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How far are cities from the x-minute city vision? Examining current local travel behavior and land use patterns in Montreal, Canada

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ABSTRACT

In the past three years the 15-minute city planning concept has captured the attention of policy makers and the public worldwide. Some regions have included it in their planning goals and others modified it to 30 min to make it more attainable in their local context. The goal of this research is to measure whether the 15- or 30-minute city goals align with current travel behaviour and land use patterns in the North American context using Montreal, Canada as the case study. In doing so, we look at which destinations are cultivating local travel patterns consistent with the 15- and 30-minute city concepts and identify any unique qualities of these areas using the 2018 Montreal origin-destination travel diaries. Our bivariate analysis finds very few destinations in Montreal where a high number of trips and high percentage of trips are ending using a sustainable mode of transport and below the 15- or 30-minute travel time threshold. We further investigate the land use patterns that align with the 15- and 30-minute city to recommend realistic planning goals and policy interventions that match the North American context. The findings from this research can be of interest to transport professionals and policy makers trying to implement the 15- or 30- minute city concepts to their regions.

1. Introduction

The 15-minute city is a popular planning concept that has captured the attention of policy makers and the general public worldwide (TED Conferences, 2021). Its core definition—that everyone can meet all their daily needs within 15 min by active travel (cycling and walking) from their home—is an easy-to-understand framework that offers an attractive vision for what cities could become (TED Conferences, 2021). For city leaders around the world looking to combat chronic traffic congestion and overcome urban challenges magnified by the COVID-19 pandemic, the 15-minute city appears to represent a promising path forward. Unlike traditional vehicle-oriented transport planning strategies, this approach prioritizes sustainable and accessible local travel. With an emphasis on walking and cycling, efficiency in transport is redefined to focus on proximity to destinations rather than fast travel speeds. In 2020, Paris became the first major city to incorporate the 15-minute city into its planning policy (Municipalité de Paris, 2022). Mayors around the world have followed suit in hopes of bringing the urban conviviality promised by the 15-minute city to their own cities (Gongadze & Maassen, 2023).

While the 15-minute city has resulted in a wave of enthusiasm around improving local accessibility, questions remain unanswered about how this strategy, developed in the Parisian context, could be applied in other cities (Birkenfeld et al., 2023). The concept of the 15-minute city was developed in response to increasing automobile dependency. Moreno envisioned a future for cities where all social functions including work, food, health, education, culture, and leisure are conducted within a 15-minute travel time radius using walking and cycling modes (TED Conferences, 2021), which can aid in transitioning the focus to more sustainable forms of urban mobility (Tsavachidis & Petit, 2022). What this definition does not make explicit is what it takes to turn aspiration into reality across different contexts.

Most cities look very different compared to the denser areas of Paris and are characterized by unique built environments, travel patterns, and cultures. For this reason, Australian cities have been advocating for other versions of the x-minute city that align with their context and are based on higher time-thresholds (Levinson, 2019; Stanley & Stanley, 2014). Melbourne, for example, has adopted a 20-minute city vision based on “the maximum time people are willing to walk to meet their daily needs locally” (Victoria, 2023). The Greater Sidney goes even further by focusing a 30-minute goal where “jobs, services, and quality public spaces are in easy reach of people’s homes” (Greater Sydney

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Commission, 2018). In North America, the prevailing separation of land uses and deeply rooted car culture makes achieving the 15-minute city particularly challenging and, similarly to the Australian example, other time thresholds may have to be considered.

The purpose of this study is to assess the extent to which existing land use and travel behaviour in the North American context align with the approach of 15- and 30-minute city goals. The 30-minute travel time threshold is also assessed to accommodate the spread and scale of North American cities compared to their European counterparts, which is based on Levinson (2019). An argument that even Moreno et al. (2023) has made for when addressing those living in semi-dense or sparsely populated areas which he terms 30-minute territories. By doing so, we aim to understand how far North American cities are from attaining such visions and to derive attainable policies.

This study expands on the work of Birkenfeld et al. (2023), which identified the characteristics of households living a 15- or 30-minute city lifestyle by switching the focus of analysis from households (origins) to destinations. We explore which destinations in Montreal, Canada are currently cultivating local travel patterns consistent with the 15- and 30-minute city concepts and identify any unique qualities of these areas. We also expand the 15-minute city original definition to include public transit along with walking and cycling as it has been described as a 'quasi-active mode' (Ermagun & Levinson, 2017), contributing to active lifestyles (Winters et al., 2017) especially in car centric contexts such as North America (Crist et al., 2021; Daley et al., 2022). Moreover, transit can be found as part of the "x-minute city" definition of several North American and Australian cities (Logan et al., 2022).

Given the historic separation of land uses characteristic of North American cities, we are interested to learn what it looks like when neighborhoods begin to evolve toward more locally accessible landscapes. Findings from this study will help to clarify the baseline from which car-dependent cities are starting from relative to the 15-or 30-minute city vision. It highlights how local accessibility at its best currently exists in a North American context and can help inform cities across different contexts in defining targets to strive for.

2. Literature review

Despite the recent surge of interest in the x-minute city, the principles of the concept have been around for decades. Prioritizing efficient access to daily destinations and centering people and community in the development of cities matches the sentiment behind the "neighborhood unit", "human scale", and even "transit-oriented development" planning approaches of the last century (Dittmar & Poticha, 2004; Kissfazekas, 2022; Perry, 2015). What unites these strategies is their attention toward the value of people's time, energy, and collective wellbeing as resistance to the auto-oriented alienation of modern cities (Abdelfattah et al., 2022). A strong body of literature points to the positive satisfaction, mental health, and physical health outcomes of short travel distances, especially at the neighborhood level, and the use of active modes (Friman et al., 2017; Humagain & Singleton, 2020; Raynor et al., 1998; Rundle et al., 2016; Smith et al., 2017; St-Louis et al., 2014), including feelings of belonging associated with the social exposure of local travel (Alexander, 1967; Te Brömmelstroet et al., 2017).

The x-minute city is the newest manifestation of local accessibility planning, responding to increased congestion and the relentless effort to travel faster and further (Moreno, 2022). To this end, it presents a paradigm shift toward higher-density, mixed-use neighborhoods that support access to essential social functions, including work, education, healthcare, commerce, and entertainment within x minutes using active modes of transport. However, efforts to bring the x-minute city to life have lacked appropriate metrics and policy direction, preventing successful implementation (Gower & Grodach, 2022). In this light, one challenge might be shortening commute trips. Boussauw et al., (2012) highlight that even though shortened commutes might follow from changes in urban structure, they are still a "niche market". Moreover, it is important to highlight that previous attempts to offer urban renewal, including increased access to public services, can fail to do so as exemplified by the "rénovation urbaine" movement in the Parisian context which has unintentionally reinforced segregation (Epstein, 2011; Fol, 2013).

Recent research has offered a range of strategies to operationalize the x-minute city model. Studies have investigated the optimal distribution of built environment features needed for local living (Gaglione et al., 2022) and evaluated accessibility to key destinations to measure progress toward the x-minute city goal (Caselli et al., 2022; Hosford et al., 2022). The ability to reach all daily needs within 15 or 30 min of active travel relies on proximity. Metrics such as Walk Score (Front Seat Management, 2014) and the multicriteria approach developed by Alexandros Bartzokas-Tsiompras and Efthimios Bakogiannis (2023) offer systems for gaging accessibility based on proximity to surrounding destinations. Other researchers have incorporated demographic data to highlight who is able to benefit from the most locally accessible locations based on socio-spatial inequalities (Calafiore et al., 2022; Weng et al., 2019). Elldér et al., (2017) have shown differences in accessibility levels by age and income while Gil Solá and Vilhelmson (2022) unveiled distinct patterns of influence of amenity density on travel behaviour across genders. On a broader note, it should be cautioned that the focus on proximity alone is not enough to foster local living as the quality and functionality of provided facilities are also key (Gil Solá, Vilhelmson & Larsson, 2018).

While the x-minute city framework has been explored from different angles, most of these efforts have focused on travel potential (Hosford et al., 2022; Kesarovski & Hernandez, 2023; Liu et al., 2024; Olivari et al., 2023; Willberg et al., 2023; Zhang et al., 2023), with few studies incorporating actual travel behaviour of local populations (Birkenfeld et al., 2023; Mariotti et al., 2022). Observed travel patterns provide valuable insights into mode choice, cultural transport norms, and where and when people move (De Witte et al., 2013; Horiuchi et al., 2023; Pucher & Renne, 2005). Additionally, the relationship between land use and travel behaviour, which is especially relevant to proximity-based planning of the x-minute city, has been well-documented (De Vos, 2015; Handy, 1992; Kockelman, 1997; Limtanakool et al., 2006). An analysis of transport patterns in non-urban areas of Europe conducted by Poorthuis and Zook (2023) revealed the particular challenges that the locales faced regarding the 15-minute city concept. Centering the lived experiences and land use realities of different areas lends contextually appropriate findings about how the x-minute city concept could be extended to other areas (Poorthuis & Zook, 2023).

Even with the rising enthusiasm from city leaders to pursue the x-minute city goal, little research has leveraged travel behavior data, such as origin-destination surveys (Birkenfeld et al., 2023), to understand current travel patterns relative to the applicability of the concept in different contexts. To date, most research has focused on the potential performance of different cities based on either accessibility measures (Hosford et al., 2022; Knap et al., 2023; Liu et al., 2024) or new walkability or cycling indexes (Bartzokas-Tsiompras & Bakogiannis, 2023; Gorrini et al., 2023). However, although valid, these approaches cannot provide insight into how current travel behaviour aligns with x-minute cities aspirations. To address this gap, our study looks toward actual travel patterns and land use data to assess the attainability of the x-minute city in North America. This approach helps to identify what it would take to achieve the x-minute city in more car dominant urban environments and how helpful the framework is for reaching local accessibility and equity goals.

3. Data and methods

3.1. Study context

Montreal is the second most populous city in Canada. It is centered around the Island of Montréal and a couple of smaller peripheral islands.

It totals a population of around 1.7 million inhabitants to a metropolitan region of 4.3 million people (StatCan, 2021). Even though no clear commitments have been made by the city in regard to the 15-minute concept, the current administration has vowed to act at the "human scale" with the objective of providing "equitable access to services and infrastructure" at the neighborhood level (Montreal, 2020). Moreover, it has made efforts to increase the current cycling infrastructure, including a new 191-kilometer express cycling network (réseau express vélo) (Montreal, 2023a). The city has also adopted a policy of street pedestrianization, which mostly happen over the summer months (Montreal, 2023b).

Montreal's public transport network is operated by 4 public transit agencies. On the island of Montreal, the bus and metro lines are operated by the Société de Transport de Montréal (STM). Buses in the two adjacent suburbs off the island are operated by Réseau de transport de Longueuil (RTL) and Société de transport de Laval (STL). Meanwhile the far suburban areas are served by both buses and commuter rail linking to the downtown core provided by Exo. The regional public transport planning and financing is led by its partner agency, the Autorité régionale de transport métropolitain (ARTM). Among its many functions, ARTM is charged with conducting an Origin-Destination (OD) survey for the greater Montréal region. The OD survey has the goal to contribute to the better planning of the local and regional public transit and road networks as well as the improvement of urban planning in the greater Montreal region (ARTM, 2020a).

3.2. Origin destination survey

In this study, x-minute city activity is modeled by assessing current travel behaviour as reported in the Montreal Origin-Destination (OD) survey. The survey is administered every five years by the regional public transport planning authority (ARTM) and our analyses draw from the 2018 edition, which is the most recently available. The data represents a 5% random sample of Montreal households, including a one-day weekday travel diary of every household member. Potential respondents are contacted randomly by phone. In the 2018 edition, 74,000 households were interviewed reflecting 360,000 trips and 170,000 people (ARTM, 2020a). Each observation represents one trip, with origin and destination data provided as latitude and longitude values. The survey collects sociodemographic information at the personal and household level, and a travel-based weighting factor is provided for every trip as an estimated projection of the number of trips it reflects in the region. Data on trips regarded origin, destinations, period of the day, trip purpose, and modes used. More details on the OD interview guide and the data collection procedures can be found at ARTM (2020b).

3.3. X-minute city framework and operationalization

The OD data is used to explore the spatial distribution of 15- and 30-minute travel patterns in the Montreal region. For the purposes of this study, an x-minute trip is defined as a trip that was completed using walking, cycling, or public transit modes within the x-minute travel time threshold. We remark that as our goal is to identify and compare areas that are currently cultivating local travel patterns to those more regionally serving, we do not include trips that could have potentially been completed within the stipulated time thresholds when using a different mode. Therefore, car trips were automatically labeled as non-15- and 30-minute trips as they were not completed using one of the qualifiable modes. We also exclude other active modes (e.g., scooters, skateboards, etc.) from our definition as travel times could not be estimated accurately.

In summary, each trip in the survey is evaluated for its compatibility with our x-minute city definition. A spatial analysis of trip destinations is then conducted to locate areas that are particularly conducive to travel as defined by the 15- and 30-minute city concepts. To do so, land use data is analyzed to gain further insight into the urban features that characterize the most locally accessible areas.

3.4. Data preparation

The survey data was first filtered to represent households that conducted all travel within the Montreal metropolitan area boundary. Trips were removed from the sample if the origin and destination locations were identical, trip details were missing, or other variables such as income were not reported. Because our analysis focuses on identifying local and regional destination hot spots, trips were removed if the trip purpose was "return home".

The x-minute city definition was then used to classify each survey trip as a 15-minute trip, 30-minute trip, or neither (all 15-minute trips were also labeled as 30-minute ones). To meet the definition, a trip must be completed within the given travel time threshold by walking, cycling, or public transit modes. Travel times between each origin-destination pair were produced through network routing using the r5r package in R as they were not provided in the origin-destination travel diaries, supported by sidewalk, bike lane, and roadway data from Open Street Map (OSM). For trips completed by walking or cycling, travel times were estimated using travel speeds of 4.5 km/h and 16 km/h, respectively (El-Geneidy et al., 2007; Silva et al., 2014). Public transit trips were routed through a network comprised of the OSM and General Transit Feed Specification (GTFS) data from all public transport agencies providing service in the study area. The r5r tool was used to calculate public transit travel times based on this network and the departure timestamp recorded for the given trip (Pereira et al., 2021). The OSM and GTFS files were downloaded from 2019 and public transport trips were simulated for Tuesday April 23rd, 2019. To our knowledge, no significant road network changes or public transport service adjustments occurred between the time of the survey and the date the travel time routing data was sourced. Through the travel time calculations procedure, trips were removed from the sample if they had OSM network routing issues ($n = 16{,}484$ trips). The final cleaned sample totaled 146, 556 trips including: 13,379 15-minute trips and 133,177 non-15-minute trips; 24,361 30-minute trips and 122,195 non-30-minute trips.

3.5. Spatial analysis

To assess the distribution of trip destinations, a hexagonal grid was produced over the greater Montreal area to represent units of equal geographic size. Each hexagon measured about 860 m across, or just over half a mile. This size was selected because it represents a reasonable local walking distance. The trip destinations from the cleaned OD data were joined to the grid to count the number of trips ending in each hexagon. The travel-based weighting factors associated with the trips were used to scale each count to a region-wide travel estimate as specified by the data provider (ARTM, 2020b). Hexagons with fewer than 20 trip destinations from the OD survey were removed due to thin data. Hexagons with 20 or more sample trips totaled 1496.

Two metrics of x-minute city behaviour were created based on this data. The first represents the number of 15- and 30-minute trips ending within the bounds of each hexagon. The second assigns a percentage based on the proportion of 15- or 30-minute trips ending in each hexagon compared to all trips ending in the hexagon. These variables provide different perspectives on measuring success toward the x-minute city goal; the former evaluating the quantity of local activity and the latter focusing on relative travel behaviour. We then combined the two metrics into a bivariate analysis to capture the interaction between them. To produce the bivariate analysis, each of the two metrics were divided into three bins. The bins were defined based on natural breaks aiming to reduce within-group and maximize between-group differences. Hexagons were labeled with one out of nine categorical values based on the combination between the two sets of low, medium, and high bins (Fig. 1).

Bin	Number of x-minute trip destinations	Percent of x-minute trip destinations
Low	100 - 500	5% - 15%
Medium	500 - 2,000	15% - 40%
High	2,000 +	40% +

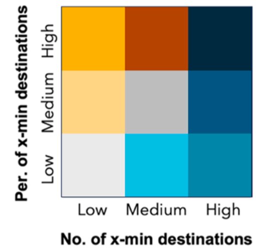

Fig. 1. Bivariate variables.

3.6. Land use analysis

With the hexagons reclassified based on ma'gnitude and proportion of x-minute city activity, we analyzed the land use distribution across each hexagon type. Land use data were obtained from the Communauté métropolitaine de Montréal (CMM) open data portal (Montréal, 2021). The CMM data are compiled from various public data sources across the region, reflecting land use designations at the most precise geographic area available. The land use designation of each geographic unit corresponds to the primary land use assigned as identified by public records from the given year. It is possible for secondary uses or uses not mentioned in the records to be excluded from the CMM database. For this study, historical land use designations from 2018 were used to align with the 2018 OD survey data.

Analyzing land use against the 15- and 30-minute city metrics helps address our research aim of identifying characteristics of the most locally accessible areas in Montreal through the x-minute city lens. To do so, the land use data were merged with the hexagonal grid and divided by hexagon-type according to the bivariate legend (for both the 15- and 30-minute thresholds). We focused on the hexagon types represented by the four corners of the legend to capture differences among areas with the highest and lowest extents of x-minute activity. For each of the eight hexagon-types (four for each of the 15- and 30-minute analyses), the total land area dedicated to each use was summed and divided by the total land area of all hexagons in the category. The output of this analysis allowed for a look into differences in land use proportions among areas that are the most locally and regionally serving.

4. Results and discussion

4.1. X-Minute city metrics

Fig. 3 shows the results of the first x-minute city metric by count of trips and percentage of trips ending in each hexagon. For the number of trips ending in a hexagon (Fig. 2A) a high concentration is observed in areas with frequent public transit. Hexagons shaded in the darkest blue represent areas attracting 4000 trips per day or more in x-minutes. Trips that align with the 15-minute city definition ends in downtown

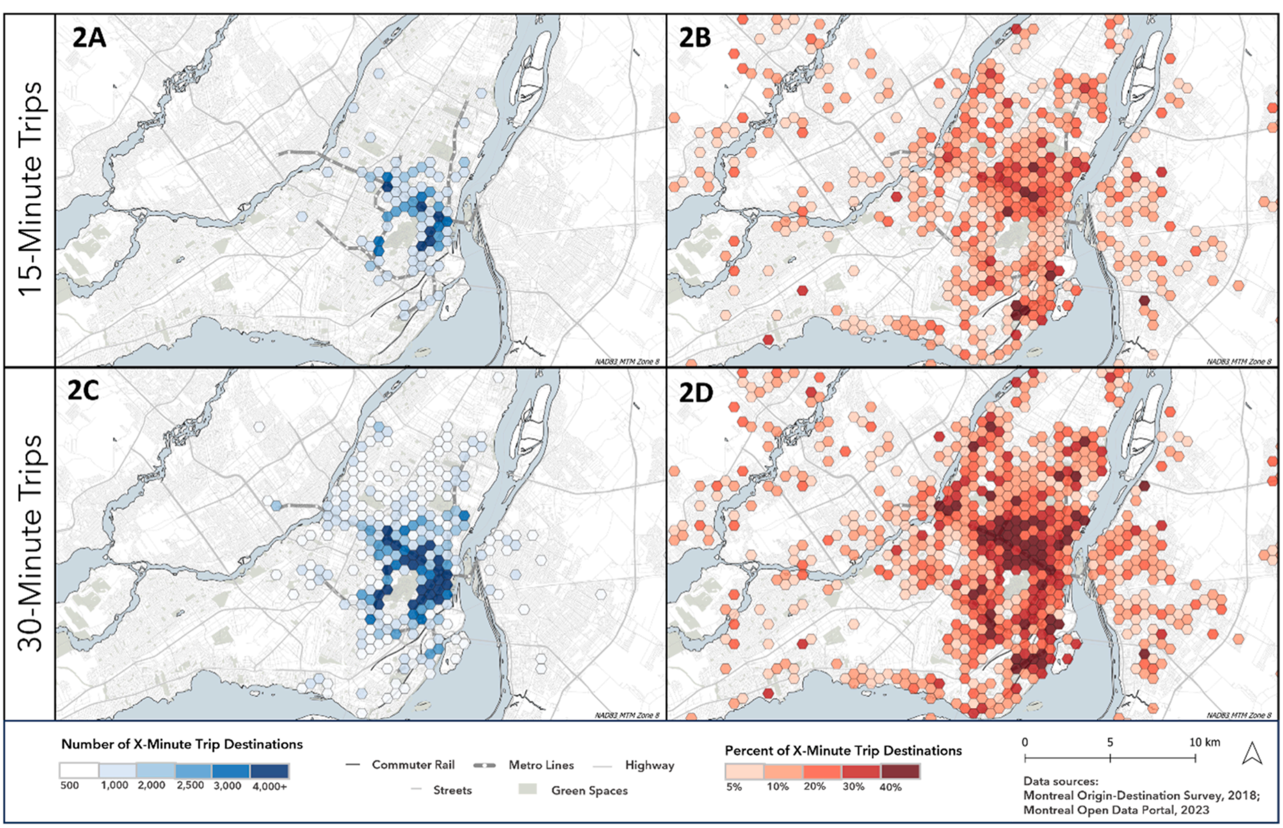

Fig. 2. The number (blue) and proportion (red) of x-minute trip destinations ending in each hexagonal area, based on the 2018 Montreal Origin-Destination one-day weekday travel survey. The top two maps measure against the 15-minute threshold and the bottom two maps are based on the 30-minute threshold.

Montreal, dense neighborhoods northwest of downtown, and near metro line junctions (Fig. 2A). Trip distribution assessed against the 30-minute threshold follows a similar pattern and reveals more hexagons with high trip counts (Fig. 2C).

The second metric, calculated as the percent of x-minute trip destinations compared to all trip destinations, points to very few areas that have high proportions of 15-minute trips (Fig. 2B). The darkest red color marks areas where almost 1 out of every 2 trips ending there align with the x-minute trip definition. Downtown, which has some of the highest counts of 15-minute trips, has notably low proportions of local activity. This is to be expected since it is a major job and commercial hub that attracts travel from across the region. The mixed-use neighborhoods to the northwest and south of downtown tend to have at least 10% 15-minute city activity, with a couple hotspots reaching 40% or more. For the 30-minute threshold, consistently high proportions of qualified trips extend along and surrounding the metro lines to the northwest and south of downtown (Fig. 2D). Some additional areas with 40% or more 30-minute trips arise to the north and southeast along the metro lines. For both the 15- and 30-minute analyses, local activity is concentrated around the center of the city, while surrounding suburban areas indicate very low proportions.

4.2. Bivariate analysis

Combining the trip count and percentage metrics into a single variable offers a view into the interaction between density and local activity. This bivariate measure differentiates areas based on the x-minute city framework to help us understand what the 15- and 30-minute city looks like in different parts of the city. In Fig. 3A (15-minute threshold) and Fig. 3B (30-minute threshold), the dark blue highlights areas that have the highest number and highest percentage of x-minute trips. Hexagons with this classification represent the densest and most locally serving parts of Montreal. There are 3 hexagonal areas that meet the 15-minute definition of this category and 33 that meet the 30-minute one in the entire region (860 hexagons).

The areas in dark yellow also have high proportions of x-minute trips but they have significantly lower trip counts. These areas most likely represent medium- to low-density residential neighborhoods with a few small commercial establishments that do not attract customers from far away. There are 6 of these hexagons on the 15-minute map and 12 on the 30-minute one.

Since "return to home" trips are removed from the calculations, the results of the bivariate analysis reveal how well destinations in each hexagon serve the local community. As such, even though areas marked in dark yellow have high proportions of x-minute city activity, the low counts of these trips indicate they are likely not accommodating a diversity of needs. On the contrary, areas marked in dark blue have both high counts and high proportions of x-minute activity, signaling that more trips are being accomplished locally. This positions areas in dark blue to be the parts of Montreal that are the most aligned with the x-minute city concept.

Hexagons depicted in light grey are the least compatible with x-minute city concept. These areas have low numbers of x-minute trips and low proportions of them. This kind of travel behaviour is indicative of locations that attract automobile travel and trips longer than the x-minute travel time. The lighter blue shaded hexagons (bottom right corner) are also characterized by low proportions of x-minute trips, but they attract a high number of them. In the 15-minute bivariate analysis, downtown Montreal is the most prominent hub of this kind of activity. It is an area that attracts travel from across the region while also offering a plethora of destinations that can be reached via a short walk, bike ride, or public transit trip from within.

In addition to the spatial visualization, it is helpful to consider the distribution of hexagonal areas across the two metrics. Fig. 4 presents a two-dimensional histogram with the number of x-minute trip destinations on the x-axis and the percent of x-minute trip destinations on the y-axis. Hexagons measured against the 15-minute threshold are displayed in blue and the 30-minute threshold is depicted in red. Dotted lines are drawn to delineate the low, medium, and high bins represented in the bivariate legend. The graph indicates a high concentration of hexagonal areas that have a low number and low percent of x-minute trips, also depicted in white on the bivariate maps (Fig. 4). This type of travel behaviour reflects common land use and transport patterns in many North American cities, characterized by separated land use and automobile dependency. The points that fall in the eight other sections of the graph represent parts of the city that are challenging this traditional land use and transport arrangement to support smaller scale travel. The points in the top three sections of the graph, also seen in dark yellow and blue on the bivariate maps, reflect areas of the city that are cultivating travel patterns that most closely align with x-minute city goals—that is, to provide an environment where residents meet all their daily needs within x-minute travel radius using sustainable modes. However, it is worth noting that none of the hexagonal areas are anywhere close to achieving the 100% x-minute city that aligns with the original definition

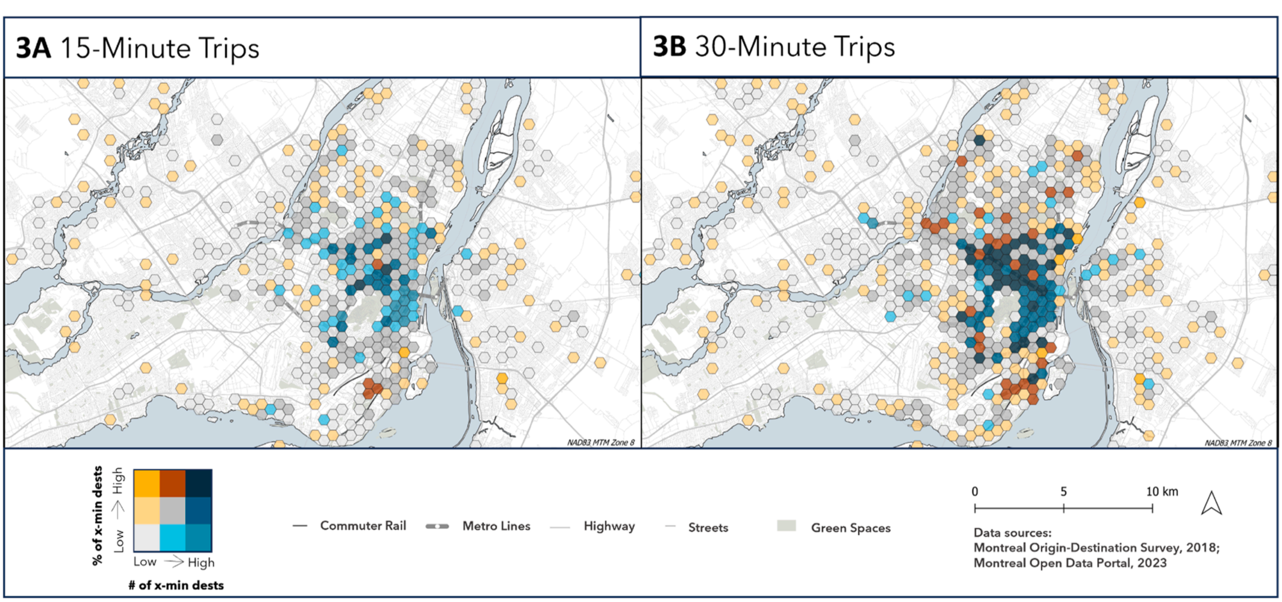

Fig. 3. Bivariate analysis of 15-minute trip destinations ending in each hexagonal area.

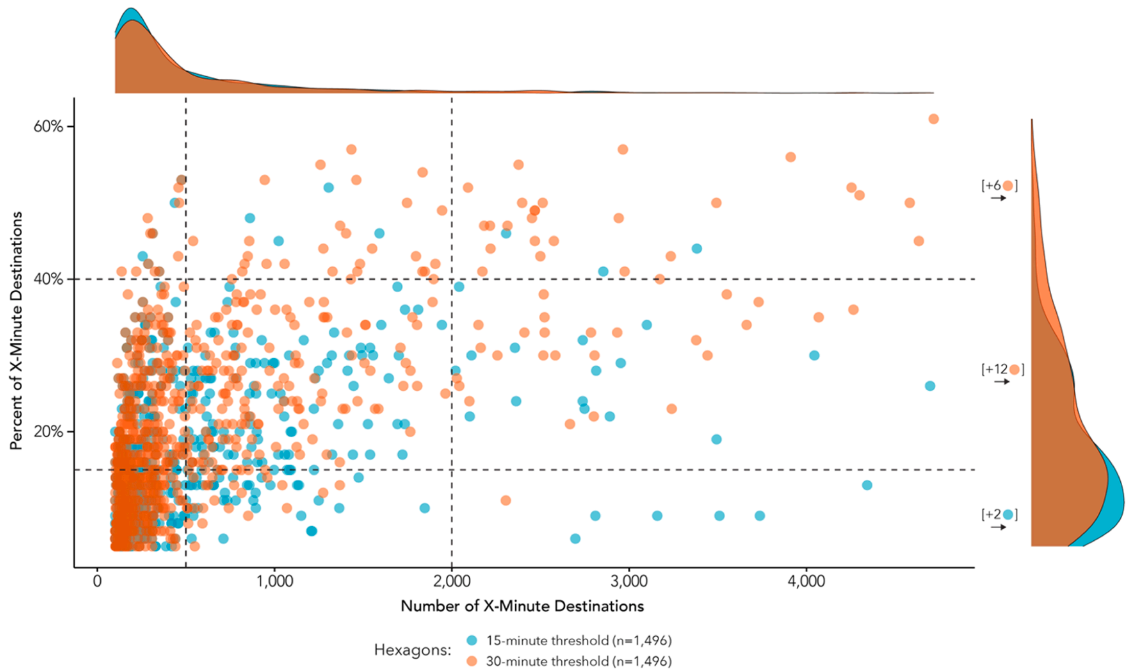

Fig. 4. Two-dimensional histogram of bivariate metrics.

of the concept. Areas with the highest proportions of local travel reach between 40 and 50% when measured against the 15-minute threshold and approach 60% against the 30-minute threshold.

These patterns highlight the challenges of achieving 15- and 30-minute city targets. As cities around the world implement the x-minute city concept, it is important to consider what kind of urban environment this goal represents and how it aligns with the existing land use and transport context in diverse settings. Perhaps in Montreal, a relatively compact city for North American standards, a 40% or 50% x-minute city environment represents the most achievable and ideal manifestation of local accessibility. These results point to the value of looking toward current travel behaviour to understand what the x-minute city means in different contexts and to create more locally informed x-minute city targets.

Fig. 5. Zoning designations of sample hexagonal areas that correspond to the 15-minute city bivariate categories.

4.3. Land use assessment

Land use policy, which determines the spatial arrangement of people and places, has a major impact on travel behaviour and accessibility. A city's ability to plan for better local accessibility relies on strategic zoning decisions that support shorter travel distances. Using the x-minute city categories defined by the bivariate legend, land use data is assessed within each hexagonal area to understand the relationship between land use and travel patterns in Montreal. Fig. 5 presents the zoning designations of hexagon samples from each of the four corners of the bivariate legend measured against the 15-minute travel time threshold.

Zoning designation samples that align with the 30-minute city bivariate categories are displayed in Fig. 6. Areas that attract high counts and percentages of x-minute trips (category B), tend to have smaller land parcels, finer grain zoning designations, and more grid-oriented street networks. Categories A and C, which have the lowest counts of x-minute trips, appear to have larger allocations of low-density housing. While all samples include some office/institutional spaces, categories C and D have particularly sizable areas designated for this use.

The total land area of all hexagons within each bivariate category were then grouped and analyzed in Fig. 7. The "*n*=" below each graph indicates the total number of hexagonal areas that align with that category of the legend. Note that the land area percentages do not add up to 100% because some zoning designations were removed from the graphs (including public infrastructure, agriculture, golf, greenspace, water, and vacant space) for simplicity.

In this visualization, land use distinctions between areas that are and are not locally accessible become clear. Most notably, hexagonal areas that most closely align with x-minute city goals (category B) have proportions of medium- and high-density housing that are not observed in any other area. This pattern is consistent across both the 15- and 30-minute analyses. Category A represents the highest degree of land use separation, with low rates of any use other than low-density housing. Although these areas cultivate local accessibility in terms of percent x-minute trips, they are unable to serve a diversity of needs and they encourage car use.

Category C demonstrates a similar emphasis on low density-housing. However, the larger proportion of land allocated toward commercial and office/institutional uses attracts more travelers who spend greater than x minutes to get there and/or commute by car. The high number of hexagons that align with category C speaks to the land use reality of separated uses and car dependency that characterizes much of Montreal. Category D hexagons have the highest proportions of very high-density housing and office/institutional. As major job and commercial hubs, these areas attract travelers from around the region while also serving the needs of residents living within.

5. Conclusion

While the x-minute city concept offers an attractive vision for the future of cities, little is known about what it means to achieve this goal in different global settings, especially in areas with historical car dependent planning practices. Our study addresses this question by analyzing observed travel behaviour and land use data to explore how the x-minute city model can be used to understand local travel patterns in the North American city of Montreal. Our aim was to identify which parts of Montreal are most conducive to x-minute city activity and understand how far the city is from local living under the standards of this planning framework. Findings show that very few areas of Montreal currently attract the type of trips that align with the 15- and 30-minute city. This is largely attributed to the fact that most North American cities were developed with intentionally separated land uses, which lengthen travel times. There are, however, distinct land use patterns that characterize the parts of Montreal that have the most x-minute city activity. These areas have the highest rates of medium- and high-density housing in the city. Conversely, areas the least identified with x-minute goals display predominant land use separation and high degrees of low-density housing.

Fig. 6. Zoning designations of sample hexagonal areas that correspond to the 30-minute city bivariate categories.

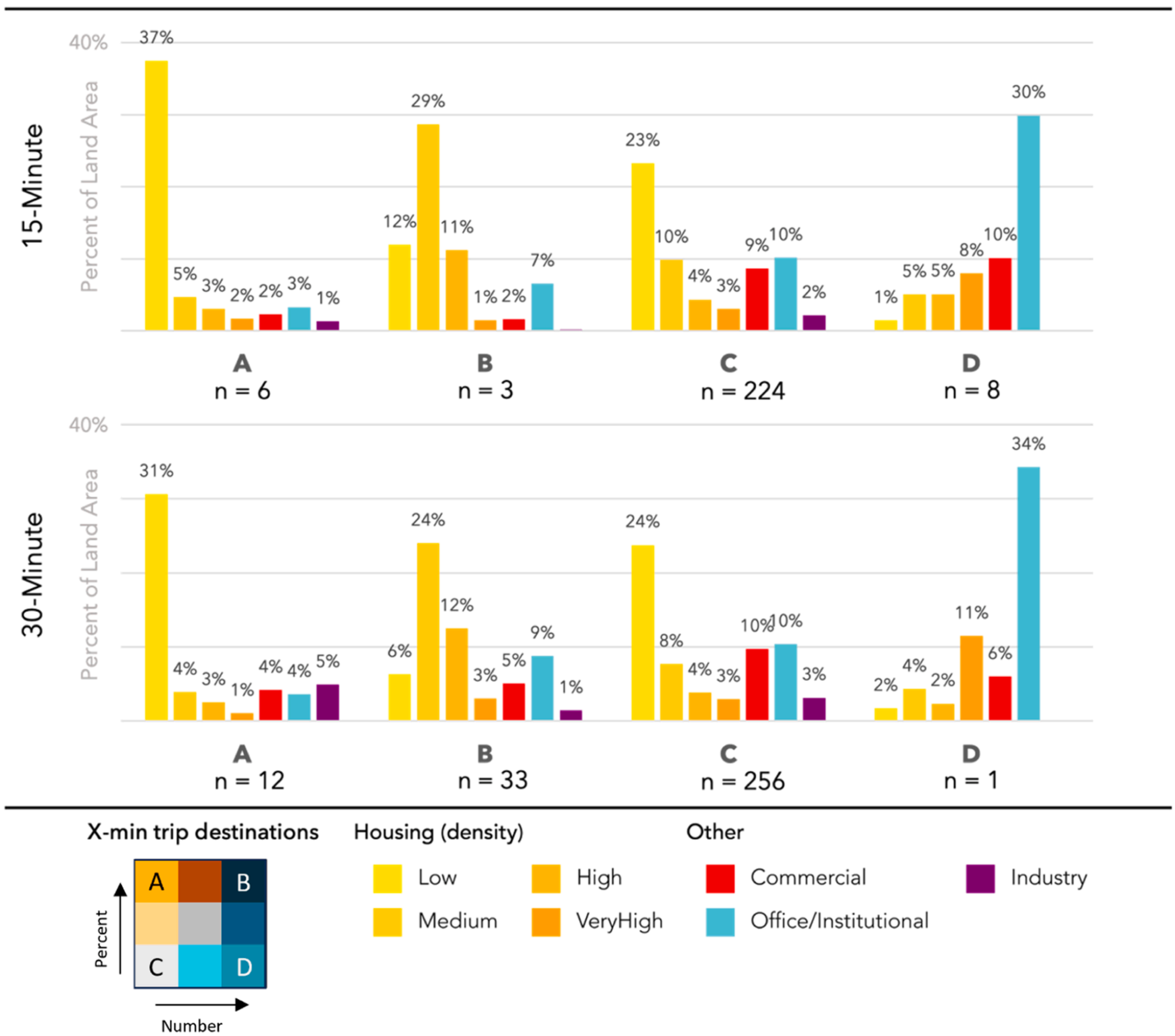

Fig. 7. Land use allocations within areas corresponding to each bivariate category.

Even though the x-minute city framework is mostly aspirational, it could be argued that cities should strive for attainable and feasible, even if bold, goals so that progress is properly measured and evaluated over time while targets are updated accordingly. In this regard, our findings demonstrate the importance of looking toward local travel behaviour to create contextually informed x-minute city targets, which could vary across the city`s territory based on identified baselines. In the areas that most resemble the x-minute city in Montreal, around 40–60% of all trips ending there were completed in x minutes or less using walking, cycling, or public transit. These rates represent what the highest degree of local accessibility currently looks like in Montreal and could serve as a target for other areas of the city granted the feasibility of changes in land use patterns, such as the increase of medium and high-density housing, and the provision of adequate sustainable transport infrastructure. It is also a possibility that even areas with higher rates of local trips could benefit from improved quality and functionality of soft infrastructure as highlighted by Gil Solá et al. (2018). Even so, it is unlikely that any area in the city would achieve full local living as envisioned by the 15-minute city concept as it is unlikely that all residents of a region would, for instance, work in the same area.

This study is not intended to propose the best x-minute city metrics for Montreal or other regions, but to instead challenge the idea that the original concept is universally applicable. Different cities, or even different regions within a city, are likely to start their journey toward local living from different historical and political contexts and require diverging planning interventions, metrics, and targets to strive for. Policy makers interested in implementing the x-minute city framework should first gain an understanding of the travel behaviour and land use landscape in their region so that they can guide x-minute city plans and metrics considering the variety of contexts across its territory.

The use of OD data comes with certain limitations in our analysis. The Montreal OD survey samples a one-day weekday travel diary from respondents, meaning our analysis does not account for weekend travel nor for variability in travel over multiple days. Additionally, the analysis was limited to using modelled travel time instead of observed travel time, which may introduce bias into the results. Future research on this topic would benefit from data based on a multi-day activity-based travel diary. There are many opportunities for future research to build on the findings from this study. Using more detailed information about destination types and trip purposes would provide more insight into the specific mix of establishments that characterize the most locally accessible areas. Future work may expand the bivariate metric developed in this study to account for diversity of trip types to capture the ability of different areas to serve a range of needs. Measuring x-minute activity based on the trip origins would add further depth to the destination-based analysis presented here.

CRediT authorship contribution statement

Carolyn Birkenfeld: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Thiago Carvalho:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Validation, Visualization, Writing – original draft, Writing – review & editing. **Ahmed El-Geneidy:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of competing interest

No conflict of interest to declare related to this article.

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References

Abdelfattah, L., Deponte, D., & Fossa, G. (2022). The 15-minute city: Interpreting the model to bring out urban resiliencies. *Transportation Research Procedia, 60*, 330–337. https://doi.org/10.1016/j.trpro.2021.12.043

Alexander, C. (1967). The city as a mechanism forSustaining human contact. *Environment for man: The next fifty years* (pp. 87–88). Bloomington: Indiana University Press, 1967.

ARTM. (2020a). *Enquete origine-destination 2018: La mobilité des personnes dans la région métropolitaine de montréal*.

ARTM. (2020b). *Guide d'utilisation des données d'enquête origine-destination 2018*.

Bartzokas-Tsiompras, A., & Bakogiannis, E. (2023a). Quantifying and visualizing the 15-minute walkable city concept across Europe: A multicriteria approach. *Journal of Maps, 19*(1), Article 2141143.

Bartzokas-Tsiompras, A., & Bakogiannis, E. (2023b). Quantifying and visualizing the 15-Minute walkable city concept across Europe: A multicriteria approach. *Journal of Maps, 19*(1). https://doi.org/10.1080/17445647.2022.2141143

Birkenfeld, C., Victoriano-Habit, R., Alousi-Jones, M., Soliz, A., & El-Geneidy, A. (2023). Who is living a local lifestyle? Towards a better understanding of the 15-minute-city and 30-minute-city concepts from a behavioural perspective in Montréal. *Canada. Journal of Urban Mobility, 3*, Article 100048. https://doi.org/10.1016/j.urbmob.2023.100048

Boussauw, K., Neutens, T., & Witlox, F. (2012). Relationship between spatial proximity and travel-to-work distance: The effect of the compact city. *Regional Studies, 46*(6), 687–706. https://doi.org/10.1080/00343404.2010.522986

Calafiore, A., Dunning, R., Nurse, A., & Singleton, A. (2022). The 20-minute city: An equity analysis of Liverpool city region. *Transportation Research Part D: Transport and Environment, 102*, Article 103111.

Caselli, B., Carra, M., Rossetti, S., & Zazzi, M. (2022). Exploring the 15-minute neighbourhoods. An evaluation based on the walkability performance to public facilities. *Transportation Research Procedia, 60*, 346–353.

Crist, K., Brondeel, R., Tuz-Zahra, F., Reuter, C., Sallis, J., Pratt, M., et al. (2021). Correlates of active commuting, transport physical activity, and light rail use in a university setting. *Journal of Transport & Health, 20*, Article 100978. https://doi.org/10.1016/j.jth.2020.100978

Daley, J., Rodrigue, L., Ravensbergen, L., DeWeese, J., Butler, G., Kestens, Y., et al. (2022). Foot-based microscale audit of light rail network in Montreal Canada. *Journal of Transport & Health, 24*, Article 101317. https://doi.org/10.1016/j.jth.2021.101317

De Vos, J. (2015). The influence of land use and mobility policy on travel behaviour: A comparative case study of Flanders and the Netherlands. *Journal of Transport and Land Use, 8*(1), 171–190.

De Witte, A., Hollevoet, J., Dobruszkes, F., Hubert, M., & Macharis, C. (2013). Linking modal choice to motility: A comprehensive review. *Transportation research part A: Policy and Practice, 49*, 329–341. https://doi.org/10.1016/j.tra.2013.01.009

Dittmar, H., & Poticha, S. (2004). Defining transit-oriented development: The new regional building block. *The New Transit Town: Best Practices in Transit-Oriented Development*, 19–40.

El-Geneidy, A., Krizek, K., & Iacono, M. (2007). *Predicting bicycle travel speeds along different facilities using GPS data: A proof of concept model.* Washington D.C., USA: Research Board.

Elldér, E., Larsson, A., Solá, A. G., & Vilhelmson, B. (2017). Proximity changes to what and for whom? Investigating sustainable accessibility change in the Gothenburg city region 1990–2014. *International Journal of Sustainable Transportation, 12*(4), 271–285. https://doi.org/10.1080/15568318.2017.1363327

Epstein, R. (2011). Politiques de la ville: Bilan et (absence de) perspectives. *Regards croisés sur l'économie*, (1), 203–211.

Ermagun, A., & Levinson, D. (2017). Public transit, active travel, and the journey to school: A cross-nested logit analysis. *Transportmetrica A: Transport Science, 13*(1), 24–37. https://doi.org/10.1080/23249935.2016.1207723

Fol, S. (2013). La politique de la ville, un outil pour lutter contre la ségrégation? *L'Information géographique, 77*(3), 6–28.

Friman, M., Gärling, T., Ettema, D., & Olsson, L. E. (2017). How does travel affect emotional well-being and life satisfaction? *Transportation Research part A: Policy and Practice, 106*, 170–180.

Front Seat Management, L. (2014). *Walk score methodology*. https://www.walkscore.com/methodology.shtml.

Gaglione, F., Gargiulo, C., Zucaro, F., & Cottrill, C. (2022). Urban accessibility in a 15-minute city: A measure in the city of Naples, Italy. In *, 60*. *Transportation Research Procedia* (pp. 378–385). https://doi.org/10.1016/j.trpro.2021.12.049

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*. https://doi.org/10.1016/j.jtrangeo.2022.103301

Gil Solá, A., Vilhelmson, B., & Larsson, A. (2018). Understanding sustainable accessibility in urban planning: Themes of consensus, themes of tension. *Journal of Transport Geography, 70*, 1–10. https://doi.org/10.1016/j.jtrangeo.2018.05.010

Gongadze, S., & Maassen, A. (2023). *Paris' vision for a '15-Minute city' sparks a global movement*. Retrieved 13/4/2023 from https://www.wri.org/insights/paris-15-minute-city.

Gorrini, A., Presicce, D., Messa, F., & Choubassi, R. (2023). Walkability for children in Bologna: Beyond the 15-minute city framework [Digital/other]. *Journal of Urban Mobility, 3*, Article 100052. https://doi.org/10.1016/j.urbmob.2023.100052

Gower, A., & Grodach, C. (2022). Planning Innovation or City Branding? Exploring How Cities Operationalise the 20-Minute Neighbourhood Concept. *Urban Policy and Research, 40*(1), 36–52. https://doi.org/10.1080/08111146.2021.2019701

Handy, S. (1992). *How land use patterns affect travel patterns: A bibliography*.

Greater Sydney Commission. (2018). *Greater Sydney Region Plan: A Metropolis of Three Cities: Connecting People*. https://greatercities.au/.

Horiuchi, J., Zimmer, A., Reginald, M., Gartsman, A., Brown, C., Limprevil, D., et al. (2023). Developing a Methodology to Identify Non-Normative Key Destinations for Transportation Planning. *Transportation Research Record*. https://doi.org/10.1177/03611981231172509, 03611981231172509.

Hosford, K., Beairsto, J., & Winters, M. (2022a). Is the 15-minute city within reach? Evaluating walking and cycling accessibility to grocery stores in Vancouver. *Transportation research interdisciplinary perspectives, 14*, Article 100602.

Hosford, K., Beairsto, J., & Winters, M. (2022b). Is the 15-minute city within reach? Evaluating walking and cycling accessibility to grocery stores in Vancouver [Article]. *Transportation Research Interdisciplinary Perspectives, 14*. https://doi.org/10.1016/j.trip.2022.100602. Article 100602.

Humagain, P., & Singleton, P. A. (2020). Investigating travel time satisfaction and actual versus ideal commute times: A path analysis approach. *Journal of Transport & Health, 16*, Article 100829.

Kesarovski, T., & Hernandez, F. (2023). Time, the other dimension of urban form: Measuring the relationship between urban density and accessibility to grocery shops in the 10-minute city. *Environment and Planning B-Urban Analytics and City Science, 50* (1), 44–59. https://doi.org/10.1177/23998083221103259. Article 23998083221103259.

Kissfazekas, K. (2022). Circle of paradigms? Or '15-minute' neighbourhoods from the 1950s. *Cities (London, England), 123*, Article 103587. https://doi.org/10.1016/j.cities.2022.103587

Knap, E., Ulak, M. B., Geurs, K. T., Mulders, A., & van der Drift, S. (2023). A composite X-minute city cycling accessibility metric and its role in assessing spatial and socioeconomic inequalities – A case study in Utrecht, the Netherlands. *Journal of Urban Mobility, 3*. https://doi.org/10.1016/j.urbmob.2022.100043

Kockelman, K. (1997). Travel behaviour as function of accessibility, land use mixing, and land use balance: Evidence from san francisco bay area. *Transportation Research Record, 1607*(1), 116–125.

Levinson, D. (2019). *The 30-minute city: Designing for access*. Network Design Lab.

Limtanakool, N., Dijst, M., & Schwanen, T. (2006). The influence of socioeconomic characteristics, land use and travel time considerations on mode choice for medium- and longer-distance trips. *Journal of Transport Geography, 14*(5), 327–341.

Liu, D., Kwan, M. P., & Wang, J. (2024). Developing the 15-Minute City: A comprehensive assessment of the status in Hong Kong [Web]. *Travel Behaviour and Society, 34*, Article 100666. https://doi.org/10.1016/j.tbs.2023.100666

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 [Article]. *Cities (London, England)*, 131. https://doi.org/10.1016/j.cities.2022.103924

Mariotti, I., Giavarini, V., Rossi, F., & Akhavan, M. (2022). Exploring the "15-Minute City" and near working in Milan using mobile phone data. *Tema-Journal of Land use Mobility and Environment*, 39–56. https://doi.org/10.6092/1970-9870/9309

Montreal. (2020). *Montréal 2030: A First Strategic Plan*. https://portail-m4s.s3.montreal.ca/pdf/montreal_2030_strategic_plan_vdm.pdf.

Montreal. (2023a). *Le REV: Un réseau express vélo*. https://montreal.ca/articles/le-rev-un-reseau-express-velo-4666.
Montreal. (2023b). *Pedestrian streets and lively public spaces all summer long*. https://montreal.ca/en/articles/pedestrian-streets-and-lively-public-spaces-all-summer-long-31971.
Montréal, C.m.d. (2021). *Données géoréférencées* https://observatoire.cmm.qc.ca/produits/donnees-georeferencees/#utilisation_du_sol.
Moreno, C. (2022). Living in proximity in a living city. *Glocalism: Journal of culture, politics and innovation*. https://doi.org/10.12893/gjcpi.2021.3.8
Moreno, C., Gall, C., Chabaud, D., Garnier, M., Illian, M., & Pratlong, F. (2023). *The 15-minute City model: An innovative approach to measuring the quality of life in urban settings 30-minute territory model in low-density areas WHITE PAPER N°3*. https://hal.science/hal-04065455.
Municipalité de Paris. (2022). Paris *ville du quart d'heure, ou le pari de la proximité* municipalité de paris. Retrieved 13/4/2023 from https://www.paris.fr/dossiers/paris-ville-du-quart-d-heure-ou-le-pari-de-la-proximite-37.
Olivari, B., Cipriano, P., Napolitano, M., & Giovannini, L. (2023). Are Italian cities already 15-minute? Presenting the Next Proximity Index: A novel and scalable way to measure it, based on open data [Web]. *Journal of Urban Mobility, 4*, Article 100057. https://doi.org/10.1016/j.urbmob.2023.100057
Pereira, R., Saraiva, M., Herszenhut, D., Braga, C., & Conway, M.. r5r: Rapid realistic routing on multimodal transport networks with r 5 in r. Findings. https://doi.org/10.32866/001c.21262.
Perry, C. (2015). The neighborhood unit. *The city reader* (pp. 607–619). Routledge.
Poorthuis, A., & Zook, M. (2023). Moving the 15-minute city beyond the urban core: The role of accessibility and public transport in the Netherlands. *Journal of Transport Geography, 110*, Article 103629. https://doi.org/10.1016/j.jtrangeo.2023.103629
Pucher, J., & Renne, J. (2005). Rural mobility and mode choice: Evidence from the 2001 national household travel survey. *Transportation, 32*, 165–186.
Raynor, D. A., Coleman, K. J., & Epstein, L. H. (1998). Effects of proximity on the choice to be physically active or sedentary. *Research Quarterly for Exercise and Sport, 69*(1), 99–103. https://doi.org/10.1080/02701367.1998.10607674
Rundle, A. G., Sheehan, D. M., Quinn, J. W., Bartley, K., Eisenhower, D., Bader, M. M. D., et al. (2016). Using GPS Data to Study Neighborhood Walkability and Physical Activity. *American Journal of Preventive Medicine, 50*(3), e65–e72. https://doi.org/10.1016/j.amepre.2015.07.033
Silva, A. M., da Cunha, J. R., & da Silva, J. P. (2014). Estimation of pedestrian walking speeds on footways. In *Proceedings of the Institution of Civil Engineers-Municipal Engineer*.
Smith, M., Hosking, J., Woodward, A., Witten, K., MacMillan, A., Field, A., et al. (2017). Systematic literature review of built environment effects on physical activity and active transport - an update and new findings on health equity. *The International Journal of Behavioral Nutrition and Physical Activity, 14*(1), 158. https://doi.org/10.1186/s12966-017-0613-9
Stanley, J., & Stanley, J.. Achieving the 20-minute city for Melbourne: Turning our city upside down. Bus Association Victoria. https://www.busvic.asn.au/sites/default/files/uploaded-content/website-content/Resources/Reports_Articles/2014_20_achieving_the_20_minute_city_for_melbourne_-_turning_our_city_upside_down_13aug2014.pdf.
StatCan. (2021). Census Profile. *2021 Census*. Retrieved 23/05/2023 from https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E.
St-Louis, E., Manaugh, K., van Lierop, D., & El-Geneidy, A. (2014). The happy commuter: A comparison of commuter satisfaction across modes. *Transportation Research Part F: Traffic Psychology and Behaviour, 26*, 160–170. https://doi.org/10.1016/j.trf.2014.07.004
te Brömmelstroet, M., Nikolaeva, A., Glaser, M., Nicolaisen, M., & Chan, C. (2017). Travelling together alone and alone together: Mobility and potential exposure to diversity. *Applied Mobilities, 2*(1), 1–15. https://doi.org/10.1080/23800127.2017.1283122
TED Conferences. (2021). *The 15-minute city | carlos moreno [Youtube]*. https://www.youtube.com/watch?v=TQ2f4sJVXAI.
Tsavachidis, M., & Petit, Y. L. (2022). *Re*-shaping urban mobility – Key to Europe's green transition. *Journal of Urban Mobility, 2*. https://doi.org/10.1016/j.urbmob.2022.100014
Victoria. (2023). *20-minute neighbourhoods*. Department of transport and planning, state government of victoria. Retrieved 01/02/2024 from https://www.planning.vic.gov.au/guides-and-resources/strategies-and-initiatives/20-minute-neighbourhoods.
Weng, M., Ding, N., Li, J., Jin, X., Xiao, H., He, Z., et al. (2019). The 15-minute walkable neighborhoods: Measurement, social inequalities and implications for building healthy communities in urban China. *Journal of Transport & Health, 13*, 259–273.
Willberg, E., Fink, C., & Toivonen, T. (2023). The 15-minute city for all?-Measuring individual and temporal variations in walking accessibility. *Journal of Transport Geography, 106*. https://doi.org/10.1016/j.jtrangeo.2022.103521
Winters, M., Buehler, R., & Götschi, T. (2017). Policies to promote active travel: evidence from reviews of the literature. *Current Environmental Health Reports, 4*(3), 278–285. https://doi.org/10.1007/s40572-017-0148-x
Zhang, D., Ma, S., Fan, J., Xie, D., Jiang, H., & Wang, G. (2023). Assessing spatial equity in urban park accessibility: An improve two-step catchment area method from the perspective of 15-minute city concept [Web]. *Sustainable Cities and Society, 98*, Article 104824. https://doi.org/10.1016/j.scs.2023.104824