Transportation Research Part A

Towards completely caring 15-minute neighbourhoods

--Manuscript Draft--

Manuscript Number:	YTRA-D-24-01720R1
Article Type:	VSI: 15-minute city
Keywords:	15-Minute City; Chrono-Urbanism; Accessibility; Mobility of Care; Inequality; Gender Gap

Corresponding Author:	Anastasia Soukhov McMaster University CANADA
First Author:	Anastasia Soukhov
Order of Authors:	Anastasia Soukhov
	Léa Ravensbergen
	Lucía Mejía Dorantes
	Antonio Páez

Abstract:	The "15-Minute City" concept has been embraced by global leaders to promote human-scale neighbourhoods with transport and land-use designs that support short trips to daily necessities. This paper bridges the 15-Minute City to "Mobility of Care", a framework that foregrounds travel to care destinations, travel done predominately by women. This focus contrasts the more commonly studied travel to employment and leisure destinations. While the 15-Minute City concept is flexible enough to consider all destination types, gendered examinations are relatively lacking in the literature, and little research to date has focused explicitly on care destinations. This gap is addressed in this paper by identifying which areas in the city of Hamilton, Canada are ‘caring 15-minute neighbourhoods’. To do so, a database of care destinations was compiled to estimate the number (using the cumulative opportunity accessibility measure) and diversity of mix (using the entropy measure) of care destinations within a 15-minute walk from residential parcels. Using data-driven machine learning techniques (Self-Organizing Maps and Decision Trees), neighborhoods were classified into 'caring 15-minute neighbourhood' typologies that are examined across residential socio-economic profiles. Our results suggest that the majority of caring 15-minute neighbourhoods are in the urban core, where more lower-income households reside. In contrast, not caring 15-minute neighbourhoods in higher-income peripheral areas. Areas that make good candidates for urban policy intervention are identified and the implications of enhancing 15-minute walkable caring access are discussed in relation to gender mainstreaming in transportation planning and limitations of this work.

Opposed Reviewers:	
Response to Reviewers:	

Cover Letter

McMaster University | SCIENCE School of Earth, Environment & Society

Department of Earth, Environment and Society, Faculty of Science
McMaster University, 1280 Main Street West
Hamilton, Ontario, Canada, L8S 4L7

October 10th 2024

Dear special issue editors Dr. Kourtit, Dr. Loo and Dr. Nijkamp,

It is with great pleasure that I write to you, on behalf of myself and my co-authors, regarding our newly written manuscript entitled: "Towards completely caring 15-minute neighbourhoods" to the *Transportation Research Part A: Policy and Practice*. We believe it is a good fit for your special issue *The 15-minute city: A transportation and accessibility challenge*. Our manuscript presents original research, has not been published elsewhere, and is not under review elsewhere.

In recent years, many have argued that transport research and practice need to engage in gender mainstreaming. Concrete ways to do so, however, are underexplored. In this paper, the Mobility of Care framework is introduced as a way to clarify the normative selection of destinations within the context of the 15-Minute City. It argues that conventional, masculinist planning focuses on capital-driven amenities (work and leisure), neglecting essential "Care Destinations" like trips to drop-off children at daycare, grocery shopping, errands, attending medical appointment. These are pertinent to all people: but especially for women, and women who are lower-income.

Through the empirical examination of Hamilton, Canada, accessibility to care destinations and the diversity of this accessibility is calculated for all residential parcels. Machine learning techniques are then used to classify areas of the city by their extent of *completely caring 15-minute neighbourhood* potential and create residential profiles along socio-economic dimensions.

Ultimately, this work bridges concepts in urban planning and gender studies. It also introduces interesting data-driven methodologies to describe these typologies in an empirical case study. We believe the paper provides valuable insights into how one could think about neighborhood design.

Thank you for considering our manuscript.

Sincerely,
Anastasia Soukhov on behalf of all the co-authors

Anastasia Soukhov, MASc, B.Eng.
PhD Candidate,
School of Earth, Environment and Society, McMaster University
Phone: (289) 937-2194
Email: soukhoa@mcmaster.ca

Title Page with author details

Towards completely caring 15-minute neighbourhoods

Anastasia Soukhov
School of Earth, Environment & Society
McMaster University, Hamilton, Ontario, Canada, L8S 4L8
Email: soukhoa@mcmaster.ca

Léa Ravensbergen
School of Earth, Environment & Society
McMaster University, Hamilton, Ontario, Canada, L8S 4L8
Email: ravensbl@mcmaster.ca

Lucía Mejía Dorantes
Consultant, Karlsruhe, Germany
Email: lucia.mejia.dorantes@gmail.com

Antonio Páez
School of Earth, Environment, and Society
McMaster University, Hamilton, Ontario, Canada, L8S 4L8
Email: paezha@mcmaster.ca

Acknowledgements
This research was funded by the Social Sciences and Humanities Research Council (SSHRC) Canada Graduate Scholarships — Doctoral program (CGS-D) held by Anastasia Soukhov.

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

Conflicts of interest: None

Manuscript Number: YTRA-D-24-01720

Response to reviewer comments on “Towards completely caring 15-minute neighbourhoods

Thank you for giving us the opportunity to submit a revised version of our manuscript to the Transportation Research Part A. In the enclosed documents, you will find the revised manuscript “Towards completely caring 15-minute neighbourhoods”.

We take this opportunity to thank the reviewers for their valuable comments that helped us to produce an improved version of the manuscript.

In the following paragraphs, you will find the detailed responses to each of the comments raised by each of the reviewers written in blue.

Reviewer #1:

- Interesting and relevant research on the "caring" 15mC. Below points in order to improve the promising manuscript:

Thank you for your comprehensive revision. In the following paragraphs you will find detailed information on how your comments were considered.

- Line 51: Why only feminist geographers (which is correct, but not exclusive) and not human geographers as a whole?

Good point. We’ve changed the text to reflect this idea: *“An increasing number of human geographers, planners and other researchers agree that urban structure influences travel, but city planning falls short in planning for a neutral identity” (pg 2)*

- Line 55: A reference is missing indicated by the ?.

The “?” was an error and has been removed. Thanks for catching this.

- Line 74: For the reader who might not be in the field, it would be helpful to elaborate on the differences between gender equality and equity.

Thank you for bringing up this point. The distinction between the two terms may not be known by all, so briefly defining both is beneficial. We’ve added a footnote to the paper that explains this nuance as follows:

The United Nations defines "gender equality" as equal rights, responsibilities, and opportunities for all genders, regardless of gender at birth[1]; they prefer "gender equality," as "equity" relates to the concept of fairness that are usually based on traditions, customs, or cultural beliefs which can perpetuate disadvantage. However, "equity," in the broader context of social justice, is widely accepted. As defined in the UNICEF Glossary of DEI terms, equity is the "process of being fair to all individuals and groups, by addressing present and historical inequality in order to work towards equality in outcomes" and may involve temporary special measures to address systemic discrimination faced by marginalized groups[2].

- Line 236: 4. "Data" is misleading as it also incorporates 4.1. "Case study context" which introduces Hamilton. I would suggest renaming the chapter.

Thanks for raising this point. To ensure clarity for all, we updated the section title to “Case study and data”.

---

[1] UN Women. (2022). *Handbook on gender mainstreaming for gender equality results*. https://www.unwomen.org/sites/default/files/2022-02/Handbook-on-gender-mainstreaming-for-gender-equality-results-en.pdf

[2] UNICEF. (2024). *Annex I: DIVERSITY, EQUITY AND INCLUSION GLOSSARY for the UNITED NATIONS COMMON SYSTEM* [UNAIDS Terminology Guidelines]. https://unsceb.org/sites/default/files/2024-01/DEI%20Glossary.pdf

Manuscript Number: YTRA-D-24-01720

Response to reviewer comments on “Towards completely caring 15-minute neighbourhoods

- Page 10, Fig. 1:"…per DA", what does DA stand for?

In our first instance of mentioning DA (at the start of the “Case study and data” section), we define the acronym: on page 9 *“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.”* However, we see we did not explicitly explain what DAs *are*. We’ve added additional explanation following the one quoted to explain.

“The DA is the most spatially granual level of publicly available Canadian census data. DAs are created by Statistics Canada for the purpose of the census and each represent between 400 to 700 people (Q1:442 and Q3:664 from Figure 1).” (also page 9)

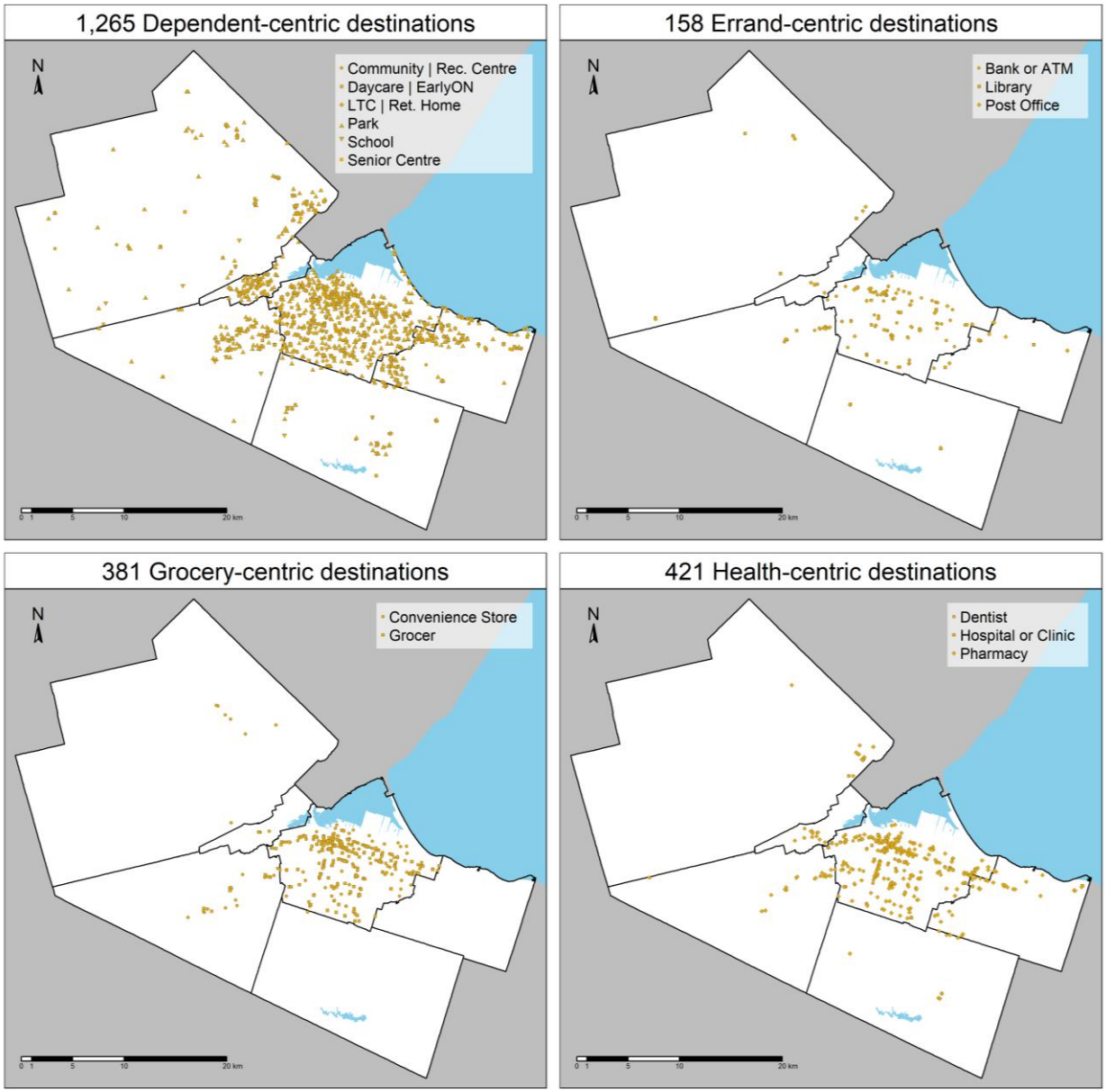
- Page 13, Fig. 3: Points are so tiny that the colors are hardly recognizable.

Good point. We’ve remade the figure by slightly increasing the point size (without making them too large as to completely cover too many neighbouring points) and changed the care destination ‘type’ to be distinguished by shape instead of colour (this may be more accessible). This version of the figure, we believe, more clearly communicates the locations of the destination data. We also increased the resolution of the figure, so the symbols edges are more crisp. We understand a static map for this point-specific data may not be the most ideal solution, but the intention of this figure is to demonstrate the location of the care destinations. While symbols may still overlap and appear small at 100% zoom, one can zoom in on the figure and further inspect the destinations. We also played around with different visualisation styles (e.g., aggregating the points (a heat map) for each destination type), but decided that just representing the locations of each point as simply as possible makes more sense for the “Case study and data” section, as the accessibility measure ultimately are ‘summaries’ of how those destinations can be accessed based on travel time. Furthermore, as also mentioned in the manuscript, the specific locations of the care destinations are freely available in the lead author’s Github repository associated with the manuscript.

We hope the new figure and thought process behind our decision is clearer now. For convenience, we’ve included the new figure below:

Manuscript Number: YTRA-D-24-01720

Response to reviewer comments on “Towards completely caring 15-minute neighbourhoods



- Page 20: A more detailed description and analysis of the maps would be interesting for the reader. The methodological approach was very detailed described, but the results are not. Please also explain/stress the importance of superclusters ideally by giving concrete examples from Hamilton.

Thank you for raising this point! We’ve update the manuscript to add additional detail that adds additional Hamilton-specific context, specifically:

- We re-created Figure 4 and 5 to display values by quartile, so the top and bottom quartiles (the highest and lowest values) can be more easily discerned. Descriptions in the manuscript of the figures have also been modified to reflect this change.
- On pg 20-22, we elaborate the supercluster explanations by adding the proportion of urbanised, suburban, and rural land-use that correspond to each supercluster. This

inclusion builds onto the previously present description referring to the summary Table 2 and Figure 7 quantifying the superclusters.
- Slightly enhanced the discussion about Figure 8, with additional references to the diversity scores and the proportion rural/suburban/urban.

We hope our enhanced discussion of the results is sufficient to satisfy your concerns.

- Page 24: Fig. 8: is placed in the middle of the text. Please rearrange.

Thanks for identifying this issue. The document was producing using LaTex and images are configuring image outputs in a template (for TRA) can result in the images placement being a bit off. We’ve corrected the placement.

- Page 27, Line 474 Hamilton is a city.

Thanks for catching this! We’ve corrected this typo, and others, in the revised manuscript. Appreciate it.

- Page 28, the gentrification issue is important to address. Maybe even giving some policy recommendations to limit the negative impacts.

Gentrification is an important topic, agreed. However, we elaborated on gentrification on the extent we did because unfortunately, the manuscript doesn’t explicitly touch on issues of gentrification as its primary objectives. For this reason, we can’t make explicit policy recommendation. But we do now add an additional sentence that this is an important issue that warrants its own investigation. Hopefully this addition to the manuscript and our justification satisfy your concern.

- Page 29, Line 534: methodology and typo

Thank you for pointing out this typo! It has been corrected.

- In general, the authors demonstrate their data-heavy approach can perform a scan on a "caring" 15mC score. However, a zoom in with more qualitative approaches (e.g. walk alongs with care givers, focus groups in order to learn about their actual needs) would give a more complete picture of the actual situation. Still, I am aware that this is not feasible to add, but it could be mentioned at the end as a need for further research.

Of course, excellent suggestion. We’ve expanded the final paragraph in the “Discussion” to underscore the need for additional qualitative and mixed methods research on this topic, as they can provide cohesive personal and lived perspectives of observed trends.

Manuscript Number: YTRA-D-24-01720

Response to reviewer comments on “Towards completely caring 15-minute neighbourhoods

Reviewer #2:

Thank you for your comprehensive review of the manuscript and all your positive comments. In the following paragraphs you will find detailed information on how your comments were considered and/or addressed in the revised manuscript.

1. Originality: Despite its acknowledged importance, the issue of "Mobility of Care" remains insufficiently explored in relationship with the "15-Minute City" concept, a gap filled by this current study. The novelty of this paper resides in its fortunate attempt to achieve two research objectives. Thus, the authors conduct an empirical examination of Hamilton, Canada, and contribute to the literature by bridging the above-mentioned concepts and creating a vivid image of what local amenities matter, but also a comprehensive picture of the socio-economic profiles of individuals who live in 15-minute caring neighbourhoods.

- We really appreciate this comment; we’re happy our objectives were clearly communicated in the manuscript.

2. Scientific Quality: From the scientific viewpoint, the manuscript's quality is indisputably convincing for many reasons. Firstly, the intersection of the "15-Minute City" concept with the "Mobility of Care" framework, with a focus solely on caregiving trips, is well-grounded in the authors' decision to address a vital yet often neglected aspect of transportation planning. In addition, the authors properly connect these frameworks and succeed in providing new perspectives on the urban planning implications for caregiving accessibility and gender equity.

Secondly, their methodological approach guarantees robust findings that are not only replicable but also adaptable to other urban areas similar to Hamilton, a mid-size city.

Thirdly, the results seem to be particularly important for urban policy and planning, because they identified areas that would benefit most from specific interventions.

Last but not least, I highly appreciate the paper's overall clarity, coherence, and relevance, as well as the academic tone of the writing which tends to be rather formal and makes use of tentative language and hedging.

- Thank you for this comment. From the beginning of manuscript drafting, we wanted to ensure the investigation of both “15-Minute City” and “Mobility of Care” concepts were relevant to transportation planning today. We also wanted to ensure the methodology and data, which is both complex and large, was carefully explained and the discussion of the results were always mediated by the limitations inherently associated with the methods. We’re happy to read that these efforts were not in vain, and you found these aspects notably positive.

3. Relevance to the Field(s) of this Journal: This manuscript demonstrates a high relevance to the field of transportation covered by this journal, due to its clear policy concern, but also because it is based on solid research and good-quality data.

- Thank you for this comment! Happy to hear we may have picked the right home for this manuscript.

4. General Comment: This paper represents an excellent contribution to the field of urban planning and mobility studies because the "Mobility of Care" concept is linked to the "15-Minute City" concept through a case study that explores the care destinations' accessibility in Hamilton, Canada. Moreover, authors employ machine learning approaches to measure caregiving in terms of 15-minute walking access and diversity, as well as to identify "Caring 15-minute neighborhoods" and their residential profiles.

- This is true. Good summary, thanks for this comment.

Manuscript Number: YTRA-D-24-01720

Response to reviewer comments on “Towards completely caring 15-minute neighbourhoods

5. Abstract: The abstract provides a solid summary of the research goals, methods, and results. Moreover, the paper's contribution to the body of knowledge is explicitly announced in the first part of the abstract, which facilitates the reader's focus on its attempt to bring novelty to the literature. Despite the limitations' omission from the abstract, the text includes various implications, such as the identification of urban policy interventions. Furthermore, the abstract is followed by eight keywords that increase the paper's discoverability and usefulness due to their appropriateness and relevance to the topic and research field.

- Thank you for this comment. We put great effort into succinctly summarizing the manuscript within the abstract. While it is true the abstract does not mention the work’s limitations, as noted in your comment, the manuscript itself carefully describes the limitations of the methods and data throughout.

6. Introduction: The introduction appears to be well-written and indisputably states the scope of the article, whilst placing the research within the broader context of urban planning and gender equity. However, the logic in targeting caregiving trips seems well set out and explicitly identifies a major deficit in the literature. In addition, the purpose of this paper proves to be two-folded, starting from the first one which attempts to redefine the local amenities importance in terms of care, and continuing to the second objective that aims to group areas according to their 'caring 15-minute neighbourhoods' categories. Accordingly, this study seeks to address the following questions: 'what destinations matter?', and 'who benefits from proximity planning?'.

- Thank you for this comment. This is a fine summary of the introduction.

7. Literature Review: The literature review section manages to situate the authors' work within the fields of urban planning and transportation and to show what they build on and talk about. Next, authors use selected literature from their field to justify their study and reinforce the niche for their work, using different types of citations (author/information/investigation prominent citation). Consequently, the adequacy of the literature reviewed is reinforced by the use of updated literature, the theoretical frameworks, and the identification of concepts and theories that they use to focus their research and refine their research design.

- Exactly, this comment provides a high-level summary of the literature review section.

8. Methodology: The methodology section is strengthened by clear and sufficient details which include the main aim and objectives of the research. Apart from its novel theoretical approach, it addresses the research objectives with the use of cumulative opportunity accessibility measures, entropy analysis, and machine learning techniques. Similarly, the dialectical approach of explaining all methodological choices is well-defended and demonstrates a profound understanding of the analytical tools used. Finally, the authors thoroughly present the study setting, instruments, data collection methods, and analysis strategies.

- Thank you for this comment. Similarly, this comment provides a high-level overview of the Methodology.

9. Results: The results of this study are persuasive and reveal significant aspects that involve the patterns of caring 15-minute neighbourhoods, as well as the socio-economic background of their residential. Equally, their approach provides sufficient pieces of evidence to consider this study accurate, reliable, valid, and replicable.

- Thank you for this comment. Like the few comments above, this comment provides a fine high level overview of the Results.

10. Discussions: On one hand, the discussion section is thoughtful and connects the findings to broader themes of urban inequality and the importance of gender-sensitive planning. Also,

the authors effectively point out the practical implications of their results and provide solid recommendations for policymakers in the field of urban planning and transportation.

On the other hand, the authors fail to highlight the limitations of their study, which could be addressed in connection with their recommendations for future research directions. For this reason, the authors should position themselves very effectively by highlighting intelligently not only the strengths of their work but also their weaknesses.

- Thank you for this comment. We’re happy you’ve positively received how we communicated the limitations of our results and possible uses of our methods by decision-makers in the urban transportation planning space.
- We also believe that we have now made a sufficient effort in highlighting the limitations of our study, particularly in the discussion of results and future research directions as this comment recommends. These limitations are mainly discussed in the “Discussion” section. For example, see the last paragraph of this section that has been enhanced to further elaborate on the work’s limitations:
    - *As is the case for all research, 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., they may be underutilized such as a parcel with a single-child household having 15-minute walkable access to two schools, as a child only needs to attend one school not two. As other examples: the trip may be physically undesirable e.g., 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 [@willberg15minuteCityAll2023]. Furthermore, the SOM methodology only incorporates aspects of spatial accessibility, and people who reside in these neighbourhoods may disagree with the neighbourhood's completely caring access grade. 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, residences 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 [@scheinerWomenComplexDaily2015]. Also different care destination types can be more or else important to different people, indicating an aspect of competition and destination quality could be considered within the accessibility measure itself. 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 methodology and findings presented identifies spatial and socio-economic variations that should be further investigated. They can be examined through additional quantitative investigation but also through qualitative and mixed methods that can capture trends at the individual and personal level.*
- And as an additional point, almost all paragraphs in the “Discussion” now end with something like “this topic warrants further investigation”, gently implying that the topic discussed relates to the results but is out of the study’s primary scope and hence may not be immediately relevant.
- We hope these changes to the manuscript address any outstanding concerns in this section.

Manuscript Number: YTRA-D-24-01720

Response to reviewer comments on “Towards completely caring 15-minute neighbourhoods

11. Conclusions: The conclusion part is concise and smoothly summarizes the key findings and their three-dimensional implications: empirical, methodological and theoretical. The authors perspicuously articulate the significance of their work and its potential impact on urban planning and gender equity. However, even though the conclusions open the door for future research, they lack consistency due to their inability to identify research limitations.

- Thank you for this comment. We viewed the Conclusions section as an opportunity to provide a high-level overview of how our manuscript contributions empirically, methodologically and theoretically. We believe the final paragraph in the Discussion section summarises the methodology’s limitations and didn’t think to include mention of them again in the following Conclusions section. However, to be abundantly clear and address your comment, we’ve added the following sentence to the end of our ‘methodological’ contributions. Specifically:
    - “*We also detail limitations associated with our data and methodology and hence our results throughout the manuscript.*”
- We considered ways of elaborating further on the limitations in this section but ultimately decided against doing so as we elaborate on the limitations of result interpretation in the final paragraph of the preceding section (Discussion, see our response to comment 10). We were also careful to detail the justification/limitations of selected methodology and data throughout the manuscript as relevant.
- We hope these adjustments in the manuscript and our justifications address concerns raised in this comment.

12. References / Bibliography: The references are relevant, up-to-date, and provide strong support for the study's theoretical framework and methodology, matching the citations in the manuscript's body text. In addition, the bibliography follows the appropriate format indicated by the journal.

- Thank you!

13. Figures: All nine figures meet the journal's author guidelines in terms of size, graphic resolution, captions, proper in-text citation. It is worth mentioning that all graphic illustrations are relevant to the study and help providing a more comprehensive image of their research process.

- Fantastic.

14. Tables: The two tables included in the data (p.12) and results section (p. 22) also meet the journal's author guidelines. The first table presents the methodological approach by including care categories, care destination types, and their sources. The second table's relevance is justified by the authors' second objective to identify and classify completely caring 15-minute neighbourghood categories (A+, A, A-, B+, B, B-, D).

- We are happy that these tables are useful in your comprehensive of the manuscript.

15. Others: The two math formulae included in the methods section (p.14, 15) respect almost all the journal's author guidelines (present variables in italics), except of the fact that they are not numbered consecutively in the order they are referred to within the text.

- Excellent point. We’ve adjusted the number of the equations in the manuscript accordingly. Thank you.

16. Reviewer's Decision Comment: This paper's overall clarity, coherence, and relevance make it a strong candidate for publication with minor revision. Firstly, the writing is precise, accessible, and manages to effectively report complex ideas to different audience categories. Also, the references are comprehensive, well-integrated, and demonstrate a strong

Manuscript Number: YTRA-D-24-01720

Response to reviewer comments on “Towards completely caring 15-minute neighbourhoods

engagement with relevant literature. Moreover, taking into consideration the underexplored issue addressed, this paper has the potential to make a meaningful contribution to academic research and urban policy field. Therefore, it is recommended for acceptance with minor revision.

- Thank you for the time you put into reading our manuscript and providing comments/feedback. We are happy you’ve positively received the manuscript and are excited to see the impact it will have on the readership of the journal. We hope our revised manuscript addresses the outstanding concerns you raised in your previous comments.

Towards completely caring 15-minute neighbourhoods

Highlights

- What destinations matter? “Mobility of Care” is joined to the 15-Minute City concept
- A case study of access to care destinations in Hamilton, Canada is explored
- 15-minute walking access and diversity of care category access is measured
- “Caring 15-minute neighborhoods” are identified through machine learning approaches
- Residential profiles of these “complete” and “caring” typologies are examined

Towards completely caring 15-minute neighbourhoods

Anastasia Soukhov[a,*], Léa Ravensbergen[a], Lucía Mejía Dorantes[b], Antonio Páez[a]

[a] *McMaster University, School of Earth, Environment & Society, Hamilton, Canada,*

[b] *Consultant, Karlsruhe, Germany,*

Keywords: 15-Minute City, Chrono-Urbanism, Accessibility, Mobility of Care, Inequality, Gender Gap

1. Abstract

The "15-Minute City" concept has been embraced by global leaders to promote human-scale neighbourhoods with transport and land-use designs that support short trips to daily necessities. This paper bridges the 15-Minute City to "Mobility of Care", a framework that foregrounds travel to care destinations, travel done predominately by women. This focus contrasts the more commonly studied travel to employment and leisure destinations. While the 15-Minute City concept is flexible enough to consider all destination types, gendered examinations are relatively lacking in the literature, and little research to date has focused explicitly on care destinations. This gap is addressed in this paper by identifying which areas in the city of Hamilton, Canada are 'caring 15-minute neighbourhoods'. To do so, a database of care destinations was compiled to estimate the number (using the cumulative opportunity accessibility measure) and diversity of mix (using the entropy measure) of care destinations within a 15-minute walk from residential parcels. Using data-driven machine learning techniques (Self-Organizing Maps and Decision Trees), neighborhoods were classified into 'caring 15-minute neighbourhood' typologies that are examined across residential socio-economic profiles. Our results suggest that the majority of caring 15-minute neighbourhoods are in the urban core, where more lower-income households reside. In contrast, not caring 15-minute neighbourhoods in higher-income peripheral areas. Areas that make good candidates for urban policy intervention are identified and the implications of enhancing 15-minute walkable caring access are discussed in relation to gender mainstreaming in transportation planning and limitations of this work.

Keywords: 15-Minute City; Chrono-Urbanism; Accessibility; Mobility of Care; Inequality; Gender Gap

*Corresponding author

Email addresses: soukhoa@mcmaster.ca (Anastasia Soukhov), ravensbl@mcmaster.ca (Léa Ravensbergen), lucia.mejia.dorantes@gmail.com (Lucía Mejía Dorantes), paezha@mcmaster.ca (Antonio Páez)

2. 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 et al., 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 et al., 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).

The term 15-Minute City is relatively new, but the concept is not. Its newfound fame under the moniker of chrono-urbanism comes to complement long-standing efforts to foster community and local travel to amenities in neighbourhood planning practice. 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 offer an opportunity for bottom-up approaches that leverage co-creation tools and meaningful resident participation to achieve equitable and just neighbourhood forms (Mahmoud and Morello, 2021). How to prescribe equitable urban forms that 'enable' contact with social opportunities (instead of 'engendering it' from the top-down) is still a matter for debate. Questions remain, including: what destinations really matter? What mode and travel time threshold is most appropriate? And who benefits? To be certain, these dimensions are under discussion among proximity-based planners who use accessibility-based tools (Silva et al., 2023; Silva and Altieri, 2022; Guzman et al., 2024). In this way, the 15-Minute City could be understood to be a normative cumulative opportunity accessibility measure (Paez et al., 2012).

An increasing number of human geographers, planners and other researchers agree that urban structure influences travel, but city planning falls short in 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). The causes for this are varied, and related to gendered social norms and cultural factors that play a role in how, where, with whom, what for, and how far we move. Women tend to travel shorter distances and more frequently (Roorda et al., 2010; Morency et al., 2011), and conduct more activities related to care no matter their stage of life (International Labour Organization, 2018; García Román and Gracia, 2022). Combined, these findings indicate that the spatial organization of activities has a different impact according to gender, and therefore the 15-Minute City concept should not be gender blind.

This work builds a theoretical bridge between the 15-Minute City and Mobility of Care concepts to answer questions about what destinations matter and who benefits from proximity planning. 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, care-related mobility can be shown to comprise a significant proportion of daily travel, characterizing approximately 30% of adults' daily trips (Sánchez de Madariaga, 2013; Sánchez de Madariaga and Zucchini, 2019; Ravensbergen et al., 2023a). We argue that 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 are of particular gendered and socio-economic importance, as women, and especially those within lower income households, complete the majority of care trips (Ravensbergen et al., 2023a). Despite care travel's importance in advancing gender equality -and equity[1] more broadly-, 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 et al., 2023; Ryan et al., 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 re-imagine what local amenities matter from the perspective of care and to define an associated accessibility and diversity of accessibility measures. And secondly, we take a data-driven approach to classify areas into 'caring 15-minute neighbourhoods' typologies and examine associated

[1]The United Nations defines "gender equality" as equal rights, responsibilities, and opportunities for all genders, regardless of gender at birth (UN Women, 2022); they prefer "gender equality," as "equity" relates to the concept of fairness that are usually based on traditions, customs, or cultural beliefs which can perpetuate disadvantage. However, "equity," in the broader context of social justice, is widely accepted. As defined in the UNICEF Glossary of DEI terms, equity is the "process of being fair to all individuals and groups, by addressing present and historical inequality in order to work towards equality in outcomes" and may involve temporary special measures to address systemic discrimination faced by marginalized groups (UNICEF, 2024).

residential profiles in an empirical examination of the city of Hamilton, Canada.

3. Review of neighbourhood planning literature

3.1. From the 15-Minute City to the NUC

In the last decades, the need for more sustainable, healthier, and livable cities has become a prominent concern. Planners and decision-makers have proposed a shift to neighbourhood planning principles centered on 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). The 15-Minute City was introduced in Moreno et al. (2021) along with four dimensions: density (in terms of people per km^2), diversity (including mixed-land use and diversity of people), the temporal and spatial proximity to essential services, and digitalisation (related concepts in Cervero and Kockelman, 1997). However, the framework presented has been criticized within academic and planning circles (e.g., Guzman et al., 2024; Mouratidis, 2024) among other things for shortfalls in terms of addressing pre-existing structural forces and individual characteristics that drive inequalities and influence who benefits or could benefit the most from such an approach (Di Marino et al., 2023; Willberg et al., 2023). A 15-Minute City for all people is an aspirational goal, but does not fully confront existing mobility and accessibility inequalities in need of redress. Without directed and context-specific solutions, this popular concept risks becoming an empty city branding exercise. (Pozoukidou and Chatziyiannaki, 2021; Gower and Grodach, 2022).

Reflective of the flexible and aspirational presentation of the 15-Minute City, the concept has been adopted by cities using a diverse range of definitions and tools along with indistinct universal approaches. A trail blazer in this respect was Portland (U.S.) in the Portland Plan (City of Portland, 2010) of April 2012. Adopted before the '15-Minute City' concept of today, this plan aimed to foster inclusive city development based on prosperity, education, health, and equity over a 30 year horizon. Central to the plan was the promotion of 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 (Portland Government, 2017), similarly taking on an "all populations" approach. Subsequently, other cities adopted proximity-based goals using similarly neutral approaches. For example, the 15-Minute City plan announced during the re-election campaign of Paris mayor Anne Hidalgo in 2020 emphasized six key social functions that should be easily accessible from any location (Ville de Paris, 2022). These locations included: housing, work, health care, groceries, education and leisure. The 15-Minute City concept 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). Teixeira et al. (2024)'s global review finds that 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. In other words: the 15-Minute City is aspirational but how do we get there and who will benefit?

The past can provide cautionary tales. While the 15-Minute City brand of planning 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 et al., 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). By 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). A critique by social scientists was an overestimation of the impact of built environment on social life. Planners, on the other hand, could not reach consensus on the specificity of the neighbourhood (i.e., population size and the type, quality, and quantity of amenity) or how neighbourhood units connect between them and the rest of the region. In response to these criticisms, neighbourhood planning proponents redefined their deterministic terminology; their prescriptive physical form would 'enable' social contact with opportunities rather than 'engendering' it.

The redefined bottom-up approach to community and neighbourhood planning was adopted in the 1980s by American New Urbanists (Trudeau, 2013), from which the 15-Minute City eventually stemmed (Kissfazekas, 2022). However, the bottom-up effectiveness of these ideas remains 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, for whom, and 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 et al., 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* is highly context-sensitive, prompting the need for further investigation.

3.2. Tools: accessibility methods, diversity measures and typology-classification

In examining how to enable improved quality of life through urban built environment, accessibility measures have become an increasingly popular tool. 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; Handy, 2020). The 15-Minute City is an amenity-provision neighbourhood planning concept aimed at enabling the creation of urban environments that enhance life quality, making it well-suited for analysis using accessibility methodologies (Guzman et al., 2024). Recent works have applied accessibility measures to investigate the 15-Minute City across different geographic scopes. For instance, in Naples, Italy (Gaglione et al., 2022), Barcelona, Spain (Graells-Garrido et al., 2021), Vancouver, Canada (Hosford et al., 2022), and in urban areas across Europe (Vale and Lopes, 2023). The "cumulative opportunity" measure has been applied in many 15-Minute City examinations. This measure quantifies how many destinations can be reached from a point in space within a given travel time threshold, pairing well with normative examinations (see Paez et al., 2012) that use travel time thresholds like x-minute cities (Logan et al., 2022). Furthermore, the cumulative opportunity measure is widely appreciated for its intuitive computation and popularity among practitioners (Handy, 2020; Handy and Niemeier, 1997; 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 et al., 2024).

Another concept that complements the assessment of the 15-Minute City regarding the diversity of opportunity types is entropy. The entropy measure, based on the Shannon-Wiener index of species diversity, expresses relative evenness within a sequence (Whittaker, 1972). In urban studies and planning literature, the concept of entropy has been used to characterize land-use mix diversity (Frank et al., 2005; Ewing and Cervero, 2010; Moniruzzaman and Paez, 2012) including to understand mobility behaviour (McBride et al., 2020; Montero et al., 2023a,b), in the context of non-work trips (Cervero and Kockelman, 1997), walking (Lu et al., 2017; Mavoa et al., 2018), and suburban sprawl (Randall and Baetz, 2015). However, entropy indices are rare in accessibility analysis. There are examples of their use as parameters within accessibility scores

for employment opportunities (Cheng and Bertolini, 2013; Dai et al., 2018) and, more recently, to describe the diversity in transit facilities (Yin et al., 2024). Given how 15-Minute Cities aim to provide access to numerous amenities, diversity of land-use is a key feature. In this way, the entropy measure theoretically complements the 15-Minute City.

Classification algorithms also show promise as a tool in the assessment of the 15-Minute City, as they have been useful in identifying mobility and spatial typologies within the transportation planning literature. Often, these algorithms take the form of machine learning approaches: in transportation, the use of Self-Organizing Maps (SOM) was pioneered by Delmelle (2012). It has been used to group U.S. neighbourhoods by minimizing dissimilarity in attributes (Delmelle, 2017). SOM has also been used to classify individuals' travel patterns according to the dissimilarity in mobility attributes along with the Decision Tree algorithm to partition the data into interpretable classifications (Victoriano et al., 2020). Other approaches include the use of spatially constrained multivariate clustering, to develop urban form typologies related to the 15-Minute City (Burke et al., 2022) and the use of k-means to analyse travel behaviour and classify metro stations based on mobility patterns (Gan et al., 2020).

3.3. Mobility of Care and feminist 15-minute neighbourhoods

Rather than focusing on *all* destinations, it is valuable to examine those related to caring activities. This framing offers a feminist perspective on urban functions that matter from a care perspective, and connects well with the 15-Minute City concept. Caring activities, which fulfill the physical, psychological, and emotional needs of others, are among the most essential and fundamental activities in society (International Labour Organization, 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 International Labour Organization (2018), women and girls perform more than three-quarters of the total amount of unpaid care worldwide, a gender gap that varies geographically (Ferrant et al., 2014). This unequal share of caring responsibilities leads to multi-faceted gendered differences: in career development, profession selection, contract type, pay gap, and time poverty, as recognized by various international organisations (EIGE, 2016; International Labour Organization, 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 et al., 2023a). 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, a common criticism leveled at the 15-Minute City (Guzman et al., 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 et al., 2023a). 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 often 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 et al., 2023a). 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 et al., 2016)), they tend to consider singular care destinations in research focusing on walkability. In summary, we reviewed the neighborhood planning framework from which the 15-Minute City concept stems and is situated within. We then reviewed tools common and useful in investigating the 15-Minute City. Finally, we introduced the Mobility of Care concept, theoretically linking it to the 15-Minute City to highlight the importance of care destinations for all but especially along gendered and socio-economic lines. The objectives of this work are two-fold, achieved through an empirical examination of Hamilton, Canada, a mid-sized city:

- First, by theoretically bridging Mobility of Care with the 15-Minute City concept, we re-imagine what

local amenities matter and calculate associated accessibility and entropy measure for care destinations.

- Second, using a bottom-up data-driven approach, we apply machine learning methodologies to classification areas into *15-minute caring neighbourhoods* and investigation their associated residential profiles along socio-economic lines.

4. Case study and data

4.1. 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 in the city (Teranet, 2021). 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. The DA is the most spatially granual level of publicly available Canadian census data. DAs are created by Statistics Canada for the purpose of the census and each represent between 400 to 700 people (Q1:442 and Q3:664 from Figure 1).

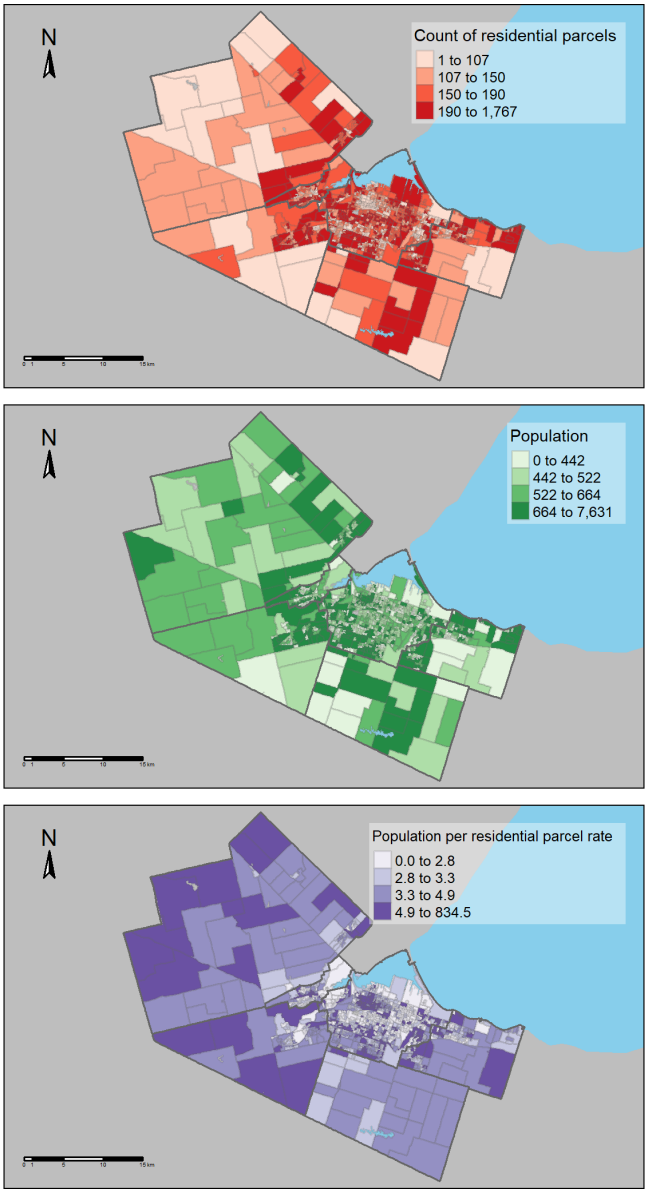


Figure 1: The number of residential parcels per DA in 2020 (top), the population (middle) retrieved from the 2021 Canadian Census, and the rate of population per parcel per DA (bottom). All scales in quartiles. Basemap shapefiles are sourced from the Open Data Hamilton Portal (Hamilton, 2023) and the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

Hamilton also exhibits spatial disparities in social and economic indicators; their spatial distribution is visualised in Figure 2. 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). Notably, the suburban areas of the city tend to have a greater proportion of children and a lower proportion of one parent households.

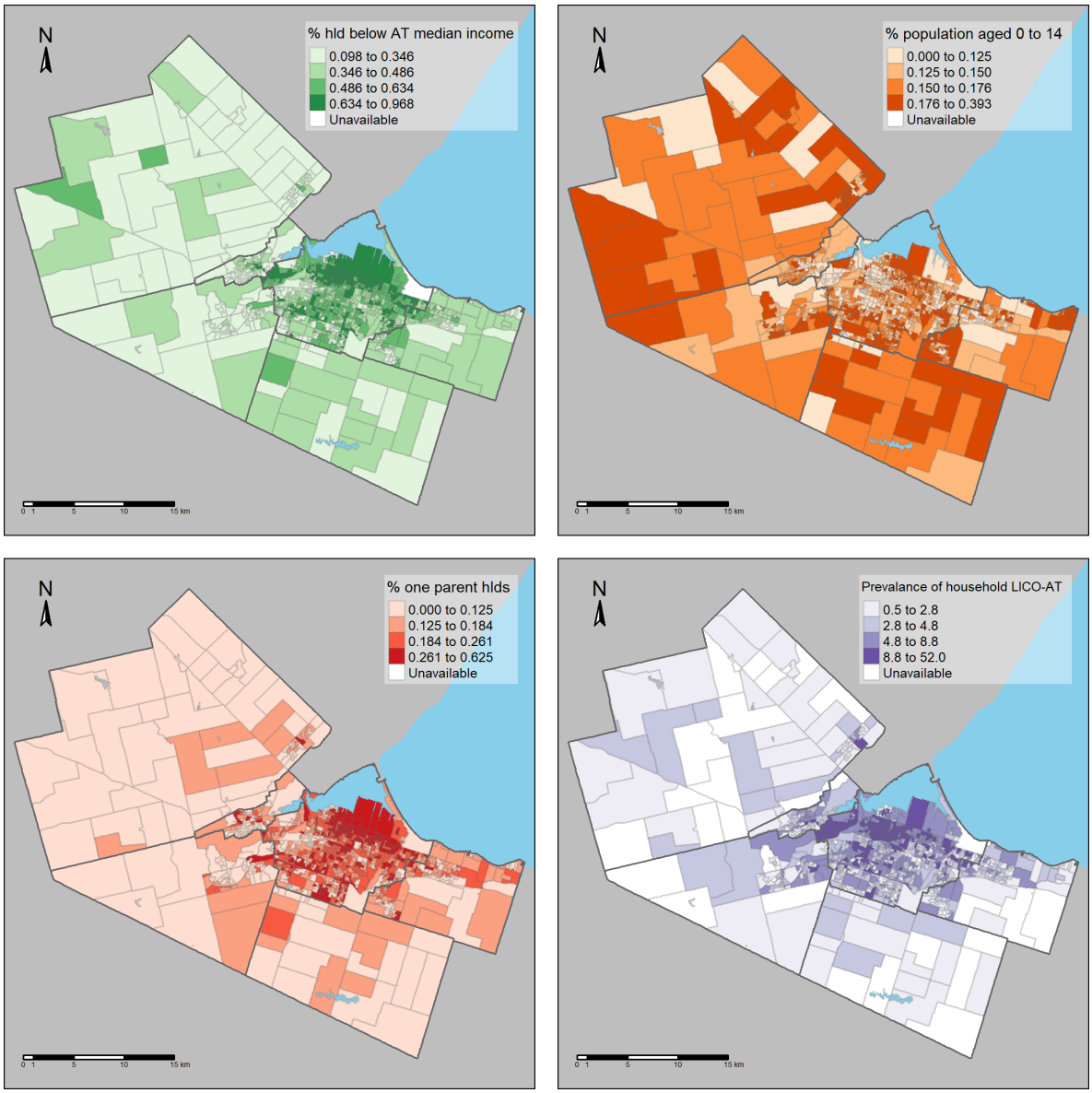


Figure 2: Socio-economic and demographic variables that characterise accessibility to care destinations retrieved from the 2021 Canadian Census. All scales in quartiles. Basemap shapefiles are sourced from the Open Data Hamilton Portal (Hamilton, 2023) and the USGS (USGS, 2010).

4.2. Care destination dataset

A spatial dataset of care destinations for Hamilton was compiled as detailed in the forthcoming work of Soukhov et al. (2024). The dataset includes 14 types of care destinations that were classified 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). Care categories, sources of data, and descriptive notes are detailed in Table 1. The spatial distribution of destination type are visualised in Figure 3 by their category.

Table 1: Description of care destinations categories, notes on data preparation and associated data sources.

Care category	Care destination types	Sources
Depedent-centric	Schools, daycares, and community centres, recreation centres, parks, senior centres, long-term care homes, and retirement homes: 1,265 locations are included.	(Hamilton 2022a, 2023, 2022c, 2022d; Ontario 2023; Ontario GeoHub 2023)
Grocery-centric	Convenience stores and grocery stores (e.g., large retailers as well as speciality food grocers, health food grocers): 381 destinations are included.	(Axle Data 2023)
Health-centric	Hospitals, pharmacies, clinics, and dentist offices: 421 destinations are identified.	(Ontario GeoHub 2023; HNHB Healthline 2023)
Errand-centric	Libraries, post offices, and banks: 158 destinations are identified.	(Hamilton 2022b; Axle Data 2023; Canada Post 2023; BMO 2023; HSBC 2023; National Bank 2023; RBC 2023; Scotiabank 2023; TD Bank 2023).

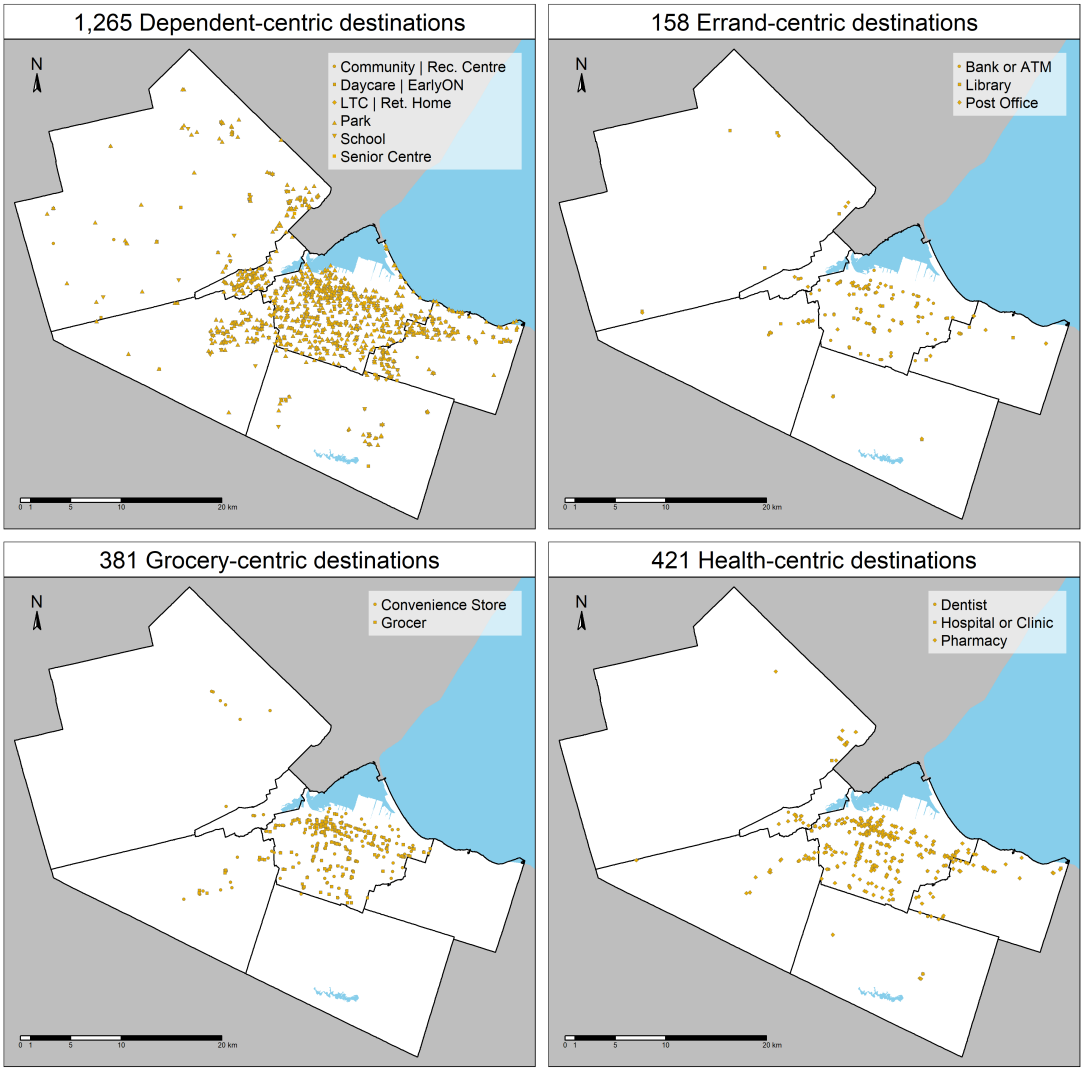


Figure 3: The locations of care destinations in Hamilton separated by the author-generated categories of: dependent-, errand-, grocery- and health- centric care categories. Basemap shapefiles are sourced from the Open Data Hamilton Portal (Hamilton, 2023) and the USGS (USGS, 2010).

4.3. Travel time to care destinations estimations

Travel behaviour to care-oriented destinations is often uncounted and hence comprehensive travel times to all destination types in Table 1 is unavailable. To overcome this gap, travel time from residential parcel locations in Hamilton and care destinations in Figure 3 are approximated assuming travel by foot at an average speed (3.6 km/hr). This estimation is done using the 'travel_time_matrix()' function from the {r5r} package (Pereira et al., 2021) using R version 4.3.2 (R Core Team, 2023). The inputs into the function are: the locations of 143,882 residential parcels as origins, the 2,225 care locations as destinations, and a

OpenStreetMap road network including walking infrastructure (Geofabrik, 2023). In line with the 15-Minute City, a maximum walking travel time of 15 minutes is specified 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.

5. Methods

The following sub-sections detail the methods to classify Hamilton into spatial degrees of *caring 15-minute neighbourhood*. First, accessibility to each of the 14 destination types from each of the 143,882 residential parcel locations is described. Second, the entropy measures used to calculate the diversity of accessibility to each of the care categories is detailed. Third, we describe how accessibility and diversity values for each parcel are input into a Self-Organizing Map (SOM) algorithm, and how the resulting clusters are analyzed using a Decision Tree algorithm to narrate residential profiles based on socio-economic variables. 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, and the socio-economic characteristics of those who are most benefited or burdened.

5.1. The cumulative opportunity measure of accessibility

To capture the quantity of spatial access to each type of destinations, a cumulative opportunity accessibility score S_i^t is calculated. Scores for each of the 14 care destination types t is calculated for every parcel i. The calculation takes the mathematical form in Equation 1:

$$S_i^t = \sum_j O_j^t \cdot f(c_{ij}) \tag{1}$$

Where:

- i is a set of parcel point origin locations.
- j is a set of care destination locations of type t.
- O_j^t is a number of opportunities of category type t at j.
- c_{ij} is the travel cost between i and j.
- $f(\cdot)$ is an impedance function of c_{ij}; within the cumulative opportunity approach, it is a binary function that takes the value of 1 if c_{ij} is less than a selected value (Handy and Niemeier, 1997).

- S_i^t is the cumulative opportunity accessibility score, the sum of opportunities reachable within $f(\cdot)$, at each i for each t.

5.2. Diversity in opportunity accessibility: the entropy measure

The entropy measure, as defined in Cervero and Kockelman (1997), is used to represent the diversity of care destination accessibility. For each parcel, a value between 0 to 1 is calculated, 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:

$$D_i = \frac{-\sum_t [S_i^t / \sum_t S_i^t \times ln(S_i^t / \sum_t S_i^t)]}{ln(n_t)} \tag{2}$$

Where:

- i is a set of parcel point origin locations.
- t is a set of care destination types (e.g., school, grocery, park, etc.)
- n_t is the count of care destination types t. In this work, this value is 14.
- S_i^t is the cumulative opportunity accessibility score, the sum of opportunities reachable within a 15-minute walk from i.
- D_i is the diversity score.

Notably, D_i represents evenness in the type of care categories a parcel can access. For example, if a parcel has an access score of $S_i^t = 0.5$ for all destination types, it will receive a diversity score of $D_i = 1$, just as if it had an access score of $S_i^t = 10$ for each destination. Conversely, a parcel may be assigned a low D_i score if its accessibility scores differ across categories, regardless of whether those scores are low or high.

5.3. Machine learning classification: SOM and Decision Trees

We use two machine learning techniques in this work. First, SOM is an unsupervised technique implemented to reduce the data dimensionality 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. An appropriate number of superclusters are selected and assigned labels based on the quantity and diversity of care access provided, i.e., the degree by each the parcel is located in

a *caring 15-minute neighbourhood*. Then, a Decision Tree is run to characterise the socio-economic profiles of who resides in neighbourhoods associated with the superclusters. 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 that used in Victoriano et al. (2020). In this work, rather than each observation representing an individual's daily mobility behaviour (with associated variables), each observation represents a parcel location with calculated care accessibility and accessibility diversity scores.

For the SOM step, the function 'trainSOM()' from {SOMbrero} R package is used (Villa-Vialaneix, 2017). The input variables include the 143,882 parcels, each as individual observation along with 15 variables: the 14 calculated accessibility scores S_i^t, normalized to the min-max range score within each t, and one diversity value D_i. 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 a node represents 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 are 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 et al., 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 related to the Mobility of Care literature are used as *features*. Features are retrieved from the 2021 Canadian Census (Statistics Canada, 2023). This step creates residential profiles of the superclusters, allowing us to explore the characteristics of residents within the superclusters 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. The Decision Tree algorithm 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 feature. 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 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 et al., 2020).

6. Results

6.1. Overview of access to care destinations

The number of care destinations that can be reached within a 15-minute walk is summarised for each of the four care categories (as defined in Table 1). The median parcel value for each DA is visualised in Figure 4 and the median parcel diversity of care destinations accessible is presented in Figure 5. Together, Figure 4 and Figure 5 represent summaries of 15 variables were inputs into the SOM algorithm.

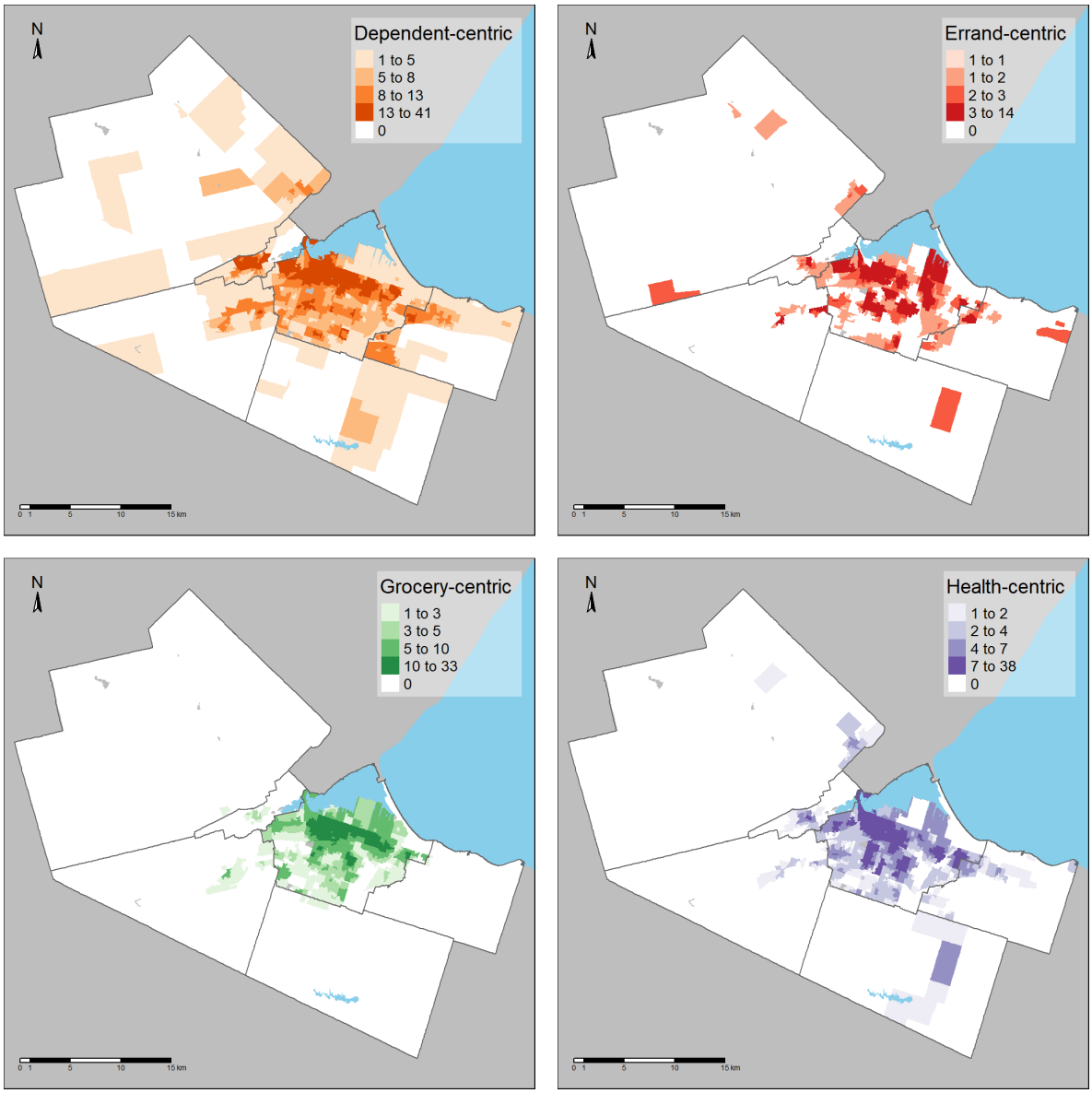


Figure 4: The number of care destinations that can be reached within a 15-min walk per care category for a median parcel in each DA. The values are a summary of the 14 acessibility scores that are inputs into the SOM. Basemap shapefiles are retrieved from the 2021 Canadian census (Statistics Canada, 2023), the Open Data Hamilton Portal (Hamilton, 2023) and the USGS (USGS, 2010). Scale is in quartiles.

Figure 5: The diversity measure based on the proportion of care category accessibility in Figure 4. These values are also 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, 2023) and the USGS (USGS, 2010). Scale is in quartiles.

6.2. Identification of completely caring 15-minute neighbourhood typologies

In Figure 4, for all care categories, access to opportunities is concentrated in downtown Hamilton (Hamilton Central), with the highest concentration (top quantiles) near the lake shore of Hamilton Central. Grocery-centric destinations follow this trend most prominently, followed by health-centric and dependent-centric caring destinations. Access to errand-centric destinations appears to most spatially homogeneous of the four care destination types, though the top quantiles are still concentrated in Hamilton Central. As the 15-minute walking accessibility to destinations is a spatially weighted summary measure of the count of destinations, Figure 4 mirrors the spatial distribution in Figure 3. In Figure 5, areas that have high diversity are broadly located in downtown Hamilton as well, however, there are exceptions. Namely, there are pockets of high diversity outside the downtown core that that score low levels of accessibility for all care categories. Similarly, there are areas with low diversity within the downtown core that have only moderate or high accessibility to certain care destination types.

Based on the SOM methodology discussed and using inputs summarised in Figure 4 and Figure 5, seven superclusters are identified as shown in the dissimilarity-index-based dendrogram (left plot of Figure 6). Seven superclusters are selected to represent the data, as they explain a high amount of the variance (over 90%; right plot in Figure 6). Each supercluster can be intuitively labelled based on the quantity of accessibility and diversity in accessibility per care category offered by a parcel, as mapped onto the SOM input grid. Labels representing grades A through D are assigned to qualify the seven superclusters. Higher grades (A+ and A) corresponding to the highest accessibility and diversity, while lowest grades (D) represent the lowest accessibility and diversity scores.

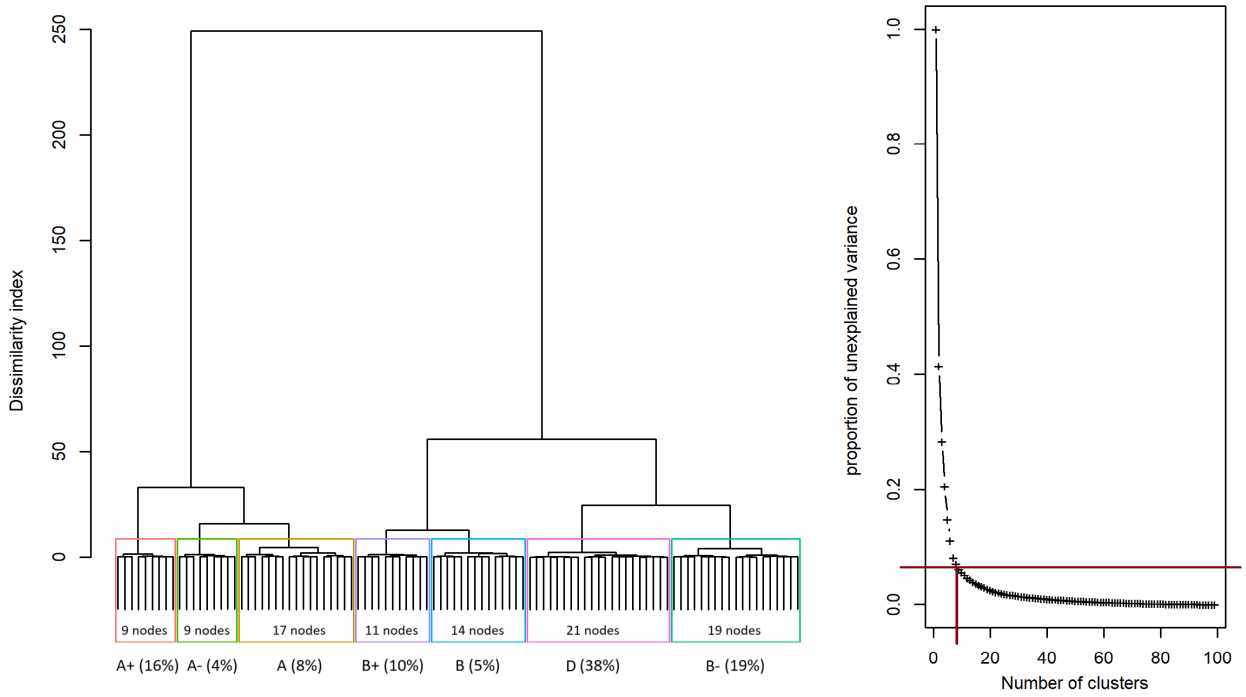


Figure 6: The seven resulting superclusters from the SOM output are represented in the dendrogram (left). As a diagnostic, the proportion of variance unexplained by the number superclusters is displayed on the right, with red lines indicating seven superclusters.

More specifically, each supercluster was labelled a grade by the authors by referring to the supercluster's descriptive statistics, as summarised in Table 2 and the boxplots in Figure 7. Additionally, the grades for each supercluster are further explained in context of the proportion of urban, suburban and rural parcels as classified by the City of Hamilton within the parcel dataset (Teranet, 2021). Notably, the majority of parcels in Hamilton are considered urban (93.4%), while suburban and rural parcels constitute the remaining 2.3% and 4.2%, respectively:

- A+ and A represent superclusters with 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 in the city and 100% are located in urban neighbourhoods. Based on the spatial access and diversity of care destination access offered by these neighbourhoods, they could be called "very caring" and "very complete".

- A- has high caring accessibility, but low diversity. These neighbourhoods could be classified as "very caring" but and "not complete". 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 contributes to reducing its overall diversity score. However, it could be characterized as a supercluster that demonstrates potential in being retrofitted to provide A+ or A level of completely caring access. 4% of all parcels are represented by the A- grade and, similar to parcels in A+ and A superclusters, 100% are located in urban neighbourhoods.

- 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. These grades represent 15% of all parcels and like parcels in A+, A and A- superclusters, 100% are located in urban neighbourhoods.

- 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- neighbourhoods could be labelled "somewhat caring" but "not complete". 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 all parcels. While the majority of parcels are still classified as urban neighbourhoods (99%), this supercluster represents 5.9% of the suburban parcels and 0.9% rural parcels in the city. These suburban and rural parcels are in proximity to urban parcels, as elaborated in the next subsection.

- D superclusters demonstrate the lowest scores all-around, representing room for land-use improvement that addresses complete and caring 15-minute access. D neighbourhoods could be classified as "not caring" and "not complete" due to the low amount of access to all care destinations offered and the care category diversity of this access. Notably, this supercluster characterizes the largest number of parcels, representing 38% of parcels in the city. Only 83% of these parcels are 'urban', and this supercluster

represents the vast majority of suburban and rural parcels in the city (94.1% and 99.1%).

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)
DEP. 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)
Comm. 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)

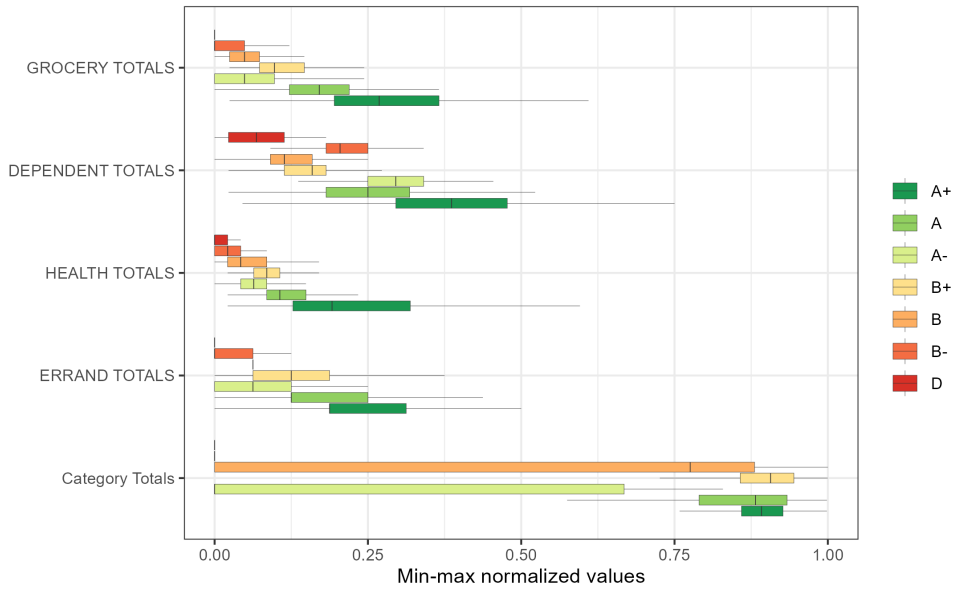


Figure 7: A boxplot demonstrating summary variables and category diversity that define the superclusters.

To spatially demonstrate where the superclusters are located, representative supercluster grades for each DA are visualised in Figure 8. This visualisation is created by grouping parcels by their DA and selecting the grade that is most dominant within that DA. For reference, the median number of parcels in each DA is 150 and supercluster grade membership within a DA is typically pure, with the median membership being 80% of a single cluster.

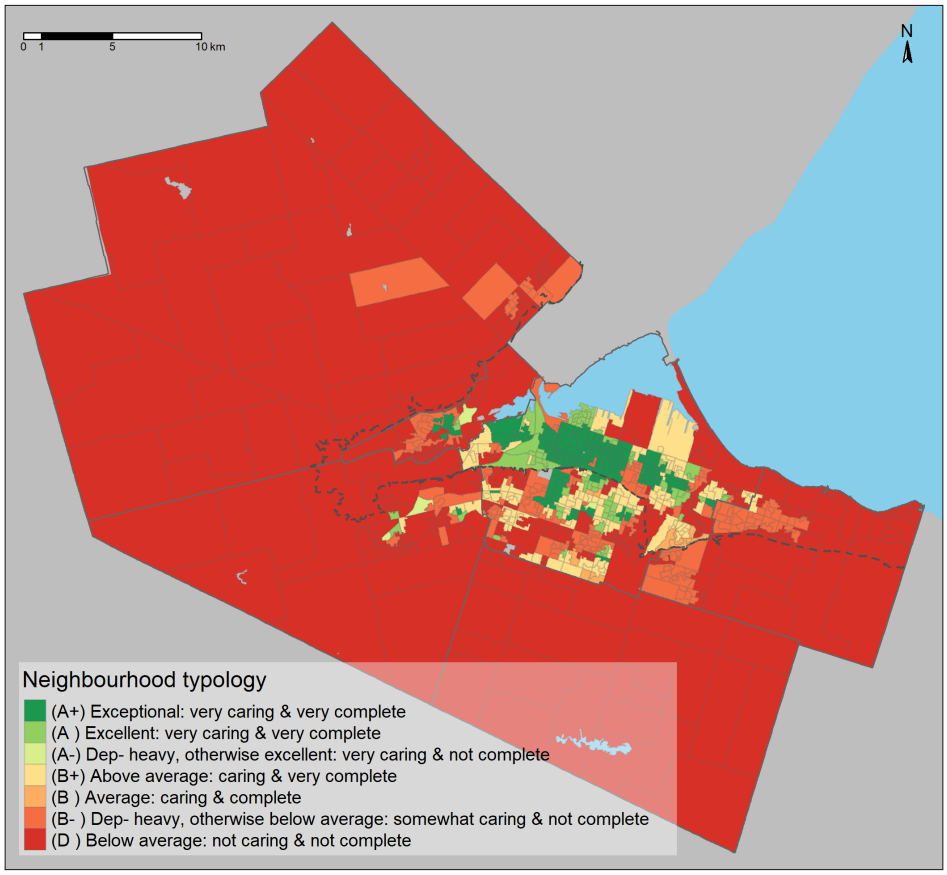


Figure 8: The maximum median parcel supercluster membership per DA. Escarpment is visualised as a grey dashed line. Basemap shapefiles are retrieved from the 2021 Canadian census (Statistics Canada, 2023), the Open Data Hamilton Portal (Hamilton, 2023) and the USGS (USGS, 2010).

Recall, the superclusters in Figure 8 are a combination of the cumulative opportunity and diversity of access measures translated into meaningful typologies through the SOM methodology. To reiterate, 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 city-wide high levels of complete caring access, which areas are city-wide average, and which areas are city-wide below average.

In Figure 8, 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 downtown core of Hamilton. The above and below average neighbourhoods (B+, B) are often proximate to the excellent and exceptional neighbourhoods and are more prevalent in south of the escarpment within the center 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 (majority rural and suburban). D neighbourhoods also tend to have the lowest diversity scores, with either no access or access to only one type of care destination category.

Furthermore in Figure 8, A- and B- grades stand out as offering high access for children-centric destinations for their grade-group but below grade-group average access in other destination types (e.g., low or lowest diversity scores). These neighbourhoods may be more suitable for populations who prioritize walkable access to children-centric 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.

6.3. Profiles of who does and does not reside in caring 15-minute 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 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 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 higher income, lower income, and middle income median household brackets.

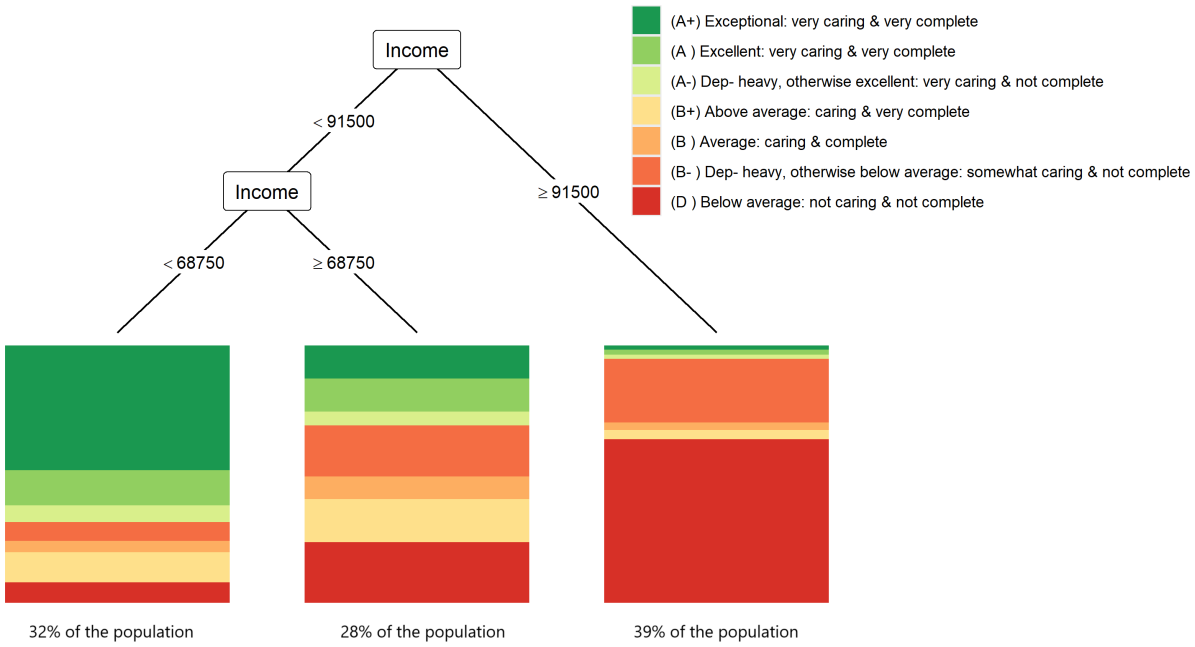


Figure 9: The Decision Tree demonstrating median household income splits and superclusters composition within each branch.

Describing Figure 9, the bar column on the right represents DAs with higher household income (>$91,500 median 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. This higher income column represents 39% of the population, the largest proportion of any of the three columns. The left column in Figure 9 corresponds to the lowest income (<$68,750 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 and 91,500) representing 28% of the population.

Though median income was the most useful in partitioning the parcels by their supercluster labels in Figure 9, other variables could also be important in partitioning the data. Namely, the following variables in order of importance and their correlation coefficient with the median household income variable in brackets,

are listed: 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 correlations 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 lower or no diploma (0.6), and most negatively with the median after-tax household income (-0.57), reflecting nationwide trends (Statistics Canada, 2024a,b). Though not all single-family households are below the LICO (i.e., 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 have A+ very completely caring access. Conversely, DAs with lower single-parent households are in DAs with a higher concentration of parcels with D not complete or caring access. These findings are notable from an equity perspective since economic disadvantaged often intersects with other socio-demographic characteristics (Ravensbergen et al., 2023b; Lightman and Good Gingrich, 2018).

7. Discussion

Spatially, Hamilton is a city that offers some completely caring 15-Minute neighbourhoods for some, but not all. There are evident spatial inequalities, with areas ranging from excellent (A+ and A), average (B+ and B), to well below average (D). Some areas, like those labelled A- and B-, show potential for improvement within their grade groups. While the downtown core has the highest concentration of *caring 15-minute neighborhoods*, certain areas outside the core do as well. This finding somewhat contrasts employment accessibility studies, such as El-Geneidy et al. (2016)'s assessment of public transit access to employment in the Greater Toronto Area (including Hamilton), where access is heavily concentrated in the downtown core, more so than appears to be present in this work. Though our paper uses a different methodology, both studies highlight distinct patterns: indeed, A+, A or A- care access is concentrated in the downtown core but it is also present in certain pockets outside of the center of Hamilton, leading to interesting conjectures. For instance, some of the A- neighborhoods likely follow land-use principles that emphasized residential proximity to amenities, similar to the NUC reviewed. The potential overlap of the NUC with caring 15-minute neighborhoods warrants further investigation.

Who currently resides in Hamilton's completely caring 15-Minute neighbhorhoods is also demonstrated to

be a somewhat 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 most Mobility of Care trips (Ravensbergen et al., 2023a). 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 now 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 will likely displaced in the coming years if current trends continue. These questions of gentrification, displacement and changing 15-Minute neighbourhoods in Hamilton are topical subjects that warrant further investigation.

In discussing policy interventions that equitably increase completely caring 15-Minute neighbourhoods in Hamilton, this work 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 accessibility for certain types of destinations but not all) are neighbourhoods with B- and A- grades. However, our work demonstrates that higher income households tend to reside in these neighbourhoods. This raises important questions for land-use policy that needs further analysis. For instance, 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 should be targeted? Who should potentially 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 include the evaluation of travel behaviour by socio-economic and demographic profiles along with qualitative perspectives, should play in planning for *equitable* 15-minute cities.

As is the case for all research, 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., they may be underutilized such as a parcel with a single-child household having 15-minute walkable access to two schools, as a child only needs to attend one school not two. As other examples: the trip may be physically undesirable e.g., 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 et al., 2023). Furthermore, the SOM methodology only incorporates aspects of spatial accessibility, and people who reside in these neighbourhoods may disagree with the neighbourhood's completely caring access grade. 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, residences 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). Also different care destination types can be more or else important to different people, indicating an aspect of competition and destination quality could be considered within the accessibility measure itself. 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 methodology and findings presented identifies spatial and socio-economic variations that should be further investigated. They can be examined through additional quantitative investigation but also through qualitative and mixed methods that can capture trends at the individual and personal level.

8. Conclusion

This work 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 (very completely caring 15-minute 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. Our work also demonstrates that residents of lower care access neighbourhoods tend to be wealthier than higher care access neighbourhoods highlighting the potential tensions in implementing sustainable land-use policy. We also detail limitations associated with our data and methodology and hence our results throughout the manuscript. 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, along with trends that warrant further investigation in future studies.

This work is of relevance to researchers 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", this work 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.

9. References

Allam, Z., Nieuwenhuijsen, M., Chabaud, D., Moreno, C., 2022. The 15-minute city offers a new framework for sustainability, liveability, and health. The Lancet Planetary Health 6, e181–e183.

Bastiaanssen, J., Johnson, D., Lucas, K., 2022. Does better job accessibility help people gain employment? the role of public transport in great britain doi:10.1177/00420980211012635.

Blumenberg, E., Pierce, G., 2017. The drive to work: The relationship between transportation access, housing assistance, and employment among participants in the welfare to work voucher program 37, 66–82. doi:10.1177/0739456X16633501.

Brody, J., 2013. The neighbourhood unit concept and the shaping of land planning in the united states 1912–1968 18, 340–362. URL: http://www.tandfonline.com/doi/abs/10.1080/13574809.2013.800453, doi:10.1080/13574809.2013.800453.

Burke, J., Gras Alomà, R., Yu, F., Kruguer, J., 2022. Geospatial analysis framework for evaluating urban design typologies in relation with the 15-minute city standards 151, 651–667. URL: https://www.sciencedirect.com/science/article/pii/S014829632200563X, doi:10.1016/j.jbusres.2022.06.024.

Cervero, R., Kockelman, K., 1997. Travel demand and the 3ds: Density, diversity, and design 2, 199–219. URL: https://linkinghub.elsevier.com/retrieve/pii/S1361920997000096, doi:10.1016/S1361-9209(97)00009-6.

Cheng, J., Bertolini, L., 2013. Measuring urban job accessibility with distance decay, competition and diversity 30, 100–109. URL: https://linkinghub.elsevier.com/retrieve/pii/S0966692313000604, doi:10.1016/j.jtrangeo.2013.03.005.

Cheng, L., Caset, F., De Vos, J., Derudder, B., Witlox, F., 2019. Investigating walking accessibility to recreational amenities for elderly people in nanjing, china 76, 85–99. URL: https://linkinghub.elsevier.com/retrieve/pii/S1361920919308119, doi:10.1016/j.trd.2019.09.019.

City of Portland, 2010. 20-Minute Neighborhoods. URL: https://www.portlandonline.com/portlandplan/index.cfm?c=52256&a=288098.

Craig, L., 2004. Time to care: A comparison of how couple and sole parent households allocate time to work and children URL: http://hdl.handle.net/1959.4/34125, doi:10.26190/UNSWORKS/264. ISBN: 9780733421396 Publisher: UNSW Sydney.

Cresswell, T., Uteng, T.P., 2008. Gendered mobilities: towards an holistic understanding, Ashgate aldershot ed., pp. 1–12. URL: https://scholar.googleusercontent.com/scholar.bib?q=info:Po-VQJ3PdC8J:scholar.google.com/&output=citation&scisdr=CgXWBZyhEKud2of3eV8:AAGBfm0AAAAAYhfxYV9SlOGokXr0aTZfNjhPI6OvxW5I&scisig=AAGBfm0AAAAAYhfxYc8iC6UkrBP7WOJiAwZK5pn99p9G&scisf=4&ct=citation&cd=-1&hl=en.

Dai, T.q., Liu, Z.b., Liao, C., Cai, H.y., 2018. Incorporating job diversity preference into measuring job accessibility 78, 108–115. URL: https://linkinghub.elsevier.com/retrieve/pii/S0264275117312465, doi:10.1016/j.cities.2018.02.003.

Delmelle, E.C., 2012. Spatial temporal dynamics of neighborhood quality of life: Charlotte, NC. Ph.D. thesis. The University of North Carolina at Charlotte.

Delmelle, E.C., 2017. Differentiating pathways of neighborhood change in 50 u.s. metropolitan areas 49, 2402–2424. URL: https://doi.org/10.1177/0308518X17722564, doi:10.1177/0308518X17722564. publisher: SAGE Publications Ltd.

Di Marino, M., Tomaz, E., Henriques, C., Chavoshi, S.H., 2023. The 15-minute city concept and new working spaces: a planning perspective from oslo and lisbon 31, 598–620. URL: https://doi.org/10.1080/09654313.2022.2082837, doi:10.1080/09654313.2022.2082837. publisher: Routledge _eprint: https://doi.org/10.1080/09654313.2022.2082837.

d'Ottawa, V., 2021. Quartier du quart d'heure | Nouveau Plan officiel | Participons Ottawa. URL: https://participons.ottawa.ca/nouveau-plan-officiel/news_feed/quartier-du-quart-d-heure.

Duarte, L.B., da Mota Silveira Neto, R., da Silva, D.F.C., 2023. The influence of job accessibility on individual labor income: Evidence for the city of recife, brazil. Journal of Transport Geography 112. doi:10.1016/j.jtrangeo.2023.103684.

EIGE, 2016. Gender in employment. URL: https://eige.europa.eu/sites/default/files/documents/ti_pubpdf_mh0216898enn_pdfweb_20170124124440.pdf.

El-Geneidy, A., Buliung, R., Diab, E., van Lierop, D., Langlois, M., Legrain, A., 2016. Non-stop equity: Assessing daily intersections between transit accessibility and social disparity across the greater toronto and hamilton area (GTHA) 43, 540–560. URL: https://doi.org/10.1177/0265813515617659, doi:10.1177/0265813515617659. publisher: SAGE Publications Ltd STM.

Ellis-Young, M., 2018. "we're just trying to help...make it a positive place": Community organizations, gentrification, and neighbourhood change in hamilton, ontario.

Ewing, R., Cervero, R., 2010. Travel and the built environment: A meta-analysis 76, 265–294. URL: http://www.tandfonline.com/doi/abs/10.1080/01944361003766766, doi:10.1080/01944361003766766.

Farber, S., Allen, J., 2019. The Ontario Line: Socioeconomic Distribution of Travel Time and Accessibility Benfits. Report. Metrolinx. URL: https://metrolinx.files.wordpress.com/2019/10/read-the-full-report-here.pdf.

Ferrant, G., Pesando, L.M., Nowacka, K., 2014. Unpaid care work: The missing link in the analysis of gender gaps in labour

outcomes. Boulogne Billancourt: OECD Development Center .

Frank, L.D., Schmid, T.L., Sallis, J.F., Chapman, J., Saelens, B.E., 2005. Linking objectively measured physical activity with objectively measured urban form 28, 117–125. URL: https://linkinghub.elsevier.com/retrieve/pii/S0749379704003253, doi:10.1016/j.amepre.2004.11.001.

Gaglione, F., Gargiulo, C., Zucaro, F., Cottrill, C., 2022. Urban accessibility in a 15-minute city: a measure in the city of naples, italy 60, 378–385. URL: https://linkinghub.elsevier.com/retrieve/pii/S2352146521009509, doi:10.1016/j.trpro.2021.12.049.

Gan, Z., Yang, M., Feng, T., Timmermans, H., 2020. Understanding urban mobility patterns from a spatiotemporal perspective: daily ridership profiles of metro stations 47, 315–336. URL: https://doi.org/10.1007/s11116-018-9885-4, doi:10.1007/s11116-018-9885-4.

García Román, J., Gracia, P., 2022. Gender differences in time use across age groups: A study of ten industrialized countries, 2005–2015 17, e0264411. URL: https://dx.plos.org/10.1371/journal.pone.0264411, doi:10.1371/journal.pone.0264411.

Geofabrik, 2023. Ontario, canada - open street map data. URL: https://www.geofabrik.de.

Gil Solá, A., Vilhelmson, B., 2022. To choose, or not to choose, a nearby activity option: Understanding the gendered role of proximity in urban settings. Journal of Transport Geography 99, 103301. URL: https://www.sciencedirect.com/science/article/pii/S0966692322000242, doi:10.1016/j.jtrangeo.2022.103301.

Gower, A., Grodach, C., 2022. Planning innovation or city branding? exploring how cities operationalise the 20-minute neighbourhood concept 40, 36–52. URL: https://www.tandfonline.com/doi/full/10.1080/08111146.2021.2019701, doi:10.1080/08111146.2021.2019701.

Graells-Garrido, E., Serra-Burriel, F., Rowe, F., Cucchietti, F.M., Reyes, P., 2021. A city of cities: Measuring how 15-minutes urban accessibility shapes human mobility in barcelona. PLoS One 16, e0250080. URL: https://www.ncbi.nlm.nih.gov/pubmed/33951051, doi:10.1371/journal.pone.0250080. graells-Garrido, Eduardo Serra-Burriel, Feliu Rowe, Francisco Cucchietti, Fernando M Reyes, Patricio eng Research Support, Non-U.S. Gov't 2021/05/06 PLoS One. 2021 May 5;16(5):e0250080. doi: 10.1371/journal.pone.0250080. eCollection 2021.

Guzman, L.A., Oviedo, D., Cantillo-Garcia, V.A., 2024. Is proximity enough? a critical analysis of a 15-minute city considering individual perceptions 148, 104882. URL: https://www.sciencedirect.com/science/article/pii/S0264275124000969, doi:10.1016/j.cities.2024.104882.

Hall, P., 2014. Cities of tomorrow: An intellectual history of urban planning and design since 1880. John Wiley & Sons.

Hamilton, 2023. City boundary. URL: https://open.hamilton.ca/datasets/dd522e1245b1461887d998c6c17edff7_13/explore?location=43.099541%2C-79.560176%2C9.73.

Handy, S., 2020. Is accessibility an idea whose time has finally come? 83, 102319. doi:https://doi.org/10.1016/j.trd.2020.102319.

Handy, S.L., Niemeier, D.A., 1997. Measuring accessibility: An exploration of issues and alternatives 29, 1175–1194. URL: http://journals.sagepub.com/doi/10.1068/a291175, doi:10.1068/a291175.

Hayden, D., 1982. The grand domestic revolution: a history of feminist designs for American homes, neighborhoods, and cities. First MIT press paperback edition ed., The MIT Press.

Hochschild, A., Machung, A., 2012. The second shift: Working families and the revolution at home. Penguin. URL: https://books.google.de/books?hl=de&lr=&id=St_6kWcPJS8C&oi=fnd&pg=PT25&ots=8IZZkZu4cf&sig=W1cAH6vLmc8SUYRgLvUUz3zfHWs&redir_esc=y#v=onepage&q&f=false.

Hosford, K., Beairsto, J., Winters, M., 2022. Is the 15-minute city within reach? evaluating walking and cycling accessibility to grocery stores in vancouver 14, 100602. URL: https://linkinghub.elsevier.com/retrieve/pii/S2590198222000641, doi:10.1016/j.trip.2022.100602.

International Labour Organization, 2018. Care work and care jobs for the future of decent work. Technical Report. International Labour Organization. Geneva. URL: https://webapps.ilo.org/wcmsp5/groups/public/---dgreports/---dcomm/---publ/documents/publication/wcms_633135.pdf.

Kissfazekas, K., 2022. Circle of paradigms? or '15-minute' neighbourhoods from the 1950s 123, 103587. URL: https://linkinghub.elsevier.com/retrieve/pii/S0264275122000269, doi:10.1016/j.cities.2022.103587.

Law, R., 1999. Beyond 'women and transport': towards new geographies of gender and daily mobility 23, 567–588. URL: http://journals.sagepub.com/doi/10.1191/030913299666161864, doi:10.1191/030913299666161864.

Levy, C., 2013. Travel choice reframed:"deep distribution" and gender in urban transport. Environment and Urbanization 25, 47–63.

Lightman, N., Good Gingrich, L., 2018. Measuring economic exclusion for racialized minorities, immigrants and women in canada: results from 2000 and 2010 22, 398–420. URL: https://doi.org/10.1080/10875549.2018.1460736, doi:10.1080/10875549.2018.1460736. publisher: Routledge _eprint: https://doi.org/10.1080/10875549.2018.1460736.

Little, J., 1994. Gender, Planning, and the Policy Process. Pergamon press ed. URL: https://books.google.de/books/about/Gender_Planning_and_the_Policy_Process.html?id=h1y0AAAAIAAJ&redir_esc=y.

Logan, T.M., Hobbs, M.H., Conrow, L.C., Reid, N.L., Young, R.A., Anderson, M.J., 2022. The x-minute city: Measuring the 10, 15, 20-minute city and an evaluation of its use for sustainable urban design. Cities 131, 103924. ISBN: 0264-2751 Publisher: Elsevier.

Lu, Y., Xiao, Y., Ye, Y., 2017. Urban density, diversity and design: Is more always better for walking? a study from hong kong 103, S99–S103. URL: https://linkinghub.elsevier.com/retrieve/pii/S0091743516302468, doi:10.1016/j.ypmed.2016.08.042.

MacIntyre, S., 2022. Her 20-minute neighbourhood. A critical feminist review of women's experiences of the 20-minute neighbourhood in Corstorphine, Edinburgh. Master's thesis. University of Groningen Faculty of Spatial Sciences Research. URL: https://frw.studenttheses.ub.rug.nl/3996/.

Sánchez de Madariaga, I., 2013. Mobility of Care: Introducing New Concepts in Urban Transport. book section 3.

Sánchez de Madariaga, I., Zucchini, E., 2019. Measuring Mobilities of Care, a Challenge for Transport Agendas.

Mahmoud, I., Morello, E., 2021. Co-creation pathway for urban nature-based solutions: Testing a shared- governance approach in three cities and nine action labs, in: Smart and Sustainable Planning for Cities and Regions: Results of SSPCR 2019—Open Access Contributions. Springer International Publishing. Green Energy and Technology, pp. 259–276. URL: http://link.springer.com/10.1007/978-3-030-57764-3, doi:10.1007/978-3-030-57764-3.

Mavoa, S., Boulangé, C., Eagleson, S., Stewart, J., Badland, H.M., Giles-Corti, B., Gunn, L., 2018. Identifying appropriate land-use mix measures for use in a national walkability index 11, 681–700. URL: https://www.jstor.org/stable/26622423. publisher: Journal of Transport and Land Use.

Mayers, R., Rallis, N., Doucet, B., Babin, C., 2023. In light of transit: Documenting the scales of urban change along the LRT line in hamilton, ontario n/a. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/cag.12890, doi:10.1111/cag.12890. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/cag.12890.

McBride, E.C., Davis, A.W., Goulias, K.G., 2020. Exploration of statewide fragmentation of activity and travel and a taxonomy of daily time use patterns using sequence analysis in california. Transportation research record 2674, 38–51.

Van der Merwe, J., 2021. Spillover gentrification? mid-sized cities within commuter sheds of global cities. URL: https://uwspace.uwaterloo.ca/bitstream/handle/10012/17628/VanderMerwe_Justin.pdf?sequence=4&isAllowed=n.

Moniruzzaman, M., Paez, A., 2012. Accessibility to transit, by transit, and mode share: application of a logistic model with spatial filters. Journal of Transport Geography 24, 198–205. doi:10.1016/j.jtrangeo.2012.02.006.

Montero, L., Mejía-Dorantes, L., Barceló, J., 2023a. Applying data analytics to analyze activity sequences for an assessment of fragmentation in daily travel patterns: A case study of the metropolitan region of barcelona. Sustainability 15, 14213.

Montero, L., Mejía-Dorantes, L., Barceló, J., 2023b. The role of life course and gender in mobility patterns: a spatiotemporal sequence analysis in barcelona. European Transport Research Review 15, 44.

Morency, C., Páez, A., Roorda, M.J., Mercado, R.G., Farber, S., 2011. Distance traveled in three Canadian cities: Spatial analysis from the perspective of vulnerable population segments. Journal of Transport Geography 19, 39–50.

Moreno, C., 2016. La ville du quart d'heure : pour un nouveau chrono-urbanisme. URL: https://www.latribune.fr/regions/smart-cities/la-tribune-de-carlos-moreno/la-ville-du-quart-d-heure-pour-un-nouveau-chrono-urbanisme-604358.html. section: La Tribune de Carlos Moreno.

Moreno, C., Allam, Z., Chabaud, D., Gall, C., Pratlong, F., 2021. Introducing the "15-Minute City": Sustainability, Resilience and Place Identity in Future Post-Pandemic Cities. Smart Cities 4, 93–111. URL: https://www.mdpi.com/2624-6511/4/1/6, doi:10.3390/smartcities4010006.

Morioka, W., Kwan, M.P., Hino, K., Yamada, I., 2023. How accessibility to neighborhood grocery stores is related to older people's walking behavior: A study of yokohama, japan. Journal of Transport & Health 32, 101668. URL: https://www.sciencedirect.com/science/article/pii/S2214140523001044, doi:https://doi.org/10.1016/j.jth.2023.101668.

Mouratidis, K., 2024. Time to challenge the 15-minute city: Seven pitfalls for sustainability, equity, livability, and spatial analysis 153, 105274. URL: https://linkinghub.elsevier.com/retrieve/pii/S0264275124004888, doi:10.1016/j.cities.2024.105274.

Mulíček, O., Osman, R., Seidenglanz, D., 2015. Urban rhythms: A chronotopic approach to urban timespace 24, 304–325. URL: http://journals.sagepub.com/doi/10.1177/0961463X14535905, doi:10.1177/0961463X14535905.

Napier, M.A., Brown, B.B., Werner, C.M., Gallimore, J., 2011. Walking to school: Community design and child and parent barriers. Journal of Environmental Psychology 31, 45–51. URL: https://www.sciencedirect.com/science/article/pii/S0272494410000502, doi:https://doi.org/10.1016/j.jenvp.2010.04.005.

Negron-Poblete, P., Séguin, A.M., Apparicio, P., 2016. Improving walkability for seniors through accessibility to food stores: a study of three areas of greater montreal. Journal of Urbanism: International Research on Placemaking and Urban Sustainability 9, 51–72. URL: https://doi.org/10.1080/17549175.2014.990916, doi:10.1080/17549175.2014.990916.

Nieuwenhuis, R., Maldonado, L.C., 2018. Single-parent families and in-work poverty, in: Lohmann, H., Marx, I. (Eds.), Handbook on In-Work Poverty. Edward Elgar Publishing. URL: https://china.elgaronline.com/view/edcoll/9781784715625/9781784715625.00016.xml, doi:10.4337/9781784715632.00016.

Omura, J.D., Hyde, E.T., Watson, K.B., Sliwa, S.A., Fulton, J.E., Carlson, S.A., 2019. Prevalence of children walking to school and related barriers—united states, 2017. Preventive Medicine 118, 191–195. URL: https://www.sciencedirect.com/science/article/pii/S0091743518303359, doi:https://doi.org/10.1016/j.ypmed.2018.10.016.

Paez, A., Scott, D.M., Morency, C., 2012. Measuring accessibility: positive and normative implementations of various accessibility indicators. Journal of Transport Geography 25, 141–153. doi:10.1016/j.jtrangeo.2012.03.016.

Palm, M., Farber, S., 2020. The role of public transit in school choice and after-school activity participation among toronto high school students 19, 219–230. URL: https://linkinghub.elsevier.com/retrieve/pii/S2214367X19302431, doi:10.1016/j.

tbs.2020.01.007.

Pereira, R.H.M., Saraiva, M., Herszenhut, D., Braga, C.K.V., Conway, M.W., 2021. r5r: Rapid realistic routing on multimodal transport networks with r5 in r. Findings doi:10.32866/001c.21262.

Portland Government, 2017. The Portland Plan Progress Report .

Pozoukidou, G., Chatziyiannaki, Z., 2021. 15-minute city: Decomposing the new urban planning eutopia 13, 928. URL: https://www.mdpi.com/2071-1050/13/2/928, doi:10.3390/su13020928. number: 2 Publisher: Multidisciplinary Digital Publishing Institute.

R Core Team, 2023. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. URL: https://www.R-project.org/.

Randall, T.A., Baetz, B.W., 2015. A GIS -based land-use diversity index model to measure the degree of suburban sprawl 47, 360–375. URL: https://rgs-ibg.onlinelibrary.wiley.com/doi/10.1111/area.12182, doi:10.1111/area.12182.

Ravensbergen, L., Fournier, J., El-Geneidy, A., 2023a. Exploratory analysis of mobility of care in montreal, canada. Transportation Research Record 2677, 1499–1509.

Ravensbergen, L., Fournier, J., El-Geneidy, A., 2023b. Exploratory Analysis of Mobility of Care in Montreal, Canada. Transportation Research Record 2677, 1499–1509. URL: https://doi.org/10.1177/03611981221105070, doi:10.1177/03611981221105070. publisher: SAGE Publications Inc.

Roorda, M.J., Paez, A., Morency, C., Mercado, R., Farber, S., 2010. Trip generation of vulnerable populations in three Canadian cities: a spatial ordered probit approach. Transportation 37, 525–548. doi:10.1007/s11116-010-9263-3.

Ryan, J., Pereira, R.H.M., Andersson, M., 2023. Accessibility and space-time differences in when and how different groups (choose to) travel. Journal of Transport Geography 111. doi:10.1016/j.jtrangeo.2023.103665.

Scheiner, J., Holz-Rau, C., 2015. Women's complex daily lives: a gendered look at trip chaining and activity pattern entropy in germany. Transportation 44, 117–138. doi:10.1007/s11116-015-9627-9.

Silva, C., Altieri, M., 2022. Is regional accessibility undermining local accessibility? 101, 103336. URL: https://www.sciencedirect.com/science/article/pii/S096669232200059X, doi:10.1016/j.jtrangeo.2022.103336.

Silva, C., Büttner, B., Seisenberger, S., Rauli, A., 2023. Proximity-centred accessibility—a conceptual debate involving experts and planning practitioners 4, 100060. URL: https://www.sciencedirect.com/science/article/pii/S266709172300016X, doi:10.1016/j.urbmob.2023.100060.

Solow, A.A., Ham, C.C., Donnelly, E.O., 1969. The concept of the neighborhood unit: Its emergence and influence on residential environmental planning and development. Graduate School of Public and International Affairs, University of Pittsburgh.

Soukhov, A., Mooney, N., Ravensbergen, L., 2024. Exploring mobility of care with measures of accessibility .

Statistics Canada, 2024a. The daily — main highlights on income of families and individuals: Subprovincial data from the t1 family file, 2022. URL: https://www150.statcan.gc.ca/n1/daily-quotidien/240819/dq240819b-eng.htm.

Statistics Canada, 2024b. Prevalence of low income among persons in one-parent families headed by an immigrant parent: An intersectional analysis. URL: https://www150.statcan.gc.ca/n1/pub/45-20-0002/452000022024001-eng.htm.

Statistics Canada, 2023. Governement of canada - census of population. URL: https://www12.statcan.gc.ca/census-recensement/index-eng.cfm.

Talen, E., 2017. Social science and the planned neighbourhood 88, 349–373. URL: https://go-gale-com.libaccess.lib.mcmaster.ca/ps/i.do?p=AONE&sw=w&issn=00410020&v=2.1&it=r&id=GALE%7CA493702956&sid=googleScholar&linkaccess=

abs, doi:10.3828/tpr.2017.22. publisher: Liverpool University Press (UK).

Teixeira, J.F., Silva, C., Seisenberger, S., Büttner, B., McCormick, B., Papa, E., Cao, M., 2024. Classifying 15-minute cities: A review of worldwide practices 189, 104234. URL: https://linkinghub.elsevier.com/retrieve/pii/S0965856424002829, doi:10.1016/j.tra.2024.104234.

Teranet, 2021. Hamilton parcel/land use data 2020.

Therneau, T., Atkinson, B., 2023. rpart: Recursive Partitioning and Regression Trees. URL: https://github.com/bethatkinson/rpart. r package version 4.1.23, https://cran.r-project.org/package=rpart.

Tronto, J.C., Fisher, B., 1990. Toward a Feminist Theory of Caring, in: Abel, E., Nelson, M. (Eds.), Circles of Care. SUNY Press, Albany, NY, pp. 36–54. URL: https://books.google.de/books?hl=de&lr=&id=sAYy_oEw6NcC&oi=fnd&pg=PA29&dq=Towards+Feminist+Theory+of+Caring&ots=H93jKUsuvt&sig=LeJy-oufC87O8kIfxhnRrpbqEw8#v=onepage&q=Towards%20Feminist%20Theory%20of%20Caring&f=false.

Trudeau, D., 2013. New Urbanism as Sustainable Development? Geography Compass 7, 435–448. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/gec3.12042, doi:10.1111/gec3.12042. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/gec3.12042.

UN Women, 2022. Handbook on gender mainstreaming for gender equality results. URL: https://www.unwomen.org/sites/default/files/2022-02/Handbook-on-gender-mainstreaming-for-gender-equality-results-en.pdf.

UNICEF, 2024. Annex i: DIVERSITY, EQUITY AND INCLUSION GLOSSARY for the UNITED NATIONS COMMON SYSTEM. URL: https://unsceb.org/sites/default/files/2024-01/DEI%20Glossary.pdf.

Urban Development Vienna, 2013. Gender mainstreaming in urban planning and urban development.

USGS, 2010. Great lakes and watersheds shapefiles. URL: https://www.sciencebase.gov/catalog/item/530f8a0ee4b0e7e46bd300dd.

Vacchelli, E., Kofman, E., 2018. Towards an inclusive and gendered right to the city. Cities 76, 1–3. URL: https://linkinghub.elsevier.com/retrieve/pii/S0264275117312040, doi:10.1016/j.cities.2017.10.013.

Vale, D., Lopes, A.S., 2023. Accessibility inequality across europe: a comparison of 15-minute pedestrian accessibility in cities with 100,000 or more inhabitants. npj Urban Sustainability 3, 55.

Victoriano, R., Paez, A., Carrasco, J.A., 2020. Time, space, money, and social interaction: Using machine learning to classify people's mobility strategies through four key dimensions 20, 1–11. URL: https://linkinghub.elsevier.com/retrieve/pii/S2214367X19302698, doi:10.1016/j.tbs.2020.02.004.

Villa-Vialaneix, N., 2017. Stochastic self-organizing map variants with the r package sombrero, in: JC, L., M, C., M, O. (Eds.), Proceedings of the 12th International Workshop on Self-Organizing Maps and Learning Vector Quantization, Clustering and Data Visualization (WSOM 2017), IEEE, Nancy, France. pp. 1–7.

Ville de Paris, 2022. Paris ville du quart d'heure, ou le pari de la proximité. URL: https://www.paris.fr/dossiers/paris-ville-du-quart-d-heure-ou-le-pari-de-la-proximite-37.

Whittaker, R.H., 1972. Evolution and measurement of species diversity. Taxon 21, 213–251.

Willberg, E., Fink, C., Toivonen, T., 2023. The 15-minute city for all? – measuring individual and temporal variations in walking accessibility 106, 103521. URL: https://linkinghub.elsevier.com/retrieve/pii/S0966692322002447, doi:10.1016/j.jtrangeo.2022.103521.

Yin, Z., Zheng, Y., Li, W., 2024. Incorporating facility diversity into measuring accessibility to transit: A case study in beijing 150, 05024018. URL: https://ascelibrary.org/doi/10.1061/JUPDDM.UPENG-4935, doi:10.1061/JUPDDM.UPENG-4935.

836 publisher: American Society of Civil Engineers.
837 Yu, C.Y., Zhu, X., 2016. From attitude to action: What shapes attitude toward walking to/from school and how does it
838 influence actual behaviors? Preventive Medicine 90, 72–78. URL: https://www.sciencedirect.com/science/article/pii/S009
839 174351630161X, doi:https://doi.org/10.1016/j.ypmed.2016.06.036.

CRediT author statement

Anastasia Soukhov: Conceptualization, Methodology, Data curation, Investigation, Visualization, Software, Writing- Original draft preparation & review and editing.
Léa Ravensbergen: Conceptualization, Investigation, Writing- Original draft preparation & review and editing.
Lucía Mejía Dorantes: Investigation, Writing- Original draft preparation & review and editing.
Antonio Páez*:* Conceptualization, Methodology, Investigation, Software, Writing- Reviewing and Editing.