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Transit station area walkability: Identifying impediments to walking using scalable, recomputable land-use measures

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Abstract: Transit station area land-use characteristics can increase or decrease the perceived costs of riding rail relative to driving or taking other modes. This paper focuses on those characteristics that create discomfort to riders who are walking between stations and destinations, with the aim of providing researchers and planners with a tool that can be used to identify pain points in any existing or potential station areas. We propose and demonstrate a scalable, recomputable method of measuring pedestrian quality for trips that relies solely on datasets readily available for almost any location in the United States, and we compare results using data from a global source, OpenStreetMap. We illustrate our tool in neighborhoods surrounding the Blue Line light rail in Minneapolis, Minnesota, calculating the population-weighted distribution of land uses within pathway buffers of walks from stations to nearby destinations. We focus on land uses that pose a disutility to pedestrians such as major highways or industrial tracts, and we compare disamenity levels across station areas. Despite their simplicity, our measures capture important differences in land-use-related pedestrian experiences and reveal the inadequacy of using circular buffers to designate and characterize station catchment areas.

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1 Introduction

Researchers and planners have long known that the land-use characteristics of transit station areas affect pedestrian experiences. An established literature finds that the nature and degree of land-use mix affects mode choice, walking, and transit ridership.[1] In addition, research that uses environmental audit methods reveals the importance to potential pedestrians of specific impediments to walking (e.g., Day et al., 2006). Such methods, however, are labor-intensive and difficult to scale, and cannot be easily employed to conduct cross-city comparisons. In this paper, we propose and demonstrate a scalable, recomputable method for generating descriptive statistics of land uses surrounding stations—or any other destinations where substantial foot traffic is expected or desirable—that complement more complex measures.

We focus on land uses that create discomfort to riders who are walking between stations and destinations, with the aim of providing researchers and planners with a tool that can be used to identify pain

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[1] See for example (Cervero, 2002; Cervero & Kockelman, 1997; Ding et al., 2019; Ewing & Cervero, 2001, 2010; Gutiérrez et al., 2011; Jun et al., 2015; Liu et al., 2021; Zhang et al., 2022).

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points in any existing or potential station areas. Our method relies solely on datasets readily available for almost any location in the United States, and we compare results using data from an open-access global source, OpenStreetMap. These data are commonly used by planners, and our easy-to-scale techniques enable quick identification of specific problem areas that impede station access and egress, which promotes large-scale comparisons within and across geographic areas. We illustrate our tool in neighborhoods surrounding the Blue Line light rail line in Minneapolis, Minnesota, calculating the distribution of land uses within pathway buffers of walks from stations to nearby destinations.

To identify areas associated with disamenities such as industrial areas, major roadways, rail tracks, or vacant lots, we leverage understanding of relationships between land use and pedestrian experiences known through prior research (Basu et al., 2022; Guo & Ferreira, 2008; Hartig et al., 2003; LaJeunesse et al., 2021; Park et al., 2014; Tribby et al., 2017). We identify geographic locations within 800 meters of stations (about one half-mile) at which light rail users are more likely to come into conflict with cars or trains or experience noise, difficult-to-traverse walkways, and other disamenities associated with industrial land, roadways, and rail tracks. We overlay grid cells on station area land-use maps, designate each grid cell according to its land use, and flag those associated with disamenities. Then, we weight each cell by the population of potential transit riders that pass through the area on the way from their census block to the station. These steps generate population-weighted pathways that we map along the Minneapolis Blue Line.

Our measures contrast with most traditional land-use indices, which do not accurately capture the most likely routes between station and surrounding blocks, or the potential number of people taking them. For example, a large industrial site may be near a station, but if few parcels lie beyond it, or few people live beyond it, then simply calculating its ratio to total land area within a radius of the station would over-weight the importance of the industrial site for pedestrian experiences. In addition, our tool uses only land use and street network data, generating measures that complement more complex assessments that, for example, characterize streetscapes. By doing so, we do not mean to suggest that more complex measures are less important or less useful, just as we do not mean to imply that local knowledge should not play a primary role in station area development planning, or that proportion of land use should be the only measure used by planners to determine walkability of a station area. On the contrary, we promote our approach as one that can draw attention to potential problem areas that require further in-depth and local investigation.

To demonstrate the feasibility of our tool with a sample application, we rely primarily on the Generalized Land-Use Survey ("GLUS") from Minneapolis. Our use of the GLUS enables us to present highly detailed and complete analysis of station areas in our chosen city. To further demonstrate our approach's potential, we also characterize station areas using only data from OpenStreetMap ("OSM"), an open-access, crowd-sourced mapping project that provides data on hundreds of cities worldwide.[2] The measures we derive using OSM are broadly consistent with those using local land-use data, suggesting that researchers can use OSM to conduct broad, global, cross-city land-use based comparisons.

Because our measures are based on land uses within buffered population-weighted pedestrian pathways between stations and destinations, our station area land use characterizations differ from those generated using circular buffers. In nearly all of the station areas in our study area, our pathway land use measures detect more exposure to land uses associated with disamenities, sometimes substantially so, than suggested by traditional circular buffer measures. Since we identify these problematic areas at the grid-cell level, we identify hyper-local areas for improvement and funding. And because land-use data like ours are widely available, our method—for which data and computer programs are publicly avail-

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[2] Boeing et al. (2022) demonstrate the general usefulness of OpenStreetMap for measuring neighborhood-level spatial indicators of urban design and transport features, using the open-access project to generate indicators for 25 cities in 19 countries.

able—can be used to map such areas in nearly any existing or potential station area and enable planners and cities to identify, avoid, mitigate, or ameliorate station area characteristics that deter transit use. As such, our method and estimates can be used to address the challenges posed by how transit users are to cover the distance between stations and their actual trip origins or destinations (Givoni & Rietveld, 2007; Liu et al., 2020; Zellner et al., 2016). We also expect researchers to find our station area land designations useful when estimating the effects of new or improved transit on outcomes such as ridership, land-use change, and property values.

We proceed as follows. In Section 2, we review existing research on the relationship between the built environment and mode choice, transit use, and walking, and clarify our contribution to this literature. We describe the study area in Section 3, discuss our methods and data in Section 4, and present our findings using local land-use data in Section 5. In Section 6, we recharacterize station areas using OpenStreetMap data. Finally, in Section 7 we discuss the implications and applications of our findings and conclude.

2 Literature review

In this section, we review the literature that relates land use to mode choice, transit use, walkability, and path choice, and establish the ways in which our paper builds on and complements this research. We begin by examining a well-established literature that focuses on the relationship between the complexity, composition, or configuration of land use and transit use. We then review papers that use environmental audit methods to generate detailed local walkability assessments. Finally, we discuss articles from urban planning and environmental psychology that provide the basis for using land-use data to identify impediments to walking.

A rich literature describes the relationship between land-use composition, configuration, and complexity and mode choice in general, on transit use in specific, on walking propensities, and on physical health. As explained by Gehrke and Clifton, (2019), composition is "the number of land-use patches or proportion of each type," and configuration "reflects the spatial arrangements, shape, and dissimilarity of landscape patches" (p. 13). Both composition and configuration can be more or less "complex." Like us, many of these papers use land-use data to characterize station areas (e.g., Cervero & Kockelman, 1997; Cervero, 2002), also see Ewing and Cervero (2001; 2010) for reviews. This literature hypothesizes that greater degrees of land-use mix around stations induces greater use of transit using entropy or dissimilarity indexes to measure mixedness.[3]

These papers typically use data from the census or geographic information systems and find that land-use diversity affects mode choice, including transit ridership. For example, Ding et al. (2019) use an entropy index and estimate that built environment characteristics explain about a third of station boarding variation in the heavy-rail network in Washington D.C. Similarly, Gutiérrez et al. (2011) find that greater levels of land-use diversity are associated with greater boarding numbers in Madrid. Jun et al. (2015) uses Bhat and Guo (2007)'s balance index measure of land-use diversity, where land use is classified into residential, manufacturing, and office categories, and find that greater levels of mix (balance) correlate with boardings in Seoul's subway system in catchment areas most immediate to stations. Zhang et al. (2022)'s simulation model of pedestrian demand suggests that denser, more diverse land-use plans in Portland can improve promotion of walking trips. And Liu et al., (2021) finds that areas with greater balance in land use increase walking for all kinds of trips in Xiamen, China, but particularly walking

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[3] While entropy indices measure the degree of balance of different land-use types in a given area, dissimilarity indexes measure how well the land uses are mixed up. For example, one could have an entropy index equal to 1 (the highest possible value) if all land uses are represented equally in an area but have a low dissimilarity index for the same area because parcels of common land-use type are clumped together. The Minneapolis Blue Line station areas are likely to have moderate levels of entropy, but low levels of dissimilarity (because of clumping).

when commuting.[4]

Areas with greater entropy (balance of land uses) or dissimilarity (spatial mix of uses), however, may not be of greater value if the balance and mix are being generated by unpleasant land uses. For example, industrial uses and rights of way do not add amenities that, when mixed well with residential and commercial uses, make for enjoyable walking commutes to stations. Instead, they may be replete with obstacles that deter passage. In addition, traditional land use indices generally do not weight land use by population that passes through the land use on specific pathways to the station, and therefore do not accurately capture the number of potential routes between station and surrounding parcels. As Guo and Ferreira (2008) puts it, "Path-based approaches better describe the actual travel decision of a pedestrian than zone-based methods (p. 462)." A disamenity passed by many potential transit riders should be weighted more heavily than one passed by few; by weighting land uses according to the populations that might experience them, along the pathways that they take, one can generate more accurate measures of pedestrian experiences in station areas.

In contrast to the more traditional land use and mode choice research, another body of literature uses labor-intensive environmental audit methods to collect data on street and neighborhood characteristics to identify specific neighborhood obstacles and walking disamenities. Boarnet et al. (2011) use the Irvine Minnesota Inventory ("IMI") to predict the effect of the built environment on physical activity and walking.[5] The inventory took two years to develop, was tested in 27 different field settings, and includes information on 162 characteristics of the built environment ranging from streetscape features like the presence of porches or sidewalk cracks, to intersection characteristics, and parcel land uses (e.g., indicating the presence of a restaurant) (Boarnet et al., 2006). Together this information offers exceptionally detailed data on the Twin Cities, Minnesota, and Boarnet et al. (2011) demonstrates that it is possible to use such data to predict behavioral outcomes among residents of those cities. Adkins et al. (2012) finds a statistical link between built environment characteristics, also recorded via an environmental audit, and survey respondents' perceptions of walkability in Portland, Oregon. Similarly, Park et al. (2014) constructs a walkability index using detailed pedestrian survey information from one station area in suburban San Francisco, and find it predicts the likelihood of walking versus taking a car. Finally, Werner et al. (2010), using data from an audit developed and described by Brown et al. (2007), finds that light rail use is more likely on more "walkable" blocks, this time in Salt Lake City, Utah. These studies offer useful levels of descriptive detail for specific cities but are difficult and costly to scale and apply to new areas.[6]

From a planning perspective, ensuring quality pedestrian experiences in station areas is of particular importance. Such areas are intended to be "pedestrian pockets," a concept central to transit-oriented development (Calthorpe, 1989; Renne & Appleyard, 2019). A related body of research focuses on observed behaviors on the "last mile" between a transit station and a destination, such as a home. This literature also finds that passengers' perception and likelihood of traveling via public transit is affected by specific characteristics of the local neighborhood's built environment (Givoni & Rietveld, 2007; Liu et al., 2020; Zellner et al., 2016). Perceptions of safety, which are affected by surrounding land use, also

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[4] Note that we have taken care here to describe the estimated relationships in this paragraph and elsewhere in this section as "correlations" or "associations," rather than causal relationships. The studies we summarize here generally do not focus on establishing causation (though they use varying degrees of caution when describing their findings). Our paper also leaves causal inference for other research, focusing instead on new measures of the built environment that can be used in exercises that probe either correlation or causation.

[5] Development of the IMI is described in Day et al., (2006) and tested in Boarnet et al. (2006).

[6] A more computationally technical literature uses street-view images and/or machine learning to describe pedestrian experiences or predict housing market outcomes (Cetintahra & Cubukcu, 2015; Naik et al., 2016; Yin et al., 2015; Yin & Wang, 2016; Zhang et al., 2018). While these methods are easier to replicate in new areas, they require techniques that are not typically used by practitioners.

affect the choice to walk and levels of satisfaction with public transit (Loukaitou-Sideris, 2006; Park et al., 2021; Venter, 2020).

Findings from both the environmental psychology and urban planning literatures underscore the importance of station area characteristics for choosing transit and provide the foundation for our use of land use to identify areas that are likely to impede or make walking unpleasant. In a landmark study on a group of randomly selected pedestrians, Hartig et al. (2003) find that in general, concrete-abundant urban environments increase stress, while natural and tree-filled environments reduce it. LaJeunesse et al. (2021) disaggregate urban land uses to understand how city surroundings affect pedestrian stress levels. They find that walking in proximity to major streets and in areas with industrial and mixed use are associated with higher stress, while traversing residential areas, forests, parks, and university campuses produces lower stress levels.

Similarly, literature on pedestrian route choice further supports the finding that land use affects walkers' choice of path. Guo & Ferreira (2008) define "pedestrian-friendly" parcels as those with retail, commerce, and mixed development, and find that paths that pass though areas with such uses are more likely to be chosen by walkers in Boston. Summarizing the literature on pedestrian route choice in general, Basu et al. (2022) report that pedestrians are more likely to choose routes that pass residential and commercial buildings, and less likely to take paths through areas with industrial uses, vacant land, or traffic. Tribby et al. (2017), for example, which uses random forest techniques to find correlates with route choice in Salt Lake City, find that noise and industrial land use deter pedestrians. They also find that on-street parking increases the chance that a route will be chosen, attributing the effect to the buffer such parking provides to automobile traffic (Marshall et al., 2008).

We develop land-used-based measures that are informed by this literature and complement more complex and labor-intensive methods of characterizing the walkability of transit station areas. We use population-weighted pathways, which pinpoint the routes that pedestrians are more likely to use, rather than examining land use in circular buffers. Because our measures are easy to scale, they enable quick identification of specific impediments to transit station access and facilitate large-scale comparisons across and within cities.

3 Study area

Our method uses publicly available land use data to develop proxy measures of the obstacles, disamenities, and problem areas that may impede pedestrian access to stations.[7] Using OSM data to create routes between stations and census blocks destinations within 800 meters (about one half-mile) of a station, we account for the fact that land use measures calculated within a circular buffer may not accurately capture the experiences of people traveling between stations and neighborhood places.

We use this method to evaluate areas within surrounding stations of Minneapolis' Metro Blue Line Light Rail, which connects Downtown Minneapolis to the Minneapolis-Saint Paul International Airport and the Mall of America via a highway and freight rail corridor along Highway 55-Hiawatha Avenue. We chose this study area because it is an instance of new rail investment retrofitted into an existing built-up urban area, and it contains a diverse set of land uses across the different stations within the corridor. We therefore follow several other papers studying travel behavior (Cao & Schoner, 2014),

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[7] Detrimental land uses may contain specific *obstacles* that directly impede walking such as uneven railroad tracks, *disamenities* like loud grain elevators, or more general *problem areas* such as roadside walkways that are exposed to strong winds. While the specific meanings of these terms as we imagine them vary to some degree, all are examples of the kinds of impediments we aim to capture in our land-use measures.

labor market accessibility (Fan et al., 2012), residential preferences (Cao, 2015), housing price appreciation (Pilgram & West, 2018) or propensity of land redevelopment (Agustini & West, 2022) in the same study area. We use pathways 800m long to be consistent with this and other prior literature that suggests that transit catchment areas are generally limited to about one half-mile (804.5 meters) from stations (Federal Transit Administration, 2011). While our findings are specific to the area we study, our method should be near-universally applicable to any location or pathway distance for which the required types of input data can be obtained.

As is described in Hurst & West (2014), the Hiawatha Avenue corridor was initially considered as an alignment for what is now Interstate 35W, only to remain in limbo for several decades before the Minnesota State Legislature approved funds that in conjunction with federal funding made the corridor the location of the region's first light rail line. Construction on the line began in 2001, and the line went into service in 2004. We focus on the six station areas in Minneapolis that are outside of downtown along the Hiawatha corridor: Franklin Avenue, Lake Street, 38th Street, 46th, 50th Street-Minnehaha Park, and Veteran's Administration (VA) Medical Center.

Figures 1 and 2 show the land uses in 800-meter buffers surrounding these stations. Highway 55-Hiawatha Avenue itself is a six-lane arterial road. It and other highways are indicated in black. The light rail line is indicated in brown, as are freight rail lines. Industrial land (in red) is concentrated just north of the Lake Street station. Single-family residential (bright yellow) and multi-family (tan) land dominate station areas surrounding 38th and 46th Street stations. Between the Lake Street and 46th Street stations, the light rail line runs along the western side of Highway 55, running in between rather than serving central portions of neighborhoods. Its stations, located within a corridor of industrial and highway land uses anchored by Hiawatha Avenue, are therefore located within what Jacobs (1961) would likely consider a "border vacuum."[8] This is exacerbated by the fact that rail passengers traveling to ultimate destinations east of Hiawatha Avenue must cross the six-lane road at grade level. Such walkers then pass through an industrial and freight rail corridor approximately 200 meters (one eighth of a mile) wide. South of 46th Street, the line splits from Hiawatha Avenue, instead running along a smaller parallel road. Recreational land, in green, is scarce along the northern portion of the line but abundant in the circular buffers around the southern stations in our study area. The southernmost station area is dominated by the institution for which it is named, the VA Medical Center, which is visible in blue, the color for "institutional" land use.

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[8] So-called "border vacuums" exist in areas proximate to features acting as borders to pedestrian activities—such as train tracks or major roads—that are of low urban vitality due to proximity to those borders. Jane Jacobs writes, "The root trouble with borders, as city neighbors, is that they are apt to form dead ends for most users of city streets. They represent, for most people, most of the time, barriers. Consequently, the street that adjoins a border is a terminus of generalized use" (Jacobs, 1961, p. 259).

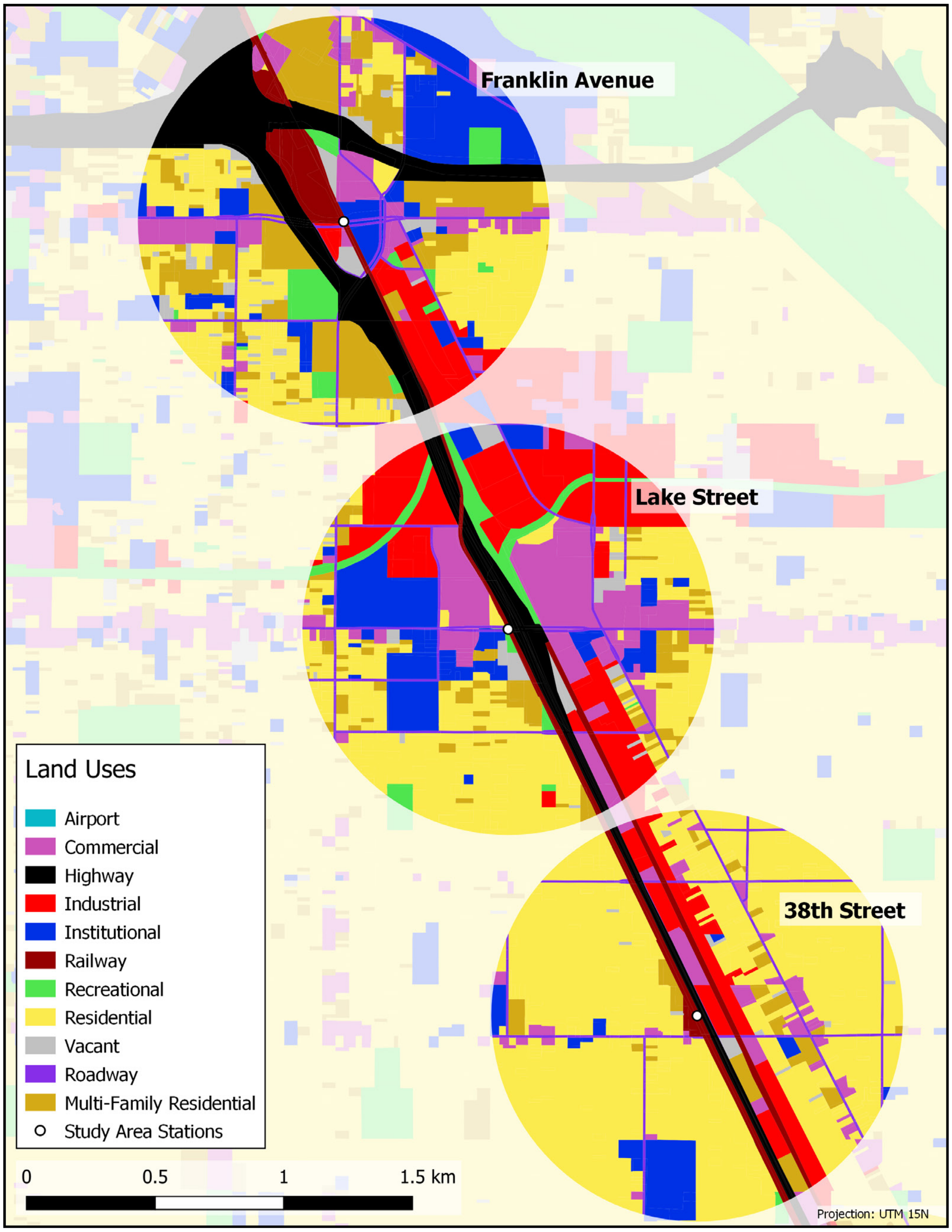

Figure 1. Map of the study area in 2020, northern portion

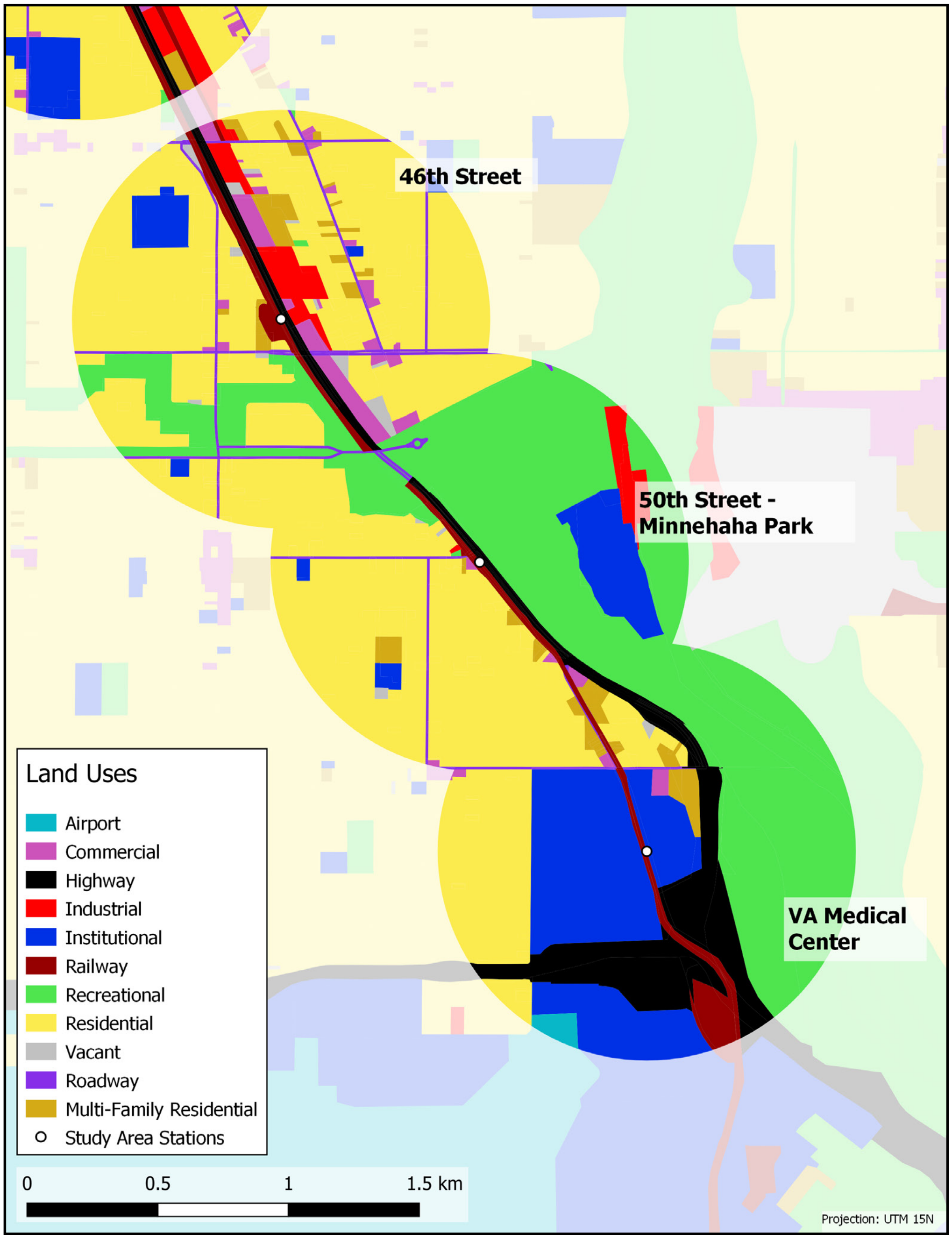

Figure 2. Map of the study area in 2020, southern portion

4 Methods and data

4.1 Data sources

In this section, we describe the data that we use to characterize pathway buffer areas in Minneapolis light rail station areas. While we use local land use data for this main exercise, later in the paper we present results based on open-source mapping data for comparison. We rely on four types of data for our primary analysis:

- **Street networks:** We obtain street network information from OpenStreetMap ("OSM") via the OSMnx Python package (Boeing, 2017), filtering the network to contain all elements of the network available to pedestrians.[9] OpenStreetMap is an online mapping service generated from volunteer efforts. It is fairly complete, and withstands groundtruthing audits (Barrington-Leigh & Millard-Ball, 2017; Bright et al., 2018). Its near-universal coverage makes it a useful data source for replicable, re-computable studies where the same analysis is performed repeatedly across a wide range of different places (Boeing, 2020, 2021).
- **Land-use data:** Land use data are taken from the Generalized Land Use Survey ("GLUS") and consist of a Shapefile containing Polygons with information on how each piece of land in Minneapolis was used in 1990, 1997, 2000, 2005, 2010, 2015, and 2020. We aggregate land uses to nine categories to obtain consistency across years: Commercial, Institutional, Multi-Family Residential, Recreational, Residential, Highway, Industrial and Railway, Roadway, and Vacant.[10] Consistent with literature reviewed above that relates walk route choice and pedestrian displeasure to land use, we identify and focus our analysis on four land uses that likely make walking unpleasant: Highway, Industrial and Railway, Roadway, and Vacant. While we report shares of the other land uses in our analysis, we remain agnostic about their effect on walking experiences.
- **Census data:** Specifically, we use census block locations and populations. For the neighborhood end of neighborhood-station trips, we rely on census block centroids from the 2010 Census; to weight each block's neighborhood-station trips, we rely on populations of each census block as recorded in the 2010 Census.
- **Station locations:** For the other end of trips, station locations are taken from a shapefile provided by the Twin Cities' regional planning authority (Minnesota Geospatial Commons, 2022).

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[9] Specifically, we filter using the custom filter with *'["highway"] ["area"!~ "yes"] ["highway"!~ "abandoned|construction|planned|platform|proposed|raceway|motorway|motorway_link|trunk"] ["service"!~ "private"]'*. This filter is more expansive than the OSMnx default for pedestrian infrastructure, yet excludes several types of roads that are only available to motorists.

[10] We group "Agricultural" (used almost exclusively for community gardens in our study area), "Golf Course," "Open Water," "Open Water Bodies," "Park, Recreational, or Preserve," "Parks and Recreation Areas," and "Water" into "Recreational;" "Airport," "Airport or Airstrip," and "Airports" into "Airport;" "Commercial," "Mixed Use Commercial," "Mixed Use Commercial and Other," "Office," and "Retail and Other Commercial" into "Commercial;" "Industrial," "Industrial Parks not Developed," "Industrial and Utility," "Industrial or Utility," "Mixed Use Industrial," and "Public Industrial (1997 only)" into "Industrial;" "Institutional" and "Public Semi-Public" into "Institutional;" "Major Four Lane Highways" and "Major Highway" into "Highway;" "Major Railway" and "Railway" into "Railway;" "Mixed Use Residential," "Single Family Attached," "Single Family Detached," and "Single Family Residential" into "Residential;" "Multi-Family Residential" and "Multifamily" into "Multi-Family Residential"; and "Public \& Semi-Public Vacant," "Undeveloped," and "Vacant/Agricultural" into "Vacant." In addition, we mark all areas that are within 5 meters of the centerline of a road labelled "primary," "secondary," "tertiary," or "trunk" as "Roadway." Since—with the exception of the Blue Line light rail—all railways in our study area are part of industrial parcels of land, we combine Industrial and Railway land uses into one category for purposes of illustrating our method.

4.2 Methods

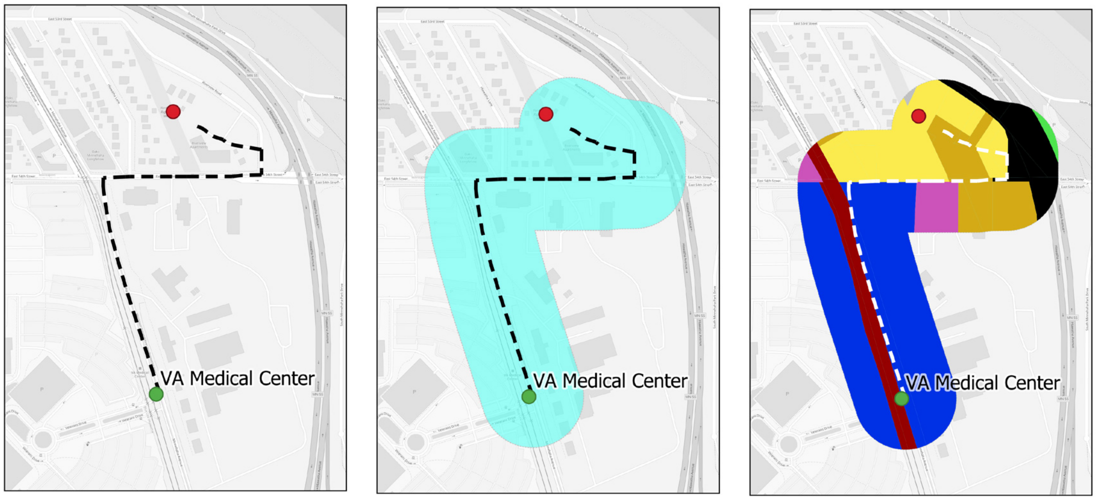
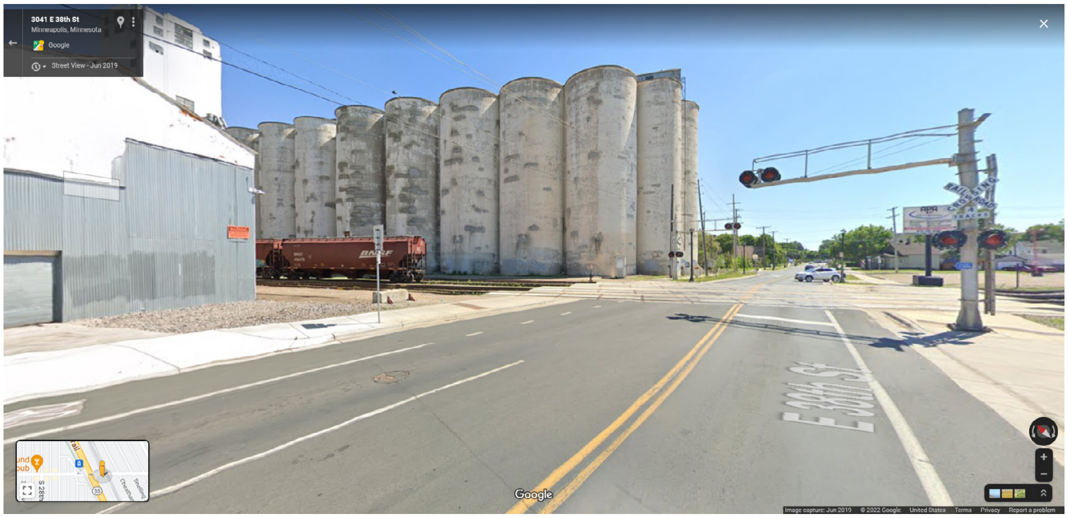


Figure 3. Illustration of routing and pathway buffer generation

We illustrate our method in Figure 3 using an example route. We start by using OSMnx to calculate street-network based routes from each light rail station in south Minneapolis to the network node closest to each census block our study area (first panel of Figure 3). Routing is performed in Python using the "OSMnx" software package, while all subsequent calculations and spatial transformations are performed in R using the "sf" software package. Since—particularly in our flat study area—pedestrians typically do not walk faster on one type of road than on another, we determine routing by having OSMnx choose the routes that minimize distance, using only paths that are available for walking. We then buffer each route by 75 meters to generate "pathway buffers" of each walk from a station (second panel of Figure 3).

(a) Grain silos on 38th Street and Hiawatha viewed from 150 meters distance.

(b) The same grain silos, viewed from 75 meters distance.



(c) The same grain silos, viewed from up close.

Figure 4. A grain silo viewed from three different distances

We chose 75 meters as a distance for buffering pathways to capture the furthest distance at which land uses may influence perceptions of how pleasant or unpleasant that walk might be. Consider the grain silos near the 38th Street Station, presented in Figure 4: From a distance of 150 meters, the grain silos act as a mere backdrop; at 75 meters, they are far more likely to impact pedestrians' experiences.[11]

Next, we subset to routes of no more than 800 meters network distance, take their "pathway buffers," intersect them with land use information, and calculate the share of the pathway buffers occupied by each land use (third panel of Figure 3). Finally, we sum areas for each land use across all paths leading to any given station and divide each land use's sum by the total amount of land in all pathway buffers for that station; weighting by the population of that census block per the 2010 US Census.[12] Because in our study area land use mixes differ substantially depending on whether they lie to the east or to the west of the station, we calculate shares separately for each side of the corridor.

Figures 5 and 6 map these population-weighted pathways, along with dotted lines indicating 800-meter circular buffers.[13] The largest number of transit users pass through warmer colored (red, orange, and yellow) areas when travelling to and from stations. Cooler colors such as blue and green indicate that a non-zero but smaller number of people experience those areas. Note that many fewer destinations fall within actual 800-meter network walking distance than within the circular buffers of the same size, and that these destinations are not located in neat radials.

Finally, to map detrimental land uses we overlay all pathway buffers generated as described above. By summing the populations of destination census blocks of those pathway buffers, we obtain a measure of how many people may experience the land use on their way to the station.

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[11] We also experimented with using a distance of 25 meters to capture only land uses located immediately along paths. Results remain essentially the same.

[12] The 2010 US Census records nighttime populations of each census block in the United States. For a measure of daytime population, one could use blocks-level employment counts from the Census Bureau's LODES WAC dataset, as weighting using block populations biases against block-station routes used primarily for work or leisure purposes.

[13] Note that some areas outside the 800 meter circular station area buffers fall within the 75 meter buffers "visible" from pathways. This phenomenon occurs when pathways begin more than 725 meters way from stations, and is particularly apparent in our maps in Figure 5 west of the Franklin Avenue station.

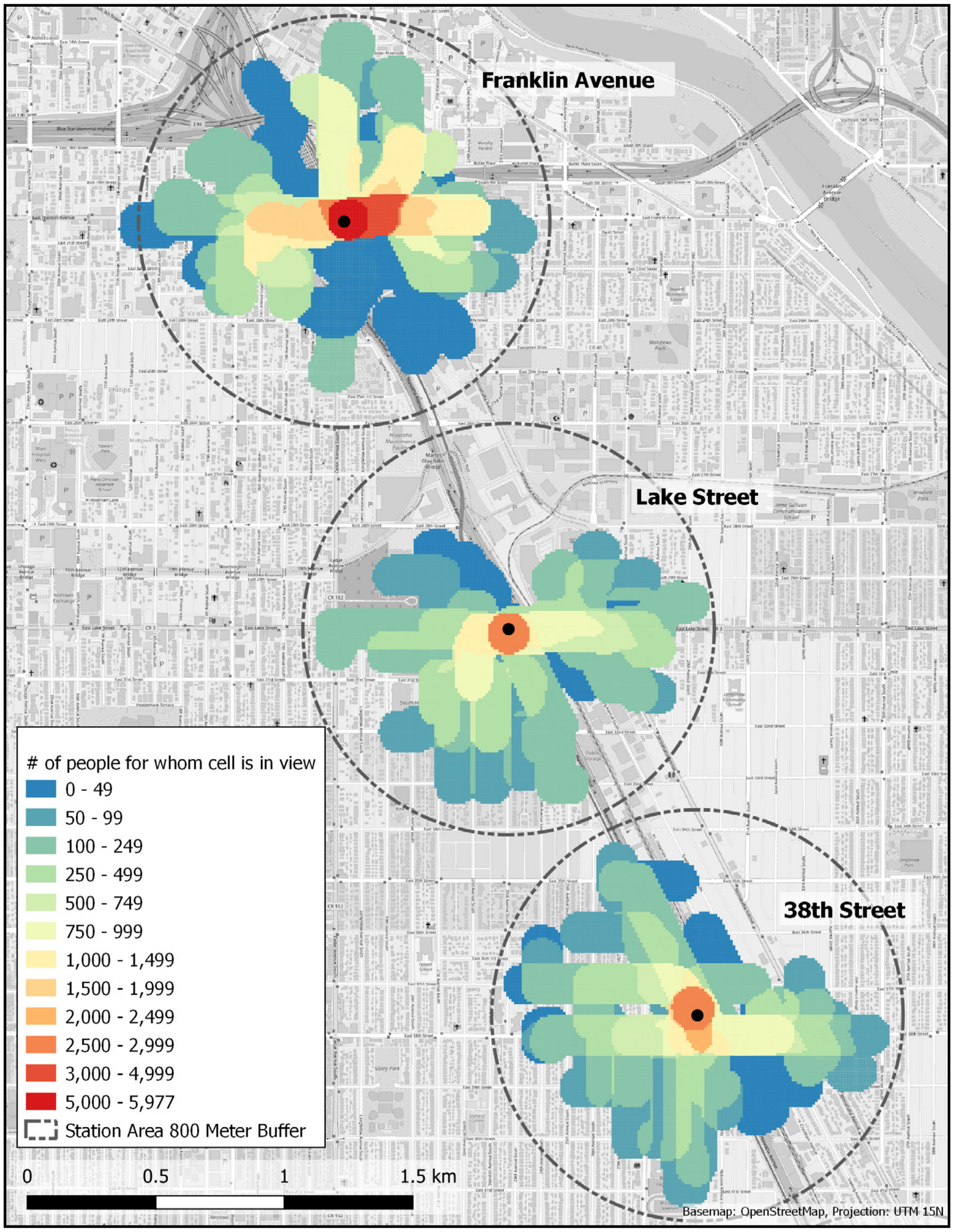

Figure 5. Northern stations population-weighted pathway buffers

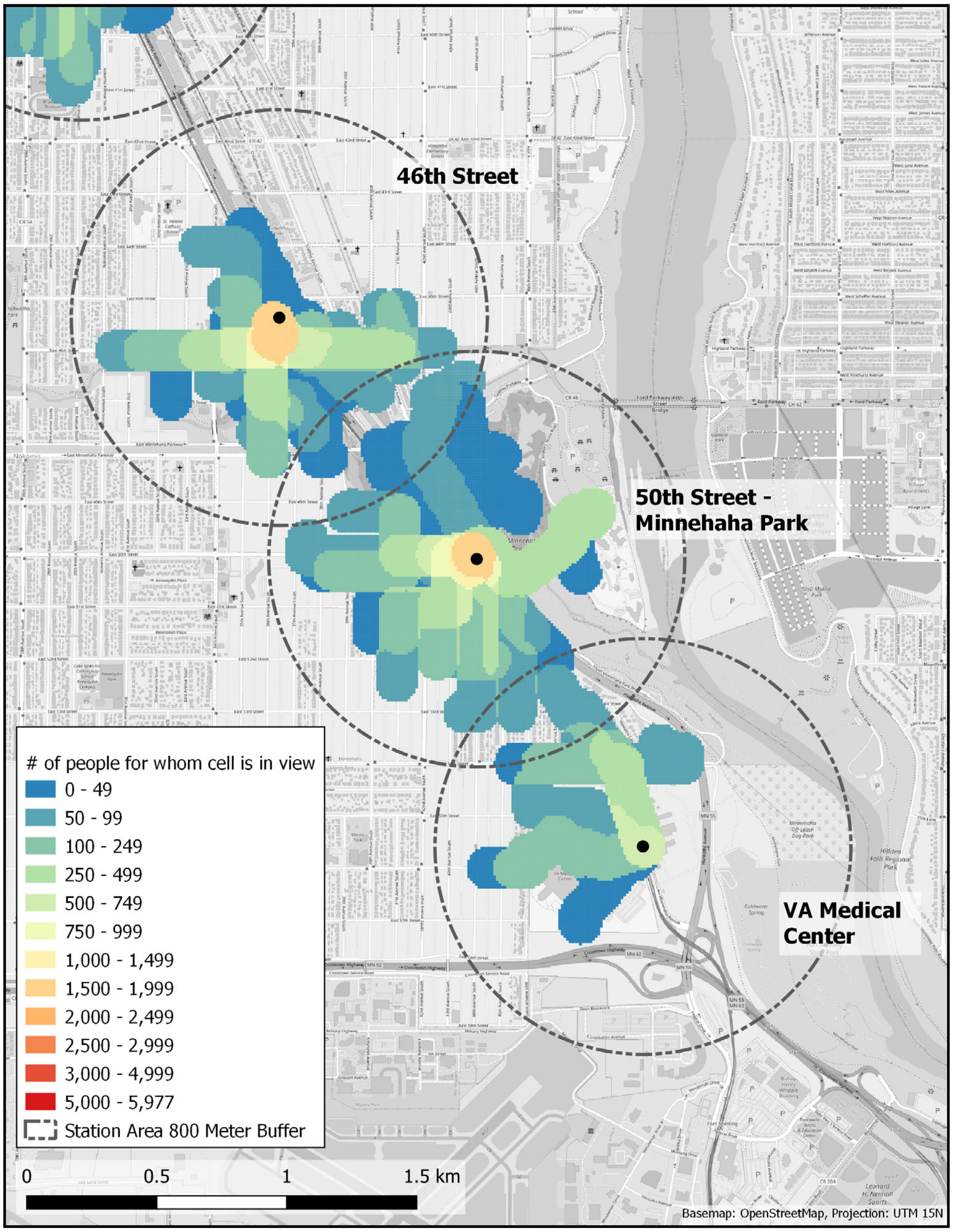

Figure 6. Southern stations population-weighted pathway buffers

5 Findings

5.1 Differences in station-to-block measures across station areas

We begin our analysis by quantifying the spatial configuration and intensity of land uses we associate with obstacles and disamenities (Highway, Industrial and Railway, Roadway, and Vacant) versus other uses encountered while traversing a route to or from a station and a neighborhood destination. Panel A of Table 1 presents land use shares in the pathway buffers along 800 meters-long station-to-census-block pathways, while Panel B shows the land use shares within a 800 meter radius around stations. Both panels enumerate the differences in land use mix between and within station areas that are visible in Figures 1 and 2. Moving from north to south along the line along the Blue Line takes passengers from neighborhoods that have greater levels of multifamily housing, commercial areas, and highway lanes, to areas that have more single-family residential neighborhoods and recreational parkland, with substantial industrial tracts east of the line separating stations from residential areas. The 50th Street-Minnehaha Park station's proximity to Minnehaha Park, a large city park with a famous waterfall (Minnehaha Falls), explains its high share of recreational use. The station at VA Medical Center is unique, as it abuts the federal territory at the southern border of the city of Minneapolis, which is dominated by the "Institutional" land of the Veterans' Administration Medical Center and Veterans' Home.

Table 1. Pathway buffers versus 800-meter circular buffer land-use shares (%), year 2020[14]

Panel A: 2020
Pathway Viewshed

	Franklin Ave		Lake Street		38th Street		46th Street		50th Street - Minnehaha Park		VA Medical Center	
	West	East	West	East	West	East	West	East	West	East	West	East
Commercial	9.2%	17.7%	14.0%	42.1%	3.4%	10.3%	1.8%	15.3%	1.3%	1.1%	1.0%	3.1%
Institutional	12.3%	25.6%	22.7%	13.3%	3.5%	2.0%	0.1%	0.0%	0.1%	22.5%	64.5%	54.3%
Multi-Family Residential	24.4%	14.7%	9.8%	3.8%	5.8%	10.8%	6.0%	5.1%	2.3%	0.8%	3.0%	6.5%
Recreational	1.2%	1.4%	2.3%	2.9%	0.0%	0.0%	13.2%	4.8%	8.7%	55.5%	0.0%	0.2%
Residential	11.4%	7.9%	26.8%	6.1%	53.9%	24.2%	50.7%	34.4%	70.4%	5.4%	20.4%	13.5%
Highway	15.2%	8.9%	9.9%	15.4%	8.4%	8.6%	6.0%	10.0%	6.7%	7.7%	0.0%	2.6%
Industrial and Railway	17.7%	9.1%	5.0%	5.3%	19.9%	33.7%	14.9%	17.3%	7.6%	6.2%	7.2%	13.2%
Roadway	6.9%	10.1%	5.7%	7.8%	3.1%	4.7%	6.1%	9.6%	2.9%	0.6%	3.9%	6.4%
Vacant	1.8%	4.7%	3.7%	3.4%	1.9%	5.7%	1.2%	3.6%	0.1%	0.0%	0.0%	0.0%
Sum of disamenity shares	41.5%	32.8%	24.3%	31.8%	33.4%	52.7%	28.2%	40.4%	17.2%	14.6%	11.1%	22.3%

Panel B: 2020
800 Meter Circular Buffers

	Franklin Ave		Lake Street		38th Street		46th Street		50th Street - Minnehaha Park		VA Medical Center	
	West	East	West	East	West	East	West	East	West	East	West	East
Commercial	5.8%	11.1%	8.4%	22.8%	1.6%	6.8%	0.4%	8.1%	0.3%	2.1%	0.3%	1.0%
Institutional	5.2%	20.2%	18.8%	5.9%	8.5%	0.7%	4.8%	0.6%	1.5%	10.9%	39.8%	7.3%
Multi-Family Residential	18.6%	20.0%	7.3%	4.5%	2.1%	5.8%	0.7%	4.6%	2.3%	1.0%	0.9%	3.8%
Recreational	4.8%	3.3%	3.3%	5.3%	0.1%	0.0%	21.0%	5.0%	7.7%	65.2%	0.0%	63.5%
Residential	26.4%	19.7%	41.6%	15.1%	82.8%	58.4%	66.3%	62.8%	83.6%	9.6%	38.0%	4.7%
Highway	23.8%	7.8%	1.9%	8.0%	0.0%	4.4%	0.0%	4.6%	0.0%	4.4%	14.3%	16.5%
Industrial and Railway	7.7%	11.3%	12.9%	31.3%	2.4%	18.6%	2.5%	8.2%	1.8%	5.3%	4.3%	2.6%
Roadway	3.1%	4.3%	4.3%	3.7%	2.2%	4.2%	3.7%	4.5%	2.4%	0.8%	0.7%	0.3%
Vacant	4.6%	2.3%	1.6%	3.4%	0.2%	1.1%	0.7%	1.7%	0.3%	0.7%	0.0%	0.2%
Sum of disamenity shares	39.1%	25.7%	20.6%	46.4%	4.9%	28.3%	6.9%	19.0%	4.5%	11.3%	19.3%	19.6%

5.2 Station-to-block pathway measures versus circular buffers

Comparing the numbers in Table 1, Panels A and B shows the importance of accounting for the location of trip origin or destination parcels when calculating land use shares and demonstrates the increased accuracy of using OSM to plot routes rather than relying only on GLUS data to measure land use areas surrounding a station.

For example, while land use shares in circular buffers indicate that the largest share of land use (31.3%) within 800 meters and east of the Lake Street station is industrial and railway, the location of this land is such that only 5.3% of population-weighted pathway pathway buffers east of the station are comprised of it. The map in Figure 5 makes this clear: The upper right-hand quadrant of the Lake Street station area has shaded pathways only very close to the station. Table 1 also shows that at the Lake Street station, pathways to census blocks east of the station pass through far more commercial land (42.1%) than comprises the eastern 800 meter circular buffer (22.8%). On the other hand, eastbound pathways

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[14] Land-use shares for the area west of VA Medical Center station do not sum to 1 because we omit "airport" land from these tables and the Minneapolis-Saint Paul International Airport falls within this station's surroundings, comprising 1.6% of the total land within 800 meters and west of the station. None of the other stations have airport land near them.

also pass through more highway (15.4%) than comprises the eastern circular buffer overall (8.0%).

The VA Medical Center Station area land use shares calculated using the two measures differ even more markedly. As shown in Figure 1, a good deal of recreational land lies east of the station alongside the Mississippi River; we find that in 2020 such land makes up 63.5% of the 800 meter buffer east of the station. But, as shown in Figure 6, there are no inhabited parcels that lie past that parkland, so the eastern circular buffer land use share wildly overstates the degree of exposure to such land that potential light rail users can experience while walking to or from the station—the eastern pathway buffer share of recreational land is nearly zero (0.2%) using our measure. Instead, walking pathways pass through the institutional land of the Veteran's Administration Hospital and Home, and residential parcels.

One type of land use in our study area disappears entirely when applying pathway buffer rather than the zone-based buffer approach: The Minneapolis-Saint Paul International Airport lies south of the VA Medical Center station area, and "airport" land comprises 1.6% of the total within 800 meters of the station. This is the only station with airport land in is vicinity; for this reason we omit "airport" land use from our tables. Notably, because there are no walkable origins or destinations within 800 meters of the VA Medical Center station and in or past the airport parcels, airport is not among the land use types detected using our pathway buffer measure, which again demonstrates the advantage of our measure over traditional circular buffers.

In general, comparison of Panel A and B in Table 1 shows that in most station areas, pathway buffer land use shares along the Blue Line in Minneapolis measure substantially lower degrees of pedestrian exposure to parcels with single-family homes ("Residential"), on both east and west sides of the light-rail line, compared to measures of land use using 800 meter circular buffers. The drop in residential shares is particularly large at the 38th Street and 46th Street stations, and dramatically affects the overall share of disamenity areas at those stations. Station-to-census block pathway measures generally detect more exposure to commercial parcels, to Highway 55-Hiawatha Avenue, and to industrial and railways. Exposure to industrial parcels, recreational land, multifamily housing, roadways, and vacant land is generally similar across the two measures.

For ten of the twelve sides (east and west) of our six station areas, pathway land use measures detect more exposure, sometimes substantially, to land uses associated with unpleasurable walking experiences: Transit users walking to Blue Line stations experience more disamenities than suggested by approaches using circular buffers.

5.3 Identification of detrimental parcels in station areas

Our method enables researchers and planners to scan maps across and within station areas to identify potential parcels for remediation and improvement, and to prioritize based on their visibility. The maps in Figures 7 and 8 isolate and aggregate the four land uses associated with disamenities and show the number of potential transit users who would pass the detrimental areas on their way to stations from the centroids of their census blocks. Looking across station areas, the maps indicate that the largest populations of potential transit users experience land uses associated with disamenities at the northern stations at Franklin, Lake, and 38th Streets. While all station areas have areas with disamenities, the southernmost stations have relatively small populations that may experience them. Our results therefore would direct planners to focus more resources on the more visible areas at northern stations. It is also interesting to note that the southern stations' detrimental areas are relatively linear, concentrated along highways, railways, and roadways, while those at northern stations are spread out more broadly in surrounding neighborhoods, because of both population and land use geographies. Neighborhoods at the northern stations may therefore offer more opportunities for improvement if rail and road are less transmutable than other land uses.

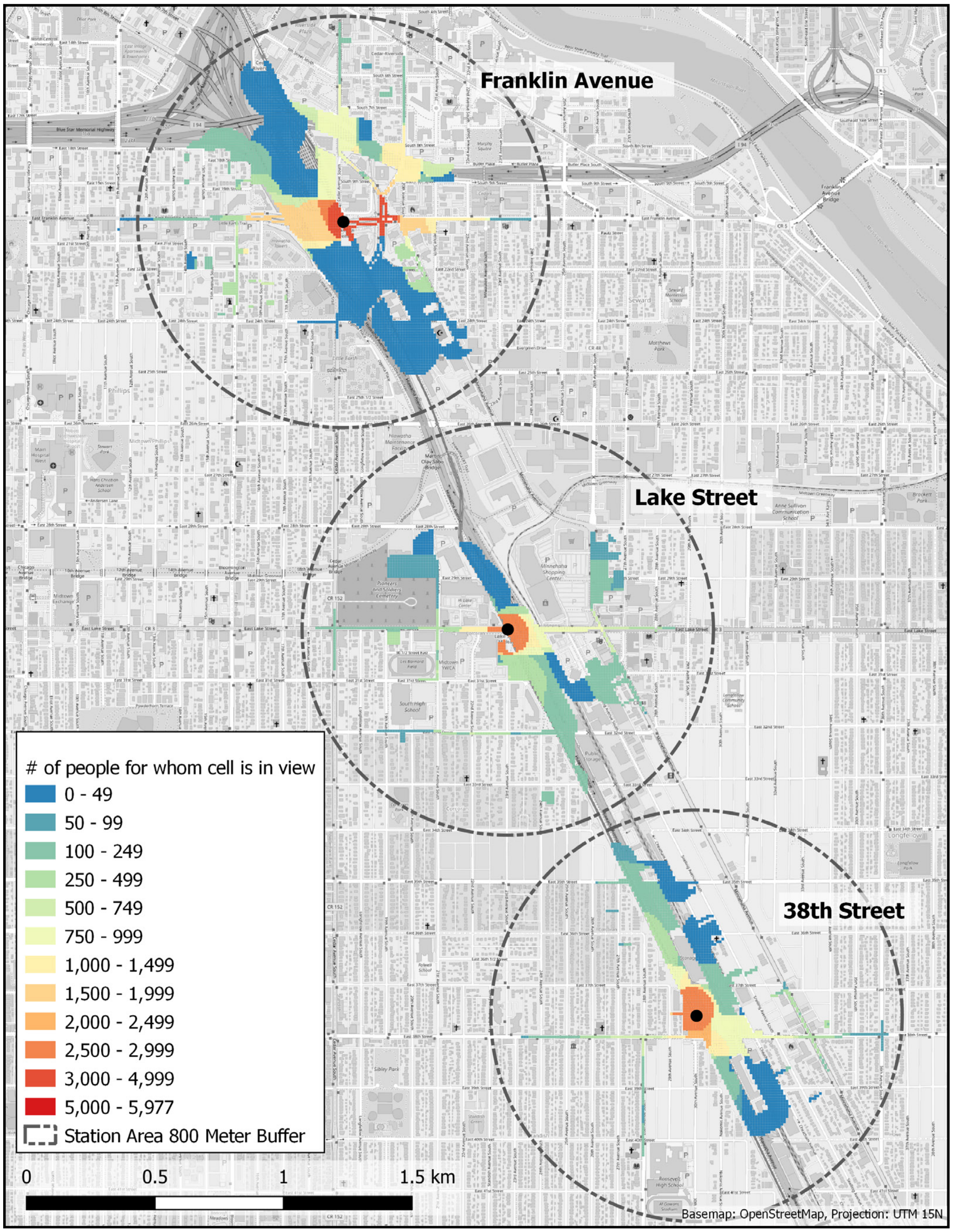

Figure 7. Northern station population-weighted pathway-buffered detrimental land uses

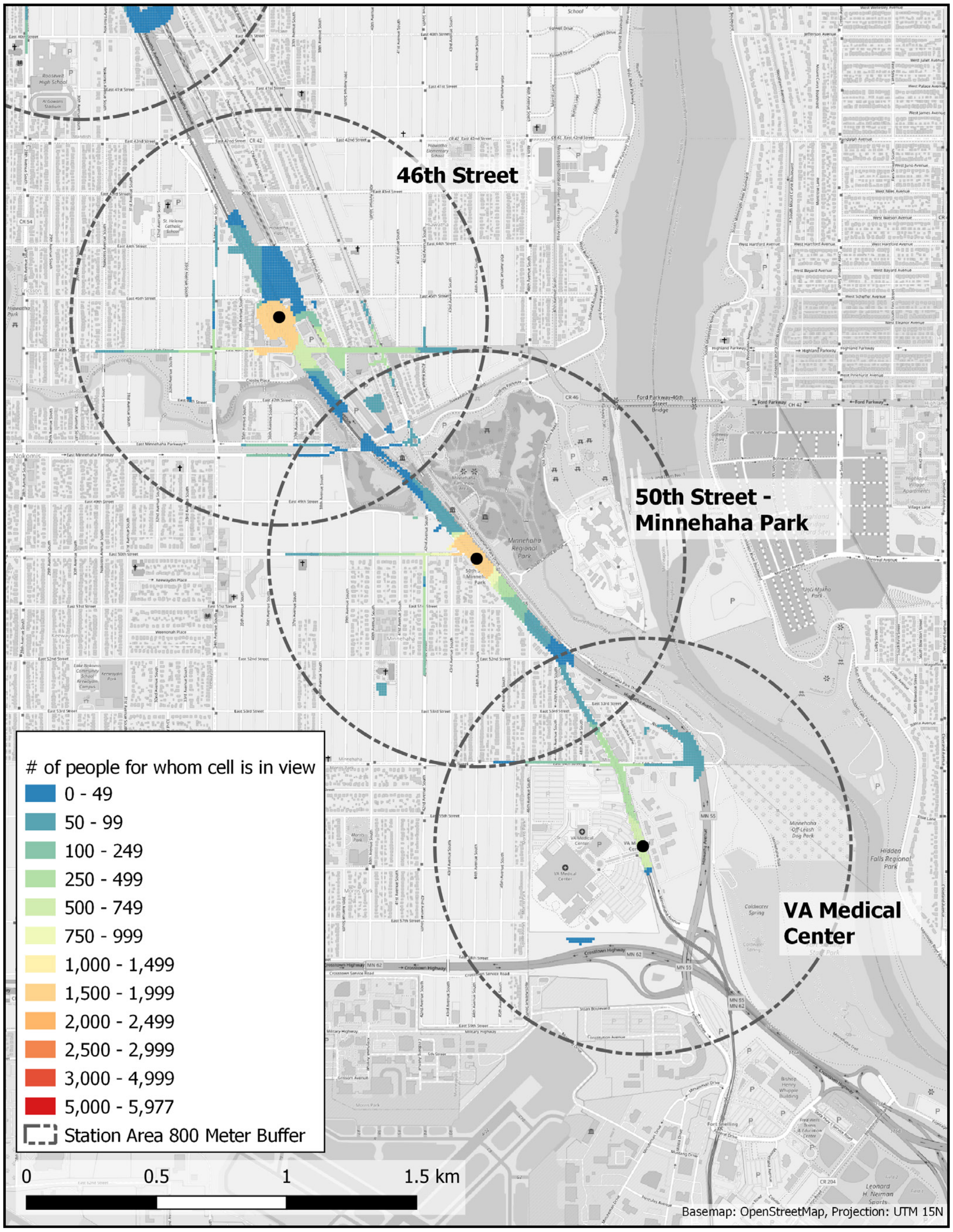

Figure 8. Southern station population-weighted pathway-buffered detrimental land uses

Researchers and planners interested in identifying the most visible detrimental land uses within a station area can also use the population weighted pathway buffer maps in Figures 7 and 8, in ways that are more informative than the circular buffer land use maps in Figure 1. For example, Figure 1 shows that at the Franklin station, industrial and rail land uses concentrate along the diagonal corridor in which the light rail locates. But pathway analysis in Figure 7 redirects us to focus on potential improvements along Franklin Avenue and Cedar Avenues, which intersect at a perpendicular just west of the station. Rather than suggesting we direct attention to the light rail corridor itself, the map of Franklin station pulls us east along Franklin Avenue, and northeast into the Cedar-Riverside areas, both vibrant commercial areas whose links to the Franklin Station are tenuous and punctuated by disamenities. The Lake Street station's most visible disamenities are more concentrated in the immediate area surrounding the boarding platform, but also extend in both directions down Lake Street, a corridor whose commercial districts are interrupted by large roadways and vacant land.

The 38th Street station map in Figure 7 shows even greater concentration of disamenities in the immediate station area, but points planners to the immediate east and southeast of the platform, where a car-oriented intersection of highway and roadway make passage particularly difficult, and where the railroad and grain elevators shown in pictures in Section 4.2 create unpleasant walking for pedestrians coming from residential areas to the east. Similar kinds of analysis can be applied to each of the station areas in the panel. By contrast, disamenities surrounding the 50th Street-Minnehaha Park, and VA Medical Center stations displayed in Figure 8 appear to be limited to highways and roadways.

In these ways, our scalable and easy to reproduce methods provide a first pass at identifying station area parcels, which, by virtue of their disamenities, may create obstacles to station area access to residents in surrounding neighborhoods.

6 OpenStreetMap as a data source for land uses

So far, this paper has presented land use shares generated from a local data source—the GLUS, a dataset specific to the Minneapolis-Saint Paul Metropolitan Area. However, the exact same pathway buffer-based approach to evaluating land uses within pathways can also rely on other sources, such as OpenStreetMap ("OSM")—the open source global volunteer mapping project. An advantage of OSM over other sources its global availability and relatively consistent recording: While sources such as GLUS—recorded by local authorities—are likely more precise and more complete than OSM, their level of detail and types of land uses recorded vary considerably from city to city. By contrast, OSM attempts to record land uses consistently across locations and does so well enough to serve as a basemap for most uses (Barrington-Leigh & Millard-Ball, 2017; Bright et al., 2018; Brovelli & Zamboni, 2018; Zhou et al., 2022). As such, OSM may be more suitable for city-to-city comparisons than reliance on several local data sources.

To generate a land use dataset comparable with GLUS—in which any given place is assigned one land use (that is, there are no overlapping land uses)—we download all OSM features with tags we consider synonymous with various land uses.[15] Further, we buffer linear road and railway features to ap-

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[15] We define different land uses as follows: Any area with a value for the variable *aeroway* is considered part of an Airport; any area with a value of "commercial" or "retail" for the variable *landuse* or a value of "commercial" for the variable building or any value for the variable *office* is considered "Commercial/Office"; any area with a value of "industrial" for the variables *landuse* or *building*, "substation" for the variable *power*, or "wastewater_plant" for the variable *man_made* is considered "Industrial"; any area with the values "college," "hospital," "library," "place_of_worship," "school," "social_facility," or "university" for the variable *amenity* or "church" or "public" for the variable *building* or the value "museum" for the variable tourism is considered "Institutional"; any area with the value "apartments" for the variable building is considered "Multifamily"; any area with the value "railway" for the variable *landuse* or the value "yard" for the variable service is considered "Railway"; any area with the values "cemetery" or "recreation_ground" for the variable *landuse*, the values "golf_course" or "park" for the variable leisure, the values "beach," "water" or "wood" for the variable natural, the value "attraction" for the variable tourism, or the value "river" for the variable water is considered "Recreational"; and any area with the value "brownfield" or "construction" for the variable landuse or the value "construction" for the variable *building* is considered "Vacant."

proximate areas perceived as railways or roadways.[16] To resolve overlaps, we assume a hierarchy of land uses, from least to most dominant in perception: Recreational land is the least dominant, followed by Multifamily Housing, Institutional, Commercial/Office, Industrial, Airport, Roadway, Highway and Railway. As all railways in our study area besides the Blue Line are industrial, we group Industrial and Railway when reporting area shares.

Table 2 shows how OSM land-use-based pathway buffer measures compare to those based on land uses from the Minneapolis-Saint Paul area's GLUS dataset. Because not all areas are tagged as any particular use in OSM, substantial areas around stations—mostly single family residential—have no recorded land use. This is reflected in the generally lower shares of all land uses in Panel B.

Overall, however, we find that OSM is a decent substitute for GLUS. For example, relative shares of disamenity-associated land uses across and within station areas measured using OSM are fairly consistent with those measured using the GLUS (compare the "Sum of disamenity shares" rows in Panels A and B in Table 2). This is good news for transport and land use researchers and planners, as OSM offers an attractive, inexpensive, consistent source of data that can be used when performing comparisons across and within different metropolitan areas worldwide (Boeing et al., 2022). At the same time, we recommend that researchers use local datasets such as GLUS wherever available when studying more local scale questions.

Table 2. GLUS versus OSM land-use measures for Blue Line station pathway buffers, 800 meters distance

Panel A: Pathway Viewshed (GLUS)

	Franklin Ave		Lake Street		38th Street		46th Street		50th Street - Minnehaha Park		VA Medical Center	
	West	East	West	East	West	East	West	East	West	East	West	East
Commercial	9.2%	17.7%	14.0%	42.1%	3.4%	10.3%	1.8%	15.3%	1.3%	1.1%	1.0%	3.1%
Institutional	12.3%	25.6%	22.7%	13.3%	3.5%	2.0%	0.1%	0.0%	0.1%	22.5%	64.5%	54.3%
Multi-Family Residential	24.4%	14.7%	9.8%	3.8%	5.8%	10.8%	6.0%	5.1%	2.3%	0.8%	3.0%	6.5%
Recreational	1.2%	1.4%	2.3%	2.9%	0.0%	0.0%	13.2%	4.8%	8.7%	55.5%	0.0%	0.2%
Residential	11.4%	7.9%	26.8%	6.1%	53.9%	24.2%	50.7%	34.4%	70.4%	5.4%	20.4%	13.5%
Highway	15.2%	8.9%	9.9%	15.4%	8.4%	8.6%	6.0%	10.0%	6.7%	7.7%	0.0%	2.6%
Industrial and Railway	17.7%	9.1%	5.0%	5.3%	19.9%	33.7%	14.9%	17.3%	7.6%	6.2%	7.2%	13.2%
Roadway	6.9%	10.1%	5.7%	7.8%	3.1%	4.7%	6.1%	9.6%	2.9%	0.6%	3.9%	6.4%
Vacant	1.8%	4.7%	3.7%	3.4%	1.9%	5.7%	1.2%	3.6%	0.1%	0.0%	0.0%	0.0%
Sum of disamenity shares	**41.5%**	**32.8%**	**24.3%**	**31.8%**	**33.4%**	**52.7%**	**28.2%**	**40.4%**	**17.2%**	**14.6%**	**11.1%**	**22.3%**

Panel B: Pathway Viewshed (OSM)

	Franklin Ave		Lake Street		38th Street		46th Street		50th Street - Minnehaha Park		VA Medical Center	
	West	East	West	East	West	East	West	East	West	East	West	East
Commercial/Office	0.5%	1.0%	5.2%	28.1%	0.2%	4.9%	2.6%	22.4%	0.2%	0.2%	0.0%	0.0%
Institutional	1.6%	7.4%	4.1%	1.3%	2.3%	0.0%	0.0%	0.0%	0.2%	24.4%	46.8%	21.5%
Multifamily	0.8%	1.8%	1.3%	1.0%	2.7%	1.8%	2.6%	3.9%	0.2%	0.1%	1.8%	3.2%
Recreational	2.4%	0.5%	3.4%	0.1%	0.0%	0.0%	9.9%	1.9%	6.9%	51.4%	0.0%	0.9%
Highway	11.7%	6.1%	9.2%	12.2%	9.8%	11.5%	6.9%	11.2%	6.1%	7.5%	0.0%	1.6%
Industrial and Railway	10.4%	6.6%	8.0%	8.8%	12.2%	27.2%	5.8%	11.8%	5.8%	6.7%	9.1%	16.2%
Roadway	10.0%	12.7%	6.4%	9.2%	3.1%	5.1%	7.0%	9.8%	3.8%	0.9%	3.7%	6.3%
Vacant	0.0%	0.4%	1.6%	4.6%	0.0%	2.3%	0.6%	0.8%	0.0%	0.0%	0.0%	0.0%
Sum of defined land uses	37.5%	36.5%	39.1%	65.4%	30.3%	52.8%	35.4%	61.7%	23.2%	91.2%	61.4%	49.6%
Sum of disamenity shares	**20.4%**	**19.8%**	**16.0%**	**22.6%**	**15.3%**	**34.7%**	**13.4%**	**22.3%**	**9.6%**	**7.6%**	**12.8%**	**22.5%**
Difference to GLUS	**-21.1%**	**-13.0%**	**-8.3%**	**-9.2%**	**-18.1%**	**-18.0%**	**-14.7%**	**-18.0%**	**-7.6%**	**-7.0%**	**1.7%**	**0.1%**

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[16] We consider the 10 meter buffer around linear railway features as "Railway," a twelve meter buffer surrounding centerlines of roadways tagged "trunk" or "motorway" to be "Highway," and a six meter buffer surrounding all other road centerlines tagged "primary," "secondary," or "tertiary" to be "Roadway" type land use.

7 Discussion and conclusion

We use widely available land use data and walking pathway buffers mapped using the publicly crowd-sourced OpenStreetMap (OSM) to derive scalable, easy-to-reproduce measures of station area land uses associated with walking disamenities. To illustrate the potential for these kinds of scalable measures, we simply report proportions of land uses around stations. Our approach can also be used as a first step toward derivation of more complex measures of station area disamenities or specific thresholds at which an area might be flagged by planners as "unwalkable."[17] Even our simple measures, however, capture the realities of pedestrian experience near stations more accurately than circular buffers, as they weight parcels according to the degree to which they are potentially experienced by the populations surrounding the station.

The literatures on mode choice and on transit ridership have indicated that the built environment surrounding stations and transit stops affects ridership. For the particular transit line studied in this paper, other researchers have previously noted that the presence of industrial facilities in station areas adversely affects walkers' experiences and may act as a deterrent to potential riders (Cao & Schoner, 2014). Our pathway buffer measure of land use complements existing measures, and could add precision to the estimation and forecasting of boardings such as that performed by Jun et al. (2015) or Gutiérrez et al. (2011).

Indeed, our measures of station area land use could improve estimation of any relationship between a transit line and its surroundings. For example, our approach captures characteristics of pathway buffers along the routes between stations and destinations in catchment areas that influence buyers' willingness to pay premiums for homes nearby. Papers that estimate the effect of new transit lines on home values that find evidence of heterogeneous effects across station areas (e.g., Mulley et al., 2018; Yang et al., 2020) may very well find that our measures explain a good deal of this heterogeneity — the more unpleasant land use is along routes from a station to homes, the less we should expect home values to appreciate upon introduction of a transit station. Our findings may therefore explain why previous research found that the Minneapolis Blue Line has had no measurable long term effect on home values (Pilgram & West, 2018), and our land use measures may be one of the omitted variables explaining instability of parameters recovered by hedonic specifications (Redfearn, 2009). Finally, our land use and pathway based measures could be used to update the effects of Twin Cities light rail on transit ridership (Cao & Schoner, 2014).

In addition, our method complements those used to generate walkability indices such as Walk Score or the National Walkability Index (developed by the U.S. Environmental Protection Agency) that characterize areas in terms of their access to opportunities (Thomas & Reyes, 2021). These indices also permit cross-sectional comparisons between large areas with relatively little labor effort. But unlike our measures, these measures are not pathway- or land-use based.

Our method may also aid practitioners in identifying heavily trafficked corridors within transit catchment areas for the sake of pedestrian improvements—projects for which, at least in the United States context, funding already exists: The Federal Transit Administration (FTA) considers all pedestrian improvements within one-half mile and all bicycle improvements within three miles of a public transit stop or station have a "*de facto* physical and functional relationship to public transportation" and therefore eligible for funding (Federal Transit Administration, 2011, p. 52046).[18] Such improvements include those that mitigate the negative experience associated with detrimental land uses such as sidewalk

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[17] For instance, our method could be combined in tandem with a walkability audit aimed to determine the severity of disamenity posed by different land uses.

[18] In addition, improvements beyond these distances may be eligible for funding if applicants demonstrate that "the improvement is within the distance that people will travel by foot or by bicycle to use a particular stop or station." For more information on funding opportunities for pedestrian and bicycle improvements in transit station areas, see Federal Transit Administration (2017).

maintenance, road "diet" reconstruction, or improvements in lighting. They may also involve broader rezoning and permitting efforts that induce transit-oriented land use change in station areas.

Our method, of course, is not perfect: First, it does not consider all forms of obstacles that may be detrimental to the pedestrian experience. For example, we are unable to account for sidewalk presence or condition, as such characteristics are not recorded in local sources like the GLUS and are inconsistently tagged in OpenStreetMap.[19] Similarly, since our method focuses on generating scalable land-use based measures of disamenities, we do not address issues such as block lengths or monotony of land use along routes that may also affect pedestrian comfort, as doing so would require adding layers of parcel-data. Second, land uses within the pathway buffer may not actually be visible from the route—or may be intentionally concealed to improve the pedestrian experience. For example, walking paths to the East of 50th Street Station—while immediately next to Highway 55—are separated from the highway by hedgerows and sound barrier walls. While this specific barrier is in fact indicated on OpenStreetMap, such interventions are not consistently recorded, and taking them into account in generating viewsheds would require a far more complex computational approach.

Ultimately, however, our measure of land use within population-weighted pathway buffers describes land uses surrounding the walks to stations in a manner that more closely resembles the pedestrian experience than a circular buffer-based measure, while remaining scalable and computationally simple. As such, it complements existing ways of describing pedestrian quality such as environmental audit measures. Indeed, nothing about our method requires the destination to be a station; it could equally be applied for other destinations where substantial foot traffic is expected or desirable —such as schools or grocery stores —and can accommodate any weighting scheme to reflect different routes' potential traffic volumes. It is recomputable for any location for census, land use, and OpenStreetMap data are available. While we attach the label "disamenity" to specific land uses, our method can accommodate whatever land-use mix desirability parameters a user prefers, enabling them to incorporate community-specific preferences about the pedestrian experience. And, our method draws attention to specific corridors traversed by potential station-to-destination paths, properly weighting and highlighting specific parcels with "ugly" land uses that fall along those corridors. Finally, we find that land use measures derived using OpenStreetMap are broadly consistent with those using local land use survey data, suggesting that researchers can use OSM to conduct broad, global, cross-city land-use-based comparisons.

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[19] For example, OSM records only about 42% of residential streets in Minneapolis as having sidewalks even though sidewalk presence is virtually universal along those streets.

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