Toward Gender-Mainstreaming Transport Planning: Measuring Multimodal Access to Care

Measuring Access to Care

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Abstract

Accessibility, the ease of reaching opportunities, is an increasingly important tool amongst transport planners aiming to foster equitable and sustainable cities. However, in present research there is a bias in accessibility analyses towards employment-centric destinations, a destination more frequent for working-aged, and often higher income, men. This paper aims to counter this gendered bias by calculating access to care destinations, all destinations required to sustain household needs such as shopping, errands, and caring for others (children and dependents). Through the creation of a novel database of care destinations in the City of Hamilton, Canada, this paper considers access to care across different modes of transport at two timeframes (15-minute and 30-minute trips) using unconstrained (cumulative opportunity) and constrained (spatial availability) measures. Results indicate that travel to care destinations by car is extensively favoured, access to care by public transit and by foot is low in all parts of the city except some areas of the inner city. Access to care by bicycle is surprisingly high in many areas of the city, even beyond the downtown core. Neighbourhoods with both low access to care and a high proportion of low-income households are also identified as areas in need of intervention. The analysis presented in this paper demonstrates one method planners can use to gender-mainstream accessibility analyses. Further, results can inform policies aiming to encourage sustainable mobility.

Keywords: Accessibility, Mobility of Care, Gender, Equity, Travel Mode

1. INTRODUCTION

A gender bias exists in transport planning whereby research and policy historically has focused on one trip purpose, the on-peak commute to work, a travel pattern more frequent amongst men[1]. To counter this bias, the concept 'mobility of care' was developed; it refers to all the travel needed to fulfil household needs (e.g., travel to grocery stores, to run errands, to pickup/ drop off children), and is a type of travel that is predominantly done by women[1,2]. Transport planning research to date has inadequately considered mobility of care, for instance, trips to care destinations such as grocery stores, schools, and daycares, are not explicitly considered in typical large-scale travel surveys[1], including major Canadian surveys such as the Transportation Tomorrow Survey[3] or the Montréal Origin-Destination Survey[4]. This results in the mislabelling of these trips into 'shopping', 'leisure', or other 'discretionary' trips[1,3]. When travel surveys are designed to explicitly capture mobility of care, preliminary research has found that it comprises approximately one third of adults' trips[1,2,5]. The omission of mobility of care in research and planning has important equity considerations, as studies have found that mobility of care are completed predominantly

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by women, especially low-income women[1,6]. For instance, in lower income households in Montréal, women complete twice as many care trips than men[6].

Mobility of care research stems from previous work examining household-serving travel. Focusing on the gender inequity found within this type of mobility; this body of work examines individual household-serving trips (e.g., grocery shopping or escorting children), and identifies the multiples roles women play within this type of mobility. Ample research on this inequity has found that women take on more responsibility for the travel needs of their children[7,8,9,10,5] and grandchildren[11] than men. In addition, women also complete the bulk of elder care within households, likely resulting in more travel for these care purposes[12] (?). Women's role in care mobility does not end there, with studies showing that women make more shopping trips and run more errands than men as well as shouldering the responsibility of planning mobilities of care even when a male partner undertakes them[9,5,13,14,15]. While this literature on gender and household-serving travel has made significant contributions to the literature of mobility of care, **-(author?)**[1] argues that focusing on separate household-serving trips results in the under-representation of mobility of care. Only by considering household-serving trips together (i.e., mobility of care), do we see that they represent approximately 30% of daily mobility.

The idea of mobility of care also warrants special sustainability considerations when planning for urban mobility. Transport planners aiming to discourage high emitting car travel and encourage low emitting travel by walking, biking, and public transit should consider mobility of care whilst informing policies. In **-(author?)**[6] study on mobility of care, Montréalers were two and half times less likely to use public transport for care trips than for work related trips. Similarly, residents were nearly two times less likely to use bicycles for care trips than for work trips. Yet, car use was almost 8% more likely for care trips than for work trips[7]. Furthermore, qualitative research in Europe has identified that this type of travel is considered easier to complete by car as it tends to include carrying items (groceries, library books, etc.) or children, which is seen as a barrier to travelling by foot, bicycle, or public transport[16]. Therefore, with this preliminary research suggesting a bias towards car travel when accessing care, transport planners should consider mobility of care when informing policies aiming to encourage sustainable urban mobility.

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[17]. Accessibility indicators can be interpreted to capture the ease of reaching destinations using a transport network - a representation of the land-use and transportation systems in a region[17,12,13]. In reflecting the gender bias of the data collected, the points of interest in many accessibility-based assessments have been home-to-work destinations[14,15]. For example, in the accessibility assessment of the Ontario Line, a subway line that will be constructed in the city of Toronto, Canada, **-(author?)**[15] highlight how this new investment will increase access to jobs for residents across the City by 1.14% overall. Jobs, however, are not the most appropriate destination for many segments of the population. Indeed, while the commute is an important trip type amongst women, on average it comprises a smaller proportion of their daily travel than men's[6]. This focus on job-access can additionally bias accessibility-gains that children and older adults who reside in impacted areas may see as well[18]. One way to counter this bias is to reframe the analysis and calculate accessibility to different destinations, such as mobility of care destinations.

In this spirit, this study expands the nascent body of work on mobility of care, a topic that has been thus far ignored due to systematic gender bias in transport research and planning, by focusing on mobility of care accessibility in the City of Hamilton. Given that preliminary research has found that certain travel modes are more commonly used for mobility of care (the private car and walking), this study also compared mobility of care accessibility across travel mode to test the hypothesis that certain modes provide more access to care destinations than others. Finally, because certain people have been found to be more likely to complete care travel than others (low-income women), this study also examines how accessibility varies across sociodemographic factors at the neighbourhood scale. In doing so, this research aims to contribute to gender mainstreaming in transport planning by conducting a feminist accessibility calculation, and to sustainable transport planning by examining the potential access to barriers to care destinations using low carbon modes (walking, cycling, and transit).

2. BACKGROUND AND METHODS

This paper focuses on the case of Hamilton, a mid-size city of approximately 500,000 residents and an economy historically (and still) connected to steel manufacturing and related manufacturing. Though a city in its own right, Hamilton lies within the urban and suburban Greater Toronto and Hamilton Area (GTHA) that spans a shoreline of Lake Ontario. The GTHA comprises seven million people, or approximately 20% of the Canadian population[19]. 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[20]. Urban and suburban landscapes play a key role in accessing care as differences in infrastructure could affect one's ability to access care destinations.

2.1. Destination database

To complete the accessibility analysis, a geospatial database of care destinations for Hamilton (e.g., full addresses of longitude and latitude) was compiled. The geospatial data was sourced from governmental open data portals[23,24], Data Axle, a consumer database compiled of businesses and companies within Canada[25] or manually through Google Maps. Each destination was categorized based on the specific type of care being accessed. Categories include child-, elder-, errand-, grocery-, and health- centric destinations. These final categories, and their sources of data, are described as follows and their spatial distribution is visualized in Figure 2.

2.1.1. Child-Centric:

This category includes the geospatial location of all child-oriented destinations such as **schools**, **daycares**, **community centres**, **recreation centres**, and **parks**: 1190 destinations are identified in the City.

- **Schools** are sourced from the Educational Institution data from Open Data Hamilton[26]. The data was then filtered, and all locations that typically do not serve children were removed including: Post-Secondary, Adult-Learning Centres, Group Homes, and Foster Care Centres. 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"*[27], were kept due to their innate connection to care.
- **Daycares** were identified from the Registered Child Care Facilities in the Ontario Open Data Portal[23] and filtered to Hamilton. Additionally, EarlyON childcare locations, defined as *"...locations for child rearing and development where parents accompany their children"*[28], were added manually from the Hamilton Child Care Registry[28].
- **Community centres**, **recreation centres**, and **Parks** were identified from the Recreation and Community Centres and Parks data from Open Data Hamilton[29,30], respectively.

2.1.2. Elder-Centric Destinations:

This category includes the geospatial locations of **senior centres**, **long-term care homes**, and **retirement homes**: 75 destinations are identified in the City. **Senior centres** are also retrieved from the Recreation and Community Centre database[30], specifically locations that contain the name "Senior Centre". **Long-term care homes** and **retirement homes** are sourced from the Ontario Ministry of Health GEOHub for Health Service Locations[31].

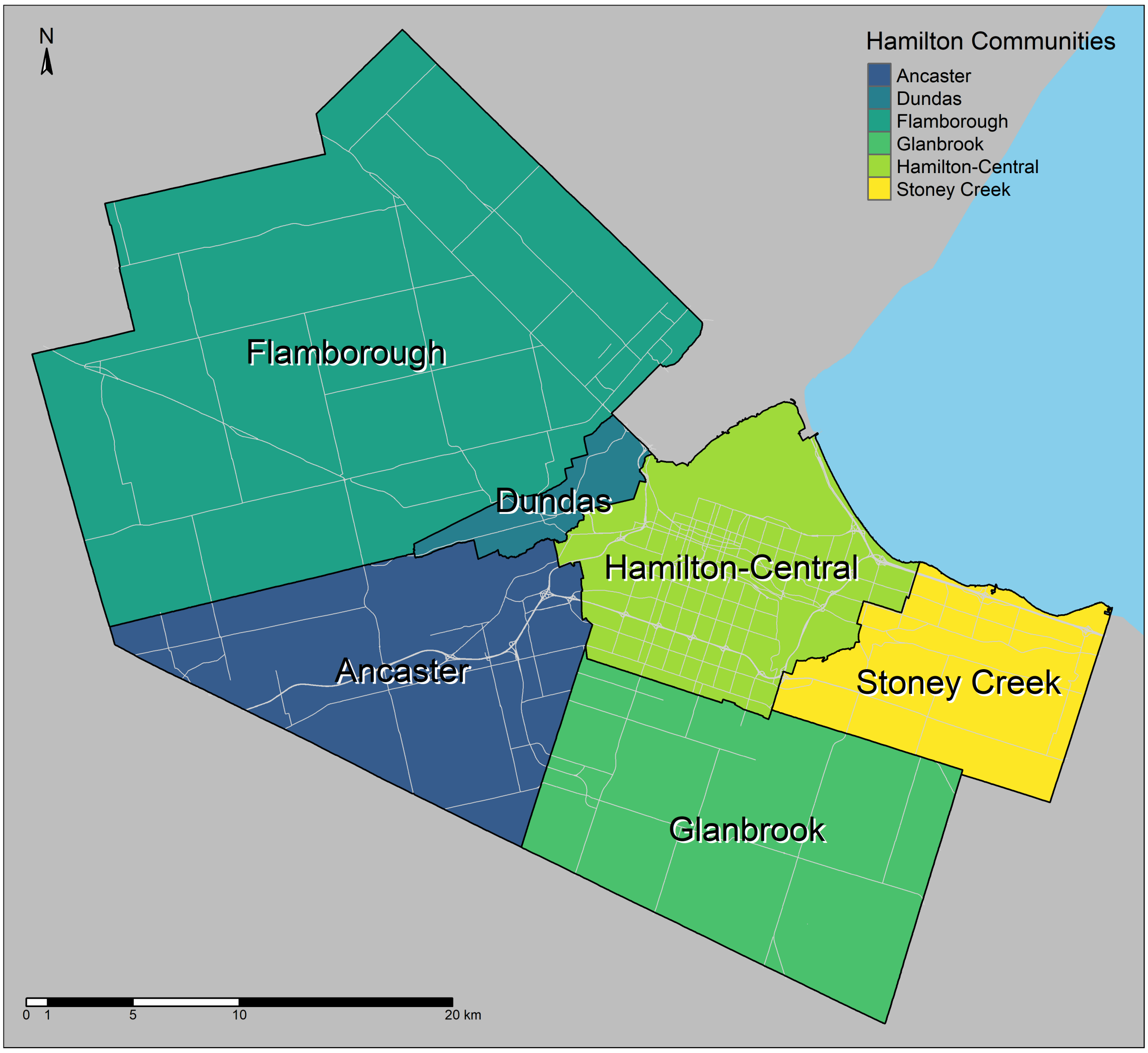

Figure 1: The six former muncipal boundaries in the city of Hamilton. Basemap shapefiles are retrieved from the Open Data Hamilton Portal[21] and the USGS[22]. Highways and arterial roads are shown in light grey.

2.1.3. Grocery-Centric:

This category includes the geospatial location of all **grocery stores**, a place a household could buy groceries ranging from convenience stores to large retail stores: 381 destinations are identified. Data is gathered from Data Axle and filtered by Company Name, Suite Number, Address, City, Province, Phone Number and Postal Code[25]. From there the type was identified e.g., grocers specialty foods, grocers retail, grocer health food, grocer wholesale, grocer curbside, grocer delicatessen wholesale, grocer convenience. Next, data was cross referenced to ensure all included locations were operational and legitimate grocery stores.

2.1.4. Health-Centric:

This category includes the geospatial location of health destination including **hospitals**, **pharmacies**, **clinics**, and **dentist offices**: 421 destinations are identified in the City. **Hospitals** and **pharmacies** were derived from the Ontario Ministry of Health GEOHub for Health Service Locations[31]. **Clinics** were manually entered with data being gathered from Hamilton Niagara Haldimand Brant Health Line – Health Service Locations[32]. Clinic data was then double checked to ensure locations were in operation. Dentistry locations were also manually entered through Google Map search filtering as well as reassessed for operational use.

2.1.5. Errand Centric:

This category includes other types of destinations that are errand-centric such as **libraries**, **post offices**, and **banks**: 158 destinations are identified in the City. In travel surveys, these destinations are often lumped in within 'grocery shopping'[9]. In this research, we distinguish these destinations from child-, elder-, grocery- and health-centric destinations. **Libraries** are derived from Hamilton Open Data Portal[33]. **Post Offices** are collected from two sources; Axle Database and then supplemented from the Canada Post Postal Office Tracker Website[25,34]. The supplemented locations from Canada Post Postal Office Tracker Website were manually entered into the database to ensure data was accurately being represented from its source. **Banks** are also derived from Axle Data and then cross referenced to ensure data quality with the ABM Bank Locator websites for the following national banking firms: Bank of Montreal, CIBC, HSBC, National Bank of Canada, Royal Bank of Canada, Scotiabank and TD Financial[35,36,37,38,39,40].

Once the care destinations were compiled, the data was validated to ensure that duplicate locations were removed. Each location was manually inspected using Google Maps to confirm if it was operational and legitimate, if not, those locations were removed. The complete care destination database was imported into RStudio for further processing and visualised in Figure 2, by category and sub-category.

For the purpose of this analysis and in absence of city-wide empirical household preferences for care destinations, all destinations are re-weighted to be equal. For example, if all count as 1 destination in our analysis, the result will favour child-centric destinations as they make up the majority of the database. As such, the five care categories are re-weighted so they each represent one-fifth of the database:

- 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. Census data and multimodal travel time estimations

To supplement the care destination database and complete the accessibility calculation, population data for the City of Hamilton was sourced from the most recent 2021 Canadian census[41]. The number of residents and the percent of after-tax low-income-cut-off (LICO-AT) residents was sourced at the highest level of spatial resolution, the dissemination area (DA). 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[42]. The {cancensus} open-sourced R package was used to access the 2021 Canadian Census data in a programmatic way[43]. Figure 3 displays the spatial distribution of the total population and the prevalence

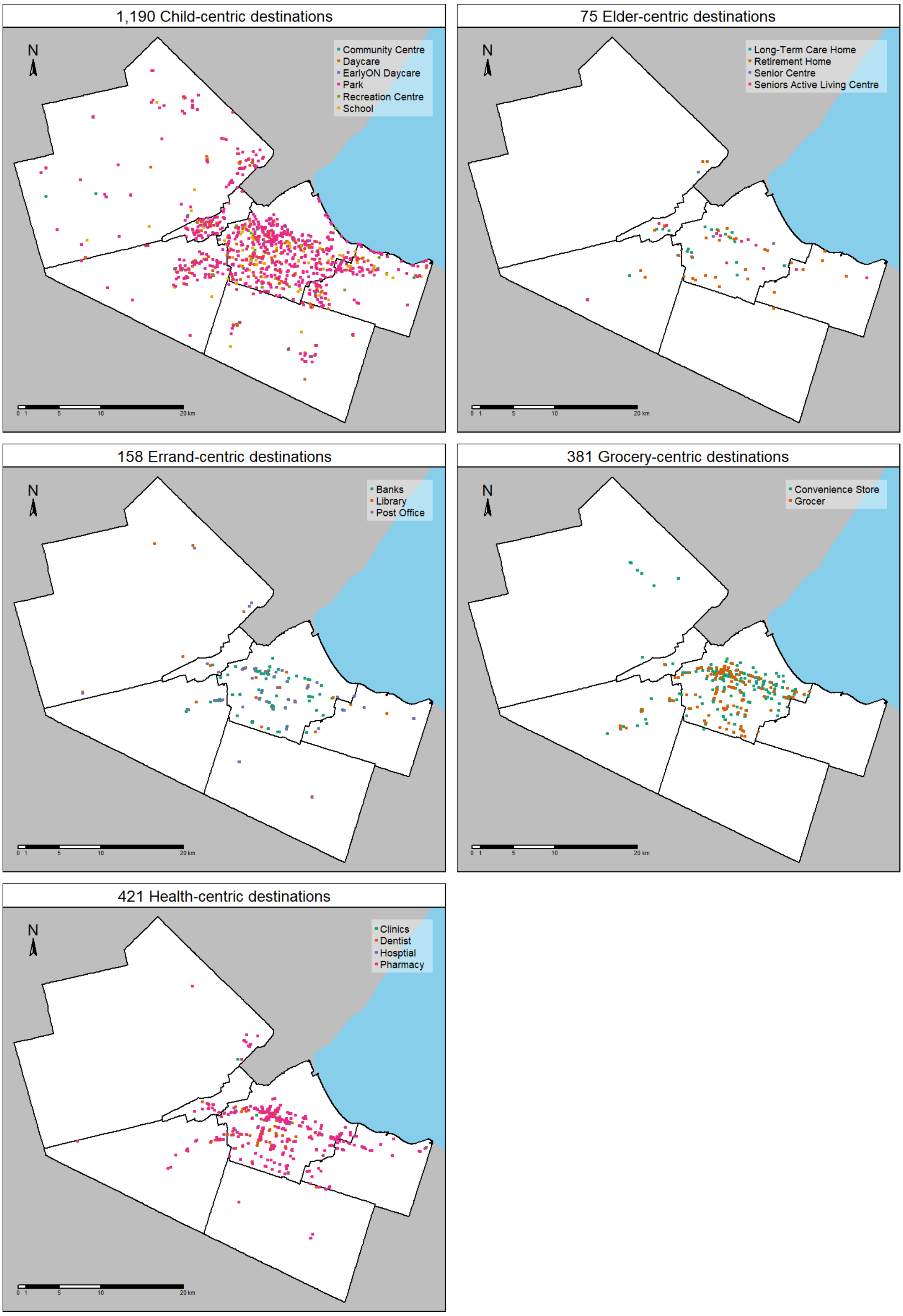

Figure 2: The geo-located points of care destinations in the City of Hamilton separated by the author-generated categories of: child-, elder-, errand-, grocery- and health- centric care categories. Locations of these destinations were retrieved through multiple sources as described in the text. Basemap shapefiles are sourced from the Open Data Hamilton Portal[21] and the USGS[22].

of LICO-AT as a percentage of the total population. Of note is the density of population and LICO-AT prevalence within Hamilton-Central.

To further investigate the spatial differences in access to care that modes offer, we use the proportion of the total population that commute by a specific mode (Figure 4). These variables are also retrieved as a long-form variable of the 2021 Canadian census using the {cancensus} R Package[41,43]. Though mode-choice used in travel to work is not necessarily reflective of the mode used to travel to care destinations, no other data is available City-wide. That said, the population predominately commutes by car, even within the more densely populated Hamilton-Central.

Travel time is conducted using the 'travel_time_matrix()' function from {r5r}, an open-source R package for rapid realistic routing on multimodal transport networks[44]. The inputs were the geometric centroids of the DA, the centroids of all care destinations, the Open Street Map (OSM) road network retrieved from Geofabrik,[45] and the static GTFS (transit network in which only urban buses operate) for Hamilton[46]. Travel times for walking, cycling, transit (with walking to stations), and car were calculated for each origin to all care destinations.

For all modes, travel times under 60 minutes based on the shortest travel-time path OSM road network were calculated. For transit and cycling modes, additional parameters were included. In estimating transit travel times, a typical Wednesday departure time at 8:00 was selected, as it is representative of relative accessibility over the course of the day[47]. Further, a departure travel window parameter of +/- 30 mins was used, so the origin-destination travel times are calculated for each minute between 7:30 to 8:30. This consider is important as transit travel times are highly sensitive to vehicle frequency and connecting transfers (see discussion of the modifiable temporal unit problem e.g.,[48]). After evaluation, the 25th percentile travel time from the distribution of travel times in the window was selected to represent each OD trip. 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 assumption 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.

2.3. Accessibility measures

Both the **cumulative opportunity** and **spatial availability** measure are used to estimate the potential access to care that each mode provides to the DA. These measures represent the aggregate zonal (DA) accessibility that populations that reside within those DA may have access.

Cumulative opportunity accessibility: takes the following general form for multi-mode 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.
- A_i^m is the unconstrained accessibility for m at each i.

Spatial availability takes the following general form for multi-mode calculation:

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

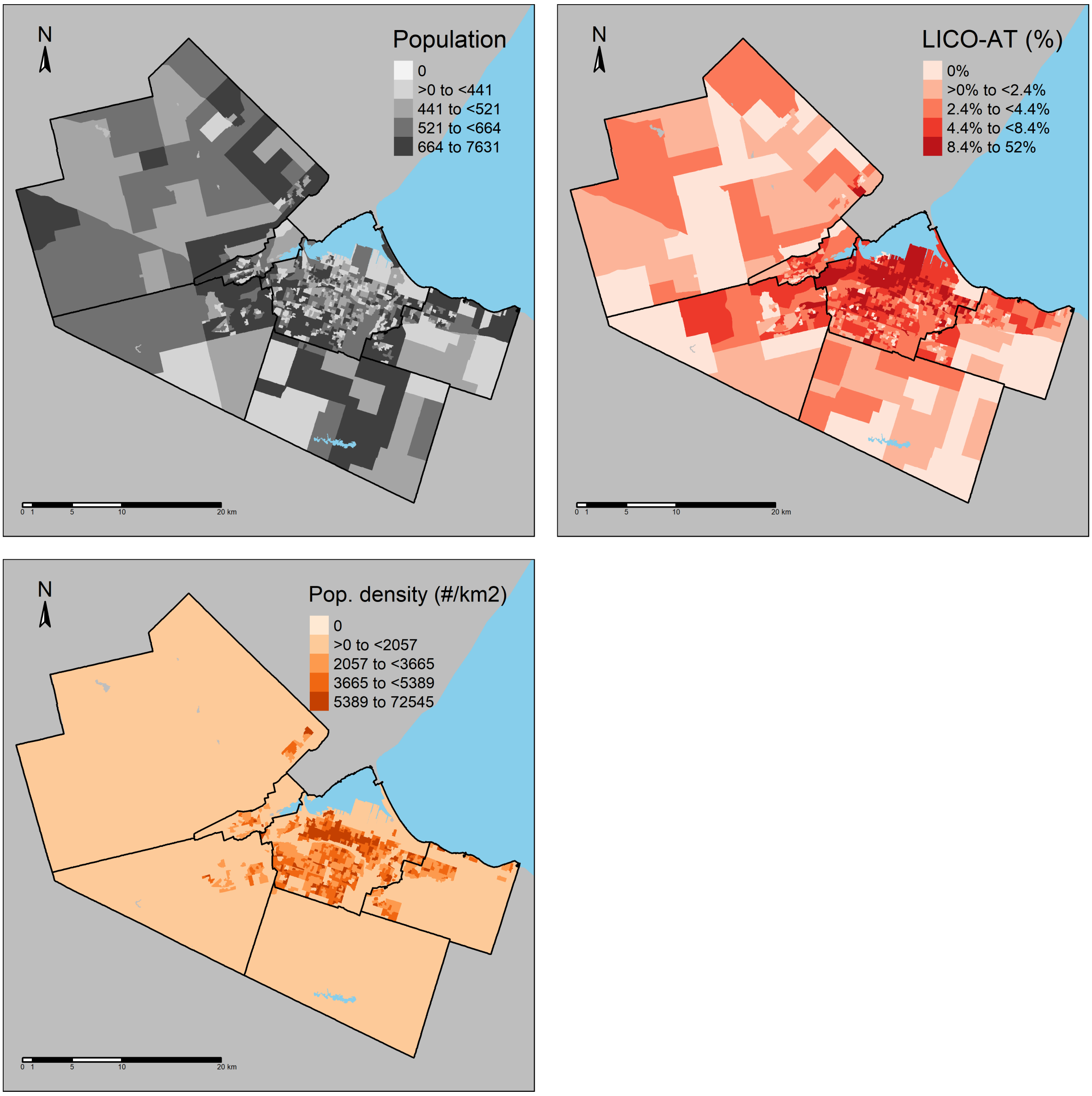

Figure 3: The total population in each dissemination area (DA), visualized with the six former muncipal boundaries in the city of Hamilton. The top plot represents the population density and the bottom plot depicts the prevalence of low-income cutt-off after taxes (LICO-AT) as a percentage of the total DA population. LICO-AT is a measure of economic disadvantage. The legend categories represent quartiles. Basemap shapefiles are retrieved from the 2021 Canadian census[41], the Open Data Hamilton Portal[21] and the USGS[22].

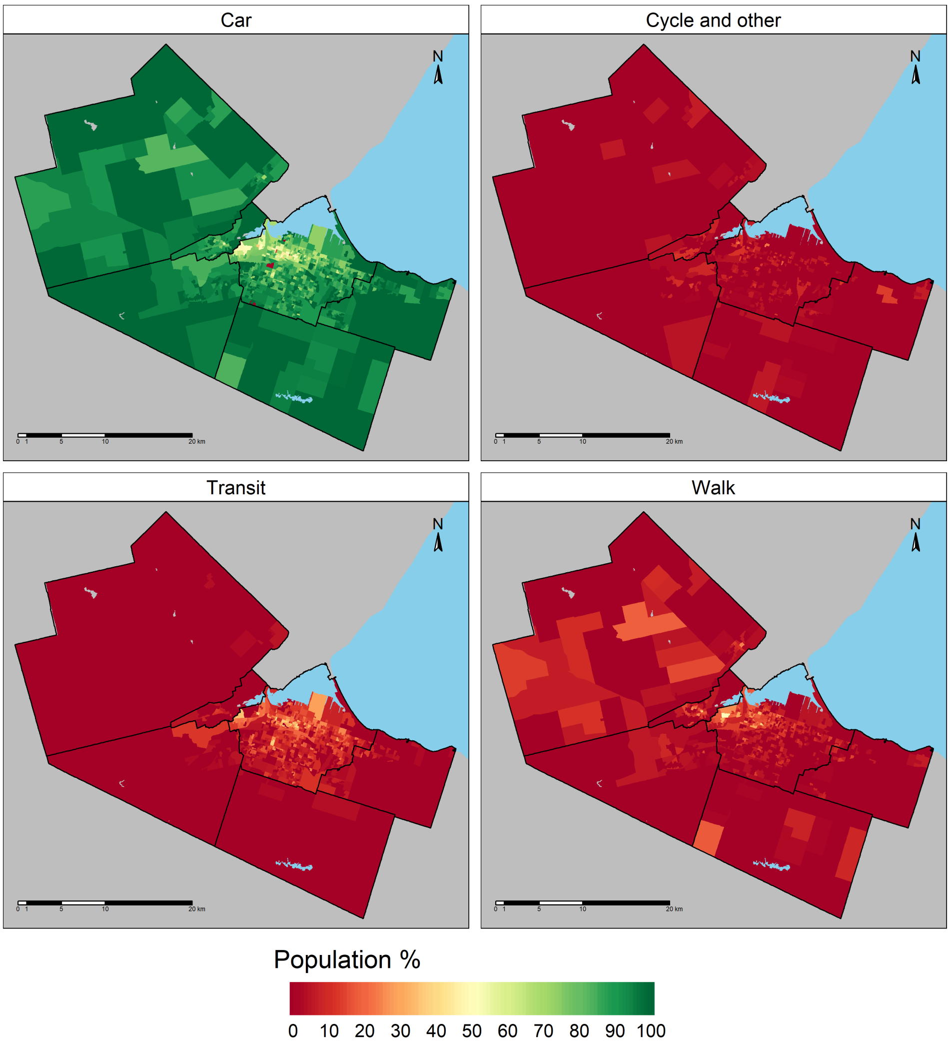

Figure 4: The proportion of mode type used for commuting (aged 15 and older employed in the labour force) in each dissemination area (DA) as provided by the 2021 Canadian census. Basemap shapefiles are retrieved from the 2021 Canadian census [41], the Open Data Hamilton Portal [21] and the USGS [22].

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 the pre-print by Soukhov et al.[49]). 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^{mc}{i} \$ *are proportions,* $\sum_m \sum_i F_i^{pm} = 1$ *and* \$ {m} *{i} F^{cm}*{i} = 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 pop
- 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 use of both constrained and unconstrained accessibility measures is strategic, as they illuminate different trends. 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 by multiple DAs is counted multiple times, so the sum of all cumulative opportunity values region-wide is not meaningful. However, cumulative opportunity measure is relative straightforward to implement, and has been widely used in accessibility research because of its simple computation (XX). The value is understood relative to the score in the region, XX opportunities can be accessed within 30 minutes from this neighbourhood - this is XXth percentile in the estimated region, a regionally high score. Comparisons of score within the region make sense, but substantive interpretation of levels of access between modes is hard to compare. We often seen, car provides more unconstrained access to opportunities than transit.

On the other hand, spatial availability is constrained[50], it incorporates the concept of the *finite*. The spatial availability value for each mode at each DA is a count of how many destinations can be accessed by that mode out of all the destinations in the region. The sum of spatial availability values across the region is constrained to equal the total number of opportunities. Proportions of each destination (supply) are allocated to each mode at each DA based on the DA-to-region-relative population (demand for opportunities) and travel impedance (travel cost to opportunities). Unlike cumulative opportunity measure, multimodal spatial availability measures can be used to extra additional meaning between modes. It can be used to illustrate in what neighbourhoods do car-drivers access *more* than their equal share of opportunities than transit-users and how much more, for instance.

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)[18]. Other literature on travel to care trends to consider 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[51] or 20.45 for cancer treatments[52]. In other care-related accessibility analyses, time-cut offs include 10 mins (for daycares)[53] and 30 mins to 1 hr (for hospitals)[54]. Furthermore, the use of a binary travel time threshold was selected, as opposed to more complex impedance functions, to simplify computation. As mentioned, region-specific empirical travel data regarding care-centric trip travel times is lacking, and this work establishes a methodology to streamline access to care interpretation and analysis for then that data is available (?).

3. RESULTS

In absence of people's travel behaviour and preference for care destinations - a bias in traditional travel surveys - we map access to all destinations assuming an equal weighting of the five categories. The results are described across: unconstrained access to care by mode across the city, constrained access by mode, and identification of intervention areas through equity considerations.

The cumulative opportunity accessibility plots for each mode are shown in Figure 5. It visualises an unconstrained count of destinations, we can interpret it as: the more destinations that can be reached by a mode, the more potential interactions and thus the potentially better. Spatial trends between the 15 minute and 30 minute threshold plots are similar (values are coloured by quantile). We can also notice three significant findings between modes: first, the access that car provides is significantly higher relative to other modes, it sets the max. value of (1939 opportunities for 15 min and 2209 opportunities for 30 mins) across all modes. Next, access by cycling is surprisingly also relatively high. And importantly, transit and walking access is great and pretty good, respectively, within Hamilton-Centre but this is not the same story in other communities.

From Figure 5, we can tell car is king, an expected outcome given the tendency of North American cities to be designed around the private car[55]. However, access by non-car modes is great (Q3 and Q4) within many DAs in Hamilton-Centre and cycling has potential, especially in the more rural communities (Q1). However, though many households use car as a commute mode, not everyone does, wants to, or can. How does the access that car provides *out compete* access given by other modes? Lets consider cycling. Though cycling provides access to many destinations, seeing the 2225 care destinations in the City as the total, how many of those are potentially available to cyclists considering motorists greater unconstrained access? We can't answer this question using unconstrained accessibility, so lets turn to constrained accessibility, shown in Figure 6.

Assuming the population that commutes by a certain mode (Figure 4) also accesses care destinations by this mode, the spatial availability per mode is displayed in Figure 6. We can observe that motorists capture the most *availability* i.e., potential access to destinations out of all destinations. This is in-part because many DAs, especially in rural communities, have 0% or exceptionally low non-car mode usage. From Figure 5 we can see that non-car modes have potential, especially cycling, but Figure 6 affirms that even though non-car modes may provide good access within Hamilton-Central (and some access in rural communities), they do not provide sufficient availability, even within Hamilton-Centre. The proportion of car users *and* their competitive travel times relative to other modes allow motorists to capture more finite access to opportunities (availability). Motorist capture more availability, even in the centre of Hamilton-Centre, than all other modes. Overall, 97% of the spatial availability is captured by 30-minute motorists that represent only 87% of the population; they capturing disproportionately more availability than their presence in the region. 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 capture 2%, 30-minute cyclist are 2% but capture 0.3%, and 30-minute walkers are 4% but capture 0.3%).

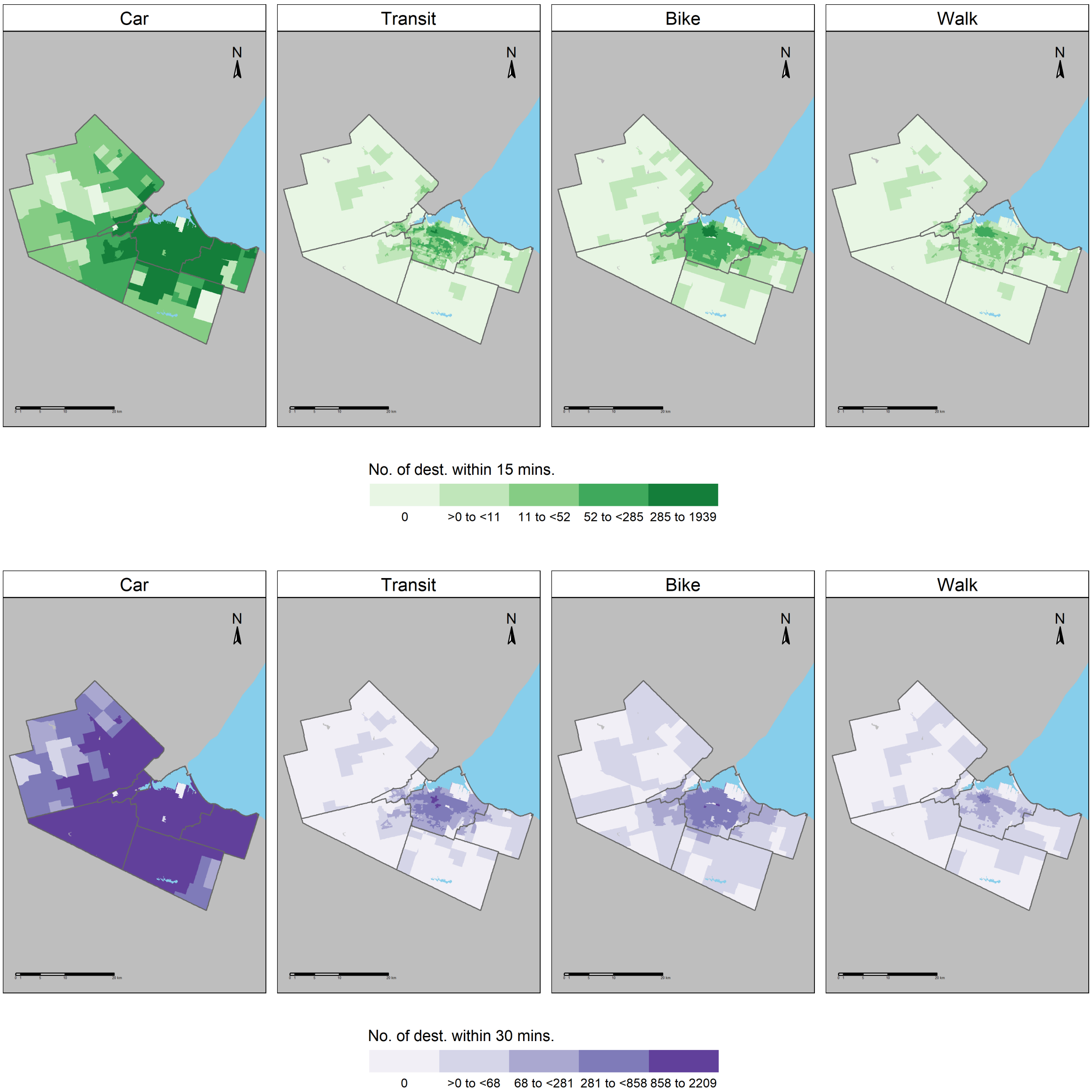

Figure 5: The cumulative opportunity measure. The number of care destinations that can be reached, per DA, within 15 mins (top) and 30 mins (bottom). Basemap shapefiles are retrieved from the 2021 Canadian census[41], the Open Data Hamilton Portal[21] and the USGS[22].

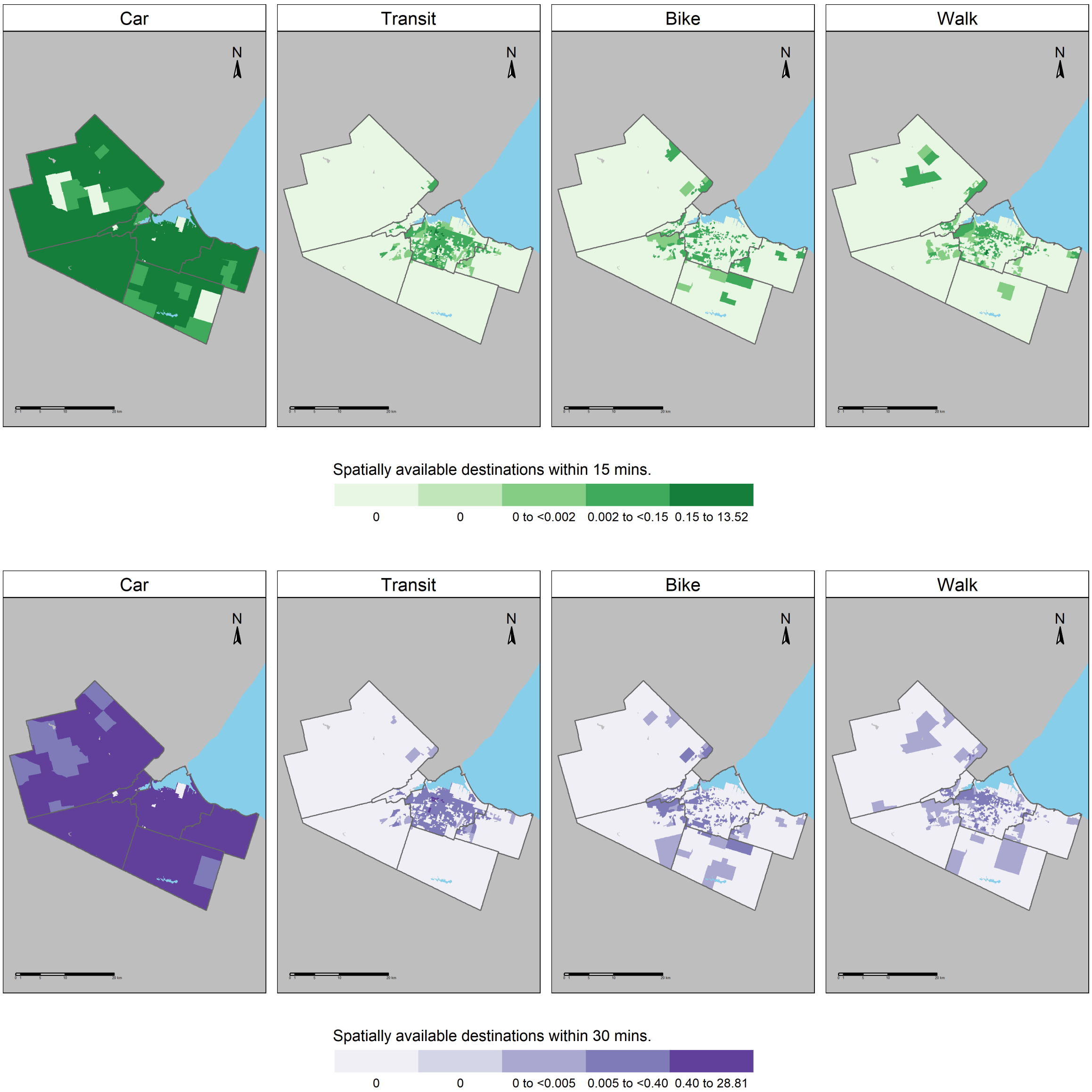

Figure 6: The spatial availability measure. The number of care destinations that can be reached, per DA, within 15 mins (top) and 30 mins (bottom). Basemap shapefiles are retrieved from the 2021 Canadian census [41], the Open Data Hamilton Portal [21] and the USGS [22].

It is difficult to tease out spatial trends in how much more availability motorists capture than other mode-users referencing Figure 6, so in Figure 7 we divide modal spatial availability per mode-using population. These values represent how much availability is captured per mode-using population in a DA. They are admittedly small, as each represents how many opportunities out of 2,225 destinations are available to the mode-using population in the DA (out of 569353 people residing in Hamilton). As in all other plots, each colour is a quantile so trends can be interpreted accordingly. In Figure 7, the motorists capture vast majority of opportunities (Q4, dark green and dark purple), but notably this is still very much true within Hamilton-Centre, where we know there are pockets where non-car user is greater than 50%. Figure 7 reinforces that if certain modes capture an exceptional amount of availability (car), than the availability left for other modes is low. Further, non-car modes have the potential to offer high access (within Hamilton-Centre) as seen in Figure 5, but as it exists now (assuming modal commute share), availability to care destinations is captured by motorists even in DAs where car mode share is under 50%.

Equity consideration and the consideration of travel time cut-off. We can see signficant difference in the correlation between LICO-AT in a DA and the modal per-capita spatial availability depending on if the 15 minute or 30 minute cut-off is considered. We can see 30 minute cut-off is more generous, especially for the motorists that can almost reach all destinations. As such, there is a weak positive correlation between for motorists (0.1583927) and cyclists (0.2288479). However, there is stronger positive correlation for those who walk (0.5715248) and use transit (0.4185431). This is in line with literature XX. Areas that are LICO-AT are clustered in higher density DAs in Hamilton-Centre, where unconstrained and constrained access by all modes is high but access is also high (or alright) for car and cycling in areas outside Hamilton-Centre (areas with lower LICO-AT).

However, relationships are different assuming a 15 minute cut-off; all modes see a weak but positive linear relationship between LICO-AT and per-capita modal spatial availability however trends are reversed. Cyclists and motorists now see a stronger relationship (cycle: 0.264636 and motorists: 0.4409378) than those who walk and use transit (walk: 0.1865794 and transit: 0.1262046). As mentioned, availability is high for all modes in Hamilton-Centre where there is high LICO-AT, but especially for faster modes like car and cycling. However, access for all modes is not high outside of Hamilton-Centre. Because Car and cycling does not have such an exceptional advantage in the rural communities consider a 15-minute cut-off, the reverse trend emerges where LICO-AT is correlated more strongly with cyclist and motorist availability. This reversal in trend highlights the importance in threshold selection as accessibility results are highly sensitive to the assumptions of travel to destinations. Echos trends in literature X. Empirical data is needed, but there is a bias in excluding considerations for care destinations in conventional survey methods XX.

Overall, between the 15-minute and 30-minute cut-offs, there is a positive relationship in per-capita availability and LICO-AT as well as cumulative opportunity and LICO-AT. We know car mode provides unconstrained and constrained access to opportunities; those who have a car are covered. But we must plan for cities that are not reliant on cars. Cycling has potential, but mostly in areas with low LICO-AT and with the consideration for some risky cycling (level 1 and 2). Further, comparing access to what cars can reach may not be the best approach – most opportunities in the city of ~500,000 can be reached within 30-minutes. Is that necessary? Should that be the goal for all modes? Or shall access by car be reduced while access by other modes increased such that availability matches the proportion of the mode-using population. Spatial availability can be used to consider these options.

4. DISCUSSION AND CONCLUSION

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[56,57]. 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.

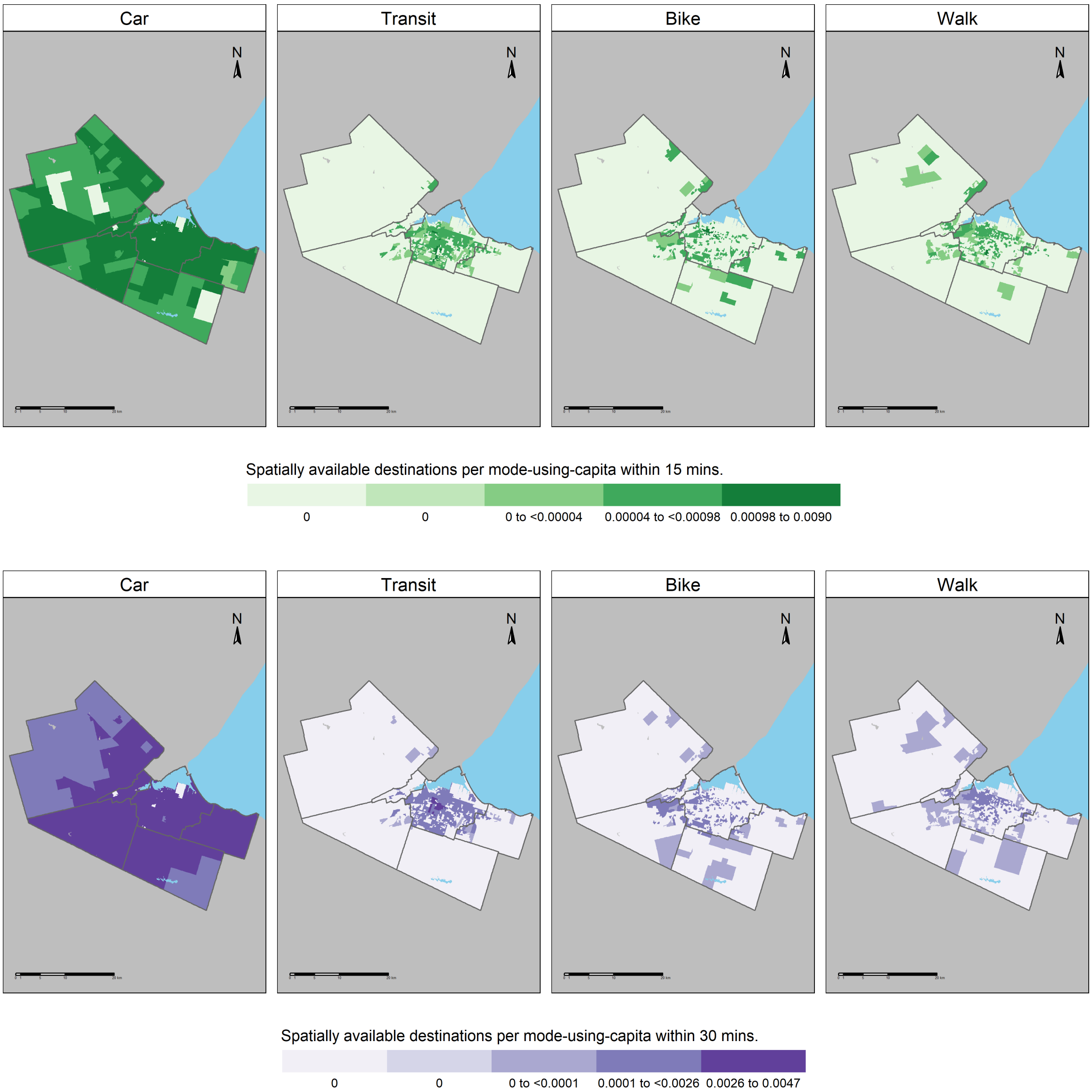

Figure 7: The spatial availability per mode-using-capita measure. The number of care destinations that can be reached per mode-using-capita, per DA, within 15 mins (top) and 30 mins (bottom). Basemap shapefiles are retrieved from the 2021 Canadian census[41], the Open Data Hamilton Portal[21] and the USGS[22].

This study also 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[6]. 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. Then again, car use may 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[16,58]. Then again, care trips tend to be shorter than other trips[6], 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[6], 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[6], 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: this may not drastically impact walking travel time accuracy, but could impact car, transit and cycling estimations. Secondly, 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. Thirdly, the cumulative opportunity accessibility measure is unconstrained and does not consider competition. It is the sum of every care destination that can be possibly reached, not taking into consideration the density of neighbouring population that may also be reaching those destinations. Fourthly, quality of the care destinations was not considered (e.g., access to a park is equal to access to a school). These limitations all contribute to how accurately results reflect the quantitative access to care landscape within Hamilton.

Future work on the accessibility of care will consider competition factors through different accessibility measures, a higher spatial level of travel time estimation, and the incorporation of different weightings of care destination categories. In addition, future work will compare care accessibility to work accessibility in Hamilton to highlight the bias in planning towards jobs as well as substantive equity critiques.

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6. AUTHOR CONTRIBUTIONS

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

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7. Appendix

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