-ownership (e.g. Klein & Smart, 2017) and can thus be used to explain how auto-dependent a neighborhood is. Specifically, we take  $A_{i,\lambda}$  and average it over the 1991 to 2016 period,  $\bar{A}_{i,\lambda}$ , as a proxy for neighborhood-level suburbanization.

We then plot how changes in social and transport disadvantage are related to this accessibility-based level of suburbanization. This is displayed in Figure 3.4. The Y-axes on these plots are values of rates of change from 1991 to 2016 for different variables computed in the previous section. The X-axes are  $\bar{A}_{i,\lambda}$  and the legend on the bottom of this figure approximately describes the type of urban form that is associated with different ranges of accessibility. Each dot represents a neighborhood and the curves displayed were fitted via a generalized additive model based on regression splines (Wood, Pya, & Säfken, 2016). The curves describe a moving-window average of how each variable has changed over time for different levels accessibility.



**Figure 3.4:** Change in SES, car ownership, and travel behaviour in Toronto by an accessibility-defined measure of urban form

The top-left of this figure shows change in SES by neighborhood. We find that pre-war neighborhoods have substantially improved in terms of SES and that suburban neighborhoods have on average slightly declined in terms of SES. This confirms previous research that has highlighted trends of gentrification occurring close to the core and a decline or stagnation in SES in many suburban neighborhoods (Ades et al., 2012; Hulchanski, 2010; Walks, 2001; Ades et al., 2016). The top-right shows that zero-car households have increased relatively evenly throughout the spectrum of urban structure, with the greatest increase occurring in the downtown core, where there are the highest levels of transit accessibility. The downtown core has also experienced the greatest increase in housing costs over this 25 year period.

Looking at the bottom two plots on changes in travel outcomes over time, we find that commute times have increased more within suburban areas, with a small bump particularly within the inner-suburbs. Only central neighborhoods have witnessed a reduction in commute times on average. Activity participation rates have declined overall, but we observe that this decline is occurring predominantly in suburban neighborhoods. Suburban areas are thus experiencing the brunt of increasing adverse travel behaviour outcomes in the region.

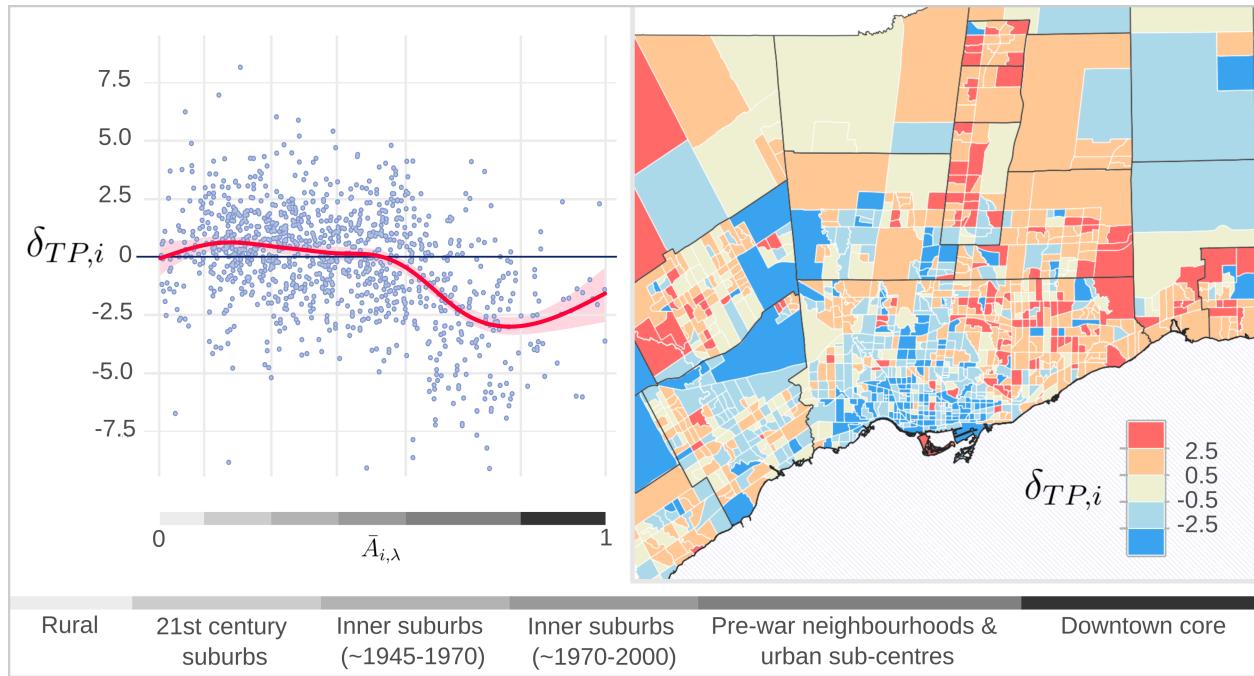
Transport poverty has been described as the compounding of both social and transport disadvantage (Lucas, 2012; Lucas et al., 2018). Accordingly, for our last piece of analysis, we generate a composite measure for examining the extent to which neighborhoods are increasing or decreasing signs of experiencing transport poverty,  $\delta_{TP,i}$ , and then visualize its spatial distribution. In particular, we are interested in whether transport poverty is increasing more within the suburbs than central neighborhoods. To generate  $\delta_{TP,i}$ , we sum the standard scores of  $\delta_{i,x}$  for five pertinent variables  $x$ : change in socio-economic status ( $SES_i$ ), transit accessibility ( $A_i$ ), percent zero-car households, mean commute times, and mean daily activity participation rates.

$$\delta_{TP,i} = \sum_x \frac{\delta_{x,i} - \mu_{\delta_x}}{\sigma_{\delta_x}} \quad (3.9)$$

The signs of each  $\delta_{i,x}$  are set that positive values of  $\delta_{TP,i}$  can be interpreted as neighborhoods with increased travel barriers and worse travel behaviour outcomes over time. Conversely, negative values of  $\delta_{TP,i}$  can be interpreted as neighborhoods where signs of transport poverty are decreasing over time, on average. Figure 3.5 visualizes the spatial distribution of  $\delta_{TP,i}$  (right) as well as plots  $\delta_{TP,i}$  relative to mean levels of transit accessibility  $\bar{A}_{i,\lambda}$  (left).

We observe that transport poverty is decreasing substantially in older, centrally located, neighborhoods; gentrifying neighborhoods with salutary levels of transit accessibility and walkable built environments. Conversely, more auto-oriented suburban neigh-

borhoods, on average, are witnessing increases in risks of transport poverty over time. There is, however, quite a bit of variation across this spectrum of urban form. The orange and red areas on the map are those in which transport poverty has increased substantially from 1991 to 2016. Clearly this has occurred in inner-suburban neighborhoods in the east (primarily in Scarborough), as well as more distant suburban areas to the east, north, and northwest. However, this is not to say that all suburbs follow this trend, there are still a number of suburban neighborhoods showing signs that transport poverty is declining over time. These tend to be a combination of neighborhoods where SES has not declined and neighborhoods where transit accessibility has improved. This is particularly evident in the western suburban areas that have witnessed improvements in transit accessibility. Overall, the key finding here is that risks of transport poverty are increasing more within auto-oriented suburban areas than compared to centrally located neighborhoods.



**Figure 3.5:** Change in transport poverty,  $\delta_{TP,i}$ , by mean level of accessibility (left). Map of change in  $\delta_{TP,i}$  (right).

### 3.5 Conclusions

Our study was not immune to limitations, and thus offers directions for future work. For one, our research focused on transport (dis)advantage in terms of transit access to destinations and auto ownership, but we did not consider other components of urban form that could either benefit or detriment urban living. For example, despite gains in transit access, suburban built environments typically remain focused on the car, which have a number of safety and environmental concerns (e.g. speed limits are greater, safe crossings are more spread out, creating barriers to active travel). On the other hand, some suburban areas offer better access to green space, which can have a positive effect on health and well-being. Future research should consider other positive and negative environmental impacts of less-centralized urban living for low-SES populations. This could prove challenging, however, since there is little readily available historic data on urban form, walkability, and access to green space.

Our study also had some other data limitations. We relied on a travel survey that represented a 5% sample of the population, limiting analysis at smaller geographic scales. Secondly, there may have been some inconsistencies with how data were collected across survey years. We did select variables that were consistently defined over time based on survey documentation, but there were likely some imperfections in interpretation and administration of survey questions. As well, in terms of data, there was likely some inaccuracy caused by the data harmonization process of apportioning data to the same spatial units. These issues are unavoidable when dealing with longitudinal survey data that has been aggregated to different areal units (Allen & Taylor, 2018).

As well, our neighbourhood-level analysis could be masking individual effects since we only analyzed change at a neighborhood level. For example, there could be more extreme levels of travel be outcomes in later years than earlier years in certain neighborhoods. However, the data are limited in that specific individuals are not tracked over time, preventing the possibility of a true individual-level panel study. These problems

highlight the need in the future for individual-level linked datasets, similarly to how medical records have been linked to census data in health research. Analyzing individual panel data would be helpful for examining pathways to suburban poverty and whether improvements in transit accessibility are either more likely to alleviate poverty or result in gentrification and displacement.

Despite these limitations and important directions for future work, our study provides solid evidence that transport poverty in Toronto is increasing more in the suburbs relative to central areas. Eastern suburbs in particular have suffered the most, indicative by having the greatest combination of increased transport and social disadvantage, and evidenced by increasing commute times and declining daily activity participation rates. Our research thus confirms theoretical pathways of transport poverty (Lucas, 2012), and moreover, shows that it is occurring more within suburban neighborhoods.

Policy to reduce these effects should thus have a two-pronged approach. The first is to curb the growth of suburban poverty through focusing on increasing the supply of affordable housing in areas with high transit accessibility, having strong rent controls, and preventing forced eviction and displacement from central to suburban neighborhoods. The second is to upgrade suburban environments through transport planning and urban design strategies that improve transit accessibility and walkability (i.e. improving accessibility at both neighborhood and regional scales). These are not new ideas. Many of them have been advocated for previously in terms of reducing the negative population health and environmental impacts associated with auto-oriented environments (Cervero & Kockelman, 1997; Ewing et al., 2003; Ewing & Hamidi, 2015), and limiting the detrimental impacts suburbanization of poverty has on increasing polarization and segregation of urban space as well as the negative impacts caused by eviction and displacement on individual well-being and community cohesion (Hulchanski, 2010; Ades et al., 2012; Walks, 2013; August, 2014, 2016). Our research provides one more important piece of evidence showing that such strategies would also be progressive options in reducing barriers to daily travel and transport-related social exclusion.

## Appendix

### Selection of distance decay parameters for measuring accessibility

For our accessibility measures, we used a negative exponential impedance function in order to weight nearby destinations more than those further away (see Section 3.3). This was defined as follows:

$$f(t_{i,j}) = e^{\beta t_{i,j}}$$

Where  $t_{i,j}$  is the travel time and  $\beta$  is a decay parameter. As we noted in the main text, we followed the advice by Östh et al. (2016) that  $\beta$  can be approximated by selecting the curve which returns 0.5 for the median travel time. This is based on their argument that such a selection can adequately approximate origin-destination trip flows in spatial interaction modelling as well as for its ease of interpretation (Östh et al., 2016). This led to the selection of  $\beta = -0.0277$  for access to jobs and  $\beta = -0.0462$  for access to non-work destinations

To further assess the validity of this selection of  $\beta$ , we first looked at previous research which has measured accessibility over multiple time periods in the Toronto region. There are four studies that we are aware of. The first, by Foth et al. (2013) claims to use a gravity-based formulation to measure access to jobs. Unfortunately, they do not describe how this function is defined. Two papers, one by Farber and Grandez (2017) and the other by Deboosere et al. (2019) use cumulative measures of accessibility in their analysis. Cumulative measures are less theoretically sound than those which use continuous decay functions as they over-simplify what is accessible by use of a single isochrone. Most applicable to our study is a recent paper Kasraian et al. (2020) who select a  $\beta$  value of -0.05 when measuring access to population in the Greater Toronto and Hamilton Area. Kasraian et al. (2020) derive this value of  $\beta$  from another rule of thumb (Batty & Sikdar, 1984), where  $\beta$  is equal to one divided by the mean travel time (20 minutes was the mean travel time for all trips selected for use in their study). They also justify their selection

based on that "travel time parameters in operational travel demand models for the region have consistently fallen within the 0.02–0.06" range (Kasraian et al., 2020). For our study, initially based on the advice from Östh et al. (2016) we used a  $\beta$  value of -0.0277 for access to jobs and -0.0462 for access to non-work destinations. These both fall within this -0.02 to -0.06 range. Moreover, if we followed the Batty and Sikdar (1984) approximation used by Kasraian et al. (2020), our values of  $\beta$  would be -0.0316 (difference of 0.0039) for access to jobs, an -0.0505 (difference of 0.0043) for access to non-work destinations. These are very close to our selected values.

For the sake of sensitivity, we computed access to jobs using  $\beta$  values of 0.02, 0.03, 0.04, 0.05, and 0.06 to show the similarity in results across this range. Below is a correlation matrix of the resulting accessibility measures.

**Table 3.6:** Correlation among measures of access to jobs by transit for different values of  $\beta$

$\beta$	-0.02	-0.03	-0.04	-0.05	-0.06
-0.02	1.000	0.985	0.950	0.903	0.850
-0.03		1.000	0.989	0.960	0.921
-0.04			1.000	0.991	0.967
-0.05				1.000	0.993
-0.06					1.000

Clearly there is quite high correlation among these measures, and selecting any value within this range (-0.02 to -0.06) would likely have only very minor differences in results, particularly since we were primarily concerned with relative changes in accessibility over time, rather than absolute values at a particular point in time.

Furthermore, we also fitted negative exponential curves based on the distribution of trips by their travel times (at minute-by-minute intervals). We did this for the two types of trip purposes and subsequent accessibility measures that we generated, for home-to-work trips ( $\beta_W$ ), and for trips to non-work activity destinations ( $\beta_{NW}$ ). The resulting values are shown below.

We find that each of these values is within a range of less than 0.01 of the  $\beta$  values used in our analysis. Extrapolating from our correlation noted above, it is unlikely that

**Table 3.7:** Values of  $\beta$  fitted from travel survey data for Toronto

Year	$\beta_W$	$\beta_{NW}$
1991	-0.0269	-0.0389
1996	-0.0255	-0.0464
2001	-0.0272	-0.0399
2006	-0.0325	-0.0426
2011	-0.0312	-0.0521
2016	-0.0279	-0.0486
All*	-0.0289	-0.0432

\*All years combined before fitting

selecting one of these fitted  $\beta$  values will result in an accessibility measure that is substantially different from what we used. In fact, when looking at the correlations between accessibility measures only 0.01 apart, they are all above 0.98.

To conclude, we believe our selection of  $\beta$  is appropriate for our analysis given precedent in the literature, fitted values from data, correlation between accessibility measures, and comparing with the range of values that have been used in previous studies (-0.02 to -0.06).

Overall, the goal of our study was focused more on the application of accessibility alongside several other socio-economic and transport-related variables to study suburbanization of poverty, rather than specifically and solely focused on developing accessibility measures. Nevertheless, we do think that more work could be done in the future to derive more accurate accessibility measures that are suitable for longitudinal analyses. Clearly our paper, and some of the other papers that we cited above, would benefit from such work to move beyond these relatively simplistic approximations. Doing so would require additional thought about how to appropriately work with matrices from multiple time periods, multiple travel modes, changes in infrastructure, and different sample sizes when fitting spatial interaction models.

## **Chapter 4**

## **Conclusion**

# References

- Ades, J., Apparicio, P., & Seguin, A.-M. (2012). Are new patterns of low-income distribution emerging in Canadian metropolitan areas? *The Canadian Geographer/Le Géographe canadien*, 56(3), 339–361.
- Ades, J., Apparicio, P., & Séguin, A.-M. (2016). Is poverty concentration expanding to the suburbs? analyzing the intra-metropolitan poverty distribution and its change in Montreal, Toronto and Vancouver. *Canadian Journal of Regional Science/Revue canadienne des sciences régionales*, 39(1/3), 23–37.
- Allen, J., & Farber, S. (2019). Sizing up transport poverty: A national scale accounting of low-income households suffering from inaccessibility in Canada, and what to do about it. *Transport Policy*, 74, 214–223.
- Allen, J., & Farber, S. (2020a). A measure of competitive access to destinations for comparing across multiple study regions. *Geographical Analysis*, 52(1), 69–86.
- Allen, J., & Farber, S. (2020b). Planning transport for social inclusion: An accessibility-activity participation approach. *Transportation Research Part D: Transport and Environment*, 78, 102212. doi: 10.1016/j.trd.2019.102212
- Allen, J., & Farber, S. (2021, March). Suburbanization of Transport Poverty. *Annals of the American Association of Geographers*, 0(0), 1–18. doi: 10.1080/24694452.2020.1859981
- Allen, J., & Taylor, Z. (2018). A new tool for neighbourhood change research: The Canadian Longitudinal Census Tract Database, 1971-2016. *The Canadian Geographer/Le Géographe canadien*, 62(4), 575–588.
- Alonso, W. (1964). *Location and land use. Toward a general theory of land rent*. Cambridge,

Mass: :: Harvard Univ. Pr.

- Anas, A., Arnott, R., & Small, K. A. (1998). Urban spatial structure. *Journal of economic literature*, 36(3), 1426–1464.
- Anselin, L. (1988). *Spatial econometrics: Methods and models*. Kluwer Academic Publishers.
- Anselin, L. (2005). Exploring Spatial Data with GeoDa: A Workbook. *Urbana*, 51.
- Ashby, B. (2016). *Transportation Tomorrow Survey 2016 Data Guide*.
- August, M. (2014). Challenging the rhetoric of stigmatization: The benefits of concentrated poverty in Toronto's Regent Park. *Environment and Planning A*, 46(6), 1317–1333.
- August, M. (2016). "It's all about power and you have none:" The marginalization of tenant resistance to mixed-income social housing redevelopment in Toronto, Canada. *Cities*, 57, 25–32.
- August, M., & Walks, A. (2018). Gentrification, suburban decline, and the financialization of multi-family rental housing: The case of Toronto. *Geoforum*, 89, 124–136.
- Badoe, D. A., & Miller, E. J. (2000). Transportation–land-use interaction: Empirical findings in North America, and their implications for modeling. *Transportation Research Part D: Transport and Environment*, 5(4), 235–263.
- Banister, D. (2018). *Inequality in Transport*. Alexandrine Press, UK.
- Batty, M., & Sikdar, P. K. (1984, April). Proximate Aggregation-Estimation of Spatial Interaction Models. *Environment and Planning A: Economy and Space*, 16(4), 467–486. doi: 10.1068/a160467
- Baum-Snow, N. (2007, May). Did Highways Cause Suburbanization? *The Quarterly Journal of Economics*, 122(2), 775–805. doi: 10.1162/qjec.122.2.775
- Blais, P. (2011). *Perverse cities: Hidden subsidies, wonky policy, and urban sprawl*. UBC Press.
- Blais, P. (2018). *Planning the Next GGH* (Tech. Rep.). Neptis Foundation.
- Blumenberg, E., Brown, A., & Schouten, A. (2018). Car-deficit households: Determinants and implications for household travel in the US. *Transportation*, 1–23.
- Blumenberg, E., & Pierce, G. (2014, January). A Driving Factor in Mobility? transporta-

- tion's Role in Connecting Subsidized Housing and Employment Outcomes in the Moving to Opportunity (MTO) Program. *Journal of the American Planning Association*, 80(1), 52–66. doi: 10.1080/01944363.2014.935267
- Bolton, K., & Breau, S. (2012). Growing unequal? changes in the distribution of earnings across Canadian cities. *Urban Studies*, 49(6), 1377–1396.
- Bourne, L. S. (1989). Are new urban forms emerging? empirical tests for Canadian urban areas. *Canadian Geographer/Le Géographe canadien*, 33(4), 312–328.
- Bourne, L. S., & Rose, D. (2001). The changing face of Canada: The uneven geographies of population and social change. *Canadian Geographer/Le Géographe canadien*, 45(1), 105–119.
- Breau, S. (2015). Rising inequality in Canada: A regional perspective. *Applied Geography*, 61, 58–69.
- Breau, S., Shin, M., & Burkhart, N. (2018). Pulling apart: New perspectives on the spatial dimensions of neighbourhood income disparities in Canadian cities. *Journal of Geographical Systems*, 20(1), 1–25.
- Bruegmann, R. (2008). *Sprawl: A Compact History*. Chicago: University of Chicago Press.
- Buliung, R. N., & Kanaroglou, P. S. (2007). Activity-travel behaviour research: Conceptual issues, state of the art, and emerging perspectives on behavioural analysis and simulation modelling. *Transport Reviews*, 27(2), 151–187.
- Burgess, E. W. (1925). The growth of the city: An introduction to a research project. In R. E. Park (Ed.), *The city* (pp. 47–62). University of Chicago Press Chicago.
- Cabrera-Barona, P., Wei, C., & Hagenlocher, M. (2016). Multiscale evaluation of an urban deprivation index: Implications for quality of life and healthcare accessibility planning. *Applied Geography*, 70, 1–10. doi: 10.1016/j.apgeog.2016.02.009
- Cao, X., & Chatman, D. (2016). How will smart growth land-use policies affect travel? a theoretical discussion on the importance of residential sorting. *Environment and Planning B: Planning and Design*, 43(1), 58–73.
- Cervero, R., & Kockelman, K. (1997). Travel demand and the 3Ds: Density, diversity, and

- design. *Transportation Research Part D: Transport and Environment*, 2(3), 199–219.
- Chen, W.-H., Myles, J., & Picot, G. (2012). Why have poorer neighbourhoods stagnated economically while the richer have flourished? neighbourhood income inequality in Canadian cities. *Urban Studies*, 49(4), 877–896.
- Chetty, R., Hendren, N., & Katz, L. F. (2016, April). The Effects of Exposure to Better Neighborhoods on Children: New Evidence from the Moving to Opportunity Experiment. *American Economic Review*, 106(4), 855–902. doi: 10.1257/aer.20150572
- Cooke, T. J., & Denton, C. (2015). The suburbanization of poverty? an alternative perspective. *Urban Geography*, 36(2), 300–313.
- Currie, G. (2010). Quantifying spatial gaps in public transport supply based on social needs. *Journal of Transport Geography*, 18(1), 31–41.
- Deboosere, R., Boisjoly, G., & El-Geneidy, A. (2019). Understanding the relationship between changes in accessibility to jobs, income and unemployment in Toronto. In *A Companion to Transport, Space and Equity*. Edward Elgar Publishing.
- DeJohn, A. D. (2019). *Transit Access to Subsidized Food Stores in the American Midwest* (Thesis).
- Delmelle, E. (2017). Differentiating pathways of neighborhood change in 50 US metropolitan areas. *Environment and planning A*, 49(10), 2402–2424.
- Ehrenhalt, A. (2012). *The Great Inversion and the Future of the American City*. New York: Vintage.
- El-Geneidy, A., Buliung, R., Diab, E., van Lierop, D., Langlois, M., & Legrain, A. (2016). Non-stop equity: Assessing daily intersections between transit accessibility and social disparity across the Greater Toronto and Hamilton Area (GTHA). *Environment and Planning B: Planning and Design*, 43(3), 540–560.
- El-Geneidy, A. M., & Levinson, D. M. (2006). Access to Destinations: Development of Accessibility Measures.
- Ewing, R., & Cervero, R. (2010). Travel and the built environment: A meta-analysis. *Journal of the American planning association*, 76(3), 265–294.

- Ewing, R., & Hamidi, S. (2015, July). Compactness versus Sprawl: A Review of Recent Evidence from the United States. *Journal of Planning Literature*. doi: 10.1177/0885412215595439
- Ewing, R., Schmid, T., Killingsworth, R., Zlot, A., & Raudenbush, S. (2003). Relationship between Urban Sprawl and Physical Activity, Obesity, and Morbidity. *American Journal of Health Promotion, 18*(1), 47–57. doi: 10.4278/0890-1171-18.1.47
- Fan, Y., Guthrie, A. E., & Levinson, D. (2012). Impact of light rail implementation on labor market accessibility: A transportation equity perspective. *The Journal of Transport and Land Use, 5*(3), 28–39.
- Farber, S., & Grandez, M. (2017). Transit accessibility, land development and socio-economic priority: A typology of planned station catchment areas in the Greater Toronto and Hamilton Area. *Journal of Transport and Land Use, 10*(1).
- Farber, S., & Páez, A. (2009). My car, my friends, and me: A preliminary analysis of automobility and social activity participation. *Journal of Transport Geography, 17*(3), 216–225.
- Foth, N., Manaugh, K., & El-Geneidy, A. M. (2013). Towards equitable transit: Examining transit accessibility and social need in Toronto, Canada, 1996–2006. *Journal of transport geography, 29*, 1–10.
- Fransen, K., Farber, S., Deruyter, G., & De Maeyer, P. (2018). A spatio-temporal accessibility measure for modelling activity participation in discretionary activities. *Travel behaviour and society, 10*, 10–20.
- Geurs, K. T., & Van Wee, B. (2004). Accessibility evaluation of land-use and transport strategies: Review and research directions. *Journal of Transport geography, 12*(2), 127–140.
- Glaeser, E. L., & Kahn, M. E. (2004). Sprawl and urban growth. In *Handbook of regional and urban economics* (Vol. 4, pp. 2481–2527). Elsevier.
- Glaeser, E. L., Kahn, M. E., & Rappaport, J. (2008). Why do the poor live in cities? the role of public transportation. *Journal of urban Economics, 63*(1), 1–24.

- Grube-Cavers, A., & Patterson, Z. (2015). Urban rapid rail transit and gentrification in Canadian urban centres: A survival analysis approach. *Urban Studies*, 52(1), 178–194.
- Habib, K. N. (2014). Household-level commuting mode choices, car allocation and car ownership level choices of two-worker households: The case of the city of Toronto. *Transportation*, 41(3), 651–672. doi: 10.1007/s11116-014-9518-5
- Hammel, D. J., & Wly, E. K. (1996). A model for identifying gentrified areas with census data. *Urban Geography*, 17(3), 248–268.
- Hamnett, C. (1991). The blind men and the elephant: The explanation of gentrification. *Transactions of the Institute of British Geographers*, 173–189.
- Handy, S. L., & Niemeier, D. A. (1997). Measuring accessibility: An exploration of issues and alternatives. *Environment and planning A*, 29(7), 1175–1194.
- Hansen, W. G. (1959). How accessibility shapes land use. *Journal of the American Institute of planners*, 25(2), 73–76.
- Hanson, S. (1982). The determinants of daily travel-activity patterns: Relative location and sociodemographic factors. *Urban Geography*, 3(3), 179–202.
- Hedin, K., Clark, E., Lundholm, E., & Malmberg, G. (2012). Neoliberalization of housing in Sweden: Gentrification, filtering, and social polarization. *Annals of the Association of American Geographers*, 102(2), 443–463.
- Higgins, C., & Kanaroglou, P. S. (2016). Forty years of modelling rapid transit's land value uplift in North America: Moving beyond the tip of the iceberg. *Transport Reviews*, 36(5), 610–634.
- Hochstenbach, C., & Musterd, S. (2018). Gentrification and the suburbanization of poverty: Changing urban geographies through boom and bust periods. *Urban Geography*, 39(1), 26–53.
- Holzer, H. J. (1991). The spatial mismatch hypothesis: What has the evidence shown? *Urban Studies*, 28(1), 105–122.
- Horner, M. W. (2004). Exploring Metropolitan Accessibility and Urban Structure. *Urban*

*Geography*, 25(3), 264–284. doi: 10.2747/0272-3638.25.3.264

Howell, A. J., & Timberlake, J. M. (2014). Racial and ethnic trends in the suburbanization of poverty in US metropolitan areas, 1980–2010. *Journal of Urban Affairs*, 36(1), 79–98.

Hulchanski, J. D. (2010). *The three cities within Toronto*. Cities Centre: University of Toronto.

Jacobs, J. (1961). *The Death and Life of Great American Cities*. Vintage.

Jones, C. E., & Ley, D. (2016). Transit-oriented development and gentrification along Metro Vancouver's low-income SkyTrain corridor. *The Canadian Geographer/Le Géographe canadien*, 60(1), 9–22.

Jones, P. (1979). Behavioural Travel Modelling. In D. Henser & P. Stopher (Eds.), (pp. 55–80). London: Croom Helm.

Kasraian, D., Raghav, S., & Miller, E. J. (2020). A multi-decade longitudinal analysis of transportation and land use co-evolution in the Greater Toronto-Hamilton Area. *Journal of Transport Geography*, 84, 102696. doi: 10.1016/j.jtrangeo.2020.102696

Kavanagh, L., Lee, D., & Pryce, G. (2016). Is poverty decentralizing? quantifying uncertainty in the decentralization of urban poverty. *Annals of the American Association of Geographers*, 106(6), 1286–1298.

Klein, N., & Smart, M. (2017). Millennials and car ownership: Less money, fewer cars. *Transport Policy*, 53, 20–29. doi: 10.1016/j.tranpol.2016.08.010

Klein, N., Tran, M., & Riley, S. (2020). “Desperately Need a Car”: Analyzing Crowdfunding Campaigns for Car Purchases and Repairs on Gofundme.com. doi: 10.31235/osf.io/8x7d2

Kneebone, E., & Garr, E. (2010). The suburbanization of poverty. *Washington, DC: Brookings Institute*.

Koenig, J.-G. (1980). Indicators of urban accessibility: Theory and application. *Transportation*, 9(2), 145–172.

Kunstler, J. H. (1994). *Geography Of Nowhere: The Rise And Decline of America's Man-Made Landscape*. Simon and Schuster.

- Lee, B. A., Oropesa, R. S., & Kanan, J. W. (1994). Neighborhood context and residential mobility. *Demography*, 31(2), 249–270.
- Levinson, D. M., & Wu, H. (2020). Towards a general theory of access. *Journal of Transport and Land Use*, 13(1), 129–158. doi: 10.5198/jtlu.2020.1660
- Levitas, R., Pantazis, C., Fahmy, E., Gordon, D., Lloyd-Reichling, E., & Patsios, D. (2007). *The multi-dimensional analysis of social exclusion* [Project Report]. <https://repository.uel.ac.uk/item/8666q>. Bristol: University of Bristol.
- Ley, D. (1986). Alternative explanations for inner-city gentrification: A Canadian assessment. *Annals of the association of american geographers*, 76(4), 521–535.
- Ley, D., & Smith, H. (2000). Relations between deprivation and immigrant groups in large Canadian cities. *Urban Studies*, 37(1), 37–62.
- Lucas, K. (2012). Transport and social exclusion: Where are we now? *Transport policy*, 20, 105–113.
- Lucas, K., Bates, J., Moore, J., & Carrasco, J. A. (2016). Modelling the relationship between travel behaviours and social disadvantage. *Transportation Research Part A: Policy and Practice*, 85, 157–173.
- Lucas, K., Phillips, I., Mulley, C., & Ma, L. (2018). Is transport poverty socially or environmentally driven? comparing the travel behaviours of two low-income populations living in central and peripheral locations in the same city. *Transportation Research Part A: Policy and Practice*, 116, 622–634.
- MacLachlan, I., & Sawada, R. (1997). Measures of income inequality and social polarization in Canadian metropolitan areas. *Canadian Geographer/Le Géographe canadien*, 41(4), 377–397.
- Manaugh, K., Badami, M. G., & El-Geneidy, A. M. (2015). Integrating social equity into urban transportation planning: A critical evaluation of equity objectives and measures in transportation plans in North America. *Transport Policy*, 37, 167–176.
- Marchetti, C. (1994). Anthropological invariants in travel behavior. *Technological Forecasting and Social Change*, 47(1), 75–88. doi: 10.1016/0040-1625(94)90041-8

- Martens, K. (2016). *Transport justice: Designing fair transportation systems*. Routledge.
- Massey, D. S., & Denton, N. A. (1988). The Dimensions of Residential Segregation. *Social Forces*, 67(2), 281–315. doi: 10.1093/sf/67.2.281
- Mattioli, G., Philips, I., Anable, J., & Chatterton, T. (2019). Vulnerability to motor fuel price increases: Socio-spatial patterns in England. *Journal of Transport Geography*, 78, 98–114.
- Miller, E. J., & Shalaby, A. (2003). Evolution of personal travel in Toronto area and policy implications. *Journal of Urban Planning and Development*, 129(1), 1–26.
- Moos, M., & Mendez, P. (2015). Suburban ways of living and the geography of income: How homeownership, single-family dwellings and automobile use define the metropolitan social space. *Urban Studies*, 52(10), 1864–1882.
- Newbold, K. B., & Scott, D. M. (2018). Insights into public transit use by Millennials: The Canadian experience. *Travel Behaviour and Society*, 11, 62–68.
- Newbold, K. B., Scott, D. M., Spinney, J. E., Kanaroglou, P., & Páez, A. (2005). Travel behavior within Canada's older population: A cohort analysis. *Journal of Transport Geography*, 13(4), 340–351.
- OECD. (2008). *Handbook on Constructing Composite Indicators: Methodology and User Guide*. OECD Publishing.
- Östh, J., Lyhagen, J., & Reggiani, A. (2016). A new way of determining distance decay parameters in spatial interaction models with application to job accessibility analysis in Sweden. *European Journal of Transport and Infrastructure Research*, 16(2).
- Ozonder, G., & Miller, E. J. (2020). Longitudinal analysis of activity generation in the Greater Toronto and Hamilton Area. *Transportation*. doi: 10.1007/s11116-020-10089-w
- Padeiro, M., Louro, A., & da Costa, N. M. (2019, November). Transit-oriented development and gentrification: A systematic review. *Transport Reviews*, 39(6), 733–754. doi: 10.1080/01441647.2019.1649316
- Paez, A., Mercado, R. G., Farber, S., Morency, C., & Roorda, M. (2009). Mobility and so-

- cial exclusion in Canadian communities: An empirical investigation of opportunity access and deprivation from the perspective of vulnerable groups. *Policy Research Directorate Strategic Policy and Research, Toronto*.
- Pampalon, R., Hamel, D., Gamache, P., & Raymond, G. (2009). A deprivation index for health planning in Canada. *Chronic Diseases in Canada*, 29(4), 178–191.
- Papaioannou, E. M., Hawkins, J., & Nurul Habib, K. M. (2020). A study of car and home ownership decisions in the face of increasing commuting expenses (CHOICE) in the Greater Toronto Area (GTA). *Case Studies on Transport Policy*. doi: 10.1016/j.cstp.2020.04.009
- Pavlic, D., & Qian, Z. (2014). Declining inner suburbs? a longitudinal-spatial analysis of large metropolitan regions in Canada. *Urban Geography*, 35(3), 378–401.
- Pereira, R. H., Schwanen, T., & Banister, D. (2017). Distributive justice and equity in transportation. *Transport Reviews*, 37(2), 170–191.
- Randolph, B., & Tice, A. (2014). Suburbanizing disadvantage in Australian cities: Sosiospatial change in an era of neoliberalism. *Journal of urban affairs*, 36(sup1), 384–399.
- Rawls, J. (1971). *A Theory of Justice*. Harvard University Press.
- Roorda, M., Morency, C., & Woo, K. (2008). Two cities, two realities?: A closer look at the evolution of trip rates in Toronto and Montreal, Canada. *Transportation Research Record: Journal of the Transportation Research Board*(2082), 156–167.
- Roorda, M., Páez, A., Morency, C., Mercado, R., & Farber, S. (2010). Trip generation of vulnerable populations in three Canadian cities: A spatial ordered probit approach. *Transportation*, 37(3), 525–548.
- Rose, D. (1984). Rethinking gentrification: Beyond the uneven development of Marxist urban theory. *Environment and planning D: Society and Space*, 2(1), 47–74.
- Ross, N. A., Houle, C., Dunn, J. R., & Aye, M. (2004). Dimensions and dynamics of residential segregation by income in urban Canada, 1991–1996. *Canadian Geographer/Le Géographe Canadien*, 48(4), 433–445.

- Sampson, R. J., Morenoff, J. D., & Gannon-Rowley, T. (2002). Assessing "Neighborhood Effects": Social Processes and New Directions in Research. *Annual Review of Sociology*, 28(1), 443–478. doi: 10.1146/annurev.soc.28.110601.141114
- Scally, C. P., & Tighe, J. R. (2015). Democracy in action?: NIMBY as impediment to equitable affordable housing siting. *Housing Studies*, 30(5), 749–769.
- Schwanen, T., & Mokhtarian, P. L. (2005). What affects commute mode choice: Neighborhood physical structure or preferences toward neighborhoods? *Journal of transport geography*, 13(1), 83–99.
- Sen, A. (2005). Human Rights and Capabilities. *Journal of Human Development*, 6(2), 151–166. doi: 10.1080/14649880500120491
- Skaburskis, A., & Nelson, K. (2014). Filtering and gentrifying in Toronto: Neighbourhood transitions in and out from the lowest income decile between 1981 and 2006. *Environment and Planning A*, 46(4), 885–900.
- Smart, M. J., & Klein, N. J. (2020). Disentangling the role of cars and transit in employment and labor earnings. *Transportation*, 47(3), 1275–1309. doi: 10.1007/s11116-018-9959-3
- Smith, N. (1987). Gentrification and the rent gap. *Annals of the Association of American geographers*, 77(3), 462–465.
- Sumka, H. J. (1979). Neighborhood Revitalization and Displacement A Review of the Evidence. *Journal of the American Planning Association*, 45(4), 480–487.
- TMG. (2016). *GTAModel V4.0 Documentation*. Travel Modelling Group, University of Toronto.
- Urry, J. (2004). The 'system'of automobility. *Theory, Culture & Society*, 21(4-5), 25–39.
- Vigdor, J. L., Massey, D. S., & Rivlin, A. M. (2002). Does Gentrification Harm the Poor? *Brookings-Wharton Papers on Urban Affairs*, 133–182.
- Walks, A. (2001). The social ecology of the post-Fordist/global city? economic restructuring and socio-spatial polarisation in the Toronto urban region. *Urban Studies*, 38(3), 407–447.

- Walks, A. (2013). *Income inequality and polarization in Canada's cities: An examination and new form of measurement*. Cities Centre, University of Toronto.
- Walks, A. (2018). Driving the poor into debt? automobile loans, transport disadvantage, and automobile dependence. *Transport policy*, 65, 137–149.
- Wegener, M., & Fuerst, F. (2004). *Land-Use Transport Interaction: State of the Art* (Tech. Rep.).
- Whitmee, S., Haines, A., Beyrer, C., Boltz, F., Capon, A. G., Dias, B. F. d. S., ... Yach, D. (2015). Safeguarding human health in the Anthropocene epoch: Report of The Rockefeller Foundation–Lancet Commission on planetary health. *The Lancet*, 386(10007), 1973–2028. doi: 10.1016/S0140-6736(15)60901-1
- Wilson, W. J. (2012). *The truly disadvantaged: The inner city, the underclass, and public policy* (2nd ed ed.). Chicago ; London: University of Chicago Press.
- Wolf, J., Loechl, M., Thompson, M., & Arce, C. (2003). Trip rate analysis in GPS-enhanced personal travel surveys. In *Transport survey quality and innovation* (pp. 483–498). Emerald Group Publishing Limited.
- Wood, S. N., Pya, N., & Säfken, B. (2016). Smoothing parameter and model selection for general smooth models. *Journal of the American Statistical Association*, 111(516), 1548–1563.
- Xu, J. (2018). *A Good Place to Age in Place? exploring the relationships between the built environment, activity participation and healthy aging* (Thesis).
- Zahavi, Y. (1974). Travel time budgets and mobility in urban areas. *Federal Highway Administration, U.S. Department of Transportation*.
- Zuk, M., Bierbaum, A. H., Chapple, K., Gorska, K., & Loukaitou-Sideris, A. (2018, February). Gentrification, Displacement, and the Role of Public Investment. *Journal of Planning Literature*, 33(1), 31–44. doi: 10.1177/0885412217716439