Gender-Mainstreaming Accessibility Analyses: Measuring Access to Care Destinations

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Abstract

Accessibility, the ease of interacting with opportunities, is an increasingly important tool amongst transport planners aiming to foster equitable and sustainable cities. However, in accessibility research there is a masculinist bias whereby employment destinations are often the default. This paper aims to counter this gendered bias by connecting the Mobility of Care conceptualisation to an empirical accessibility analysis of care destinations in the City of Hamilton, Canada. Care destinations are the destinations required to sustain household needs such as shopping, errands, and caring for others (children and other dependents). Through the creation of a destination dataset, this paper considers access to care across different modes of transport at two travel time thresholds (trips shorter than 15-minutes and 30-minutes) using unconstrained (cumulative opportunity) and competitive-constrained (spatial availability) measures. Results generally indicate that travel to care destinations by car is exceptionally high, and access by public transit, cycling and by foot is low across the city with some exceptions in the inner city. Noteably, there are distinctions between both methods: unconstrained access illustrates a more highly optimistic landscape for non-car modes, while competitive and constrained access demonstrates a conceptually more realistic spatial distribution of care destination availability. Neighbourhoods with both low spatial availability to care and a high proportion of low-income households are also identified as areas in need of intervention. The manuscript and analysis is computationally reproducible and openly available to promote reproducible practice in transportation science. The analysis presented demonstrates methods planners can use to gender-mainstream accessibility analysis. Further, results can inform policies aiming to encourage sustainable mobility.

Keywords: Accessibility, Mobility of Care, Gender, Cumulative Opportunity, Spatial Availability

1. INTRODUCTION

A gender bias exists in transport research and policy[1,2,3]. The field has historically focused on one trip purpose; the on-peak commute to work. While many women do, of course, work, the commute is still a travel pattern more frequent amongst men[1]. Women, on the other hand, have been found to complete more household-serving travel than men, such as escorting children[4,5,6,7], shopping, and errand trips[5,8,9].

Though research on the gendered distribution of household-serving travel has existed for decades, it was only in 2013 that Sánchez de Madariaga[1] coined the term Mobility of Care, i.e., all the travel needed to fulfill household needs (e.g., a combination of travel to grocery stores, errands, and pick-up / drop-off of children). The term was developed to highlight how these household-serving trips are systematically under-represented, under-counted, and rendered invisible due to masculinist biases in transport planning. Take, for instance,

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how trips to household sustaining destinations are categorized in typical large-scale travel surveys[1]. In the Greater Golden Horseshoe Area's (encompassing the Greater Toronto and Hamilton Area) Transportation Tomorrow Survey (TTS)[10] respondents are given the following options to categorize their trip origins and destinations: home, work, school, daycare, facilitate passenger, marketing/shopping, other, or unknown. While home-work and home-school trips are easily identified, care trips are more challenging to measure. Many marketing/shopping trips are likely for care purposes (e.g., groceries), but others are likely for leisure. While escort trips are likely well captured under the categories 'daycare' or 'facilitate passenger', trips to run errands or to attend health appointments are not clearly captured. Responds likely categorize many of these trips as 'other' or even 'unknown'. The focus of the survey is on what is a 'typical' trip to work or school[10]. Other trips are as a by-product, 'non-typical' and minimialised in importance. Of course, people's travel behaviours are complex and surveys must balance detail with summary. However, what is seen as a 'typical' trip continues to shape transport and land-use, and this aggregation steers data-driven solutions from counted and observed home -work/-school based trips.

When travel surveys are designed to explicitly capture mobility of care, preliminary research has found that it comprises approximately one third of adults' trips[1,11,12]. Given the large proportion of daily travel that mobility of care comprises, these trips should be explicitly captured in transport research. Further, the current under-reporting of mobility of care in research and planning has important equity considerations. Not only are mobility of care trips completed predominantly by women, this gendered discrepancy is greater in low-income households[1,12]. For instance, in lower income households in Montréal, women complete 50% more care trips than men[12].

The power of the Mobility of Care concept lies in its ability to highlight the masculinist bias in transport research – travel for care appears insignificant because travel surveys are not written to capture it[1]. Travel surveys, however, are but one tool used by transport researchers and practitioners. Another popular tool in transport planning and research is accessibility, an indicator that quantifies "the potential of opportunities for interaction" as defined in the seminal work of Hansen[13]. Accessibility indicators can be interpreted as the ease of reaching destinations using transport networks - a byproduct of mobility and a representation of the people's interaction with land-use and transportation systems[13,14,15]. The points of interest in many accessibility-based assessments have been home-to-work destinations[16,17,18,19]. For example, in the accessibility assessment of the Ontario Line, a subway line that will be constructed in the city of Toronto, Canada, Farber and Allen[17] highlight how this new investment will increase access to jobs for residents across the City by 1.14% overall. While much has been learnt in these analyses, moving away from jobs as the default destination may open opportunities for gender-mainstreaming accessibility analyses. Indeed, jobs are not always the most significant destination for many segments of the population. As discussed, women's commutes comprise on average a smaller proportion of their daily travel than men's[12]. This focus on job-access can additionally bias accessibility-gains that children and older adults who reside in impacted areas may see as well[20]. One way to counter this bias is to reframe accessibility analysis by explicitly considering destinations involved in mobility of care.

Reframing accessibility analyses to incorporate mobility of care is also pertinent to the promotion of sustainable travel modes in cities. Research has found that people are less likely to use public transport or bicycles for care trips[12] and more likely to make these trips by car[21,12]. A lack of access to care destinations by bicycle and transit may contribute to these trends. Mobility of care are also more commonly completed by foot than the commute to work[12]. Whether there is a relationship between these travel behaviors and people's access to care destination using different modes, however, remains unknown, as mobility of care is largely uncounted.

In this spirit, this study foregrounds the theoretical mobility of care concept by calculating the accessibility to care destinations or multiple modes in an empirical case study of Hamilton, Canada. Two place-based accessibility measures are used to motivate the discussion: one unconstrained measure (cumulative opportunity) and another competitive and constrained measure (spatial availability[22]). The cumulative opportunity measure demonstrates the potential access to all destinations within 15-minutes and 30-minutes. This measure is widely appreciated for its intuitive computation[14,23,16,24] but critiqued for its omission of competition effects[25,22,26,27]. To respond to this critic, spatial availability of care destinations per mode is also calculated as an additional and arguably more conceptually realistic reflection of opportunity availability. This research aims to contribute to gender mainstreaming in transport planning by demonstrating an approach to a feminist accessibility calculation through two accessibility measures.

2. BACKGROUND AND METHODS

This paper focuses on Hamilton, a mid-size city of approximately 500,000 residents and an economy historically (and still) connected to steel manufacturing and related manufacturing. Hamilton lies within the urban and suburban Greater Toronto and Hamilton Area (GTHA)[10]. The GTHA is home to seven million people, or approximately 20% of the Canadian population[28]. Hamilton is divided into six regional communities: Hamilton Central, Dundas, Ancaster, Flamborough, Stoney Creek and Glanbrook (Figure 1). Each of these regions demonstrate different characteristics of the urban and suburban landscape of the city. Hamilton Central is the densest and most urbanized of the six, and the five periphery regions of Dundas, Ancaster, Flamborough, Glanbrook and Stoney Creek are significantly more suburbanized with the furthest periphery regions being undeveloped or rural owing to their inclusion in the region's greenbelt[29]. These urban, suburban, and rural landscapes likely play a key role in accessing care as differences in transport infrastructure could affect one's ability to access care destinations.

Further, the entire manuscript and all analysis is conducted in R and RStudio. All work is computationally reproducible and openly available in the lead author's GitHub repository.

2.1. Destination dataset

To complete the accessibility analysis, a geospatial dataset of care destinations for Hamilton (e.g., full addresses of longitude and latitude) was compiled. The geospatial data was sourced from provincial and municipal open data portals[32,33], Data Axle, a consumer dataset compiled of businesses and companies within Canada[34] or manually through Google Maps. Each destination was categorized based on the specific type of care being accessed. Categories include child, elder, grocery, health, and errand -centric destinations Of note are errand-centric destinations, in conventional travel surveys these destinations are often lumped in within 'grocery shopping'[5]. In this research, they are distinguished from child-, elder-, grocery- and health-centric destinations These final categories, and their sources of data, are detailed in Table 1 and their spatial distribution and sub-categories are visualised in Figure 2.

Table 1: Details on the preparation and data sources of care destinations.

Care category	Sources	Data preparation notes
Child-centric	Ontario and Hamilton open datasets: (O. D. Hamilton 2022a, 2022c, 2022d; Ontario 2023; C. of Hamilton 2023)	DSchools, daycares, and community centres, recreation centres, and parks: 1,190 locations are included. After manual review, all locations that typically do not serve children were removed including: Post-Secondary, Adult-Learning Centres, Group Homes, and Foster Care Centres. Further, through examination some Section 23 institutions defined as *"centres for children who cannot attend school to meet the needs of care or treatment, and rehabilitation"* (Ontario - Ministry of Education 2023), were kept due to their innate connection to care.
Elder-centric	Ontario and Hamilton open datasets: (O. D. Hamilton 2022d; GeoHub 2023)	Senior centres, long-term care homes, and retirement homes: 75 destinations are identified.

Care category	Sources	Data preparation notes
Grocery-centric	Open Data Axle dataset (Data 2023)	Grocery stores, namely a place a household could buy groceries ranging from convenience stores to large retail stores: 381 destinations are identified. Data is filtered by Company Name, Suite Number, Address, City, Province, Phone Number and Postal Code. The type was then identified e.g., grocers specialty foods, grocers retail, grocer health food, grocer wholesale, grocer curbside, grocer delicatessen wholesale, grocer convenience. Data was crossreferenced to ensure all included locations were operational and legitimate grocery stores.
Health-centric	Ontario and Hamilton-specific healthcare services datasets: (GeoHub 2023; Healthline 2023)	Hospitals, pharmacies, clinics, and dentist offices: 421 destinations are identified. Hospitals and pharmacies were retrieved while clinics and dentistry clincs were manually scraped from a healthcare services database and checked via Google Maps to remove non-operational locations and confirm dentistry-orientation.
Errand-centric	Hamilton libraries (O. D. Hamilton 2022b), post office locations (Data 2023; Post 2023), and datasets of all national bank chains (Montreal 2023; Hongkong and (HSBC) 2023; N. Bank 2023; Canada 2023; Scotiabank 2023; T. T. D. Bank 2023).	Libraries, post offices, and banks: 158 destinations are identified. Post offices are retrieved from a mix of databases, and duplicates are removed. Banks are also derived from Axle Data and then cross referenced to ensure data quality with the a Bank Locator website for all national banking firms (Bank of Montreal, CIBC, HSBC, National Bank of Canada, Royal Bank of Canada, Scotiabank and TD Financial).

For the purpose of this analysis and in absence of city-wide household preferences for care destinations, all locations are re-weighted to make each category conceptually equivalent. If this was not done, the results will favour access to child-centric destinations as they make up the majority of the dataset. Accessibility literature has weighted destinations (amenities) using a variety of method such as estimated capacity of destinations[35] or origin-destination flows from travel surveys[36,24]. However, this work's focus is on household-serving care destinations, so many destinations do not have traditional 'capacities' like health care facilities have beds. Origin-destination flows to all care destinations also have not been counted within the TTS[10]. So, in this analysis, the five care categories are re-weighted to represent one-fifth of the dataset. Conceptually, this simplistic re-weight assumes the population potentially interacts with all categories and all locations within each category equally. In absence of empirical data for amenity weight calibration, this methodological assumption is a limitation.

- Child-centric (1190 destinations each at 0.3739496),
- Elder-centric (75 destinations each at 5.9333333),
- Errand-centric (158 destinations each at 2.8164557),
- Grocery-centric (381 destinations each at 1.167979) and,
- Health- centric (421 destinations each at 1.0570071) .

2.2. Population data

To supplement the care destination dataset and complete the accessibility calculation, population data for the City of Hamilton is sourced from the 2021 Canadian census using the {cancensus} R Package[37,38]. Three categories of variables are selected: the population, the percent of after-tax low-income-cut-off (LICO-AT), and the primary commute mode used was sourced at the highest level of spatial resolution, the level of the dissemination area (DA).

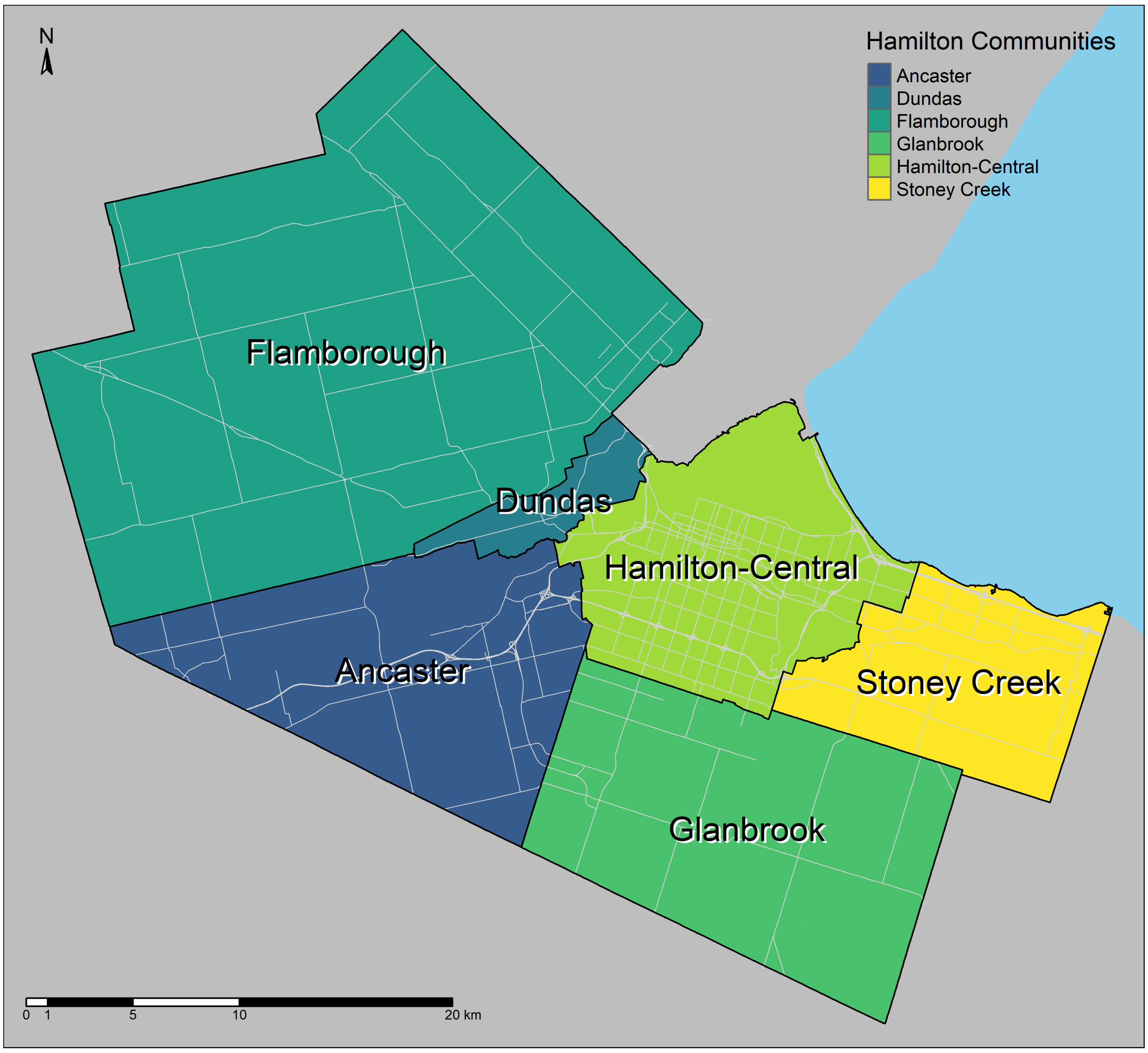

Figure 1: The six former muncipal boundaries in the city of Hamilton. Basemap shapefiles are retrieved from the Open Data Hamilton Portal[30] and the USGS[31]. Highways and arterial roads are shown in light grey.

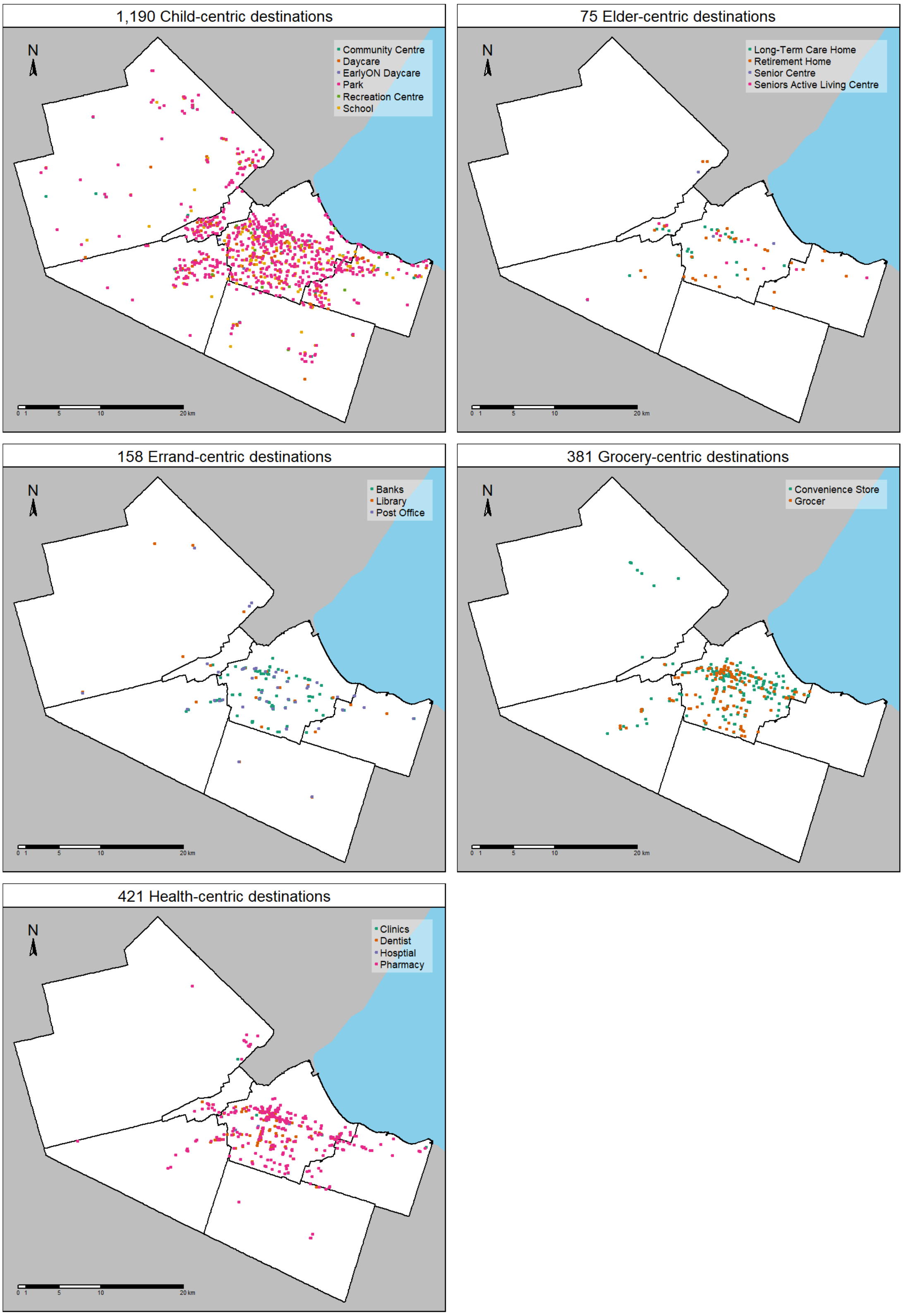

Figure 2: The geo-located points of care destinations in the City of Hamilton separated by the author-generated categories of: child-, elder-, errand-, grocery- and health- centric care categories. Locations of these destinations were retrieved through multiple sources as described in the text. Basemap shapefiles are sourced from the Open Data Hamilton Portal[30] and the USGS[31].

LICO-AT is a composite indicator included in the census that reflects the proportion of households spending 20% more than the area average on food, shelter and clothing[39]. The {cancensus} open-sourced R package was used to access the 2021 Canadian Census data in a programmatic way[38]. Figure 3 displays the spatial distribution of the total population and the prevalence of LICO-AT as a percentage of the total population. Of note is the density of population within Hamilton-Central (oranges) and the cluster of high density and high LICO-AT prevalence near the shoreline in Hamilton Central (dark purple-oranges).

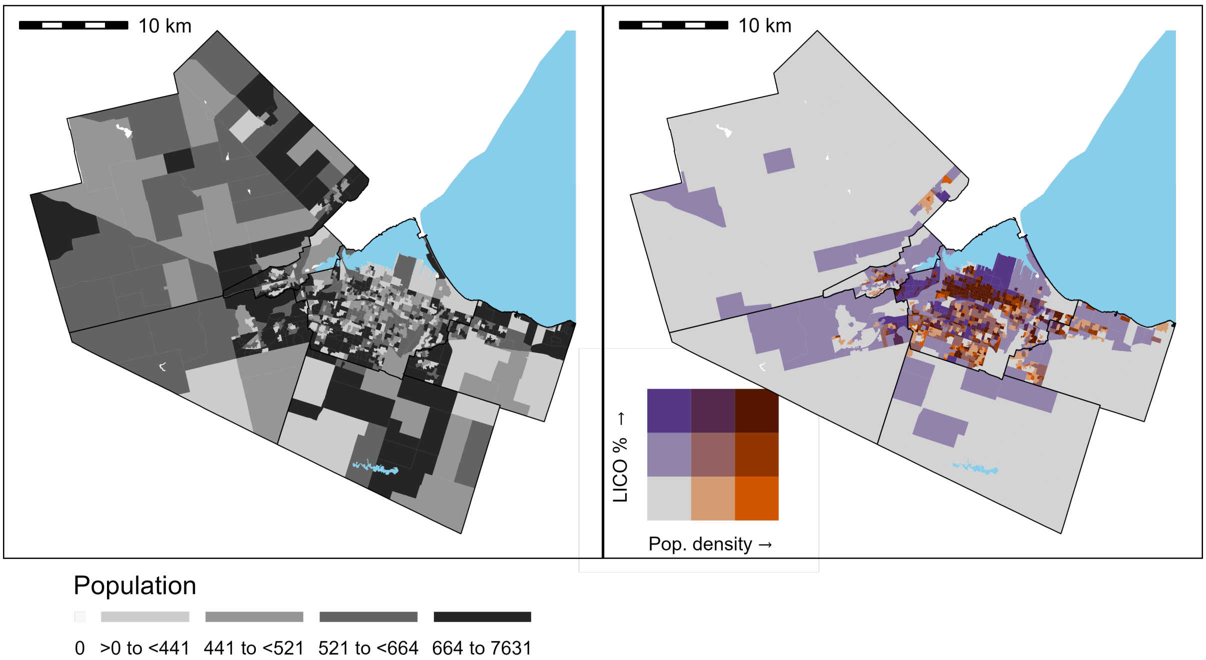

Figure 3: The total population in each dissemination area (DA), visualized with the six former muncipal boundaries in the city of Hamilton. The left plot represents the population and the right represents the population density versus the low-income cutt-off after taxes (LICO-AT) as a percentage of the total DA population. LICO-AT is a measure of economic disadvantage. The legend categories represent quartiles. Basemap shapefiles are retrieved from the 2021 Canadian census[37], the Open Data Hamilton Portal[30] and the USGS[31].

Further, the population proportion that commutes by a specific mode (car, transit, walk, or cycle/other) is visualised in Figure 4. Though mode-choice used in travel to work is not necessarily reflective of the mode used to travel to care destinations, no other data to our knowledge is available at a granular level City-wide that centers mobility of care. Of note, the population generally commutes by car (50% or higher, is yellow to green), even within the more densely populated Hamilton-Central. However, for transit and walking, a group of DAs near the shoreline within Hamilton-Center have the highest proportion of transit users and those who walk to work (yellows in the plots that are otherwise red i.e., below 15%). Those same DAs are also relatively dense and have a high prevalence of LICO-AT (Figure 3).

2.3. Multimodal travel time estimations and accessibility measures

As empirical travel behaviour to care-oriented destinations is uncounted, it is approximated in the estimation of travel time to all locations and the calculation of accessibility.

Travel times by walking, cycling, transit and car is calculated for each DA to the destination point using the 'travel_time_matrix()' function from {r5r}, an open-source R package for rapid realistic routing on multimodal transport networks[40]. Inputs are point locations of origins, destinations, a street network, and transit routes/schedules. The origin of each DA and destination location is assumed to be its geometric centroid, the Open Street Map (OSM) network[41] is the road network input, and the Hamilton static GTFS

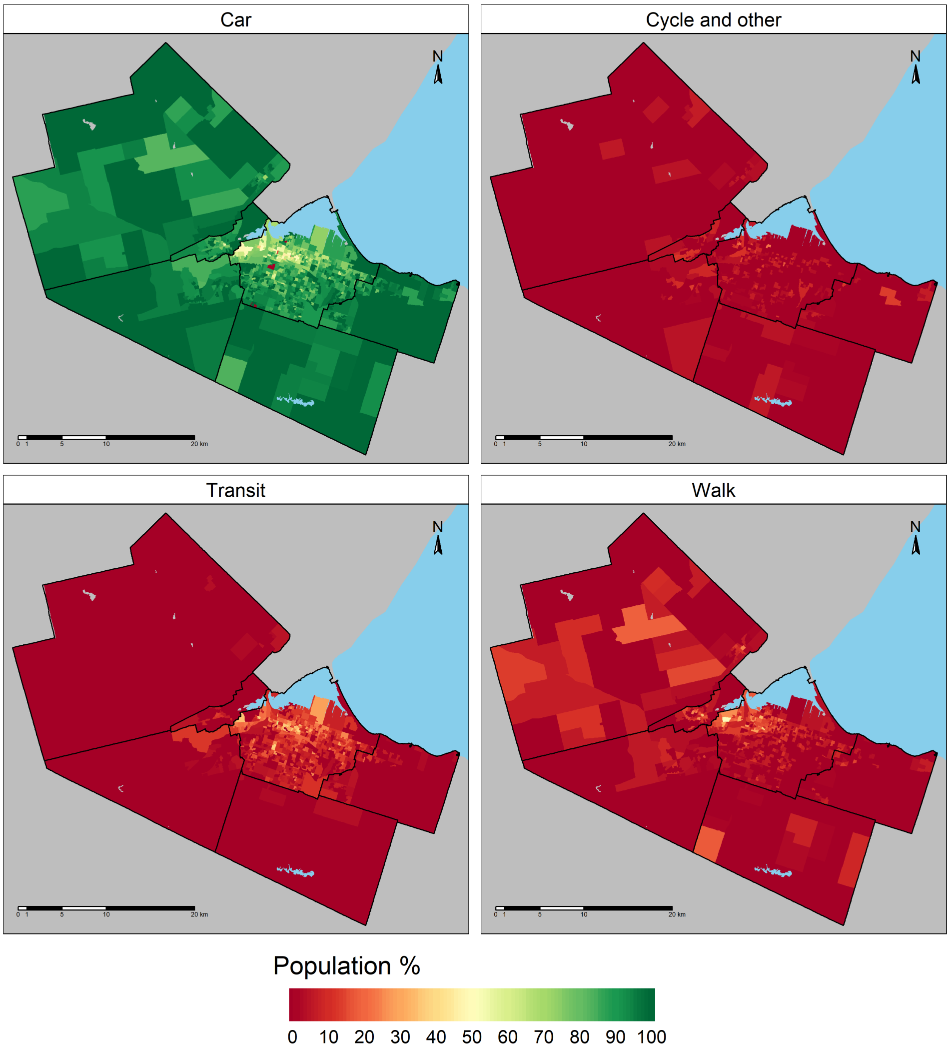

Figure 4: The proportion of mode type used for commuting (aged 15 and older employed in the labour force) in each dissemination area (DA) as provided by the 2021 Canadian census. Basemap shapefiles are retrieved from the 2021 Canadian census[37], the Open Data Hamilton Portal[30] and the USGS[31].

(transit network in which only urban buses operate)[42] provides transit schedules linked to the road network. For all modes, travel times under 60 minutes based on the shortest travel-time path OSM road network are calculated.

For transit and cycling modes, additional parameters were included. For transit, a typical Wednesday departure time at 8:00 was selected, as it is representative of relative accessibility over the course of the day[43]. Further, a departure travel window parameter of $\pm$ 30 mins was used so times are calculated for each minute between 7:30 to 8:30. Selecting a sufficiently wide window is an important consideration as travel times are sensitive to transit vehicle frequency and connecting transfers (see discussion of the modifiable temporal unit problem e.g.,[44]). Further, for transit travel times the 25th percentile time from the distribution of travel times in the departure window was selected to represent each origin-destination travel time. This travel time indicates that 25% of trips from that origin to destination have a travel time that is that length or shorter. This assumption provides an optimistic perspective of transit travel times. For cycling travel times, the default parameter for cycling routes of level 1 or 2 traffic level of stress, dedicated or separated cycling lanes respectively, was selected. The level of traffic stress is variable associated with links of the OSM road network.

Both the **cumulative opportunity** and **spatial availability** measure are used to estimate the potential access to care that each mode provides to the DA. From the cumulative opportunity measure, the DA level values represent the potential interaction with reachable destinations a population located at DA could access using a given mode. The interpretation of the spatial availability measure is different: each DA level values are a proportional value of all the care destinations in Hamilton. Each proportional value represents the potential availability of reachable care destinations to a mode-using population located at the DA.

Cumulative opportunity accessibility: takes the following general form for multi-modal calculation:

$$A_i^m = \sum_{j=1}^{J} O_j \cdot f^m(c_{ij}^m)$$

Where:

- i is a set of origin locations.
- j is a set of destination locations.
- m is a set of modes.
- O_j is a number of opportunities at j, in our case weighted.
- c_{ij}^m is the travel cost between i and j for each m.
- $f^m(\cdot)$ is an impedance function of c_{ij}^m for each m; within the cumulative opportunity approach, it is a binary function that takes the value of 1 if c_{ij}^m is less than a selected value[23].
- A_i^m is the unconstrained accessibility for m at each i.

Spatial availability, on the other hand, takes the following general form for multi-modal calculation:

$$V_i^m = \sum_{j=1}^{J} O_j \; F_{ij}^{tm}$$

Where:

- i, j, and m is a set of origin locations, destination locations, and modes respectively.
- O_j is a number of opportunities at j, in our case weighted.
- F_{ij}^{tm} is a balancing factor for each m at each i. It depends on the size of the populations at different locations that demand opportunities O_j, as well as the cost of movement in the system $f(c_{ij})$.
- V_i^m is the constrained accessibility (spatial availability) for m at each i; the sum of V_i^m for all m at each i is equivalent to the total sum of opportunities in the region (i.e., $\sum_j O_j = \sum_i V_i = \sum_m \sum_i V_i^m$).

What makes spatial availability stand apart from other competitive measures is the multimodal balancing factor F_{ij}^{tm} (discussed in **(author?)** [45]). F_{ij}^{tm} implements a proportional allocation mechanism that ensures the sum of all spatial availability values at each i always matches the total number of opportunities in the region. F_{ij}^{tm} consists of two parts: the first is a population-based proportional allocation factor F_i^{pm} that models the mass effect of the gravity model and the second is an impedance-based proportional allocation factor F_{ij}^{cm} that models the cost effect. Both factors consider competition: F_i^{pm} estimates a proportion of how many people are in each i and using each m relative to the region and F_{ij}^{cm} estimates a proportion of the cost of travel from i to j at each i using each m relative to the region. As both F_i^{pm} and F_i^{mc} are proportions, $\sum_m \sum_i F_i^{pm} = 1$ and $\sum_m \sum_i F_i^{cm} = 1$). Both factors are combined to equal the total balancing factor F_{ij}^{tm} which is used to calculated V_i^m as follows:

$$F_{ij}^{tm} = \frac{F_i^{pm} \cdot F_{ij}^{cm}}{\sum_{m=1}^{M} \sum_{i=1}^{N} F_i^{pm} \cdot F_{ij}^{cm}}$$

Where:

- The factor for allocation by population for each m at each i is $F_i^{pm} = \frac{P_i^m}{\sum_m \sum_i P_i^m}$. This factor makes opportunities available based on demand.
- The factor for allocation by cost of travel for each m at i is $F_{ij}^{cm} = \frac{f^m(c_{ij}^m)}{\sum_m \sum_i f^m(c_{ij}^m)}$. This factor makes opportunities available preferentially to those who can reach them at a lower cost.

The travel impedance threshold used in both measures is 15 minutes and 30 minutes; each measure is calculated eight times, once for each four modes and assuming a travel time cut-off of 15 minutes or less and another assuming a travel time cut-off of 30 minutes or less. The selection of the travel time threshold was informed by the literature. Only one study to date has calculated the average travel time to all different categories of care destinations (16 minutes by car and 36 by public transport) [12]. Other literature typically considers trips to one type of care category (e.g., health, or school, or grocery stores) Here, travel times vary by care category (e.g., 15 minutes to grocery shopping [46] or 20.45 for cancer treatments [47]. In other care-related accessibility analyses, time-cut offs include 10 mins (for daycares) [48] and 30 mins to 1 hr (for hospitals) [49]. 15 and 30 minutes were selected to broadly reflect this past research. The use of a binary travel time threshold, as opposed to more complex impedance functions, was selected to simplify communication of assumed travel behaviour. As mentioned, lacking region-specific empirical data regarding care-centric travel, this work establishes a methodology to streamline access to care interpretation and analysis for when that data is available.

his work uses both constrained and unconstrained accessibility measures to elucidate different interpretations of access to care. As an unconstrained measure, cumulative opportunity measure counts all the destinations that can be reached from each DA within a travel cost, for each DA. From a region-wide perspective, a destination that can be reached is counted multiple times by all DAs that can reach it, so the sum of all cumulative opportunity DA values in the region is not meaningful. Simply, if walking-mode provides access to some number of opportunities within a 30 minutes, car-mode provides some greater access within 30 minutes, and the access that walk-mode is not discounted by the population using car-mode and the greater number of opportunities they can potentially access. However, cumulative opportunity measure is intuitive to implement, a part in why it has been widely adopted in accessibility research and considered a introductory method to more advanced accessibility measure [15].

On the other hand, spatial availability is constrained accessibility measure that considers competition [22]. It incorporates the concept of the *finite*: opportunities are numbered in the region so they can be potentially interacted with more or less based on the travel impedance offered by the zone (i.e., the travel cost on the transport network) as well as how densely or sparsely the zone is populated with opportunity-seeking opportunities. This is especially important considering population-distinct characteristics like selected travel modes. In a North American context, car-modes can potentially access more opportunities (unconstrained) because of their higher range relative to transit. But if opportunities are considered finite, high car mobility may take-up a higher share of opportunities from populations using modes that offer lower mobility, especially in zones where there is a high population and car-using modal split. Cumulative opportunities does not consider the relative population-demand for care destinations while spatial availability does: the use of these two measure illustrates distinct results.

3. RESULTS

3.1. UNCONSTRAINED ACCESS

The cumulative opportunity accessibility plots for each mode are shown in Figure 5. They visualise an unconstrained count of care destinations that can be reached by each mode from each DA. Zonal values can be interpreted as: the higher, the more potential interaction with care destinations. This greater potential is conceptualised as a positive outcomes of well functioning land-use and transport networks[50,51,52]. Spatial trends between the 15-min and 30-min threshold plots are similar (values are grouped by quantile). Three significant findings between modes are identified. First, the access that the car-mode provides is significantly higher relative to other modes. Travel by car results in the greatest maximum number of potential interactions to care destinations (1939 opportunities for 15-min and 2209 opportunities for 30-mins). Next, access by cycling is also relatively high. It provides the second most opportunities for interactions after travel by car, and affords at least one opportunity for interaction in more DAs than walking and transit use. Finally, access by transit is high and walking is also relatively high within Hamilton-Central but otherwise low.

From Figure 5, car-mode offering high accessibility to destinations is an expected outcome given the car-oriented design of North American cities[53]. However, access by non-car modes is great within many DAs in Hamilton-Central (Q3 and Q4). As well, cycling provides some access to destinations (Q1) in more rural communities. While car ownership is high in Hamilton, not everyone has access to a private vehicle: 13% of Hamilton households[54] own zero vehicles. Unconstrained access is insightful in illustrating the spatial accessibility to destinations that people may have, but it does not account for how the overall access provided by the transportation systems to destinations is allocated to different mode-using populations. This lack of consideration may conjure misleading conclusions, namely the inflated promise of lower access-providing modes.

3.2. CONSTRAINED ACCESS

Consider cycling: the access provided by this mode looks promising when examining the results of the cumulative opportunity measure (Figure 5) in part because interpreting cycling access against the much higher access providing car-mode is difficult. So in conceptualising the amount of accessibility available in the region as a total, in other words constraining accessibility in the region and proportionally allocating it to mode-using populations based on their population and travel cost balancing factors, one can answer how many opportunities are available to those using the cycling-mode considering the allocation to the other three mode-using populations. This comparison cannot be addressed using unconstrained accessibility, but can be explored using constrained accessibility, shown in Figure 6.

This study's calculation of spatial availability (Figure 6) assumes the population commutes using a certain mode (proportions shown in Figure 4) also accesses care destinations by this mode. From Figure 6, it is apparent that those who use car-modes are allocated the most spatial availability i.e., the proportion of spatial access to destinations out of all spatial access to destinations in the region. A similar spatial trend is found in the unconstrained accessibility analysis (Figure 5) for both travel time thresholds. However, in Figure 6, constrained accessibility considers population and results are in-part due to the exceptionally high proportion of car-using populations (especially in rural communities) as well as car-mode's relatively competitive travel time. There is a higher car-using population and the car-mode has low travel times to destinations allowing the car-mode using population in each DA to capture the majority of spatial availability. Figure 5 only sheds light on how much unconstrained accessibility the car-mode can potentially provided to people within a DA.

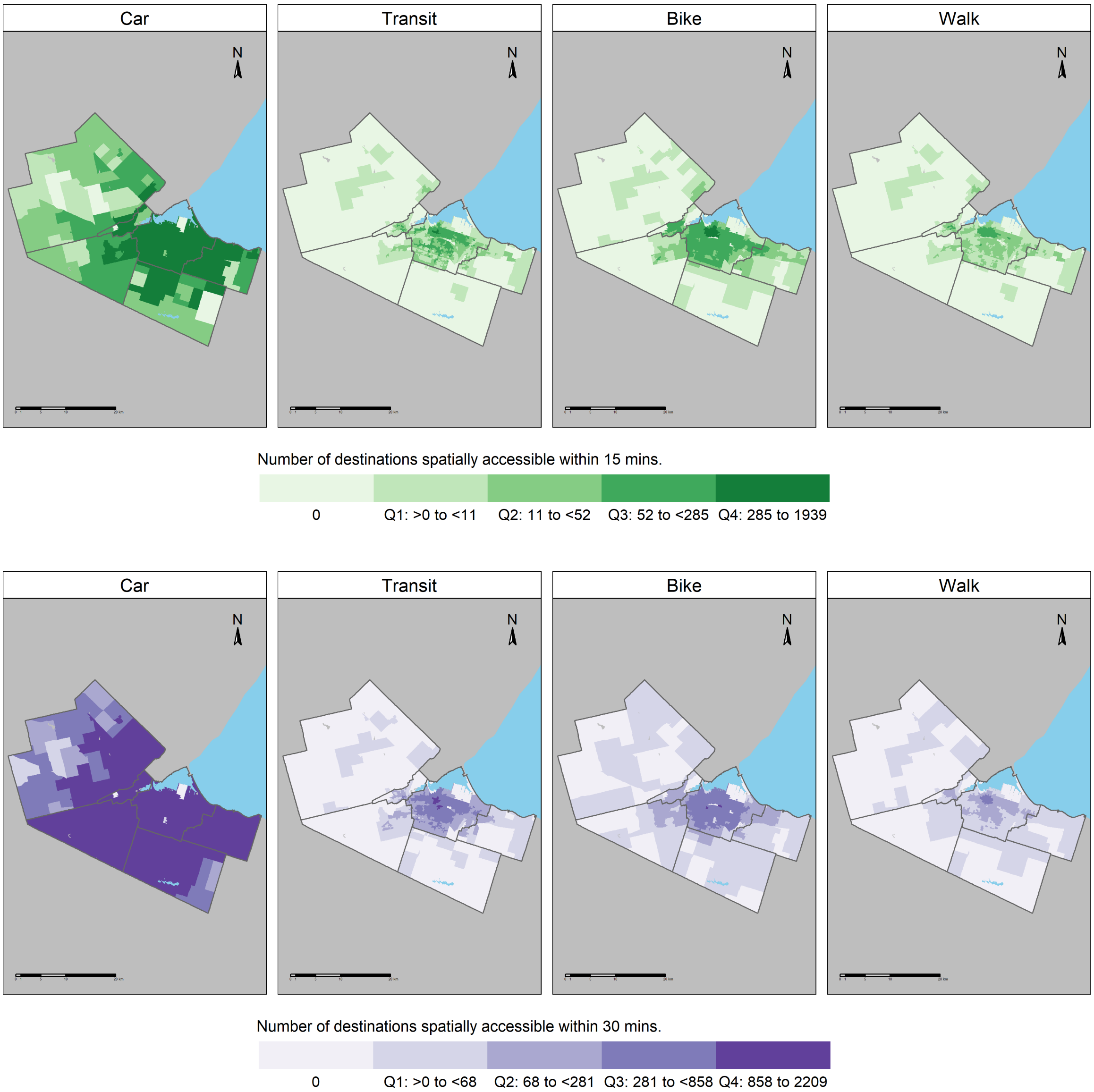

Figure 5: The cumulative opportunity measure. The number of care destinations that can be reached, per DA, within 15 mins (top) and 30 mins (bottom). Basemap shapefiles are retrieved from the 2021 Canadian census[37], the Open Data Hamilton Portal[30] and the USGS[31].

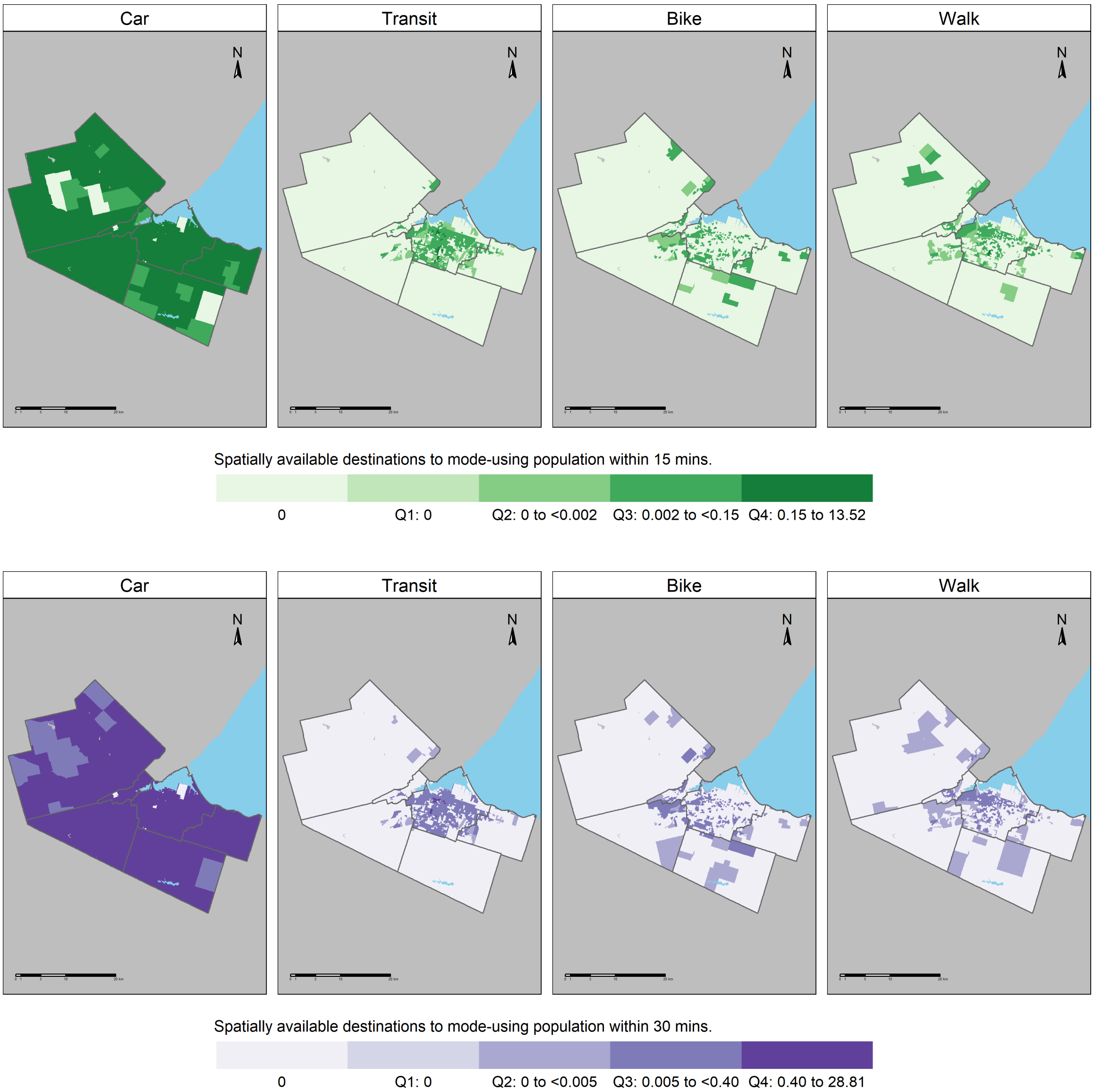

Figure 6: The spatial availability measure. The number of care destinations that can be reached, per DA, within 15 mins (top) and 30 mins (bottom). Basemap shapefiles are retrieved from the 2021 Canadian census[37], the Open Data Hamilton Portal[30] and the USGS[31].

While the unconstrained accessibility analysis (Figure 5) demonstrates that non-car modes are promising in urban areas, as well as cycling in rural communities, Figure 6 demonstrates a more nuanced perspective. Though non-car modes may provide good unconstrained accessibility within Hamilton-Central (and some access in rural communities), they do not provide similar levels of spatial availability. Car-using populations capture more spatial availability, even in the centre of Hamilton-Central, than all other modes. Note the lower number of Q3 and Q4 values within and radiating outwards from Hamilton-Central for non-car modes in Figure 6 compared to Figure 5. Differences between the two measures follow a similar descriptive trend for both travel times.

The proportion of spatial availability allocated to a mode-using population can also be directly compared. This sheds light on what mode, and in what region, a mode-using population captures more than its equal share of spatial availability. Overall, 97% of the spatial availability is taken by 30-minute motorists that represent only 87% of the population; they have disproportionately more availability than their population's presence in the city. They capture this availability from non-car mode using populations that exists in high proportions by with lower spatial availability (i.e., 30-minute transit users are 7% but take 2%, 30-minute cyclist are 2% but represent 0.3%, and 30-minute walkers are 4% but are allocated 0.3%)

The key interpretation from Figure 6 is that if certain modes capture an exceptional proportion of availability, than the availability left for other modes is lower overall. This does not necessarily have to align with the unconstrained accessibility that mode offers. As noted, non-car modes have the potential to offer higher unconstrained access (within Hamilton-Central) in Figure 5. But as it exists (assuming modal commute shares), the majority of spatial availability to care destinations can still be captured by motorists even in DAs where car mode share is under 50% (such as Hamilton-Central, see proportions in Figure 4)

3.3. EQUITY CONSIDERATION

To draw insights on who may reside in DAs where populations are advantaged with higher modal spatial availability, a cross-tabulation of low-high spatial availability & LICO-AT prevalence and high-no spatial availability & LICO-AT prevalence is visualised in Figure 7. The modal spatial availability is divided by the mode-using population in each DA, resulting in the rate of modal spatial availability. LICO prevalence is the proportion of population that falls below the low-income cut-off after-tax (see Figure 3). Figure 7 can be interpreted as follows: residents who use a specific mode in a "yellow" DA reside in a DA that offers below average spatial availability (i.e., below or equal to the the 50th percentile (median) levels of spatial availability per mode-using population) and the population within the DA has a high LICO-prevalence (i.e, 80th percentile or higher (8.4% or more)).

Notice the green DAs for the car-driving population and presence of yellow DAs for non-car modes within Hamilton-Central: Figure 7 reinforces findings from Figure 6. Even in Hamilton-Central where there is high proportion of LICO prevalence, car-mode using populations who reside in green DAs are still offered high levels of spatial availability. However, car ownership is not always possible for low-income households and the lack of ownership acts as a barrier to accessing economic and economic-support opportunities for low-income households[55] when alternative modes are insufficient[56]. For this reason, populations below the LICO may rely on non-car modes, and the introduction of policies that increase access to care-destinations should be considered.

From Figure 7, the majority of yellow DAs are within the centre of Hamilton-Central, specifically for cycle- and walking populations. Policies increase the number of available care-destinations within Hamilton-Central, improve conditions that decrease LICO prevalence, as well as policies that make car-modes less spatial availability advantaged (i.e., encourage modal shift and decrease travel time) such as traffic calming measures should be further investigated through the lens of mobility of care. Ultimately, policies that both redistribute spatial availability from car-driving populations as well as support the access to household-serving economic-related opportunities can be a way forward.

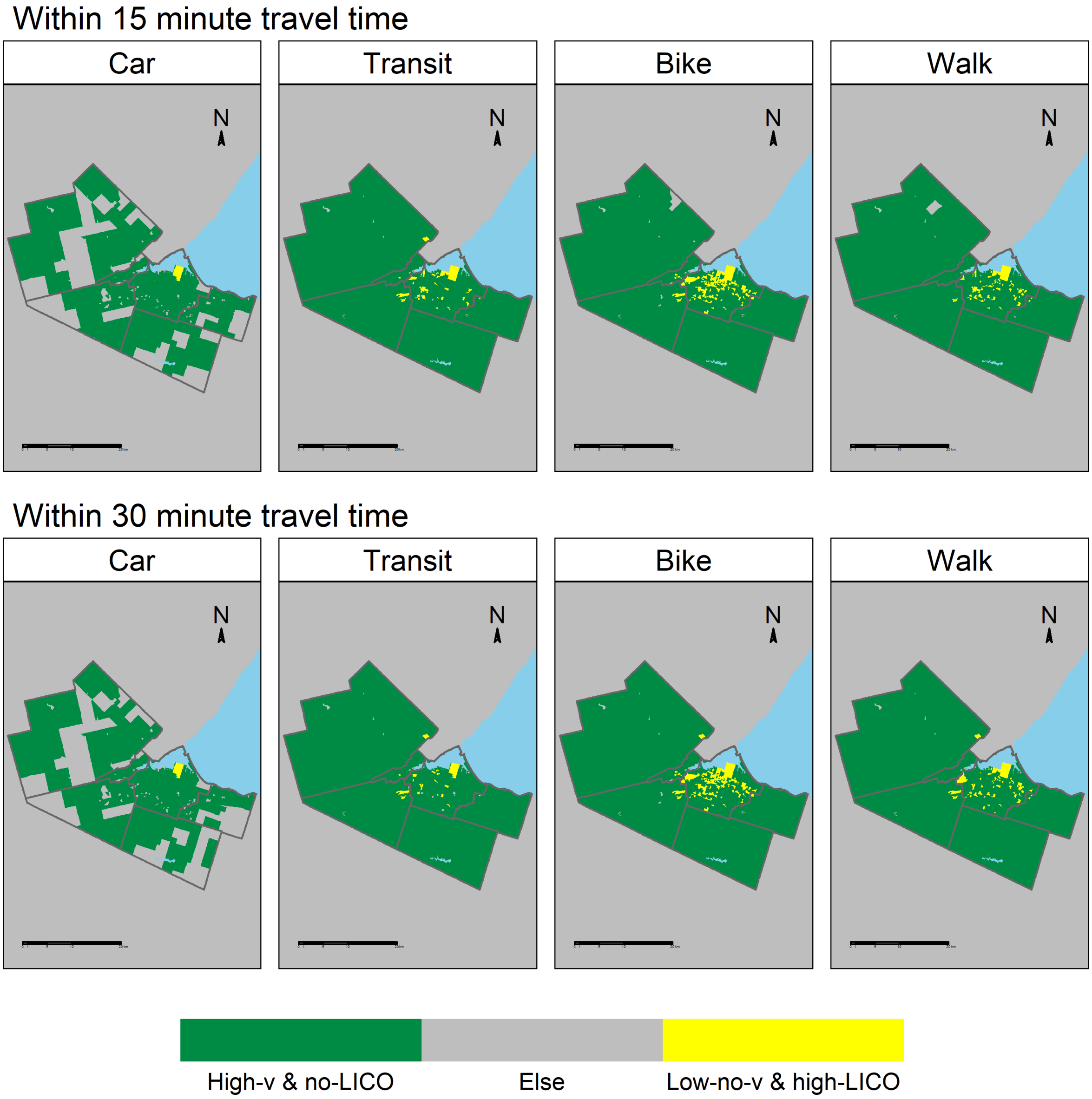

Figure 7: The spatial availability per mode-using-capita measure versus high-income cut-off . The number of care destinations that can be reached per mode-using-capita, per DA, within 15 mins (top) and 30 mins (bottom). Basemap shapefiles are retrieved from the 2021 Canadian census[37], the Open Data Hamilton Portal[30] and the USGS[31].

4. DISCUSSION AND CONCLUSIONS

This paper is first to conduct an exploratory feminist accessibility analysis of care destinations – one that counters the current literature's emphasis on employment-related travel, a travel more significant for men, and especially wealthy and educated men[2,57]. Its aim is to challenge assumptions often made in transport planning tools (i.e., that work is the most important place to access), and to provide a tangible example of how one could gender-mainstream accessibility analyses.

This paper also contributes to accessibility research by implementing both an unconstrained (cumulative opportunities) and constrained (spatial availability) multimodal accessibility measure. The unconstrained measure demonstrates the potential interaction with care destinations that each mode offers from each DA within a 15- and 30- minute travel time thresholds. The constrained measure incorporates the assumed proportion of mode-using population and mode-specific travel time to demonstrate the potential interaction with destinations that each DA has available to a mode-using population. The distinction between the constrained and unconstrained measures are clarified, namely that potential interaction may be over-inflated, especially for the lower range non-car modes, when considering unconstrained access over spatial availability. Unconstrained access may demonstrate over-inflated promise for active transport modes. The consideration of both unconstrained and constrained access can encourage a shift in perspective. Motorists are generally estimated high unconstrained access to many care destinations as well as exceptionally high spatial availability. Those who use alternative modes, have low unconstrained access and, in certain DAs, and even lower levels of availability as car-using populations are allocated a disproportionate number of opportunities in the region. Spatial Availability is a way of conceptualising accessibility as a city-wide total and each calculated value is a proportion so it can be easily placed relative to all others in the city. However, it relies on assumptions on who is "demanding" the destinations, and how those assumptions are made are a subject of ongoing discussion[27,26].

Further, this study contributes to the literature on sustainable travel behaviour. Results indicate that care is most easily accessed in Hamilton by car, an unsurprising result given its car-oriented design. Previous research has found that mobility of care are more frequently completed by car or by foot than by transit or by bicycle[12]. It is possible that the car's ability to provide higher access to care destinations, as observed in this study, shapes this tendency to complete care trips by car. Car use may also be more frequent for care trips because these trips tend to involve carrying things (e.g., groceries) or people (e.g., children). Indeed, past qualitative work has found that many prefer travelling by car for this type of trip due to convenience and increased safety[21,58]. Then again, care trips tend to be shorter than other trips[12], making them ideal for more sustainable travel modes, such as active modes (walking, cycling) and public transport. The low access to care by foot identified in this study is discouraging, given both people's tendency to use this mode for care trips[12], and the benefits of walking as a travel mode, both for individuals, cities, and the environment. Somewhat unexpectedly, access to care was found to be low by transit and by foot and relatively high by bicycle. Given that low income women, in particular, seem to be transit reliant for care trips[12], this result highlights both a potential bias against care trips by transit and the equity implications of that bias. Though past work has found that many barriers exist for cycling for care[59,60,61], the results of this study highlight the great potential of the bicycle for easily accessing care.

The preliminary nature of this research also comes with its limitations as a result of data availability. Firstly, the travel time estimations assume free-flow network conditions: while impacting estimated travel times, estimated congested conditions may not have a drastic impact on spatial accessibility calculations[62], especially for cycling and walking modes. Secondly, the use of a specific travel time cut-off instead of a more complex travel impedance function, can have a significant impact on accessibility results. To add reliability, two travel-cost thresholds were selected. Thirdly, the geometric centroids of DAs (origins) and destinations (all care destinations) were used as inputs for travel time calculations. DAs are created for the purpose of the census: they vary in area and centroids may not necessarily align with where that population may be beginning their journey to care destinations. Fourthly, quality of the care destinations was not considered (e.g., access to a park is equal to access to a school) and the way populations who reside in DAs travel to care destinations is unavailable. These limitations all contribute to how accurately results reflect the quantitative access to care landscape within Hamilton.

Future work on the accessibility of care could use a higher spatial level of travel time estimation, and the incorporation of different weightings of care destination categories. In addition, future work could compare care accessibility to work accessibility in Hamilton to highlight the bias in planning towards jobs as well as substantive equity critiques. Further, the manuscript and all analysis is computationally reproducible and openly available in the lead author's GitHub repository to promote reproducible practice in transportation science.

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5. Appendix

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