Identifying 15-minute neighbourhoods with complete caring potential

Anastasia Soukhov

Léa Ravensbergen

Lucía Mejía Dorantes

Antonio Páez

# Abstract

The “15-Minute Neighbourhood” concept has been adopted by leaders around the world as a way to promote human-scale cities. The concept emphasizes a transport and land-use mix that supports short-trips to daily necessities by foot or bicycle from ones’ residence. This study adopts the 15-minute neighbourhood concept through the lens of “Mobility of Care”, a framework that foregrounds travel to care destinations, travel done predominately by women, in contrast to the better-studied travel to employment and leisure. While the 15-minute neighbourhood concept is flexible enough to consider all destination types, gendered examinations are relatively lacking in the literature and no research to date has focused explicitly on care destinations. In this study, we address these gaps by identifying which areas in Hamilton, Canada have the potential to be ‘caring 15-minute neighbourhoods’. To do so, a database of care destinations was compiled and used to estimate both the number (cumulative opportunities indicator) and diversity of mix (entropy measure) of destinations reachable within a 15-minute walk from all residential parcels. Parcel-level results were classified into ‘caring’ (quantity of reachable opportunities) and ‘complete’ (diversity of care destinations) neighbourhood typologies of varying degrees using machine learning techniques (Self-Organizing Maps (SOM) and hierarchical clustering). Inequalities in the relationship between the identified caring typologies and social-economic indicators of who currently reside in the neighbourhoods were then explored. Our results suggest the majority of ‘caring and complete’ neighbourhoods are within the urban core where a higher proportion of lower-income households reside. Contrawise, neighbourhoods that are ‘not caring and not complete’ are located in peripheral regions that tend to have higher household incomes. Further, certain neighbourhoods in suburban and rural communities are ‘caring and somewhat complete’, showing the potential to become ‘complete’ through possible urban policy intervention. Implications of neighbourhoods that have a high potential to be improved, and socio-demographic characteristics associated with income such as single-parent households and economic poverty are discussed. Taken together, this study offers a theoretical bridge to connect Mobility of Care and the 15-minute neighbourhoods concept, a data-driven classification and clustering methodology to assess neighbourhoods on a ‘caring and complete’ continuum, and discussion of implications relevant to gender mainstreaming within transportation planning.

Keywords: Accessibility; 15-Minute Neighborhoods; Chrono-Urbanism; Cities of Proximity; Mobility of Care; Inequality; Gender Gap;

# Introduction

The “15-Minute City” has been recently adopted by leaders as a way to promote human-scaled cities (Teixeira et al. 2024). As introduced in Moreno et al. (2021), the 15-Minute City is a urban planning model based in chrono-urbanism, a theory that emphasizes the positive impact on quality of urban life when urban space becomes multi-rythmic, in opposition to the segregation of urban time and space for individual uses and mobility (Mulíček, Osman, and Seidenglanz 2015; Moreno 2016). It is in opposition to the forces that supported the formation of single-use neighbourhoods such as industrial Fordism and single-use zoning (Mulíček, Osman, and Seidenglanz 2015; Moreno 2016). The “15-Minute City” refers to a city where relevant destinations within a walkable (or bikeable or transit supportive) radius are reachable by all. This form of neighbourhood planning would allow individuals to reclaim time spent on car mobility, giving way to sustainable modes and prompting urban spaces that are responsive to human needs and environmental sensibilities (Allam et al. 2022).

Though the term 15-Minute City is relatively new, neighbourhood planning practice aiming to foster community and local travel to amenities is not. As recent examples, planned neighbourhoods dominated post-WWII built urban form: the Neighbourhood Unit Concept in the western world (Brody 2013) and a parallel concept of the “mikrorayons” neighbourhoods in the Soviet Union (Kissfazekas 2022). Along different dimensions, these planning forms have been extensively critiqued (Talen 2017). In this respect, neighbourhood planning approaches such as the 15-Minute City concept are being re-embraced by some, but from bottom-up perspective using co-creation tools and meaningful resident participation to achieve equitable and justice neighbourhood forms (Mahmoud and Morello 2021). How to equitably prescribe urban form that ‘enables’ contact with social opportunities (instead of ‘engendering it’ from the top-down) is still under debate. For instance, questions such as *what* are destinations that matter, by what mode and travel time threshold, and *for whom* remain under discussion among proximity-based planners who frequently use accessibility-based tools (Silva et al. 2023; Silva and Altieri 2022; Guzman, Oviedo, and Cantillo-Garcia 2024).

From another perspective, feminist geographers, urban planners and other research groups agree that urban structure influences travel, but city planning fails short when planning for a neutral identity. In contrast, cities ought to be planned according to the multiple identities of the inhabitants (Vacchelli and Kofman 2018; Urban Development Vienna 2013). Researchers have demonstrated how mobility patterns differ according to gender (Law 1999; Cresswell and Uteng 2008; Levy 2013; Little 1994; Tronto and Fisher 1990). Gender and social norms and cultural factors play a role in how, where, with whom, what for, and how far we move. Women have higher activities related to care (ILO 2018), no matter at what life stage they are (García Román and Gracia 2022). For all these reasons the spatial organization of activities has a different impact according to gender, the 15-Minute City concept cannot be gender blind.

To clarify questions surrounding the 15-Minute City concept of what destinations matter and for whom, this work builds a theoretical bridge to “Mobility of Care”. The Mobility of Care term was coined in Sánchez de Madariaga (2013); it refers to all travel required to sustain the needs of a household, such as grocery shopping, escorting children, travelling to health appointments, and running errands. While decades of research have examined types of household-serving trips (e.g., shopping trips, escorting to school), Sánchez de Madariaga (2013) was the first to consider them all as one category. In doing so, Mobility of Care is shown to be a significant proportion of daily travel, characterizing the trip purpose of approximately 30% of adults’ trips (Sánchez de Madariaga 2013; Sánchez de Madariaga and Zucchini 2019; Ravensbergen, Fournier, and El-Geneidy 2023). We argue Mobility of Care is especially relevant to the 15-Minute City, as care trips are necessary for *all* people and they most often occur at the local level. Moreover, care trips take on tremendous gendered and socio-economic importance, as women, and especially those from lower income households, complete the majority of care trips (Ravensbergen, Fournier, and El-Geneidy 2023). Despite care travel’s importance in advancing gender equality and equity broadly, the examination of mobility of care and access to care destinations have been under-examined relative to employment destinations. This is especially pertinent in accessibility research that has largely focused on employment points of interest e.g., (Farber and Allen 2019; Duarte, Mota Silveira Neto, and Silva 2023; Ryan, Pereira, and Andersson 2023).

The objectives of this research are two-fold. First, we aim to theoretically bridge Mobility of Care with the 15-Minute City concept to to re-imagine what local amenities matter and define an associated accessibility and diversity of accessibility measure. Second, taking a bottom-up data-driven approach, we apply a classification and clustering machine learning methodologies to support the bottom-up identification of *15-minute caring neighbourhoods* through an empirical examination of the mid-cited city of Hamilton, Canada. These neighbourhoods are then interpreted on the continuum of having (and not having) the region-relative land-use and transportation infrastructure to support *completely caring* access. Who currently resides in which neighbourhood is examined, and ways to further expand the care accessibility story are discussed.

# Review of neighbourhood planning literature

## From the 15-Minute City to the NUC

In the last decades, the need for more sustainable, healthier, and livable cities have received significant attention. Planners and decision-makers have proposed alternatives to mobility-based neighbourhood planning principles to ones that center proximity to urban functions (Pozoukidou and Chatziyiannaki 2021). In this context, the 15-Minute City is now in the public spotlight (Logan et al. 2022; Moreno et al. 2021). In Moreno et al. (2021) where the 15-Minute City concept was introduced, four universal dimensions are outlined: density (in terms of people per km), diversity (including mixed-land use and diversity of people), the temporal and spatial proximity to essential services, and digitalisation. However, the framework presented has been criticized within academic and planning circles (Guzman, Oviedo, and Cantillo-Garcia 2024). Critiques highlight the concept falls short in addressing the pre-existing structural forces and individual characteristics that drive inequalities, influencing who benefits or could benefit the most from such a paradigm (Di Marino et al. 2023; Willberg, Fink, and Toivonen 2023). A 15-Minute City for all people is an aspirational ideal, but how will existing mobility and accessibility inequalities be addressed. Without directed and context-specific solutions, this increasingly popular concept risks becoming a place-branding slogan (Pozoukidou and Chatziyiannaki 2021).

Reflecting the flexible and aspirational presentation of the 15-Minute City; cities that have adopted the concept have done so using a diverse range of definitions and tools along with indistinct universal approaches. A trail blazer was Portland, US in the Portland Plan (Portland 2010) of April 2012. Adopted before the ‘15-Minute City’ concept of today, it aims to foster an inclusive city development based on prosperity, education, health, and equity over a 30 year horizon. The plan aims to promote neighbourhood self-sufficiency and connectivity to city centers and centres of employment. The progress report describes a high-level focus on equitable service delivery to all residents with equity concerning topics related to racial equity and people with disabilities (Government 2017), similarly taking on an “all populations” approach. Later, other cities also incorporated proximity-based goals into their plans, adopting similar neutral entity approaches. For instance, in the plan that later catapulted the 15-Minute City into public discourse: Paris mayor Anne Hidalgo proposed a 15-minute city plan in her 2020 re-election campaign that foregrounded six social functions that should be easily accessible from any location, namely: housing, work, health care, groceries, education and leisure (Paris 2022). These ideas inspired language in the agendas of other cities in the Western world such as Ottawa, in the Canadian context, who also adopted a 15-Minutes approach in their recent Official Plan (d’Ottawa 2021). From the review of worldwide practice literature in Teixeira et al. (2024), the 15-Minute City concept is in early phases of implementation around the world and the diverse range of definitions, strategies, and instruments present a significant knowledge and implementation gap: the 15-Minute City is aspirational but *how do we get there and whom will benefit*?

The past can shed light on cautionary tales. While the 15-Minute City concept is new, neighbourhood planning to improve society outcomes is not: in fact the literature has drawn parallels from the 15-Minute City to Clarence A. Perry’s Neighbourhood Unit Concept (NUC) from the 1930s (Kissfazekas 2022). The NUC is a socio-spatial normative scheme widely adopted by government agencies (and the real-estate community) in the Western world after the Second World War (Talen 2017; Solow, Ham, and Donnelly 1969). Pairing well with the objectives of planning agencies at the time, Perry’s NUC would allow for efficient mass-building of cellular units that prioritized the perceived functional needs of women and children: each unit providing proximate access to an elementary school and supporting community facilities, shopping, parks and housing (Talen 2017; Brody 2013). The NUC primarily prioritized local service provision, though Perry had confidence in good design’s contribution to ‘neighbourhood spirit’ (Hall 2014). From the NUC’s conception until the end of the 1960s, planners’ aspirational attempts to prescribe social meaning to the neighbourhood’s physical form had been criticized to near extinction (Talen 2017). By social scientists, the overestimation on the impact of built environment on social life was critiqued. By other planners, the inability to agree on the specificity of the neighbourhood (i.e., population size and the type, quality, and quantity of amenity) as well as how neighbourhood units are connected to other neighbourhoods and the rest of the region. In response to these criticisms, neighbourhood planning proponents redefined deterministic terminology; their prescriptive physical form will ‘enable’ social contact with opportunities rather than ‘engendering’ it.

The re-defined bottom-up approach to community and neighbourhood planning has been adopted by New Urbanists, from which the 15-Minute City stems (Kissfazekas 2022); however, the effectiveness of these bottom-up processes remain to be seen due to the contemporary nature of the concept. Though, related research can be examined. In recent years, the question of *how can physical form be planned to enable an improved quality of life, and for whom with what outcomes* has occupied the urban planning research agenda. For instance, the examination of low-income households access to transportation and their likelihood of gaining employment (Blumenberg and Pierce 2017; Bastiaanssen, Johnson, and Lucas 2022) or the relationship between children’s access to public transit and participation in after-school activities (Palm and Farber 2020). A new wave of researchers and practitioners focused on local and context-specific relationships with the proximity to destinations have also emerged (Silva et al. 2023; Silva and Altieri 2022). As reviewed in the city plans that have adopted 15-Minute City approaches, the NUC’s criticisms, and recent urban planning research, the question of *how to enable improved quality of life through urban built environment* has shown to be highly context-sensitive, with the need for further investigation.

## Tools: accessibility methods, diversity measures and typology-classification

In examining how to enable improved quality of life through urban built environment, an increasingly popular tool have been accessibility measures. These measures are a way to quantify the ease of reaching destinations from a given point in space and have been used to examine urban areas through just and sustainable city planning agendas (Vale and Lopes 2023; S. Handy 2020). As the 15-Minute City is an amenity-provision neighbourhood planning concept which aims to enable urban environment that improves life quality, its analysis lends well to the use of accessibility tools (Guzman, Oviedo, and Cantillo-Garcia 2024). Foreseeably, recent works have applied accessibility measures to investigate the 15-Minute City across various geographic scopes. For instance, in Naples, Italy (Gaglione et al. 2022), Barcelona, Spain (Graells-Garrido et al. 2021), Vancouver, Canada (Hosford, Beairsto, and Winters 2022), and in urban areas across Europe (Vale and Lopes 2023). The “cumulative opportunity” measure has been applied to many 15-Minute City accessibility examinations. This form of accessibility quantifies how many destinations can be reached from a point in space within a given travel time threshold, pairing well with examinations that have a normative travel time threshold, like the 15-Minute City. Furthermore, the cumulative opportunity measure is widely appreciated for its intuitive computation and popularity among practitioners (S. Handy 2020; S. L. Handy and Niemeier 1997; L. Cheng et al. 2019). However, accessibility measures other than the cumulative opportunity have also been applied, reflecting the diversity of measures in the literature (Guzman, Oviedo, and Cantillo-Garcia 2024).

Another method which compliments the assessment of the 15-Minute City as it relates to the diversity of opportunity types, is entropy. The 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 (see review in Whittaker 1972). It has also been used in social sciences to comprehend the occurrence of social events in a structured manner specially with regard to life trajectories (Ritschard and Studer 2018). In the realm of urban studies and planning literature, the malleable concept of entropy has been 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). As well, it has been used to understand mobility behaviour (McBride, Davis, and Goulias 2020; Montero, Mejı́a-Dorantes, and Barceló 2023a, 2023b). 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 (J. 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. However, entropy measures theoretically compliment the 15-Minute City concept.

In addition, classification algorithms have been useful tools in the identification of mobility and spatial typologies in relation to transportation planning. Machine learning approaches have often been deployed. For instance, Burke et al. (2022) uses spatially constrained multivariate clustering, a regionalisation technique, to develop urban form typologies related to the 15-Minute City. The k-means algorithm is another popular method; Gan et al. (2020) applies it to analyse travel behaviour and classify metro stations based on mobility patterns. Similarly, (Montero, Mejı́a-Dorantes, and Barceló 2023b, 2023a) cluster travel behavior profile typologies representing different population segments and place of residence in Barcelona Metropolitan Area. Combing classification techniques is also common; for instance, Delmelle (2017) uses self-organizing maps (SOM) algorithm to group US neighbourhoods by minimizing dissimilarity in attributes before applying k-means for further classification. Similarly, Victoriano, Paez, and Carrasco (2020) uses SOM to classify individuals’ travel patterns according to the dissimilarity in mobility attributes and uses the decision tree algorithm to partition the data into interpretable classifications.

All-in-all, within the context of examining the 15-Minute City, a variety of tools have been applied in the literature. However, the question of *15-minute cities for whom* sill demands further examination. This work aims to bridge the concept of the 15-Minute City with another normative framework: Mobility of Care.

## Mobility of Care and feminist 15-minute neighbourhoods

Rather than focusing on *all* destinations, it may valuable to examine those related to caring activities. This re-framing offers a feminist perspective on *what* urban functions matter, connecting well with the 15-Minute City concept. Caring activities, which meet the physical, psychological, and emotional needs of others, are among the most essential and fundamental activities in society (ILO 2018). Yet, they are the most unequal, undervalued, and even devalued activities worldwide. Conventionally, caring activities have been borne on women’s shoulders (Hayden 1982; Hochschild and Machung 2012). According to ILO (2018), women and girls perform more than three-quarters of the total amount of unpaid care worldwide, a gender gap that varies geographically (Ferrant, Pesando, and Nowacka 2014). This unequal share of caring responsibilities leads to multifaceted gendered differences: in career development, profession selection, contract type, pay gap, and time poverty, as recognized by various international organisations (EIGE 2016; ILO 2018). In terms of spatial and transportation planning, almost one third of daily trips are for care purposes (Sánchez de Madariaga 2013; Sánchez de Madariaga and Zucchini 2019; Ravensbergen, Fournier, and El-Geneidy 2023). 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 an undercurrent of research had examined these unique household-serving trips over the decades, her seminal work was the first to consider all these trips as one category and demonstrate how mobility of care is a significant proportion of daily travel.

The Mobility of Care concept also explicitly integrates inter-sectional equity considerations. In considering Mobility of Care within the 15-Minute City one could address a common criticism leveled at the 15-Minute City (Guzman, Oviedo, and Cantillo-Garcia 2024). Perhaps unsurprisingly given the gendered division of care work discussed, 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 is 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). 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). As a product of the masculinst bias in planning, transport surveys and tools most of the times do not directly capture mobility of care, which re-enforces the idea that these trips are not a significant part of daily mobility. In this respect, the feminist perspective of the cities of proximity is still underestimated with only few examples on the topic (Gil Solá and Vilhelmson 2022; MacIntyre 2022).

Pairing well with the focus on shorter trips and the potential use of sustainable modes within the 15-Minute City, Mobility of Care trips are more local, shorter-distance and trip-chained. Compared to the trip to work, mobility of care trips are more frequently completed by foot, and less frequently by transit or bicycle (Ravensbergen, Fournier, and El-Geneidy 2023). However, little work to date examines walking to care destinations through the Mobility of Care framework. Though there is ample literature that examines walking to 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)), they tend to consider singular care destinations in research focusing on walkability.

The objectives of this research are two-fold. - First, we aim to theoretically bridge Mobility of Care with the 15-Minute City concept to re-imagine what local amenities matter and define an associated accessibility and diversity of accessibility measure. - Second, taking a bottom-up data-driven approach, we apply a classification and clustering machine learning methodologies to support the bottom-up identification of *15-minute caring neighbourhoods* through an empirical examination of the mid-cited city of Hamilton, Canada. These neighbourhoods are then interpreted on the continuum of having (and not having) the region-relative land-use and transportation infrastructure to support *completely caring* access. Who currently resides in which neighbourhood is examined, and ways to further expand the care accessibility story are discussed.

# Data

## Case study context

This work focuses on Hamilton, Ontario, a mid-sized city on the shore of Lake Ontario. Hamilton has a heterogenous land-use, with a populated and dense urban core, surrounded by suburban development, which is itself surrounded by rural communities. The Niagara Escarpment runs through Hamilton, and results in a city with two key elevations: a more dense lower city that contains the downtown core and the elevated suburban development referred to as ‘the Mountain’. In this work, we analyse the residential parcel centroids, 143,882 locations. We aggregated the points at the level of Canadian Census Dissemination Area (DA) along with the 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). |

Hamilton also exhibits spatial disparities in social and economic indicators; their spatial distribution is visualised in [Figure 2](#fig-Fig2). The densely populated inner city is characterised by lower average incomes, and a higher prevalence of households living under the low-income cutoff thresholds (LICO). Noteably, the suburban areas of the city tend to have a greater proportion of children and a lower proportion of one parent households.

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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). |

## Care destination dataset

A spatial dataset of care destinations for Hamilton was carefully compiled. The dataset includes 14 types of destinations that were placed by authors in ( *work removed for double-blind review* ) into four categories: dependent-centric (e.g., the destinations for child- and elder-centric escorting trips), grocery-centric, health-centric, and errand-centric. Notably, these categories were generated following the travel purpose categories created in the mobility of care research by Sánchez de Madariaga and Zucchini (2019). Category sources of data and preparation notes are detailed in [Table 1](#tbl-Tbl1). The spatial distribution of destination type are visualised in [Figure 3](#fig-Fig3) by their category.

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| Table 1: Details on the preparation and data sources of care destinations.   | Care category | Sources | Data preparation notes | | --- | --- | --- | | Depedent-centric | (Hamilton 2022a, 2023, 2022c, 2022d; Ontario 2023b; Ontario GeoHub 2023) | Schools, daycares, and community centres, recreation centres, parks, senior centres, long-term care homes, and retirement homes: 1,265 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. | | 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 cross-referenced 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 clinics 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. | |
| 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). |

## Travel time to care estimations

Summarized in the literature review, empirical travel behaviour to care-oriented destinations is often uncounted and thus travel time is unavailable. Hence in this work, travel time from the residential parcel locations and care destination locations is approximated for walking assuming an average speed (3.6 km/hr) using the ‘travel\_time\_matrix()’ function from the {r5r} package (Pereira et al. 2021). The inputs into the function are: the 143,882 locations of residential parcels as origins, the 2,225 care locations as destinations, and a OpenStreetMap road network including walking infrastructure (Geofabrik 2023). In theme with what destinations can be reached within 15-Minutes, a maximum walking travel time of 15 minutes is selected, and an origin-destination travel time matrix of the shortest travel time from origin to destination is calculated. The resulting matrix contains 2,014,502 rows, representing walking travel times from each parcel to reachable care destinations within 15 minutes.

# Methods

In the following sections, the methods taken to calculate the accessibility to each of the 14 destination types from each of the 143,882 residential parcel locations are detailed. Then, the entropy measures used to calculate the diversity of accessibility to each of the care categories is described. Subsequently, the accessibility and diversity of accessibility values associated with each residential parcel location are fed into a self-organizing map (SOM) algorithm. The resulting output is then classified into 7 superclusters the amount of “caring access” and “completeness” of this access. A Decision Tree, using the superclusters as features and socio-economic variables for the populations who reside in the city as lavels, is generated to identify patterns on who may benefit (or be excluded from) the potential of Completely Caring 15-Minute Neighbourhoods.

In sum, this methodology presents a data-driven approach to examine what neighbourhoods in a city have the potential to provide 15-minute caring access, at what level of intensity and completeness, as well as in who may be residing in areas that benefit the most.

## Accessibility: the cumulative opportunity measure

To capture the quantity of access to each type of destinations, a cumulative opportunity accessibility score is calculated. 14 scores for each type of care destination is calculated for every parcel . The calculation takes the following mathematical form:

Where:

* is a set of parcel point origin locations.
* is a set of care destination locations of type .
* is a number of opportunities of category type 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 (S. L. Handy and Niemeier 1997).
* is the cumulative opportunity accessibility score, the sum of weighted opportunities reachable within , at each for each .

## Diversity in opportunity accessibility: the entropy measure

To represent the diversity of care destination accessibility, the entropy measure is used. A value is calculated for each parcel that ranges between 0 to 1, where 1 represents total evenness in the number of care opportunities in each category that can be reached.

The mathematical formulation takes the following form:

Where:

* is a set of parcel point origin locations.
* is a set of care destination types (e.g., school, grocery, park, etc.)
* is the count of care destination types . In this work, this value is 14.
* is the cumulative opportunity accessibility score, the sum of weighted opportunities reachable within a 15-minute walk from .
* is the diversity score. As represents evenness in type of categories, so if a parcel has a access score of =0.5 for all types of destinations it will be assigned = 1 in the same was as if it had a score of =10 for each type of destination. Contrariwise, a parcel can be assigned a low score if it has low but different accessibility scores for each category as well as if it has high but different scores for each category.

## Machine learning classification: self-organizing maps and decision trees

In this work, we use two machine learning techniques. First, SOM is an unsupervised technique implemented to reduce the data dimensional and create interpretable clusters related to the intensity and completeness of caring access. This is done by imputing each parcel as an observation with its associated accessibility and diversity attributes, and the data being rearranged onto a two-dimensional space based on its minimizing dissimilarity in its neighbourhood. Then, a decision tree is run to characterise the socio-economic profile of who resides in neighbourhoods associated with certain (in)complete and (un)caring accessibility clusters. Together, this combined approach leverages the unsupervised data-driven classification power of the SOM with the interpretation of decision trees. The procedure used in this work is similar to the approache used in Victoriano, Paez, and Carrasco (2020). However, instead of each observation representing an individual’s daily mobility behaviour (with associated variables), here each observation represents a parcel location with calculated care accessibility and diversity of type of care accessibility scores.

For the SOM step, the SOM implementation in the function ‘trainSOM()’ from {SOMbrero} R package is used (Villa-Vialaneix 2017). The input variables include the 143,882 parcels, each as individual observations along with 15 variables: the 14 calculated accessibility scores , normalized to the min-max range score within each , and one diversity value . Otherwise, defaults for all other parameters are assumed, relying on the data-driven heuristics embedded in the ‘trainSOM()’ function. Consequently, a 100 node (10 by 10 grid) SOM structure using euclidean distance and square topology is produced. Simply put, the SOM algorithm proceeds as follows: a 2D grid of nodes is created as specified by the analyst, where each node will represent a point in the reduced-dimensional space. Upon initialization, each node is assigned a random weight vector of the same dimension as the input data (in our case, 15). From the input data, a random observation with its associated weight vector (i.e., one parcel point with 15 variables) is selected and the Euclidean distance between its weight vector and all nodes in the grid is calculated. The node with the smallest distance (i.e., the smallest dissimilarity) is labelled the ‘best matching unit’ as it is the node that best represents the input observation. After this best matching unit is identified, its own weight and its neighbouring nodes are updated to become more like the input observation. The process of finding best matching units and updating their weights is repeated for every observation, multiple times, until the results converge. As mentioned, this competitive learning process produces a 100 node SOM structure where each observation (parcel) is assigned to 1 node with an associated dissimilarity index. The SOM output is typically examined through a dissimilarity dendogram and an associated dissimilarity variance explained plot to select an appropriately representative ‘superclusters’ (Villa-Vialaneix 2017; Victoriano, Paez, and Carrasco 2020).

For the decision tree step, the supercluster-classified parcels identified in the SOM step are used as *labels* and socio-economic and demographic indicators available from the 2021 Canadian Census (Statistics Canada 2023) related to the mobility of care literature are used as *features*. This step is used to profile the superclusters so we may explore who reside in what supercluster in a data-driven way. To estimate the decision tree, the ‘rpart()’ function in the {rpart} R package is used (Therneau and Atkinson 2023); default parameters for classification splitting along with each value being weighted by the population present in the associated DA is assumed. To summarize the decision tree algorithm, it is a supervised learning technique that begins by splitting a subset of the input data into branches based on a selected feature with the lowest impurity score (i.e., the least mixing of label membership within a branch). This process is recursively repeated for each data subset, selecting the next best features. Ultimately, the data is classified into distinct classes, with class membership explained by traversing the branches defined by the features that characterise the partitions within the decision tree. Notably, the absence of features from the decision tree does not necessarily imply they are irrelevant for classification, rather, they are just less relevant than other features. Put another way, when considering features that are highly correlated, such as income level and LICO, not all relevant variables may be present in the tree (Victoriano, Paez, and Carrasco 2020).

# Results

## Overview of access to care destinations

How many care destinations can be reached within a 15-minute walk is summed for each of the four care categories defined in [Table 1](#tbl-Tbl1). The median parcel value for each DA is visualised in [Figure 4](#fig-Fig4) and the median parcel diversity of care destinations accessible is presented in [Figure 5](#fig-Fig5). Together, [Figure 4](#fig-Fig4) and [Figure 5](#fig-Fig5) represent the 15 variables that served as inputs into the SOM algorithm.

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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. The values are a summary of the 14 acessibility scores that served as inputs into the SOM. Basemap shapefiles are retrieved from the 2021 Canadian census (Statistics Canada 2023), the Open Data Hamilton Portal (Hamilton 2023b) and the USGS (USGS 2010). |
| Figure 5: The diversity measure based on the proportion of care category spatial accessibility (figure 4). These values are a summary of the 15th input into the SOM. Basemap shapefiles are retrieved from the 2021 Canadian census (Statistics Canada 2023), the Open Data Hamilton Portal (Hamilton 2023b) and the USGS (USGS 2010). |

## Identification of (in)completely (un)caring neighbourhoods

In [Figure 4](#fig-Fig4), the concentration of opportunities for all category types is centered in the downtown of Hamilton, with the highest concentration being in the lower city (near the lake shore) and pockets of the high concentration further from the shoreline. Grocery-centric destinations appear to be the most concentrated, followed by health-centric and dependent-centric caring destinations. Errand-centric destinations are the most sprawled. In many ways, [Figure 4](#fig-Fig4) mirrors the spatial distribution of care destinations ([Figure 3](#fig-Fig3)) as the range of 15-minutes of travel is small. In [Figure 5](#fig-Fig5), areas that have high care accessibility tend to have high diversity as well, though there are exceptions in pockets of the city outside the downtown core that have lower but equally low levels of accessibility for all care categories.

Based on the SOM methodology discussed, 7 superclusters are identified from the 10 by 10 grid of SOM nodes. As diagnostics for the selection of the number of superclusters, the dissimilarity-index-based dendrogram with the proportion of parcels represented in each supercluster alongside the variance explained plot is visualised in [Figure 6](#fig-Fig6). Labels representing grades A to D qualifying the 7 superclusters are then assigned. These grades as also reflected in [Figure 6](#fig-Fig6) and represent the quantity of accessibility and diversity in accessibility per care category. Higher grades (A+ and A) corresponding to the highest accessibility and diversity, while lowest grades (D) representing lowest accessibility and diversity scores.

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| Figure 6: The 7 resulting superclusters from the SOM the 10 by 10 grid output represented in a dendrogram (left) and the proportion of variance unexplained by cluster (right). |

The grade for each supercluster was carefully assigned by the authors by referring to descriptive statistics and their interesting trends. These statistics are summarised in [Table 2](#tbl-Tbl2) and in the boxplots in [Figure 7](#fig-Fig7).

* A+ and A have exceptionally high caring accessibility for all destination types and high diversity scores in the top quantile or above. Together, these grades represent 24% of all parcels.
* A- has high caring accessibility, but low diversity. Interestingly, A- is like A but with much higher dependent-centric destinations, particularly parks, schools, and daycares, with only moderately high scores for all other destination types. This disbalance lowers its overall diversity score. However, it can be characterized as a supercluster that demonstrates potential in being retrofitted to provide A+ level completely caring access. This grade represent 4% of parcels.
* B+ and B superclusters present about average completely caring access. These superclusters can serve as the benchmark for what ‘average’ completely caring access in Hamilton currently looks like and they represent 15% of parcels.
* B- provides above average dependent-centric destination access, particularly parks, daycares and schools, but below average access to other destination types and hence has low diversity scores. B- is like A- as it demonstrates complete caring 15-minute potential if retrofitted. As these parcels demonstrate caring access to some destinations, they may have the potential to be retrofitted to support complete access to all caring destination types. This grade represents 19% of parcels.
* D superclusters demonstrate the lowest scores all-around, representing room for land-use improvement that addressed complete and caring 15-minute access. This supercluster characterizes the most number of parcels, representing 38% of parcels in the city.

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| Table 2: Mean and (standard deviation) of each SOM classified cluster by input variable and additional summary variables. Variables included in the SOM algorthim are in regular case, while additional summary variables are indicated by ALL CAPITAL LETERS.   |  | A+ | A | A- | B+ | B | B- | D | TOTAL | | --- | --- | --- | --- | --- | --- | --- | --- | --- | | GROCERY TOTALS | 12.2 (5.7) | 7 (3.1) | 2.8 (2.6) | 4.8 (2.5) | 2.7 (2.2) | 1 (1.6) | 0.5 (1.2) | 3.6 (5.1) | | Convenience Store | 8 (4) | 4.5 (2.6) | 2 (2.1) | 3 (1.9) | 1.8 (1.6) | 0.8 (1.2) | 0.4 (0.9) | 2.4 (3.4) | | Grocer | 4.2 (2.8) | 2.6 (1.5) | 0.7 (0.9) | 1.9 (1.2) | 0.9 (1) | 0.2 (0.6) | 0.1 (0.4) | 1.2 (2) | | DEPENDENT TOTALS | 17.5 (5.8) | 11.5 (4.3) | 13.4 (3) | 6.7 (2.4) | 5.3 (2.4) | 9.5 (2.4) | 2.9 (2.1) | 8.1 (6.2) | | Community or Rec. centre | 1.3 (1) | 0.7 (0.9) | 1 (0.8) | 0.2 (0.4) | 0.2 (0.4) | 0.4 (0.6) | 0.1 (0.3) | 0.4 (0.8) | | Daycare or EarlyON | 4.9 (2.2) | 3.3 (2.1) | 3.9 (2.3) | 1.8 (1.4) | 1.6 (1.5) | 3 (1.5) | 0.6 (0.8) | 2.2 (2.2) | | LTC or retirment home | 1.1 (1.3) | 0.5 (0.8) | 0.4 (0.7) | 0.3 (0.6) | 0.2 (0.5) | 0.3 (0.6) | 0.2 (0.4) | 0.4 (0.8) | | Park | 6.9 (3) | 4.8 (2.3) | 5.6 (2.2) | 3.2 (1.6) | 2.5 (1.4) | 3.9 (1.6) | 1.7 (1.3) | 3.6 (2.6) | | School | 2.8 (1.5) | 2.1 (1.1) | 1.9 (1.2) | 1.2 (0.8) | 0.7 (0.7) | 1.8 (0.9) | 0.4 (0.5) | 1.3 (1.3) | | Senior centre | 0.5 (0.9) | 0.3 (0.5) | 0.5 (0.7) | 0.1 (0.2) | 0.1 (0.4) | 0.1 (0.3) | 0 (0.2) | 0.2 (0.5) | | HEALTH TOTALS | 11.1 (6.3) | 5.8 (2.8) | 3.6 (1.8) | 3.9 (1.8) | 2.9 (1.9) | 1.5 (1.4) | 0.6 (1) | 3.4 (4.7) | | Dentist | 4.1 (3.4) | 2.2 (2) | 0.8 (1.1) | 1.4 (1.4) | 0.9 (1.1) | 0.3 (0.7) | 0.1 (0.4) | 1.1 (2.2) | | Hospital or clinic | 0.6 (0.7) | 0.3 (0.5) | 0.3 (0.6) | 0.2 (0.5) | 0.3 (0.7) | 0.1 (0.3) | 0 (0.2) | 0.2 (0.5) | | Pharmacy | 6.4 (3.7) | 3.3 (1.5) | 2.5 (1.3) | 2.3 (1.2) | 1.7 (1.2) | 1.2 (1.2) | 0.4 (0.8) | 2.1 (2.7) | | ERRAND TOTALS | 3.9 (2) | 2.5 (1.4) | 1.1 (1) | 2.2 (1) | 1 (0.6) | 0.3 (0.6) | 0.1 (0.4) | 1.2 (1.8) | | Bank or ATM | 2.2 (1.8) | 1.5 (1.2) | 0.4 (0.5) | 1.5 (1.1) | 0.7 (0.7) | 0.1 (0.3) | 0 (0.2) | 0.7 (1.2) | | Library | 0.5 (0.5) | 0.3 (0.5) | 0.2 (0.4) | 0.1 (0.2) | 0.1 (0.2) | 0.1 (0.3) | 0 (0.2) | 0.2 (0.4) | | Post office | 1.2 (0.8) | 0.7 (0.7) | 0.5 (0.8) | 0.6 (0.7) | 0.3 (0.5) | 0.1 (0.3) | 0 (0.2) | 0.4 (0.7) | | Category diversity | 0.9 (0.1) | 0.8 (0.2) | 0.3 (0.3) | 0.9 (0.1) | 0.6 (0.4) | 0 (0.1) | 0 (0) | 0.3 (0.4) | |
| Figure 7: A boxplot demonstrating summary variables and category diversity that define the superclusters. |

To spatially demonstrate where the superclusters are located, representative supercluster labels for each DA in visualised in [Figure 8](#fig-Fig8). This visualisation is created by grouping parcels by their DA, calculating the median supercluster label for each label, and selecting the label that is most dominant within that DA. For reference, the median number of parcels in each DA is 150 and supercluster label membership within a DA is typically pure, with the median membership being 80% of a single cluster.

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| Figure 8: The maximum median parcel supercluster membership per DA. Escarpment is visualised as a grey dashed line. |

The resulting superclusters visualised in [Figure 8](#fig-Fig8) are a combination of the cumulative opportunity and diversity of access measures translated into meaningful typologies through the SOM methodology. Accessibility is the measure of *potential* interaction, e.g., how many care destinations one could reach within a 15-minute walk, these typologies are useful in identifying which areas of the city are providing regionally high levels of complete caring access, which areas are regionally average, and which areas are regionally below average. Furthermore, neighbourhoods which provide disbalanced access can be further investigated.

In [Figure 8](#fig-Fig8), it can be observed that the excellent and exceptional neighbourhoods (A, A+), which are very caring and very complete 15-minute neighbourhoods, are located within the center of the city and closest to the shoreline in the Lower City. The above and below average neighbourhoods (B+ B) are often proximate to the excellent and exceptional neighbourhoods and are more prevalent in the Mountain part of the center of Hamilton. The escarpment is a physical barrier, with few pedestrian-accessible access points to traverse; hence the typologies describing neighbouring DAs separated by the escarpment are often different. Below average (D) neighbourhoods are located in peripheral areas outside the center of Hamilton, in areas where urban form is characterised by lower density residential housing and auto-dependent mobility.

Furthermore in [Figure 8](#fig-Fig8), A- and B- grades stand out as offering high access for children-centric destinations for their grade-group but below group-average access in other destination types. These neighbourhoods may be more suitable for populations who prioritize walkable access to destinations like schools, parks and daycares, and find access to other types of caring destinations less important. These neighbourhoods also stand out as demonstrating potential to be retrofitted to provide more complete access if additional destination types were located within their neighbourhoods.

## Profiling of who resides in (in)completely (un)caring neighbourhoods

To enhance the meaning of the superclusters beyond a descriptive and spatial conceptualisation of “caring” and “complete”, *who?* resides in what neighbourhood is investigated through the Decision Tree results. The input features of the Decision Tree are the supercluster labels and the feature variables are various population-weighted socio-demographic characteristics of the 2021 Canadian Census, namely: median household income, % below the median household income, % LICO prevalence, average number of children per household, % population aged 0 to 14, % not in the labour force, % not employed, Gini index on adjusted household after-tax income, % visible minority, % 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 higher than 30% income on housing), % of tenant households in subsidized housing, % of tenant households in core housing need, % no certification or with only a highschool diploma.

Of all the included input variables, *median household income* proved to be the most meaningful in partitioning the superclusters data. [Figure 9](#fig-Fig9) provides the Decision Tree with the significant splits in median household income and the proportion composition of supercluster along each branch for three terminal Decision Tree nodes. While the algorithm is unable to homogenously use each supercluster, [Figure 9](#fig-Fig9) is helpful to report a narrative of who may reside in what caring/complete supercluster. Particularly, the Decision Tree demonstrates a more pure supercluster membership for only two of the three terminal decision tree nodes: supercluster A+ (exceptional completely caring access) and D (not caring and complete access). For reference, the city-wide mean household income is 81,316 (SD: 25,239 and median: 80,000). The notable splits for income are $91,500 $68,750, or between $68,750 and $91,500, roughly split by lower income, middle income, and higher income median household brackets.

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| Figure 9: The decision tree demonstrating median household income splits and superclusters composition within each branch. |

Describing [Figure 9](#fig-Fig9), the bar column on the right represents DAs with higher household income. In these DAs, the majority of parcels are labeled as D superclusters, i.e not caring or complete 15-minute neighbourhoods. Within this higher-income-representing bar column, the second highest proportion of supercluster membership are B- parcels. B- parcels are low in most amenity types except a few child-centric destinations and show promise in being more easily improved than the D parcels. The higher income column represents 39% of the population, the largest proportion of any of the three columns. The left column in [Figure 9](#fig-Fig9) correpnds to the lowest income, i.e., below 68,750 CAD median household income, and accounts for 32% the population. It is dominated by A+ parcels along with A and A- parcels, in the largest quantities relative to other bar columns, however, proportions of all other superclusters are also present. The middle column is defined by parcels with a mix of supercluster classifications and represents DAs with middle households incomes, between 68,750 CAD and 91,500 CAD representing 28% of the population.

Though median income was the most useful in partitioning the parcels by their supercluster labels in [Figure 9](#fig-Fig9), other variables are still important. Namely, the following variables were also important (in order of importance and correlation coefficient with the median household income variable in brackets): the % below the median household income (-0.89), % single parent household (-0.57), % no certification or with only a highschool diploma (-0.49), the average number of children per household (0.38), % not in the labour force (-0.41), % LICO prevalence (-0.67), and % who walk to work (-0.37).

It is notable that median household income is highly or moderately correlated with many of these important variables, and discussing these correlation is useful for interpretation alongside the Decision Tree diagram. For instance, single-parent families are most positively correlated with the proportion of households being in the bottom income distribution (-0.89) and low or new degree (0.6), and most negatively with the median after-tax household income (-0.57), reflecting nationwide trends (Government of Canada 2024b, 2024a). Though not all single-family households are below the LICO (single-family households are not highly correlated with LICO at the DA-level in Hamilton), DAs with higher concentrations of single-family households and LICO prevalence tend to be A+ completely caring 15-minute neighbourhood. Conversely, DAs with lower single-parent households are in DAs with a higher concentration of F parcels. These findings are notable from an equity perspective and in considering caring 15-minute policy interventions, especially since economic disadvantaged often intersects with other socio-demographic characteristics.

# Discussion

Geographically, Hamilton is city that offers very completely caring 15-Minute neighbourhoods for some, but not everyone. There are evident spatial inequalities in areas that are, are not, and are somewhere between a caring and complete 15-minute neighbourhood (from labels A+ and A being excellent, B being about average, D being well below average, and A- and B- demonstrating potential in their grade group). The downtown core of the city has the most *caring 15-minute neighbourhoods*, but many pockets of the suburbs do as well. Though this contrasts what may be seen when considering employment opportunities (as in the work of El-Geneidy et al. 2016), the paper’s findings align with the neighbourhood unit planning literature reviewed. As many North American Suburbs, Hamilton followed certain characteristic design patterns that were initially designed to be proximate to amenities, coinciding with the conceptualisation of *caring 15-minute cities* (Ali 1991).

Who currently resides in Hamilton’s completely caring 15-Minute neighbhorhoods is also an optimistic story. Parcels that provide A+ completely caring access tend to be in DAs that are economically disadvantaged. Economic disadvantage tends to intersect with other identities such as gender (Lightman and Good Gingrich 2018). And as reviewed in this work, all women and especially those from lower income households tend to complete the most mobility of care trips (Ravensbergen, Fournier, and El-Geneidy 2023). Furthermore, lower-income households tend to also be single-parent households. Broadly, single-parent households are more likely to be time-disadvantaged (Nieuwenhuis and Maldonado 2018), and tasked with a higher proportion of care duties (Craig 2004). In this way, the most economically disadvantaged groups having A+ complete and caring access is an optimistic finding. However, Hamilton is experiencing gentrification (Ellis-Young 2018); rents are rising along the future light rail transit corridor and throughout the city (Van der Merwe 2021; Mayers et al. 2023). Toronto, Hamilton’s larger and higher-rent neighbouring city, is spilling gentrification into Hamilton’s downtown core, (re)producing neighbourhoods based on Toronto’s middle class identities (Mayers et al. 2023). In these ways, the lower income residents of Hamilton’s A+ neighbourhoods are more likely to be displaced, which is matter of wellbeing and justice. There are few low-rent choices that provide the same exceptional level of access as the downtown core, hence lower household income residents that currently reside in A+ neighhourhoods would likely need to relocate to a different city.

In discussing policy interventions that equitably increase completely caring 15-Minute neighbourhoods in Hamilton, this work’s presents a methodology to create city-wide relative typologies and investigate who currently resides in what neighbourhood, as a stepping stone for further investigation. Neighbourhoods with the lowest grades (D) and with the highest potential in being improved (i.e., high accessibiltiy for certain types of destinations but not all) are neighbourhoods with B- and A- grades. However, the work’s findings demonstrate a mismatch in household income and completely caring access. Is it equitable to focus policy on ameliorating neighbourhoods that are already higher-rent though they tend to be more rural, single-use zoned and car-dependent (parcels with D grades)? Further, of the parcels that provide high child-centrics but low otherwise, A- parcels (better access) tend to be in DAs with lower-income households more so than B- parcels (lower access than A-). From the perspective of ameliorating land-use to support the equitable distribution of 15-minute caring neighbourhoods which areas be targeted? Who should benefit, and how? If the policy initiative is targeted to specific neighbourhoods: sustainability linked to car dependency and equity are in-tension. This harkens to what role a planned neighbourhood, and bottom-up planning approaches that should be adopted to achieve equitable 15-minute cities.

As all research work, the results should also be interpreted along with methodological assumptions. This work measures spatial accessibility which is a measure of potential interaction with all reachable destinations from an origin. These destinations however may not be relevant to people at an origin, e.g., the may be underutilized (walkable access to 2 schools is unneeded, as a child only needs to attend 1 school), the trip physically undesirable (the walk may be along an arterial with high traffic speeds, making the trip unlikely to ever happen by foot), or the average walking speed assumed may not reflect the walking speeds of all populations (Willberg, Fink, and Toivonen 2023). Further, people who reside in these neighbourhoods may also disagree with the neighbourhood’s label. The grade labels are region-relative (e.g., high accessibility in Hamilton may be subjectively insufficient for some) and they do not consider subjective perceptions that influence accessibility (e.g., though a neighbourhood has many opportunities, it may not feel safe to access them). Furthermore, accessibility is calculated from the point of residential parcels. Care trips are not necessarily completed from home, in-fact, they are often completed in complex trip-chains (Scheiner and Holz-Rau 2015). In this way, the results flatten the dynamic patterns of care trips. These methodological assumptions should all be taken together when interpreting the results. In this way, the methodologyand findings presented identifies spatial and socio-economic trends that should be further investigated.

# Conclusion

This study makes three types of contributions to the transportation and city planning literature: empirical, methodological and theoretical. At the empirical level, areas of the mid-sized City of Hamilton have been typified by their degree of ‘15-Minute Caring Neighbourhood’ potential. Methodologically, we applied the longstanding accessibility measure of cumulative opportunities and entropy to classify spatial areas based on how many destinations could be reached in a 15-minute walk and the diversity of destination type. These values were then clustered using a novel machine learning approach, SOM, to generate meaningful typologies for discussion and further comparison with socio-economic composition of the area. We find A+ and A 15-minute caring neighbourhoods are located within the downtown core and in certain suburban pockets of the city, while the peripheral regions provide D level caring access. A- and B- areas are also identified as neighbourhoods that already support a high amount of children-centric destination access, and could be improved to provide better complete care access. Theoretically, our work puts forth an explicitly caring 15-Minute Neighbourhod conceptualisation, bridging the Mobility of Care and the 15-Minute City concepts. We discuss how measuring caring neighbourhoods can be explicitly considered within city planning.

Our work is of relevance to research and practitioners planning equitable and sustainable cities. Instead of prescribing an urban form design principle, such as “all local amenities should be within a 15-minute walking distance”, it instead examines an empirical example to determine which areas in the city have the *potential* to be 15-minute neighbourhood based on the existing spatial accessibility offered by the urban environment and walking transport network. To this end, this data-driven methodology introduces a way to identify neighbourhoods that have potential, almost have potential, and are far from containing this potential to support future context-specific qualitative work.

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