Towards caring 15-minute neighbourhoods

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# Abstract

The 15-Minute City is a normative conceptualisation gaining ground in urban planning: it frames neighbourhoods as responsive to human needs and environmental sensibilities, where most daily necessities can be reached within a 15-minute walk or bike ride (Allam et al. 2022). As a related tool, accessibility measures (the ease of reaching opportunities) are increasingly important amongst transport planners aiming to foster just and sustainable cities (Vale and Lopes 2023). Both the 15-Minute City and accessibility measures are flexible enough to consider all destination types holistically however, gendered examinations have been lacking in the literature. For instance, accessibility analyses have historically focused on employment-centric and discretionary travel, types of travel more frequent for working-age and higher-income men.

To counter this masculinist bias, this study investigates a way to gender-mainstream the 15-Minute City through a care lens (e.g., Law 1999; Cresswell and Uteng 2008; Levy 1992, 1991, 2013) supported by the Mobility of Care framework (coined by Sánchez de Madariaga (2013)). Mobility of Care emphasizes the importance of travel to unpaid work (care trips) in contrast to the better-studied travel to employment and leisure. While all three trip types (work, care, and leisure) are essential, care trips are often relatively shorter-distance, proximate to residential/work/school, and comprise approximately 30% of adults’ daily trips (Sánchez de Madariaga and Zucchini 2019; Ravensbergen, Fournier, and El-Geneidy 2023; Mejía-Dorantes, Montero, and Barceló 2021); fitting well within the 15-Minute City conceptualisation.

Our study provides an empirical example that maps the 15-Minute City onto the Mobility of Care framework. Specifically, it identifies which areas in Hamilton, Canada are ‘caring 15-minute neighbourhoods’. To do so, a database of care destinations is created using secondary data. In this database, care destinations include all places associated with sustaining household tasks needed for the reproduction of life namely: shopping (e.g., groceries), errands (e.g., libraries), health (e.g., dentist), and caring for dependents (e.g., schools). This database is used to estimate the number and mix of care-destinations that can be reached within a 15-minute walk- and cycling- sheds from census centroids. Typologies are generated to illustrate which neighbourhoods can and to what degree facilitate 15-minute access to care.

Results indicate only a few neighbourhoods outside of the downtown core are ‘care-complete’, i.e., contain a sufficiently high mix of care destinations from all categories and sub-categories. However, some neighbourhoods are almost ‘care-complete’ and provide 15-minute access to some care categories. Our study frames these neighbourhoods on the continuum of ‘caring’ and in need of further intervention. The quantitative investigation conducted provides a high-level picture of what neighbourhoods (and their underlying land-use) are connected to transport infrastructure that can support reaching care-destinations.

Taken together, this study provides a theoretical bridge to connect 15-Minute Cities, accessibility analysis and Mobility of Care framework for the purpose of informing policy choice aimed to encourage just and sustainable mobility.

# Introduction

Caring is one of the most fundamental activities in societies, which has allowed humanity to survive and evolve. It involves activities targeted to meet physical, psychological, and emotional needs of others (ILO 2018). Yet, it is one of the worst devalued, underpaid, and unequal activities worldwide. Traditionally, caring activities have remained on women’s shoulders. Even though the society has evolved, and nowadays women attain higher educational levels and tend to work out of home more than ever before, the bulk of care remains (at any stage of her lifecourse) heavily on her shoulders. The Second Job or the Second Shift remains in all industrial societies, mostly women’s work (Hayden, 1982 (?Citation)) (Hochschild and Machung 2012).

This unequal share of caring responsibilities leads to gendered differences in among others, career development, differences in contract types and decision-making positions, unbalanced share of women in certain professions, gender pay gap, time poverty, as recognised by different international organisations (European Institute for Gender Equality, 2016 (?Citation)) (ILO 2018). In fact, already the first feminists in the United States observed that domestic labor was the most relevant basic cause of women’s inequality (Gordon 1976) (Hayden, 1982 (?Citation)).

According to the (ILO 2018), women and girls perform more than three-quarters of the total amount of unpaid care work and two-thirds of care workers are women. The caring economy is part of the women-dominated industries, it is characterised by the evaluative discrimination, which is only one of the dimensions of the gender pay gap (Mejia-Dorantes 2019). Especially in the case of domestic workers, care workers are most of the times women and migrants’ workers, with poor working conditions, and many times associated with informal jobs which imply lack of labour rights, no social and health protection, susceptible of exploitation, one of the poorest working conditions across the care economy as the ILO observes (ILO 2018). Care workers becomes disrespected, leading to a devaluation of their activity, and consequently remains as one of the less well-paid occupations a person can undertake.

If we turn our attention to the urban planning perspective, Caring is a major human activity that may take form in all urban settings, in all transport modes, all times a day and year, and yet it is not described as neither origin nor destination, and until recently, it was inexistent.

Researchers from various fields have highlighted that western modern industrial societies have imposed a physical separation of the private sphere from the public one, splitting production and reproduction, public and private spaces or simply work and home, concentrating on the economic outcome of being mobile (Cresswell and Uteng 2008; Law 1999; Levy 2013; Little 1994; Tronto and Fisher 1990). The man with legal rights, paid labour public sphere and woman in the private sphere, dependent, with family duties, personal relations and unpaid labour (Tronto and Fisher 1990). In this line, Cresswell and Uteng (2008) described how masculinity was related to mobile and active, whereas femininity to static. As an example of this dichotomy, transport planning historically framed non-work/school trips as ‘non-mandatory’ activities, downgrading these activities in comparison to work.

Women have consistently been found to complete more mobility of care trips than men. In one study, mobility of care comprised 32% of women’s daily trips compared to 28% of men’s. While this gap was significant, it was found to be far greater in lower income households where women complete 20% more care trips than men (Ravensbergen, Fournier, and El-Geneidy 2023). This gendered division in mobility of care is perhaps unsurprising as women tend to complete a disproportionate amount of household-serving labour, such as caring for children and other dependents, preparing meals, cleaning, and running errands, when compared to men (Moyser and Burlock 2018). This gender gap varies geographically (Ferrant, Pesando, and Nowacka 2014). In Canada, adult women complete 1.9 hours, on average, more of unpaid care than men every day (Moyser and Burlock 2018). This labour is essential, and a large component of daily life.

From this research motivation, Sánchez de Madariaga coined the term ‘mobility of care’ in 2013 to refer to all travel required to sustain the needs of a household, such as grocery shopping, escorting children, travelling to health appointments, and running errands (Sánchez de Madariaga 2013). While decades of research had examined these unique household-serving trips, her seminal work was the first to consider all these trips as one category. In doing so, she showed how mobility of care is a significant proportion of daily travel. Indeed, in her original work, and in the studies that have followed, it appears that approximately 30% of adults’ trips are for care purposes (Sánchez de Madariaga 2013; Sánchez de Madariaga and Zucchini 2019; Ravensbergen, Fournier, and El-Geneidy 2023). Sánchez de Madariaga not only shows how important these mobility of care trips are, but also highlights the ways in which “mobility of care is systematically under-represented in any analysis of urban transport” (p. 37). Transport surveys and tools do not directly capture mobility of care, which re-enforces the idea that these trips are not a significant part of daily mobility.

Cities have simplified individuals as a universal and neutral entity. As a result, public spaces are differently experienced depending on our multiple identities. Indeed, asymmetric in the distribution of time of citizens is deeply anchored with the public and private spaces organization within cities. In this light, we focus on the potential access to destinations of care through an empirical case study of the mid-sized city of Hamilton, Canada. We acknowledge that caring is composed by actors and activities but aim to spotlight the role that the urban environment plays on our daily lives, on easing our participation and on exercising our rights to the city as individuals with multiple identities. Our work hopes to contribute to a fruitful discussion that may trigger urban and transport policy interventions that increase gender-equity in caring activities among all actors.

## Feminist 15-minute neighbourhoods

Within the backdrop of urban planning and ‘mobility of care’, we connect our work to the 15-minute neighbourhood concept.

The spatial structure of cities and regions has been described in different ways and its advantages and disadvantages has been discussed with regard to a wide variety of issues, for example, regarding health, the environment, economic, social and equity impacts. After the traditional monocentric vision of the city with a core Centre Business District (CBD), other alternatives appeared, especially due to the expansion of cities caused by the automobile and motorized transport. The polycentric urban planning emerged based on the idea of sub-centers (or multiple business centers) with their own services and functions, well-connected among other surrounding areas, where the links between land-use and transport were optimised. Economic activities (such as retail or commercial office development) and job centers played an important role in shaping the spatial structure (Schneider 1981; Sweet, Bullivant, and Kanaroglou 2017). This concept may have different interpretations depending on the spatial and geographical scales (Hall 2009).

In the last decades, the need for more sustainable, healthier, and liveable cities has received more attention. Planners and policy makers have proposed different alternatives where residents reach “essential activities” within walkable or cycling distances, reducing the need for using motorised transportation modes. The 15-minutes cities, 20-minutes or x-minutes cities, have been long under the spotlight. This approach has also received the name of Chrono-urbanism or the “cities of proximity” (Logan et al. 2022; Moreno et al. 2021).

In the international context, there are different examples that highlight the importance of good access to different services and amenities within walkable distances. Probably one of the first cities to adopt the proximity approach was Portland. The Portland Plan (Portland 2010) was adopted by the City Council on April 25, 2012 aiming at fostering an inclusive city development for the following 30 years. The plan is based on the following principles: prosperity, education, health, and equity. The progress report states that equity should be achieved, an Office of Equity and Human Rights was established focusing on equitable service delivery to all residents. Nonetheless the progress report only measures progress on topics related to racial equity or people with disabilities (Government 2017).

In Paris, the adoption of the 15-Minute city put into the spotlight this approach. In Paris, they targeted six social functions that had to be easily accessible at any part of the city: housing, work, health care, groceries, education and leisure (Paris 2022). In 2021, Ottawa also adopted a 15-Minutes approach in the new City of Ottawa Official Plan (d’Ottawa 2021).

More recently, Moreno et al. (2021) considers four dimensions on how the 15-minute city framework: density (in terms of people per sq.km); diversity (including mixed-land use and diversity of people; the temporal and spatial proximity to essential services (residential areas, work, commercial areas, education centres, health facilities and other basic institutions) and digitalisation.

It can be observed that the feminist perspective of the cities of proximity is still underestimated. Only few examples exist that specifically target this issue (Gil Solá and Vilhelmson 2022; MacIntyre 2022).

Even if we are on the right direction to facilitate caring activities, develop human-centred urban areas, the chrono-urbanism needs to set the ground on aspects that specifically target caring activities and gender. Similarly, it is necessary to provide alternatives to measure progress on this important issue. On the other hand, an intersectional approach to understand how different personal identities interact in our daily day activities in the cities is necessary. There is still room for improvement.

## Mobility of care and mode-constraints

Given that almost one third of daily trips are for care purposes (Sánchez de Madariaga 2013), it is important to plan for mobility of care. There are also equity considerations to consider: as discussed, women, and especially low-income women, complete this travel more than men. Planning for mobility of care may also warrant different considerations because mobility of care trip characteristics differ from other trips, notably those of the commute to work. For instance, many of these trips are made through trip-chains, i.e., when a non-work-related stop is made during the commute. Women have been found to do so more than men, which is understood as being due to their need to balance unpaid-household serving care and paid employment (e.g., picking up groceries or children on the way home from work) (Ravensbergen, Fournier, and El-Geneidy 2023; Scheiner and Holz-Rau 2015).

Further, compared to the trip to work, mobility of care trips are more frequently completed by car and by foot, and less frequently done by transit or bicycle (Ravensbergen, Fournier, and El-Geneidy 2023). Evidence for why this modal difference is observed exists. For instance, it is possible that walking is more common for care than for work trips because care trips tend to be short (Ravensbergen, Fournier, and El-Geneidy 2023). In other words, if care destinations are closer to the home, it is more likely that these destinations are walkable. Ample literature examines the benefits and barriers to walking care destinations, such as schools (e.g., (Omura et al. 2019; Yu and Zhu 2016; Napier et al. 2011)) and grocery stores (e.g., (Morioka et al. 2023; Negron-Poblete, Séguin, and Apparicio 2016)). Little of this work uses the mobility of care framework. Instead, it tends to consider singular care destinations in research focusing on walkability.

In car dependent cities, cycling commute rates tend to be low. Emerging evidence has found that they are even lower for care trips than for work trips. For instance, in Montréal it is estimated that 2% of work trips completed by adults are done by bicycle, while only 1.1% of care trips are done using this sustainable travel mode (Ravensbergen, Fournier, and El-Geneidy 2023). Qualitative research has also found that in car-dependent contexts, many consider it inappropriate and unsafe to conduct escort trips by bicycle (Ravensbergen, Buliung, and Sersli 2020; Sersli et al. 2020). Then again, other studies have uncovered the joys inherent in travelling by bicycle with children (McIlvenny 2015). This qualitative evidence has also found that the bicycle is excellent for trip-chaining owning to its flexibility and ease of parking, and that grocery shopping can be done by bicycle, though this can require some additional materials (e.g., paniers) and competencies (e.g., knowing where to put your groceries)(Ravensbergen, Buliung, and Sersli 2020). Research in the Netherlands, a high-cycling context, has found that parents can and do use their bicycles to complete mobilities of care. Indeed, one study compared women with children’s bicycle behaviours to those without children and found that the having a child did not change the amount of cycling done, but the characteristics of cycling trips: mothers’ trips tended to center around their childrens’ needs (Eye and Ferreira 2015). Taken together, it is evident that the bicycle has potential to serve mobility of care: it is flexible, low-cost, and used for these trips in many contexts. Other barriers to this travel mode seems to exist in low-cycling contexts.

The difference in uptake of public transport for work compared to care trips is staggering. In Montréal, it is estimated that 18.7% of trips to work are made by transit. In contrast only 5.8% of care trips are made using transit (Ravensbergen, Fournier, and El-Geneidy 2023). While research examining accessibility to care destinations by transit exists (e.g., (Michael J. Widener et al. 2015; Michael J. Widener et al. 2017; Niedzielski 2021; Ermagun and Tilahun 2020)), little research examines why few people use this sustainable transport mode for mobility of care. Though transit use for mobility of care is low, one study found that is it is significantly higher for low-income women. Indeed, approximately 16% of low-income women in Montreal were found to use transit for care trips (compared to 4% of high income women) (Ravensbergen, Fournier, and El-Geneidy 2023). In many cities, public transport is not designed to meet household demands in a convenient way (Dowling 2000; Grant-Smith, Osborne, and Johnson 2016). Given how low transit use is for care trips amongst the general population, it is possible that many of these low-women using transit are transit-dependent. In other words, they may be using transit for care trips because they do not have access to a car, and not because transit is their preferred travel mode.

It appears that the car is the preferred travel mode for mobility of care. In one study, car use was higher for mobility of care trips than the commute to work (82.3% vs. 74.7%) (Ravensbergen, Fournier, and El-Geneidy 2023). Further, the rate of car use is higher amongst trips that are part of a chain than those that are not (85.28% v. 78.09%) (Ravensbergen, Fournier, and El-Geneidy 2023). Some studies found that a car is viewed as the easier way to incorporate unpaid mobility of care into one’s daily travel as it provides convenience and mitigates concerns about traffic and stranger danger Carver, Timperio, and Crawford (2013). Others, however, have found that women are more likely to complete household-serving travel duties by alternative modes than men due to their lower car access (Scheiner and Holz-Rau 2012; Vance and Iovanna 2007). It seems that car use may be preferred for mobility of care trips, but planning mobility of care for the car may leave those who do not have access to a car, many of them low-income women, with difficult mobility of care trips.

The discussion around mobility of care and travel mode may also be relevant to larger spatial trends, including gendered spatial entrapment. Feminist geographers have noted for decades the spatial impact of women’s disproportionate household-serving labour. A relationship has been noted whereby many women’s household responsibilities results in job searches that emphasize job opportunities that are near the home and part-time or with flexible hours to allow for care responsibilities. This leads to a lower probability of securing higher paid, and often further afield, employment (Hanson 2010; Law 1999; Hanson and Pratt 1988; England 1993). This trend has been found to be surprisingly resilient, with improvements only taking places slowly (Wheatley 2013). Evidence has also shown that this spatial entrapment can be more in car dependent contexts, as access to cars impacts employment rates (Ong and Miller 2005), and is lower amongst women, and especially women of colour (Matsuo 2020).

Taken together, there appears to be a preference for travel by car for mobility of care trips. This is problematic, however, in at least two major ways. First, cars are less sustainable than other modes of transport. Normalizing car use for care trips does not advance the low-carbon transport transition that most cities are aiming for (at least in principle!). Since care trips tend to be short, they are also perfect candidate to be completed by bus, bicycle, or by foot. That is, if these alternative and sustainable modes are planned with care in mind. Second, there is equity concerns with assuming people are accessing care destinations by car. Many people, and low-income women in particular, do not have access to a car. Some are also experiencing a degree of spatial entrapment. Having safe and convenient access to care destinations using alternatives to the private car is especially important for those who must rely on these options regardless of whether they are well planned.

RESEARCH OBJECTIVES:

1. 15 minute cities stem from conventional methods that ignore mobility of care perspectives. There is an applied way of doing this,
2. Use of the innovative destination dataset
3. Mid-size typical Canadian city, how frequently do we find these caring neighbourhoods (potential - accessibility).
4. Who enjoys them and who does not? Clustering methodology.
5. Types of profiles will emerge – i.e. with LICO > X + Prevalence of children >Y + walking accessibility score > U + diversity score > W = “caring neighbourhood”

WE SHOULD ALSO ADD DISCUSSION ON WHAT SOCIO-ECONOMIC AND DEMOGRAPHIC VARIABLES ARE SIGNFICANT IN THE CONTEXT OF MOBILITY OF CARE + 15 MINUTE CITY

# Data and Methods

## Case study context

In Canada, women have become more educated and have an achieved an increased participation in the labour market (Government of Canada 2023a). In fact, the educational level of women has surpassed most men (Government of Canada 2023b). Reports observe that the gender pay gap has narrowed but disparities persist (Drolet and Mardare Amini 2023; Pay Equity Office 2023). According to the statistics, in Ontario between 1998 to 2022 the gender gap narrowed but still women make 87 cents on average for every dollar made by a man (Pay Equity Office 2023). All reports observe that it affects women differently, women with disabilities, immigrants, indigenous or racialized suffer especially from the gender pay gap. Similarly to other countries worldwide, the occupational segregation remains and women are segregated into lower paid job classes and there is a dominance of women in minimum wage jobs (Drolet and Mardare Amini 2023). Furthermore, women are underemployed, and make up most part-time work. In this respect, the lack of childcare alternatives enforces this obligatory part-time work (Coalition 2022). All researchers and organisations agree that an intersectional approach is of utmost importance to better plan policies to enforce gender equality.

* Next: we describe Hamilton’s land-use context; communities which are urban, rural, suburban. Also describe the residential parcels summary statistics, ~140,000 points, aggregated at the level of Canadian Census DA. See parcel, population and population per parcel plots in [Figure 1](#fig-Fig1):

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| Figure 1: The number of residential parcels per DA in 2020 (top), the population (middle) retrieved from the 2021 Canadian Census, and the rate of population per parcel per DA (bottom). All scales in quartiles. Basemap shapefiles are sourced from the Open Data Hamilton Portal (Hamilton 2023b) and the USGS (USGS 2010). |

Some of the socio-economic and demographic variables that characterise accessibility and the diversity of accessibility to care destinations are pictured in [Figure 2](#fig-Fig2):

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| Figure 2: Socio-economic and demographic variables that characterise accessibility to care destinations retrieved from the 2021 Canadian Census. All scales in quartiles. Basemap shapefiles are sourced from the Open Data Hamilton Portal (Hamilton 2023b) and the USGS (USGS 2010). |

## Estimated travel times

Here we will describe the estimated 15-minute walk travel times using {r5r}, from all residential parcel points to all care destinations assuming default walking speed (3.6km/hr) and OSM road network for Hamilton. Provide summary statistics.

## Care destination dataset

A spatial dataset of care destinations for Hamilton was compiled; sources include provincial and municipal open data portals (Ontario 2023b; Hamilton 2023c), Data Axle, a consumer dataset compiled of businesses and companies within Canada (Axle Data 2023) and manual retrieved through Google Maps. Each destination was categorized based on the specific type of care being accessed following the mobility of care research by Sánchez de Madariaga and Zucchini (2019). Initial categories include child, elder, grocery, health, and errand -centric destinations. For the purpose of this study, child- and elder- centric are combined to represent a ‘dependent-centric’ category. Category sources of data and preparation notes are detailed in [Table 1](#tbl-Tbl1). Their spatial distribution and sub-categories are visualised in [Figure 3](#fig-Fig3).

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| Table 1: Details on the preparation and data sources of care destinations.   | Care category | Sources | Data preparation notes | | --- | --- | --- | | Child-centric | (Hamilton 2022a, 2023, 2022c, 2022d; Ontario 2023b) | Schools, 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 2023a), were kept due to their innate connection to care. | | Elder-centric | (Hamilton 2022d; Ontario GeoHub 2023) | Senior centres, long-term care homes, and retirement homes: 75 destinations are identified. | | Grocery-centric | (Axle 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 GeoHub 2023; HNHB 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 (Hamilton 2022b), post office locations (Axle Data 2023; Canada Post 2023), and datasets of all national bank chains (BMO 2023; HSBC 2023; National Bank 2023; RBC 2023; Scotiabank 2023; TD 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 Data Axle and then cross-referenced to ensure data quality with a Bank Locator website for all national banking firms. | |

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| Figure 3: The locations of care destinations in Hamilton separated by the author-generated categories of: dependent-, errand-, grocery- and health- centric care categories. Basemap shapefiles are sourced from the Open Data Hamilton Portal (Hamilton 2023b) and the USGS (USGS 2010). |

## Methods

Cumulative opportunity method; 15-minute normative catchment for walk mode is used to represent the 15-minute neighbourhood concept. This has been done in previous literature such as Vale and Lopes (2023), Graells-Garrido et al. (2021) and Gaglione et al. (2022).

In this work, the cumulative opportunity score is calculated for each parcel and aggregated by care category and takes following mathetical form:

Where:

* is a set of parcel point origin locations.
* is a set of destination locations.
* is a set of care categories.
* is a number of opportunities of category at .
* is the travel cost between and .
* is an impedance function of ; within the cumulative opportunity approach, it is a binary function that takes the value of 1 if is less than a selected value (Handy and Niemeier 1997).
* is the unconstrained accessibility, the sum of weighted opportunities reachable within , at each for each .

*Entropy* measure has been widely used to characterise the diversity of land-use mix in early work by Frank et al. (2005) based on the species diversity Shannon-Wiener index that expresses relative evenness throughout a sequence (this measure among other species diversity indices of the time are reviewed in Whittaker (1972)). In the realm of urban studies and planning literature, it has since been widely used to characterise the diversity in land-use mix (Ewing and Cervero 2010), especially in the context of active modes (Lu, Xiao, and Ye 2017; Mavoa et al. 2018) and suburban sprawl (Randall and Baetz 2015). Work that has used diversity indices alongside accessibility analysis are scarce, though examples of its use as parameters within accessibility scores in the case of employment opportunities (Cheng and Bertolini 2013; Dai et al. 2018) and more recently to describe the diversity in transit facilities (Yin, Zheng, and Li 2024) are present. To the authors knowledge, the use of an entropy measure to reflect the diversity in care destination amenity types and in context within a 15-minute neighbourhood, has yet to be done.

As such, the entropy measure is used to reflect the diversity of care destinations categories. The value ranges from 0 to 1, with 1 representing total evenness in the number of care opportunities in each category that can be reached. is a parcel, is the category of care destinations, is the count of care destination categories (in this work 4), is the spatial accessibility of care destinations within a 15-minute walk for a parcel, and is the diversity. As represents evenness in categories, a parcel can be assigned a diversity of 1 if it has =1 of each category or if it has =100 of each category. Contrariwise, it can be assigned a low score if it has low but different scores for each category as well as if it has high but different scores for each category.

Self organizing map (**SOM**) is used to cluster the types of neighbourhoods by their magnitude in 15-minute walking accessibility to caring opportunities and diversity in these opportunities and profile these clusters based on their socio-economic characteristics. SOM is a type of artificial neural network (ANN) trained using unsupervised learning that produces a two-dimensional representation of the input space. It is a dimensionality reduction method as it applies competitive learning by way of a neighbourhood function thereby preserving the topological properties of the input space and producing combinations of the input space that we intuitively profile. It has been used in transportation related research, e.g., Victoriano, Paez, and Carrasco (2020).

The SOM procedure is broken into 2 steps: first, five superclusters of the four scores and the diversity score are identified. The number of superclusters strike a balance between variance explained and supercluster interpretation in what we define as ranging from “not caring” to “very caring” and “not complete” to “complete”. Second, the superclusters are profiled using a variety of socio-economic and demographic indicators that the mobility of care literature finds significant ([Figure 2](#fig-Fig2)).

# Results

Accessibility per category [Figure 4](#fig-Fig4):

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| Figure 4: The number of care destinations that can be reached within 15 min walk per care category for a median parcel in each DA. Scales are in quartiles. These are four of five inputs into the superclusters. Basemap shapefiles are retrieved from the 2021 Canadian census (Statistics Canada 2023), the Open Data Hamilton Portal (Hamilton 2023b) and the USGS (USGS 2010). |

Diversity [Figure 5](#fig-Fig5):

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| Figure 5: The diversity measure based on the proportion of care category spatial accessibility (figure 4). Scale is in tertiles. The fifth input into the superclusters. Basemap shapefiles are retrieved from the 2021 Canadian census (Statistics Canada 2023), the Open Data Hamilton Portal (Hamilton 2023b) and the USGS (USGS 2010). |

Superclusters based on accessibility per category and diversity (the two above figures). 5 clusters are identified, see their dendrogram (right) and grid map (left) in **?@fig-Fig6**:

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| Figure 6: The 5 resulting superclusters from the SOM output (left) and the associated dendrogram structure (right). |

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| Figure 7: The 5 resulting superclusters from the SOM output (left) and the associated dendrogram structure (right). |

The constitution of the superclusters in shown in the decision tree diagram in [Figure 8](#fig-Fig7). Decision trees area a supervised learning technique, which can use the results of the clustering algorithm as labels, and the input variables as features. The clustering algorithm performed well as class membership is relatively homogeneous as the majority of bar plots consist of a supermajority of one type of supercluster class membership, i.e., supercluster 5 are parcels that have an Errand-centric access of less than 0.5 opportunities (bottom quartile), a diversity score of less than 0.277 (bottom tertile), and any Dependent-centric access score of greater than 0.5 (and can take on any value of the remaining input variables). This technique provides a data-driven approach to supercluster formation which we then attribute meaning to.

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| Figure 8: The decision tree profiles of the SOM output. |

The dendrogram demonstrating the supercluster class membership of each parcel in [Figure 8](#fig-Fig7) is summarized, with our interpretation, as follows: - Very caring (mean category accessibility between 4 to 18.6 and total accessibility median of 46) - very complete (diversity index of mean 0.9 and median 0.90) (SCluster 2) - Caring (mean category accessibility between 2.1 to 9 and total accessibility median of 18) - complete (div index of mean 0.81 and median 0.82) (SCluster 1) - Somewhat caring (mean category accessibility between 0.2 to 6 and total accessibility median of 13) - complete div index of mean 0.71 and median 0.74) (SCluster 4) - Somewhat caring (mean category accessibility between 0.2 to 6 and total accessibility median 7) - not complete (div index of mean 0.36 and median 0.40) (SCluster 3) - Not caring (mean category accessibility between 0 to 4.7 and total accessibility median of 3) - not complete (div index of mean 0.02 and median 0) (SCluster 5)

To further visualize supercluster membership, we spatially demonstrate which supercluster best describes each parcel in [Figure 9](#fig-Fig8) (top plot): the median parcel’s supercluster membership per DA is tabulated and the majority membership is represented. Visually, the super clusters closely follow the quartile split of the accessibility to care destinations (all categories combined) and tertile split of the diversity scores (visualised in [Figure 5](#fig-Fig5)).

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| Figure 9: The median parcel supercluster membership (top). The parcel median total accessibility (bottom). The parcel m Basemap shapefiles are retrieved from the 2021 Canadian census (Statistics Canada 2023), the Open Data Hamilton Portal (Hamilton 2023b) and the USGS (USGS 2010). |

To enhance the meaning of the superclusters beyond a spatial conceptualisation of “caring” and “complete”, was *who?* resides there. We implement another decision tree in which the population-weighted socio-demographic characteristics of the parcels (retrieved from the 2021 Canadian Census) are input variables and the resulting output are ‘socio-domographic superclusters’ of the caring/complete superclusters. The input variables included: % households below median household after-tax income, LICO prevalence, average number of children per household, % not in the labour force, Gini index on adjusted household after-tax income, % visible minority, % population aged 0 to 14, % single parent household, % who walk to work (relative to bike, care/truck/van, public transit and ‘other’), % of owner household in core housing need (i.e., inadequate housing structure or paying higer than 30% income on housing), % of owner households with a mortgage, % of tenant households in subsidized housing, % of tenant households in core housing need, % no certification, diploma or degree (relative to population with high school, college, or university certificate, diploma or degree).

Of all the variables, those that proved to be significant in profiling the five superclusters were only four variables: % households below median household after-tax income (bottom income), % population aged 0 to 14, % single parent household, and LICO. See [Figure 10](#fig-Fig9) that provides the splits. Unfortunately, the supercluster membership is not as homogeneous as the caring/complete supercluster dendrogram ([Figure 8](#fig-Fig7)). However, we can interpret the socio-demographic superclusters (five that result) as labels to tell a narrative of who may reside in what caring/complete supercluster.

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| Figure 10: The dendrogram of the supercluster demographic profiles.. |

(NOTE: for reference, see the old bivariate map in the appendix for comparison)

In [Figure 10](#fig-Fig9), discussing from right-to-left, parcels in DAs with 45% of the population below the median or lower (richer) are often classified with poor accessibility: either “Somewhat caring and not complete” SC3 or “Not caring and not complete” SC5, where parcels within DAs with a higher proportion of single parent households (13% and above) are most often SC3 and below are most often SC5. For parcels with higher than 45% of bottom-income (poorer), those with a high proportion of children (age 0 to 14) are also likely to be within the “Somewhat caring and not complete” SC3 - just like parcels in richer and more-single-parent DA counterparts.

These findings related to potential child-care access are notable: single parents provide more care and hence may be more likely to choose, if they are able, more accessible neighbourhoods than the rest of the population in the same household income grouping. In a Canadian and U.S. context, households with children may locate to catchments with ‘better’ schools, often more suburban with lower potential access scores overall.

Interestingly, parcels in DAs with lower than 13% children population demonstrate a better accessibility to care destination story. Parcels within DAs that constitute more than 45% population below median household income (poorer) - especially above 9.8% LICO (low income cut-off prevalence - likely to be the poorest) are often within “Very caring and very complete” SC1. Parcels located in DAs with the same lower median income and child population but have *lower* than 9.8% LICO (not the poorest) also have good accessibility, as they are most often in “Caring and complete” SC1 as well as being in most often in the “Somewhat caring and complete” SC4 relative to other parcels.

Our findings illustrate differences in patterns of 15-minute walk accessibility to care destinations most prominently profiled by income, low-income prevalence, children and single-parent status.

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# Appendix

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| Figure 11: A bivariate map of the cumulative opportuninities map (aggregated per category at DA) and the diversity measure. Amenity diverse = diviersity index above the region median. Caring/Complete = accessibility value above the region median. The Basemap shapefiles are retrieved from the 2021 Canadian census (Statistics Canada 2023), the Open Data Hamilton Portal (Hamilton 2023b) and the USGS (USGS 2010). |