The Report Committee for Arman Rajaeian
Certifies that this is the approved version of the following Report:

Austin, Texas Parkland Active Transportation Accessibility: A GIS Network Analyst Based Approach

APPROVED BY
SUPERVISING COMMITTEE:

Gian-Claudia Sciara, Supervisor

Alex Karner

Austin, Texas Parkland Active Transportation Accessibility:
A GIS Network Analyst Based Approach

by

Arman Rajaeian

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Dedication

This report is dedicated to my mother and father, who have provided me with unimaginable opportunity.

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Abstract

Austin, Texas Parkland Active Transportation Accessibility: A GIS Network Analyst Based Approach

Arman Rajaeian, M.S.C.R.P.

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Supervisor: Gian-Claudia Sciara

This report measures pedestrian and bicyclist accessibility to parklands in Austin, Texas. An overview of current parkland and active transportation planning practices in Austin is given to properly set the scope of study. Past literature regarding the measurement of spatial accessibility is reviewed to formulate a methodology with which to conduct the analysis. In particular, a framework is presented to create formalized pedestrian and bicyclist network datasets within ArcMap's Network Analyst. Using these specialized network datasets, accessibility measures are calculated using origin destination travel between census block groups and parklands within Austin. From these calculated accessibility measures, levels of equity amongst various socioeconomic groups are studied in order to ascertain if there are any discrepancies between different groups level of access to parklands and availability of active transportation infrastructure. Findings indicate that no significant discrepancy in levels of access to parklands exist between socioeconomic groups studied, pointing to an equitable environment for Austin citizens.

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INTRODUCTION

There is no question that parkland and green spaces are essential staples of urban agglomerations worldwide. Parkland is a critical addition to cities across the globe, and their presence can be found within the urban fabric regardless of density, from the neighborhood parks of most suburban areas to large-scale metropolitan parks in urban centers. This research paper's focus and methodology is primarily concerned with analyzing active transportation accessibility to parklands within Austin, Texas. The overwhelming inclusion of parklands and their presence amongst the built environment can be attributed to the multiple uses and wide-ranging utility that can be derived from parkland and open spaces. Within the background section of this report we detail the various nuanced benefits connected to parklands and active transportation, especially in the context of Austin, TX, to give a better understanding of why parkland access was chosen as the research topic. The analysis itself has been conducted under the framework of a Geographic Information System (GIS), in this case Esri's ArcMap 10.4. Following the research methodology of past researchers in the geospatial, applied geography, and urban planning fields, GIS tools have been implemented to study the level of access and equity Austin citizens have to local parklands. In the Literature Review section of this report, we will detail past research in quantifying accessibility and research pertaining to analyzing access to public services in the realm of GIS.

The inclusion of parkland to this study and their accessibility can be used as a gauge to compare and contrast different metropolitan regional competitiveness, with higher parkland and acreages and accessibility separating the further behind industrial societies focused on economic development from the more culturally oriented societies focused on improving quality of life (Oh, 2007). In particular, the research presented here extends beyond simply looking at citizen access to parklands, and instead opts to study active transportation networks as the bridging link that connects people to parks. In the methods section of this report we will detail the steps taken to properly configure a GIS environment to study active transportation access between census block groups and parkland around Austin. The findings section elaborates on the GIS analysis itself, taking into account several demographic and economic based performance measures to gauge parkland accessibility. Finally in the discussion section of this report we examine implications stemming from our analysis relating to different socioeconomic groups level of access to Austin parkland.

As people continue to choose to live in urban areas, the price of land is likely to greatly increase due to high demand (Henderson-Wilson et al., 2017). A challenge arises in the municipality to balance the amount of sustainable infrastructure to maintain environmentally beneficial qualities of the city (Henderson-Wilson, 2017). Indeed, rapid urbanization has shown to have an effect on the amount of green space allocated within a municipality, with research indicating this loss of green space leads to poorer citizen health and a decreased quality of life (Brown, 2014). This is an unfortunate signal, as we can argue with "increasing empirical evidence [. . .] that the presence of natural assets (i.e. urban parks and forests, green belts) and components (i.e. trees, water) in urban contexts contributes to the quality of life in many ways" (Chiesura, 2004). These benefits most obviously include environmental factors such as the purification of air and water resources, filtering of wind and noise, etc. (Chiesura, 2004). However, other factors such as improved citizen health and economic vitality should also be considered when realizing the benefits of urban parkland.

The inclusion of parks in a community greatly increase the chances of citizens "to reconnect with the natural environment which is beneficial to people's health and wellbeing" (Brown, 2014). These net gains in wellbeing are brought on by providing citizens opportunities for "physical activity, social interaction, escape, and enjoyment of nature" (Brown, 2014). Understanding how much of an impact these open spaces can have on the surrounding population is critical, as we are living "in times of increasing obesity, cardiovascular disease, and mental health disorders" and need to "fully understand the benefits of parks so that we optimize the preventative and remedial impacts they have on people's health and wellbeing" (Henderson-Wilson, 2017). Indeed, many empirical studies have been conducted to prove this point, including a Danish study showing the relationship between "proximal green spaces and lower levels of obesity and stress" (Henderson-Wilson, 2017).

Taking into account the positive health and environmental externalities of local parkland, a large amount of evidence indicates these externalities continue forward on boosting the economic standing of the community surrounding parklands. For example, the positive health outcomes of parkland visitation like improved well-being and an increase in physical and mental performances "can directly (increased work productivity) and indirectly (less time lost through illness) improve incomes" (Tempesta, 2015). The purification of air found in green spaces can lead to a municipality's reduction in cost of mitigating pollution (Chiesura, 2004). The very presence of natural resources in a community such as an abundance of trees or water features has shown to increase property values, and therefore municipal property tax collections as well (Chiesura, 2004).

Active transportation, namely walking and bicycling, have recently come to the forefront of planning and transportation practitioners "in pursuit of smart growth goals and carbon-intensive travel reduction, as well as public health promotion" (Li, 2015). "Walkable neighborhoods with well-connected sidewalks, more street intersections, mixed land use, access to diverse destinations, and smaller block sizes are associated with higher levels of physical activity, lower probability of being overweight or obese, better mental health, and enhancing social capital" (Li, 2015). Parkland enters into this equation as we know the presence of open space is a direct incentive for citizens to have a tangible 'destination' to walk or bike too. Reflecting a change in consumer demands, it has become apparent that city planners are increasingly focusing their attention on coordinating development that is centered on transit and pedestrian friendly environments. With most of the residential communities that comprise our urban areas lacking this walk-friendly environment, "homes in neighborhoods with pedestrian-oriented design features should be capitalized into higher sale prices, thereby generating much-needed revenue from property taxes to finance pedestrian, bicycle, and transit projects" (Li, 2015).

AUSTIN PARKLAND & ACTIVE TRANSPORTATION BACKGROUND

Austin Municipal Park Planning

Austin is the centrally located, capital city of Texas with a total civilian municipal population of 907,776 as of 2016 (U.S. Census Bureau). For anyone who has lived in or visited Austin, it is apparent that parklands are abundant. From various small scale neighborhood parks to the large Zilker Metropolitan Park in central Austin, parks are deeply embedded within the city's fabric. The Austin Parks and Recreation Department is the designated city agency in which park jurisdiction falls. A key guiding document for park planning in Austin is the Parks and Recreation Department's *Strategic Plan 2017 - 2021.* The document leads the city through various visions, goals, and budgetary guidelines as they relate to parklands in the short term.

From the *Strategic Plan 2017 - 2021* we learn that currently there are exactly 300 parks of various sizes spread throughout Austin. This equates to 20,236 acres of green space available for use by residents. A series of goals, strategic initiatives, action strategies, and tasks are delineated by the department in order to maintain and articulate immediate goals for planning in the next five years. Key to the analysis is the Park and Recreation Department's commitment "to contributing to the health and vitality of all Austinites by developing leadership opportunities for youth, promoting health, and wellness, and fostering community engagement throughout the city" (Strategic Plan 2017 - 2021, 2016). Specifically, an action strategy within the report aims to conduct a "geographic gap analysis and use assessment of Park and Recreation Department facilities". As later in our report we aim to delve into any potential discrepancies that may exist between demographic groups through the lens of geospatial analysis, it is validating to see the same sentiment is shared amongst Austin's professional municipal practitioners.

The abundance of parkland available in Austin, as well as the established literature regarding its planning, was the predominant reason parkland was chosen as the public facility to measure access to with GIS methods. GIS data for parkland was readily available, and represents a public facility that is in theory spatially equally dispersed around the municipality. The positive externalities behind parkland, which we will go into further detail describing later in this section, validate the necessity to research if this equal dispersion is correct, or if certain subgroups of the population lack access to this crucial public facility.

Austin Active Transportation Planning

Active transportation is any transportation mode that solely relies on physical activity to move people, with the most common modes being walking, cycling, skateboarding, roller-skating, and scootering. Key agencies in the planning and construction of active transportation infrastructure are the City of Austin Transportation Department (ATD) and the City of Austin Public Works. Responsible for a wide array of duties pertaining to Austin's road network, ATD and Public Works are also tasked with implementing active transportation improvements for the city. Through the publication of two comprehensive plans, the *City of Austin Sidewalk Master Plan* and *City of Austin 2014 Bicycle Plan,* the city has delineated the current state of affairs with active transportation infrastructure, and their future trajectories.

The City of Austin Sidewalk Master Plan published by Public Works was last updated in the summer of 2016, and was created through a partnership between city planners and private consultants. Its creation was spurred by the goals of encouraging walking as a viable mode of transport as well as helping alleviate traffic congestion and in effect diminishing air pollution and increasing citizen's health (Austin Sidewalk Master

Plan, 2016). The plan is predominantly focused on achieving these goals by creating a system to identify areas in which sidewalk infrastructure needs to be built out and prioritize areas with existing infrastructure for improvements. This careful planning strategy is necessitated by the city's limited funding streams directed at active transportation.

Currently there are 2,400 miles of built out sidewalk infrastructure in Austin, however an even greater amount is missing, with 2,580 miles of sidewalks missing from critical segments of the roadway (Austin Sidewalk Master Plan, 2016). An estimated $1.64 billion is required for a full sidewalk build out, and at current levels of annual funding this task would take 192 years for completion (Austin Sidewalk Master Plan, 2016). Thus the necessity to index sidewalk construction into prioritization rankings. The key recommendation based on priority rankings is the creation of a 10-year New Sidewalk Program, which targets "high" and "very high" priority sidewalks located within a ¼ mile of schools, bus stops, and parks to coordinate the build out of 39 miles of newly constructed sidewalk infrastructure over the next 10 years. The priority rankings also heavily take into account the aspect of "completing the network" or planning for as little gaps in sidewalk infrastructure as possible. In the context of this report's GIS analysis, this is extremely important as we will later discuss technical issues in attempting to geospatially evaluate an incomplete network.

The *2014 Austin Bicycle Plan* is the ATD's latest iteration of comprehensively producing a bicycle plan for the city, replacing the previous 2009 version. The report serves as a guiding document for the department's bicycle planning, with the stated goals of increasing bicycle network connectivity, increasing cyclist ridership, increasing rider safety, and offering a more equitable bicycling environment for all users. Emphasis is put on planning to capture 'short trips' or trips under 3 miles along routes that connect bicyclists to schools, shopping, and parkland (2014 Austin Bicycle Plan, 2014). This is a direct response to the notion that short trips are the most likely to convert automobile users into cyclists or walkers. Analysis conducted within the plan suggests that routes deemed to be highly trafficked short trips (i.e. connecting users from their homes to parks) be converted into protected bicycle lanes, to fit the 8-80 rule where cyclists ranging from 8 to 80 years old should feel comfortable riding along the bicycle network (2014 Austin Bicycle Plan, 2014).

As of the *2014 Austin Bicycle Plan* publication date, 210 miles of miles of bicycle lanes span the roadways. However, there are still many barriers facing cyclists in Austin, including "gaps in the network caused by freeways, intersections and disconnected facilities, as well as a lack of awareness and acceptance of bicyclists" (2014 Austin Bicycle Plan, 2014, p. 25). The overwhelming sentiment of cyclists safety reflects in the need to build out more protected bicycle lanes, which Austin only contains 20 miles of (2014 Austin Bicycle Plan, 2014). With only 36% of the city's arterial roadway containing bicycle lanes of any kind, the push for implementing safer cycling infrastructure coordinated by studying highly trafficked, short trip routes is a major tenet of the report. This leads back to the notion of residents having non-motorized access to key destinations, and in the context of this report, parkland. It's mentioned accessing parkland via bicycling is naturally a less invasive process, while planning for motorized park access may detract from the intended purpose of parkland (2014 Austin Bicycle Plan, 2014). Expansive parking lots and in-roads within parkland diminish the total supply and quality of green spaces, while bicycle lanes and bicycle storage facilities require way less invasion of our natural resources.

It is evident that although the City of Austin has a lot of work ahead in building out sidewalks and bicycle lanes, it is actively working on measured and calculated steps to increase active transportation infrastructure with the limited budget and scope it is currently operating under. By publishing official planning documents that serve to guide sidewalk and bicycle infrastructure development, it sends a clear signal that these are important components for Austin's overarching transportation network. Furthermore, it validates the work conducted within this report itself as we aim to measure the strength of the sidewalk and bicycle lane networks ability in providing access for Austin citizens to parkland. The results from our analysis could potentially go to help guide planning for future infrastructure build out or improvement.

Health & Wellbeing Benefits of Parkland Access

A primary reason for this report's intent in measuring access to parklands is that parks are public facilities that provide numerous positive externalities. For citizens living in urban areas, there is no doubt respite from the monotonous concrete landscape is required from time to time. Parkland and greenspaces are the ideal and intended environment chosen to break from urban areas, ironically with the most accessed of them nestled within the urban fabric. The notion that parkland can play a significant role in urban residents' mental and physical health is not a new concept, and has been at the intersection of multiple fields including psychology, biology, ecology, geography, and public health / medicine (Maller et al., 2009). The shift of the majority of the world's population away from rural areas and into dense urban cities means urban parkland is the only means for many city dwellers to access nature.

Since the inception of official urban parkland in the 19th century, park planning practitioners have always intended for positive health externalities to be a key component of a park's purpose. In a time when urban areas were ridden with crime and disease, parkland was viewed as an answer to relieving the increasing social stress brought on by urban life as well as providing a "green lung" for cities to combat the increasing rise of industry (Maller et al., 2009). Parkland today has since evolved into something much larger, and while it now aims to address a variety of modern contexts, its underlying mission remains. Indeed, parklands now "vary in size, shape, quality, and character, and hence satisfy the whole spectrum of opportunities for contact with the natural world at various levels" including recreation / leisure, social interaction, viewing nature, and spiritual activities (Maller et al., 2009).

Increasing research has shown simply being in the presence of or the viewing of green spaces can relieve stress and tension amongst urban dwellers. A field study conducted at Chungnam University in South Korea researched the psychological behavior of 20 male students traditionally confined to urban landscapes. (Ju-Young et al., 2011). Over a period of two days the students were split into two groups and asked to simply view identical natural and urban areas for 15 minutes with their heart rates being monitored and undergoing psychological tests after the viewing was complete. It was found that heart rates while viewing the natural landscape were lowered viewing the natural setting and heightened viewing the urban setting, with a statistically significant measure of stress relief in relation to natural landscape viewing (Ju-Young et al., 2011). Further performance indicators from the psychological tests in tension-anxiety, depression, anger-hostility, fatigue, and confusion showed significant decreases in all indicators while viewing nature and the opposite for urban settings, showing that "subjects felt more comfortable, soothed, natural and vigorous when viewing the green landscape rather than the urban one".

The inherent ability for parkland to induce physical activity is also a major component of generating positive health outcomes. It is suggested that urban residents live increasingly indoor lives, and with that fall into a more sedentary lifestyle (Maller et al., 2009). Parkland located within urban areas creates an environment where opportunities in physical activity, health improvement, education in sport, and connecting with nature are allowed to flourish (Maller et al., 2009). This physical activity component of parkland benefits does not start and end with parkland, but also in the access of parkland. As contemporary city planning has allowed for the proliferation of cars and their required roadways, less attention has been paid to alternative modes of travel connecting citizens to vital destinations. Active transportation modes such as walking or biking work on alleviating these issues, both in tempering the side effects of traffic congestion and environmental pollution, but also providing a mode of travel that results in health benefits to the user (Mueller et al., 2015). Knowing that "globally, more than 30% of all adults are estimated to perform insufficient physical activity", there still exists a need for research studying the impacts parkland and active transportation access can provide to humans overall health and well-being (Mueller et al., 2015).

Economic Factors Considered in Planning Urban Parkland

Cities stand not only to derive positive health related externalities from their parklands, but from a slew of economically related ones as well. However, municipalities may find a tough time generating or quantifying urban parkland's value due to the non-priced environmental benefits attributed to parks such as proper landscapes, shading, higher air quality, erosion control, and environments for recreation and leisure (Tyrvainen, 1996). Furthermore, as cities grow larger and denser, municipalities may find difficulty in balancing their limited land area between developments for growing populations, or allocating parkland for their numerous benefits to cities (Poudyal, 2009). Many researchers looking to quantify economic value of parkland have employed hedonic pricing methods (HPM) which is most commonly used in the real estate property market, using real market transaction indicators like transaction data and pricing to estimate similarly related benefits (Tyrvainen, 1996). Variables chosen in the HPM for estimating benefits of parkland may include total park acreage in a neighborhood, total length of trails, and amenities within parkland.

A study was conducted in Finland by employing a hedonic pricing method for analyzing the economic value the property market derived from the proximity of urban forests. Three environmental variables were analyzed by the HPM: distance to the nearest wooded recreation, direct distance to the nearest forested area, and the relative amount of forested areas in the housing district (Tyrvainen, 1996). Through the analysis the author found that all three variables had a positive correlation on higher apartment market prices, with the research indicating that "increased size of the lot and amount of forested areas in the housing area as well as nearness to watercourse and recreation area increased apartment prices" (Tyrvainen, 1996). The author reflects that it is crucial for municipalities to determine the monetary value of their parklands in order to not only justify park planning endeavors to the public, but balance differing land uses properly backed by proper analysis (Tyrvainen, 1996).

MEASURING ACCESS LITERATURE REVIEW

As urban and transportation planning have matured over the last half-century, researchers have devoted an increasing amount of attention to studying the ways accessibility can be measured to analyze citizen's access to public resources and services. Accessibility in and of itself is a dynamic term that fits into many working definitions depending on context, potentially indicating "affordability, acceptability, availability and spatial accessibility" (Apparicio et al., 2008). In the context of this report and the literature reviewed, we are referring to geographic accessibility, or the ease in which citizens can reach locations or services separated in space (Apparicio et al., 2008; Nicholls, 2001). There is no single consistent or correct method for gauging accessibility in this context, and rather various geometrical accessibility measures studying total distance or time from origin to destination are employed to study levels of access (Neutens et al., 2010). Modern methods of quantifying spatial accessibility almost always employ Geographic Information Systems (GIS) to aide in the analysis. This research fits into a broader attempt at understanding equity in access for various socioeconomic groups, or "the fairness or justice of a situation or distribution" (Nicholls, 2001). These efforts are made for municipal practitioners to better index and plan for the allocation of public services to serve the needs of their community in the most equitable outcome possible (Mladenka, 1977; Talen 1998).

Although with the advent of GIS the study of geographic access and equity to various locations and public services has proliferated, research and interest in this domain has existed long prior. Originally spurred by the lack of empirical analysis pertaining to geospatial accessibility and equity, the work of Kenneth Mladenka in the 1970's and 1980's serves as a foundation for understanding how municipalities plan and analyze their public services. Mladenka (1977), forming a service equality research question, cites previous research related to African Americans preferences in public services (schools, recreation, police, and garbage) which found that "blacks were most dissatisfied with recreational services" over many other grievances such as weak political systems and discrimination (Mladenka, 1977, p. 74). A correlational study of park facilities in Houston was first conducted, contrasting park acreage with socioeconomic variables at the census tract level, and through the regression found no indication of inequality of park facilities existing between predominantly white and black communities. However, Mladenka (1977) notes this sheds little light on the spatial distribution of parklands in Houston, and therefore expands the analysis with the elementary method of linearly measuring the distance to parkland from random points within all Houston census tracts. Results from this linear analysis coincided with the correlational analysis, showing that less affluent communities in fact live in closer proximity to parkland than more affluent ones (Mladenka, 1977).

Expanding on his and other researcher's findings, Mladenka (1989) studied the spatial allocation of parkland facilities in Chicago between 1962 and 1983 through a regression model with a focus on economic variables such as median family income and home ownership (Mladenka, 1989). By looking at parkland facilities within white and black wards the analysis found that by the end of the 22-year period studied, facilities in white and black wards were "virtually identical" (Mladenka, 1989, p. 579). The findings indicate "class appears to have displaced race as the crucial detriment of [municipal] distributional choices" (Mladenka, 1989, p. 581). In particular, population shifts such as whites moving out of the urban core and being replaced by minorities in communities where longstanding parkland existed accounted for this outcome. This challenged previous notions of race being a determinant of inequitable public service distribution, and shifted to a more nuanced look at how class and political clout may play larger roles instead. Overall, the early work of Mladenka laid the groundwork for understanding how accessibility directly correlates with urban public service equity, setting up a framework for future researchers looking to study how geospatial access affects various socioeconomic groups.

With the breakthrough of GIS software in the 1990s, research regarding geospatial access and equitability shifted away from simply studying "normative" factors comprising access to establishing a formal methodology and process to quantify accessibility aided by GIS software (Anselin and Talen, 1998, p. 596). Previous studies had been limited in their attempt at linking public service distributions to factors causing poor access and inequity due to the employment of the "container method" such as the one used by Mladenka (1977) which "constrains the notion of access to the presence or number of facilities in a unit of observation" such as census tracts or wards (Anselin and Talen, 1998, p. 597). With the help of computational algorithms in GIS, geospatial access could move beyond simple measurements such as areal distance within arbitrary geographic units (e.g. census tracts), and move into a realm where spatiotemporal factors such as dynamic travel time and network distance could be measured with relative ease. As certain municipal goods such as parks and libraries are not exclusionary based on their geographic setting (i.e. everyone can access all parks and libraries in their towns), GIS opened the door to analyze how the spatial distribution of services is correlated to socioeconomic variables over complete geographic features (networks), rather than being compartmentalized into arbitrary municipal units (Anselin and Talen, 1996).

Although GIS programs created an environment where modeling systems of geospatial access was quick and effective, much debate and literature arose on the topic of which *accessibility measures* were best suited for quantifying levels of access and equity. Anselin and Talen (1998) in their study of playground access in Tulsa, Oklahoma compared the conventional "container approach" of counting facilities in geographic boundaries against three measures utilizing the street network based on origin-destination correlation: the 'gravity potential' which weighs a destinations size with the friction of distance from an origin, 'travel cost' which simply sums the total or averages the distance from an origin to any number of destinations, and 'minimum distance' which represents the shortest network distance between an origin and the nearest service type destination (Anselin and Talen, 1998, p. 599 - 600). They found that the accessibility measure chosen in the analysis results in differing outcomes, with the choice ultimately in the hands of the researcher and how they characterize distance between origin and destinations in their study (Anselin and Talen, 1998).

Neutens (2010) in his report comparing accessibility measures characterizes these distance-based measures as "place-based accessibility measures" due to the fact they explore various ways proximity correlates between origin and destination. These place-based accessibility measures necessitate the creation of a modal network within a GIS environment, where characteristics regarding distance and speed can be modeled in the analysis depending on variables studied (Neuten, 2010). With the proper modal network configured, shortest network length and shortest network time between origins and destinations can be calculated. Calculating shortest network length is best suited for studying access to proximal destinations that can be reached on foot, while shortest network time is better suited for trips made by vehicle or transit (Apparicio, 2008). Using either network length or network time, common accessibility measures for quantifying access between origin and destination include "1) the distance to the closest service, 2) the number of services within n meters or minutes, 3) the mean distance to all services, 4) the mean distance to n closest services, and 5) the gravity model" (Apparicio, 2008, p. 4). Further analysis within the accessibility measures can be employed to measure equity, with methods such as employing cumulative distributions to see how different subgroup populations compare with one another, or by reclassifying the average accessibility distance or time by population-weighted means (Neutens, 2010; Apparicio, 2008).

The implementation of the various accessibility measures detailed above have been used in numerous studies relating to parkland access and active transportation. Talen (1997) aimed to study the distributional equity of park access by pedestrians in Pueblo, CO and Macon, GA. A "covering" distance of 1 and 2 mile radii was created around census block group centroids to be used as destinations within the analysis, with the caveat being the street network and the associated shortest lengths determine whether certain block group centroids could access parkland in under 1 or 2 miles. The measurement of access by the "covering method" or "number of services within n meters" suited this analysis as "parks do not have definite boundaries for their constituents" and "the use of distance to facilities as a metric yields similar values for access in neighboring locations" (Talen, 1997, p. 7). By comparing the spatial clustering of similar socioeconomic variables against the clustering of block groups with high park access, Talen (1997) concluded that higher park distribution tended to reside in lower-income neighborhoods, while more affluent neighborhoods tended to have a further network distance from parks, perhaps indicating that these communities are automobile centric enclaves.

Smoyer-Tomic et al. (2004) employed the minimum distance accessibility measure in their study of playground accessibility and equity in Edmonton, Canada, citing "playgrounds are typically highly localized facilities with small service areas" as the reason for opting for minimum distance analysis (Smoyer et al., 2004, p. 289). However, Euclidean (as the crow flies) distance was chosen over shortest length network distance due to the researcher's inability to corroborate a proper pedestrian network that would emulate children's travel to playgrounds (Smoyer et al., 2004, p. 289). Variables for assessing equity included population-weighted means of children present, as well as socioeconomic variables like household income which would highlight inequity if low-income households had poorer access to playgrounds than more affluent households (Smoyer et al., 2004). The minimum distance analysis resulted in positive results, finding that playground access was higher in areas with lower-income households, as well as a significant albeit weaker correlation with higher access in areas with higher concentrations of children.

Nicholls (2001) showed the importance of measuring distance through network distance techniques rather than linear distances by comparing both accessibility measures in a study of park access in Bryan, Texas. Producing access maps through both the linear radius method and network method, it is apparent the latter method generated a more realistic representation of surrounding community's pedestrian access to parkland when compared to Euclidian buffers. Although the linear radius technique inevitably included more citizens accessing parkland, the network distance method rendered results indicating no form of inequity through the studies equity measures, thus showing a clear avenue for municipal practitioners to move beyond buffering techniques into methods which more accurately display a service area of a public good (Nicholls, 2001).

While the implementation of a complete street network in GIS can be useful, the creation of multi-modal networks incorporating multiple modes of travel offer a more nuanced way to analyze real-life, on the street conditions of travel. If a city were able to properly maintain GIS layers that accurately represent the spatial distribution of various transportation infrastructure pieces, and incorporate that into a unified dataset, the level of analysis conducted would be greatly increased. This is due to the fact that the unified network dataset would digitally represent where each diverging piece of transportation infrastructure is occurring physically, offering an increased level of geographic accuracy.

Assumptions of where certain transportation activities do or do not occur would be eliminated.

Farber et al. (2014) created a transit-pedestrian network dataset to more accurately study spatiotemporal accessibility to grocery stores in Cleveland, Ohio. By using GIS geoprocessing tools to turn transit feed data into GIS feature classes containing spatiotemporal attributes, and combining these features with a street network which could be traversed only at pedestrian speeds, a network dataset was created that modeled combined pedestrian and transit travel between origins and destinations. This type of multi-modal network opened the door to analyze access in the variability of transit scheduling, finding that grocery store access was clearly less time intensive depending on the time of day chosen (Farber et al., 2014). It is important to note many municipalities across the country have active transportation infrastructure networks (sidewalks and bike lanes) with physical gaps in connectivity between segments. When attempting to model these networks independently in a GIS environment, a user will be left with an incomplete network with 'islands of connectivity' that cannot be traversed with network analysis tools. Therefore there exists a need to corroborate active transportation networks with other forms of data to model complete connectivity. Kent and Karner (2018), studying the equitability of bicycle lane networks in Baltimore, Maryland used City of Baltimore Level of Traffic Stress (LTS) data, which is a ranking system indicating the level of stress a cyclist faces on street network segments. By transposing this data into GIS feature classes, a modified street network dataset acted as a routable and complete bicycle network dataset that more accurately represented the cycling environment, more so than the street network. Presumably the transposition of LTS data to form a complete bicycle network dataset was undertaken to fill in the gaps present in the actual Baltimore bicycle lane network.

RESEARCH QUESTION

As we have thus far learned, the City of Austin has an abundance of parkland, a public facility that should (theoretically) be equally dispersed spatially or at least equally accessible to all residents of the city. These parklands exude positive externalities such as promoting healthiness, reducing pollution, and increasing a community's economic vitality. Therefore, it is imperative that a public facility of this caliber truly be easily accessible by all residents of the municipality regardless of social or economic standing. Keeping this in mind, the primary question this report aims answer is the following: is access to parklands by walking and bicycling truly equal across the City of Austin's socioeconomic groups, or are there are varying levels of access amongst them? Furthermore, the primary mode to analyze this access is active transportation modes, in this case walking and biking. This is due to these modes extremely low barrier for entry as well as their active component naturally lending itself to parklands positive health externalities. Measuring parkland access amongst Austin's different socioeconomic groups can help us understand what level of equity currently exists regarding parkland access, and which groups could be targeted for improvement.

METHODS AND DATA

The methodology of this report is predominantly concerned with the creation of connected network datasets from sidewalk and bike lane GIS feature classes published by the City of Austin with the goal of performing an origin-destination accessibility analysis. Representing pedestrian and cyclist access to parks in their own formalized GIS network datasets rather than modeling them onto street networks has shown to more accurately display the spatial access available to residents, and better informs municipal practitioners on resource allocation and planning (Nicholls, 2001). Data sources for GIS shapefiles came from the City of Austin Open GIS Portal, while socioeconomic variables for use in equity measures came from U.S. Census Bureau American Community Survey (ACS) 2016 data 5 year data. The primary issue in creating a geographically accurate pedestrian network dataset is that sidewalk infrastructure in Austin is frequently disconnected from other segments of sidewalk infrastructure. Upon review of the sidewalk shapefile provided by the city, it became apparent the reality of gaps in the city's sidewalk infrastructure necessitated the merging and creation of a street-sidewalk network to complete connectivity between these two feature classes. On the other hand, the bike lane shapefile from the city represents a connected and routable network, and as such it was decided the analysis in looking at cyclist's access to parklands would be conducted entirely on the bike lane network alone.

Our level of analysis for measuring resident access to parkland was the census block group, the smallest geographic unit available from the ACS data. Austin city limits were chosen as the study area and since block groups were chosen as the unit of geographic measurement, any census block group intersecting Austin city limits was also included in the analysis. Origins in the analysis are the census block group centroids, and carry socioeconomic information at the block group level such as racial population numbers and median household income. Destinations in the analysis are City of Austin parks, but are represented in various ways in the analysis depending on the accessibility measure being calculated. Point features along the vertices of parklands were used as destinations when looking at the minimum distance measure to better represent the multiple entry points of parks, while parkland centroids were used in the geographic threshold measure to see how many parks were accessible by each mode within specified distances. The *minimum distance* accessibility measure was employed, with network analyst finding the shortest length between a census block group centroid (origin) and the nearest parkland vertex point (destination). The *distance threshold* accessibility measure was also employed, with network analyst modeled to find all routes between census block group centroid (origin) and all parkland's within a ½ mile network distance (destination). These accessibility measures were then used as the basis of calculating equity measures regarding race and median home value contained in census block groups. Race was assigned to a census block group by simply determining the population of such group in a block group.

Data Acquisition & Survey Area

GIS shapefiles published by multiple departments at the City of Austin reside within a unified online library on the city's website. Free and open for download by the public, the online portal houses many civic-focused shapefiles and other GIS-related data. We were able to gather all of the necessary shapefiles to be implemented in our analysis from this single source, with the exception of the census block group's shapefile, which came from U.S. Census TIGER/Line shapefiles. The following is a brief list of GIS shapefiles gathered for analysis:

- City of Austin Complete Street Network (line feature class)
- City of Austin Municipal and Extrajudicial Boundaries (polygon feature class)
- City of Austin Parkland (polygon feature class)
- City of Austin Bicycle Lanes (line feature class)
- City of Austin Sidewalks (line feature class)
- U.S. Census Bureau Travis County Census Block Groups (polygon feature class)

Socioeconomic data to be used in comparing accessibility and assessing equity with racial demographic data obtained through Table B03002 of the U.S. Census Bureau, delineating population data by race, and for the purposes of this analysis was cleaned to include four predominant racial categories by census block group: White alone, Black alone, Asian alone, and Hispanic or Latino alone. Median household income data was obtained through Table 19013 of the U.S. Census Bureau, which simply states a census block group's median household income. These two tables were cleaned up and joined together for a resulting table containing each census block group's racial population numbers and median household income, to be later used calculating accessibility measures.

With all of the necessary GIS feature classes collected, our survey area was able to be finalized. Austin city limits was chosen as the preliminary scope of study however the geographic units being analyzed, census block groups in this case, rarely if ever perfectly fit inside municipal boundaries. The Austin municipal boundary was transposed on top of all Travis County census block groups, showing the reality that census block groups found along the periphery of Austin city limits fall unevenly inside and outside municipal boundaries. Therefore to minimize areas being neglected by the study, an analytical operation in GIS called *Intersect* was conducted to find all census block groups that intersect along Austin municipal boundaries. These intersected census block groups were ultimately included in our study area, due to 1) these areas include and are serviced by City of Austin active transportation infrastructure, 2) the need to include, and not exclude, as many areas as possible within the study, 3) avoid confusion by parsing geographic units that fall within municipal boundaries out of the analysis, and 4) the option to control distant census block groups out of the analysis with the geographic threshold accessibility measure. **FIGURE 1** visualized the final study area, showcasing Austin city limits and census block groups included within the study, as well as the locations of parkland included within the analysis.

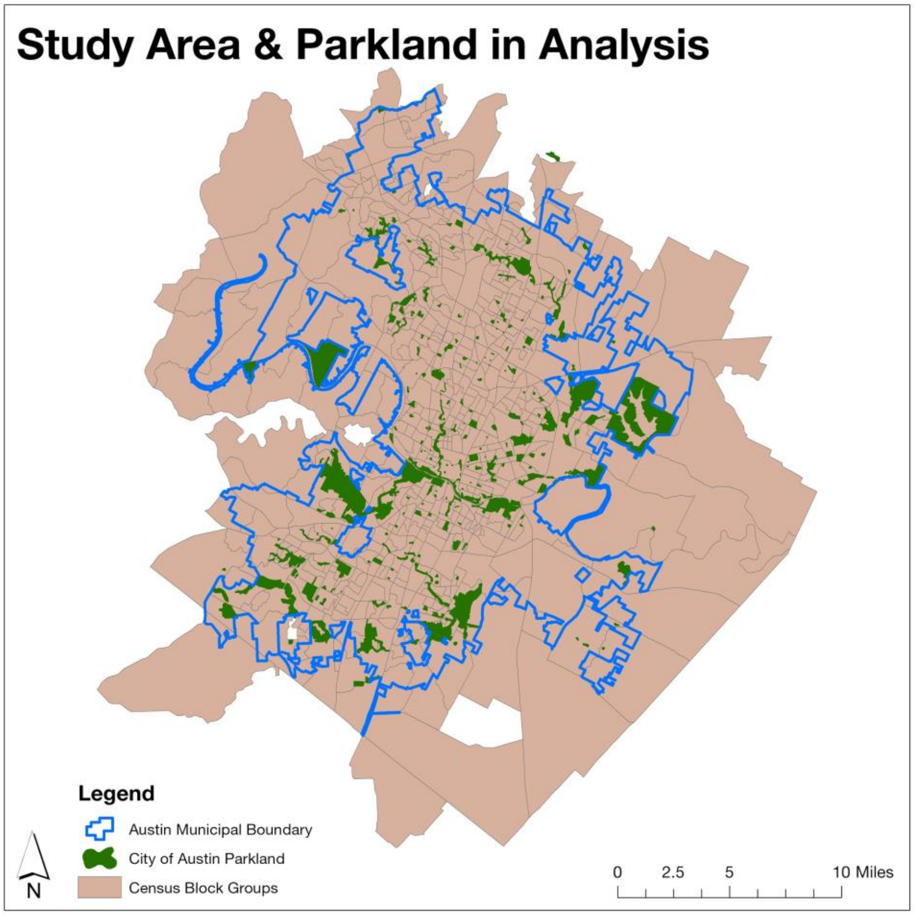

FIGURE 1: Map showing extent of study area and parkland included within analysis

Creating Complete Active Transportation Network Datasets

As we saw within the literature review of this report, many studies researching accessibility to public services simply opt to utilize existing street GIS feature classes as their network in which access is measured. Although the street network can arbitrarily contain attributes that represent walking or biking modal behavior, street feature classes fail to portray the reality of active transportation infrastructures geographic extent across a municipality. For example, a street network dataset will be unable to accurately represent safe walking routes, as all street segments in a street network dataset are represented equally. While an analyst manually differentiate street segments, this is a labor-intensive process and still fails to accurately represent where sidewalks physically appear in the built environment. With GIS at our disposal, it was possible to move beyond street segment lines as the singular feature class comprising a network, and to append the sidewalk GIS feature class onto the street network to create a hybrid sidewalk-street network dataset.

The creation of a bike lane network was more straightforward, with a fully connected bike lane shapefile already available from the City of Austin, a routable network could be produced without the need to fill in gaps with a street network. In this report we utilize an extension for Esri ArcMap called *Network Analyst.* Network Analyst allows for a range of models of accessibility between different points to be explored when a proper network is inputted within it. Specifically, we employed a tool within Network Analyst called OD-Cost Matrix, which takes in as inputs a number of origins and calculates network distances to a number of destinations. In this case our origins are census block group centroids, and destinations are parkland (represented in various ways). The methods listed here, describing the creation of these pedestrian/cyclist network datasets, offers practitioners an avenue to advance their level of analysis in any form of pedestrian or cyclist geospatial issue. Furthermore, as the creation of these active transportation infrastructure network datasets crucial caveat is the existence of detailed sidewalk and bike lane GIS feature classes, it can be a wakeup call for municipalities need for consistently updating and maintaining their GIS inventories to best represent the state of infrastructure in their respective cities.

The difficulty in unifying a street GIS feature class with a sidewalk or bike lane GIS feature class is the geographic discrepancy between the two features. For example, street GIS feature classes are commonly represented as street centerlines, while sidewalks are represented as the actual lines in which they are located geographically. This discrepancy in our data was much more pronounced between streets and sidewalks, as sidewalks were found to be present on both sides of the street with a small gap between them and the street centerline, while the bike lane feature class coincided with street centerlines except where they diverge into their own paths. Furthermore, the sidewalk shapefile from the City of Austin represents the reality of infrastructure in place, with various areas of Austin containing sidewalk "islands" that lack connectivity to other sidewalk features. If these features were geographically concurrent (even taking into account sidewalk islands) a simple merging of street and sidewalk/bike lane features would produce a routable network. Discrepancies between the street and sidewalk shapefiles were inevitably significant and pronounced, and necessitated further geoprocessing to create connectivity between streets and sidewalk feature classes. However, taking into account the bike lane shapefile connectivity and coincidence with the street network, a network was created solely using this feature class. This way bicycle accessibility could be measured along existing bike lanes in Austin, and not depend on the street network to fill in gaps.

The need to integrate streets and sidewalk features into a unified network dataset that is able to traverse both street segments and sidewalk segments is due to the inherent variability of people accessing parks. Many pedestrians may find their walk to the park taking place on a mix of both the street and available sidewalks. Pedestrians will prefer using a sidewalk, but in the absence of them, will opt to walk on the street if they deem it safe enough to traverse. Creating a network that can model this mixing of on-street and on-sidewalk travel is thus critical to get an accurate representation of pedestrian behavior in accessing parkland in Austin, where as we have learned, infrastructure can be sparse or nonexistent in certain areas. The 'inspiration' for our method of corroborating street and sidewalk/bike lane feature classes into their own respective unified networks came from Farber (2014). Recall in a grocery access study, Farber et al. (2014) created a transit-pedestrian network dataset, specifically through a geoanalytical tool called *Add GTFS to a Network Dataset.* This tool is able to take in GTFS transit data, and create feature classes representing transit lines and stops, while also creating 'connector features' to any other network, in the case of Farber et al. (2014), the street network which was acting as a conduit for a pedestrian network. This creation of 'connector features' was the basis in which we were able to corroborate the creation of Austin streets and sidewalk/bike lane network datasets.

The process to create connectivity between sidewalk features and street features is as follows, with **FIGURE 2** showing a visual representation of the sidewalk-street connectivity process:

1. Using the *Feature Vertices to Points* data management tool, endpoints were created at each sidewalk segment vertexes.
2. Using the *Snap* geoprocessing tool, the newly created sidewalk segment endpoints were transferred and snapped onto the street network feature class.

3. Two new attributes were created in the sidewalk and street network endpoint attribute tables which calculated the x and y coordinates of each new endpoint.
4. Using the *XY to Line* geoprocessing tool, the x and y coordinate attributes of both the sidewalk/bike lane endpoints (x_coord1 and y_coord1) and snapped to street endpoints (x_coord2 and y_coord2) were entered, resulting in the creation of a line between the two end points.
5. Using the *Integrate* data management tool, coincident vertices were created amongst the snapped to street endpoints and the street network itself, an invisible process which would allow connectivity between these two feature classes when creating the network data set later on in Network Analyst.

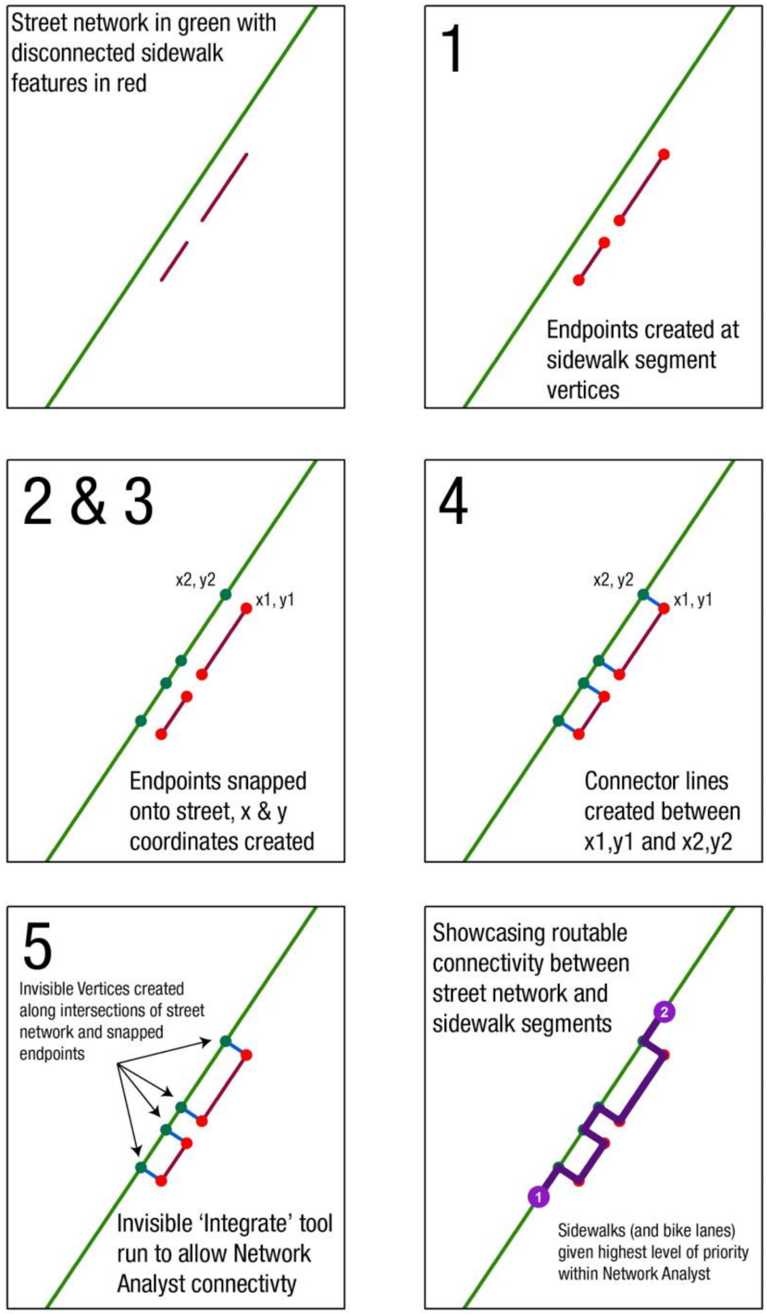

FIGURE 2: Detailed process in creating connectivity between street / sidewalk features

Configuring Network Analyst and Network Attributes

With proper connectivity (i.e. a network dataset that is able to traverse both street and sidewalk segments) created between the street features and sidewalk features data, we were able now able to configure formalized street-sidewalk and bike lane network datasets to be used in analyzing accessibility. The creation of the bike lane network dataset was a straightforward process, with the bike lane shapefile being inputted as the sole feature for the dataset into Network Analyst**.** From there a single attribute was created titled "Total_Length", which would accumulate an attribute from the bike lane shapefile called "Shape_Length" between any origin and destination. "Total_Length" accumulates distance in feet, and could be inferred into miles during the data analysis portion of the project. **FIGURE 3** shows the final geographic extent of the bike lane network dataset across our study area.

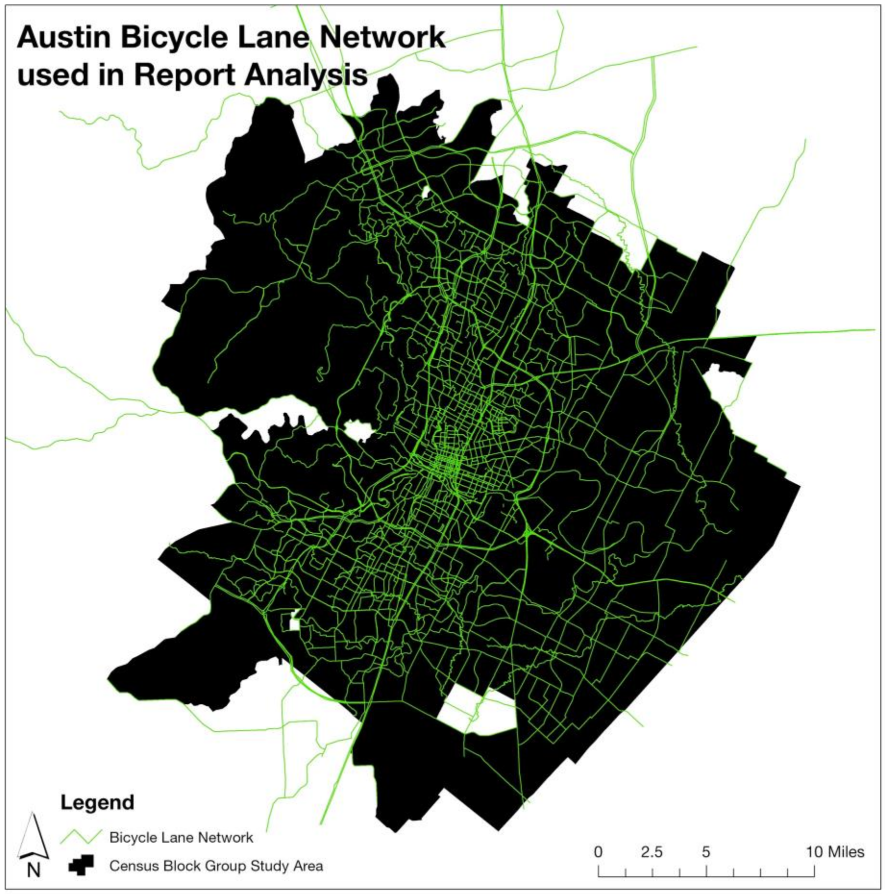

FIGURE 3: Bike Lane Network Dataset

The creation of the street-sidewalk network dataset was a more nuanced process involving more configuration within Network Analyst. Instead of a singular feature being inputted as was the case in the bike lane configuration, five feature classes were necessary:

- Austin Street Segments (Edge Feature)
- Austin Sidewalk Segments (Edge Feature)
- Street / Sidewalk Connector Segments (Edge Feature)
- Sidewalk Segments Endpoints (Junction Feature)
- Sidewalk Segments Endpoints Snapped to Streets (Junction Feature)

These five feature classes ultimately comprise a unified street-sidewalk network dataset, with the edge features being segments in which the network is able to traverse, and the junction features being points in which you can jump between different edge features. Network Analyst requires formal a formal connectivity policy to be configured between all inputted features, and this can be seen in **FIGURE 4.** Each edge feature is assigned to a connectivity group, with junction features able to link different connectivity groups together. In this case, the street segments are linked to the street-sidewalk connector lines through the snapped endpoints junction feature. From there connectivity continues ‘down’, with the street-sidewalk connector lines passing connectivity onto the sidewalks through the sidewalk endpoint junctions.

Source	Connectivity Policy	1	2	3
Austin_Street_Segments_Proje_1	End Point	☑	☐	☐
Sidewalk_No_Driveways_1	End Point	☐	☐	☑
Sidewalk_Street_Connector_Line_1	End Point	☐	☑	☐
Sidewalks_With_Endpoints_1	Honor	☐	☑	☑
Sidewalks_With_Endpoints_Snapped_To_Stre...	Override	☑	☑	☐

FIGURE 4: Street-Sidewalk Network Dataset Connectivity Policy

Next, a series of attributes were built into the street-sidewalk network dataset that would allow Network Analyst to accumulate both the total travel distance and the distance covered by sidewalks between any origin and destination. “Total_Length” is the same attribute created within the bike lane network dataset, and accumulates the network distance in feet between an origin and destination. “Sidewalk_Length” is an attribute that specifically accumulates distance in feet only on the portion of a route that occurs on sidewalk segments. By dividing “Sidewalk_Length” against “Total_Length” we can calculate the percentage of a trip between an origin and destination that was taken on sidewalks, opening the door to use this within accessibility measures. Lastly, a ‘restriction’ attribute titles “Sidewalk_Priority” was created, placing the highest level of importance onto the networks sidewalk segments. This set up an environment where when Network Analyst is calculating trips between an origin and destination, priority will always be placed on traversing sidewalk segments rather than street segments, only to defer to the street when sidewalks are absent. The completed street-sidewalk network dataset can be seen in **Figure 4,** showing its geographic extent across our study area, with sidewalks segments represented in blue and street segments represented in grey.

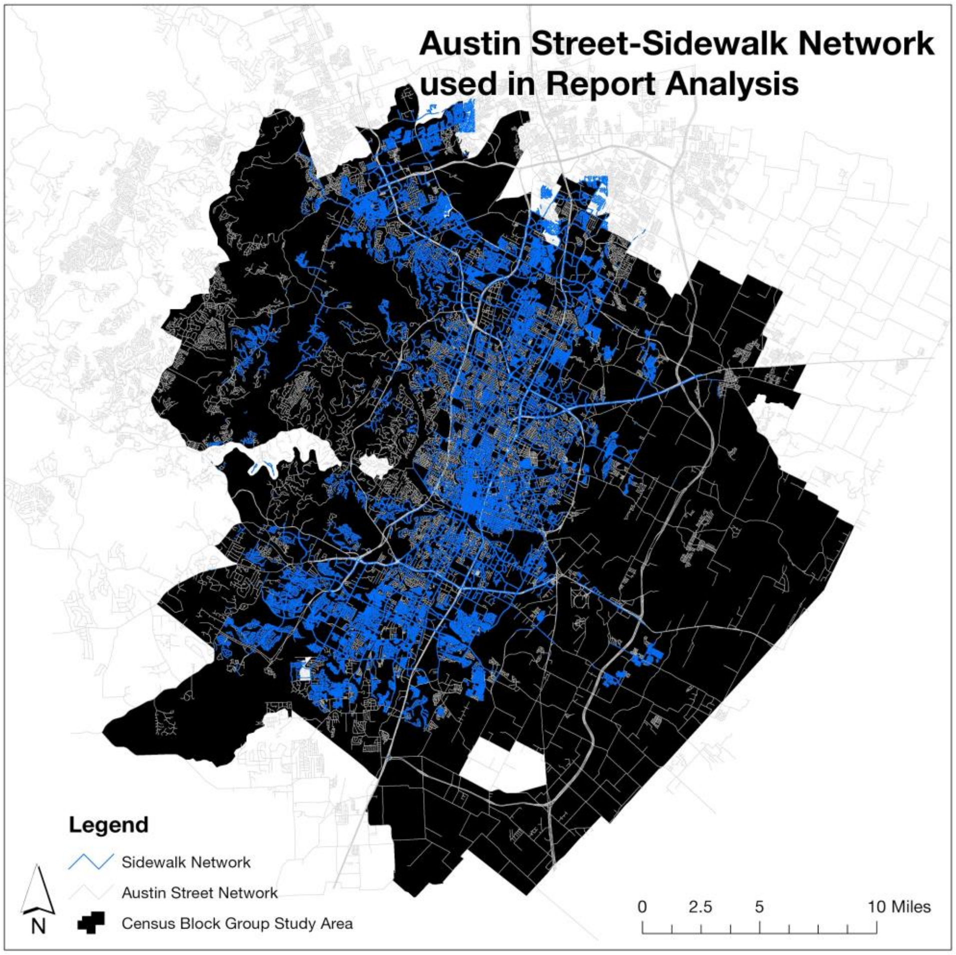

FIGURE 5: Street-Sidewalk Network Dataset

With both of our active transportation networks configured, we employed a tool built into Network Analyst called *OD-Cost Matrix.* This tool takes in two inputs, origins and destinations, and calculates "Lines" between the two depending on parameters set by the user. Although the "Lines" generated by OD-Cost Matrix appear as Euclidean lines, in reality they represent network traversals between origin and destination. Parameters may include the number of destination facilities to find, or a geographic extent to search for facilities within an origins radius. Details on the various ways OD-Cost Matrix was configured for our study are detailed within the next section.

Accessibility and Equity Measures

Two primary accessibility measures were employed by this study to ascertain the results of the OD-Cost Matrix results conducted on our street-sidewalk and bike lane network datasets. The first is *Minimum Distance,* an accessibility measure that within the context of this study simply finds the nearest destination (parkland) from an origin point (census block group centroids). The second is *Distance Threshold,* an accessibility measure that sets a network distance from each origin point (census block group centroids) as a maximum limit for traversal, and finds all destinations available (parklands) within this distance. Both of these measures are easily implemented within OD-Cost Matrix, and can reveal important statistics regarding accessibility including average travel distance/time to the nearest facility across any number of geographic units or total amount of facilities (e.g. park acreage) within a specified distance from a geographic unit.

Inherent differences in network dataset configuration, specifically the fact that the sidewalk network is a hybrid street-sidewalk network dataset, while the bike lane is the sole source feature in the bike lane network dataset, means different outputs from the OD-Cost Matrix analysis will arise. Most notable is that the street-sidewalk OD-Cost Matrix calculates a percentage of each trip between origin and destination that took place on sidewalk segments. The bike lane OD-Cost Matrix analysis happens entirely on the bicycle lane network, and will not return a percentage of trips happening on bike lanes as it will all be 100%. As such, we will present our methodology for calculating accessibility measures separately for both the street-sidewalk network dataset and bike lane network dataset. From these generated accessibility measures, we can apply socioeconomic data to infer levels of equity. *Population-Weighted Means* were used to explore demographic equity measures, comparing the accessibility measures we calculated against different racial groups' population numbers in a census block group. For an economic equity indicator, *Geographic Thresholds* were employed, selecting census block groups for only those that fall under the median household income for Austin, attempting to explore the level of access less affluent census block groups have to parkland.

Measuring Access by Foot

TABLE 1 displays all of the pedestrian accessibility measures employed, with their origin and destination inputs, statistical outputs, and a description of the measure.

Accessibility Measure	GIS Origin Input	GIS Destination Input	Statistical Output	Measure Description
Minimum Distance	Census Block Group Centroids (point feature)	Parkland Border Vertex Points (point feature)	Average minimum distance to parklands across all Census Block Groups	The minimum network distance between origins and the first nearest destination is calculated
Distance Threshold (1/2 Mile)	Census Block Group Centroids (point feature)	Parkland Centroids (point feature)	1) Average distance to parklands within 1/2 mile across all Census Block Groups 2) Average amount of parkland acreage within 1/2 mile across all Census Block Groups	All network distances between origins and any destination within network 1/2 mile is calculated
% of Minimum Distance on Sidewalk	Census Block Group Centroids (point feature)	Parkland Border Vertex Points (point feature)	Average percentage of trips taking place on sidewalks between origin and nearest destination across all Census Block Groups	The percentage of a trip taking place on sidewalks between an origin and the first nearest destination is calculated
% of Distance Threshold on Sidewalks (1/2 Mile)	Census Block Group Centroids (point feature)	Parkland Centroids (point feature)	Average percentage of trips to parkland taking place on sidewalks within 1/2 mile	The percentage of a trip taking place on sidewalks between an origin and all destinations within a 1/2 mile is calculated

TABLE 1: List of pedestrian accessibility measures employed in analysis.

The Minimum Distance and Distance Threshold for measuring pedestrian accessibility was calculated in different ways in order to generate different descriptive statistics from the OD-Cost Matrix Results. The largest difference between how these accessibility measures ended up being executed was the way in which Austin parkland was represented as destinations within OD-Cost Matrix. For Minimum Distance the decision was made to create GIS point features at a park's boundary vertices. This made it so each park had numerous points along its border, representing various entry points into that respective parkland. Because for Minimum Distance we are simply looking at the closest park from a census block group's centroid, when OD-Cost Matrix is calculating the shortest distance to a park it will automatically snap the nearest park boundary vertex point as the destination to be reached. However, for Distance Threshold, we are attempting to see how many parks can be reached within a specified distance, and the use of boundary vertices would create confusion within OD-Cost Matrix, as it would continually locate vertex destinations at the nearest park from a census block group centroid. To remedy this, the decision was made to represent each park destination as a single centroid. That way, once OD-Cost Matrix has calculated the network distance to one park, it can continue searching for parks within the specified distance threshold. A visual representation of these two destination point features can be seen in **FIGURE 6.**

FIGURE 6: Park Boundary Vertex and Park Centroid Destination Point Features

Minimum Distance was calculated on the street-sidewalk network dataset between all census block groups and the nearest parkland boundary's vertex point, and the average across all census block groups of all these distances is the statistical output to be gleaned. In addition to this, the percentage of all these minimum distances taking place solely on the sidewalk network was also calculated, also with an average of these distances across all census block groups as the statistical output. For Distance Threshold, a limit of ½ mile was chosen, representing a 10-minute walk time to a park if a 3 mph speed is assumed for pedestrians (Carey, 2005). All parkland distances reachable within a ½ mile network distance from a census block group centroid was calculated. Statistical output from this analysis is the average distance to parks within ½ mile across all census block groups, as well as the average acreage of parkland across all census block groups that is reachable within ½ mile. The average percentage of trips under ½ mile across all census block groups taking place on the sidewalk network was also calculated.

Utilizing the calculated accessibility measures, socioeconomic information was contrasted against them to generate equity measures. Looking at each census block group's population of four race/ethnicity categories (White alone, Black alone, Hispanic or Latino alone, and Asian alone), population weighted means were calculated for each accessibility measure. By calculating population weighted means, we can infer a performance measure of that group's level of access across the study area. From this compartmentalization of accessibility measures by race, differences between racial groups can be studied to infer levels of equity. Furthermore, looking at each census block group's median household income, a geographic threshold was made controlling for block groups that fall under Austin's median household income of $60,939 (US Census Bureau), and looked at the accessibility measures only for these block groups. This approach ultimately reduces the number of census block groups in the analysis to only include those under the city's median household income. With this equity statistic, we can compare it against the city wide accessibility measure average, and infer if less affluent census block groups have higher or lower levels of access than the general population. With these equity measures in place, we can get an idea of how different racial populations compare with one another in pedestrian accessibility to parkland, as well as how economically disadvantaged areas compare to the city as a whole.

Measuring Access by Bike

TABLE 2 displays the cycling accessibility measures employed, with their origin and destination inputs, statistical outputs, and a description of the measure.

Accessibility Measure	GIS Origin Input	GIS Destination Input	Statistical Output	Measure Description
Minimum Distance	Census Block Group Centroids (point feature)	Parkland Border Vertex Points (point feature)	Average minimum distance to parklands (under 4 miles) across all Census Block Groups	The minimum network distance between origins and the first nearest destination is calculated. Destinations over 4 miles away excluded.
Distance Threshold (2 Miles)	Census Block Group Centroids (point feature)	Parkland Centroids (point feature)	1) Average distance to parklands within 2 mile across all Census Block Groups 2) Average amount of parkland acreage within 2 miles across all Census Block Groups	All network distances between origins and any destination within network 2 mile is calculated

TABLE 2: List of cycling accessibility measures employed in analysis.

Calculating accessibility measures for cyclists access to parkland followed a similar structure to our pedestrian accessibility measures, with the exception that since the analysis was conducted entirely on a bicycle network dataset, no percentage of trips taking place on bike lanes was calculated. For Minimum Distance, parkland boundary vertex points were used as destinations, while parkland centroids were used as destinations for Distance Threshold. For Minimum Distance, OD-Cost Matrix calculated the shortest network distance between census block group centroids and the nearest parkland boundary vertex point, with the statistical output being the average distance across all census block groups to the nearest park. However, a parameter was inputted into OD-Cost Matrix to cut off the search for destinations after 4 miles. This was decided after preliminarily running the analysis and noticing outlying census block groups in the periphery of Austin having abnormally large minimum network distances to parklands. In order to now skew results for the majority of centrally located census block groups, the 4 mile limit for minimum distance was placed, controlling for the minority of outlying census block groups. In a way, this becomes a hybrid Minimum Distance / Distance Threshold accessibility measure. For Distance Threshold, a limit of 2 miles was chosen, representing a 12 minute bike ride along the bike lane network if a 10mph speed is assumed (Allen et al., 1998; Bernardi and Rupa, 2013). As was the case when looking at pedestrian access, all parkland centroids reachable within a 2 mile network distance from a census block group were accumulated, with the statistical outputs being the average network distance to parks within 2 miles across all census block groups, as well as the average amount of park acreage available within 2 miles across all census block groups. Equity measures calculated for cyclists follow the same procedure as ones calculated for pedestrians.

FINDINGS

Access to Austin Parks by Foot - Minimum Distance

The minimum distance between census block group centroids and parkland boundary vertex points was computed in OD-Cost Matrix, utilizing our street-sidewalk network dataset. In total, 557 census block groups and the accompanying shortest network distance to the nearest parkland was calculated. No distance threshold was placed on the analysis, and as such all census block groups within the study area were included. **FIGURE 7** shows a map of the OD-Cost Matrix results, with linear links between origin and destination representing the shortest network length between the two.

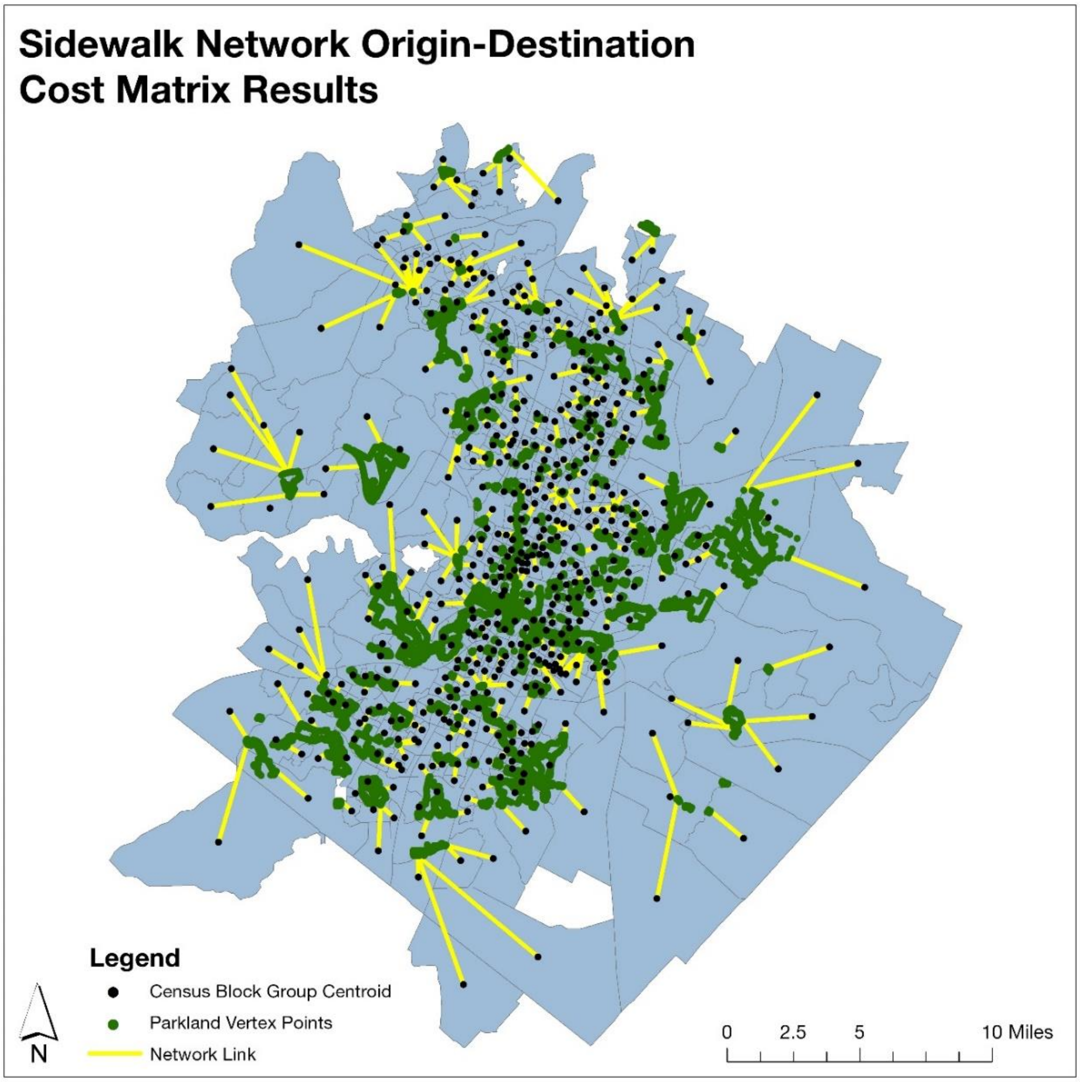

FIGURE 7: Sidewalk Network Minimum Distance OD-Cost Matrix Results

For all Austin residents across all census block groups, the average shortest distance between census block group centroid origins and parkland boundary vertex point destinations was .79 miles. Approximately 56% of the shortest distance trips to parklands for residents across all census block groups take place entirely on the sidewalk network, with the rest occurring along street segments. Population weighted means for each census block group for White, Black or African American, Asian, and Hispanic or Latino populations were calculated. All four population weighted mean indicators fell above the city-wide shortest distance average, having significantly higher trip distances, with Black or African American residents having the shortest minimum distance to parkland at 0.94 Miles, while White residents had the longest minimum distance to parkland at 1.13 Miles. Looking at population weighted means for the four races share of trips occurring on the sidewalk network, Asian residents had the highest level of sidewalk availability at 59.59% while Hispanic or Latino residents lack sidewalk connectivity the most with 51.94% of their nearest parkland trips occurring on sidewalks. Considering only census block groups that fall under Austin's median household income ($60,939), both accessibility measures saw slight increases in performance. The average minimum distance to parkland dropped to .62 miles (1 km exactly), and sidewalk availability and connectivity for completing trips to parkland increased to 61%. **TABLE 3** below lists all of the accessibility and equity measures calculated from the Minimum Distance Pedestrian OD-Cost Matrix Analysis.

Pedestrian Minimum Distance Accessibility & Equity Measures	
Accessibility Measures	
Average Minimum Distance to Nearest Park Across all Census Block Groups	.79 Miles
% of Minimum Distance Trips Taking Place on Sidewalk	55.95%
Equity Measures	
Population Weighted Means - Minimum Distance across all Census Block Groups	
White Alone	1.13 Miles
Black or African American Alone	0.94 Miles
Asian Alone	1.11 Miles
Hispanic or Latino Alone	1.03 Miles
Population Weighted Mean - % of Minimum Distance Taking Place on Sidewalk	
White Alone	52.35%
Black or African American Alone	52.20%
Asian Alone	59.59%
Hispanic or Latino Alone	51.94%
Geographic Threshold - Census Block Groups Under Austin Median Household Income ($60,939)	
Avg. Minimum Distance to Nearest Park	.62 Miles
Avg. % of Trips Taking Place on Sidewalk	61.02%

TABLE 3: Pedestrian Minimum Distance OD-Cost Matrix Analysis Results

Access to Austin Parks by Foot - Distance Threshold

After examining the shortest distances residents had to the nearest parkland, we expanded the analysis to look at each census block group's access to all parklands available within a ½ mile distance. A distance limit parameter was inputted into OD-Cost Matrix to search for all parklands accessible from a ½ mile network distance of a census block group's centroid. This ½ mile limit significantly reduced the number of census block groups able to access parkland, with only 291 out of the 557 total census block groups within our study area being outputted from the OD-Cost Matrix analysis. Across these distance threshold controlled census block groups, the average distance to all parkland within a ½ mile network distance for residents within these restricted census block groups was 0.34 miles. An average of 61.71% of all trips to parkland within ½ mile of a census block group centroid occur on the sidewalk network, with residents having an average of 30.64 acres of parkland available to them. Population-weighted means calculated for the various racial groups accessibility to parklands within ½ mile resulted in their average distance virtually falling exactly on the city-wide average, with Asian residents gaining a miniscule uptick in distance to 0.35 miles. Weighting the sidewalk coverage percentage by the population of various races however highlighted notable differences, with Asian residents having a high 74.03% of their ½ mile trips to parks accessible by sidewalk, while white residents were the only group to fall under the city wide average at 60.03% sidewalk availability within this distance threshold context. Lastly, controlling geographically for census block groups falling under the city's $60,939 median household income, the average distance to parkland within ½ mile remained consistent with the city-wide average, while the percentage of trips to parks occurring on sidewalks increased modestly to 67.84%. **TABLE 4** below lists all of the accessibility and equity measures calculated from the Distance Threshold Pedestrian OD-Cost Matrix Analysis.

Pedestrian 1/2 Mile Distance Threshold Accessibility & Equity Measures		
Accessibility Measures		
Average Distance to Parkland within 1/2 Mile Across all Census Block Groups		0.34 Miles
% of 1/2 Miles Distance Threshold Trips Taking Place on Sidewalk		61.71%
Average Amount of Acreage within 1/2 Mile Across all Census Block Groups		30.64 Acres
Equity Measures		
Population Weighted Means - 1/2 Mile Distance Threshold across all Census Block Groups		
	White Alone	0.34 Miles
	Black or African American Alone	0.34 Miles
	Asian Alone	0.35 Miles
	Hispanic or Latino Alone	0.34 Miles
Population Weighted Mean - % of 1/2 Mile Distance Threshold Trips Taking Place on Sidewalk		
	White Alone	60.03%
	Black or African American Alone	67.40%
	Asian Alone	74.03%
	Hispanic or Latino Alone	67.97%
Geographic Threshold - Census Block Groups Under Austin Median Household Income ($60,939)		
	Avg. of Distance Threshold Trips to Parkland within 1/2 Mile	.33 Miles
	Avg. % of Trips Taking Place on Sidewalk	67.84%

TABLE 4: Pedestrian Distance Threshold OD-Cost Matrix Analysis Results

Access to Austin Parks by Bike - Minimum Distance

Moving onto our bike lane only network dataset, an OD-Cost Matrix analysis was conducted to explore the minimum distance between census block group centroid origins and parkland boundary vertex point destinations. It is important to remember that for our minimum distance accessibility measurement along the bicycle network, a distance limit of 4 miles was built in as a parameter to restrict the minority of distant, peripheral census block groups from skewing the data. Solely relying on the bicycle network without joining it to the street network has the added benefit of exploring accessibility as it occurs exclusively on bike lane infrastructure, but also the drawback of not being able to shorten cycling distances through short-cuts within the street network. This distinction ultimately limits our cycling analysis to geographically established bicycle lanes built by the City of

Austin. Preliminarily running the minimum distance OD-Cost Matrix for our bicycle network, it became apparent residents living in peripheral census block groups were traveling abnormally large distances across City of Austin bike lanes to reach City of Austin parkland. This is perhaps a limitation of our GIS data, as we limited this study to solely focus on shapefiles provided by the City of Austin. As such, census block groups that were included in the study area, yet fell 'half-in, half-out' of Austin City Limits, were quite a distance from established City of Austin parkland. This was not as large of an issue when studying pedestrian access to parkland, due to the ability to 'fall back' onto the street network to complete trips between origin and destination. By placing a distance threshold within our minimum distance accessibility measure, we could filter out of the analysis these outlying observations. In all, out of the 557 total census block groups within our study area, 521 were able to reach the nearest parkland vertex point destination from their centroids. **FIGURE 8** shows a map of the OD-Cost Matrix results for our bicycle lane minimum distance analysis, illustrating linear links between origins and destinations, as well as census block groups incapable of reaching parkland within 4 miles along City of Austin bike lanes.

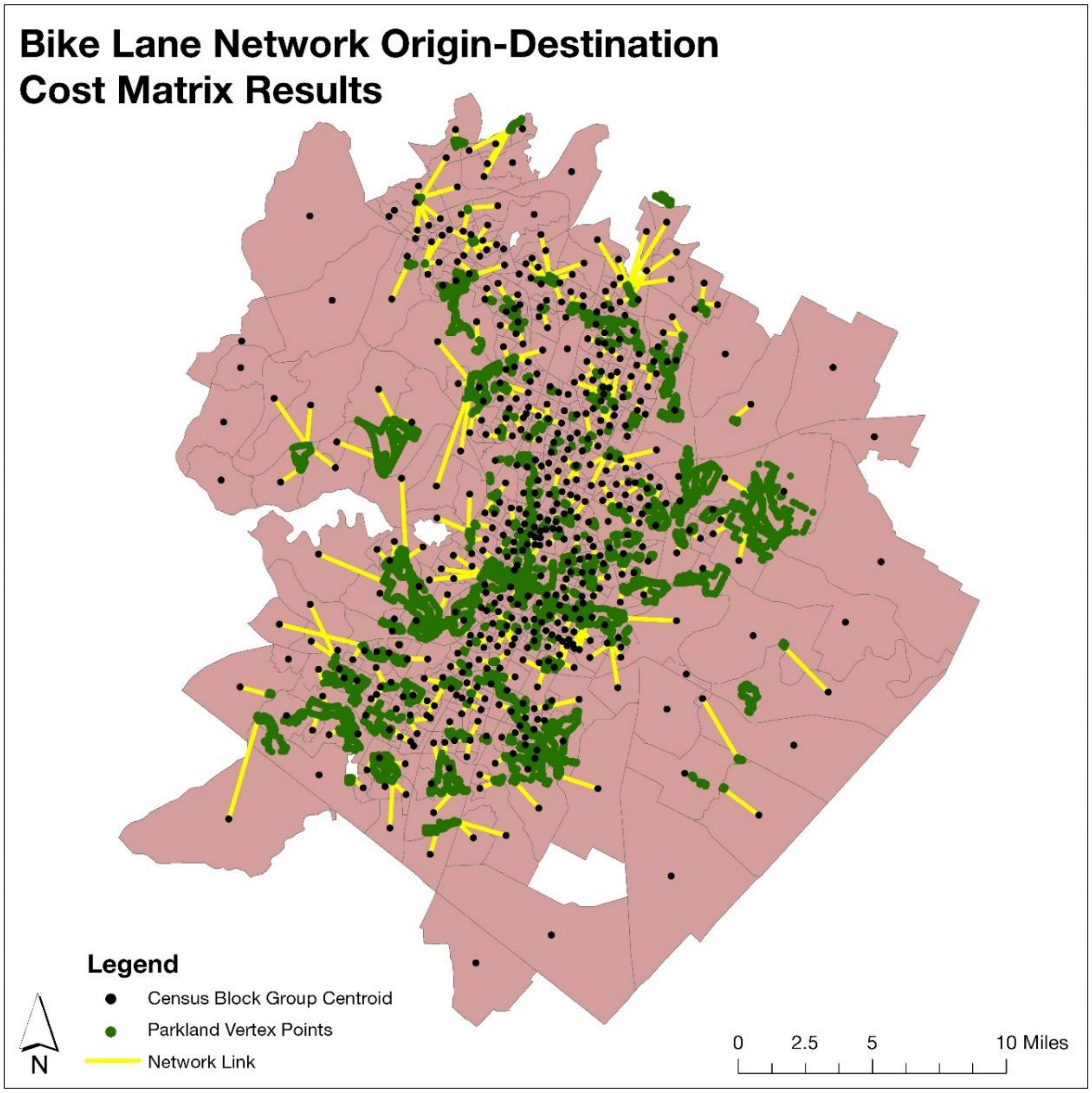

FIGURE 8: Bike Lane Network Minimum Distance OD-Cost Matrix Results

The results show that in the 521 census block groups able to reach a single park within 4 miles, residents have an average minimum distance was 0.54 miles to the nearest parkland, a distance much smaller than the maximum 4 miles network distance allowed. It should be noted that this takes place 100% along established bike lanes, and assuming a modest 10 mph cycling speed, the average time to reach a park by biking is approximately 3 minutes. Population weighted means for the various races in question show slightly increased distances, however all races fall under ¾ miles to reach the closest park, with Hispanic or Latino residents having the shortest distance to accessing parkland, a distance consistent with the city wide average of 0.54 miles. Geographically controlling for census block groups under the Austin median household income, we see that these residents actually have a greater level of accessibility at 0.48 miles. Overall, cycling access strictly along the bike lane network to the nearest parkland is strong, with all populations examined having incredibly short travel distances. **TABLE 5** below lists all of the accessibility and equity measures calculated from the Minimum Distance Bicyclist OD-Cost Matrix Analysis.

Bicyclist Minimum Distance Accessibility & Equity Measures	
Accessibility Measures	
Average Minimum Distance to Nearest Park Across all Census Block Groups	.54 Miles
Equity Measures	
Population Weighted Means - Minimum Distance across all Census Block Groups	
White Alone	0.64 Miles
Black or African American Alone	0.57 Miles
Asian Alone	0.73 Miles
Hispanic or Latino Alone	0.54 Miles
Geographic Threshold - Census Block Groups Under Austin Median Household Income ($60,939)	
Avg. Minimum Distance to Nearest Park	.48 Miles

TABLE 5: Bicyclist Minimum Distance OD-Cost Matrix Analysis Results

Access to Austin Parks by Bike - Distance Threshold

For the Distance Threshold bike lane accessibility measure, a distance limit of 2 miles was chosen, which represents an approximate 12 minute bike ride to parkland assuming 10 mph. From census block group centroid origins, OD-Cost Matrix computed all accessible parkland within a 2 mile network distance. Because the distance threshold was much smaller than it was when calculating minimum distance, we saw that a total of 446 census block groups out of the 557 within the study area being included in this data set. This means residents within 111 census block groups were unable to reach a single park in under 2 miles along the bike lane. However 3,154 parks were reached within this 2 mile distance threshold, with overlap amongst different census block groups. Looking at residents within census block groups able to reach parklands through trips under 2 miles, the average distance for was 1.27 miles city wide. On average, 151.44 acres of parkland is available within 2 miles of census block group centroids. Population weighted means for various races access to parks within 2 miles rendered results virtually consistent with the city wide average. Controlling for census block groups that fall under the median household income, the average trip to parklands within 2 miles was 1.29 miles. This equity measure result was the only geographic threshold equity measure calculated in the study (in addition to Pedestrian Minimum Distance, Pedestrian Geographic Threshold, Bicyclist Minimum Distance) in which the households under median household income were less advantageous than the city wide average, albeit at a minuscule and insignificant scale (1.27 vs 1.29 miles). **TABLE 6** below lists all of the accessibility and equity measures calculated from the Minimum Distance Bicyclist OD-Cost Matrix Analysis.

Bicyclist 2 Mile Distance Threshold Accessibility & Equity Measures	
Accessibility Measures	
Average Distance to Parkland within 2 Miles Across all Census Block Groups	1.27 Miles
Average Amount of Acreage within 2 Miles Across all Census Block Groups	151.44 Acres
Equity Measures	
Population Weighted Means - 2 Mile Distance Threshold across all Census Block Groups	
White Alone	1.28 Miles
Black or African American Alone	1.27 Miles
Asian Alone	1.27 Miles
Hispanic or Latino Alone	1.25 Miles
Geographic Threshold - Census Block Groups Under Austin Median Household Income ($60,939)	
Avg. of Distance Threshold Trips to Parkland within 2 Miles	1.29 Miles

TABLE 6: Bicyclist Distance Threshold OD-Cost Matrix Analysis Results

DISCUSSION

Overall, the results from our accessibility and equity analysis measuring pedestrian and cyclists access to parkland point to positive outcomes. Pedestrians on a city-wide scale have an average distance of 0.79 miles of walking to reach the first nearby piece of parkland, indicating the average Austin resident across all census block groups has access to parks in under 15 minutes of walking. When restricting walking distance to under ½ mile, or a trip under 10 minutes, we see the average distance reduce to only 0.34 miles. However, we saw that limiting the walking distance to parks under ½ mile shrinks the total number of census block groups able to access parks by half, going from 557 census tracts to 291, a 52% reduction of the cities census block groups. On average this ½ mile network area radiating out from census block group centroids offers residents able to access parks in under a ½ mile walk 30.4 acres of parkland. This means that effectively half of Austin's census block groups are unable to walk to parkland within ½ mile, and the geographic extant of this restriction can be seen in **FIGURE 9.**

The results from our cycling accessibility measures outperformed pedestrian parkland accessibility measures. The average minimum distance between all census block groups and the nearest park along the bicycle network is only 0.54 miles, and this is without the addition of utilizing the street network. This speaks volumes on the strategic placement of existing bike lanes, as we can infer cyclists have routes to parkland that are not only quickly accessible, but occur entirely on some form of City of Austin bike lanes. A distance threshold of 2 miles was chosen to measure cycling access to all parkland within this distance, a unit comparable to the pedestrian distance threshold of ½ mile when thought of in regards in time taken to reach the maximum distance (roughly 10 minutes for both measures). Here we see that cyclists on average have a distance of 1.27 miles to reach parkland. However, the geographic extent of census block groups able to reach parks by biking is much larger than what we saw in the sidewalk network dataset, with 446 out of the 557 census block groups in the study area included. Furthermore, the total amount of park acreage accessible to cyclists eclipses pedestrian's park acreage access fivefold, at 151.44 acres of parkland vs 30.64 acres, respectively.

Cycling's advantage to accessing parks over the pedestrian mode both for the minimum distance and distance threshold measures inherently lie in biking's speed advantage over walking. While objectively speaking, the biking measures outperformed pedestrian measures, this is not a detriment to accessing parks by walking, and we can see pedestrians still have modest access to parklands. Furthermore, the pedestrian dataset contained all census block groups within the study area, while the cycling dataset excluded distances over 4 miles, so in a way the analysis conducted on the street-sidewalk network dataset is a true representation on conditions occurring at the street level. **FIGURE 9 and FIGURE 10** visualizes the results of the street-sidewalk and bike lane network dataset distance threshold accessibility measures. They show the geographic extant of census block groups able to either walk or bike to parkland within their specified distance thresholds, as well as the associated average distance for each census block group.

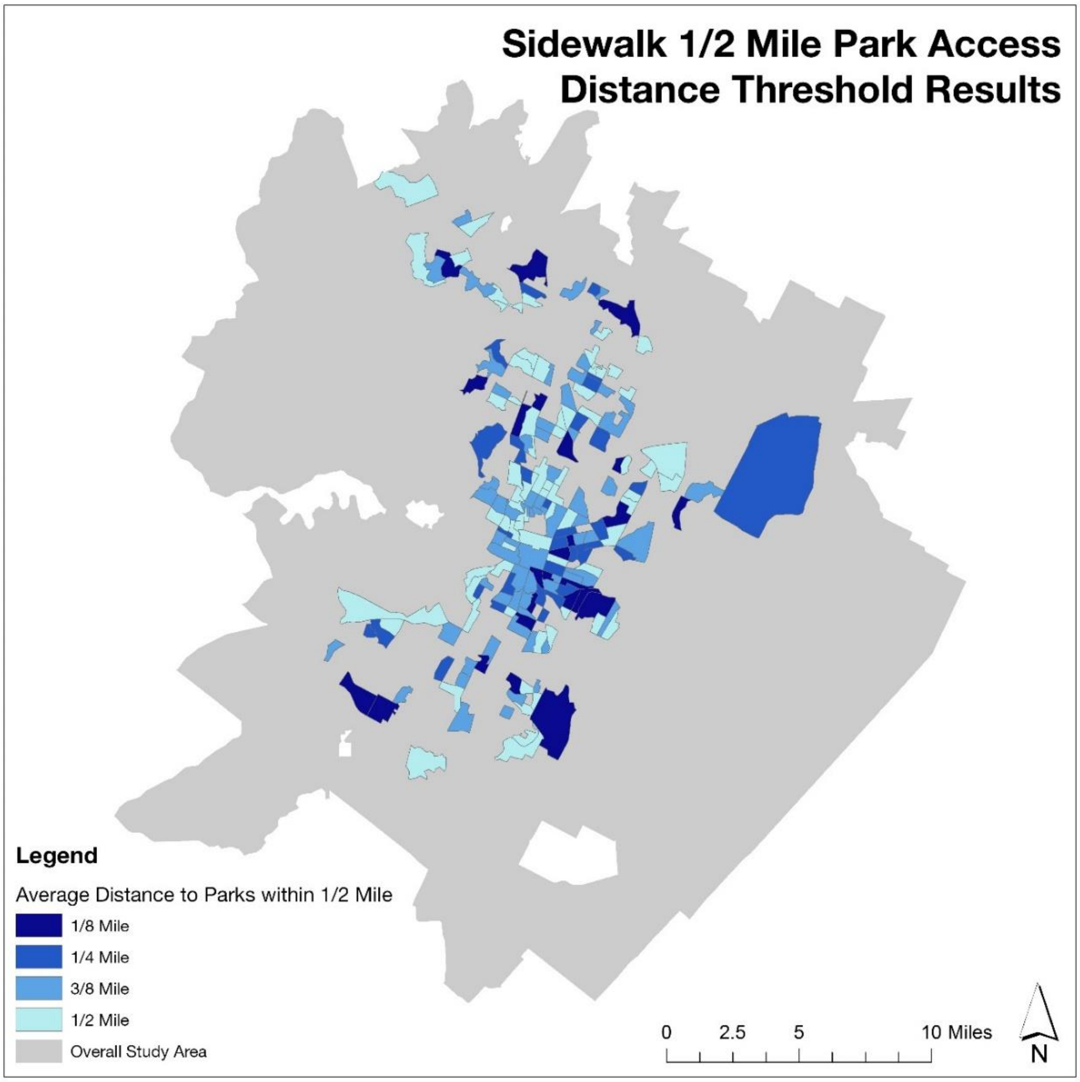

FIGURE 9: Pedestrian Distance Threshold Results by Census Block Group

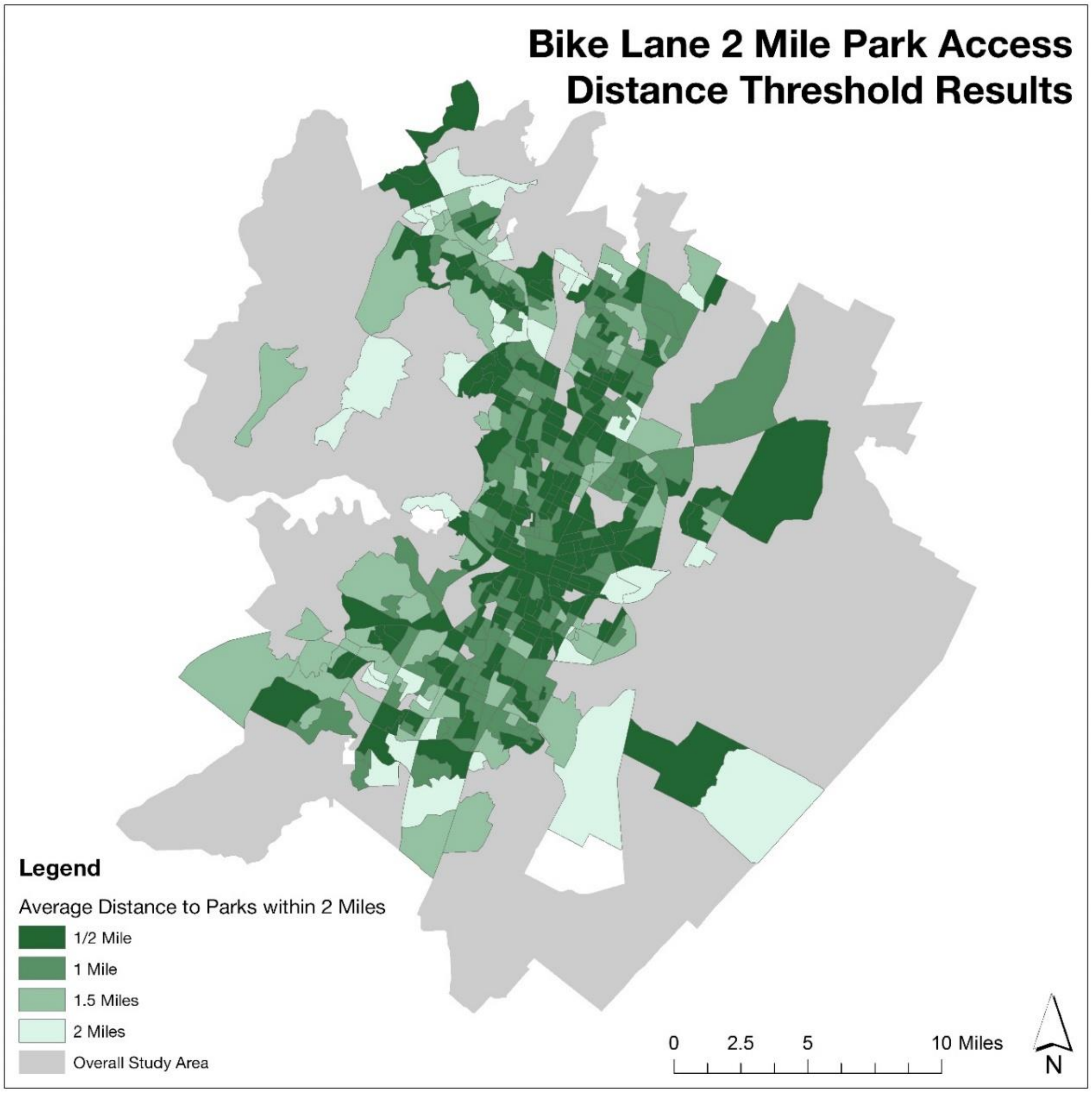

FIGURE 10: Bicyclists Distance Threshold Results by Census Block Group

Specifically looking at the percentage of pedestrian trips to parkland occurring exclusively on sidewalks, we can see results pointing to moderate accessibility and equity. The relationship between total distance to parkland and the percent of those trips occurring on sidewalks is intrinsically inverse. In an ideal situation you want lower distances between origin and destination, while wanting higher percentages of that trip to occur on the sidewalk network. We plotted the results from our pedestrian Minimum Distance analysis, looking at the correlation between each census block group's total distance to the nearest park and the share of that trip that occurred solely on the sidewalk network, which can be seen in **FIGURE 11.** This scatter plot points to positive results, as most of the census block groups are clustered within areas of low minimum distances to parkland, while retaining a high percentage of sidewalk availability to complete those trips.

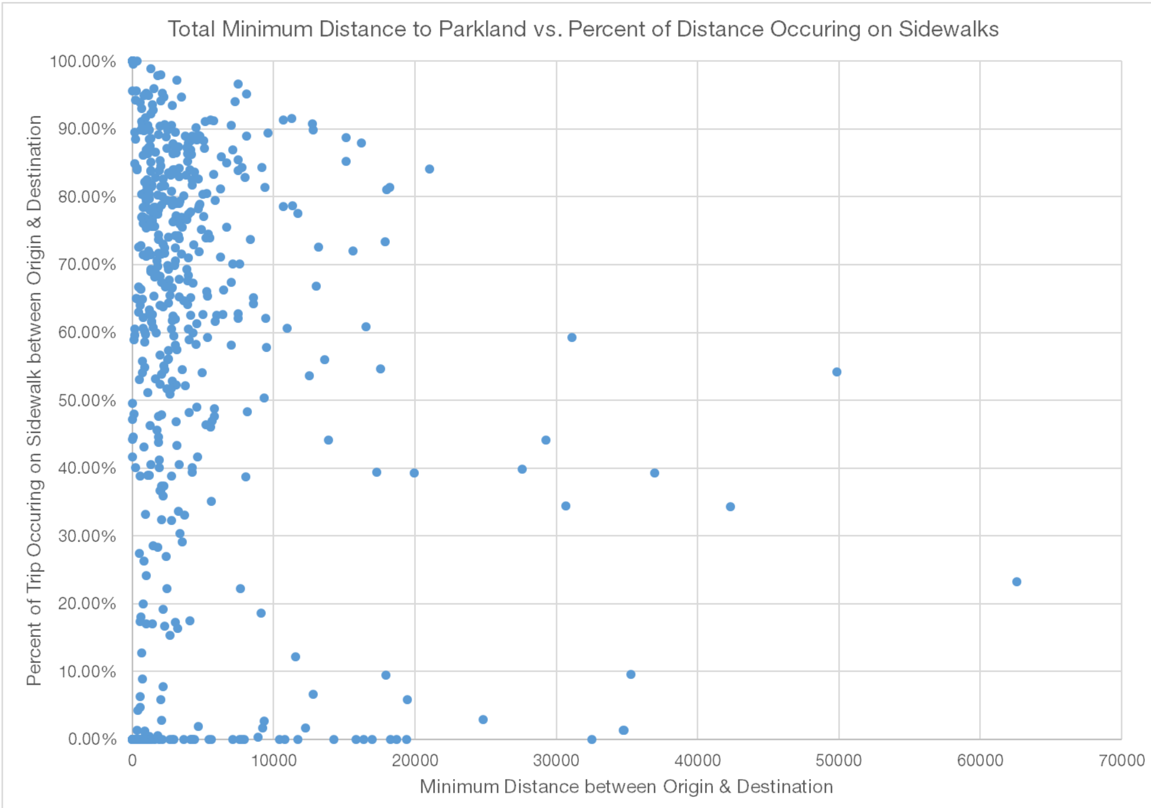

FIGURE 11: Scatterplot of pedestrian minimum distance (meters) and % sidewalk availability

City wide, the average percent of sidewalk availability to complete a trip's total length to the nearest park was 55.95%. This is an acceptable outcome when remembering that Austin has an extreme lack of sidewalks, and in fact lacks more sidewalk infrastructure than it contains, with 2580 miles of absent sidewalk for the existing 2400 miles of built out sidewalks. Summing up absent sidewalks and built out sidewalks and dividing by built out sidewalks ((2400+2580)/2400) we see that Austin has 48% of its total road network built out with sidewalks. This approximate 56% of sidewalk availability falls much higher than the city's build out. This fact points to smart strategies in building out sidewalks near critical public facilities, namely parkland. Furthermore, the percentage of sidewalk availability increased to 62% when looking at our ½ mile distance threshold. These outcomes point to validate work being conducted by municipal planners at Austin's Transportation Department, specifically in their goals to focus sidewalk connectivity and availability centered around parkland and other necessary public facilities.

Looking at sidewalk availability from an equity standpoint, our results are mixed. The population weighted means calculated for minimum distance sidewalk percentage by race actually show every racial group, except Asian residents, attain fewer percentage points of sidewalk availability compared to the city wide average. However no racial group falls under 50% sidewalk availability, and White, Black, and Hispanic residents are shown to have approximately 52% sidewalk availability for trips to the nearest park. When looking at population weighted means for the ½ mile distance threshold sidewalk percentage by race, Black, Asian, and Hispanic residents are shown to have a much larger percentage of sidewalk available to them for completing trips to parks than the city wide average of 62%. Asian residents once again have a very high amount of sidewalk availability for their trips to parklands within ½ mile at 74%, but Black and Hispanic residents are shown to have around 67% sidewalks available for trips to parks within ½ mile. White residents slightly fell below the city wide average at 60%, however overall this is insignificant.

Indeed, every measure of equity calculated within this analysis seems to point to positive outcomes that, strictly pertaining to pedestrian and cyclist's access to parkland, are equitable and fair. The census block groups falling under the city's median household income performed exceptionally well compared to the city overall. We saw that census block groups under the median household income had shorter pedestrian minimum distances to parks (.62 vs .79 miles), had more sidewalk available for completing pedestrian nearest park trips (61.02% vs. 55.95%) and trips to all parks within ½ mile (67.64% vs.

61.79%), as well as shorter cycling minimum distance trips. The measures calculated between the different racial groups also point to outcomes that virtually place each race equally when it comes to parkland access. This may indicate that pedestrian and cycling infrastructure as well as parkland planning has been equally distributed to households with less economic advantages. Furthermore as we have learned, having the proper active transportation infrastructure and access to parkland can have beneficial externalities such as health improvements and improved housing prices, which is most crucially needed for less affluent communities.

CONCLUSION

Within this report we have articulated and detailed a process in which planning practitioners and researchers can more accurately analyze pedestrian and cyclist accessibility to any facility under a GIS framework. In the context of Austin, TX we studied pedestrian and cyclist accessibility to the city's parklands to examine whether discrepancies exist between levels of access between socioeconomic groups. This was important to study due to the numerous positive externalities that are linked to accessing parklands, including increasing citizen health, reducing pollution, and increased community vibrancy and economic vitality.

Past studies have focused on analyzing accessibility in GIS through the utilization of street network data to form complete network datasets in which network travel between origin and destination could be accumulated. This report aimed to move past using street network GIS feature classes and attempt to measure accessibility through formalized pedestrian and bicyclist GIS network datasets. By forming these formalized networks, pedestrian and bicyclist accessibility measures are much more accurately represented against the reality of active transportation infrastructure that currently exists in Austin. Our creation of a sidewalk-street network dataset also had the added benefit of accumulating the total sidewalk distance of a trips total length, allowing insight into the state of pedestrian facilities today and where improvements can be made in the future.

Our findings indicate that from an equity standpoint, Austin is doing a good job in not only planning parkland spatially so that all socioeconomic groups have a fair share of access, but also that the active transportation infrastructure that leads people to parkland is adequate. Sidewalk availability for trips to parkland measured for each census block group's racial population weighted means show that in many instances certain under represented racial groups have higher levels of access depending on the measure, or levels of access that are not far off from the city wide average. Furthermore when looking at populations that fall under the median household income, we see these less affluent households actually have significantly higher levels of access to parkland across almost all accessibility measures, indicating they live in areas with high concentrations of parkland as well as higher levels of sidewalks and bike lanes. Lastly we saw that when comparing the same time it takes to walk or bike to parks, bicycling access allows residents much more acreage of parkland at their disposal, as well as shorter distances to traverse to reach the nearest park.

Our analysis solely considered park accessibility, however a slew of other factors could potentially shed light on Austin's park equity such as facilities contained within parks. However the findings from our analysis point to positive outcomes regarding Austin's resident's access to parks. Our findings validate work being conducted at City of Austin Parks and Recreation, Transportation, and Public Works Departments by showing no significant discrepancies between different socioeconomic groups access to parklands, or through availability of infrastructure. While this is good news for The City of Austin, they must remain vigilant in continuing their support and funding for parkland and active transportation facilities, as they are a crucial component of their city and the lives of their residents.

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