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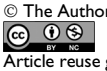
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Equity Implications of Shared Micro-Mobility in the Suburbs: A Spatial Analysis of Shared E-Scooter Use in Different Built and Social Environments

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Abstract

Electric-powered standing kick scooters, otherwise known as e-scooters, have recently been introduced in hundreds of cities around the world as part of rent-to-use shared micro-mobility systems. Despite being a potentially sustainable and equitable travel mode, relatively little analysis has been done on the impact of shared micro-mobility on transportation equity, specifically in the suburban context. The shared e-scooter pilot program in Brampton, Ontario, Canada, presents an opportunity to examine this topic within the context of a Canadian suburban community. Our study explores the use of shared e-scooters (trips per sq km per day) in Brampton, in relationship to suburban built environment types and social and economic marginalization at the neighborhood level. First, a Getis-Ord G_i^* (local "hot spot") analysis identified localized hot-spots of shared e-scooter demand and implied that, at least in some contexts, higher trip rates are concentrated in marginalized neighborhoods. Next, spatial regression analysis (spatial lag model) demonstrated associations between dimensions of marginalization and e-scooter use rate, where higher rates of shared e-scooter use were observed in neighborhoods that have higher household instability, and higher concentrations of racialized and immigrant populations. The findings also suggest that the benefits of shared e-scooters may not be different in neighborhoods with high concentration of economically marginalized population, or low labor force participation. In addition, no relationship was observed between built environment types and e-scooter use. Findings will inform future micro-mobility policy in North American suburban areas, while contributing to the growing body of work on e-scooter use and equity.

Keywords

e-scooters, shared micro-mobility, equity, suburban, built environment, spatial analysis

Since their first introduction as a shared micro-mobility option in 2017, electric-powered standing kick-scooters (knowns as e-scooters) have grown to be popular, representing 43.9% of shared micro-mobility (which includes shared e-scooter and bicycle) trips in the U.S. and Canada in 2023 (*1*). Shared e-scooters have demonstrated their potential for both positive and negative travel-related outcomes, making their use and management an area of interest for policymakers and researchers.

Because of the novelty of shared e-scooters as an emerging public transportation solution, research on this form of micro-mobility is still evolving. Key topics researched to date include safety of use, trip patterns, rider characteristics, and environmental sustainability (*2–8*). At this time, relatively little research has investigated equity implications of shared e-scooter systems, although some researchers found promising results related to higher use by equity-deserving groups (*9*, *10*). More specifically, findings from existing research report high potential e-scooter use by female, younger, and

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non-white people, indicating that some marginalized groups may benefit from having access to them (*10*, *11*).

Previous empirical analysis of e-scooter trip data has found that e-scooters are commonly used for short trips, for transportation over recreation, and, in some contexts, for trips connecting to public transportation (*6*, *12–14*). There is also some evidence of e-scooters replacing short automobile trips in some circumstances (*15*, *16*). Researchers have previously argued that, in areas with limited public transportation service, there is an increased potential for e-scooters to complement public transit trips or provide increased mobility (*5*, *17*). Existing research demonstrates promising results in this regard, reporting higher ridership in areas of low bus stop density and limited route frequency (*18*, *19*). At least hypothetically, then, e-scooters can offer more transportation choices in suburban neighborhoods that have poor accessibility to public transportation. In such contexts, a higher rate of e-scooter use, especially among socially and/or economically marginalized groups with limited transportation options, may imply transportation equity. However, most existing research explores shared micro-mobility in urban areas, while research focusing on suburban communities is scarce (*6*, *9*, *10*). Our study contributes to the emerging shared micro-mobility literature by examining shared e-scooter use in a suburban municipality in Canada, and how it varies across various marginalized (versus less-marginalized) communities.

We also recognize the difference in built environment characteristics between suburban and urban areas. Previous research focused on urban, as opposed to suburban, areas has reported a connection between e-scooter use and built environment characteristics such as land use, proximity to public transportation, and population density (*6*, *20*). Suburban built form is different because of low-density development patterns and segregated land uses, which are connected by car-oriented transportation networks (*21*). In the suburban context, there is also a lack of diversity within and between neighborhoods, with regard to built environment characteristics including population or household density, public transportation accessibility and land use mix, among others. As a result, built-environment-related influences on shared micro-mobility use may be different in suburban areas than what has previously been reported in more urban contexts.

In this study, we use e-scooter trip data obtained from private-sector shared e-scooter providers to explore the following research questions in the context of the City of Brampton, a suburban municipality in Ontario, Canada: 1) What is the correlation between neighborhood-level social and economic marginalization and shared e-scooter usage in a suburban community? and 2) What is the correlation between suburban neighborhood types and shared e-scooter usage? Findings from this study will offer insight into e-scooter use in a suburban municipality, specifically on the topic of its relationship to neighborhood-level built and social environment characteristics. The focus on a suburban, as opposed to urban, context is novel, offering a valuable contribution to the emerging literature, and also informing policymaking in a growing number of suburban municipalities, which are introducing shared micro-mobility to their transportation ecosystems.

Study Design

Conceptualization of Transportation Equity

Transportation influences quality of life, as the ability to travel affects educational, employment, social, and housing opportunities a person can access (*22*). Those who are unable to participate in different types of activity in society because of transportation barriers are more likely to experience social exclusion, material deprivation, and poor health outcomes (*23*, *24*). Further compounding this issue, marginalized and equity-deserving population groups, such as low-income and visible minority (identified as individuals who are non-Caucasian in race and non-white in color) are more likely to experience reduced transportation options, making them more vulnerable to negative outcomes such as increased amount of time spent commuting and limited accessibility to employment opportunities (*22*, *23*, *26*). Considering equity in the provision of transportation services is pivotal in the pursuit of social equity.

Improving transportation systems is inherently a part of the creation of a just city, and the measurement of equity, fairness, and accessibility of transportation services for different socio-demographic groups is one way to ensure this (*26*, *27*). In this context, when planning for just or fair transportation services, a focus on equitable transportation outcomes should be a critically important policy goal. Our study focuses on vertical equity, which recognizes social diversity and acknowledges distinct transportation opportunities and needs across various social and economic groups (*28*, *29*). Based on this principle, a vertically equitable shared micro-mobility system should be designed with particular attention to those who are more in need of alternative transportation options, such as those who are facing various forms of economic and social marginalization. To ensure broader equity in a shared micro-mobility system, vehicles must be made available, affordable, and practically usable by equity-deserving population groups, enabling greater freedom of movement to relevant daily destinations. In this paper, we focus specifically on the rates of e-scooter use in marginalized communities, and conceptualize that

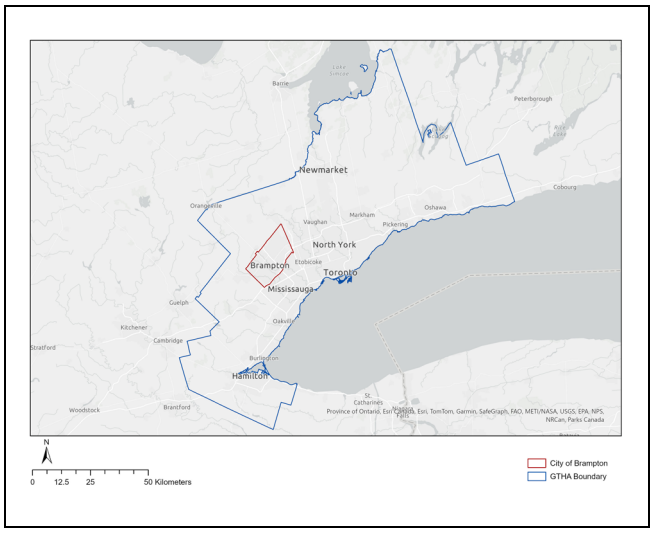

Figure 1. Study area.
Note: GTHA = Greater Toronto and Hamilton Area.

a higher level of e-scooter use among equity-deserving population groups will be a desirable policy outcome. Future work should also consider factors such as accessibility of vehicles and cost of use to address other critical equity barriers.

Study Area

Our study area is the City of Brampton, a suburban municipality located within the regional municipality of Peel in the Greater Toronto and Hamilton Area (GTHA), Ontario, Canada (Figure 1). We conducted a spatial analysis at the scale of dissemination area (DA), which is the smallest geographic scale of measurement available across all datasets used. Population counts and boundaries for Brampton's 623 DAs were obtained from Environics via SimplyAnalytics. Within the City of Brampton, the average number of households per DA was 295 in 2023 (*30*).

Previously, it was not legal to operate e-scooters in the province of Ontario. The ministry of transportation launched a 5 year e-scooter pilot program in 2019 to allow municipalities to host temporary shared e-scooter systems and report back on their findings (*31*). Shared e-scooter pilots were identified as an effective way to monitor benefits and adapt regulation and policies based on local context (*32*). Multiple suburban municipalities in the GTHA, including the City of Brampton, have capitalized on this pilot, selecting private e-scooter operators to run shared micro-mobility systems in their jurisdictions. Under the city's 2 year e-scooter pilot program, which was introduced in spring, 2023 (and more recently, was extended until 2027), three private vendors operate shared e-scooters between the months of April and November, suspending operations during the winter months of December to March. Operators are responsible for ensuring compliance to program rules, which include restrictions on where users can ride vehicles, end trips, and park vehicles. As part of their operations, vendors re-distribute vehicles within the service area and swap out vehicle batteries in accordance with demand. Brampton adopted a city-wide roll-out of their shared e-scooter pilot program, meaning that these shared micro-mobility vehicles are available throughout the city.

Notably, Brampton identified transportation equity and sustainability as a specific goal in its 2023 Official Plan, and acknowledged first- and last-mile connections and increased accessibility to public transportation options as relevant and timely, as they contribute to increased sustainability and equity (*33*). However, at the time of this study, Brampton has no policy targeting equity in e-scooter use or availability.

The City of Brampton is ideal for this study because of its suburban nature and demographic makeup. Brampton has experienced significant employment growth in recent decades but, with regard to the urban environment, much of the municipality is dominated by low-density residential neighborhoods, and a clear separation between residential and other land uses further amplify the suburban nature of this municipality (*34*). However, Brampton has some areas with concentrations of high-rise residential housing, as is common in aging Canadian post-war suburban communities (*21*). The transportation system is largely automobile-oriented with a traditional street hierarchy and wide curvilinear streets within low-density residential neighborhoods. While the municipality is served by Brampton Transit (local) and GO Transit (regional), public transportation options and frequency of service are very limited. Not surprisingly, residents are largely dependent on personal automobiles for travel. In 2021, over 85% of Brampton residents commuted to work in a personal automobile, compared with just over 10% who used public transportation (*35*). In addition, over half of Brampton workers travel outside of the municipality to reach their place of employment, making it home to many regional commuters, which is another common feature of a suburban municipality (*35*).

Brampton has a high proportion of visible minority (i.e., non-Caucasian and non-white) populations, new immigrants (commonly known in Canada as the "newcomers") and many low-income residents (*36*). In the Canadian context, it is common to find high concentrations of marginalized population groups in suburban municipalities near bigger urban centers, and this trend has become more common in recent decades because of the housing unaffordability crisis,

which is particularly prevalent in major cities such as Toronto.

Data

Shared E-Scooter Rides. With support from the City of Brampton, we obtained anonymized vehicle trip data with origin and destination locations (geographic coordinates), directly from two of the three private e-scooter operators providing service in Brampton, pertaining to trips made by users for the entire 2023 season (April to November). This included a total of 145,424 trips taken over a period of 224 days across all neighborhoods in Brampton. Using this data, we estimated shared e-scooter demand based on the number of shared e-scooter trips per sq km per day within a DA, measured at the DA of trip origin.

Marginalization. To identify the DAs in Brampton with high concentrations of equity-deserving households, we used Public Health Ontario's Ontario Marginalization (ON-Marg) Index data (*37*). This publicly available dataset utilizes 18 demographic and socioeconomic variables from the 2021 Canadian Census of Population and a factor analysis approach to record geographical concentrations of four types of marginalization across the province of Ontario, and reports four distinct dimensions or "factors" of marginalization. A higher factor score implies a greater degree of marginalization (measured as standard deviation from the mean), compared with the provincial average. The four marginalization dimensions are:

1) Households & dwellings—Represents family and neighborhood instability. Contributing census variables include the proportion of people living alone, those living in apartments, those who are not married, those who do not own their dwelling, those who moved within the last 5 years, proportion of population who are 18 years of age or older (reverse-coded), and the average number of people in a dwelling (reverse-coded).
2) Material resources—Represents the inability to access and attain basic material needs relating to housing, food, clothing, and education. Contributing census variables include the proportion of adults without a high-school diploma, single parents, those considered low-income, those unemployed, households requiring major repairs, and percentage of income derived from government transfer payments.
3) Age & labor force—Represents the concentration of various types of people who may not have income from employment. Contributing census variables include the proportion not participating in the labor force, proportion of elderly residents, and the ratio of dependents in a household.
4) Racialized & newcomer populations—Represents the concentration of immigrant and racialized population. Contributing census variables include the proportion of the population considered to be recent immigrants and those who self-identify as a visible minority (that is, persons who are non-Caucasian and non-white).

For the purpose of this study, we used the ON-Marg data for DAs within the City of Brampton. However, since the original marginalization scores are reported in reference to the Ontario-wide averages, we normalized the data using the mean-normalization method that can be expressed as Equation 1:

$$X_{\text{normalized}} = (X - \mu)/(X_{\max} - X_{\min}) \quad (1)$$

where

X = the original score of a marginalization dimension from ON-Marg index,

μ = the Brampton average for a marginalization dimension,

$X_{\min}$ = the minimum score within Brampton for that marginalization dimension, and

$X_{\max}$ = the maximum score within Brampton.

Four normalized scores were computed, which rescaled four marginalization dimensions with reference to their mean and the range within Brampton, allowing unbiased comparisons between the effects of four marginalization dimensions. The ON-Marg dataset did not have values for all four marginalization dimensions for 41 DAs within our study area, likely because of missing values on one or more of the socio-demographic characteristics. These DAs were removed from the final data table used in statistical analysis.

Commute Characteristics. We explored three variables related to commute characteristics within each DA: 1) proportion of people with commute duration of under 30 min, 2) proportion of people who work within their census subdivision (CSD) (i.e., municipality), and 3) proportion of people who commute using a private car. Data from the 2021 Canadian census was used for this purpose and two DAs with missing values for these census questions were removed from the final dataset.

Built Environment. The relationship between the neighborhood built environment and travel behavior are often conceptualized in terms of the "5Ds," namely—density of urban development, diversity of land use, neighborhood design characteristics, accessibility to destinations, and distance to public transportation (*38*, *39*). This

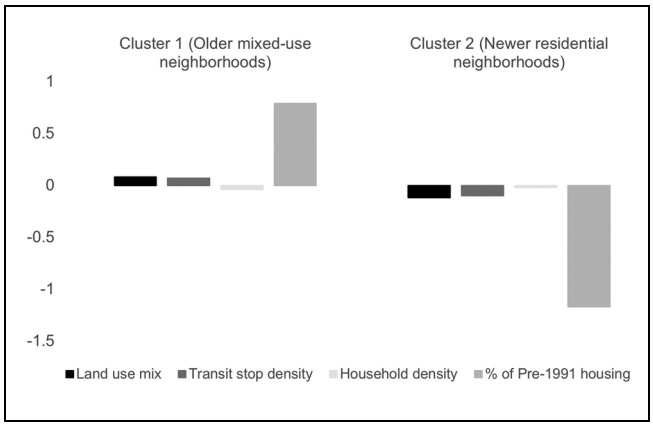

Figure 2. Cluster means related to built-environment characteristics, for two neighborhood types.

conceptualization has been widely utilized in urban planning literature to examine travel behavior, including active transportation behavior. In this study, to form an understanding of the suburban built environment, we examined four variables within each DA: 1) household density (z-score), 2) land use mix (z-score of density of points of interest related to: wholesale trade; retail trade; finance, insurance, and real estate; services; and public administration), 3) neighborhood maturity (the proportion of buildings that were built before 1991), and 4) density of transit stops (z-score). Household density captures the density of urban development, land use mix captures both diversity and destination accessibility, and transit stop density represents the accessibility to transit. Lastly, we used data on neighborhood maturity as a simplified measure to capture differences in neighborhood design characteristics, separating post-1990s suburbs from older, more central, neighborhoods, many of which have since been re-urbanized/intensified.

One DA within our study area had exceptionally high household density (i.e., an outlier), which was excluded from further analysis. Data was obtained from the City of Brampton GeoHub, Environics via SimplyAnalytics, and DMTI Spatial Inc (*40*).

Data Analysis

Cluster Analysis of Neighborhood Types. Most existing research has explored individual built environment characteristics in relation to their potential influence on travel behavior (*6*, *20*). However, in the suburban context, there is a lack of diversity within and between neighborhoods, with regard to built environment characteristics, creating challenges for statistical analysis. More importantly, a road user's experience in their neighborhood is influenced through a combination of factors, instead of individual built environment characteristics, which offer benefits/motivations or create barriers to mobility (*41*). To this end, an exploration of the "overall" built environment is important to inform policy. In our study, we adopted a *k*-means cluster analysis approach to identify neighborhood types within the City of Brampton, following a similar approach previously applied by other prominent urban scholars (*42*, *43*). This approach identified distinct groups of neighborhoods where those in the same "cluster" demonstrated similar built environment characteristics.

A two-cluster solution converged most rapidly and produced the most interpretable results, with a reasonable distribution of the sample between each cluster. The between-to-total sums of squares ratio was 28.6%, and the two clusters explained 64.4% variations in the data. The first cluster (older mixed-use neighborhoods; $n = 346$) included neighborhoods with a higher proportion of pre-1991 buildings, higher land use mix, and a higher density of transit stops. By contrast, cluster 2 (newer residential neighborhoods; $n = 233$) comprises neighborhoods with newer buildings, lower land use mix, and relatively less access to transit stops. Figure 2 shows the cluster means for the two neighborhood types.

Spatial Analysis of E-Scooter Use. To explore spatial patterns of shared e-scooter use in Brampton, we first applied a global Moran's *I* analysis using the queen's contiguity spatial weighting approach (which estimates spatial weight based on neighboring or bordering spatial units, identified based on common edges and vertices), to the average daily shared e-scooter trips per sq km (*44*, *45*). A contiguity-based approach is appropriate in this context because of variability in shapes and sizes of our spatial units (i.e., DAs) (*44*, *45*). A total of nine DAs did not have a neighbor, and we removed them from further analysis, bringing the total DAs included in our analysis to 570.

The global Moran's *I* analysis demonstrated statistically significant spatial autocorrelation of e-scooter trip rates within the city (Moran's $I = 0.438$; $p < 0.01$), indicating that nearby DAs may demonstrate similar e-scooter trip rates, regardless of other social characteristics (*46*). To address this, we applied spatial analysis methods to explore our data.

First, we conducted a local spatial autocorrelation analysis to identify localized concentrations of high shared e-scooter use within the study area. To this end, we conducted the Getis-Ord Gi* analysis (otherwise known as the local "hot spot" analysis) with queen's contiguity weight matrix. The analysis identified statistically significant spatial clusters or localized concentrations wherein DAs with higher-than-average e-scooter use rate were also surrounded by neighbors with higher-than-average e-scooter use rate (*47*).

Table 1. Characteristics of the Dissemination Areas (DAs) Included in the Spatial Regression Analysis

Characteristic	DAs included in study ($n = 570$)		
	Mean	SD	%
Average daily e-scooter trips	5.80	9.51	
Marginalization dimensions			
Households & dwellings marginalization	0.33	0.15	
Material resources marginalization	0.27	0.11	
Age & labor force marginalization	0.23	0.11	
Racialized & newcomer populations marginalization	0.48	0.16	
Commute characteristics			
Proportion of people with a work commute under 30 min	0.52	0.11	
Proportion of people who commute to work via car	0.85	0.09	
Proportion of people who work within their census subdivision of residence	0.43	0.10	
Neighborhood type			
Older mixed-use eighborhoods			60.53
Newer residential neighborhoods			39.47

Note: SD = standard deviation.

Next, we conducted a spatial regression analysis to address our research questions and explore the social- and built-environment-related correlates of average daily shared e-scooter trip rates per sq km (e-scooter demand) within the City of Brampton. In addition, we included neighborhood-level commute characteristics as covariates in our analysis. Our preliminary diagnosis identified four clear outliers in the dataset (i.e., very high number of trips per sq km per day in four DAs). After excluding these outliers, our spatial regression analysis included data from a total of 566 DAs.

Within the broader approach to spatial regression analysis, a spatial error model considers spatial autocorrelation by accounting for the impact of unmeasured independent variables (i.e., spatial dependence in the residuals) (*46*). By contrast, a spatial lag model addresses spatial autocorrelation by including a spatial lag independent variable to account for spatial dependence, or the possibility of the dependent variable (i.e., rate of shared e-scooter use in a DA) being influenced by the neighboring observations (*46*). We considered both spatial error and spatial lag model types during our preliminary diagnostics. However, for average daily shared e-scooter trips, the robust Lagrange multiplier test indicated the spatial lag model (coef. = 49.7765, $p < 0.01$) as the more appropriate spatial analysis approach.

We conducted spatial analysis in two steps. First, and as a preliminary exploration, we estimated eight bivariate spatial lag models, for each of the independent (i.e., explanatory) variables considered in our analysis. After this preliminary exploration, a multivariate spatial lag model was estimated to explore adjusted or unconfounded correlation between shared e-scooter use rate and the independent variables explored in this study. Statistical significance is reported at $p < 0.05$ (95% confidence interval).

Results

Within Brampton, between April and November of 2023, an average of 5.8 ($\pm$ 9.5) shared e-scooter trips originated every sq km within a DA (Table 1). With regard to commute characteristics, 85% of residents, on average, commuted using a private car, and 57% worked outside of their own CSD (i.e., municipality). Also, 53% of residents in an average DA traveled less than 30 min to work.

Local Clusters of E-Scooter Trips

The Getis-Ord Gi* analysis of the average daily e-scooter trips revealed several statistically significant local hot spots of higher trip rates. Three hot-spots are recognizable in Figure 3, which further confirms the presence of spatial autocorrelation in shared e-scooter trip rates. These hot spots roughly align with downtown Brampton, the popular recreational destination of Chinguacousy Park, and the area around Sheridan College (a large public community college).

When visually comparing hot spots of trip origins and the geographical distribution of social/economic marginalizations within the city (Figure 4), we observed some overlaps between high trip rates and marginalization, implying that, at least in some geographical contexts, higher trip rates are concentrated in marginalized neighborhoods. The DA surrounding Sheridan College, in the southwest of the study area, for example, is a hot spot for trip rates and an area of high marginalization in every dimension. The area around downtown Brampton, however, is a statistically significant hot spot for trips, but the area does not show a concentration of high racialized &

newcomer populations, despite the other three marginalization dimensions being high in the area. Fewer, and less statistically significant, hot spots of trips are also seen around Chinguacousy Park and align with higher concentrations of households & dwellings and material resources marginalizations. The statistical associations between average daily e-scooter trip rate and various dimensions of marginalization were explored more closely using spatial lag models.

Correlates of E-Scooter Trip Rates

Results of our bivariate spatial regression models (Table 2) indicate that households & dwellings marginalization, material resources marginalization, and racialized & newcomer populations marginalization were associated with higher shared e-scooter trip rates. In contrast, neighborhood-level marginalization related to age & labor force was not associated with DA-level shared e-scooter trip rate.

With regard to neighborhood type, our bivariate model found a positive association between e-scooter trips and older neighborhoods (Table 2). For other potential covariates, a high car dependence (higher proportion of residents commuting via car) was associated with lower e-scooter trip rate.

Figure 3. Hot spots for average daily e-scooter trip rates.

Figure 4. Distribution of marginalization dimensions.

Table 2. Bivariate Spatial Regression (Spatial Lag) Model Results for the Average Daily E-Scooter Trips ($n = 566$)

Characteristic	Coeff.	SE	*Z*-value	Probability
Households & dwellings marginalization	9.74	1.49	6.53	<0.001*
Material resources marginalization	5.00	1.93	2.59	0.010*
Age & labor force marginalization	1.53	2.01	0.76	0.449
Racialized & newcomer populations marginalization	4.96	1.80	2.75	0.006*
Proportion of people with a work commute under 30 min	−0.75	1.97	−0.37	0.704
Proportion of people who commute to work via car	−13.33	2.34	−5.69	<0.001*
Proportion of people who work within their census subdivision of residence	0.29	2.03	0.14	0.886
Older mixed-use neighborhoods (ref: newer residential neighborhoods)	0.94	0.44	2.14	0.032*

Note: Coeff. = coefficient; SE = standard error.
*$p < 0.05$ statistical significance.

Table 3. Multivariate Spatial Regression (Spatial Lag) Model Results for the Average Daily E-Scooter Trips ($n = 566$)

Characteristic	Coeff.	SE	Z-value	Probability
Constant	3.46	3.13	1.10	0.269
Household & dwelling marginalization	9.64	1.80	5.37	<0.001*
Material resources marginalization	−1.58	2.06	−0.77	0.443
Age & labor force marginalization	2.87	2.21	1.30	0.19
Racialized & newcomer populations marginalization	5.87	1.70	3.44	0.001*
Percent with a work commute under 30 min	−0.35	2.11	−0.17	0.436
Percent who commute to work via car	−8.26	2.63	−3.14	0.002*
Percent who work within their census subdivision of residence	−1.64	2.11	−0.78	0.436
Older mixed-use neighborhoods (ref: newer residential neighborhoods)	0.35	0.55	0.64	0.520
Model fit				
Pseudo R^2	0.52			
Akaike information criterion (AIC)	3,447.29			
Diagnostics for spatial dependence				
Rho (spatial autoregressive coefficient)	0.61			<0.001*
Likelihood ratio test	204.92			<0.001*

Note: Coeff. = coefficient; SE = standard error.
*$p < 0.05$ statistical significance.

Results from our multivariate spatial lag model (Table 3) identified three significant independent variables and good model fit (pseudo $R^2 = 0.52$). To further confirm that a spatial regression model is more suitable than a simple linear regression model in this context, a lower Akaike information criterion (AIC) and statistically significant likelihood ratio test was achieved. A statistically significant value for *rho* further indicates that the lag model has accounted for spatial dependence of the dataset.

Results from the spatially weighted lag model indicate that a higher rates of e-scooter use was associated with neighborhoods that face housing & dwelling marginalization (a 10% increase in marginalization was associated with 9.64 more trips per sq km per day), and also racialized & newcomer/new immigrant concentration (a 10% increase in marginalization was associated with 5.87 more trips per sq km per day) (Table 3). Unlike our bivariate results, the multivariate analysis did not identify any correlation between e-scooter use and material resource-related marginalization (i.e., economic marginalization). The age-&-labor-force-related marginalization also remained statistically not-significant.

Interestingly, after adjusting for other variations, neighborhood type was no longer associated with e-scooter trip rate. With regard to other covariates, the model indicates that the percentage of DA residents commuting to work via car had a negative association with trip rates (Table 3).

Discussion and Conclusion

In the context of limited research on shared micro-mobility in suburban municipalities, we examined shared e-scooter usage in the City of Brampton, Canada, in relation to its association with various measures of marginalization. We also explored the association between shared e-scooter use rate and neighborhood types, with an acknowledgement of a lack of built environment diversity in a suburban setting.

Over the past decades, population in Canadian suburban municipalities, particularly in those located near major cities, have become increasingly diverse, as many new immigrants (also known as newcomers) and low-income households moved to these suburban communities in search for affordable housing options (*48*, *49*). This trend has led to a worsening spatial mismatch between residents' housing and employment (*50*). In addition, automobile-centric transportation systems and the lack of robust public transportation services have created additional mobility challenges to those who have limited access to cars or cannot drive (which is common among many non-Caucasian new immigrants). In this context, our paper advances the emerging literature that focuses on equity implications of shared micro-mobility, and specifically e-scooters. The findings also make a novel contribution by offering a suburban perspective, when most existing micro-mobility research has focused on urban areas.

Our use of a spatial analysis approach in this study confirms that spatial dependence exists in shared e-scooter use. In other words, we found that the daily rate of e-scooter use may be influenced by use rates in nearby neighborhoods, regardless of the characteristics of these neighborhoods. By accounting for this spatial dependency, our findings provide more nuanced context to the relationship between shared e-scooter use and socio-demographic and built environment characteristics. With regards to the built environment in Brampton, the results from our spatial regression model contradict previous

findings about connections between e-scooter use and neighborhood characteristics (*6*, *20*). Instead, our results imply that, in a suburban context, where there is a lack of land use diversity, and accessibility to public transportation is poor overall, physical environmental conditions may not have an important influence on average shared e-scooter use (trips per sq km per day) at a DA level. At the same time, a negative correlation between car-based commute and shared e-scooter use rate indicates that the benefits of this new form of shared micro-mobility may be best utilized by providing service to those without access to a car or, generally, have limited mobility options.

Local hot spot analysis and the results from the spatial regression model indicate that average daily shared e-scooter trips are positively correlated with households & dwellings marginalization, and racialized & newcomer populations marginalization, essentially demonstrating that more trips take place in areas where residents are more likely to be from visible minority (i.e., non-Caucasian and non-white) or newcomer (i.e., new immigrant) populations and living in smaller households, rented residences, and apartment-style residences. This finding is encouraging, and implies that in a suburban commuter community, shared micro-mobility may benefit some marginalized groups that have historically demonstrated mobility challenges and spatial mismatch (*51*). However, the results also showed a lack of correlation with the remaining two marginalization dimensions (material resources, and age & labor force). Overall, these findings suggest that shared e-scooter systems in a suburban municipality such as the City of Brampton may address some social equity issues by providing reasonable mobility options in neighborhoods with unstable housing conditions and with high concentrations of racialized groups. While the benefits may not be significantly higher in neighborhoods with high concentrations of economically marginalized population and neighborhoods that have low labor force participation, these neighborhoods may not be negatively affected by the introduction of shared micro-mobility.

For Brampton and other similar suburban communities, the findings from our analysis suggest several possible avenues for future policy related to the shared micro-mobility systems. Trip origins are systematically concentrated in locations with lower rates of car-based commuting, indicating that a gap in the current transportation network is potentially being filled by shared e-scooters. The results also indicate that the shared e-scooter systems may be addressing some transportation equity challenges. Cumulatively, these findings make suburban communities great candidates for equity-focused micro-mobility policies, wherein policy may specifically promote shared micro-mobility use in areas with higher concentrations of marginalized residents, not only through increased supply but also considering their practical usability and affordability to ensure increased equity.

While our findings offer novel insights into the equity implications of the shared e-scooter systems in suburban communities, several limitations to the work are worth mentioning. First, our paper reports findings based on aggregate-level analysis (trips per sq km per day in a DA). While this was the best approach in the context of available data, our model results do not capture heterogeneity of travel behavior among those living within a DA/neighborhood. Second, of the three private sector shared micro-mobility providers who operate in the City of Brampton, only two of them shared their trip records with our research team. While there was no difference in the geographical reach in service between providers, we acknowledge that our analysis does not include all trips taken using shared e-scooters during the study period. Third, in the creation of the framework for spatial analysis and regression, a queen's contiguity approach was selected for its applicability to unevenly sized neighborhoods, but it is possible that more rigorous testing would be able to identify a weight matrix that would provide a better overall model fit for spatial regression models. In addition, and because of limitations in data availability, our results could not be validated to confirm wider implications of our findings. Future work could perform further testing to quantify the effect of spatial dependence on e-scooter distribution. Outside of the models used in this project, additional tools, such as the Monte Carlo test, can demonstrate how spatial dependence changes across geography. As mentioned above, the creation of a more complex spatial weight matrix or the use of more complete independent variable sets would also aid in this.

Lastly, looking at the needs of the municipalities, it is important to monitor the impacts of shared micro-mobility systems as they mature. Our study, similar to most existing research, offers only a snapshot of e-scooter use patterns, using data from one operating year (April to November, 2023). To ensure and monitor equitable access of shared micro-mobility devices and their impacts, systematic exploration of travel behavior across various population groups, before versus after the introduction of micro-mobility, is much needed.

As shared e-scooter systems become more common, specifically in Canada and similar countries where the governments look to evaluate their shared micro-mobility policy, research findings from existing pilot programs can provide valuable and much-needed insights into the ways in which shared micro-mobility is affecting communities. Specifically important are studies that

examine the implications of this new form of public transportation to broader transportation goals such as environmental sustainability and transportation equity. Results from our study offer important insights with regard to transportation equity and implies that e-scooter systems may help some marginalized groups overcome their mobility barriers. Our results also indicate that, in a suburban context, residential neighborhoods may see just as much e-scooter use as centrally located mixed-use neighborhoods, offering additional policy and economic rationales for providing services strategically across a municipality, instead of focusing only on the commercial core of a municipality. More efforts should be made to understand the connection between the uniqueness of suburban built environments and shared micro-mobility use.

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: S. Cullen, R. Mitra; data collection: S. Cullen; analysis and interpretation of results: S. Cullen, R. Mitra; draft manuscript preparation: S. Cullen. All authors reviewed the results and approved the final version of the manuscript.

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