Active Transportation and Health Equity in Markham, Ontario

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the centre for active transportation

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Contents

Executive Summary

The Centre for Active Transportation (TCAT) at Clean Air Partnership (CAP) initiated this research project to understand how to better leverage the health benefits of active transportation (AT) in equitable planning practices. Canadian suburbs, which have seen some of the largest population growth (Gordon, Hindrichs, & Willms, 2018), were noted as an area especially lacking in previous research. Through discussions with the City of Markham and York Region Public Health, this project was conceptualized to fill this gap.

Current standards in incorporating health, equity and health equity in municipal AT planning were first assessed by comparing five AT plans released in the previous two years. Brampton, Kingston, Toronto, Windsor and Saanich, British Columbia were chosen to facilitate this comparison. Aspects of equity were seen to be present in all five plans, though often implicit, and mentions of health emphasized the physical while failing to incorporate local health data relevant to their contexts.

Residents of the Regional Municipality of York were found to have had certain socioeconomic factors (being an older adult, a visible minority and having a lower household income) that were directly associated with lower Active Living Environment [ALE] scores in their area. These factors were also linked to chronic health outcomes (specifically obesity, diabetes and heart disease) in sometimes unexpected directions. The City of Markham, Ontario was then used as a case study site to better understand the suburban context. The concentration of three marginalized populations (adults over the age of 65, visible minorities and low-income residents) in an area were analyzed in relation to both AT infrastructure and pedestrian/cyclist collision risk from 2015-2019. Areas with higher concentrations of low-income residents were shown to be associated with a higher risk of collision. Areas with higher concentrations of older adults were shown to be associated with fewer roads with cycling infrastructure but more roads with traffic calming measures.

Evident in this project was the complex nature of the relationships between marginalized groups, AT infrastructure and health. Limitations include the cross-sectional nature of the data that was mostly analyzed at the area level. Additional nuances not explored include the quality of said AT infrastructure. As municipalities continue to strengthen their integration of health, equity and health equity in AT planning, this project aims to contribute to the role that research plays in planning for public health.

Introduction

The goal of this research project was to assess the place of health, equity and health equity considerations in active transportation, using the City of Markham in the Regional Municipality of York as a case study.

Facilitating equitable access to healthy built environments, particularly in challenging suburban environments where few people cycle, is a primary focus for The Centre for Active Transportation (TCAT) at Clean Air Partnership. Through its Active Neighbourhoods Canada Network, TCAT has used a participatory planning approach to engage diverse voices in re-imagining neighbourhoods design, as well as a community bike hub approach to build suburban bike culture in the Greater Toronto Area (GTA), most recently through Markham Cycles. Through this work, the lack of research linking active transportation (AT) to health in these communities was recognized. Markham, Ontario, a large suburban city north of Toronto, emerged as a potential case study site because of the City of Markham's partnership in Markham Cycles, and to help inform the development of their Active Transportation Plan currently underway.

Discussions with the City and York Region Public Health helped shape the final project phases, which are 1) examining current municipal planning practices regarding health, equity and health equity; and 2) contributing to the body of research through a spatial analysis that assesses the relationship between AT and health, specifically for marginalized groups.

The Place of Health and Health Equity in Active Transportation

Intersecting fields of both geography and public health, research on the built environment has shown its complicated relationship to human health (Renalds, Smith, & Hale, 2010). Despite the challenges that lie in trying to understand complex human mobility (Chum & O'Campo, 2013), Canadian research in the field has increased steadily in the last decade (McCormack et al., 2019). Active transportation (AT), or "using your own power to get from one place to another" (Government of Canada, 2014), is one such type of mobility that typically refers to walking or cycling. A form of physical activity, AT use has largely been associated with positive health outcomes such as reduced rates of chronic disease (Creatore et al., 2016; Ryan, Cooke, Kirkpatrick, Leatherdale, & Wilk, 2018), though null examples exist (Lukmanji, Williams, Bulloch, Dores, & Patten, 2020; McCormack & Shiell, 2011).

Environments that facilitate AT among residents provide resources to do so safely through sidewalks, cycling infrastructure and more (Ontario Ministry for Transportation, 2012). As expected, areas with larger populations and more attractions have more AT resources. And with this increase of resources comes an increase in AT use (Wasfi, Steinmetz-Wood, & Kestens, 2017), though area socioeconomic factors such as income (Luan, Ramsay, & Fuller, 2019), may attenuate this relationship. For Canadian municipalities, planning for the increased access to AT resources for marginalized groups such as low-income residents (Battista & Manaugh, 2019) is an emerging consideration.

Knowing who does and does not have access to AT resources thus also predicts who has access to the health benefits of AT. The National Collaborating Centre for Determinants of Health defines health equity (2013) as a state in which "all people can reach their full health potential and should not be disadvantaged from attaining it because of their race, ethnicity, religion, gender, age, social class, socioeconomic status or other socially determined circumstance". For active transportation, this can mean examining the inequitable distribution of infrastructure (Winters, Fischer, Nelson, Fuller, & Whitehurst, 2018), collisions (Delmelle, Thill, & Ha, 2012) and chronic disease prevention (Matheson, White, Moineddin, Dunn, & Glazier, 2010) among marginalized communities (Booth et al., 2013).

Incorporating Health and Health Equity in Municipal Transportation Planning

As most active transportation infrastructure is managed by municipalities, the role of municipal planning as a public health intervention has garnered recognition (Arnason, Tanuseputro, Tuna, & Manuel, 2019). To understand how municipalities are currently approaching their transportation planning with an eye to health and health equity, five municipal plans (Brampton, Ontario (2019); Kingston, Ontario (2018); Saanich, British Columbia (2018); Toronto, Ontario (2019); and Windsor, Ontario (2019)) were analyzed. These five plans were chosen due to their recent publication (plans published in 2018 or later were considered); to emphasize Ontarian municipalities (though Saanich was included as an award-winning Western Canada example); and ensure comparisons were of cities within both urban and suburban contexts.

Plans were assessed on how consistently equity was included in the planning process and how holistically they described health outcomes (**Table 1**). The planning process was broken up into "Research and Analysis", "Consultation" and "Evaluation and Monitoring" as these were the most prominent stages for incorporating equity. We describe "explicit" equity considerations as when plans name and contextualize the inclusion of historically marginalized groups. "Implicit" equity considerations are the subtle inclusion of these groups without such context. Health on the other hand was not assessed for its addition at specific stages. Instead, the different types of health (physical, mental, community and environmental) served as indicators for inclusion.

Finally, each equity and health aspect was summarized on a 4-point scale: *No Integration* (the plan did not acknowledge or incorporate equity or health element into planning); *Emergent* (the plan acknowledged but did not incorporate equity or health element into planning); *Established* (the plan showed incorporation of equity or health element into planning); and *Strong* (the plan showed consistent and strong incorporation of equity or health element into planning). The results can be seen in **Table 1.**

All municipalities analyzed incorporated some equity considerations into their planning process, but they ranged on how consistently and explicitly they did so. Windsor did this most extensively – their research and analysis phase included identifying priority areas centered on equity and low presence of AT infrastructure; they targeted marginalized groups for consultation; and their post-implementation evaluation included metrics geared towards equity. Brampton, Kingston and Toronto also considered a broad range of marginalized groups but with less consistency. Saanich's equity considerations only included those of physical accessibility (though they did this the strongest), which limited its ability to plan for other equity seeking communities.

Similar to the scientific literature on the effects of AT on health, all plans emphasized physical benefits the most when talking about health. Municipalities with the most holistic understanding of health included Saanich, Toronto and Windsor. These plans cited additional mental, community and environmental benefits of AT. Saanich and Windsor took the extra step of committing to supporting future research. No plan however cited local rates of health outcomes (such as obesity or diabetes) or made the link between these local rates and expected impacts of implementing the AT plan.

While not a comprehensive analysis, this scan shows that incorporating health and equity considerations into transportation planning varies greatly across municipalities. Both research and policy play a role in pushing this work forward. Clarifying equity objectives and developing equity performance indicators to reach these goals are among the key suggestions for policymakers (Manaugh, Badami, & El-Geneidy, 2015). For researchers, illustrating the link between policy outcomes, such as resulting access to AT resources, and health equity is equally important. Using a case analysis of the City of Markham in the Regional Municipality of York, this research project contributes to the latter goal.

Table 1: Breakdown of municipal transportation plan comparison from No Integration to Strong.

No Integration | Emergent | Established | Strong

		Toronto (Cycling Only)	Brampton (AT)	Kingston (AT)	Windsor (AT)	Saanich (AT)
EQUITY	**Equity in Research + Analysis**	• Integrated physical accessibility by ensuring AODA compliance and following the complete streets guidelines • Used City of Toronto equity metric on neighbourhoods to identify 31 improvement areas that would have high priority	• Integrated physical accessibility by encouraging work that exceeds AODA requirements • Used neighbourhood income, senior homes and health care centres as a metric when analyzing areas that would have high priority	• Integrated physical accessibility by encouraging work that exceeds AODA requirements and following the complete streets guidelines	• Integrated physical accessibility by ensuring AODA compliance and following the complete streets and AAA guidelines • Used a neighbourhood equity analysis to find areas with high concentrations of under-served populations that would have high priority • Analyzed gender trends in transportation mode use	• Integrated physical accessibility by following the AAA guidelines and ensuring accessible detours during construction and maintenance
	Equity in Consultation	• Consulted with neighbourhood improvement area representatives		• Consulted with youth organizations	• Conducted focus groups targeted towards hard-to-reach groups	• Consulted with youth and adults with disabilities
	Equity in Evaluation + Monitoring	• Concerns raised by community post-implementation incorporated into changes			• Measures of success include proportion of women, children and seniors who are using AT	

		Toronto (Cycling Only)	Brampton (AT)	Kingston (AT)	Windsor (AT)	Saanich (AT)
HEALTH	**Physical**	• Cited active lifestyles, fewer rates of cardiovascular diseases and other chronic diseases as a benefit	• Cited active lifestyles, fewer rates of cardiovascular diseases and other chronic diseases as a benefit	• Cited active lifestyles, fewer rates of cardiovascular diseases and other chronic diseases as a benefit	• Cited active lifestyles, fewer rates of cardiovascular diseases and other chronic diseases as a benefit • Supporting research on benefits of active living on health	• Cited active lifestyles, fewer rates of cardiovascular diseases and other chronic diseases as a benefit in plan and public communication • Supporting research on benefits of active living on health
	Mental	• Cited a reduction of mental illnesses as a benefit		• Cited a reduction of mental illnesses as a benefit	• Cited an increase in mental wellness as a benefit	
	Community	• Cited an increase in social connections as a benefit • Cited a decrease in health care costs as a benefit		• Cited a decrease in health care costs as a benefit	• Cited an increase in social connections as a benefit	• Cited an increase in social connections as a benefit
	Environmental	• Cited a decrease in GHG emissions, traffic-related pollution and improved local air quality as a benefit	• Cited a decrease of GHG emissions as a benefit in plan and public communication • Considered impacts of new routes on environment	• Considered impacts of new routes on environment	• Cited a decrease of greenhouse gas emissions as a benefit • Supporting research on the impacts of vehicle emissions on local air quality	• Cited a decrease of greenhouse gas emissions and congestion as a benefit

Moving to the Suburbs: A Case Analysis of Markham, Ontario

Suburban areas provide a unique context in studying active transportation. In Canada, the suburbs have seen the majority of Canada's population growth (Gordon et al., 2018) and thus new potential for residents to walk or cycle to their destinations. In the Greater Toronto Area (GTA), this potential is especially evident in short trips to and from public transit (Mitra, Smith Lea, Cantello, & Hanson, 2016).

The fourth most populous municipality in the GTA, Markham, Ontario has experienced intense urban development since the early 1980s. Its residents, totalling 328,490 as of the 2016 Census, boast a diversity of racial identities and cultures (Ansari, 2018). Ensuring equitable access to AT for this population means understanding the spatial distribution of marginalized groups and existing resources. The findings of this project will provide an active transportation case analysis of a diverse Canadian suburb and will ideally enrich equity considerations in urban planning research and active transportation policy development.

Active Transportation and Chronic Disease Outcomes in York Region

Introduction

This portion of the analysis uses publicly available data from the Canadian Community Health Survey (CCHS) to understand the relationship between AT infrastructure and self-reported chronic disease outcomes in York Region. York Region is located directly north of the City of Toronto and contains the case study site of this report, Markham, Ontario. The active living environment (ALE) score was developed in 2019 (Herrmann et al.) to measure built environment features that are conducive to AT. The most recent version, based on 2016 data, summarizes street connectivity, population and destination density in a 5-point scale (1 being a low active living environment and 5 being a high active living environment) that is calibrated to AT rates in the area. The ALE score is routinely linked to datasets such as the CCHS and is publicly available, making it a useful metric for practitioners. In research, it has been shown to be associated with certain general and physical health measures (Colley, Christidis, Michaud, Tjepkema, & Ross, 2019), but less so with mental health measures (Lukmanji et al., 2020). Combined with select socioeconomic factors, the data was modelled to understand the differences in prevalence for self-reported obesity, diabetes and heart disease for this population.

Methods

Data

The combined 2015/2016 cycles of the CCHS were used. The CCHS is a nationally representative health survey conducted by Statistics Canada that includes respondents from over 100 health regions (administrative areas created by provinces) in a complex sampling strategy that provides estimates of self-reported health measures. The CCHS data was accessed through the Canadian Socio-Economic Information Management System at the Computing in the Humanities and Social Sciences, University of Toronto.

Sample

For this analysis, respondents under the age of 18 were excluded, as were those who did not have valid responses to questions pertaining to BMI, heart disease and diabetes status. In total, 1,536 respondents were included in the analysis who were weighted to represent 896,800 residents of the region.

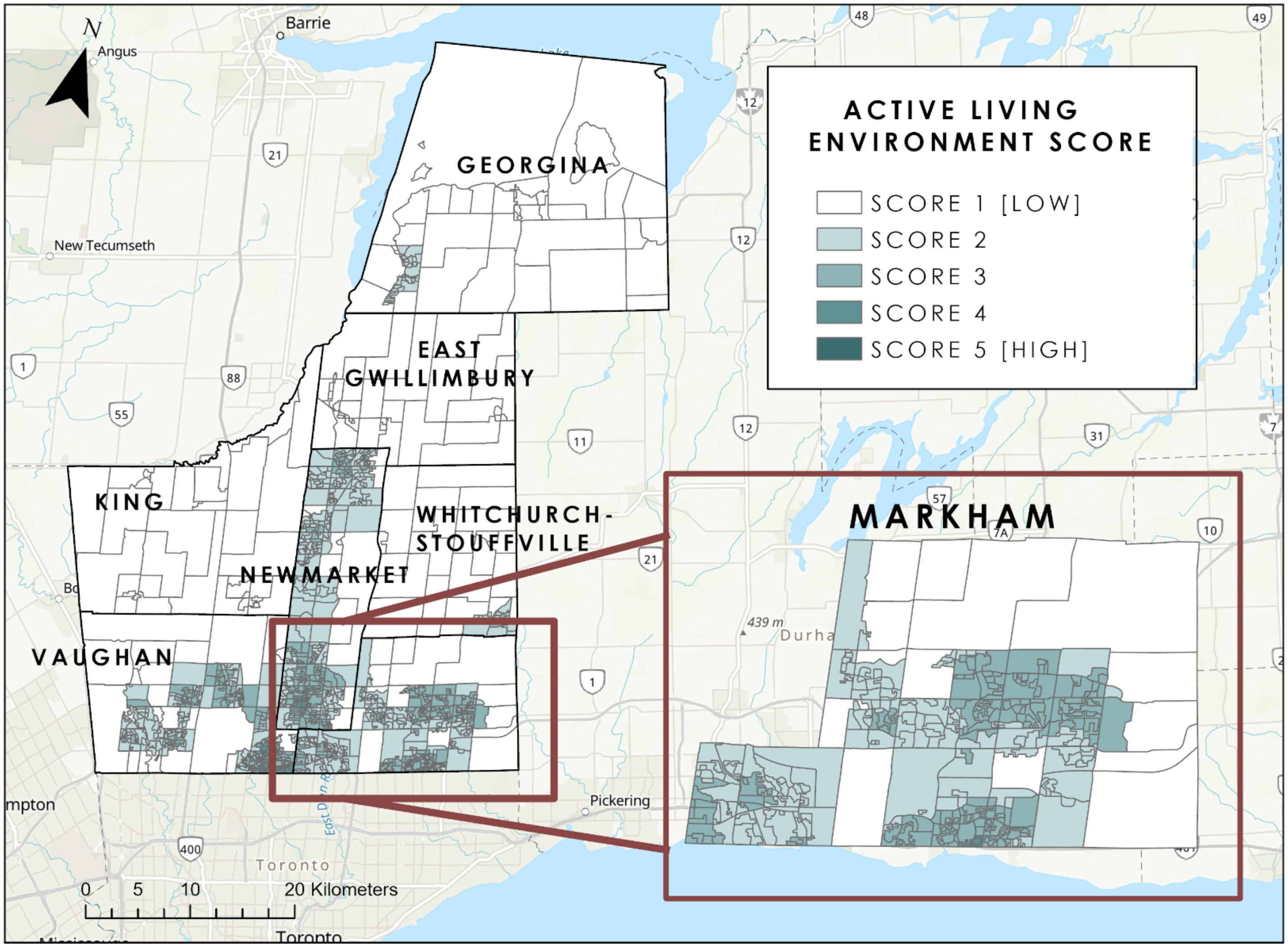
Measures

Several equity-related factors were included: visible minority status (white and non-white); household income (in $20,000 income groups); and education level (did not complete high school, completed high school and completed some post-secondary education). The built environment was summarized with the Active Living Environment (ALE) score (Herrmann et al., 2019). In addition to the equity and built environment measures, biological characteristics well-known to be associated with obesity, heart disease and diabetes were included (Danaei et al., 2009); specifically, age, sex and smoking history (never smoker, current smoker and former smoker). Older adults are defined here as those over the age of 65. The outcomes of interest were obesity (indicated here by a BMI of 30.0 or higher), self-reported diabetes and self-reported heart disease. All measures, excluding the ALE score, are based on participant self-report.

Statistical Analysis

The distribution and clustering of ALE scores at the dissemination area level across York Region was assessed using Moran's I and mapped in ArcGIS Pro. Associations between equity factors and ALE score were determined ordinal logistic regression. To prepare the CCHS data for analysis, multiple imputation was conducted as a sufficient proportion of respondents (~18%) did not answer all questions related to the factors of interest. Multiple imputation fills missing values with plausible responses (imputed values) and creates multiple data sets (here, m=20) that include each plausible response. The Hosmer-Lemeshow-Sturdivant strategy (Hosmer, Lemeshow, & Sturdivant, 2013) was used to build a model that would explain the complex relationships between biological, equity and built environment factors. A Poisson model was used to fit the data and the results are summarized using prevalence ratios, a fraction that compares the prevalence of the outcome between a group in reference to a baseline group. Statistical analysis was done using SAS 9.4.

Figure 1: Active Living Environment score by dissemination area in the Regional Municipality of York Region. A score of 1 represents a low active living environment; a score of 5 represents a high active living environment.



SOURCES: ESRI, HERE, GARMIN, FAO, NOAA, USGS, © OPENSTREETMAP CONTRIBUTORS, AND THE GIS USER COMMUNITY

Results

Marginalized Groups and ALE Score

In York Region, the distribution of ALE scores remains low (right skewed), with a maximum of 4 (out of 5) and a median of 2 (see **Figure 1**). The odds ratios for equity factors and dissemination area ALE score are summarized in **Table 2**. Statistically significant associations were seen across all equity factors (except for a single household income group). Older adults had a lower odds of residing in higher ALE score environments (OR 0.97), as did visible minorities (OR 0.56) and lower household income groups (OR for <$20, 000: 0.60; OR $20, 000-$39, 999: 0.86;OR $60, 000-$79, 999: 0.74). In contrast, those with a lower education had higher odds of living in a higher ALE score environment (OR less than high school: 1.29; OR at least high school: 1.15).

Health Outcome Modelling

The prevalence ratios of factors included in the model are summarized in **Table 3**.

Obesity: Being a woman was significantly associated with a lower prevalence of obesity, while increasing age and having a past smoking history were significantly associated with a higher prevalence. Having less than a post-secondary education had mixed associations. A lower household income was significantly associated with a higher prevalence of obesity. Being a visible minority was significantly associated with a lower prevalence of obesity. Living in an area with a lower ALE score was significantly associated with a higher prevalence of obesity.

Heart Disease: Being a woman was significantly associated with a lower prevalence of heart disease, while increasing age and having a past smoking history were significantly associated with a higher prevalence. Having less than a post-secondary education and a lower household income were significantly associated with a lower prevalence of heart disease. Visible minority status had no significant association. Living in an area with a lower ALE score was significantly associated with a lower prevalence of heart disease.

Diabetes: Being a woman was significantly associated with a lower prevalence of diabetes, while increasing age and smoking were significantly associated with a higher prevalence. Having less than a post-secondary education was significantly associated with a higher prevalence of diabetes. Having a lower household income had mixed associations. Being a visible minority was significantly associated with a higher prevalence of diabetes. Living in an area with a lower ALE score was significantly associated with a lower prevalence of diabetes.

Table 2: Odds ratios (ORs) and corresponding p-values for the univariate associations of equity factors to ALE class in York Region. Statistically significant ORs (p-value < 0.05) are in **bold.**

	ALE Class	
	OR (95% CI)	p-value
Older Adult	**0.97 (0.96, 0.98)**	**<.0001**
Visible Minority Status	**0.56 (0.51, 0.61)**	**<.0001**
Household Income		
<$20, 000	**0.60 (0.59, 0.61)**	**<.0001**
$20, 000-$39, 999	**0.86 (0.85, 0.87)**	**<.0001**
$40, 000-$59, 999	0.99 (0.98, 1.01)	0.2718
$60, 000-$79, 999	**0.74 (0.73, 0.75)**	**<.0001**
$80, 000+	Reference	Reference
Education		
Less than HS	**1.29 (1.24, 1.36)**	**<.0001**
Highschool	**1.15 (1.09, 1.21)**	**<.0001**
Post-secondary	Reference	Reference

Table 3: Prevalence ratios (PR) and p-values from multivariate Poisson model in York Region. Statistically significant PRs (p-value < 0.05) are in **bold.**

	Obesity		Diabetes		Heart Disease	
	PR (95% CI)	p-value	PR (95% CI)	p-value	PR (95% CI)	p-value
Sex						
Male	Reference	Reference	Reference	Reference	Reference	Reference
Female	**0.65 (0.58, 0.73)**	**<.0001**	**0.53 (0.51, 0.55)**	**<.0001**	**0.60 (0.58, 0.62)**	**<.0001**
Age						
18-29 yr	Reference	Reference	Reference	Reference	Reference	Reference
30-39 yr	**2.48 (1.84, 3.36)**	**<.0001**	**2.67 (2.50, 2.86)**	**<.0001**	**0.41 (0.37 0.44)**	**<.0001**
40-49 yr	**3.20 (2.20, 4.66)**	**<.0001**	**5.31 (5.00, 5.66)**	**<.0001**	**0.28 (0.26, 0.31)**	**<.0001**
50-50 yr	**3.34 (2.50, 4.46)**	**<.0001**	**4.42 (4.12, 4.74)**	**<.0001**	**1.35 (1.27, 1.43)**	**<.0001**
60-69 yr	**3.25 (2.28, 4.65)**	**<.0001**	**14.40 (13.55, 15.30)**	**<.0001**	**3.34 (3.15, 3.54)**	**<.0001**
70-79 yr	**2.47 (1.57, 3.89)**	**0.0005**	**23.66 (22.00, 25.43)**	**<.0001**	**4.75 (4.46, 5.05)**	**<.0001**
80+	**1.92 (1.15, 3.20)**	**0.0151**	**14.84 (13.38, 16.46)**	**<.0001**	**10.80 (10.12, 11.51)**	**<.0001**
Smoker						
Never	Reference	Reference	Reference	Reference	Reference	Reference
Current	1.01 (0.78, 1.31)	0.9203	**1.35 (1.12, 1.61)**	**0.0028**	**0.26 (0.19, 0.33)**	**<.0001**
Former	**1.18 (1.07, 1.30)**	**0.0016**	1.08 (0.98, 1.18)	0.1049	**1.73 (1.60, 1.86)**	**<.0001**
Visible Minority						
White	Reference	Reference	Reference	Reference	Reference	Reference
Non-White	0.77 (0.59, 1.00)	0.0521	**1.64 (1.34, 2.02)**	**<.0001**	1.12 (0.98, 1.29)	0.1023
Education						
Less than HS	**0.64 (0.57, 0.74)**	**<.0001**	**1.67 (1.52, 1.83)**	**<.0001**	**0.85 (0.78, 0.92)**	**0.0002**
Highschool	**1.08 (1.01, 1.16)**	**0.0327**	**1.28 (1.16, 1.41)**	**<.0001**	**0.70 (0.65, 0.75)**	**<.0001**
Post-secondary	Reference	Reference	Reference	Reference	Reference	Reference
Household Income						
<$20,000	**1.67 (1.39, 2.01)**	**<.0001**	**1.39 (1.33, 1.45)**	**<.0001**	**0.90 (0.84, 0.95)**	**0.0002**
$20,000-$39,999	1.02 (0.85, 1.22)	0.8244	**0.63 (0.60, 0.65)**	**<.0001**	**0.70 (0.66, 0.73)**	**<.0001**
$40,000-$59,999	**1.53 (1.21, 1.92)**	**0.001**	**1.91 (1.85, 1.97)**	**<.0001**	**0.64 (0.61, 0.66)**	**<.0001**
$60,000-$79,999	1.10 (0.88, 1.38)	0.3779	**0.86 (0.83, 0.89)**	**<.0001**	**0.52 (0.50, 0.54)**	**<.0001**

$80,000+	Reference	Reference	Reference	Reference	Reference	Reference

Table 3 Continued.

	Obesity		Diabetes		Heart Disease	
	PR (95% CI)	p-value	PR (95% CI)	p-value	PR (95% CI)	p-value
ALE Class						
1	0.93 (0.82, 1.05)	0.2226	**0.22 (0.21, 0.24)**	**<.0001**	**0.27 (0.25, 0.28)**	**<.0001**
2	**1.27 (1.11, 1.44)**	**0.0008**	**0.63 (0.60, 0.66)**	**<.0001**	**0.34 (0.32, 0.35)**	**<.0001**
3	**1.11 (1.01, 1.22)**	**0.0192**	**0.71 (0.66, 0.77)**	**<.0001**	**0.30 (0.29, 0.32)**	**<.0001**
4	Reference	Reference	Reference	Reference	Reference	Reference

Discussion

The results from this analysis both support and contradict initial hypotheses. The built environment, measured through the ALE score, had mixed relationships to health depending on the outcome. As seen in other studies, living in an area with a lower ALE score was associated with an increased prevalence of obesity (Colley et al., 2019). However, it was also associated with a decreased prevalence of heart disease, contrary to other works (Chiu et al., 2016; Chum & O'Campo, 2013).

Similarly, the findings showed mixed interpretations for equity factors. For example, lower educational attainment was associated with a lower prevalence of obesity and heart disease but a higher prevalence of diabetes. One *a priori* hypothesis, that non-white residents would have a higher prevalence of diabetes, was validated by this analysis. Another hypothesis, that lower income households would have a higher prevalence of heart disease, was not.

Contextualizing these findings with the relationship between the socioeconomic factors and ALE score is important. As all equity factors were statistically significant with the ALE score, this may point to residential self-selection. Residential self-selection describes how residents choose neighbourhoods based on several individual factors and preferences (Mokhtarian & Cao, 2008). Here, it may mean that older adults, visible minorities and lower-income households face barriers to residing in areas with higher ALE scores that is difficult to quantify and obscures the relationship between the ALE score and health outcomes. This is a well-known limitation of using cross-sectional data such as the CCHS and bolsters the need for future research using longitudinal study designs to further parse out these relationships.

Marginalized Communities and Pedestrian and Cyclist Collision Risk in Markham

Introduction

Focusing on Markham, Ontario, the most populous municipality of York Region, the second step in the analysis uses spatial modelling to illustrate the ecological relationship between areal residential makeup and collision risk. The dissemination area, the smallest geographic unit drawn by Statistics Canada, is used here with a network buffer to best describe resident mobility. Marginalized groups of interest included the percentage of the population that were older adults (over the age of 65), a visible minority or living in low-income. Combined with connectivity measures, the Besag-York-Mollié model (BYM) was used understand the differences in collision risk depending on the marginalized group density as seen in previous studies (Rothman, Macarthur, Wilton, Howard, & Macpherson, 2019).

Methods

Data

The 2016 Census was used (for population counts as well as marginalized group percentages) and accessed through the Canadian Socio-Economic Information Management System at the Computing in the Humanities and Social Sciences, University of Toronto. Pedestrian and cyclist collisions from 2015-2019 (a five-year interval) were provided by the City of Markham. Street connectivity was accessed through the City of Markham's Open Access portal.

Measures

A 1 kilometre-network buffer was used around the centre of the dissemination area and all measures were calculated within this buffer zone (including population and marginalized group counts). Here, equity-related factors were incorporated using the percentage of the population in a dissemination area that were an older adult (over the age of 65), were a visible minority or lived in a low-income household. The percentage was used here instead of raw counts because of the varying population density across the city. Road and intersection density were included in the model to control for connectivity. The outcomes of interest were collision rates and increased risk. Collisions were those involving a pedestrian or cyclist within Markham from 2015-2019.

Statistical Analysis

Initial mapping and visualization were done in ArcGIS Pro. The Besag-York-Mollié model (BYM) (Besag, York, & Mollié, 1991) with a Poisson distribution to understand the relationship between equity-related factors and collision rates while adjusting for the underlying population in the offset. Integrated nested Laplace approximations (INLA) were used through the R-INLA project to estimate risk ratios. Risk ratios, a fraction that compares the risk of collision for every increase in the variable of interest. Geocoding of collisions was done in ArcMap and modelling was done using R.

Results

Collision Risk Modelling

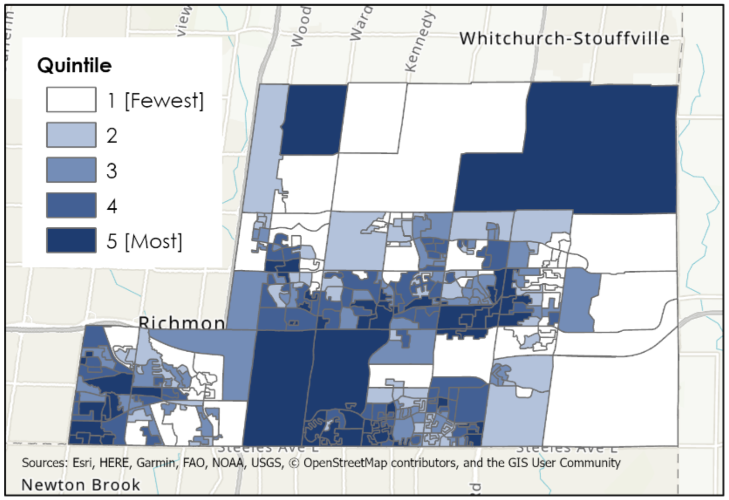
The relative risks associated with factors included in the model are summarized in **Table 4**. Of all the factors included in the model, only the percentage of low-income residents in a dissemination area was associated with the risk of collisions. For every 1 unit increase in this percentage, the risk of collision increased by 5%.

Table 4: Risk ratios (RR) multivariate BYM model in Markham. Statistically significant PRs (credible intervals do not contain 1.00) are in **bold.**

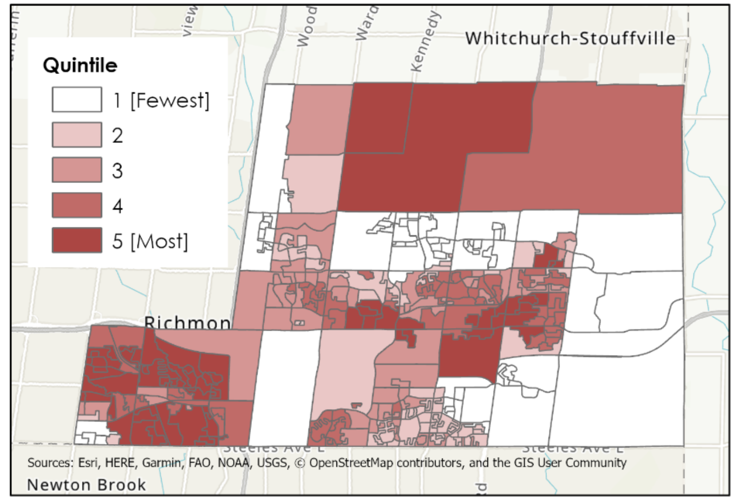
	Model 1 RR (95% CrI)	**Model 2 RR (95% CrI)**	**Model 3 RR (95% CrI)**	**Full Model RR (95% CrI)**
Road Density	0.97 (0.91, 1.03)	0.97 (0.91, 1.03	1.00 (0.94, 1.07)	1.00 (1.00, 1.00)
Intersection Density	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)	1.00 (1.00, 1.00)
% Older Adult	1.02 (1.00, 1.04)	-	-	1.01 (0.98, 1.03)
% Visible Minority	-	**0.99 (0.99, 0.99)**	-	0.99 (0.99, 1.00)
% Low-income	-	-	**1.04 (1.02, 1.05)**	**1.05 (1.03, 1.07)**

Figure 2: Collisions and marginalized community quintiles in Markham from 2015-2019 within dissemination area network buffer.

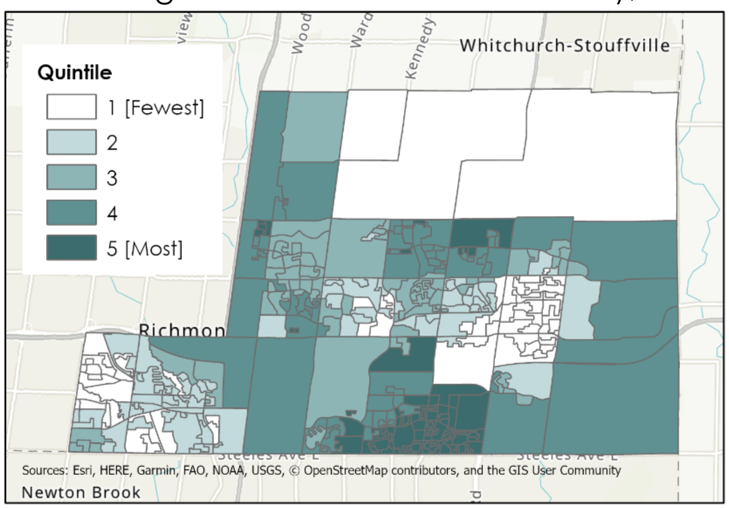
Collision Rate per 1,000 Persons, 2015-2019



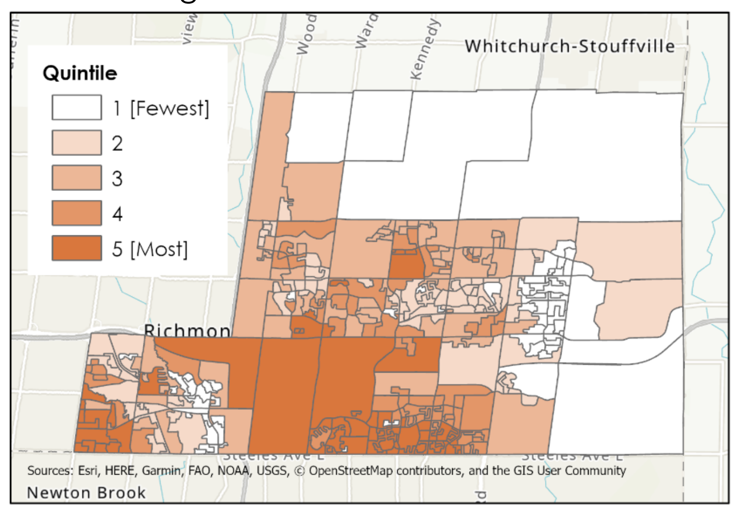
Percentage of Residents – Older Adults, 2016



Percentage of Residents – Visible Minority, 2016



Percentage of Residents – Low-income, 2016



Discussion

When adjusting for the underlying population distribution, only the percentage of low-income residents resulted in a difference in risk. This finding confirms previous study findings that similarly show increased risk based on residential income (Osama & Sayed, 2017; Rothman et al., 2019). Possible explanations for this finding include unsafe road conditions or a lack of AT infrastructure in areas with predominately low-income residents. It is important to note that as an ecological/area-based study, this finding cannot to be attributed to individuals but dissemination areas as a whole.

This analysis confirms the need for spatial techniques in understanding the distribution and associated risks of collisions. When analyzing marginalized group distribution in particular, areas with higher percentages of older adults, visible minorities and low-income residents showed significant clustering when measured using Moran's I (results not shown here). This validates the continued use of spatial modelling in lieu of non-spatial regression techniques whose assumptions are invalidated.

Active Transportation Infrastructure and Marginalized Communities in Markham

Introduction

The last part of the analysis also uses spatial modelling to describe the relationship between areal residential makeup and AT infrastructure. Through a partnership with the City of Markham, data on sidewalk, cycling infrastructure and traffic calming location was available. Cycling infrastructure includes bike lanes, cycling tracks, multi-use pathways and on-street edge lines. Paved shoulders and shared roadways were excluded from this analysis. On-street edge lines are painted lines on the road of varying width that are not dedicated solely for the use of cyclists but may be used by them. In Markham, edge lines are 2 metres in width with no bike signage and may also be used for parking. Traffic calming measures include low-speed roads (<30 km/h) and roads with speed bumps, chicanes, medians or raised intersections.

These types of measures are not as easily accessible as the active living environment (ALE) score (nor does the ALE score capture them), though they are facilities that are more directly relevant to municipal planners seeking to understand gaps in the network. These facilities were again measured according to a 1km network buffer from the dissemination area. The Kelejian-Prucha model (SAC) relates the population that are older adults, a visible minority or living in low-income to these facilities. A lack of equity in AT infrastructure has been shown in previous studies in similar contexts (Winters et al., 2018).

Methods

Data

The 2016 Census was used (used for population counts as well as marginalized group percentages) and accessed through the Canadian Socio-Economic Information Management System at the Computing in the Humanities and Social Sciences, University of Toronto. AT infrastructure was provided through a partnership with the City of Markham, specifically location of cycling infrastructure, sidewalks and traffic calming measures. Street connectivity was accessed through the City of Markham's Open Access portal.

Measures

A 1 kilometre-network buffer was used around the centre of the dissemination area and all measures were calculated within this buffer zone (including population and marginalized group counts). Here, equity-related factors were incorporated using the percentage of the population in a dissemination area that were an older adult (over the age of 65), a visible minority or lived in a low-income household. The percentage was used here instead of raw counts because of the varying population density across the city. The outcomes of interest were the percentage of the road network with AT infrastructure (again, the percentage was used here due to varying road density). Specifically, the percentage of the road network with sidewalks, cycling infrastructure and traffic calming measures were used.

Statistical Analysis

Initial mapping and visualization were done in ArcGIS Pro. The "top-down" strategy was used to choose the appropriate spatial model for the data (LeSage & Pace, 2010). This method lead to the choice of the Kelejian-Prucha Model (SAC) (Kelejian & Prucha, 1998) to understand the relationship between equity-related factors and active transportation infrastructure in a dissemination area. The direct effects (Golgher & Voss, 2016) were primarily used to interpret the relationship. The direct effect is change in the outcome in the *immediate* areal unit for an increase of the variable of interest in the *immediate* area. Statistical analysis was done using R.

Results

Infrastructure Modelling

The direct effects of factors included in the model are summarized in **Table 5**.

Sidewalk: The % of the road network with sidewalks significantly increases as the population count increases. For an increase of 1, 000 persons in a dissemination area, the % of the road network with sidewalks increases by 1%. None of the marginalized group measures were statistically significant.

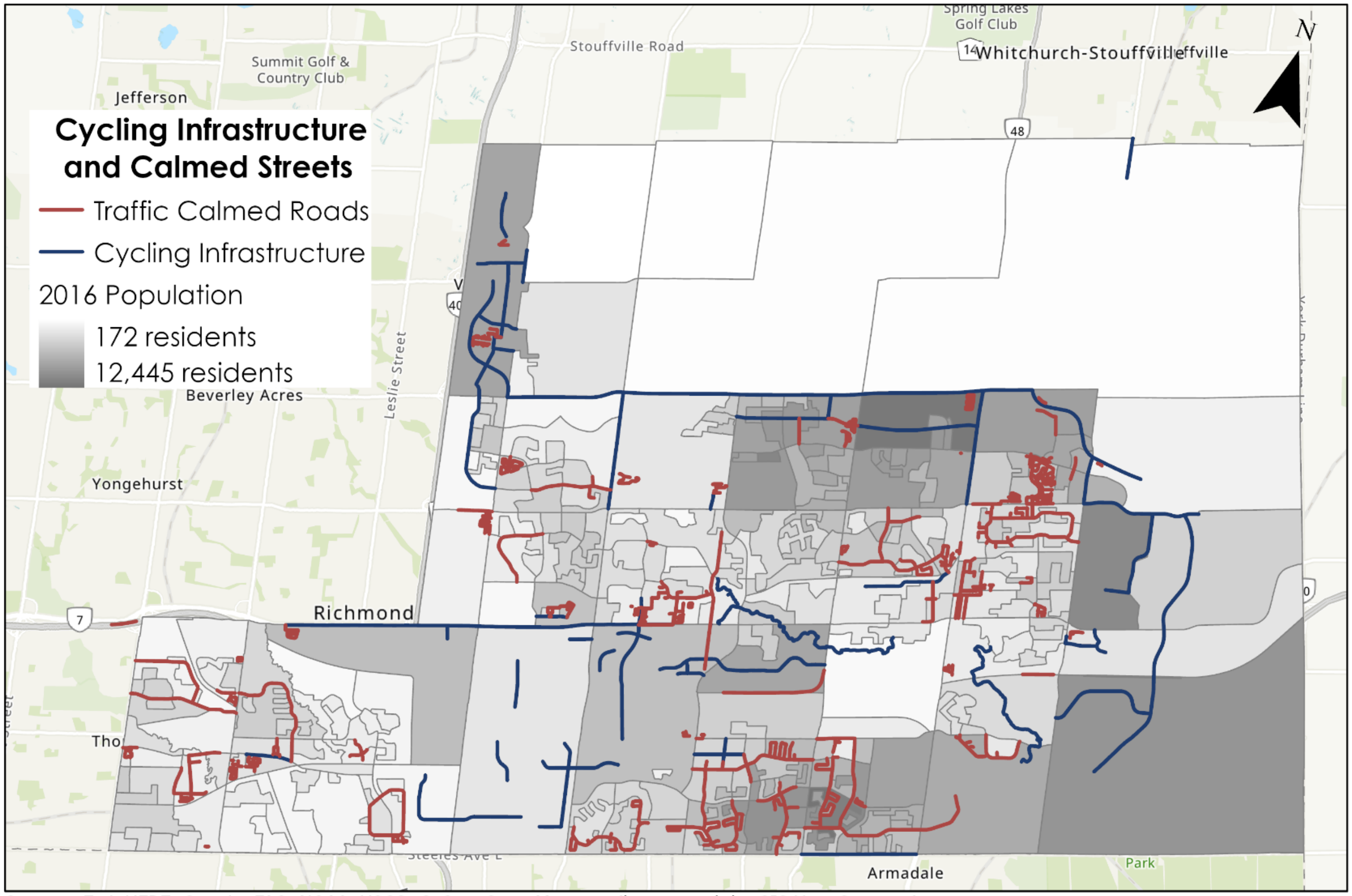
Cycling Infrastructure: The % of the road network with cycling infrastructure significantly increases as the population count increases. For an increase of 1, 000 persons in a dissemination area, the % of the road network with cycling infrastructure increases by 0.3%. The % of the road network with cycling infrastructure significantly decreases as the % of older adults increases. For an increase of 1% in the % of older adults, the % of the road network with cycling infrastructure decreases by 0.2%.

Traffic Calming: The % of the road network with traffic calming significantly increases as the population count increases. For an increase of 1, 000 persons in a dissemination area, the % of the road network with traffic calming increases by 0.8%. The % of the road network with traffic calming significantly increases as the % of older adults in the area increases. For an increase of 1% in the % of older adult residents, the % of the road network with calming increases by 0.7%.

Table 5: Direct Effects (DE) and p-values from multivariate SAC model in Markham. Statistically significant DEs (p-value < 0.05) are in **bold.**

	% of Roads with Sidewalks		% of Roads with Cycling Infrastructure		% of Roads with Traffic Calming	
	DE	p-value	DE	p-value	DE	p-value
Population	**0.001**	**0.003**	**0.0003**	**0.034**	**0.0008**	**0.006**
% Older Adult	-0.024	0.967	**-0.215**	**0.015**	**0.683**	**7.335×10^{-5}**
% Visible Minority	0.100	0.137	0.068	0.116	0.038	0.464
% Low-income	-0.280	0.137	-0.037	0.635	-0.161	0.238

Figure 3: Population of Markham, Ontario in 2016 as measured by a 1km network buffer. Cycling infrastructure, specifically bike lanes, multi-use pathways, cycle tracks and edge lines are shown, as well as traffic calmed streets.



Sources: Esri, HERE, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community

Discussion

The only factor that had significant effect on all three AT measures was population count, indicating that these measures are most often found in denser parts of the city. This may suggest an equitable distribution of AT infrastructure for these groups, though it is worth noting that differences in *quality* of AT infrastructure may still exist. For example, this analysis did not differentiate between sidewalk presence on one or both sides of the street and the definition of cycling infrastructure included urban road shoulders (2-metre edge lines painted next to the road curb for roads without other dedicated space for cycling). In suburban environments, where road space is more abundant, urban road shoulders present a unique opportunity to calm traffic while also increasing cycling facilities. In 2018, Markham installed edge lines on all two-lane, collector roads across the city with sufficient width. However, the quality and relative safety of urban road shoulders as a form of cycling infrastructure is debatable. Understanding access specifically to safer types of AT infrastructure may provide insight as to the continued increased collision risk in areas with more low-income residents. Thus, to truly draw conclusions on equitable access, research that discerns between these important differences is needed.

Contrary to initial hypotheses, the percentage of visible minorities or low-income residents had no significant effect on AT infrastructure, though this has been seen elsewhere (Winters et al., 2018). Markham is well-known for its racial and ethnic diversity and the median here for the percentage of visible minorities across dissemination areas was over 75%. This means that in most of Markham, visible minorities are in fact the *majority*. And, similar to the distribution of low-income residents, this population is clustered in the city's most densely populated areas. Living in population dense areas where the need for AT infrastructure is more obvious (as seen here in the positive associations between population counts and AT measures) may contribute to more equal access for these groups that is unique to this context.

Conclusion

As health, equity and health equity are increasingly key considerations in the discussion on AT, research on its impact must provide insights on which to base future directions. Seen in this research project, these relationships are complex and intersecting. Older adult, visible minority and low-income populations in Markham, Ontario show strong independent spatial patterns that dictate access to AT facilities. These patterns exist in other Canadian cities as well (Winters et al., 2018). However, as seen in this report, the distribution of these groups is unique to this context and caution must be used when generalizing to disparate contexts.

Similarly, health equity, displayed here through collision risks and chronic disease outcomes for marginalized groups, showed interesting results. Areas with more low-income residents exhibited higher risks for pedestrian or cyclist collisions, which points to a need for policy interventions to improve public health. The differing impacts of socioeconomic factors also extend to types of health outcomes.

Limitations of this research project include the lack of individual, longitudinal based data for analysis. As a largely cross-sectional ecological study, many nuances of place and health are muddled. Complex human mobility not easily estimated by residential boundaries and self-selection into preferred built environments are among the largest, though unavoidable, consequences of this type of analysis. Additionally, the quality of AT infrastructure was not explored here. Differentiating between sidewalks on one or both sides of the road, types of traffic calming measures and cycling infrastructure are important next steps in research.

This project does contribute however in its integration of health equity into both complex spatial analysis and policy implications. Municipal policymakers are strengthening their integration of equity into AT plans, as seen in our scan. Incorporating context-specific research such as this project on health and access will continue to aid in recognizing the municipal policies as a public health intervention (Arnason et al., 2019). Public health researchers can also contribute by leveraging available health data through partnerships with transportation divisions. These areas provide enormous potential for both research and practice to instill the ideals of health and equity more intentionally into future work.

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