

WALKABILITY IN TUCSON:
AN OVERVIEW OF CURRENT TRENDS AND GROWTH POTENTIAL

By

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Abstract

In the United States, the transportation sector was responsible for 28% of 2016 GHG emissions—the largest contribution of any industry (U.S. EPA, 2018). To reduce dependence on fossil fuels and mitigate their effects, active modes of transportation, like walking, need be planned for. This study provides an overview of walking in Tucson, AZ and subsequent guidance for future development through a) an assessment of walk-mode splits, b) a survey on residential preferences for walking, and c) a built environment case study analysis. It found that walking constituted 11% of all trips, compared to motorized vehicles, which accounted for more than 80% of all trips. Percentage of respondent walk and car trips varied significantly by income and trip purpose. Both Tucson residents and existing literature identified destination proximity as the most important built environment factor considered in deciding to walk. A complete streets project that incorporated many built environment features found to improve walkability (e.g., street connectivity, accessibility, walking infrastructure) but failed to account for destination proximity had little impact of walking behavior. To better promote walkability in Tucson, emphasis on coordination between transportation and land use planning and connection of walkability to social and cultural values is necessary.

Table of Contents

Abstract	2
Introduction	5
Background	5
Research scope, questions, and approach	5
Literature Review	7
The Built Environment and Walkability	7
Walkability and the Environment	8
Walkability and Local Economies	8
Walkability and Public Health	9
Walkability and Society: Benefits and Disparities	10
Current Trends and Patterns	11
Methodology	12
The 2009 National Household Travel Survey (NHTS)	12
2018 Pilot Study on Walkability in Tucson	13
Case Study of the Corbett Porch Complete Streets Project	13
Data and Analysis	14
The 2009 National Household Travel Survey (NHTS)	14
2018 Pilot Study on Walkability in Tucson	18
Case Study of the Corbett Porch Complete Streets Project	23
Discussion and Recommendations	24
Limitations	26
Recommendations	27
Future Research	29
References	30
Appendix A	33
2018 Pilot Study Report	33
Appendix B	44
Summary of Tucson Policies Related to Walkability	44

Table of Tables

Table 1 Tucson travel survey household and respondent descriptive statistics _____	14
Table 2 Frequency and Percent of Trips by Mode _____	15
Table 3 Percent of Total Trips Made by Each Respondent by Mode _____	16
Table 4 ANOVA Results - Percentage of Respondent Walk Trips and Car Trips Across Race Categorizations ____	16
Table 5 ANOVA Results - Percentage of Respondent Walk Trips and Car Trips Across Income Categorizations	17
Table 6 ANOVA Results - Percentage of Respondent Walk Trips and Car Trips Across Trip Purposes _____	17
Table 7 Features of or in the built environment that facilitate walking, their operational definitions, and the number of times each feature appeared in one of 22 articles searched. _____	18
Table 8 Summary of research surveyed, including study location and year published.* _____	19

Table of Figures

Figure 1 Imageability, visualized.....	7
Figure 2 Percentage of Trip Purposes Made by Walking, Driving, or Another Mode.....	18
Figure 3 Importance of built environment factors for walkability in Tucson.....	20
Figure 4 Frequency of travel to the grocery store, work, and school averages	21
Figure 5 Participant responses to walking frequency statements	22

Introduction

Background

In the face of global climate change, rapid urbanization presents a major 21st Century planning problem. Greenhouse gases (GHGs) play a major role in the acceleration of climate change. These GHGs—e.g., CO_x, NO_x, and chlorofluorocarbons (CFCs)—trap heat in our atmosphere in a process commonly known as the greenhouse effect. This process is expedited and amplified by air pollution, which is largely produced through the use of fossil fuels as a primary energy source around the world (Ramanathan & Feng, 2009).

One of the difficulties in addressing contributions to climate change is that fossil fuel emissions are not localized—the negative externalities of individual auto use burden larger regional and global communities through the greenhouse effect and fast atmospheric transport of pollutants (Ramanathan & Feng, 2009). As the world becomes increasingly urbanized, fossil fuels seem even more important in powering our daily lives: cities are responsible for the use of 75% of the world’s energy supply and 80% of global greenhouse gas emissions (Newman, Beatly, & Boyer, 2017).

In the United States, the transportation sector was responsible for 28% of 2016 GHG emissions—the largest contribution of any industry (U.S. EPA, 2018). To reduce dependence on fossil fuels and mitigate their devastating effects, active modes of transportation, like walking, should be planned for. Yet, an ‘urban sprawl’ development pattern is pervasive in U.S. cities. This low-density expansion and development of urban places and the built environment places reliance on the private automobile as a primary transportation mode.

A paradigm shift in urban development should facilitate walking and other active modes in the built environment. If walk trips can substitute private vehicle trips, a reduction in vehicle miles traveled (VMT), and subsequent transportation-related GHG emissions, is expected. Additionally, walking has positive effects on community social and economic sustainability. Residents who walk as a major mode of transport within their communities have decreased risks of heart disease (Frank, et al., 2006). Neighborhoods with ample pedestrian infrastructure see economic growth and development due to increased shop accessibility, efficient use of land, and community ties to local businesses (Litman, 2003). To take advantage of these benefits, cities can plan for *walkability*, a measure of how well the built environment facilitates walking. This metric considers pedestrian safety, comfort, and proximity to commercial locations among other factors. Planning with walkability in mind will lead to more successful, thriving communities.

Research scope, questions, and approach

Actively reducing fossil fuel emissions at the local level by promoting walkability and implementing walkable urban design can both reduce a location’s GHG emissions as well as provide case-study insight for other regions to plan for walkability specific to their communities.

This study focused spatially on Tucson, Arizona. The city and its surrounding areas continue to see rapid population growth and development—Tucson’s city population is just over a half million people, with more than one million residents living in the greater metro area (U.S.

Census Bureau, 2017). The intense heat of the summer months makes the city a particularly interesting case study of how extreme temperatures might require a unique built environment to make walking an attractive and viable form of transportation. The Southwest U.S. is expected to see higher temperatures overall and less predictable rainfall (Gonzalez, et al., 2018), along with more record-setting hot days (Walsh, 2014). Because of this, analysis of what features make people walk in these conditions is important and relevant to the broader research problem of reducing greenhouse gas emissions in these climate types. Tucson as a study area is thus important as it bridges concepts of adaptability and resilience (learning how to design for warmer climates) and prevention and mitigation (reducing greenhouse gas emissions) for climate change.

Furthermore, Tucson's recent initiatives to support multi-modal travel and increase public safety would benefit from a more comprehensive analysis of place-specific walkability attitudes. In 2018, the City adopted a "complete streets" policy aimed at promoting safety, accessibility, equity, and economic vitality (City of Tucson, 2018). This establishes a new dedication of the City in supporting policies and planning visions that give ample street space to pedestrians, cyclists, transit systems, and cars alike. This is an important step toward increasing pedestrian safety state- and city-wide. Arizona had the highest rate of pedestrian deaths in 2017, at a rate double the national average; in Tucson, pedestrian deaths have been on the rise since 2016, doubling between 2016 and 2017 from 12 to 25 (The Associated Press, 2018).

This study aims to provide an overview of walking travel in urban households in Tucson, AZ and subsequent guidance for future development through a) an assessment of walk-mode splits, b) a survey on residential preferences for walking, and c) a case study analysis of a project that incorporates key built environment features known to improve walkability.

The following outlines considered research questions and strategies:

1. How often, and for what trip purposes, are Tucsonans currently using walking as a transportation mode?
2. What built environment features or perceptions would promote walkability in Tucson, and how do these compare to the factors identified as important in existing literature?
3. Do the built environment factors identified as improving walkability have an impact on travel behavior?

It was hypothesized that, due to poor infrastructure and harsh climate conditions, walking is infrequently used as a transportation mode in Tucson.

Literature Review

The environmental, economic, and social benefits of walkability are becoming increasingly recognized by municipalities. Low-density, sprawled, and single-use land areas lower human physical activity, spike obesity rates (and related health problems), and are associated with higher levels of pollution and GHG emissions due to reliance on the automobile as a main mode of transport (Frank, et al., 2006). Walkability indices show a clear inverse relationship between walkable urban form and both daily vehicle miles traveled and pollutant emissions (Frank, et al., 2006).

The Built Environment and Walkability

The bulk of current walkability literature has identified features of the built environment that facilitate walking. A general assessment of a particular area's walkability can be compiled based on physical features of the built environment, urban design qualities, and individual experience-based reactions (Ewing & Bartholomew, Eight Qualities of Pedestrian- and Transit-Oriented Design, 2013). Physical design features might include sidewalk width and condition, traffic volume, and human density. Urban design qualities for evaluation include legibility/imageability, connectivity, human scale, and complexity (see **Figure 1**). Other physical features that have been identified to contribute to a positive walking experience are aesthetic quality, maintenance, landscaping, and design coherence (Johansson, Sternudd, & Kärrholm, 2016). When combined with the analysis of individuals' reactions, such as opinions on safety and comfort level, these features can be used to predict walking behavior.

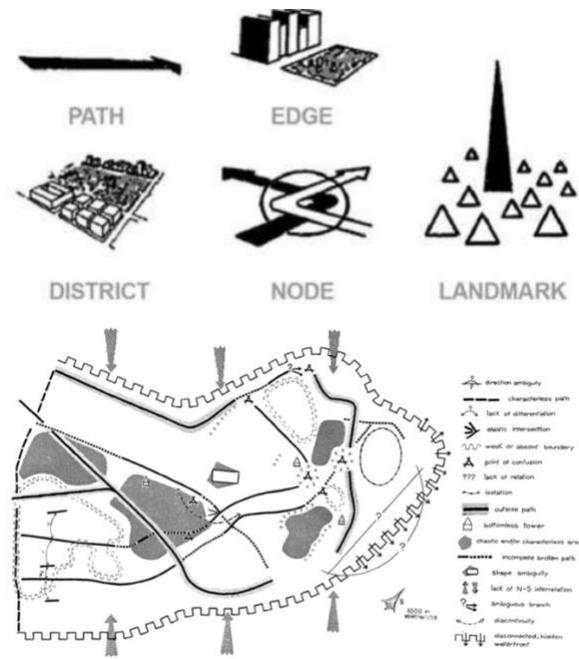


Figure 1 Imageability, visualized

Images from urban planner Kevin Lynch's *The Image of the City* (1960), which proposed that successful cities are imageable because they reduce user stress and confusion. According to Lynch, an imageable city was based on recognized surroundings through paths, edges, districts, nodes, and landmarks.

A pilot study by the author in spring of 2018 revealed eight major features of the built environment in an analysis of 22 research articles on the subject: land-use mix, residential density, traffic safety, street connectivity, accessibility, walking infrastructure, aesthetics, and crime safety. This research is integrated into this study (see **2018 Pilot Study on Walkability in Tucson**).

Other features of the built environment that promote walkability include traffic calming measures, mixed-use development, connectivity and crossing safety, and outdoor environmental quality. Traffic calming measures include narrow or curved roads, speed bumps, and low-speed limits (Kenworthy & Newman, 2014). These measures slow down motorized vehicle traffic by making drivers more cautious, increasing pedestrian and cyclist safety. A case study by Kenworthy & Newman (2014) found a significant decrease in fatal accidents (57%) in residential neighborhoods after traffic calming measures were implemented, and a 43% decrease in motor vehicle crashes with pedestrians overall.

Mixed-use development combines residential, commercial, and public common spaces. This close proximity results in more walking trips compared to traditional suburban sprawl (Calthorpe, 2014). Within neighborhoods, connectivity via a grid design facilitates more walking trips than neighborhoods with lots of cul-de-sacs and low mobility (Thornton, Pearce, & Kavanagh, 2011; Calthorpe, 2014). Additionally, the quality of the outdoor environment affects travel behavior: when outdoor quality is good, more optional and social activities happen outdoors (Ghel, 2014).

Walkability and the Environment

The environmental benefits of walking are largely dependent on its substitution for private automobile trips as a travel mode, helping to scale back GHG emissions that contribute to global climate change. Given the majority of vehicles today run on petroleum, there is a need to find substitute technologies or modes of transportation that decouple mobility from this finite resource. Current use of gasoline in cars is not sustainable (i.e., substitutes are not being implemented at an appropriate rate compared to use) (Woodcock, 2007), and the transportation sector is the top industry contributing to CO₂ emissions (Rothengatter, 2010). High walkability areas can help remedy this problem, as “relocating to areas with higher neighborhood accessibility...[is] related to less automobile use” (Leslie, et al., 2007). For example, a study conducted in King County, WA found that, controlling for demographics (e.g., race, gender, income, education) a 5% increase in walkability features was correlated with a 6.5% decrease in vehicle miles traveled per person (Frank, et al., 2006).

Walkability and Local Economies

In addition to its environmental benefits, walkability can support local economies. Traffic calming creates a safer urban environment for pedestrians, reducing air pollution and enhancing pedestrian street activity, which can support nearby businesses (Kenworthy & Newman, 2014), while neighborhood connectivity increases community mobility and accessibility to local businesses (Calthorpe, 2014). Enhanced social interactions that result from more walkable space connect residents to their communities, increasing their inclination to support local businesses (Ghel, 2014). Ultimately, “the greater mixing of uses means that residents of these cities

typically have many shops, services, and cafes within a walkable range...pedestrianizing much of their urban centers has been a positive one...economically” (Beatly, 2014).

Walkability and Public Health

In addition to GHG emissions, motor vehicles emit a variety of air pollutants that cause major health problems and chronic disease, including “respiratory morbidity, allergic illness and symptoms, cardiopulmonary mortality...myocardial infarction and a possible link to lung cancer” (Woodcock, 2007). Encouraging people to walk instead of drive reduces these emissions, mitigating their effects on public health. Additionally, replacing short trips with walking allows motorists to achieve daily recommended levels of physical activity (Woodcock, 2007).

Walking has also been observed as a great way for seniors to remain active and achieve daily recommended levels of exercise. For senior populations, especially those who live in more suburban areas, access to commonly frequented locations—such as grocery stores—was critical in their ability to utilize walking as a mode of transport (Negron-Poblete, Séguin, & Apparicio, 2016). Increased links between suburban neighborhoods were marked by connected streets and total distances to these frequented locations. In the broader context of suburban development, the prevalence of urban sprawl has negatively affected the health of populations of all ages, as it is linked with increased rates of obesity and chronic diseases (Ewing, 2014). Ultimately, this identifies a need to incorporate planning for walkability at a neighborhood level as well as on larger urban and regional scales.

In addition to physical health, improved mental health outcomes have been the focus of some walkability research. For example, Gidlow et al. (2010) investigated the relationship between physical and social environments to both physical and mental health in the UK. Measures of self-reported health, socio-demographics, and perceived neighborhood environments were gathered and used in a regression analysis. The results showed the diversity of land use as the most significant factor in positive physical health outcomes and perceived social support as the most significant factor in positive mental health outcomes. If walkability policy aims to facilitate an environment full of social support, it can move toward the goal of supporting inhabitants’ mental overall wellbeing – not just the physical.

Walkability research concerning public health is lacking broader non-place-based conclusions. A study by Kerr et al. (2013) identified the importance of physical activity to public health but asserted that there is a lack of generalized data to support policy initiatives for federal governments and international collaboration opportunities. It outlined one promising effort between 12 countries to contribute to an International Physical Activity and Environment Network (IPEN). The IPEN study is representative of a large-scale citizen science data collection effort to gather walking statistics from 15,000 participants. Participants represent locations across a diverse number of built environment and socioeconomic standpoints. The researchers’ hope is to collect more widely applicable information on walking in the built environment for public health promotion on a global scale.

Walkability and Society: Benefits and Disparities

The social benefits of walkable urban spaces have long been touted in planning theory. Author and activist Jane Jacobs asserts that walking, “much more than any other mode of transportation...allows the observer to be in the environment more fully, and to integrate what is seen with the knowledge and experiences stored in one’s mind” (1961). In a similar sentiment, architect and consultant Jan Gehl claims walkable design leads to more social interaction, which “offers a wealth of sensual variation...living cities are...ones in which people can act with one another [and] are always stimulating because they are rich in experiences” (2014). In planning practice, the social benefits of walkability have not been as widely explored despite the value of social capital in human health.

Residents in high-density neighborhoods close to downtown areas generally feel more of their daily locations are accessible by foot (Rogers, Halstead, Gardner, & Carlson, 2011). Rogers et al. found that over 50% of residents of this neighborhood type walk every day or several times per week—compared to only 23% in more suburban neighborhoods—to complete errands or necessary activities. Further, the researchers found rates of social capital are higher overall for more walkable neighborhoods (although this difference is not always statistically significant). Walkable development and mixed-land use can also be linked to food security. Neighborhoods that combine high walkability with either high social cohesion or low crime see residents purchasing and eating a higher percentage of fruits and vegetables (Calise, Chow, Ryder, & Wingerter, 2018). Thus, walkable development prompted by mixed-use can help erase food deserts, or areas where fresh, healthy foods are not sold nearby and are not accessible for all. Streets are “critical to building vibrant, healthy, and sustainable communities. Streets should be seams in the community – not barriers – providing every member of the community the opportunity to get safely where they need to go and also provide a quality common space to experience, explore and discover their city” (Living Streets Alliance, 2016).

Differences in walkable urban design that exist based on resident demographics and socioeconomic status indicates a level of inequality in some communities’ ability to be physically active (and to reap the subsequent benefits of physical activity). In a study of St. Louis neighborhoods, those where residents were predominantly black were found to be 15 times more likely to have sidewalk obstructions and 38 times more likely to have uneven sidewalks than their white counterparts (Kelly, Schootman, Baker, Barnidge, & Lemes, 2007). Additionally, blocks with the highest poverty rates displayed more “physical disorder” (e.g., rundown buildings, poor street quality). Explanations include a significant difference in neighborhood investment based on race- and income-level demographics, lowering overall physical activity opportunities and quality of life for people of color and low-income households as related to the built environment.

The bulk of current research on walkability has focused solely on “gross qualities,” like population density, connectivity, and park proximity (Ewing, Handy, Brownson, Clemente, & Winston, 2006). Research exploring the cultural and political factors that may influence an area’s walkability is critically important to understanding it holistically. In a case study of elementary schools, high crash and crime rates in lower-income, predominantly Hispanic identifying neighborhoods skewed perceived safety, ultimately impacting the rates of walking for youth (Zhu & Lee, 2008). This finding was reiterated in a similar elementary school case study by

Ahmed et al. (2015), which found that public safety was a major factor influencing walkability in low-income neighborhoods while physical elements of the built environment were of secondary importance. In a qualitative case study of five predominantly Mexican-American neighborhoods near and in Tucson, Arizona, Ingram et al. (2017) interviewed several neighborhood residents while walking in neighborhoods about their experiences. Neighborhood residents cited proximity to family, social cohesion, personal interaction, and security as key determinants for walking as a mode of transportation. The study concluded that both public health and planning fields would benefit from additional research on cultural links to walkability. This research ultimately led to the development of a toolkit to lead qualitative pedestrian studies (Landgrave-Serrano, Adkins, Iroz-Elardo, Ingram, & Oden, 2019).

New research is also revealing nuanced (and sometimes conflicting) relationships between walkability, accessibility, income, and mental health. A case study of neighborhoods across Seattle, WA and Baltimore, MD found that high-income neighborhoods featured significantly more walkable built environments (based on mixed-uses, residential density, accessibility to amenities, and street connectivity) than their lower-income counterparts (Sallis, et al., 2011). Based on their results, the authors pushed for environmental justice in public policy to address disparities in urban design. However, another study by Smith et al. (2017) found that travel behavior differed *within* walkable environments: more affluent residents tended to take advantage of new pedestrian and biking infrastructure than less affluent residents. In another analysis, Hart et al. (2017) found that high walkability in affluent areas was correlated with lower rates of depression symptoms among affluence households residents, but in lower-income households, the trend was reversed—in this case, high walkability was correlated with a greater number of participants experiencing depression systems. A potential explanation for this result is accessibility: a highly walkable built environment may provide high *spatial* access to a community's amenities, but lower-income households may have limited *economic* ability to take advantage of these amenities while being surrounded by others with more resources. The contradictions presented here call both for more attention on community design to increase the walkability of lower-income areas, but also for an examination of features other than physical infrastructure and upscale amenities that create walkable environments.

Current Trends and Patterns

Societal dependence on the automobile has negative consequences beyond environmental damage. As cities become more sprawled, the amount of time people spend behind the wheel is reaching new heights. Increased proportions of time spent driving lead to an increased amount of driving induced stress, which manifests in more aggressive driving patterns and anxiety (Rasmussen, Knapp, & Garner, 2000). The percentage of income spent on transportation has also seen an increase in recent years, offsetting the benefits (such as lower housing and land costs) given by living further from a city's urban core (Hartell, 2017). These additional negative factors make walkable development more imperative.

In recent years, designing urban spaces for walking has been on the rise. Demographic shifts show a return in the desire to live in downtown areas compared to suburban ones (Gallagher, 2014). Thus, planning initiatives that reduce automobile dependence (as well as its economic and social costs, such as air pollution and congestion) are gaining steam. If walking as a mode of transportation were a viable alternative to auto travel, it could slow the acceleration of global

climate change and allow the development of less-sprawled, high-density cities. Given the potential hazards climate change has in store for many coastal areas, this might be a necessary design factor to plan for future migration and climate adaptation.

Methodology

This study utilizes a triangulated, mixed-methods research approach in addressing the research questions. This strategy allows for a more thorough analysis of findings than a single qualitative or quantitative approach could alone (Caruth, 2013) and is designed such that each technique provides complementary information to the others. First, statistical analysis of the 2009 National Household Travel Survey (NHTS) data was conducted to determine how often and for what purposes Tucson residents walk (or not), as well as how these behaviors differ across various demographic and socioeconomic groups. Then, a 2018 pilot study by the author is used to provide a more recent supplement to walking frequency for various trip types in Tucson. This study also includes a) a literature review of the most frequently cited built environment features that lead to walkability environments, which is compared to b) a survey of Tucson residents' that captures the features they most consider when deciding to walk for a trip. Finally, a recent "complete streets" project in Tucson that incorporates many built environment components typically linked to walkability is evaluated for its impact on changed behaviors. Future policy and practice recommendations are derived in the concluding remarks in consideration of these three components

The 2009 National Household Travel Survey (NHTS)

The Pima Association of Governments (PAG) participated in the 2009 NHTS Add-On Program to expand the number of sampled households from Pima County incorporated into the survey. The NHTS is a travel diary survey that explores household-level travel behavior. The NHTS publishes data available for public use with limited geospatial information. The Pima County add-on sample was generously provided to the author by PAG, still with limited geospatial information to protect participant confidentiality. It should be noted that results from this analysis do not reflect PAG standards or regulations, nor should they be used to justify funding prioritization. Rather, they are used to provide a general overview of walking patterns and behaviors in Tucson.

All PAG NHTS analysis was processed in IBM SPSS software. To limit the sample to households in Tucson, the PAG data were constrained only to households listing Tucson zip codes. Only households where 100% of household members participated were included. To specifically look at walking behaviors centered around ones' place of residence, the sample was limited to view home-based trips only. Finally, only those households labeled as being in urban areas (as opposed to rural) were included in the analysis¹.

¹ Note that households were parsed into urban and rural categories by the 'URBRUR' binary variable. The HBHUR variable placed households into five categories: urban, suburban, second city, town and country, and unassigned. Households in the sample fell into all of these categories except 'unassigned'. Thus, after limiting to urban households by the 'URBRUR' variable, it was assumed that the sub-categories of urban, suburban, second city, and town and country were all still in urban contexts; the sample was not further limited by the 'HBHUR' variable to analyze how walking may vary across these urban subcategories.

Household-, person-, and trip-level data were used in the analysis. Household level statistics included vehicle ownership, household size, and income. Trip-level data were used to derive a summary of trip modes and trip purposes. Trip-level data were aggregated into person-level data using household and person IDs, such that each person sampled constituted one row of data. This allowed for analysis of respondent race and ethnic identity, as well as the percentage of all trips taken by walking. Trip-level data were also aggregated by trip purpose and household income to compare the breakdown of the percentage of walk trips across these variables.

2018 Pilot Study on Walkability in Tucson

A pilot study completed by the author in spring 2018 aimed to investigate which features of the built environment promote walkability in Tucson and how those features compared to those listed as being important for walkability in the literature. Further, it sought to gain some insight into Tucsonans' current travel behaviors. This research was structured around a cross-sectional design. A literature review was performed to determine which built environment factors were frequently listed as being critical to walkability. Then, a questionnaire was developed using Qualtrics software. The questionnaire had participants rank built environment factors by the level of importance in their decision to walk for a trip. Additionally, the questionnaire assessed participants' current use of walking as a mode of transport, and had participants identify features in their neighborhood-built environments that they liked or disliked. Relevant results are included in the following section, and the full study, including a more detailed methodology and presentation of results, is appended here in **Appendix A** with department and instructor consent.

Case Study of the Corbett Porch Complete Streets Project

In fall of 2018, Living Streets Alliance initiated a complete streets project, the 'Corbett Porch' intervention, intervention at the intersection of 6th Ave. and 7th St. Earlier that year, a pedestrian was hit while crossing the street at the project site by a driver who fled the scene. Therefore, increasing pedestrian safety was a major goal of the intervention. The project utilized low-cost materials to reclaim valuable space for cyclists and pedestrians along the stretch. The project is temporary, as the intersection will undergo major renovations for Tucson's Downtown Links project. However, it serves as a case study for future initiatives.

Living Streets Alliance collaborated with Dr. Arlie Adkins and a group of students at the University of Arizona, including the author, to assess the impact of the project. Collected data at the 6th Ave. and 7th St. intersection included vehicle, bicycle, and pedestrian counts, vehicle speed, and an evaluation of vehicle and pedestrian stopping and crossing behavior. Data were collected before the intervention in early October of 2018 and after the intervention in mid to late November 2018; additional data on vehicle volume and speed collected in early September 2018 was provided by the City of Tucson. Only a brief summary of relevant results is presented in this document. More information on this project is available upon request.

Data and Analysis

The 2009 National Household Travel Survey (NHTS)

The 2009 NHTS captured 1,455 households with over 2,700 residents and just under 9,000 trips in Tucson. Descriptive information about these households is captured in **Table 1**.

Table 1 Tucson travel survey household and respondent descriptive statistics

HOUSEHOLD	N	Minimum	Maximum	Mean	Median
Household Size	1455	1	8	2.13	2
Household vehicles	1455	0	23	1.88	2
Household income	1348	< \$5,000	> = \$100,000	\$50,000 - \$54,999	\$45,000 - \$49,999
RESPONDENTS	N	% of Total	N, Hispanic identifying	%, Hispanic identifying	
Respondent race/ethnicity	2725	--	326	12	
White	2396	87.5	6148	6.2	
Black	30	1.1	2	6.7	
Asian	29	1.1	0	0.0	
American Indian	27	1.0	7	25.9	
Native Hawaiian/Pacific	5	0.2	0	0.0	
Multiracial	40	1.5	6	15.0	
Hispanic/Mexican	142	5.2	140	98.6	
Other	23	0.8	19	82.6	
Refused	33	1.2	4	12.1	

American Community Survey (ACS) 2013-2017 5-year estimates indicated an average household size of 2.41 in Tucson, just slightly greater than in the NHTS sample (U.S. Census Bureau, 2017). Most Tucson households have two vehicles available, with median ownership falling between one and two vehicles sample (U.S. Census Bureau, 2017). However, these same estimates reveal a median income of \$39,617, which is below the lower limit of median household income in the NHTS sample—\$45,000. Thus, the NHTS sample represents a sample of households that are wealthier and slightly smaller than in Tucson overall.

ACS 5-year estimates reveal 73.1% of Tucsonans identify as white alone, with only 44.9% identifying as white alone, not Hispanic or Latino (U.S. Census Bureau, 2017). Of the 87.5% of NHTS sample respondents identifying as white, only 12% also identify as Hispanic, indicating that 75.5% of the NHTS sample identifies as white alone and claiming no Hispanic identity².

In Tucson, 42.9% of the population of any race claims a Hispanic or Latino identity, with 39.2% specifying Mexican identity (U.S. Census Bureau, 2017). This claim is compared to only 12% of

² The NHTS only considered Hispanic, but not Latino, identities.

the NHTS sample population claiming Hispanic Identity, and only 5.2% specifying Mexican identity. Further, the NHTS sample is under-representative of Tucson’s Black, American Indian and Alaska Native, Native Hawaiian and Pacific Islander, and Asian populations, which make up 6.7%, 4.8%, 0.4%, and 4.5% of the population, respectively.

These differences between the NHTS sample and ACS 5-year estimates overall do place a limitation on this analysis, such that it is unclear whether travel behavior in the NHTS is representative of Tucson’s population overall. There may be other variables at play in these differences as well. For example, the ACS 5-year estimates include data for all persons within Tucson census block groups, while the NHTS sample has been limited to households within Tucson zip-code areas that are also considered to be in urban places (as opposed to rural).

Trip Mode Summary

A summary of 8,906 trips by mode is displayed in **Table 2**. Motorized vehicles made up the largest proportion of trips, with cars accounting for 46%. Walking was the most frequently used non-motorized vehicle mode, accounting for 12% of trips made—only a fraction compared to trips made by car.

Table 2 Frequency and Percent of Trips by Mode

	Frequency	Percent
Motorized Vehicle		
Car	4140	46.4
Van	720	8.1
SUV	1510	16.9
Pickup truck	1021	11.4
TOTAL	7391	82.8
Active and Public Transit		
Walk	1031	11.6
Bicycle	129	1.4
Local public bus	67	0.8
School bus	108	1.2
City to city bus	4	0
TOTAL	1339	15
Other		
Motorcycle	49	0.5
Other truck	24	0.3
Light electric vehicle/golf cart	18	0.2
Taxicab, special transit	17	0.2
Commuter, tour, shuttle bus	23	0.2
Airplane, other	45	0.5
TOTAL	176	1.9
OVERALL	8906	100

Variances in Trip Mode and Purpose

The percentage of walk and car trips for each respondent (relative to each respondents' total trips) are displayed in **Table 3**, with respondents grouped by race and income levels.

Table 3 Percent of Total Trips Made by Each Respondent by Mode

Race	Mean % Walk Trips*	Mean % Car Trips*
White	10.05	84.33
Black	13.06	66.11
Asian	17.82	81.32
American Indian	7.41	80.25
Native Hawaiian/Pacific	0.00	95.00
Multiracial	5.29	87.58
Hispanic/Mexican	7.44	87.58
Other	4.35	89.13
Refused	16.11	72.78
Median Income		
<\$24,999	15.34	76.81
\$25,000-\$49,999	10.08	83.60
\$50,000-\$74,999	9.18	85.99
>\$75,000	8.00	86.32

* Percentages displayed are relative to the total number of trips made by each respondent

Asian respondents made the greatest percentage of their total trips by walking, on average (17.8%). None of the five Native Hawaiian/Pacific (Islander)-identifying respondents made trips by walking; respondents in this group made 95% of their trips by car, on average. Black respondents made the lowest percentage of their trips by car on average (66.1%) and the second-highest percentage of their trips by walking on average (excluding 'Refused' respondents, 13.1%). Respondents across groups, on average, made more than half their trips by car. An analysis of variance showed the effect of the NHTS race categorizations on respondent percentages of walk and motorized vehicle trips was not significant (see **Table 4**).

Table 4 ANOVA Results - Percentage of Respondent Walk Trips and Car Trips Across Race Categorizations

		Sum of Squares	df	Mean Square	F	Sig.
% Walk Trips	Between Groups	9049.57	10	904.96	1.57	0.11
	Within Groups	1572991.71	2726	577.03		
	Total	1582041.28	2736			
% Motorized Vehicle Trips	Between Groups	19096.52	10	1909.65	2.04	0.03 (0.22)*
	Within Groups	2557639.77	2726	938.24		
	Total	2576736.30	2736			

*Note: Percentage of respondent walk and motorized vehicle trips failed the homogeneity of variance required for ANOVA interpretation. A Welch test was performed as a non-parametric equivalent; the result confirmed non-significance for % Walk Trips and found % Motorized Vehicle Trips to not vary significantly by race categorization (p=0.22).

Examining median income groups, those in the lowest-income cohort (<\$24,999) made 15.3% of their trips by walking, and 76.8% of their trips by car, on average. Those in the highest-income cohort (>\$75,000) made 8.0% of their trips by walking, and 86.3% of their trips by car, on average. An analysis of variance showed the effect of income categorization on respondent percentages of walk and motorized vehicle trips to be significant (see **Table 5**) — the percentage of respondents’ trips made by walking and by driving varied significantly by income group.

Table 5 ANOVA Results - Percentage of Respondent Walk Trips and Car Trips Across Income Categorizations

		Sum of Squares	df	Mean Square	F	Sig.
% Walk Trips	Between Groups	16063.71	3	5354.57	9.22	0.00
	Within Groups	1479892.30	2549	580.58		
	Total	1495956.01	2552			
% Motorized Vehicle Trips	Between Groups	28885.91	3	9628.64	10.17	0.00
	Within Groups	2414132.90	2549	947.09		
	Total	2443018.80	2552			

Note: Percentage of respondent walk and motorized vehicle trips failed the homogeneity of variance required for ANOVA interpretation. A Welch test was performed as a non-parametric equivalent, which confirmed the significance levels in the ANOVA.

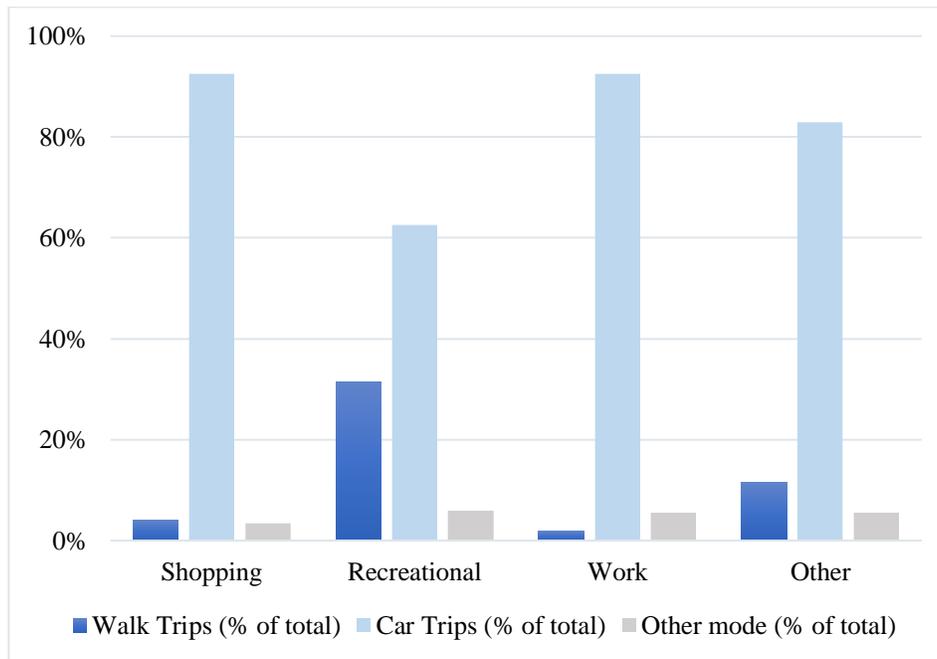
Figure 2 displays the percentage of each trip purpose made by walking and driving. 92% of shopping and work trips were made by motorized vehicle, compared to just 4% and 10% of trips made by walking, respectively. 32% of social or recreational trips were made by walking—half the number of social/recreational trips made by motorized vehicle. An analysis of variance revealed the type of trip purpose on respondent percentages of walk and motorized vehicle trips was significant (see **Table 6**).

Table 6 ANOVA Results - Percentage of Respondent Walk Trips and Car Trips Across Trip Purposes

		Sum of Squares	df	Mean Square	F	Sig.
% Walk Trips	Between Groups	119.74	3.00	39.91	310.51	0.00
	Within Groups	1145.80	8914.00	0.13		
	Total	1265.54	8917.00			
% Motorized Vehicle Trips	Between Groups	106.65	3.00	35.55	393.59	0.00
	Within Groups	805.15	8914.00	0.09		
	Total	911.81	8917.00			

Note: Percentage of respondent walk and motorized vehicle trips failed the homogeneity of variance required for ANOVA interpretation. A Welch test was performed as a non-parametric equivalent, which confirmed the significance levels in the ANOVA.

Figure 2 Percentage of Trip Purposes Made by Walking, Driving, or Another Mode



2018 Pilot Study on Walkability in Tucson

Existing Literature Reveals Common Built Environment Features That Promote Walkability

A literature review of 22 research articles revealed eight major features of/in the built environment that contribute to fostering a walkable urban environment. These built environment features are summarized in **Table 7**. The authors and studies referenced are summarized in **Table 8**.

Table 7 Features of or in the built environment that facilitate walking, their operational definitions, and the number of times each feature appeared in one of 22 articles searched.

Built Environment Feature	Operational Definitions	Frequency Mentioned	Mentioning authors
Land-use mix/proximity	Mix of residential and commercial buildings within neighborhood locations	18	Leslie, Cerin, Van Dyck, Manaugh, Gebel, Rosenberg, Carr, Smith, Sundquist, Frank, Rundle, Litman, Gebel, Lovasi, Forsyth, Gauvin, Lo, Gallimore
Residential density	Population or developmental density within a neighborhood	15	Leslie, Cerin, Van Dyck, Duncan, Gebel, Rosenberg, Carr, Brown, Smith, Sunquist, Frank, Rundle, Gebel, Gauvin, Gallimore
Traffic safety	Slow speed limits, narrow streets, speed bumps, car traffic density	12	Leslie, Cerin, Van Dyck, Duncan, Gebel, Rosenberg, Carr, Marshall, Frank, Litman, Forsyth, Lo

Street connectivity	The degree to which streets connect to other streets and major intersections	11	Leslie, Cerin, Van Dyck, Duncan, Rosenberg, Carr, Brown, Sundquist, Gebel, Gauvin, Lo
Accessibility	Connectivity between streets and other development, and ease of access to connection pathways	9	Cerin, Manaugh, Litman, Gebel, Lovasi, Forsyth, Gauvin, Lo, Gallimore
Walking infrastructure	Sidewalks, crosswalks, traffic signals, streetlights, and other infrastructure that supports walking	8	Leslie, Cerin, Rosenberg, Brown, Marshall, Smith, Forsyth, Gallimore
Aesthetics/perception	Street cleanliness, building upkeep, green space	6	Leslie, Rosenberg, Brown, Ewing, Gebel, Forsyth
Safety from crime	Low crime rates, streetlights, community surveillance	5	Leslie, Cerin, Rosenberg, Forsyth, Lo

Table 8 Summary of research surveyed, including study location and year published.*

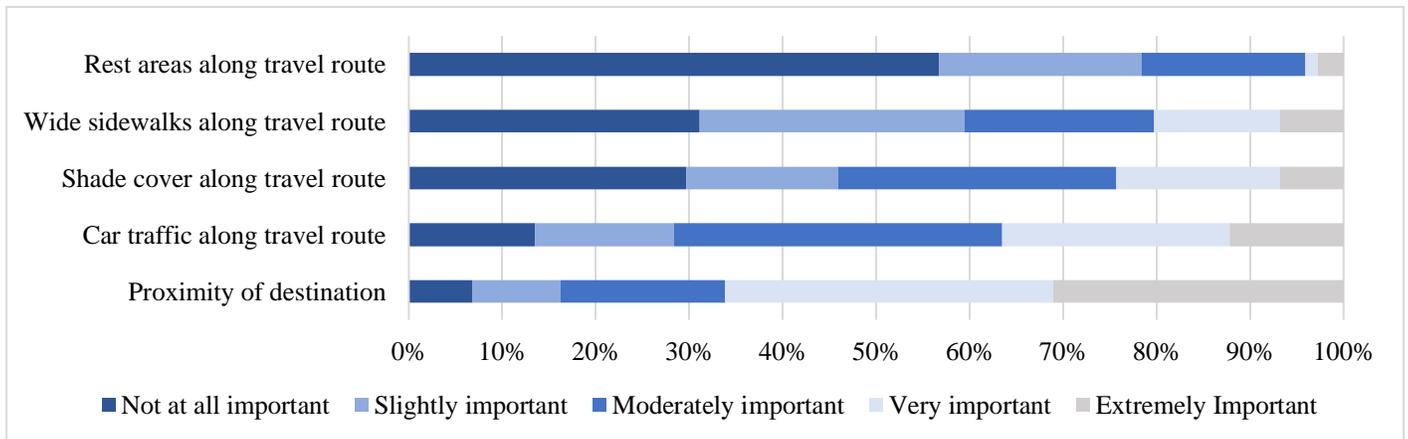
Leading author	Study area location	Year published
Leslie	Adelaide, Australia	2003
Carin	King County, WA	2006
Van Dyck	Ghent, Belgium	2010
Duncan	Across US Metro Regions	2011
Manaugh	Montreal, Canada	2011
Gebel	Adelaide, Australia	2009
Rosenberg	San Diego, Boston, Cincinnati	2009
Carr	Rhode Island	2010
Brown	Salt Lake City, UT	2009
Marshall	Vancouver, BC	2009
Smith	Salt Lake County, UT	2008
Frank	Seattle, WA; Baltimore, MD	2010
Rundle	NYC	2009
Ewing	Across US Metro Regions	2006
Litman	N/A (general)	2003
Gebel	Adelaide, Australia	2011
Lovasi	NYC	2009
Forsyth	Across US Metro Regions	2008
Gauvin	Montreal, Canada	2005
Lo	N/A (general)	2009
Gallimore	Across US Metro Regions	2011

*Full citations can be found in **Appendix A**

Destination Proximity Heavily Influences Tucsonans' Decision To Walk

74 Tucsonans responded to the distributed Qualtrics questionnaire. Survey respondents were asked to rank five built environment factors from 1 (not important at all) to 5 (extremely important) based on how much each factor influenced their decision to walk as a mode of transportation. The built environment factors and average response values are summarized in **Figure 3**.

Figure 3 Importance of built environment factors for walkability in Tucson



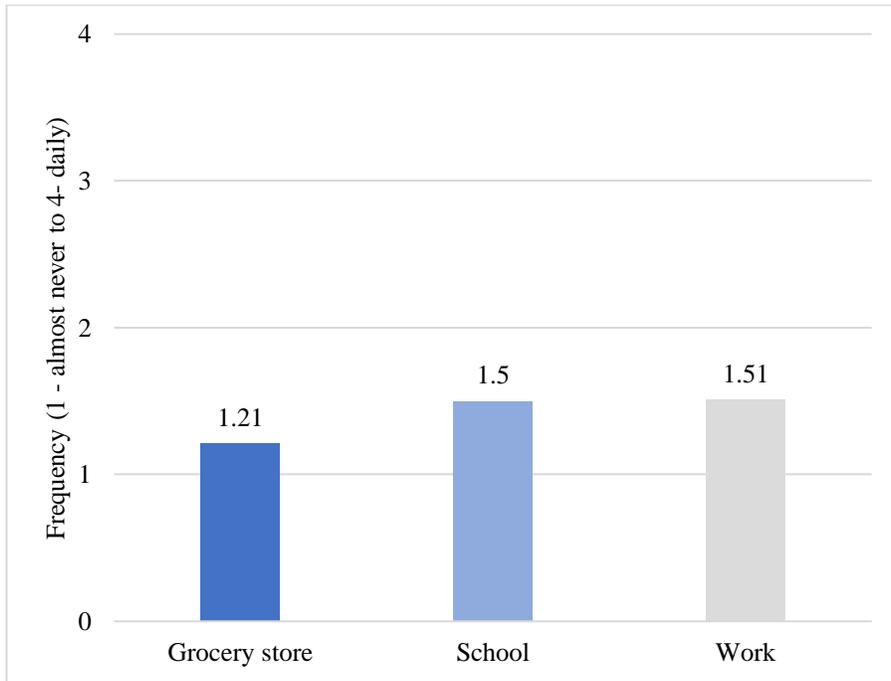
Survey results indicate that **destination proximity** is the most important built environment factor that Tucsonans' contribute when deciding to walk as a mode of transport. This corresponds to **land-use mix** being the most frequently mentioned built environment feature to support walkability in the reviewed literature. Generally, locations outside a 0.25-mile radius not considered to be within a comfortably walkable distance, and the threshold used to test walkability in research is typically a 0.25-mile radius (Yang & Diez-Roux, 2012; Pivo & Fisher, 2011).

The number of rest areas along the travel route, which could be considered in the literature review categories of 'walking infrastructure' or 'aesthetics/perception,' ranked as the least important built environment feature, and as not important overall. It should be noted that none of these features came close to an average of 5 ('Extremely Important'), instead ranking as moderately to slightly important.

Walking is Not Currently a Main Mode of Transport in Tucson

Most Tucsonans do not currently use walking as a mode of transport to get to common destinations. When asked how often travel to the grocery store, work, or school was on foot; respondents indicated a frequency of a few times a month to almost never (based on recoded values, on a scale from 1, almost never, to 4, daily). These results are summarized in **Figure 4**.

Figure 4 Frequency of travel to the grocery store, work, and school averages

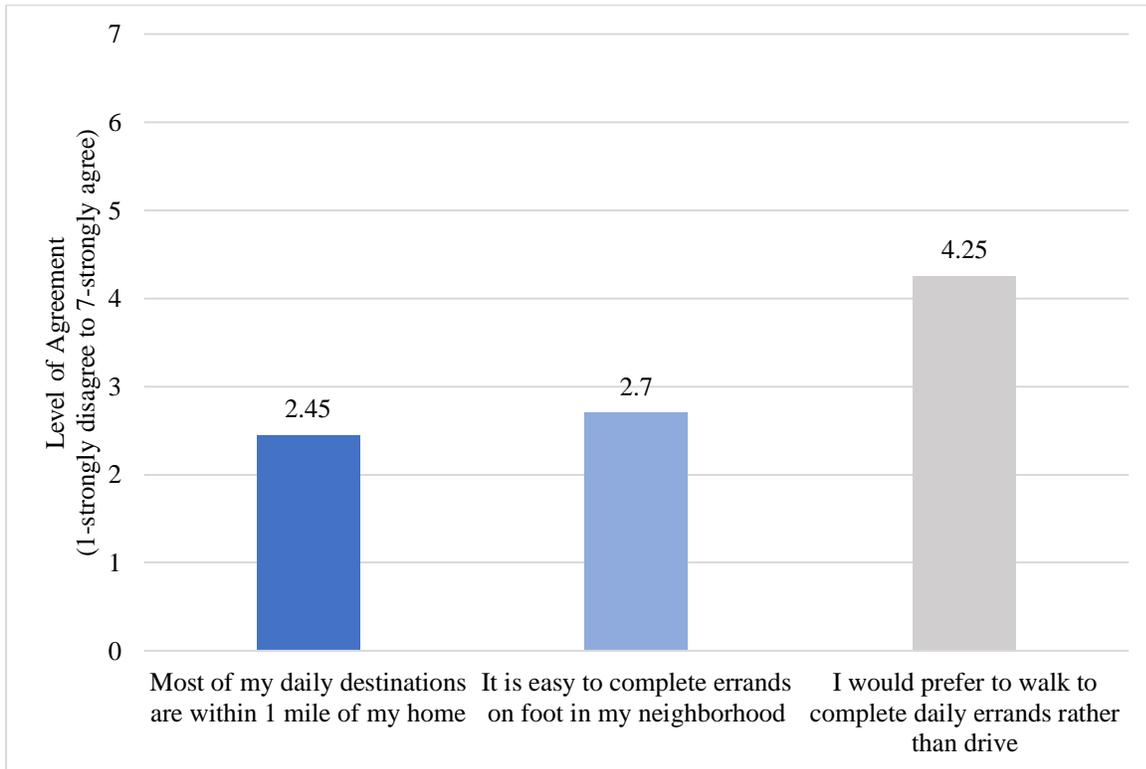


Respondents were asked to select their level of agreement with the following statements, from a scale of 1 (strongly disagree) to 7 (strongly agree):

1. Most of my daily destinations are within 1 mile of my home.
2. It is easy to complete errands on foot in my neighborhood.
3. I would prefer to walk to complete daily errands rather than drive.

The results are summarized in **Figure 5**. The strong level of disagreement with the first two statements may be related to the infrequency of walking trips revealed in **Figure 4**. In response to ‘I would prefer to walk to complete daily errands rather than drive,’ Tucsonans felt fairly neutral, but were slightly in agreement. However, this could be a result of poor walkability. Increased walkable development may increase Tucsonans’ level of agreement with this statement.

Figure 5 Participant responses to walking frequency statements



Tucsonans Wish They Had to Drive Less to Complete Daily Activities

Notably, in response (Yes = 1, and No=2) to the last survey question ‘Do you wish you had to drive less to complete daily activities, travel to work, etc.?’ , all respondents said yes. Although they may not currently prefer to substitute driving trips with walking trips, this indicates that investment in walking, biking, and transit infrastructure in Tucson would be aligned with Tucsonans’ wants and needs.

When asked to list liked and disliked neighborhood features, participant responses revealed common themes. Common neighborhood features favored by participants included **proximity to common destinations, low traffic levels, low sound pollution, and well-maintained roads and paths**. Common neighborhood features participants disliked included **poor sidewalk and road conditions, excessive traffic, limited access to services and activities, and lack of streetlights**. These features should be taken into consideration for future neighborhood development in Tucson, especially if walkability is promoted, because when participants’ perceptions are positive about their neighborhoods, they are more likely to choose walking as a transportation mode (Gebel, Bauman, & Owen, 2009).

Case Study of the Corbett Porch Complete Streets Project

Recently, several planning and policy documents have encouraged more walkable and multi-modal design, including Plan Tucson, the Infill Incentive District, and the Complete Streets ordinance. More detailed information on how these documents relate to walkability can be found in **Appendix B**. The main findings from the Corbett Porch Case Study are briefly summarized here.

Overall, this project planned for traffic safety, street connectivity, accessibility, walking infrastructure, and aesthetics/perception – five of the eight built environment features the reviewed literature from the previous section identified as promoting walkability. Of the specific features Tucsonans considered important, the project compensates for sidewalk width by reclaiming parts of the street and aims to restrict car traffic on the travel route. However, data analysis illuminates more shortcomings of the Corbett Porch intervention than successes concerning the project's goals. Namely, there were no significant differences observed in vehicle or bicycle volume, pedestrian activity, or car stopping behavior (with the exception of 'in crosswalk' stops, which significantly increased from pre- to post-intervention).

That being said, there are many limitations of this study, and further analysis is really needed to make a more definitive conclusion about the project's impacts. The sample sizes for data collection were very small, which may skew any statistical tests performed. Additionally, data was taken immediately before and after the project intervention, and behavior may continue to change as the project becomes more well-known throughout the community. Further, this project is one of the first of its kind in Tucson and is representative of a larger community push for walkable space. As such, the project is by no means a failure, and its impact should continue to be monitored.

Discussion and Recommendations

Discussion of the results of this research are parsed out by the initially presented research questions in the following subsections.

How often, and for what trip purposes, are Tucsonans currently using walking as a transportation mode?

Both the 2009 NHTS and 2017 pilot study components spoke to this question. The NHTS revealed that most trips (~83%) are taken by motorized vehicle. Walking was the most frequently used active mode of transportation, constituting 12% of all trips. Cycling and public bus amounted to just 1.4% and 0.8% of all trips, respectively.

These NHTS results were reiterated by the 2017 pilot study on walkability. Survey results showed that Tucsonans rarely walked to frequently visited locations (i.e., grocery store, school, work). Tucsonans also indicated that many of their frequently visited locations were over a mile away from home, and that running errands on foot were not easy, which provide some explanatory context for the lack of walk-mode trips.

The NHTS filled in a gap of the 2017 pilot study when it came to demographic and socioeconomic indicators and gave a broader overview of the relationship between trip purpose and travel mode. Asian Tucsonans' in the NHTS sample made the highest percentage of their trips by walking, on average (~18%). They were followed by Black Tucsonans, who made ~13% of their trips by walking on average. Black Tucsonans also made the lowest percentage of their trips by car (66%), while Native Hawaiian/Pacific (Islander) Tucsonans' made the highest percentage of their trips by car (95%). However, the percentage of trips made by walking or biking did not vary significantly by racial identity. Further, racial identities expressed in the NHTS sample do not fully align with those in Tucson's greater population, and so travel behavior exhibited in the NHTS may not be fully representative of all Tucsonans'.

When it comes to income, a generally observed trend was an increase in the percentage of trips made by walking and a decrease in the percentage of trips made by driving as income decreased. Respondents in the lowest income category (\leq \$24,999) made 15% of their trips by walking and 77% of their trips by driving, compared to those making \geq \$75,000, who made just 8% of their trips by walking and 86% of their trips by driving. It was also found that the percentage of walk and car trips varied significantly across income categories.

Examining trip purpose revealed that most work and shopping trips (92%) were made by motorized vehicle, compared to just 4% and 10% of work and shopping trips made by walking, respectively. Recreational trips had the greatest share of walk-trips (32%), but a majority of trips in this category (64%) were made by motorized vehicle.

Overall, Tucsonans' are not walking as a main form of transportation across trip purposes, racial identities, and income groups. However, 82% of the pilot study survey respondents indicated they would prefer to drive less to complete daily activities. This reveals that Tucsonans would be receptive to development that supported alternate modes of transportation, including walking.

What built environment features or perceptions would promote walkability in Tucson, and how do these compare to the factors identified as important in existing literature?

The 2018 pilot study literature review and Tucson resident survey shed light on this question. The literature review revealed eight major features of/in the built environment that contribute to fostering a walkable urban environment. These included land-use mix/proximity, residential density, traffic safety, street connectivity, accessibility, walking infrastructure, aesthetics/perception, and safety from crime, in order of most to least frequently mentioned.

94% of survey respondents indicated location proximity was an important factor in their decision to walk as a mode of transport—making it the most important factor overall and aligning it with the results of the literature review. This result means that more mixed-use development should be considered to increase Tucson’s walkability. However, the risk of gentrification and displacement that might come with additional infill development should be considered. Discussions between the city, planners, and community residents are important to make sustainable and equitable decisions with regard to this matter.

It should be noted that this may be an important place-specific result. Tucson’s extreme summer heat may limit the walkable distance for some folks even lower than the generally considered 0.25-mile radius. The survey was also conducted in the spring, as temperatures began to rise after an unusually hot 2018 winter. Thus, survey respondents may have placed additional emphasis on destination proximity in their answers. However, this is purely conjecture, and future research on how travel behavior might change seasonally is necessary.

Do the built environment factors identified as improving walkability (by either Tucson residents or the literature) have an impact on travel behavior?

Overall, the Corbett Porch project did not seem to significantly impact pedestrian activity or safety, despite its inclusion of five of the eight built environment features the reviewed literature from the previous section identified as promoting walkability: traffic safety, street connectivity, accessibility, walking infrastructure, and aesthetics/perception.

One potential explanation for this result is that the project did not address destination proximity, which is the most important built environment factor contributing to walkability for Tucsonans. The site’s location is in a C-3 commercial zone extending from Stone Ave. to Main Ave³. Mid-rise commercial development is permitted here, but provisions can be made for other uses. Additionally, this area is included in the Infill Incentive District (IID), zoning overlay implemented by the City to encourage more infill, transit-oriented development (see **Appendix B** for more information). The site’s new zoning overlay (Urban Overlay District 1) allows for a greater variety of land uses (retail/trade, civic use, recreation, industrial, commercial, residential) and offers incentives for developers, such as increased building height allowances and density thresholds as well as exemption from parking requirements.

³ Zoning overlays and information provided by City of Tucson GIS service ‘Map Tucson’, at <https://maps.tucsonaz.gov/maptucson>

Currently, the intersection houses several businesses, including Exo Roast Co., Tap & Bottle, Desert Vintage, Let's Sweat, Miller's Surplus, the Royal Room, and Anello Pizza. The site is also en route to downtown, historic 4th Ave., and the Ronstadt Transit Center. Despite its close proximity to other heavily commercial areas, the project is over 0.25-miles away (the general walkability threshold) from the nearest more residential neighborhoods (e.g., Iron Horse, Dunbar Springs). Thus, destination proximity is not fulfilled except for those living on 4th Ave. or downtown. Lack of a complete sidewalk network and bike lanes, poor road conditions, heavy car traffic, and poorly maintained underpasses act as barriers for active transportation to and from the project site. These barriers will grow even larger once the Downtown Links project directs freeway traffic through this area.

Despite major limitations, the project is one of the first of its kind near Tucson's downtown. Data collection efforts need to be continued before making any definitive assessments about the project's impact. From a broader perspective, the project's implementation in a city whose urban form was built by and for the car is a success in and of itself. Regardless of the outcomes of this particular project, its role in the larger "complete streets" movement is a promising step for Tucson's future development. Disruptive technologies, like autonomous vehicles, have the potential to drastically alter status-quo transportation systems, for better or for worse. The Corbett Porch intervention sends the powerful message that the streets are and will continue to be for all users, no matter what changes may come. As analysis continues, the project serves as a reminder of that message to city planners, policymakers, and engineers.

Limitations

Key limitations expressed throughout this study are listed below:

- The NHTS sample was not fully representative of Tucson's greater population. The NHTS sample was, in general, more white and wealthier than Tucson's population overall.
- The NHTS sample data is from 2009. Much development has happened in the city since then, which may make the data outdated in giving a clear picture of walking behavior now. However, much of that development is concentrated in certain areas of town (i.e., downtown/University).
- The 2018 Pilot Study questionnaire was distributed in Spring as temperatures were starting to rise. It is unclear if walking behaviors change with seasonality (this is likely given Tucson's hot summers but could not be addressed with this data).
- Count data for the Corbett Porch case study was highly limited, and small sample sizes may account for some of the lack of significance in the project's impact. Further, post-intervention data was taken soon after implementation, and gathering more data as folks become aware of the project and used to the changes would give a clearer picture of the project's impact.

Recommendations

In providing a broad overview of current walking trends in Tucson, the culmination of the research also highlights two key recommendations for future development. First, more coordination between transportation and land use planning is necessary for increased walkable development. Namely, More parity between transportation planning projects and land use planning goals should be established—while Tucson has several planning initiatives aimed at developing multi-modal and pedestrian-oriented spaces (see **Appendix B**), transportation projects seem to counteract these efforts. A regular framework for interaction and co-development between transportation and land use departments can encourage this process. The gap here is likely due to the state of our current transportation success metrics and plan requirements.

Additionally, this research highlights that the built environment is not a sole explanatory variable for walking behavior. There is still a large research gap investigating the social drivers and outcomes of walkable environments. Dedicating more effort to this research area can help us plan more holistically for walkable urban places. Both recommendations are explored further below.

Coordination between transportation and land use planning

Improved parity between transportation planning projects and land use planning goals should be established to build a more walkable Tucson. While recent planning initiatives (e.g., the Infill Incentive District, Complete Streets Ordinance) consider pedestrian activity and its subsequent benefits, regional transportation projects (e.g., the Downtown Links project, the Broadway Boulevard expansion) continue to prioritize vehicle travel with little (if any) consideration for other modes. Tucson's transportation projects for pedestrian infrastructure are often more reactive than proactive, namely in that safety features are added after a pedestrian casualty in an area.

It is important to note that several staff in Tucson's Department of Transportation are starting to shift away from historic trends for a more multi-modal city. The implementation timescale and requirements to adhere to the RTP and TIP seem to be the critical barriers on this front. For example, the Broadway Boulevard Improve Project had its origins in the 1980s but has yet to start being built. However, funding attached for the project includes certain stipulations that limited the ability for both current TDOT staff and the public to update the project to meet the city's present needs, not those (inaccurately) projected in 1980. Unfortunately, this seems to be a common trend in transportation planning, and a new framework for transportation project implementation that allows for more flexibility in required transportation planning documents is necessary.

The reason that such a framework has yet to come may be that it is ambiguous who should initiate such a process—TDOT? The Regional Transportation Authority? The Planning Commission? The mayor and council? The state legislature? Much of the intersection of transportation and land use currently is focused on transportation impacts on a parcel level vs. at a city- or regional-level, and not on timescale and implementation frameworks.

Developers often have to complete transportation impact analyses (TIAs), and then become subject to fees or project changes to mitigate their impact on the transportation system. Given the prominence of level of service (LOS)⁴ as a transportation success metric, road widening is often a required mitigation measure. Yet, this may not even be an effective way to decrease congestion and increase LOS. In a study of Los Angeles road widenings, Manville (2017) finds that laws requiring such mitigation are unjustified by traffic predictions, are not based on evidence of potential effectiveness, and do not have clear measurable goals:

“Cities adopted parcel-level mitigations not because they were shown to work, but because other ways to address congestion were politically or fiscally unfeasible... the standards underlying [these laws] are often in error, and in some cases simply unverifiable. Such immunity to measurement is antithetical to sound policy, but—perversely—the pursuit of a largely unmeasurable goal helps ensure the law’s persistence, because it leads planners to largely ignore the law’s nominal purpose and instead emphasize its measurable process. The law, in short, is all tree and no forest; while its intent may be to alter outcomes on the network of streets, all of its stakeholders are focused on individual parcels” (Manville 2017, p. 390).

Further, LOS has come under criticism for valuing vehicle-movement over people-movement, promoting excess roadway capacity, and encouraging sprawling development (Dumbaugh, Tumlin, & Marshall, 2014). Municipalities are beginning to explore metrics of system performance that extend beyond trip-based mobility—vehicle miles traveled, greenhouse gas emissions, safety, and equity, to name a few—and Tucson should follow suit. A regular framework for interaction and co-development between transportation and land use departments can begin to address problems with transportation project implementation and evaluation to remove barriers preventing more walkable development in the city. These departments must also work together to promote land use mix/proximity, residential density, traffic safety, street connectivity, accessibility, walking infrastructure, aesthetics, safety from crime.

Connection of walkability to social and cultural values

One shortcoming of this research is its lack of emphasis on social and cultural drivers of walkability. A previously cited study by Landgrave-Serrano et al. (2019) comparing predominantly Mexican-American and Non-Hispanic White neighborhoods provided new insight into the importance of the social environment and walkability. Through on-street interviews, the research team found that elements of the physical environment (maintenance, lighting, street crossings, sidewalk presence, shade trees) were more important drivers of walking in Non-Hispanic White neighborhoods, while aspects of the social environment (social interaction, community identity, social cohesion, crime/security) were more important drivers in Mexican-American neighborhoods. This research resulted in the development of a Qualitative Pedestrian Environment Data (QPED) toolkit, a practical tool available for collecting information on pedestrian social environments. Such a tool can help researchers and practitioners better understand the social and cultural drivers of walking.

⁴ LOS is a common transportation performance metric that evaluates roadways based on motorist delay and free-flow speed (Dumbaugh, Tumlin, & Marshall, 2014).

This research is particularly important, as it is currently a blind spot in walkable development. The Corbett Porch case study revealed that even a project that includes features for a walkable built environment may have no real impact on travel behavior. If decisionmakers can better understand a) the social and cultural drivers of walking and b) their relative influence, then they can plan policies to foster such drivers as complements to infrastructure-based projects. Relying on infrastructural development alone to foster walkability in Tucson is, at best, a less effective approach than when combined with socially-oriented policies, and at worst, a critically uninformed (and subsequently highly ineffective) strategy.

Future Research

Based on the previous recommendations, the following is a non-exhaustive list of potential projects or actions to promote walkability in Tucson:

- An overview of Tucson's transportation plans, their legal authority, and their relationship to state and federal law
- A series of facilitated workshops with city and county policy decisionmakers, TDOT, the RTA, The Pima County Transportation Department, and the Tucson Planning Department aimed at creating a framework for consistent inter-department interaction
- Development of a statistical model and practical tool, calibrated to Tucson, to estimate walking behavior
- Use of the QPED tool developed by Landgraves et al. to learn more about Tucson's social environment and its relationship to walkability
- An updated Household Travel Survey in Tucson to collect more up-to-date data for analysis of walking behavior

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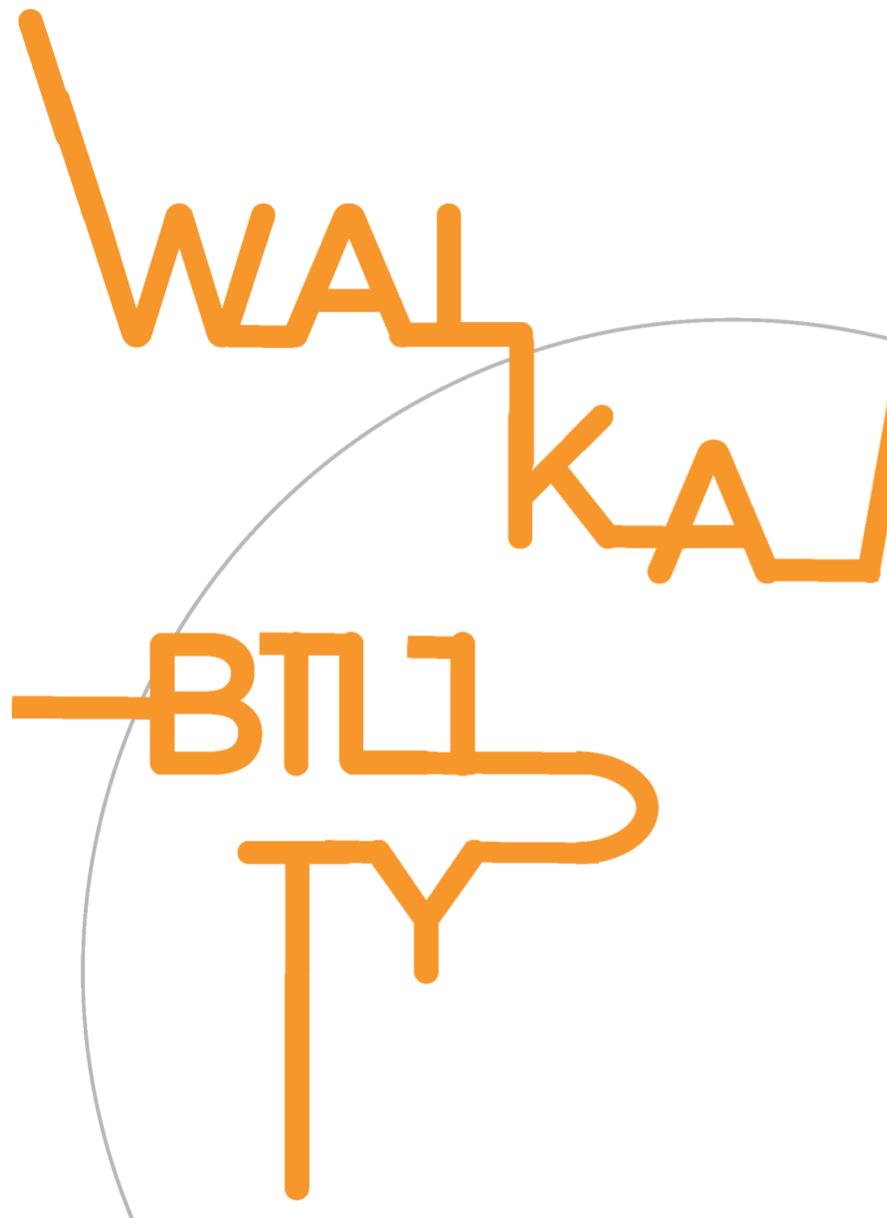
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Appendix A

2018 Pilot Study Report

Originally prepared for SBE 380 – Research Methods in Spring of 2018



LOWERING TUCSON'S CARBON FOOTPRINT

Can Tucsonans lower one footprint by increasing another?

GABBY ABOU-ZEID

*SBE 380
PILOT STUDY*

INTRODUCTION

Greenhouse gases have played a major role in global climate change. The greenhouse effect, where gases like CO₂, NO_x, and CFCs (chlorofluorocarbons) trap heat in our atmosphere, is accelerated and masked by air pollution, much of which comes from the use of fossil fuels as a primary energy source (Ramanathan & Feng, 2009). These fossil fuels, like oil, promote our automobile driven society. In order to reduce our dependence on fossil fuels and mitigate their effects, alternate modes of transportation (including public transport, biking, and walking) should be explored.

In particular, walking produces the least amount of greenhouse gas as a mode of transport. Additionally, walking can have positive effects on a community's social and economic sustainability. Those who walk as a major mode of transport have decreased risks of heart disease and obesity (Frank et al 2006). Additionally, communities that cater to the pedestrian see economic growth and development due to increased shop accessibility, efficient use of land, and community ties to local businesses (Litman 2003). Communities can plan for this by looking at **walkability**, a measure of how successfully the built environment facilitates walking as a transportation mode. Planning with walkability in mind will lead to more successful, thriving communities.

RESEARCH QUESTIONS

While walkability and its benefits can be planned to suit every local community differently, the problem of climate change, air pollution, and dependence on fossil fuels is a prevalent **global issue**. Pollution issued from one area of the world can have negative consequences on other locations via the greenhouse effect and fast atmospheric transport of pollutants (Ramanathan & Feng 2009). As the world becomes continually urbanized, fossil fuels seem even more important in powering our daily lives: cities are responsible for the use of 75% of the world's energy supply and 80% of global greenhouse gas emissions (Newman et al 2017).

WHAT FEATURES OF THE BUILT ENVIRONMENT PROMOTE WALKABILITY IN TUCSON?

HOW DO THESE COMPARE TO THE FACTORS IDENTIFIED AS IMPORTANT IN EXISTING LITERATURE?

HOW CAN WE USE THIS KNOWLEDGE TO PLAN FOR WALKABLE DEVELOPMENT?

In recent years, designing urban spaces for walking has been on the rise, which is evident given the emergence of the term walkability in current literature. With the rise of downtowns and decline of the suburbs, the ability to reduce automobile dependence (as well as its economic and social costs) is more appealing. If walking as a mode of transportation could be a viable alternative to auto travel,



it could slow the acceleration of global climate change and allow the development of less-sprawled, high-density cities. Given the potential hazards climate change has in store for many coastal areas, this might be a necessary design factor to plan for future migration and climate adaptation.

The research at hand will provide a framework to guide future development in Tucson in a way that promotes walkability by assessing what factors are important to Tucsonans when it comes to walking. Additionally, it could provide insight for the creation of a walkability index specifically for hot and dry climate types that could be applied to other geographic locations, and even spur a movement to create indices based on climate type in a broader, widespread movement.

The goals of the proposed study include assessing Tucsonans' current attitudes and habits regarding walking, identifying built environment features that would make Tucson more walkable according to its residents, and gathering secondary data outlining factors that contribute to a walkable built environment for comparison. The culmination of these goals would contribute to a larger want to determine if walkability factors in the built environment are specific to place and climate type, and also to provide guidance for future walkable development in Tucson.

THE RESEARCH AT HAND WILL PROVIDE A FRAMEWORK TO GUIDE FUTURE DEVELOPMENT IN TUCSON IN A WAY THAT PROMOTES WALKABILITY. ADDITIONALLY, IT CAN PROVIDE INSIGHT FOR CREATING A WALKABILITY INDEX SPECIFICALLY FOR HOT AND DRY CLIMATE TYPES.

LITERATURE REVIEW

Walkability is a subject of interest in the 21st century given rapid rates of urbanization and climate change. As a result of these factors, urban planning as a field has come to acknowledge the **benefits of walkability** as a mode of transport and criticize traditional planning modes. Low-density, sprawled, and single-use areas decrease human physical activity, spike obesity rates (and subsequent health problems) and cause increased pollutant emissions due to reliance on the automobile as a main mode of transport (Frank et al. 2006). Studies, such as that conducted by Frank et al., have found that a neighborhood's level of walkability is directly proportional to residents' level of physical activity and inversely proportional to their BMI. Walkability indices also accurately predict daily vehicle miles traveled and pollutant emissions.

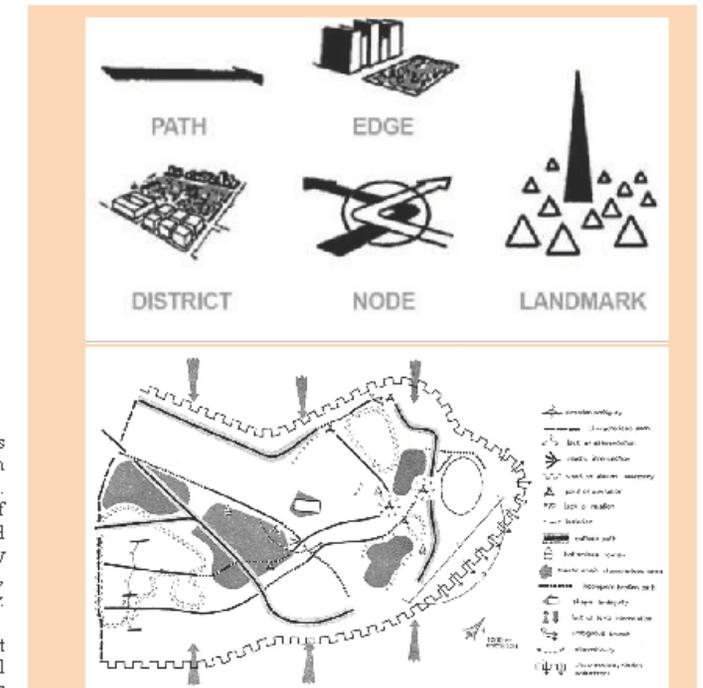
Furthermore, societal dependence on the automobile has negative consequences beyond environmental damage. As cities become more sprawled, the amount of time people spend behind the wheel is reaching new heights. This has led to an increased amount of driving induced stress, which manifests in more aggressive driving patterns and anxiety (Rasmussen et al. 2000). The percentage of income spent on transportation has also seen an increase in recent years, offsetting the benefits (such as lower housing and land costs) given by living further from a city's urban core (Hartell 2017). These additional negative factors make increased walkable development more imperative.

There is an abundance of research examining various features which create a walkable environment. In general, an assessment of walkability can be compiled based on **physical features of the built environment, urban design qualities, and individual experience-based reactions** (Ewing and Bartholomew 2013). Physical design features might include sidewalk width and conditions, traffic volume, and human density. Other urban design qualities for evaluation are legibility/imageability, connectivity, human scale, and complexity. When combined with analysis of individuals' reactions, such as opinions on safety and comfort level, these features can be used to predict walking behavior.

Despite recent advancements, diversity in existing research is necessary. Previous research on walkability has focused solely on "gross qualities", like population density, connectivity, and park proximity to create an index (Ewing et al. 2006). Looking over more nuanced qualities of the urban environment as measures of walkability might reveal additional benefits or stronger correlation to improved human health. Authors Ewing et al. found that walkability is strongly statistically significantly related to 5/9 urban design qualities (imageability, enclosure, human scale, transparency, complexity), with human scale as the most important factor in the study.

Additionally, the **health benefits** of walkability have been robustly studied in recent years, but **social benefits** have not been as widely explored despite the value of social capital in human health (Rogers et al. 2011). Residents in more dense neighborhoods close to downtown generally feel more of their daily locations are accessible by foot. Of the people in these type of neighborhoods, over 50% of them walk every day or several times per week, compared to only 23% in more suburban neighborhoods, to complete errands or necessary activities. Rates of social capital are higher overall for more walkable neighborhoods, although this difference is not always statistically significant.

Discrepancies in urban design can cause some neighborhoods to be more walkable than others based on demographic makeup, meaning there may exist inequality in ability to be physically active (and to reap the subsequent benefits of physical activity) (Kelly et al. 2007). Predominantly black neighborhoods were found to be 15 times more likely to have **sidewalk obstructions** and 38 times more likely to have **uneven sidewalks** than their white counterparts by Kelly et al. Additionally, blocks with the highest poverty rates often have more physical disorder (e.g., rundown buildings, poor street quality). There is a prominent difference in neighborhood investment based on race and income level demographics, lowering the overall physical activity opportunities and quality of life for black and low-income residents.



IMAGEABILITY, VISUALIZED

Images from urban planner Kevin Lynch's *The Image of the City* (1960), which proposed that successful cities are imageable because they reduce user stress and confusion. According to Lynch, an imageable city was based on recognized surroundings through paths, edges, districts, nodes, and landmarks.

PROPOSED METHODS

STUDY AREA

The research area is Tucson, Arizona and smaller surrounding towns and cities (Oro Valley, Marana, and South Tucson). Tucson's population reached a half million by 2002 (more including the entire metro area), and the city continues to see rapid growth and development in its central and surrounding areas. This growth is spurred by a number of factors, including the presence of the University of Arizona, as well as the location of many technical firms (e.g., Raytheon).

Tucson's location in the Sonoran Desert makes it a primary location for analysis of a hot and dry climate. The intense heat in the desert summers certainly makes the outdoor environment an extreme one, which is important to consider when designing for walking as a mode of transportation. As record temperatures continue to be set with the acceleration of climate change (Pollack & Shen 1998), analysis of what makes people walk in these conditions is important and relevant to the broader research problem of reducing greenhouse gas emissions. Tucson as a study area is thus important as it bridges concepts of adaptability (learning how to design for warmer climates) and prevention (reducing greenhouse gas emissions) to climate change.

Figure 1 shows a map of the study area.

RESEARCH DESIGN

The research is structured with a cross-sectional design. Current literature will be collected and gathered to determine factors of importance that contribute to a more walkable built environment. Then, a questionnaire will be developed using Qualtrics software. The questionnaire will have participants rank the initially collected walkability factors in terms of importance when deciding to walk to complete daily activities. Additionally, the questionnaire will assess participants' current use of walking as a mode of transport, and identify features in participants' neighborhood built environments that they like or dislike.

A conceptual framework for the research design is outlined in Figure 2.

PROPOSED METHODS

1. Search existing literature on Google Scholar (via UA Database access) to find background information on / features that contribute to walkability. Literature should be **peer reviewed**

Keywords include walkability, walkable design, transit-oriented development, urban design AND pedestrian, urban design AND walking, walking AND transportation

FIGURE 1 Tucson and the surrounding study area



KEYWORDS INCLUDE WALKABILITY, WALKABLE DESIGN, TRANSIT-ORIENTED DEVELOPMENT, URBAN DESIGN, PEDESTRIAN, WALKING AND TRANSPORTATION

2. Create list of factors identified in found literature that have been identified as improving walkability (i.e. "built environment factors")

- Note features mentioned in each piece of literature
- Record how many and which pieces of literature name that factor as one of importance/as a measure of walkability
- Note the location of researchers' institutions or programs
- Organize findings in a table (see 'Table 2' for example organization)
- easeure of walkability
- Note the location of researchers' institutions or programs and years each literature article was published
- Organize findings in a table(s) (see 'Table 3' for example organization)

3. Select 5-10 built environment factors to test importance of in Tucson (or, other area of study)

- Factors can be the most popular from the literature search, or others potentially specific to the area of study that did not come up

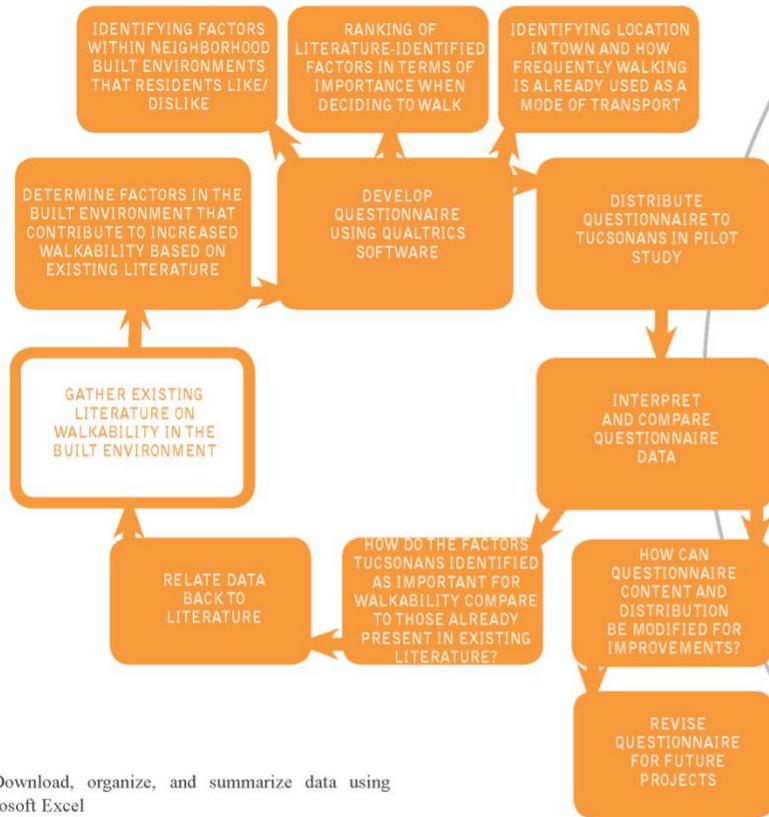
4. Build a survey using Qualtrics software including:

- Questions where participants must **rank the factors** identified in previous step in terms of their importance when deciding to walk to complete an errand or activity
- Questions where participants indicate their current preference to walk as a mode of transportation vs. using other modes based on their area of town
- Questions where participants identify how frequently they walk to common locations, like work or school
- Questions where participants have space to elaborate on which neighborhood features they like and dislike
- Be sure to add recoded values to text-based data

5. Distribute questionnaire link digitally (across social platforms and email) and in-person using electronic tablets to record user answers

- Facebook
- Instagram
- UA students and other Tucson (or area of study) residents via email
- In person: at grocery store via tablet
- **Snowball sampling** – ask participants to pass the survey along to others

FIGURE 2 Proposed conceptual framework



6. Download, organize, and summarize data using Microsoft Excel

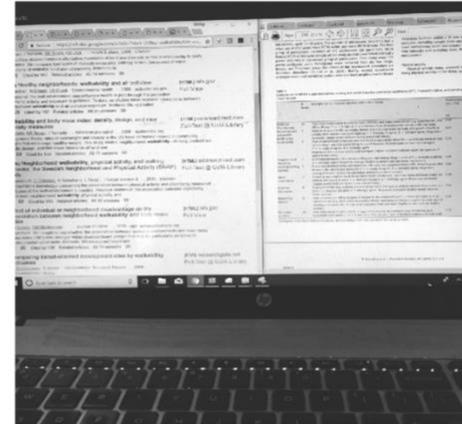
- Calculate means for Likert-scale questions and text-based questions with recoded values to summarize attitudes and feedback
- **Make note of the following based on mean values:**
 - How important were certain factors compared to others?
 - How likely are Tucsonans (or study area residents) already to walk as a transportation mode?
 - How often are Tucsonans walking to commonly visited locations?

HOW IMPORTANT WERE CERTAIN FACTORS COMPARED TO OTHER BASED ON MEASURES OF CENTRAL TENDENCY?
 HOW LIKELY ARE TUCSONANS (OR STUDY AREA RESIDENTS) ALREADY TO WALK AS A TRANSPORTATION MODE?

- Create a list of liked and disliked features from open-ended text based survey questions
 - What features should be included into future neighborhood design to promote walking? What features should be excluded?
 - Note patterns in participants' answers
 - Categorize responses as **physical features, urban design qualities, or individual reactions**

7. Compare summaries to those found in current literature to determine if Tucsonan's (or study area residents) preferences matched those of participants in other studies

- Did participants identify the same built environment factors as the literature as important to walkability? If not, **try to identify factors that might contribute to the study area's differences** (e.g. demographics, climate). Use this to draw conclusions about the need for place-specific walkability indices.



**LAND-USE MIX
 RESIDENTIAL DENSITY
 STREET CONNECTIVITY
 TRAFFIC SAFETY
 INFRASTRUCTURE**



DATA SOURCES AND MEASURES

TABLE 1 Descriptions of measures, data types, data sources, and purpose

Measure	Data Type	Data Source	Purpose
Built environment features and walkability background information	Secondary	Academic Journals via UA Library Databases*	Identification of built environment features that promote walkability
Importance of built environment features when considering walking as a mode of transport	Primary	Questionnaire	Determining if Tucsonans' opinions match those found in the literature; determining if walkability indices should be place/climate specific
Frequency/ability to use walking as a mode of transport currently	Primary	Questionnaire	Identifying Tucson's walkability generally overall
Liked/disliked neighborhood features	Primary	Questionnaire	Identifying features to include or exclude for future walkable development

PILOT STUDY RESULTS

EXISTING LITERATURE REVEALS COMMON BUILT ENVIRONMENT FEATURES THAT PROMOTE WALKABILITY

A literature analysis of 22 research articles revealed **eight** major features of/in the built environment that contribute to fostering a walkable urban environment. These built environment features are summarized in **Table 2**. The authors and studies referenced are summarized in **Table 3**.

- LAND-USE MIX
- RESIDENTIAL DENSITY
- TRAFFIC SAFETY
- STREET CONNECTIVITY
- ACCESSIBILITY
- WALKING INFRASTRUCTURE
- AESTHETICS
- CRIME SAFETY



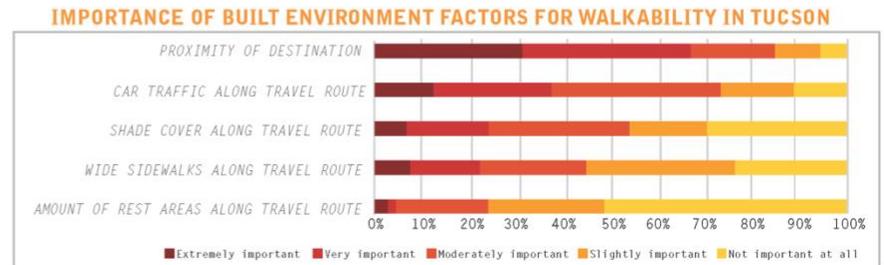
TABLE 2 Features of or in the built environment that facilitate walking, their operational definitions, and the number of times each feature appeared in one of 22 articles searched. Mentioning authors are listed.

Built Environment Feature	Operational Definitions	Frequency Mentioned	Mentioning authors
Land-use mix/proximity	Mix of residential and commercial buildings within neighborhood locations	18	Leslie, Cerin, Van Dyck, Manaugh, Gebel, Rosenberg, Carr, Smith, Sundquist, Frank Rundle, Litman, Gebel, Lovasi, Forsyth, Gauvin, Lo, Gallimore
Residential density	Population or developmental density within a neighborhood	15	Leslie, Cerin, Van Dyck, Duncan, Gebel, Rosenberg, Carr, Brown, Smith, Sundquist, Frank, Rundle, Gebel, Gauvin, Gallimore
Traffic safety	Slow speed limits, narrow streets, speed bumps, car traffic density	12	Leslie, Cerin, Van Dyck, Duncan, Gebel, Rosenberg, Carr, Marshall, Frank, Litman, Forsyth, Lo
Street connectivity	The degree to which streets connect to other streets and major intersections	11	Leslie, Cerin, Van Dyck, Duncan, Rosenberg, Carr, Brown, Sundquist, Gebel, Gauvin, Lo
Accessibility	Connectivity between streets and other development, and ease of access to connection pathways	9	Cerin, Manaugh, Litman, Geberl, Lovasi, Forsyth, Gauvin, Lo, Gallimore
Walking infrastructure	Sidewalks, crosswalks, traffic signals, streetlights, and other infrastructure that supports walking	8	Leslie, Cerin, Rosenberg, Brown, Marshall, Smith, Forsyth, Gallimore
Aesthetics/perception	Street cleanliness, building upkeep, green space	6	Leslie, Rosenberg, Brown, Ewing, Gebel, Forsyth
Safety from crime	Low crime rates, streetlights, community surveillance	5	Leslie, Cerin, Rosenberg, Forsyth, Lo

DESTINATION PROXIMITY IS THE MOST IMPORTANT BUILT ENVIRONMENT FACTOR INFLUENCING TUCSONANS' DECISION TO WALK

74 Tucsonans responded to the distributed Qualtrics questionnaire. Survey respondents were asked to rank five built environment factors from **1 (not important at all)** to **5 (extremely important)** based on how much each factor influenced their decision to walk as a mode of transportation. The built environment factors and average response values are summarized in **Figure 1** and **Table 3**.

FIGURE 1 Important of built environment factors to Tucsonans



HOW CAN THE BUILT ENVIRONMENT PROMOTE WALKING?

WALKABILITY IS A MEASURE OF HOW MUCH A CERTAIN ENVIRONMENT IS EASY, PLEASANT, AND VIABLE TO WALK IN AND AROUND. THERE ARE MANY FEATURES IN THE BUILT ENVIRONMENT THAT INCREASE AN AREA'S WALKABILITY.

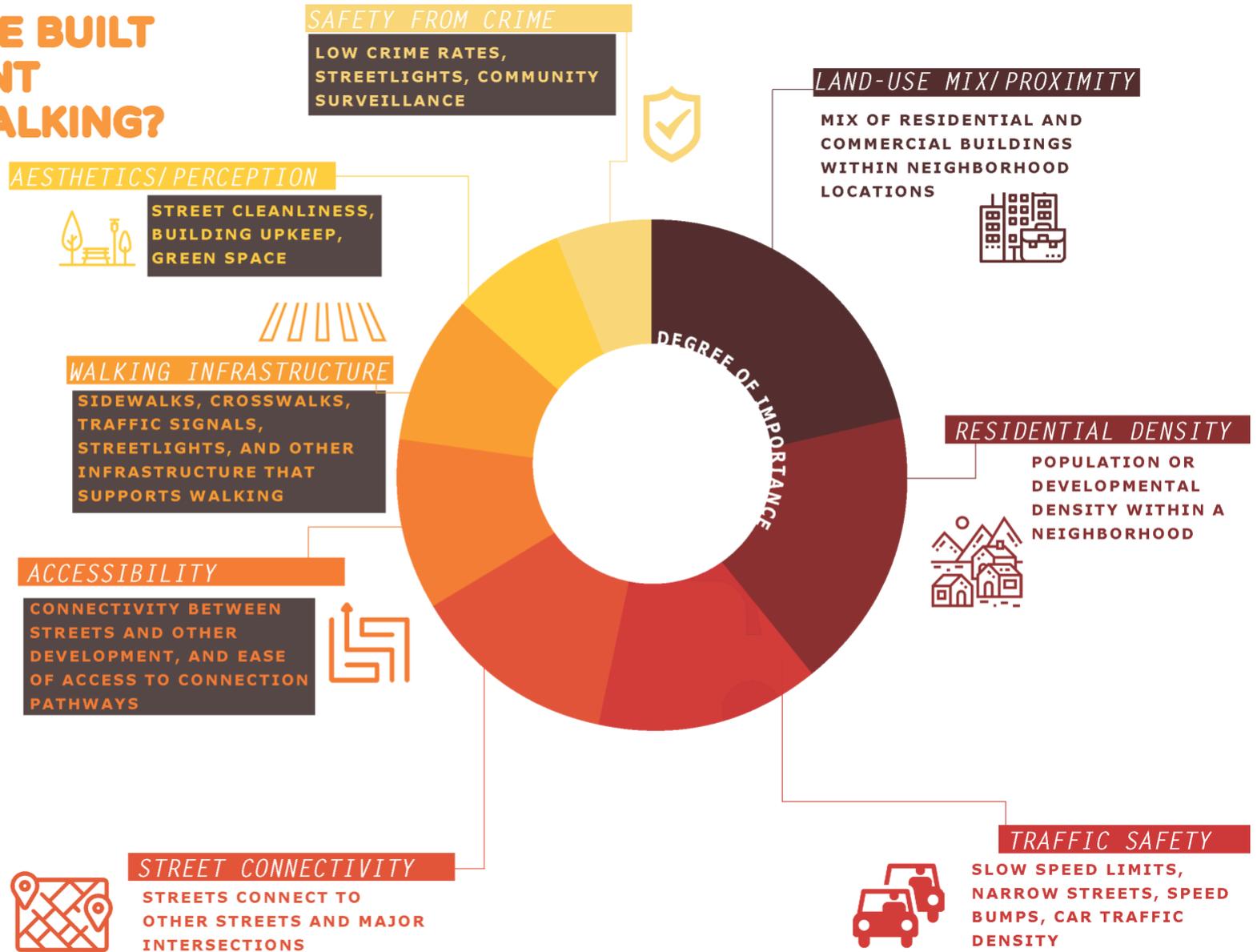


TABLE 3 Summary of research surveyed, including study location and year published.*

Leading Author	Study Area Location	Year Published
Leslie	Adelaide, Australia	2003
Cerin	King County, Washington	2006
Van Dyck	Ghent, Belgium	2010
Duncan	Across US Metro Regions	2011
Manaugh	Montreal, Canada	2011
Gebel	Adelaide, Australia	2009
Rosenberg	San Diego, Boston, Cincinnati	2009
Carr	Rhode Island Counties	2010
Brown	Salt Lake City, Utah	2009
Marshall	Vancouver, Canada	2009
Smith	Salt Lake County, Utah	2008
Frank	Seattle, WA ; Baltimore, MD	2010
Rundle	NYC	2009
Ewing	Across US Metro Regions	2006
Litman	N/A	2003
Gebel	Adelaide, Australia	2011
Lovasi	NYC	2009
Forsyth	Across US Metro Regions	2008
Gauvin	Montreal, Canada	2005
Lo	N/A	2009
Gallimore	Across US Metro Regions	2011

*Full citations can be found in the *References* section at the end of this document.

This reveals that **destination proximity** is the **most** important built environment factor that contributes to Tucsonans' choice of walking as a mode of transport. This corresponds to land-use mix being the most frequently mentioned built environment feature to support walkability in current literature. The **amount of rest areas along travel route**, which could be considering walking infrastructure or aesthetics/perception, ranked as the **least** important built environment feature, and as not important overall. Land-use mix should be focused on for further development in Tucson, because destination proximity is a very important factor in the decision to walk. Generally, locations over 1 mile away from ones' starting point are not considered to be within a comfortably walkable distance (Pivo 2011). It should be noted that none of these features came close to an average of 5 (extreme importance), instead ranking as moderately to slightly important. Future analysis should consider a **wider range of built environment features** for testing in order to determine those that are extremely important in convincing Tucsonans to walk.

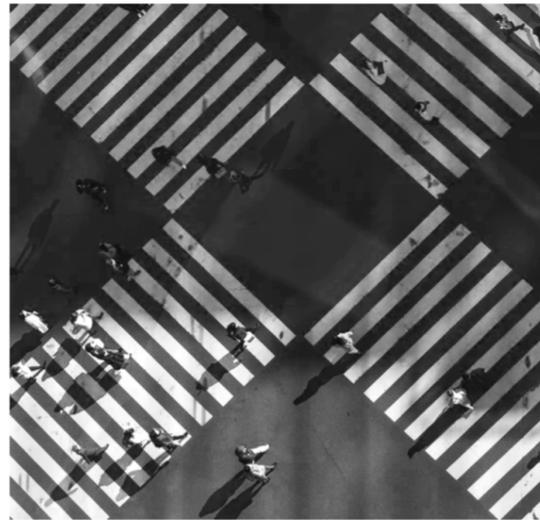


TABLE 4 Built environment factors and their average ranking from 1 (not important at all) to 5 (extremely important) based on questionnaire responses.

Built Environment Factor	Responses	Level of Importance
Proximity of destination	73	3.74
Car traffic along travel route	72	3.11
Shade cover along travel route	74	2.49
Wide sidewalks along travel route	67	2.45
Amount of rest areas long travel route	66	1.50

WALKING IS NOT CURRENTLY A MAIN MODE OF TRANSPORT IN TUCSON

Most Tucsonans don't currently use walking as a mode of transport to get to common destinations. When asked how often travel to the **grocery store, work, or school** was on foot, respondents indicated a frequency of a few times a month to **almost never** (based on recoded values, on a scale from 1, almost never, to 4, daily). These results are summarized in **Figure 2**.

Respondents were asked to set their level of agreement with the following statements, from a scale of 1 (strongly disagree) to 7 (strongly agree).

1. MOST OF MY DAILY DESTINATIONS ARE WITHIN 1 MILE OF MY HOME.
2. IT IS EASY TO COMPLETE ERRANDS ON FOOT IN MY NEIGHBORHOOD.
3. I WOULD PREFER TO WALK TO COMPLETE DAILY ERRANDS RATHER THAN DRIVE.

The results can be seen in **Figure 3**. The strong disagreement for statements 1 and 2 correlates to infrequency of walking trips revealed in **Figure 2** because walkable destinations, again, are typically considered to be between 0.25 to one mile from original destinations (Pivo 2011). **However**, it should be noted that, for various socioeconomic reasons, destinations outside of this range may need to be accessed for those without a car or adequate access to public transportation. Thus, increasing walkability in greater than 1 mile buffers in some areas may be beneficial.

Although statement 3 revealed Tucsonans would not currently prefer to walk over drive as a mode of transport to complete current activities, this could be a result of poor walkability. Increased walkable development may increase agreement with this statement.

FIGURE 2 Frequency of travel to grocery store, work, and school averages (1-almost never to 4-daily) of 74 respondents.

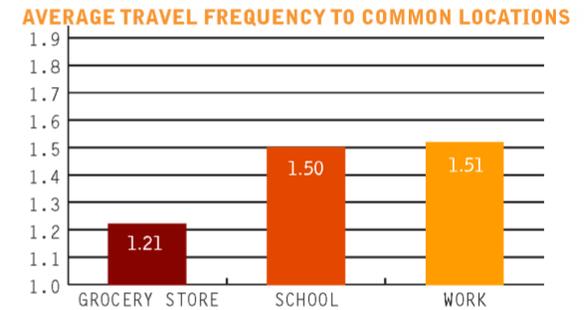
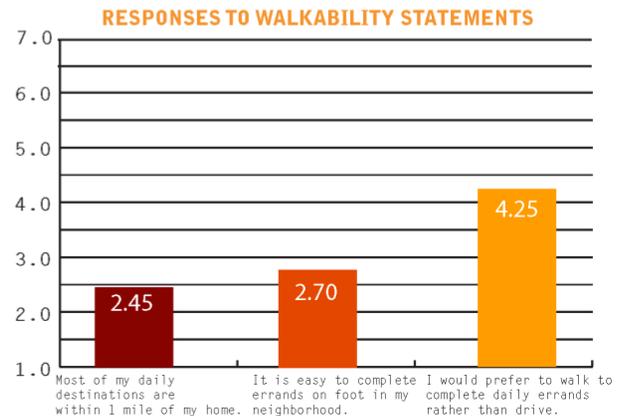


FIGURE 3 Participant responses to walking frequency statements from 1 (strongly disagree) to 7 (strongly agree).



TUCSONANS WISH THEY HAD TO DRIVE LESS TO COMPLETE DAILY ACTIVITIES

All participants (n=74) answered the last survey question, which read: **Do you wish you had to drive less to complete daily activities, travel to work, etc.?** ‘Yes’ was recoded as 1, and ‘No’ was recoded as 2. The average of the responses was **1.16**, indicating a vast majority of respondents would prefer to drive less. This indicates that investment into research and infrastructure to support walkability and alternative transport in Tucson would be aligned with Tucsonans’ wants and needs.

When asked to list liked and disliked neighborhood features, participant responses revealed common themes. Common neighborhood features favored by participants (n=68) included **proximity to common destinations, low traffic levels, low sound pollution, and well-maintained roads and paths**. Neighborhood features participants (n=64) disliked included **poor sidewalk and road conditions, excessive traffic, limited access to services and activities, and lack of streetlights**. These features should be taken into consideration for future neighborhood development in Tucson, especially if walkability is promoted, because when participants’ perceptions are positive about their neighborhoods, they’re more likely to choose walking as a transportation mode (Gebel 2011). However, Tucsonans might still opt to choose another method of transportation (public transit, cycling) over driving and walking with improved infrastructure.

SIGNIFICANCE

Overall, results from the pilot study demonstrated a need for more walkable development in Tucson. 82% of respondents indicated they would prefer to drive less to complete daily activities. This reveals that Tucsonans would be receptive to development that supported alternate modes of transportation, including walking. Given that there is a wave of interest surrounding Tucson’s future development projects, such as the large housing structures proposed for 4th Ave, introducing sustainable transportation as a benefit for Tucson’s community is imperative sooner rather than later.

Additionally, the study illuminates which features should be developed in order to encourage Tucsonans specifically to walk more. 94% of respondents indicated location proximity was an important factor in their decision to walk as a mode of transport. This means that more mixed-use development should be considered to increase Tucson’s walkability. However, the danger of gentrification and displacement that might come with market-rate downtown housing should also be avoided. Discussions between the city, planners, and community residents are important to make sustainable decisions with regard to this matter.

This study has also indicated a lack of walkability in Tucson’s current built environment, given that a majority of respondents don’t currently walk to frequently visited locations. The indication of community support for projects that increase walkability might carry some influence for city planners in their decision making.

FUTURE STUDY RECOMMENDATIONS

The following adjustments should be made from the original pilot study. Adjustments have been included in the proposed methods.

SEARCH CURRENT LITERATURE BEFORE DEVELOPING QUESTIONNAIRE

Despite best intentions to start collecting data right away, diving more into literature on built environment features that promote walkability would have been beneficial before developing the questionnaire. While some articles were reviewed beforehand, the majority were surveyed after questionnaire development. The built environment features included in the questionnaire were thus more based on previous knowledge than important factors identified by current research, making comparison between Tucsonans’ preferences and the preferences of other study populations difficult.

Additionally, a more in-depth literature review completed beforehand would have revealed some interesting ideas for question variety. For example, photo of various streetscapes could have been included, and participants could have identified features they liked and disliked, or ranked multiple streets on perceived walkability.

REFINE RESEARCH QUESTIONS

The research questions presented at the beginning of this document were as follows:

1. What factors are of primary importance to Tucsonans when considering walking as a form of transportation?
2. How do these compare to the factors identified as important in existing literature?
3. What aspects of the built environment do Tucsonans like or dislike about their neighborhoods?

However, only the first survey question truly addressed the first two research questions, and because the built environment factors were not pulled from thorough literature analysis, the information obtained to answer these questions was lacking.

The last question was addressed by asking participants to identify neighborhood features they liked and disliked. However, this research question should have focused in on built environment features that make for a comfortable **walking** environment specifically. Additionally, many questions in the middle of the survey addressed a research question absent from the beginning of this document that provides valuable insight:

4. What are Tucsonans’ current walking patterns and attitudes?

FUTURE STEPS

In addition to addressing the previous issues, future analysis or studies might benefit from or include...

- Varying questionnaire distribution methods to increase response rates (i.e., not only rely on electronic distribution)
- Incorporating more random sampling (since most survey respondents were likeminded family and friends, results may have not accurately represented the target population of all Tucsonans)
- Identifying neighborhoods in Tucson that align with participants likes/dislikes, and developing a second survey to determine perceived walkability of residents of those neighborhoods (to determine whether the presence of various factors actually influence behavior)
- Hosting community panels to answer questions/distribute information on walkability and its benefits
- Gathering a team to propose walkable development projects to city planners and government officials

THANK
YOU

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Appendix B

Summary of Tucson Policies Related to Walkability

Plan Tucson

In 2013, Plan Tucson was adopted by Tucson’s Mayor and Council as the city’s new general plan. Since the last iteration of Tucson’s general plan in 2001, Plan Tucson represents an updated long-term framework to “guide future actions with the understanding that how the city has grown in the past will not necessarily work in the future” (City of Tucson, 2013, p. 1.2). The plan contains four chapters – an introduction to the plan’s purpose and the context in which it was written, a background on Tucson’s planning history, an outline of various focus areas, and a framework for implementation.

The four focus areas identified in the third chapter of the plan are the social, economic, natural, and built environment. As explored in a review of the literature on walkability, each focus area is relevant given the topic’s social, environmental, and economic benefits, as well as its frequent implementation through the built environment. Mentions or policies relevant to walkability in each focus area are outlined in the following subsections. **Table 1** outlines listed goals and policies outlined in each section related, directly or indirectly, to walkability. The subsections are also described in the following subheadings:

The Social Environment

This chapter section has the most subsections, which include housing, public safety, parks and recreation, arts and culture, public health, urban agriculture, education, and governance and participation. Many of the eight goals related to each of these categories are related to or enhanced by walkable communities. The city calls for housing diversity with “multi-modal access to basic goods and services” – the explicit call out for multi-model access indicates the city is thinking beyond the automobile, and housing diversity adds an emphasis on housing availability across income levels. Given that low-income households face increased barriers for how they may travel (Blumenberg & Pierce, 2012; Glaeser, Kahn, & Rappaport, 2008), this is a particularly important goal. The section also calls for a community and neighborhood public space safety, safe community and secure neighborhoods”, which are important indicators of an area’s walkability (Kenworthy & Newman, 2014). Further, public health is defined as being physical, mental, economic, and environmental, all of which are outcomes enhanced by a walkable built environment.

Many of the policy measures suggested here can enhance walkability. Considering access to basic goods and services, as well as housing for the most vulnerable communities, is in support of more walkable urban design, given that low-income households have less agency over how they can travel (Blumenberg & Pierce, 2012). Mentions of multi-modal pathways and improvements to streetscape design more directly influence walkability in the built environment through physical networks and improvements.

The Economic Environment

The goal here of embodying a vibrant community that benefits residents and attracts visitors is related to walkable urban environments’ support for thriving local economies. Many of the policies suggested are related to enhancing Tucson’s local economy through its distinctions as a

Table 1 – Plan Tucson Walkability Oriented Policies (City of Tucson, 2013)

Subsection	Goals related to walkability ¹	Policies ¹
The Social Environment	<ul style="list-style-type: none"> • A mix of well-maintained, energy-efficient housing options with multi-modal access to basic goods and services, recognizing the important role of homeownership to neighborhood stability. • A safe community and secure neighborhoods. • A community that is healthy physically, mentally, economically, and environmentally. 	<ul style="list-style-type: none"> • Evaluate the social, physical, and spatial needs related to housing program design and location, including neighborhood conditions and access to basic goods and services. • Address the housing needs of the most vulnerable populations in the community, including those at risk of homelessness. • Pursue design for public spaces and encourage design for private spaces that incorporates principles of defensible space. • Develop an urban multipurpose path system that provides mobility options, with recreational and health benefits, to access parks, residential areas, places of employment, shopping, schools, recreational facilities, transportation hubs, natural resources, and watercourses for people of all abilities. • Implement site specific and neighborhood-scaled development strategies that incorporate cultural heritage and the arts. • Pursue land use patterns; alternate mode transportation systems, including multipurpose paths; and public open space development and programming that encourage physical activity, promote healthy living, and reduce chronic illness. • Support streetscape and roadway design that incorporates features that provide healthy, attractive environments to encourage more physical activity.
The Economic Environment	<ul style="list-style-type: none"> • A community whose vibrant economy and quality of life benefits residents and attracts visitors. 	<ul style="list-style-type: none"> • Increase and promote environmentally sensitive businesses, industries, and technologies, including desert adapted technologies and goods and services tailored to the special needs of Tucson as a desert community. • Expand opportunities to fulfill local needs with locally produced goods and services to help Tucson capture a greater market share and advance a sustainable economy. • Contribute to workforce stability and advancement through support of ancillary services, such as transportation, childcare, nutrition, and healthcare. • Promote and support local, minority-owned, independent, and small businesses involved in the sale and purchase of locally produced goods and services. • Enhance the community attributes that are mutually beneficial to the business climate and quality of life for residents, including a safe environment, recreational opportunities, multi-modal transportation, a vibrant downtown, distinctive neighborhoods, excellent education, primary and secondary employment opportunities, and arts and entertainment venue • Support the expansion of passenger and freight multi-modal transportation services to better connect Tucson to regional and international markets and destinations. • Promote Tucson as a premier healthy lifestyle, outdoor, and recreational destination for cycling, hiking, bird watching, astronomy, nature, desert ecology, golf, spas, wellness, and healthcare.

The Natural Environment	<ul style="list-style-type: none"> • A reduction in the community’s carbon footprint, and greater energy independence. • A community that is resilient and adaptive to climate change. • A comfortable, attractive, and pollution-free environment. 	<ul style="list-style-type: none"> • Create and maintain a connected urban greenway system for non-motorized mobility and to provide human and environmental health benefits.
The Built Environment	<ul style="list-style-type: none"> • An urban form that conserves natural resources, improves and builds on existing public infrastructure and facilities, and provides an interconnected multi-modal transportation system to enhance the mobility of people and goods. 	<ul style="list-style-type: none"> • Identify historic streetscapes and preserve their most significant character- defining features. • Integrate land use, transportation, and urban design to achieve an urban form that supports more effective use of resources, mobility options, more aesthetically-pleasing and active public spaces, and sensitivity to historic and natural resources and neighborhood character. • Support development opportunities where a) residential, commercial, employment, and recreational uses are located or could be located and integrated, b) there is close proximity to transit, c) multi-modal transportation choices exist or can be accommodated d) there is potential to develop moderate to higher density development, e) existing or upgraded public facilities and infrastructure provide required levels of service, and f) parking management and pricing can encourage the use of transit, bicycling, and walking • Ensure urban design that a) is sensitive to the surrounding scale and intensities of existing development, b) integrates alternative transportation choices, creates safe gathering places, and fosters social interaction, c) provides multi-modal connections between and within building blocks, d) includes ample, usable public space and green infrastructure, and e) takes into account prominent viewsheds • Locate housing, employment, retail, and services in proximity to each other to allow easy access between uses and reduce dependence on the car. • Design and retrofit streets and other rights-of-way to include green infrastructure and water harvesting, complement the surrounding context, and offer multi-modal transportation choices that are convenient, attractive, safe, and healthy. • Continue to explore and monitor opportunities to increase the use of transit, walking, and bicycles as choices for transportation on a regular basis. • Create pedestrian and bicycle networks that are continuous and provide safe and convenient alternatives within neighborhoods and for getting to school, work, parks, shopping, services, and other destinations on a regular basis. • Reduce required motor-vehicle parking areas with increased bike facilities for development providing direct access to shared use paths for pedestrians and bicycles. • Participate in efforts to develop a coordinated regional, multi-modal transportation system that improves the efficiency, safety, and reliability of transporting people and goods within the region and to destinations outside of the region.
¹ Language taken directly from Plan Tucson documentation (City of Tucson, 2013)		

place. Walkable urban environments can help support local businesses through enhanced community connections and convenient shopping destinations. Further, the creation of multi-modal networks to support recreational tourism is critical to recognize that Tucson, for what it lacks in urban walkability, is making strides in recreational facilities available for walking. For example, the Loop provides over 100 miles of trails for walking and biking.

The Economic Environment

The goal here of embodying a vibrant community that benefits residents and attracts visitors is related to walkable urban environments' support for thriving local economies. Many of the policies suggested are related to enhancing Tucson's local economy through its distinctions as a place. Walkable urban environments can help support local businesses through enhanced community connections and convenient shopping destinations. Further, the creation of multi-modal networks to support recreational tourism is critical to recognize that Tucson, for what it lacks in urban walkability, is making strides in recreational facilities available for walking. For example, the Loop provides over 100 miles of trails for walking and biking.

The Natural Environment

Goals related to reducing carbon footprint, adapting to climate change, and improving air quality are all related to walkability's potential influence on car ownership. More walkable environments facilitate it as an easier mode than driving a car, making modal shifts that get at those goals. With regard to walkability specific policies, the creation of urban greenway systems points at more non-auto accessibility with both public and environmental health implications.

The Built Environment

Given walkability's facilitation through the built environment, this section dealt most directly with the subject. The goal of an urban form that provides a connected, multimodal transportation system is directly related to more walkable facilities in the city. Goals include better integration of transportation and land uses, which is key because mixed-use and infill development make walking more viable for an increased number of trip purposes. Supporting development close to existing facilities runs along the same lines. Policy goals even directly call out leveraging multimodal networks to reduce car dependence and cite reducing in parking as another pressure to do so.

Also mentioned here is the quality of the streetscape. In line with historic preservation, a goal is to keep historic streets attractive to walk along. Further, policies suggest retrofitting existing infrastructure or promoting new builds that included bicycle or pedestrian improvements. Finally, policies dedicated the plan to continue exploring how active transportation modes can be used on a regular basis for transport to school, work, shopping, services, but also for recreation.

Infill Incentive District

The Infill Incentive District was adopted in 2015 as an amendment to the City’s zoning codes. The IID establishes overlay zoning, where developers can choose to abide by pre-existing underlying zoning or with new zoning, the latter of which generally offers more freedom and flexibility of development by removing restrictions and providing economic incentives (City of Tucson, 2015). The new zoning applies to sites for use change, expansion, or new or re-development. Land uses covered in the zoning include office space, bars, educational space, entertainment, attached and multifamily residential, food service, sales, and mixed use.

Goals of this effort include the encouragement of infill development “that supports the creation of urban neighborhoods that are pedestrian and transit-oriented”, protecting historic structures through offering incentives. Building design standards oriented at achieving these goals, and related to walkability are summarized in **Table 2**.

Table 2 Infill Incentive District Pedestrian Considerations (City of Tucson, 2015).

Subsection	Considerations relevant to pedestrians and/or walkability ¹
Streetscape design	<p>Pedestrian-orientation: Projects shall be pedestrian-oriented and comply with all of the following standards:</p> <ul style="list-style-type: none"> a. New construction shall have architectural elements/details at the first two floor levels; b. Buildings shall provide windows, window displays, or visible activity on the ground floor for at least 50 percent of frontage; c. A single plane of facade shall be no longer than fifty feet without architectural detail; d. Front doors shall be visible or identifiable from the street and visually highlighted by graphics, lighting, or similar features; e. Parking areas for comprehensive development or redevelopment of a site shall be located at the rear or side of the building. <p>Changes of use and expansion of existing structures may use the site's current parking configuration:</p> <ul style="list-style-type: none"> f. Parking structures shall be designed so that parked vehicles are screened from view at street level through incorporation of design elements including, but not limited to, landscaping, pedestrian arcades, occupied space, or display space; g. Existing sidewalk widths shall be maintained so as to provide effective, accessible, connectivity to adjoining properties. Sidewalks may be widened to accommodate a project's design characteristics. Where no sidewalks exist, sidewalks shall be provided. Outdoor seating and dining areas and landscaping may be located in the sidewalk area where safe and effective sidewalk width around the design feature can be provided; h. To the extent practicable, bus pull-outs shall be provided where bus stops are currently located; and i. If drive-through service is proposed, it shall not interfere with pedestrian access to the site from the right-of-way.
Shade	<p>Shade shall be provided for at least 50 percent of all sidewalks and pedestrian access paths as measured at 2:00 p.m. on June 21 when the sun is 82 degrees above the horizon. Shade may be provided by trees, arcades, canopies, or shade structures. The use of plantings and shade structures in the City right-of-way is permitted to meet this standard. The shade provided by a building may serve to meet this standard.</p>
Vehicle circulation and parking	<ul style="list-style-type: none"> a. All parking area access lanes (PAALs) adjacent to buildings shall have pedestrian circulation paths between the PAAL and the building, with a minimum width of six feet. b. All new parking shall be designed so that vehicles are not visible from the adjoining street level, through incorporation of pedestrian arcades, occupied space, or display space.
Plaza and open space	<ul style="list-style-type: none"> a. Five percent of the gross floor area of new construction shall be provided in public plazas or courtyards. Open space plazas, courtyards, and patios are landscaped outdoor areas designed to accommodate multiple uses, from large gatherings of the people for performing arts to smaller gatherings. The plazas and courtyards will be one of the ways that spaces and uses can be linked. The requirement of this section may be waived or reduced by the PDSO Director upon a written finding during the review process that the development enhances the downtown pedestrian environment even with a smaller percent or elimination of the requirement. b. Views of all historic properties and all natural elements surrounding the Downtown should be considered during design. Plazas, courtyards, and open spaces shall be sited to include views to other public spaces, where feasible. c. Neighborhood linkages shall be maintained throughout Downtown.
<p>¹ Language taken directly from Infill Incentive District Ordinance (City of Tucson, 2015).</p>	

Complete Streets Ordinance

In 2018, Tucson joined the quickly growing number of municipalities in passing a ‘complete streets’ initiative. Championed by local non-profit group Living Streets Alliance, the draft policy highlights six goals, reproduced here from the adopted ordinance (City of Tucson, 2018):

1. **Safety** – Complete Streets provide a safe travel experience to all and designing Complete Streets is a safety strategy to eliminate preventable traffic fatalities.
2. **Accessibility** – Complete Streets serve people of all ages and abilities.
3. **Equity, Diversity, And Inclusivity** – Complete Streets elements are implemented equitably and inclusively throughout the city.
4. **Land Use** – Complete Streets incorporate context sensitive, flexible design approaches and consider the surrounding community’s current and expected land use and transportation needs in an interconnected manner.
5. **Environment** – Complete Streets preserve and protect Tucson’s environment and increase health by providing opportunities for active transportation (walking, biking, etc.) reducing vehicle miles traveled, and decreasing pollution caused by motor vehicles.
6. **Economic Vitality** – Complete Streets help spur economic development by supporting business and job creation and by promoting resiliency in the workforce through access to multiple mobility options.

Compared to other complete streets policies, Tucson’s is fairly progressive in its inclusion of equity, diversity, and inclusivity as a goal. This goal “will facilitate equitable transportation investments and inclusive community engagement to help mitigate socio-economic, racial/ethnic, and health-related disparities while advancing mobility and access to opportunities” (City of Tucson, 2018).

Further, given Tucson’s high pedestrian fatality rate, listing safety as the number one goal seems in line with the city’s needs. The complete streets policy aligns with both Plan Tucson and the IID, utilizing the policies and incentives set by those to further promote multi-modal access to the city specifically. Performance measures include updating documents, training and hiring new staff, engaging the public, investment in complete streets projects, travel behavior measurements (including reduced VMT), safety, equity, health, air quality, economic vitality, green infrastructure and shade, accessibility and connectivity.

The major downside of this policy is that it is an ordinance; an additional level of accountability would better ensure that the goals and performance measures set forth would actually be enforced. However, this is a huge step for Tucson, and we will have to wait and see what the full impact of the ordinance will be.