Re-Drawing the Planners' Circle: Analyzing Trip-Level Walk Distances across Two National Surveys

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Abstract

Problem, Research Strategy, and Findings:

For decades, planners have been drawing circles of radius ¼ mile to determine easily walkable distances for neighborhood and activity-center planning. However, the radius of such "planners' circles," or walksheds, is often more informed by convention than by data. Here we examine walk-trip distances based on two national household travel surveys for the United States and Germany. We describe how walk distances vary by personal and trip characteristics, with a particular focus on trip purpose and pedestrian age. We conduct both univariate and multivariate analyses to compare patterns between the United States and Germany. The multivariate analysis examines quantile regressions for 50th, 75th, and 90th percentile to understand both typical and longer walk distances. The observed distances that people walk vary significantly across age groups, trip purposes, and national contexts. Leisure trips tend to be longest, while shopping and errand trips tend to be shortest. There are substantial differences between the United States and Germany in the average lengths of walks (mean/median walk distance, Germany=1490/980 meters; 0.93/0.61 miles, US=970/530 meters; 0.60/0.33 miles) and in the effects of independent variables. A significant portion of the variation in walk-trip distances between the US and Germany is likely due to Germany's higher-quality walk environments.

Takeaway for Practice:

Rather than always resort to ¼ mile or 400 meter radius, planners can use the data here to customize the size of the planners' circle, or walkshed, they draw to take into account the primary trip purposes and demographic segments under consideration. Moreover, planners can draw circles with a shorter radius corresponding to the 50th percentile to plan for the most common walk-trip lengths, while also considering larger circles corresponding to the 75th and 90th percentiles in order to provide more supportive and safer pedestrian environments for longer trips.

Keywords

Pedestrians; Walk Distances; International Comparison; Quantile Regression; Walkshed

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Introduction: Re-Drawing the Size of the Planners' Circle

A classic exercise in urban planning practice for understanding walk accessibility is drawing the pedestrian walkshed. Because walking is both the most sustainable mode and the mode with least impacts on infrastructure and congestion, maximizing walking is integral to how planners design both activity centers and neighborhoods. Drawing ¼ mile and ½ mile radii to guide urban planning dates back at least to Clarence Perry's concept of the Neighborhood Unit (Berke et al., 2006). To this day, planners routinely draw a ¼-mile or ½-mile circles around the center of a neighborhood or an activity center to understand the current walk accessibility of a study area and how it might be improved. Improvements can be created through the addition of new land uses, or in some cases, by adding sidewalks or paths to create more direct routes.

However, the size of the walkshed has for years been informed more by convention than by data. For example, the "Pedestrian Pocket" assumes that most people will be willing to walk ¼ mile (400 meters) (Calthorpe, 1989). Another, more recent, planning concept is the 20-minute neighborhood (City of Portland, 2020), which suggests that trip distances of 1 mile (1600 meters) are possible when planning for walkability. Planners have developed and adopted several conventional standards, such as these, with limited empirical foundations. In order to provide a more informed basis for drawing the planners' circle, we ask the question of how far will people walk to travel where they want to go? Our goal in this paper is to provide an empirical basis for how large to draw the urban planning circle (or circles, as may be appropriate).

We systematically analyze the range of observed walk distances based on two large-scale studies of travel behavior in the US and Germany; both national surveys including numerous walk trips (Germany: 186,673; United States: 81,288). Note that the walk trip, rather than the total distance walked for a person, is our primary unit of analysis. We also identify that the walkshed should vary based primarily on two key factors: trip purpose and age. Depending upon the trip purposes being planned for and the target demographics considered, this planning circle should either expand or contract. Furthermore, although we are not able to examine the question of urban design directly, the comparison between the US and Germany, where walk distances are considerably longer, provides a potential indication of how better urban design might facilitate longer walk trips.

We are aware that the distances that people currently walk may not be the distance that they are willing to walk. However, proximity increases the probability that a walking trip will occur. So, we employ this simple rationale to obtain a range of acceptable walk distances. If 50% of walk trips are of a given distance, we consider this a moderate walk, achievable by most adults. If 25% of walk trips are of a given distance or greater, we consider this a long walk. And if 10% of walk trips are of a given distance or greater, we consider this a viable walk. By providing the 50th, 75th, and 90th percentile walk distances, we offer a comprehensive guide of empirically based walk-trip distances, and therefore a range of potential radii for the planning circle.

The next sections of the paper are as follows. The second section is a literature review of variables that influence walking behaviors; we find that a large number of variables influence walking behaviors, including trip characteristics, demographics, and built environment features. We then transition to our research questions at the conclusion of the literature review. Then we discuss the two national household travel data sets and describe our approach to univariate and multivariate analysis, including quantile regressions. Next, we summarize regression results, identifying the trip purpose and traveler age as the two most influential factors in regard to trip distance. This section includes a series of figures of 50th, 75th, and 90th percentile walk distances that can be useful in planning practice. In the discussion section that follows, we consider how our results differ from conventional wisdom and identify a range of practical applications for typical walk distances. We also discuss reasons why walk-trip distance tends to be longer in Germany than in the United States. The final section briefly summarizes the entire paper and its major findings.

Literature Review: Determinants of Walking Behavior

We searched the Scopus and Web-of-Science databases, as well as Google Scholar for peer-reviewed literature on determinants of walking published since 2005. We used the search terms: walk, walking, and pedestrian in combination with several determinants of walking, such as the built environment, land use, or trip distance. The search revealed 47 studies that focused on determinants of walking. Of those studies, nine were reviews of the literature, summarizing 42 papers' findings on average per review (ranging from 22 to 62).

In the 38 original papers we reviewed, individuals were the unit of analysis for most studies (21). At the same time, 12 articles analyzed trips or routes, and three analyses focused on the neighborhood or household level. Six individual-level studies investigated walking of children or adolescents exclusively, and six studies focused on walking to and from public transport stops and stations. Geographically, a plurality of our papers was from North America (22). Seven studies analyzed data from Europe, four from Australia, and six from countries in Asia—with one study comparing walking on two continents. The majority of articles (34) focused on walking in specific cities or neighborhoods, often collecting original survey data from that geography, but some studies also used national-level data. Most studies employed quantitative data and methods of analysis. Twenty-eight (28) studies employed some form of linear or non-linear regression models for data analysis—several adjusting for spatial autocorrelation or the clustering of respondents. Some relied on descriptive analysis combined with t-tests, chi-square-tests, and analysis of variance.

In the studies reviewed, researchers measured the dependent variable for walking behavior in a variety of ways: As the frequency of walk trips during a day, week, or month; the number of minutes walked and the intensity of walking during a specific time period; the decision of making a walk trip or not; choosing to walk compared to other modes of transportation; satisfaction or comfort of a walk trip; walking route choice; as well as walking distance. Studies on walking distance either analyzed total walking distance during a specific timeframe, walking distance to a destination such as a food market or to and from public transport stops, as well as the length of entire routes for specific trips and trip purposes.

Built Environment and Land Use

Built environment and land use are critical determinants of the decision to walk, and influence route choice, trip frequency, and in particular, walking distance (Daniels & Mulley 2013, Sun et al. 2014, Frank et al. 2007, Chen 2017, El Geneidy et al., 2014, Wang & Cao 2017). Analyses linking walking to the built environment and land use are diverse, making it challenging to summarize across studies (Handy 2005). Several papers analyze walking distance from and to transit—finding shorter walking distances to bus stops and longer distances to train stations (Daniels & Mulley 2013; El-Geneidy et al. 2014; Wang & Cao 2017). Mixed land uses around public transport, particularly workplaces, are related to shorter walking distances (for transit egress)–especially in downtown areas (Wang & Cao, 2017). Similarly, the built environment around transit stops also influences the likelihood to walk—again with the most substantial impacts in downtown areas, especially for short trips (Scheiner, 2010). Guo (2009) found that pedestrians did not consistently choose the shortest route when walking from transit stops to jobs and homes in areas close to transit. Pedestrian-friendly built environments can prompt people to choose egress routes that entail longer walking times (Guo and Ferreira, 2008).

The built environment also influences walking for other trip purposes. The presence of destinations within walkable distance, like parks, shops, or services, increases the likelihood of walking (Pikora et al., 2003; Davison et al., 2006). Perceived access and the number of destinations are positively correlated with walking (McCormack et al., 2004). Individuals walked more frequently for recreation when higher quality recreational destinations were available (Sugiyama et al., 2012). The odds for walking increase when community establishments, such as supermarkets, farmers' markets, or small food stores are within 400 (1/4 mile) and 800 meters (1/2 mile) (Gunn et al., 2017). Population density is also associated with greater odds of walking (Frank et al., 2007).

Greater pedestrian network connectivity is associated with longer walking distances per trip and an increased likelihood of walking (Sun et al., 2014). Connectivity of the street network and sidewalk supply increase (utilitarian) walking (especially for men) (Sugiyama et al. 2012; Wendel-Vos et al. 2007). Ewing & Cervero (2010) find that intersection density is a better predictor for the likelihood of walking than street connectivity.

Actual walking distance and route choice depend on perceived comfort and route environment—often resulting in longer distances than the shortest path (Koh and Wang, 2013; Dessing et al., 2016). For example, pedestrians are less likely to choose routes with a high number of roadway crossings, car traffic, poor air quality, no sidewalks, no crosswalks, or few pedestrian traffic lights (Ferrer, 2015; Koenigstorfer, 2018; Rodriguez et al., 2015; Pikora et al., 2003). However, McCormack et al. (2004) found a positive association between perceived high-volume traffic and the likelihood of walking. Additionally, open space and retail presence increase the likelihood of choosing that route (Guo & Loo 2013). Traffic safety and demographics moderate these effects (Agrawal, 2008; McCormack et al., 2004). For example, Borst et al. (2009) found that elderly residents in urban districts in the Netherlands prefer walking on busy streets and streets with zebra crossings but no traffic lights. Forsyth et al. (2009) point out that people considered less healthy tend to walk in more highly dense areas (compared to large-block areas). In contrast, unemployed people and retired people tend to walk in large block areas.

Route Aesthetics

Perceived aesthetics of walking routes influence walking frequency and distance, particularly for recreational trips (Sugiyama et al., 2012). Reported walking frequency is higher in neighborhoods or along routes with pleasing aesthetics or scenery (McCormack et al., 2004; Herrmann et al., 2017). Pedestrians deviate from the shortest possible path to enjoy shade, scenery, green spaces, the presence of people, and street-level shops (Chen, 2019; Bunds et al., 2019; Koenigstofer, 2018; Koh et al.,2013; McCormack et al., 2004; Handy et al., 2007). Additionally, pedestrians opted for longer routes to avoid high levels of automobile traffic, as well as air and noise pollution (Bunds et al., 2019; Koenigstorfer, 2018; Dessing et al., 2016).

Season/Temperature

Temperature and seasons help determine walking distance with longer walking distances in the summer than the winter based on studies in Denmark and the United States (Kaplan et al., 2016; Yang et al., 2012). However, research has been inconclusive on the seasonal effect on walking frequency (Yang & Diez-Roux., 2012; Kaplan et al., 2016). People walk longer in warmer weather, preferably in the cooler mornings and in the shade (Koerniawan et al., 2015).

Demographic/Socioeconomics

Researchers typically analyze demographics and socio-economic factors as determinants of walking, but most often as controls alongside other variables. Findings are mixed for many demographic and socio-economic variables. For example, while some studies do not find any difference in walking distance, time, frequency, or speed between men and women (Kim 2015; Frank et al. 2007), the majority of studies report a greater likelihood to walk, more walk trips, longer walk distances, and greater intensity of walking for men (Chen 2019; Yang & Diez-Roux 2012; Lee 2005; Berrigan & Troiano 2002).

Similarly, some studies report a lower likelihood to walk and shorter walk distances for lower-income groups (Herrmann et al. 2017; El-Geneidy et al., 2014; Yang & Diez-Roux, 2012; Berrigan & Troiano, 2002), while others report the opposite (Mondal et al. 2015; Frank et al., 2007). Wang & Cao (2017) find that correlations between demographics and walking distance are very weak. Several studies report more walking for younger and older adults (Gunn et al., 2017; Larsen et al., 2010). Based on national data for the United States. Yang & Diez-Roux (2012) report that Blacks walked the greatest distances and for the longest durations. Mexican Americans and immigrants were least likely to walk or had lower walking trip rates (Herrmann et al., 2017; Berrigan & Troiano 2002). Having a driver's license and easy access to a car reduces walking distance per trip and the probability to walk for children and young adolescents (Kaplan et al., 2016; Pont et al., 2009). However, El-Geneidy (2014) has found that households with more cars are associated with longer walking distances for all age groups.

Attitudes

Some studies indicate that personal attitudes influence walking. For example, individuals with concerns about environmental issues and those interested in physical activity tend to walk longer distances and routes—and seek to avoid highly polluted areas (Bunds et al., 2019; Manaugh & El-Geneidy, 2013). Pedestrians who value convenience walk shorter distances than average (Manaugh & El-Geneidy, 2013). A preference for walking increased walk trip frequency (Handy et al., 2007). Concern about pedestrian safety is associated with less walking, and safer walking options may have the potential to increase walking (Handy et al. 2007; Pikora et al., 2003). One study found that parents' traffic and personal safety attitudes did not influence a child's likelihood of walking (Pont et al., 2009). Research suggests that attitude and built environment may be related because individuals who prefer walking may choose to live in more walkable neighborhoods (Handy et al., 2007).

Trip Purpose

Several studies examine trip purpose and walking. In the United States, the most common trip purpose for walking, accounting for 35.4% of all walk trips, was social/recreational (Kuzmyak et al., 2014). Trips to work only accounted for 4.5% of walk trips in the United States; however, walk commutes boasted some of the furthest distances with averages near 1 mile (Kuzmyak et al., 2014). Iacono et al. (2008) found that recreational trips are the longest, with school and commute trips next, and shopping and restaurant trips being the shortest. Trips to schools and community resources also tend to have longer walk distances, whereas trips to shopping, restaurants, and cafes have been linked to shorter walk distances (Gunn et al., 2017; Iacono et al., 2008; Kuzmyak et al., 2014). While individuals may walk longer distances to some destinations than others, all significant destination types have shown strong distance-decay effects (Durand et al., 2016; Millward, Spinney, & Scott, 2013; Mondal et al., 2015; Nurul Habib et al., 2014).

Time of Day of Trip

Less investigated than trip purpose is the role of time of day on walking behavior. A study in Nanjing, China, found distances to rapid rail transit were longer during the morning peak than the afternoon peak (Zhao & Deng, 2013). However, a Montreal study found that walk distances to transit are slightly shorter during the morning peak (El-Geneidy et al., 2014). A study in Denmark found that the odds of walking were higher during the weekends than weekdays, whereas the day of the week was insignificant in other studies (Kaplan et al., 2016; Mondal et al., 2015).

Our study stands out from this body of literature in several respects. As opposed to the dominant focus on the number of walk trips taken or total distance walked per person, this study concentrates on the walk trip as the unit of analysis; this allows us to hone in on how closely activities need to be arranged to abet walk trips, i.e., the radius of the planners' walk circle. Secondly, in contrast to the existing literature, we employ national data sets and examine the full range of trip purposes. By analyzing national data, we lose some of a regional study's specificity but gain generalizability across geographic settings. Lastly, we compare and contrast data from two countries – the United States and Germany – both relatively wealthy countries with high vehicle ownership levels. This comparative framework yields some additional insights into the drivers of walk-trip distance. Our research questions, therefore, are as follows:

- What is the distribution of observed trip-level walk distances?
- How do trip-level walk distances vary with known individual, household, and trip characteristics?
- How do trip-level walk distances vary across national contexts with generally wealthy, vehicle-owning populations?
- What are the missing elements, absent from our empirical data but suggested by other lines of evidence, that may influence trip-level walk distances?

Methodology: Walk Trip Data from Two National Surveys

United States' and Germany's National Household Travel Surveys

The United States and Germany both conducted national household travel surveys in 2017, and these surveys are similar in many respects. Both are nationally representative surveys with population and trip weights provided for person-level and trip-level analyses. Both cover the full range of trip purposes and travel modes, and both are surveys of travel for households over 24 hours. Both data sets include children five years and older; we include children to understand the distribution of walk distances for children's' trips to school and other social walking trips. There are some differences between the surveys as well. One of the most important differences is that shortest-path algorithms were used to calculate distances in the US, whereas, in Germany, distances are self-reported. Another difference is that the US dataset provides information for household incomes, whereas access to this information for Germany was denied. Finally, another difference is that the US flags loop trips—trips starting and ending at the same location—whereas the German data set does not. Loop trips tend to be longer; we discuss this complexity later in the results section.

Some trip purpose categorizations, such as work-related travel, are slightly different between the US and Germany. For the US, we combined "family/personal business" and "medical/dental trips" to create a category called Errands. US trip purposes "visits to friends and relatives" were combined with "social/recreational trips" to create a category called Leisure. For Germany, we assigned "leisure trips" and "companion trips" to the category Leisure. While in the category School/Church, there are church trips in the US dataset, there is no trip purpose explicitly labeled church trips in the German dataset. Once harmonized across the two data sets, the final trip purpose categories are: To/From Work; Work-Related; Shopping; School/Church; Errands; and Leisure. Note that the trip file for each NTS only records full data for each trip's primary mode in both the US and German data sets. There is data on whether to trip to and from transit was a walk trip, but that data does not include walk trip distance.

Both data sets report trip mode, so it is easy to determine walk trips. However, as all responses are user-generated, some error is possible. Therefore, we excluded all walk trips with a total trip length over 10 kilometers (6.2 miles) or an average speed of over 10 kilometers per hour (6.2 miles per hour). We allowed "fast" walk trips if the reported trip time was 5 minutes or less because survey participants may misreport the trip duration. For example, if a participant knows how far they walked but not how long, they could report a trip duration of 1 minute, resulting in an incorrect speed estimate. Although some of the removed long or fast trips may be walk trips, many may not be, and such extreme values might bias the analysis. This data cleaning process resulted in 78,854 walk trip observations in the US data set and 160,716 observations in the German data set.

There are several advantages and disadvantages to using national travel surveys for the analysis of walking trip distance. The large sample size is an advantage and allows for detailed yet accurate multivariate analysis. The ability to compare results between two different countries with similar surveys, the US and Germany, is another advantage. One disadvantage of using national travel survey data is that it is challenging to determine the built environment correlates of walk-trip distances. However, this is not necessarily better with most regional travel surveys. These often focus on motorized travel and only capture a few walk trips, and such trips are scattered across large metropolitan areas. Most studies of the built environment and walk distance use specialized data sets collected via GPS devices, intercept surveys, or new mobile big-data vendors (Rodriguez et al., 2015; Sevtsuk, 2018).

Table 1 shows basic descriptive statistics on trip distance and duration for both the US and Germany. The median trip distance is 528 meters (0.33 miles) in the US, but the mean is much higher at 968 meters (0.60 miles), and there is a sizable standard deviation (1163 m/0.72 mi.) reflecting the lengthy right tail of the distribution. The median speed is 3.5 kilometers per hour (2.2 miles per hour). In

Germany, the median trip distance is 980 meters (0.61 miles), and the mean is likewise higher at 1485 meters (0.92 miles), with a large standard deviation (1641 m/1.02 mi.).

[Insert Table 1 about here]

Figure 1 shows the observed trip distance distribution in the United States and Germany in 400-meter bins (approximately ¼ mile). The number of trips drops quickly with distance, with the most US trips recorded in the 0-399 meter bin (38.0%, US) followed by the 400-799 meter bin (25.9%, US) and then falling rapidly thereafter. This decline with increasing distance is consistent with the extensive literature documenting that pedestrians prefer shorter trips. In contrast to the US, in Germany, the largest proportion of walk trips are in the 400-800 meter bin (23.4%). Also, in Germany, the drop in trip distance is less abrupt compared to the US. For example, almost 17% of trips exceed 2000 meters (1.24 miles).

[Insert Figure 1 about here]

Univariate Analysis: Analyzing Each Independent Variable

First, we conducted a univariate analysis of available variables to see if they had statistically significant correlations with walk distance, to examine the relative size of these effects, and to make comparisons across countries. For the univariate analysis, we ran separate linear regressions for each independent variable with walk trip length as the dependent variable, setting the constant term to zero and including trip weights. These regressions yield the average distance walked for each category of each independent variable. We analyzed the following independent variables this way: age, day of the week, educational attainment, sex, household income, household size, occupation, trip purpose, trip start time, and vehicle ownership. We also examined the residential density of the home census tract and household income for the US data.

Quantile Regression: Analyzing a Range of Walk-Trip Lengths

Next, we ran trip-weighted quantile regressions on walk distances with the variables common to both the US and Germany data sets for the 50th, 75th, and 90th percentiles. The variables we included in these quantile regressions were age, sex, occupation, household size, vehicle ownership, day of the week, harmonized trip purpose, and time of day. If variables were missing, we dropped those observations, resulting in a slightly smaller data set (68,290 in the US and 160,716 in Germany). Table 2 illustrates the number of observations available in each data set at each stage in the analysis. For the US, we also provide results excluding loop trips from the Leisure trip category because Leisure loop trips are longer on average than non-loop Leisure trips (28.6% of US Leisure trips are loop trips, and non-loop trips are 21.6% shorter in average length). We set each variable's default category close to the central value to minimize the number of statistically significant categories. We report the quantile regressions results in the Technical Appendix and in interpretive figures (Figures 2 and 3) to facilitate their use in planning practice.

[Insert Table 2 about here]

Results: Describing the Factors that Influence Walk-Trip Distance

Variables that Correlate with Trip-Walk Distance: Univariate Analysis

All categories of all variables were statistically significant ($p<0.01$), likely due to the large sample sizes of the two surveys. However, many categories only displayed small differences in average walk distances.

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For example, in the US, the average walk trip length on Wednesday (916 m/0.57 mi.) is not substantially different from the average walk trip length on Monday (931 m/0.58 mi.). Detailed tables from the univariate analysis are available in the Technical Appendix.

The variables that show the largest differentiation across categories are trip purpose and age of the pedestrian. There are also large differences between typical walk distances in the US and in Germany. Trip purpose also shows a contrast between the US and Germany. Work (956 m/0.59 mi. US; 985 m/ 0.61 mi. Germany) and School (843 m/0.52 mi. US; 840 m/0.52 mi. Germany) trips are quite similar in mean length for both countries. However, Leisure (1095 m/0.68 mi. US; 1824 m/1.13 mi. Germany) and Errand (622 m; 0.39 mi. US; 1129 m; 0.70 mi. Germany) trips are longer in Germany, with Shopping trips also tending towards greater lengths in Germany. In the US, the youngest cohort (age 0-17; 1124 m/0.70 mi.) walks the longest distances on average; however, in Germany, the youngest cohort walks the shortest distances on average (1100 m/ 0.68 mi.), with both middle-aged (age 50-69; 1574 m/0.98 mi.) and senior adults (1535 m/0.95 mi.) walking longer average distances. In the US, seniors (882 m/0.55 mi.) walk the shortest average distances. The only other outstanding feature is that in Germany, walk distances on Sunday (1990 m/1.24 mi.) are much longer than on other days

The remaining differences are relatively small. Men (1029 m/0.64 mi. US; 1395 m/0.87 mi. Germany) walk slightly further than women (928 m/ US; 1373 m Germany). Occupation appears to make little difference. Household size does not display any apparent trends. Greater vehicle ownership correlates with longer average walk-trip distances in both countries. Education, income, and residential density variables are only available in the US datasets. Educational attainment and income both show little relationship with average walk distances in the US. Residential density shows a clear downward trend; average walk-trip distances are longer in low-density residential environments than high-density ones.

Differences and similarities between the US and Germany in the univariate analysis are suggestive. In both countries, Leisure trips are, on average, the longest. In the US, the youngest cohort journeys the longest distance. In contrast, in Germany, it is the middle-aged cohort, which suggests that cultural factors may play a more significant role than physical ability in explaining these differences. Walk trips are longer in the morning in the US and in the afternoon in Germany. This may relate to trip purpose, with commuting trips typically in the morning and Leisure trips in the afternoon or may relate to differential climates with hotter average temperatures in the US discouraging lengthy midday trips.

Explaining the Length of Walk Trips with Quantile Regression

The quantile regressions are mainly consistent with the univariate linear regressions above, but some differences are apparent. In the US data, children walk further than adults across all three percentiles in terms of demographic characteristics. Males, individuals in larger households (3+ persons), persons whose occupation is at-home or other, and persons with more household vehicles walk longer trip distances and show more substantial differentials at the higher percentiles. In terms of trip purposes, the ordering of trip lengths from longest to shortest is Leisure, Work (commuting), School, and then other trip types. These differentials in distances are more significant at higher percentiles. Morning trips are longer, with distance differentials increasing with higher percentiles, and late-night trips are shorter for the 75th and 90th percentiles. Full quantile regression results for each percentile, including statistical significance, are available in the Technical Appendix.

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In Germany, in terms of demographics, ages 50+ show longer trip lengths, and under 18 show shorter trip lengths across all percentiles, with the effect of age increasing at the 75th and 90th percentiles. Persons who are retired, persons in two-person households, and persons that own more cars have walk trips that are longer than average across all percentiles; car ownership has a more substantial effect in the 75th and 90th percentiles than in the 50th. In terms of trip characteristics, Sunday trips and midday trips (1:00 PM-3:59 PM) are the longest, with an increasing differential for the larger percentiles on Sundays. Saturdays are slightly longer than weekdays, but other days of the week do not vary substantially in trip length. German Leisure trips are much greater in length than other trip purposes, and such differentiation increases at the higher percentiles; School trips are the second-longest.

We provide interpretive figures (Figure 2 and Figure 3) of the quantile regression below. We focus on the two independent variables that provide the most differentiation and the most applicability across planning contexts: Trip purpose and traveler age.

[Insert Figure 2 about here]

[Insert Figure 3 about here]

While we cannot summarize all of the detail in the figures via any single number, it is notable that travel for practical purposes in the US can often be over 1000 meters (0.62 miles) in length. For non-loop Leisure trips, the 90th percentile exceeds 1500 meters (0.92 miles) in length. Likewise, in Germany, travel for practical purposes can approach 2000 meters (1.24 miles), and for Leisure (including loop trips) can exceed 4000 meters (2.49 miles). While the general rule is that shorter walk trips are more likely than longer ones, trips of varying lengths are not unusual, depending upon the walker's age and the trip purpose. Land-use planning for walkability should account for this wide variation in observed walk trip distances.

Some of our results analyzing trips are counterintuitive, i.e., that people living in lower-density environments walk longer distances on a per-trip basis. Therefore, to supplement our analysis of walk-trip distance, we also examined walk-trip frequency for persons. Therefore, we were especially interested in exploring the relationship between density, average walk-trip length, and walk-trip frequency. As Table 3 illustrates, in both Germany and the US, walk trip frequency increases as residential densities increase. No doubt, as other studies have confirmed, people living in higher-density environments walk more often and more in total distance over a given time period (Frank et al.2007; Sun et al., 2014; Gunn et al.2017; Larsen et al., 2010; Barnett et al., 2017). Nevertheless, on a trip-level basis, individual walk trips in lower-density environments tend to be longer. Such an extended trip length is logical because destinations are likely to be more distant in such lower-density environments.

Discussion: Drawing More Accurate Planners' Circles

Urban planners have been drawing ¼ mile circles for neighborhood and activity-center planning at least as far back as Clarence Perry's Neighborhood Unit in 1929. In recent years, concepts centered on walkability have continued to gain currency, such as the 15-minute city or the 20-minute city (Da Silva et al., 2020). Walkability is receiving even more attention now that the COVID crisis has re-centered many peoples' work environment around their homes. Therefore, the activities that are easily reachable from home have taken on increased importance. For years, such planning circles have been drawn based upon rules of thumb and convention. Our analysis steps into this breach and undergirds this common planning practice of drawing walksheds with more robust empirical findings.

By examining 50th, 75th, and 90th percentile walking distances, we allow planners to consider the most common walk trip distances, as well as facilitate longer walk trips that may be less frequent. We think the range of guidelines provided here offers a more nuanced picture for the appropriate radii for drawing the planners' circle. Despite the widely adopted convention of 400 meters or ¼ mile, our data suggest that depending upon the context, walk travel for practical and discretionary purposes can often exceed 1000 meters (0.62 miles) in both the US and Germany.

We identify two variables as most influential in how large the planning circle should be drawn: traveler age and trip purpose. Leisure trips tend to be the longest, especially leisure loop trips, followed by work and school trips, and then other trip purposes tend to be shorter. In the US, younger people are most likely to walk further, while middle-aged people walk the greatest distances in Germany. The other trip and demographic variables examined appear to be much less important as determinants of walk-trip distance.

The planners' circle already has a wide number of planning applications. It can be used both for planning new, New Urbanist neighborhoods and for retrofitting existing neighborhoods. For New Urbanist neighborhoods, drawing the planners circle around the neighborhood center can help plan the relative locations of land-use arrangements for such mixed-use communities. For existing neighborhoods, planners can draw such walksheds to identify the need to introduce new uses or identify new pedestrian routes to shorten distances to destinations.

Regarding infill development, more communities are planning not just for traffic impacts but also for their implications for the quality of the walking environment (District Department of Transportation, 2019). Infill development also requires drawing an appropriate planners' circle to determine the appropriate radius for analyzing impacts on the pedestrian environment. For example, if a planner were analyzing the walkshed for a restaurant, they might refer to the 75th percentile for 30-49 year-olds for Leisure trips excluding loops. Therefore, the planner would set this walkshed at 1100 meters (0.68 miles) in the US context (see Figure 3).

Another area of potential application is planning safe routes to schools and parks. Current guidance from the National Recreation and Parks Association suggests that planners should consider a ½ mile or 800-meter radius when planning park access (National Parks and Recreation Association, 2016). Examining our results on non-loop Leisure trips indicates that the maximal impact area might be 600 meters (0.37 miles) or less, but also that a significant share of trips (25%) to parks might span 1000 meters (0.62 miles) or more. Besides, planning for park access might also vary by the age groups targeted in the planning process.

Despite the richness of these data sets, some critical factors are absent from this data. In particular, as other research shows, a quality built environment facilitates longer walk distances, including such factors as connected pedestrian networks, the presence of shade, the presence of parks and retail (Guo, 2009; Guo & Loo, 2013; Rodríguez et al., 2015). We believe that a significant portion of the discrepancy between German and US walk distances is due to more walk-friendly environments in Germany. Therefore, a US planner who thinks that their planning environment is highly walkable might want to consider the results from Germany as well as those from the US in considering the radius of their planning circle.

These differences in the walking environment's quality between the two countries also most likely reflect different planning traditions. In both countries, the movement of automobiles has been at the center of transport planning since the end of WWII. However, since the early 1970s, transport planning in German cities has increasingly concentrated on pedestrians. German planners have implemented such measures as sidewalks on both sides of the street, installing well-lit crosswalks, incorporating pedestrian signals, no right turn on red, and establishing car-free pedestrian zones in many city centers. Moreover, German cities have traffic calmed large shares of their residential neighborhoods (often 75% and more of the entire urban road network)—restricting automobile speeds to 30km/h (18.6 miles/hour) or less in such areas. Many suburban developments in the US do not have sidewalks and often lack pedestrian crosswalks—even at bus stops. Moreover, most American cities have speed limits of 25 mph or higher, even in residential areas, and car-free zones are unusual. Better infrastructure for pedestrians combined with lower speeds for car traffic are the likely factors that make walking more convenient and safer in Germany (Buehler and Pucher, 2021).

Beyond the independent variables we could analyze, many variables are missing from the respective national household travel surveys. In addition to more walk-friendly environments, longer walk distances in Germany may be partially due to cultural differences that favor walking as a transport mode. Another reason is that shortest path algorithms are used to calculate distances in the US, which likely underestimates some walk trip lengths. The fact that older Germans tend to walk longer distances while younger Americans also do suggest that cultural factors may play a larger role than physical ability in walk distance. Besides, weather may also be a pivotal factor, which is indicated by Germans' tendency to walk longer distances mid-day. In comparison, Americans tend to walk longer distances in the morning. The literature shows that appropriate weather likely facilitates longer walk distances (Kaplan et al., 2016; Kuzmyak et al., 2014; Yang et al., 2012)

Conclusion: A Richer Set of Empirical Data for Pedestrian Planning

Urban planners have been drawing ¼ miles circles for neighborhood and activity center planning since Clarence Perry's 1929 Neighborhood Unit. We analyze data from two national travel surveys in the United States and Germany to provide an empirical basis for how large to draw such planners' circles, or walksheds. We find that the radius of the planners' circle should depend upon two key analysis variables, trip purpose, and traveler age, as well as an additional variable that we were not able to control for explicitly, the quality of the built environment. Based on the existing literature on walk-related travel behavior, we believe that a supportive walking environment is a major factor, but not the sole factor, in explaining why Germans tend to walk so much further than Americans. Results are also suggestive that cultural factors and weather may, in addition, play a significant role in shaping how far people will walk.

To inform how large to draw the planners' circle, we systematically examine national data on walk-trip distances from the United States and Germany while taking various trip and personal characteristics into account. We develop multivariate quantile regressions of the 50^{th}, 75^{th}, and 90^{th} percentile of trip length. Indisputably, walking is made more likely when available destinations are closer, trips of 1 kilometer (0.62 miles) or more are not uncommon for various trip purposes both in the United States and

Germany (See Figures 2 and 3). Therefore, planners can use these results to draw customized planners' circles based on the specific trip purposes and traveler ages they are considering. Furthermore, they can use 50th, 75th, and 90th percentiles to plan for the most common trips as well as to consider planning for the possibility of longer walk trips.

Although in some ways, walking may be the most important mode of all, the research community suffers from a severe lack of detailed data about walking in comparison to motorized modes. We encourage the collection and dissemination of more detailed walk-trip data, including origins, destinations, trip lengths, trip times, and routes, to uncover additional insights into the factors affecting this crucial mode of travel. Given the new possibilities offered by mobile data collection, such detailed walk-trip data may be around the corner. When such data become available, researchers can refine analyses such as this one to account for the considerable influence of factors such as detailed measures of the built environment and weather.

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