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Are all streets created equal? Measuring the differences in the built environment among streets with various socioeconomic characteristics in Montréal, Canada

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ABSTRACT

Streets play an important role in shaping urban landscapes and sustaining city life. Through streetscape design, cities can foster vibrant and inclusive neighborhoods that cater to the diverse needs of their residents. Our research aims to determine whether variations at the microscale level of the built environment exist among streets of similar typologies across diverse socioeconomic neighborhoods in Montréal, QC, Canada. The short version of the Microscale Audit of Pedestrian Streetscapes (MAPS-Mini) tool was used to assess microscale features essential for creating high-quality built environments. Assessments were conducted using Google Street View and in-person site visits to ensure a comprehensive analysis of the tool's effectiveness across different methodologies and urban contexts. Results show significant disparities in the quality of the built environment across various socioeconomic neighborhoods. Despite having identical typologies and characteristics, streets in lower-income areas generally exhibit poorer built environment quality, highlighting that streets are not always created equal in Montréal. This trend is particularly evident in medium and high-density neighborhoods. Less than a third of the audited streets were deemed to have high-quality built environments. This paper can be of value to practitioners working towards addressing disparities in the built environment to create equitable, healthy, and livable communities.

1. Introduction

Streets play an important role in shaping urban landscapes and sustaining city life. Their built environment can encourage interactions among residents, promote alternative modes of transport such as walking and cycling, support local economic activities, and enhance the livability of urban areas (Gehl, 2011; Whyte, 1980). Through streetscape design, cities can foster vibrant and inclusive neighborhoods that cater to the diverse needs of their residents and improve their overall quality of life (UN-Habitat, 2022). Given the importance of streets, it becomes imperative to consider how their design intersects with broader social equity goals. Planning for equity strives to ensure equal access to opportunities for all residents (American Planning Association, 2019). Centered around the improvement of citizens' quality of life, it involves developing safe and attractive neighborhoods that support the physical and mental well-being of their population (Agyeman, 2013; McLaren and Agyeman, 2015). The integration of social and spatial equity considerations entails identifying areas for improvement in the built environment, especially in areas inhabited by more vulnerable populations (i.e., lower-income households).

While streets have the potential to foster a sense of community, certain typologies and built environment elements can inadvertently discourage such interactions, particularly in more car-centric and poorly maintained urban areas (Agyeman, 2013). Street designs that prioritize automobile circulation over pedestrian access can fail to provide inviting environments conducive to community interaction (Agyeman, 2013; Jacobs, 1961). However, cities are now progressively moving away from historical car-centric planning approaches to towards implementing more active transport infrastructures, particularly in the post-pandemic context (Cleckley, 2021). Achieving equity involves ensuring accessibility for diverse users, especially those in lower-income areas (Dasgupta, 2021). Integrating pedestrian and cycling amenities, along with greenery, into street design can support these goals by enhancing comfort, safety, and attractiveness, particularly for children,

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women, and the elderly (Agyeman, 2013; UN-Habitat, 2022). Streets that are well-designed support these interactions, nurturing stronger community bonds and enhancing the well-being, behavior, and happiness of residents (Elokda, 2017; Mehta, 2007; Talen, 1999). Thus, exploring social equity within streetscapes is essential for creating thriving cities.

Montréal, Canada is a mosaic of neighborhoods with diverse characteristics encompassing culture, history, population demographics, and urban fabrics. This diversity makes Montréal an ideal case study for examining equity in urban streetscapes. The city's Solidarity, Equity, and Inclusion Plan guides efforts to improve the quality of life of the city's diverse populations, with a particular focus on vulnerable groups (Ville de Montréal, 2021). Drawing on Montréal's Charter of Rights and Responsibilities, which mandates that: "The city is both a territory and a living space in which values of human dignity, tolerance, peace, inclusion, and equality must be promoted among all citizens" (Réseau Quartiers Verts (RVQ), 2017, p. 8), the plan outlines 71 actions to create secure and inclusive urban environments. However, despite an articulate goal to improve the built environment, the plan lacks specific street design interventions.

This research aims to evaluate the built environment of streets with similar characteristics, including population density, across different socioeconomic neighborhoods within Montréal. By examining the attributes of theoretically identical streets, the study seeks to identify any potentially overlooked disparities between neighborhoods of varying socioeconomic statuses Microscale features of the streets such as trees, benches, and sidewalks can significantly enhance streetscapes' enjoyability, making environments more attractive for pedestrians, cyclists, and residents (Carlson et al., 2019). These elements are also quicker and cheaper to adjust than larger-scale urban planning efforts. Thus, this research concentrates on microscale elements to provide actionable insights for the streets of Montréal. The short version of the Microscale Audit of Pedestrian Streetscapes (MAPS-Mini) tool is used to assess microscale features essential for creating high-quality built environments (Sallis et al., 2015). The assessments are conducted both through Google Street View and through in-person site visits to ensure a comprehensive analysis and validate the tool's effectiveness across different methodologies and urban contexts. For cities to achieve their sustainability goals, they need to create and maintain equitable liveable environments that promote physical activity and social interaction. Understanding the impact of socioeconomic status in different neighborhoods on street design is an essential step to highlight areas of improvements and potential interventions as to maximize the benefits of resource allocation and set funding priorities. The study provides evidence-based guidance for street design and revitalization projects, offering invaluable insights to urban planners, designers, and policymakers especially those working towards applying equity perspectives in their projects.

2. Literature review

Streets, when well designed, can become dynamic places that serve not only as thoroughfares but as vibrant spaces for social interactions and diverse activities (Park and Garcia, 2020). Urban planners should recognize streets as essential social public spaces that fulfill the human need for interactions beyond home and work (Mehta, 2007; Mehta and Bosson, 2018). To foster livable streets, a shift away from car-centric designs is imperative, requiring a generous allocation of space for pedestrian amenities (Whyte, 1980). The careful design of public spaces, including streets, holds the potential to significantly enhance urban vibrancy and encourage greater overall use. The built environment and its perception can influence behavior in public spaces (Boarnet et al., 2011; Hsieh and Chuang, 2021), with optional activities being particularly susceptible to its quality (Gehl, 2011).

The built environment of streets can be analyzed at multiple scales: macroscale, mesoscale, and microscale. The macroscale focuses on aspects such as land use, transport networks, block lengths, intersection density, building density, as well as street connectivity (Koo et al., 2023). The mesoscale, which zooms in on the neighborhood level, examines similar elements to the macroscale (Kim et al., 2014). At the microscale, streetscape elements and amenities are assessed. These features influence the attractiveness and safety (both from traffic and crime) of streets and, consequently, the experiences of pedestrians and cyclists (Carlson et al., 2019). All these scales are important and influence one another. Microscale elements, usually the quickest and easiest to modify, can significantly promote active transport among residents of varying ages and physical health statuses (Koo et al., 2023; Sallis et al., 2015).

Research shows that improving the microscale of streets by incorporating numerous high-quality public amenities (parks, urban furniture, bicycle racks, street trees, mixed land uses, etc.), enhances their vibrancy and supports diverse social activities (Mehta, 2007; Miranda et al., 2021). The built environment of streets plays a role in shaping people's perceptions and walking behavior, prompting deviations from their primary trip trajectory to engage with desirable elements (Miranda et al., 2021). This dynamic interaction creates opportunities for spontaneity and active participation in city life. The growing recognition of the social, economic, and functional importance of streets is reflected in the creation and adoption of design guidelines aimed at enhancing the safety and inclusivity of streets (National Association of City Transportation Officials, 2013).

Different tools and methodologies for assessing the quality of the built environment of streets have emerged in the literature, primarily involving observational audit surveys. One notable tool is the Microscale Audit of Pedestrian Streetscapes (MAPS), designed to evaluate the walkability of urban areas with a focus on elements conducive to physical activity (Cain et al., 2014; Millstein et al., 2013). This tool was adapted from the consolidation of other instruments used across the United States (Brownson et al., 2004). One of these tools is the prominent Neighborhood environment walkability scale (NEWS) which consider concepts and subscales discussed in the urban planning literature such as residential density, land use mix-access, street connectivity, walking and cycling facilities, aesthetics, pedestrian traffic safety, as well as crime as safety (Cerin et al., 2006). To facilitate ease of use by practitioners, MAPS-Mini was derived from the broader 120-item original MAPS tool, with which it shows high correlation ($r = 0.85$) (Sallis, 2015). It specifically targets microscale features related to pedestrian and cyclist experiences, helping to identify easily modifiable attributes. It comprises an on-site auditing survey of 15 built environment features, including sidewalks, trees, crosswalks, benches, bicycle paths, etc., which can significantly enhance active transport. By concentrating on the microscale of neighborhoods, MAPS-Mini allows for the identification of features that are easy to modify and cost-effective, potentially leading to significant improvements when implemented extensively (Daley et al., 2022).

Although observational auditing tools for the built environment were originally designed for in-person field observations, recent studies have increasingly adapted them for virtual completion (Aghaabbasi et al., 2018; Fox et al., 2021; Kurka et al., 2016; Marshall and McAndrews, 2017; Miranda et al., 2021; Phillips et al., 2017; Steinmetz-Wood et al., 2019). These online audits utilize modified versions of the MAPS tools or other virtual auditing tools such as Virtual-STEPS, which draws inspiration from MAPS (Kurka et al., 2016; Steinmetz-Wood et al., 2019). Leveraging Google Earth's Aerial and Street View functions, online audits combine high-resolution imagery for comprehensive assessments. Research comparing in-person and online audit results consistently demonstrates extremely high levels of agreement between the two methods, indicating that virtual audits are reliable and valid (Kurka et al., 2016; Steinmetz-Wood et al., 2019). However, online assessments may exhibit slightly lower reliability when evaluating elements related to aesthetics, maintenance, and conditions due to temporal variation in the built environment. Additionally, Google imagery provides distorted images of reality, as the images are captured with a wider angle than human vision and are not taken at human eye level. Despite this, overall, online observation auditing tools are advantageous to use, as they present almost identical results to in-person ones, and they reduce costs, eliminate travel times, and enhance auditors' safety.

While many studies have focused on how built environment factors influence walkability (Fonseca et al., 2022) and how objective and perceived walkability influence many aspects including physical activity and health (De Vos et al., 2023; Frank et al., 2010; He et al., 2021; Spittaels et al., 2009; Wang and Yang, 2019), few have focused on the variations in the built environments for different socioeconomic neighborhoods (James et al., 2017; Lesan and Gjerde, 2021). In the available literature, the focus is mainly on the impact of the built environment on physical activity. For example, through reviewing 17 articles, Adkins et al. (2017) find that the built environment has a weaker effect on walking and physical activity for disadvantaged groups in comparison with advantaged ones. To our knowledge, no study has used walkability auditing tools to compare streets across neighborhoods with different income levels and population densities. This research aims to fill that gap, exploring whether streets in Montréal vary in quality based on the socioeconomic status of their residents.

3. Methodology

3.1. Selection of neighborhoods and streets

The selection of the neighborhoods to study in Montréal began with categorizing them into low, middle, or high-income groups using 2021 Canadian census data (Statistics Canada, 2023). In this context, neighborhoods were defined as Montréal island's census tracts (CT). Median household income categories were established as follows: low income (below $30,000, including those without income), middle income (between $30,000 and $60,000), and high income (above $60,000). The percentages of low, middle, and high-income households for each CT were taken into consideration. Different income thresholds were tested to avoid disproportionate results. Ultimately, the distribution was as follows: 38 % for low-income, 33 % for middle-income, and 29 % for high-income. A bivariate map was created to cross-reference population density with income levels of each CT, enabling the identification of neighborhoods with similar population densities but varying income levels (Fig. 1). This method facilitated the selection of streets for comparative analysis.

A shapefile of streets in Montréal was overlayed with the bivariate map of the neighborhoods. A total of 30 streets were selected for assessment and organized into 10 sets, with three streets in each. Each set included one street from a low-, middle-, and high-income neighborhood with the same population density. Each of the 10 sets was assigned a letter (A–J) as an identifier (Fig. 2). Three sets represented low-population density neighborhoods (A–C), three represented medium-population density neighborhoods (D–F), and four represented high-population density neighborhoods (G–J). Four sets of high-population neighborhoods were examined, rather than three, due to their prevalence in Montréal's spatial distribution and the hypothesis that these neighborhoods are likely to exhibit greater variability in design.

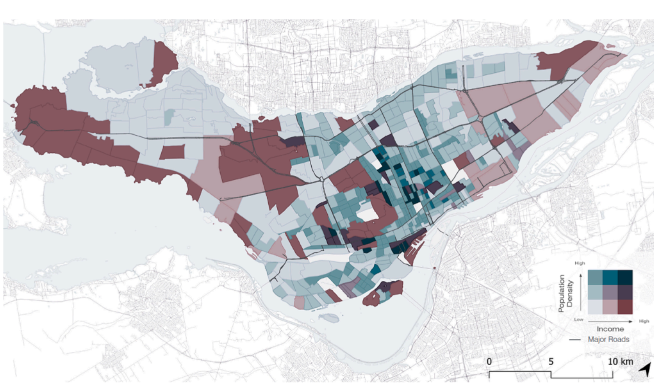

Fig. 1. Montréal neighborhoods' population density and median household income.

Streets in each set were matched based on specific criteria to ensure comparability, including a minimum segment length of 150 m, a street width of about 20 m, and a speed limit below 50 km/h. In some cases, the segment location represented only a portion of certain very long streets that traverse multiple neighborhoods with varying characteristics. When a set of streets appeared to match on GIS, they were cross-referenced on Google Street View to ensure visual similarity in terms of composition and building density.

This study uses the MAPS-Mini tool due to its high relevance and systematic approach in evaluating the built environment of streets. MAPS-Mini is useful in identifying elements that can be improved throughout the island of Montréal. Observational audit surveys can be conducted twice: once virtually, using Google Street View, and once through in-person site visits. A dual-method approach allows for a comprehensive analysis and comparison of the reliability of virtual versus in-person audits. Insightful commentary on the strengths and potential limitations of MAPS-Mini can highlight any discrepancies and nuances in the results. Ultimately, the study aims to present the most accurate evaluation of the quality of the built environment of streets.

3.2. Data collection

The MAPS-Mini tool was selected as the observational audit survey to guide the assessment of the selected streets. Data was manually collected twice: once virtually using Google Street View, and once in person through site visits. The original MAPS-Mini tool's survey question list (Sallis, 2015), available online, was used in this study. However, certain questions were modified to better align with the purpose and accuracy of this study. The survey consisted of 15 questions, with scoring aligned with the original tool. The scoring system results in a total score of 21 points, which is then converted into a percentage. This percentage corresponds to a category indicating the quality of the built environment.

In the original MAPS-Mini, there were separate questions for the presence/absence of pedestrian walk signals and marked crosswalks at street intersections. Given that some of the streets in this study were highly residential with one-way streets and low car speed limits, the presence of a walk signal seemed unnecessary. Thus, the MAPS-Mini question was modified to include any type of traffic-calming measure located on the street or at the intersections, such as stop signs, narrowed walkways, and speed bumps. In Montréal, bicycle-sharing (BIXI) is available to residents as a popular alternative to other modes of transit such as the metro, commuter rail, LRT, and bus, especially in the central areas. Therefore, the question regarding the presence or absence of public transit stops on the street segment was extended to also consider presence of BIXI stations.

Using the modified MAPS-Mini questionnaire (Appendix A), each street was evaluated both through virtual data collection and in-person site visits. Virtual data collection took place at the end of March 2024 and throughout April 2024. The MAPS-Mini survey was conducted by navigating through Google Street View from the first to last intersection in each segment in both street directions. In cases where evaluated street segments had more than two intersections, proportions were calculated to determine the presence of certain elements at 'one' or 'both' intersections. If over 50 % of intersections featured the elements, they were classified as 'both' intersections, scoring more points.

Google Maps aerial view aided in identifying transit stops along the studied streets. Public transport stops on streets intersecting with the evaluated streets were excluded from the count since they were not

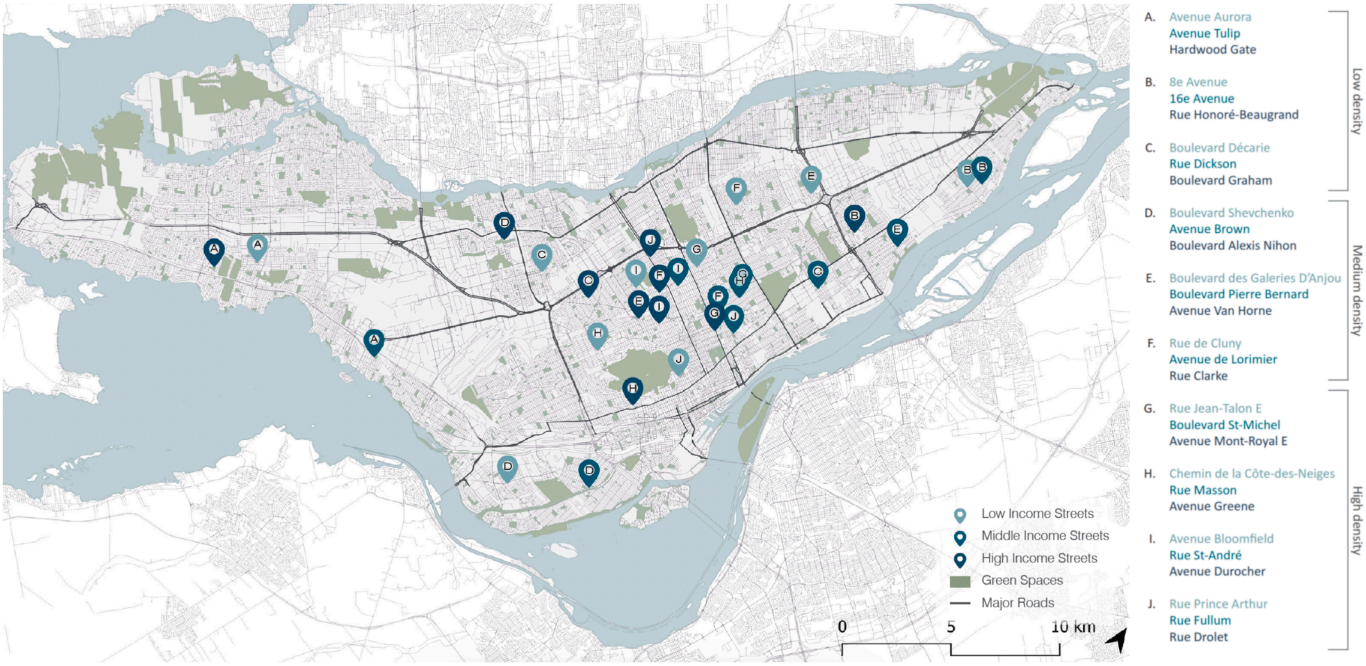

Fig. 2. Location of studied streets by population density and income level in Montréal.

officially located 'on' the studied street. Aerial satellite imagery was also used to estimate the density of the tree canopy providing shade to active transport users. Parks located solely at the end of the studied streets, rather than along the pedestrian pathways, were disregarded. Finally, streets with minimal buffers, such as irregularly spaced small trees, were still considered as buffers despite offering limited additional safety from traffic.

The in-person site visits took place from the end of April 2024 to the beginning of May 2024. These visits occurred during daylight hours (between 11 am and 7 pm) on days with sunny spring weather conditions. In addition to conducting the MAPS-Mini survey on-site, photographs were taken at pedestrian eye level as supplementary documentation, in case future validation is needed. These photographs were taken from a perspective more aligned with active transport viewpoints compared to Google Street View imagery, which is captured from a vehicle and above human eye level.

Fig. 3. MAPS-Mini intervals by online (Google Street View) and in-person site visit assessments for the 30 streets, categorized by population density and income level.

4. Results and discussion

4.1. Results from the MAPS-Mini street assessment

Using the MAPS-Mini tool, each evaluated street was assigned a score reflecting the quality of its built environment, ranging from 0 % (very poor quality) to 100 % (excellent quality). To compare online and site visit assessments, the percentage scores of the assessed streets were categorized into 20 % increments, each representing a different level of built environment quality in Fig. 3. Across the two different assessment methods, comparative analysis of scores for low, middle, and high-income streets reveals notable variations. Generally, low-income streets have built environments that scored equal to or lower than their counterparts, with a few exceptions such as the low population density set A (both through online and site visits assessments). Among the thirty streets assessed, seven showed significant score variations between the Google Street View and in-person site visits audit surveys, resulting in different "quality of the built environment" categories. These changes were only observed in low and middle-income streets, as high-income streets maintained similar scores, resulting in the same built environment categories across both assessment methods.

The Google Street View survey revealed that most streets were rated as having fair quality. Notably, low-income neighborhoods had a higher prevalence of streets whose built environment rated poorly, compared to middle and high-income neighborhoods, which only had one or two streets in this category. The low-rated streets in middle and high-income neighborhoods were also located in low-density areas. High-income neighborhoods had a greater number of streets rated above 60 %, indicating the good quality of their built environment. Overall, only one of the thirty streets was rated as excellent and was located in a high-income area. None of the streets received a very poor rating (scoring between 0 and 20 %) that would point to a very urgent need for improvement.

The in-person site visits yielded slightly different results. The majority of streets' scores lowered, but many of them did not change to the extent of making them switch categories. Overall, more streets were rated as having a fair environment through in-person site visit assessments. Both low and middle-income neighborhoods had more streets rated as having a poor-quality built environment. However, middle-income neighborhoods had two streets rated as having a good quality environment, unlike low-income neighborhoods, which had none. High-income neighborhoods had several streets rated as good and beyond. The lowest-rated streets were mostly in low-density neighborhoods, however, none of them had a very poor rating. Medium-density neighborhoods exhibited the best scores.

These results show an income-based disparity between the different neighborhoods where the low-income streets are more likely to have poorer built-environment quality than middle- and high-income areas. This reflects the imbalanced allocation of city resources, highlighting the necessity of providing functional, well-equipped, safe, and appealing streets to all residents to allow for equal access to opportunities for physical activity, social interaction, and recreation. These opportunities yield positive health outcomes (Sallis et al., 2009), and allow for better community engagement and social participation (Hassen and Kaufman, 2016). Similarly, focusing on improving the streetscape design for low-density environments is essential to facilitate social interaction, increase attachment and satisfaction with the neighborhood, as well as improve the sense of walkability and safety (Abass and Tucker, 2021).

4.2. Built environment street features

A summary of the 15 built environment features surveyed by MAPS-Mini, categorized by income level and population density is presented in Table 1.

Most streets incorporate at least one type of traffic calming measure. As the literature indicates, the presence of multiple measures enhances perceptions of traffic safety and prioritizes pedestrians (Gehl, 2011; Whyte, 1980). Among all the studied streets, only two streets (out of 30) lacked traffic calming measures entirely, and both were located in high-density and low-income neighborhoods. Some streets adopted intriguing approaches to calming traffic. For instance, a street featured a walkway made from bollards, which are easier to install than planted concrete curbs. Another had a narrowed paved walkway with urban furniture placed in the middle of the street, effectively slowing down cars throughout the street segment.

Nearly all of the streets evaluated had curb ramps, facilitating navigation for individuals with disabilities and parents with strollers. Among all the studied streets, only one street, located in a low-density high-income neighborhood lacked ramps entirely, as it did not have a sidewalk, making accessibility difficult for all residents. While most of these ramps were simple slopes on the sidewalks, some streets featured tactile surfaces to guide visually impaired people. While the existence of curbs is important, there must be further examination of the accessibility criteria for these ramps to ensure their full functionality for wheelchair users (Bennett et al., 2009). Low-income neighborhoods are the most lacking in marked crosswalks, as only 4 out of the 10 examined low-income streets had at least one visible marked crosswalk at the intersection. Overall, many streets had faded crossings, while others had freshly repainted ones. However, this shortcoming in design is not only relevant to low-income neighborhoods as it exists in high-income neighborhoods with 50 % of the examined streets lacking clearly marked crosswalks. Many low-density neighborhood streets were also

Table 1
Frequency of presence of high-quality built environment features across evaluated streets (from in-person visits).

Built environment features	Neighborhood characteristics					
	Income level			Population density		
	Low (10 streets)	Middle (10 streets)	High (10 streets)	Low (9 streets)	Medium (9 streets)	High (12 streets)
1. Traffic calming measures	80 %	100 %	100 %	100 %	100 %	83 %
2. Ramps at the curb	100 %	100 %	90 %	89 %	100 %	100 %
3. Marked crosswalks	40 %	70 %	50 %	33 %	56 %	67 %
4. Commercial or mixed land use	30 %	10 %	40 %	22 %	11 %	42 %
5. Public parks	20 %	40 %	40 %	22 %	56 %	25 %
6. Public transit stops	70 %	50 %	70 %	33 %	67 %	83 %
7. Ample streetlights	50 %	30 %	60 %	22 %	56 %	58 %
8. Benches	60 %	40 %	70 %	22 %	67 %	75 %
9. Bicycle path	10 %	10 %	30 %	22 %	22 %	8 %
10. Well-maintained buildings	20 %	20 %	10 %	22 %	22 %	8 %
11. Graffiti (absence)	30 %	50 %	70 %	78 %	44 %	33 %
12. Sidewalks	90 %	100 %	100 %	89 %	100 %	100 %
13. Well-maintained sidewalks	30 %	10 %	20 %	33 %	22 %	8 %
14. Buffers from traffic	40 %	40 %	50 %	22 %	33 %	67 %
15. Abundant tree coverage	30 %	50 %	80 %	33 %	89 %	42 %

missing marked crosswalks, even where they were needed. For example, one street had a stop sign and pedestrian school corridor signaling, yet there was no visibly marked corridor for pedestrians. Despite most of the streets incorporating traffic calming measures, marked crosswalks remain essential as an extra layer of safety for pedestrians, especially for non-intersection crossings. Table 1 shows that the decrease in population density is associated with lower existence of marked crosswalks, with 33 %, 56 %, and 67 % of the streets having clear marked crosswalks in low, medium, and high-population density neighborhoods, respectively. This issue can be particularly dangerous for pedestrians, as vehicles may travel faster and be less attentive to pedestrians in lower-density environments. This problem needs to be addressed throughout Montréal.

Land uses varied among the assessed streets, with the primary land use being residential. Only eight of the assessed streets were mixed-use, and these were mainly located in high-density areas (Fig. 4). Mixed-use design, along with high-density and pedestrian-oriented amenities, is a critically important factor in inducing non-auto travel and street activity, fostering social engagement and high-levels of physical activity (Cervero and Kockelman, 1997; Mumford et al., 2011). Therefore, it is not a surprise that the mixed-use streets in high-density areas streets had higher pedestrian activity, as these streets foster the concept of place-making with the abundance of activities and destinations (Gehl, 2011; Mehta, 2007; Project for Public Spaces, 2007).

One-third of the studied streets featured public parks of varying sizes and quality, with low-income neighborhoods having the least amount in the studied sample. Most parks were located in medium-density neighborhoods. Some parks lacked greenery, while others were missing amenities. The lower number of parks in lower-income neighborhoods may be associated with the fear of green gentrification and displacement of long-term residents (Cole et al., 2017; Miller, 2019). However, gentrification should not be synonymous with displacement (Zuk et al., 2017) and these concerns should not prevent the city from providing low-income neighborhoods with adequate green spaces, which are linked to numerous positive health outcomes, including improvements in cardiovascular health, stress reduction, and overall well-being (Twohig-Bennett and Jones, 2018).

Nineteen of the studied streets featured public transit stops and/or bicycle-sharing stations. These stops were well distributed across neighborhoods of varying income levels but they were mainly located in medium and high-density areas. Several of the evaluated street segments did not have bus stops directly on them; however, transit stops were present on adjacent streets, intersecting streets, or on the next segments of the same street. Following the MAPS-Mini tool, these nearby stops were not included in the microscale assessment, despite their proximity, which still provided residents with good accessibility to public transport.

The MAPS-Mini tool assessed only the presence or absence of street lighting, defined as lights on one or both sides of the sidewalks to prioritize pedestrian safety. Approximately half of the evaluated streets lacked sufficient lighting, with streetlamps often positioned in the middle of the street (on a median strip) or on only one side of the street instead of both. These deficiencies were observed across neighborhoods of varying income levels but were particularly common in low-density areas. On some streets, the lamppost designs have unique shapes that enhance the appeal of certain streets, allowing pedestrians to appreciate these aesthetic details.

Numerous benches were observed along the streets, primarily in medium and high-density neighborhoods. Both low-income and high-income neighborhoods had a similar number of seating areas. The design, orientation, and placement of benches varied across the studied streets. Some were perpendicular to the streets, occasionally facing each other in pairs, others faced the streets directly, while some had their backs to the street. These variations are important as previous studies found that people's seating preferences are influenced by specific decisions on location, orientation, and seating arrangement in relation to surrounding land-use activities (Lesan and Gjerde, 2021). Whyte (1980) also stressed on the importance of diverse sitting space, such as benches with various designs, building ledges, and steps, to encourage the use of public space. The provision of adequate seating in public spaces has long been recognized as a crucial element for promoting social interaction, improving the sense of comfort and safety, and increasing walkability (Alexander et al., 1977; Gehl, 2011; Marcus and Francis, 1998; Speck, 2012). Despite the existing variations found in the examined streets, most people observed sitting on the benches were either waiting for the bus or located on streets with mixed land uses.

Only five of the evaluated streets had bicycle paths, all of which were unprotected painted bicycle lanes. These lanes were distributed evenly across areas with varying income and density areas. Notably, rue Aurora seemed to have new street infrastructure, including a bicycle lane. However, this lane was replacing a sidewalk, resulting in a configuration where one side of the street featured a bike lane while the other maintained a sidewalk. This design still prioritizes space for automobiles, highlighting the continued emphasis on car traffic (Elokda, 2017).

The MAPS-Mini tool operated such that if even just one building on a street was damaged, the entire street's rating for building maintenance would suffer. Consequently, the majority of streets in neighborhoods of all income levels and densities featured damaged buildings. These poor conditions manifested as rusty exteriors, boarded-up windows, cracks, material discoloration, chipped paint, or an exposed wall. Often, these issues varied in severity, with some buildings starkly contrasting against others that were well-maintained, disrupting the visual harmony of the built environment. As a pedestrian, this discordance noticeably impacted the overall aesthetic appeal of the space.

Graffiti or tagging was frequently observed across the studied streets, with the majority found in low-income and high-density neighborhoods. While tagging and graffiti can be bothersome, they paled in comparison to the nuisance posed by litter during site visits, which often cluttered pedestrian pathways directly. The cleanliness of streets emerged as a bigger concern, especially considering that much of the graffiti was

Fig. 4. Mixed-use streets in high-density areas (Left) Chemin de la Cote-des-Neiges. (Right) Avenue Mont-Royal E.

positioned out of direct sightline for pedestrians. However, litter was not accounted for in the MAPS-Mini survey. Several streets littered with garbage lacked trashcans, a feature that could help alleviate the problem, as streets equipped with proper waste disposal were generally cleaner.

All of the streets had sidewalks, except for two streets in low-density neighborhoods, namely Avenue Aurora (high-income area) and Hardwood Gate (middle-income area), where the sidewalk abruptly ended (Fig. 5). The MAPS-Mini tool focused solely on the presence and upkeep of sidewalks. However, during site visits, it became evident that other factors such as sidewalks with diverse materials, colors, and designs, enhanced the walking experience by adding visual interest. Additionally, wider sidewalks provided a more comfortable and secure walking environment. This was particularly noticeable when comparing standard sidewalks with overlapping cedar fences and angled trees with protruding roots, causing uneven surfaces.

An overwhelming number of sidewalks across the evaluated streets exhibited severe neglect in maintenance. Only six streets, mainly located in low-density neighborhoods, were in proper condition without any tripping hazards that could potentially endanger distracted pedestrians and those with limited mobility. These issues were predominantly identified during site visits rather than through Google Street View, as parked cars and other obstructions often obscured the view of the sidewalk's condition. Since the site visits occurred at the beginning of spring, it is plausible that the observed damages could be associated with the aftermath of winter. While road construction activities for roadways were observed, there appeared to be little to no effort directed toward sidewalk repairs and improvements.

Thirteen assessed streets featured buffers from roadways, primarily in the form of street trees. However, their specific characteristics varied, including the trees' maturity and dimensions, their placement, and the spacing between them. These buffers were found in neighborhoods with different socioeconomic levels, primarily in high-density areas. The most comfortable buffer was observed where there was a clear separation from the sidewalks. On other streets, trees serving as buffers punctuated the standard sidewalks, requiring pedestrians to sometimes alter their paths to navigate around tree protrusions.

Some of the streets exhibited greater tree coverage than others, enhancing the walking experience. Streets with the most trees were located in high-income and middle-density areas, while low-income and low-density neighborhoods had very few. As the site visits were conducted in spring before the trees' foliage reached full bloom, the level of shading was deduced from the number and size of the street trees. While the presence of trees was primarily evaluated for shade and comfort, their mere presence contributed to creating more inviting and aesthetically pleasing environments. Despite trees sometimes being situated on median strips (Fig. 6), they still significantly enhanced the streets' appeal, even though they provided limited shading.

One element enhancing the enjoyment and attractiveness of the built environment of streets, not accounted for in the MAPS-Mini auditing surveys, was the presence of public art. The observed art took various forms, from sidewalk art to murals adorning the sides of buildings, and even painted street parking lanes. Despite some art being on parking lanes, pedestrians rather than car occupants were the ones appreciating it. No trend related to the income and density levels of neighborhoods was observed, as these three streets were the only ones that had any public art.

Public art transformed the walking experience, making the environment more engaging and stimulating, rather than solely convenient and comfortable. While it may not be practical or necessary to install public art on every street, particularly in low-density neighborhoods, it is beneficial for high-density streets with substantial pedestrian and cyclist traffic to consider incorporating public art to enhance livability and enjoyment. Certain streets had a lot of infrastructure and amenities but still lacked appeal, appearing mundane despite meeting functional criteria.

4.3. Policy design recommendations

Addressing disparities in the built environment is essential for creating equitable, healthy, and livable communities. The results of this research suggest that greater focus and resources should be directed towards improving the quality of streets at the microscale in Montréal as most of the studied streets were rated as having poor to fair built environments, with only one street achieving an excellent rating. Additionally, particular focus should be directed towards lower-income neighborhoods, which typically suffer from poorer street design.

Policy recommendations include investing in active transport infrastructure and prioritizing maintenance, especially in lower-income neighborhoods. These efforts should be coupled with increased community engagement to address the diverse needs and concerns of residents. Leveraging established programs like Quartiers verts, actifs et en santé (QVAS) and Réseau quartier verts du Canada (RQV) can facilitate these inclusive approaches. To mitigate gentrification and the displacement of long-term residents, initiatives to improve streetscapes should be complemented by equitable development policies. These policies include preserving affordable housing through legal protection, adopting inclusionary zoning practices, providing financial support to residents in need, etc. Such measures aim to ensure that vulnerable populations benefit from improved public spaces.

Inclusive urban planning strategies that encourage community engagement and participatory planning is crucial to ensure that the needs, priorities, and concerns of diverse residents are adequately addressed in urban planning decisions, ensuring that streets are accessible and welcoming to all residents, regardless of their neighborhood socioeconomic level (Ahmed et al., 2019; Sanoff, 2000). Implications for urban design, transport, and land use planning include establishing clear equity guidelines to ensure equal access to amenities across different socioeconomic areas. Conducting ongoing assessments of street quality and maintenance is essential for the continuous upkeep of built

Fig. 5. Low-density neighborhoods' streets lacking sidewalks. (Left) Avenue Aurora. (Right) Hardwood Gate.

Fig. 6. Trees situated on median strips. (Left) Boulevard Pierre Bernard (Right) Avenue Brown.

environments. Special attention should be given to repairing damaged buildings across all neighborhoods and addressing issues such as graffiti and litter in low-income, high-density areas where these problems are most prevalent. Pedestrian safety could be improved by incorporating marked crosswalks in low-income, low-density neighborhoods. To create more pleasant and environmentally friendly urban spaces, the number of public parks, planted buffers, and street trees should be increased, especially in low-income areas. To enhance safety and comfort, more street lighting and benches should be installed in low-density areas.

Promoting mixed-use development is important to create vibrant and diverse streetscapes that cater to various activities and services, contributing to a more dynamic urban environment across the island. Many strategies can be implemented to promote mixed-use development such as revising zoning regulations to allow the integration of residential, commercial, and recreational spaces within close proximity and creating hubs for businesses and services (Levine, 2006). One motive for revising zoning regulations is to capitalize on large-scale transportation projects under construction in the region and encourage transit-oriented development (TOD), which is a presently available opportunity for Montréal with its new light-rail system under construction. However, it has been found that only a limited number of municipalities have made significant bylaw changes in recent years to support TOD plans around the light-rail, missing out on opportunities to implement mixed-use zoning and increase urban densities (Soliz et al., 2024). Another approach to encouraging investments in mixed-use projects is through tax incentives such as property tax abatements, tax credits, or exemptions. However, the effectiveness of these incentives depends on the applied tax regime (Taranu and Verbeeck, 2022); thus, this strategy requires elaborate investigations by professionals in finance, law, public administration, and real estate development in collaboration with urban planners and all other fields involved in land development.

These recommendations come with challenges that must be addressed through careful planning and prioritization. First, extensive audits of the streets are needed, along with effective data management, clear communication of responsibilities, and reliable deadlines. Since financial resources are often limited in public projects, municipalities should focus on cost-effective changes initially. For example, areas lacking sidewalks can see significant improvements by installing bollards to separate pedestrian and vehicle traffic, with more substantial sidewalk construction to follow when resources allow. These small interventions can create a ripple effect, gradually enhancing the quality of the built environment. Larger-scale improvements, such as changing zoning regulations and developing mixed-use projects, require a clear vision of the city's future with principles of equity and sustainability at its core. This vision should ensure that underserved communities are provided with equitable living environments that promote their well-being.

5. Conclusion

Microscale-built environment features play a crucial role in the liveliness, appeal, and comfort of streets (Gehl, 2011; Mehta, 2007; Miranda et al., 2021). In this research, the MAPS-Mini tool was used to examine whether streets are created equal in Montréal, Canada. Fifteen street features were evaluated in thirty streets in neighborhoods with varying population density and income levels, resulting in scores that determine the quality of the built environments. Despite having similar typologies and characteristics, streets in lower-income areas exhibited poorer built environment quality, overall, highlighting the inequality in street design in Montréal. These variations underscore the need to incorporate social and spatial equity considerations into urban planning. This trend was particularly evident in medium and high-density neighborhoods.

Conversely, one low-income street displayed an atypical pattern, scoring higher than those in wealthier areas. These disparities are further highlighted when comparing individual street elements, suggesting a need for targeted microscale interventions to address inequities in amenity provision and distribution. Priority in revitalization projects should be given to lower-income neighborhoods with the poorest-quality environments. Overall, the assessment indicates that most streets in Montréal require improvements. Urban design efforts are needed across the island, as less than a third of the studied streets were deemed to have a good quality environment. The overwhelming majority were categorized as having a fair-quality environment, indicating room for improvement.

Adapting the MAPS-Mini tool for Google Street View assessments, though convenient, presents challenges in evaluating certain built environment features. As the literature has warned, Google Street View imagery is captured from a car's perspective and can be obstructed by various elements. For example, the abundance of on-street parking adjacent to sidewalks frequently obstructs online views of sidewalk conditions and maintenance. Sidewalks and building conditions were the main microscale features causing discrepancies between the Google Street View and in-person site visit scores.

Although the site visits were conducted under consistent weather conditions, Google Street View images varied, showing sunny, rainy, and snowy conditions across different streets, which hindered some online evaluations. The imagery across Montréal was not captured uniformly throughout the year, leading to additional challenges when assessing street maintenance during winter. Due to their more temporary nature, features such as graffiti and tripping hazards on sidewalks displayed variability between online and in-person evaluations. Even marked crosswalks showed differences, with many of them faded from the winter snow. This study demonstrates that conducting street assessments using Google Street View has more flaws than the literature suggests, as score changes were observed for the majority of streets, with some showing clear discrepancies in overall scoring.

Despite these limitations, some advantages of virtual observations were noted. Google aerial and satellite imagery proved effective for specific assessments. For example, aerial views quickly identified transit stops and routes, providing a comprehensive overview of their distribution. Moreover, as the site visits occurred in spring, trees lacked foliage, complicating the assessment of tree canopy shading. Satellite imagery, combined with street view from site visits, offered a better evaluation of the percentage of sidewalks shaded from the sun. Overall, combining virtual and in-person methods proved to be very useful and efficient, allowing for a thorough review of streets. Researchers using the MAPS-Mini tool should use both assessment approaches, but it is important to note that in-person assessments are more accurate and thorough. They offer a more natural and human perspective that aligns with pedestrian experiences.

Addressing disparities in the built environment is crucial to creating equitable, healthy, and livable communities. Key policy recommendations include conducting regular assessments to monitor street quality and develop strategies that promote equitable access to high-quality environments, establishing equitable policies and guidelines to mitigate green gentrification and resident displacement during streetscape improvements, encouraging community engagement in street design, investing in active transport infrastructure and prioritizing maintenance, promoting mixed-use development, and focusing on cost-effective interventions when managing limited financial resources.

Our methodology can be applied to other cities worldwide to examine socioeconomic disparities in street design. Identifying areas for improvement and setting priorities using appropriate economic and policy evaluation tools can help practitioners and decision-makers focus their efforts on addressing street design inequalities, which have significant implications for individual issues such as the health and well-being of the citizens (Sallis et al., 2009), as well as global concerns, such as climate change (Csete and Buzasi, 2016; Dover and Massengale, 2014).

Future research can combine walk-along interviews and field observations to enable researchers to gain deeper insights into individuals' experiences by observing their neighborhood contexts and reactions firsthand (Carpiano, 2009). This method allows researchers to identify residents' street element preferences more accurately than merely showing pictures and asking people to speculate about what it might be like to be a pedestrian or cyclist in those areas. These interviews can explore a range of questions, regarding the interviewee's perceptions, activities, and inclinations to use the streets. This integration could reveal which elements of the built environment truly attract people to certain streets and whether their usage is influenced by amenities, social factors –such as the presence of others– or both. Even experiencing streets as an auditor during site visits differed significantly from evaluating them virtually or through photos, as it directly exposes them to tripping hazards, missing infrastructure, and stressful crossings. Additionally, in-person experiences can reveal new elements that influence the pedestrian experience, such as traffic noise. High levels of traffic noise can make streets very uncomfortable and unpleasant for pedestrians, even if they have amenities to support their activities.

Future research utilizing the MAPS-Mini tool should include assessments conducted through site visits at night. This approach can provide valuable insights into the adequacy of street lighting, as the strength and distribution of light can significantly vary after dark, impacting safety and visibility for pedestrians and vehicles. Certain questions of the MAPS-Mini tool may be further adapted. For instance, the original auditing survey accounts for the number of parks, rather than their size. However, the size and quality of parks can potentially increase their appeal. A recommendation for future adjustments to the tool is to provide options for answering this survey question similar to the tree coverage question, in terms of the percentage of park area adjacent to the street. The MAPS-Mini tool should also consider sidewalk widths and characteristics beyond mere presence and upkeep, as these factors can influence pedestrian experience, comfort, and safety. Additionally, with sufficient resources, multiple assessors could audit the same street segments, allowing inter-rater reliability to be evaluated and thereby enhancing the audits' consistency, validity, and reliability.

Finally, assessments could extend beyond microscale assessments of individual street segments to explore the mesoscale. This broader perspective would involve examining elements like transit stops, mixed-use, and commercial areas, as well as bicycle lanes at the neighborhood level. By doing so, researchers can gain a more nuanced understanding of the quality of streets within a neighborhood.

CRediT authorship contribution statement

Elitza Kraycheva: Writing – review & editing, Writing – original draft, Visualization, Validation, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hisham Negm:** Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation. **Madhav G. Badami:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Ahmed El-Geneidy:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A:. Maps-Mini questions

Intersection

1. Is a pedestrian walk signal present or traffic calming measures on the street/at the intersections (stop signs, speed bumps, narrowed walkways at intersection, pedestrian island)?
   - No (0)
   - Yes, at one intersection (1)
   - Yes, at both intersections (1)
2. Is there a ramp at the curb(s)?
   - No (0)
   - Yes, at least at one curb at one intersection (1)
   - Yes, at all curbs at one intersection (1)
   - Yes, at both intersections but not at all curbs (1)
   - Yes, at all curbs at both intersections (2)
3. Is there a visible marked crosswalk?
   - No (0)
   - Yes, at one intersection (1)
   - Yes, at both intersections (1)

Land Use

4. What is the type of land use
   - Industrial or vacant (0)
   - Green space (parks, accessible forest) (0)
   - Residential (0)
   - Institutional (education, governmental) (1)
   - Commercial (1)

   - Mixed (1)
5. How many public parks are present?
   - 0 (0)
   - 1 (1)
   - 2+ (2)

Amenities

6. How many public transit stops are present, including Bixi stations?
   - 0 (0)
   - 1 (1)
   - 2+ (2)
7. Are streetlights installed? (e.g., are there streetlights on both sides of the street?)
   - None (0)
   - Some (1)
   - Ample (2)
8. Are there any benches or places to sit? (including bus stop benches)
   - No (0)
   - Yes (1)
9. Is there a designated bike path?
   - No (0)
   - Sharrow (0)
   - Painted line (1)
   - Physical barrier-multiuse path (2)
   - Physical barrier-bollard (2)
   - Physical barrier-concrete/grass buffer (2)

Aesthetic

10. Are the buildings well maintained?
    - 0–99 % (0)
    - 100 % (1)
11. Is graffiti/tagging present? (do not include murals)
    - No (1)
    - Yes (0)

Sidewalks

12. Is a sidewalk present?
    - No (0)
    - Yes, on one side (1)
    - Yes, on both sides (1)
    - Pedestrian street (1)
13. Are there poorly maintain sections of the sidewalk that constitute major trip hazards? (e.g. heaves, misalignment, cracks, overgrowth, incomplete sidewalk)
    - No sidewalk present (0)
    - A lot (More than 25 % of sidewalk) (0)
    - Some (Less than 25 % of sidewalk) (0)
    - None (1)
14. Is a buffer present?
    - No sidewalk present (0)
    - No (0)
    - Yes, on one side (1)
    - Yes, on both sides (1)
15. What percentage of the length of the sidewalk/walkway is covered by trees, awnings or other overhead coverage?
    - No sidewalk present (0)
    - 0–25 % (0)
    - 26–75 % (1)
    - 76–100 % (2)

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