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Examining Disparities in Walkability, Recreational Places and Aesthetics in the City of Cambridge, Massachusetts

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Abstract

Background: Walkability is a cornerstone of healthy and sustainable cities, yet research often emphasizes infrastructure while overlooking aesthetic and cultural features such as public art. These built environment components may not be equitably distributed across neighborhoods, raising concerns about disparities in access to health-promoting spaces.

Objective: This study examines whether sidewalks, recreational open spaces, pedestrian ramps, community gardens, and public art landmarks are equitably distributed across neighborhoods with differing levels of social vulnerability in Cambridge, Massachusetts (MA).

Methods: Using 2020 U.S. Census block groups as the unit of analysis, we integrated multiple geospatial datasets, including sidewalk polygons, recreational open spaces, pedestrian ramps, community gardens, and public art landmarks, and the overall Social Vulnerability Index (SVI). In QGIS, we calculated sidewalk coverage as the percentage of block group land area occupied by sidewalks, computed the total acreage of recreational open spaces, and counted the number of pedestrian ramps, community gardens, and public art landmarks per block group. These metrics were merged with SVI data. Statistical analyses in R Studio included descriptive comparisons, correlations, and regression models to test whether higher vulnerability was associated with lower walkability level, and fewer recreational and aesthetic amenities.

Results: Across 87 block groups in Cambridge, MA, regression analyses showed that higher social vulnerability was positively associated with sidewalk coverage ($\beta = 0.24$, $p = 0.04$), indicating that more vulnerable neighborhoods had greater sidewalk presence. Conversely, social vulnerability was negatively but not significantly associated with open space acreage ($\beta = -24.76$, $p = 0.087$) and with pedestrian ramps ($IRR = 0.62$, $p = 0.071$). Community gardens and public art landmarks showed no significant associations with social vulnerability.

Conclusions: This study highlights the importance of considering both infrastructure and cultural features in equity-oriented walkability research. Findings can inform urban planning and public health strategies to reduce disparities in access to safe, walkable, and aesthetically enriched environments.

Keywords: Aesthetics; Environmental Justice; Recreational Places; Sidewalks; Walkability

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1. Introduction

The significant impact of neighborhoods' walkability levels on people's overall health has been well explained by current literature.[1,2] Several studies have shown that higher walkability of the built environment significantly reduces multiple chronic diseases, such as obesity, diabetes, hypertension, and depression.[2–5] Additionally, a higher level of walkability helps promote social engagement and decrease social isolation and loneliness.[6,7] However, socially and economically disadvantaged communities often face limited access to high walkable neighborhoods,[8–10] such as sidewalks and open spaces,[9,11] raising concerns about environmental justice and health equity.[12]

In addition to the walkability of neighborhoods, other factors play a crucial role in the community's health, which is also documented well by the existing literature. Some of these factors include, but are not limited to, open spaces,[13] parks and greenery,[14] and art and aesthetics[15] of the built environment.[16] Indeed, recent studies are emerging in terms of how recreational open areas, as well as public art, aesthetic design, and cultural landmarks, contribute to community cohesion,[17] perceived safety,[18] and mental health.[19,20] In particular, the overall attractiveness of urban spaces and positioning aesthetics as an essential dimension of equitable and health-promoting environments are receiving lots of attention from scholars in recent years.[21–23] For example, public art not only beautifies neighborhoods but may also foster a sense of belonging, cultural expression, and social cohesion.[24,25] Yet, walkability, recreational open spaces, and art are rarely incorporated holistically into assessments of walkability or evaluated for their equitable distribution.

Equity in walkability and art in the built environment requires examining both the presence of basic infrastructure and the integration of cultural and aesthetic amenities.[26,27] In the United States, disparities in these resources may intersect with broader social vulnerability, also defined as a community's resilience to external stresses on health, such as poverty, housing instability, or limited access to transportation.[28,29] The Centers for Disease Control and Prevention's Social Vulnerability Index (SVI) provides a widely used framework to capture these dimensions across neighborhoods.[30] This tool, developed by the Agency for Toxic Substances and Disease Registry (ATSDR),[31] is widely used in various studies, like disaster management,[32] but rare in the intersection of public health and the built environment era. Indeed, a limited number of studies have relied on this important index to determine disparities in walkability and aesthetics of the built environment.[33] Therefore, there is a significant gap between integrating SVI with geospatial measures of sidewalks, open spaces, and public art, in order to assess whether vulnerable communities face systematic inequities in access to both functional and cultural urban features.

This study focuses on Cambridge, Massachusetts, a city with a dense urban fabric, vibrant cultural life, and pressing equity challenges.[34] Besides, this city has provided the public with a great dataset (i.e., https://www.cambridgema.gov/GIS),[35] which has enabled conducting equity analyses in such a realm. By integrating geospatial data on sidewalks, recreational open spaces, pedestrian ramps, community gardens, and public art landmarks with block group-level SVI data, we examined whether walkability-related infrastructure and cultural features were equitably distributed across neighborhoods with varying levels of vulnerability. This approach expands traditional measures of walkability by including both functional and aesthetic components, contributing to a more comprehensive understanding of equity in the built environment.[36] In addition, the idea of bridging urban design and planning to public art and social vulnerability, as well as the methodology used in this study (e.g., geospatial analyses),[37] can be replicable in other areas to examine inequities in access to both infrastructure and cultural amenities, inform local planning decisions, and guide policies that foster healthier, more inclusive, and aesthetically enriched communities.

2. Methods

2.1. Study area

This study was conducted across all block groups of the City of Cambridge, Massachusetts (MA, *N*=87).

2.2. Measurements

The built environment infrastructure: We used multiple variables related to the built environment infrastructure derived from the City of Cambridge's open GIS database.[35] GIS basemap development for the City of Cambridge, MA, encompasses the city's land area, as well as an area surrounding the Charles River shoreline and Boston's Charles River shoreline. Digital photogrammetry was used to create the basemap data at a scale of 1" = 40'.[35] The list of the used variables includes sidewalks, recreational open spaces, pedestrian ramps, community gardens, and public art landmarks.

Social Vulnerability: Neighborhood social vulnerability was measured using the Centers for Disease Control and Prevention (CDC)/Agency for Toxic Substances and Disease Registry (ATSDR) Social Vulnerability Index (SVI).[38] SVI was originally developed at the census tract level; however, a valid and reliable SVI at the Block Group (BG) level has been published by Harvard University,[39] a dataset that we used for the purpose of our study. Both the overall SVI and its four component themes were available, but the present analysis focused on the overall score, as it provides a comprehensive summary of vulnerability by integrating multiple social, economic, and housing-related factors into a single measure.[38]

Sidewalk and recreational open space coverage: The proportion of each block group's land area occupied by sidewalks was calculated in QGIS. Sidewalk percentage of area was obtained via the Summarize Within tool and divided by total block group land area, then multiplied by 100 to produce the percentage. The recreational open spaces attribute was considered as the acreage occupying each block group.

Counts of amenities: The number of pedestrian ramps, community gardens, and public art landmarks within each block group was derived using the Spatial Joins tool. Each amenity was represented as a raw count rather than normalized by area, to reflect the absolute distribution of resources across neighborhoods.

Social Vulnerability Index (SVI): The overall SVI score (range 0-1) was merged to each block group from the Harvard dataset, which has taken the SVI from the CDC/ATSDR (originally at the census tract level),[38] and turned it into the block group level.[39] Higher values indicate greater social vulnerability.

Population: Population counts for each block group were obtained from the 2020 Decennial Census United States Census Bureau.[40]

2.3. Statistical analysis

Analyses were performed in R Studio.[41] First, descriptive statistics were computed for all variables. The primary analysis assessed the association between neighborhood social vulnerability and the distribution of walkability and cultural amenities. For outcomes measured as counts (i.e., pedestrian ramps, community gardens, and public art landmarks), Poisson regression models were estimated with the overall SVI score as the main predictor and block group population included as a covariate. Models were specified with robust standard errors to account for potential heteroskedasticity. Results are reported as incidence rate ratios (IRRs) with 95% confidence intervals. For the continuous outcome (i.e., percentage of sidewalk coverage, the acreage of recreational open spaces), ordinary least squares (OLS) regression was applied, regressing sidewalk percentage and the acreage of recreational open spaces on SVI controlling for block group population, with robust standard errors. All statistical tests were two-tailed, with p-values <0.05 considered statistically significant.

3. Results

Table 1 presents the descriptive statistics of built environment and vulnerability variables across Cambridge block groups (N=87). On average, the percentage of sidewalk coverage averaged 58% of block group land area (SD = 0.21, range = 0.10-0.99). Block groups also contained on average 9.69 acres of recreational open space (SD = 35.99, range = 0-315.81), 52.53 pedestrian ramps (SD = 26.90, range = 0-112), 0.16 community gardens (SD = 0.43, range = 0-2), and 7.22 public art landmarks (SD = 12.64, range = 0-63). The overall SVI averaged 0.36 (SD = 0.21, range = 0.01-0.89). Population counts per block group ranged from 394 to 2,529, with a mean of 1,370 residents.

Poisson regression models assessed associations between SVI and count-based amenities (Table 2). After adjusting for population at the block group level, none of the associations reached conventional levels of statistical significance, although some patterns emerged. Community gardens showed a negative but non-significant association with vulnerability (IRR = 0.10, 95% CI: 0.01-1.85, p = 0.123). Pedestrian ramps also trended toward lower counts in higher-vulnerability neighborhoods (IRR = 0.62, 95% CI: 0.37-1.04, p = 0.071). In contrast, public art landmarks did not vary significantly by social vulnerability (IRR = 1.33, 95% CI: 0.35-5.11, p = 0.674).

As shown in Table 3, linear regression models evaluated the relationship between SVI and continuous outcomes. Results indicated a positive and statistically significant association between sidewalk coverage and social vulnerability (β = 0.24, SE = 0.11, t = 2.06, p = 0.04, 95% CI: 0.01- 0.47). This suggests that more vulnerable neighborhoods had slightly higher sidewalk coverage relative to less vulnerable areas. By contrast, recreational open space acreage was inversely associated with vulnerability, though this relationship was not statistically significant (β = -24.76, SE = 14.31, t = -1.73, *p* = 0.087, 95% CI: -53.23 - 3.71). While not conclusive, the direction of the effect indicates that block groups with higher vulnerability may contain fewer acres of open space.

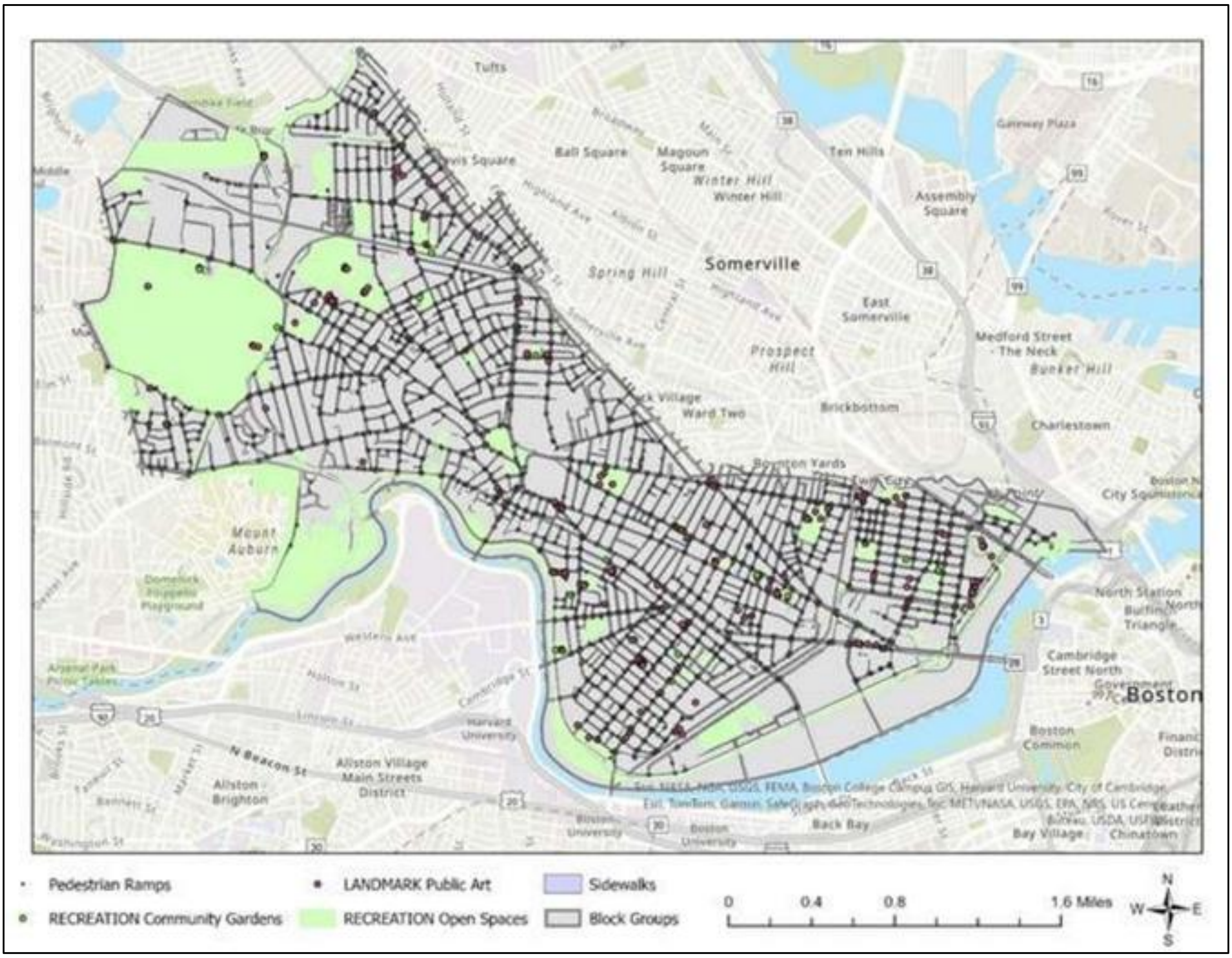

Figure 1 Distribution of Built Environment Features in Cambridge, Massachusetts, Block Groups N=87

Table 1 Descriptive statistics of built environment variables and social vulnerability across block groups in Cambridge, MA (N = 87)

Variables	Objects	Mean	Standard Deviation (SD)	Min	Max
Community gardens	87	0.16	0.43	0	2
Recreational open spaces (Acres)	87	9.69	35.99	0	315.81
Pedestrian ramps	87	52.53	26.90	0	112
Landmark public art	87	7.22	12.64	0	63
Percentage of sidewalks per block group	87	0.58	0.21	0.10	0.99
Overall social vulnerability	85	0.36	0.21	0.01	0.89
Population numbers	87	1370.02	487.80	394	2529

Table 2 Poisson regression models (Incidence Rate Ratios) of built environment resources on overall social vulnerability, controlling for population and block group area in Cambridge, MA (N = 87)

Variables	**Incidence Rate Ratio (*IRR*)**	**Standard Error (*SE*)**	***Z***	***p*>|*z*|**	**[95% conf. interval]**
Community gardens	0.10	0.15	-1.54	0.123	0.01 1.85
Pedestrian ramps	0.62	0.16	-1.81	0.071	0.37 1.04
Landmark public art	1.33	0.91	0.42	0.674	0.35 5.11

Table 3 Linear regression models of built environment features on overall social vulnerability, controlling for population in each block group in Cambridge, MA (n = 87)

Variables	**Coefficient**	**Standard Error (*SE*)**	***t***	***p*>|*z*|**	**[95% conf. interval]**
Percentage of sidewalks per block group	0.24	0.11	2.06	0.04	0.01 0.47
Open space (Acres)	-24.76	14.31	-1.73	0.087	-53.23 3.71

4. Discussion

Based on social vulnerability, this study examined equitably distributed walkability-related infrastructure and cultural features across neighborhoods in Cambridge, MA. By integrating geospatial datasets with the SVI, we assessed sidewalks, recreational open spaces, pedestrian ramps, community gardens, and public art landmarks at the block group level. The findings provide a nuanced picture of how social vulnerability intersects with the built environment's functional and aesthetic components.

Our results revealed considerable patterns regarding the distribution of built environment features across Cambridge neighborhoods. First, sidewalk coverage was positively associated with neighborhood social vulnerability, suggesting that more vulnerable block groups in Cambridge had greater sidewalk presence. This finding diverges from much of the literature, which often documents infrastructural deficiencies in socially and economically disadvantaged areas.[42,43] For example, a study conducted by Neckerman et al.[44] investigated walkability in New York City and showed that disadvantaged neighborhoods had lower-quality pedestrian environments, including broken sidewalks and limited maintenance, even when sidewalk coverage was present. Similarly, another study showed that minority populations and, in some cases, poorer populations suffered from poor sidewalk connectivity.[45] However, a study by Thomas et al[33] revealed a similar pattern, showing a higher percentage of sidewalk coverage in socially vulnerable neighborhoods in terms of housing and transportation. The city of Cambridge's positive association between social vulnerability and sidewalk presence may also reflect its historical urban form and long-standing municipal investment in walkability.[46] Unlike sprawling suburban areas with less typical sidewalks, Cambridge's dense street grid and planning mandates have ensured that sidewalks are a fundamental and nearly universal feature.[47] In addition, city policies may have prioritized vulnerable neighborhoods for infrastructure improvements, such as accessibility upgrades and sidewalk repairs, as part of equity-driven initiatives.[48]

The availability of recreational open spaces was inversely associated with social vulnerability, though this relationship was not statistically significant. The negative coefficient indicates that block groups with higher levels of social vulnerability may have fewer acres of parks and recreational land. This pattern is consistent with broader evidence showing that disadvantaged neighborhoods often experience limited access to green space and its associated health benefits.[49] While inconclusive, this finding raises concerns about disparities in opportunities for outdoor recreation, physical activity, and stress reduction.[16] For count-based amenities, pedestrian ramps showed a trend toward lower numbers in higher socially vulnerable areas, though this result did not achieve statistical significance either. Meanwhile, community gardens and public art landmarks showed no consistent relationship with neighborhoods' social vulnerability. These results suggest that while certain forms of infrastructure (e.g., sidewalks) may be equitably or preferentially distributed across Cambridge, MA, other amenities, particularly those linked to recreation and accessibility, need deeper investigation that accounts for factors such as land availability, historical zoning policies, funding priorities, and community advocacy.

4.1. Strengths and limitations

This study has several notable strengths. First, it integrates multiple dimensions of the built environment, including both functional infrastructure (i.e., sidewalks, ramps, open spaces, and community gardens) and cultural features (i.e., public art). Most equity-focused walkability research emphasizes transportation-related infrastructure,[1,36] while our approach broadens the scope to include aesthetic and cultural amenities. Second, the study leverages high-quality geospatial data from the City of Cambridge,[35] which provides detailed and up-to-date mapping of sidewalks, open spaces, and cultural landmarks. Combining these datasets with the SVI at the block group level offers a novel way to evaluate how neighborhood vulnerability intersects with both infrastructure and aesthetics. Third, the use of geospatial analyses in QGIS enabled precise measurement of sidewalk coverage as a proportion of block group area and the aggregation of amenities through spatial joins. Finally, statistical analyses were conducted using robust regression techniques. Poisson regression was applied for count-based amenities, and linear regression for continuous measures (i.e., sidewalk coverage and recreational open space acreage), with models adjusted for population size. This analytic strategy accounts for potential confounding and provides interpretable results regarding equity in access to amenities.

On the other hand, several limitations must be acknowledged. First, the study's sample size was relatively small (N=87 block groups). While block groups provide a fine-grained geographic unit, the limited number reduced statistical power, particularly for variables with high variability, such as recreational open space acreage. This may explain why some associations, though directionally meaningful, did not reach statistical significance. Second, the study relied on cross-sectional data, which prevents causal inference. The observed relationships may reflect both historical planning decisions and ongoing municipal interventions, but temporal sequencing cannot be established. Third, the analysis emphasized quantity rather than quality of amenities. For example, sidewalk coverage does not capture sidewalk condition or accessibility, recreational open space acreage does not account for usability or safety, and public art counts do not consider visibility, community relevance, or maintenance. These qualitative aspects may significantly influence the health and social benefits of amenities. Lastly, the generalizability of findings may be limited. Cambridge is a compact, historically urbanized city with relatively strong municipal investments in walkability and cultural programming. Patterns observed here may differ in suburban, rural, or less resource-rich settings.

4.2. Implications and future directions

Despite the limitations mentioned, the results have important implications for policymakers and urban designers. Urban planning and public health efforts in Cambridge and similar cities should recognize that equity is multidimensional, meaning that some resources may be equitably distributed while others remain uneven. In particular, attention should be directed toward ensuring equitable access to recreational open space and accessibility infrastructure, as these features provide critical health benefits for vulnerable populations.[50] Policymakers should also continue to integrate cultural and aesthetic features into walkability planning, recognizing their potential contributions to social cohesion and community well-being. Future studies should expand beyond Cambridge to larger samples of cities, allowing for more robust statistical analysis and generalizability. Incorporating measures of quality (e.g., sidewalk condition, park amenities, or public art quality and usability) would provide a richer understanding of how infrastructure disparities affect health outcomes. Moreover, longitudinal analyses could assess how changes in social vulnerability over time correspond to shifts in walkability and cultural resources.[51]

5. Conclusion

The findings of our study underscore the complexity of equity in the built environment. Infrastructure and cultural features do not always follow the same distributional patterns. Sidewalk coverage may be equitably distributed due to citywide mandates or baseline density, while recreational open spaces and pedestrian ramps, which require more spatial or financial resources, may lag in vulnerable neighborhoods. The absence of disparities in public art could reflect Cambridge's strong citywide investment in cultural programming. However, the lack of variation may suggest that art installations are concentrated in commercial or civic centers rather than residential neighborhoods. In conclusion, broader geographic contexts should be examined in future research to ensure sufficient statistical power and enhance the robustness of equity assessments.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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