Evaluating Walkability and Bikeability in a Campus Setting

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abstract: *This study identifies how well a road or a pathway can serve the needs of pedestrians and cyclists on a university campus. An audit of campus walkability and bikeability is designed to capture objective and perceived aspects of road use for bikers and walkers. By analyzing the audit results, we present the walkability and bikeability scores of every road segment on 2 maps created using GIS to identify the patterns of road quality. Advantages and challenges of using an audit as well as suggestions are made for campus decision-makers to enhance green transportation.*

Now more than ever, planning and health officials encourage sustainable transportation modes. For instance, to mitigate the negative health effects of obesity, the Centers for Disease Control and Prevention (CDC) recommend at least 30 minutes of physical activity a day and a moderate-intensity aerobic activity such as brisk walking for 150 minutes a week (U.S. Department of Health and Human Services [HHS], 2016). Following this, researchers have investigated the role of built-environment and travel behavior on healthy modes of travel such as walking and biking (Rodríguez & Joo, 2004; Shay & Khattak, 2012). As Shafer, Lee, Turner, and Hughart (1999) succinctly put it, "quality of life . . . is achieved through increased interaction with other community members . . . and with the surrounding environment" (p. 1).

Sidewalks and bike lanes are critical facilities that help alleviate obesity at all age levels. Some studies show a significant relation between the availability of walking and biking facilities and residents' preferences for transportation modes other than automobiles and public transit (Ball, Bauman, Leslie, & Owen, 2001; Humpel, Marshall, Leslie, Bauman, & Owen, 2004; Hoehner, Brennan Ramirez, Elliott, Handy, & Brownson, 1994; Rodríguez & Joo, 2004). Higher use of these alternatives to automobiles can ultimately lead to better health (HHS, 2001). These factors are critically related to recommendations for young adults who are as a group at risk of becoming obese (HHS, 2003). The introduction of everyday walking and biking or utilitarian walking and biking can increase physical activity for this group (McCracken, Jiles, & Blanck, 2007). College campuses can, therefore, be one of the best locations to increase utilitarian walking and biking for students, faculty, and staff.

Typically, streets and roads in and around college campuses are better than those in residential areas. With higher population density and a demand for cleanness and quiet, walking and biking are often more suitable means of transportation on campus. Not only can walkability and bikeability determine public health and safety as well as the quality of life on campus, they are also important components of environmentally sensitive transportation, economic vitality, and neighborly interaction. The construction of walkways and bikeways determines the level of campus design.

This study serves two major aims. First, it identifies the spatial patterns of walkability and bikeability levels of a university campus. Second, it evaluates the strengths and weaknesses of the biking and walking infrastructure on that campus. Following this, it provides pragmatic recommendations to fulfill the needs of pedestrians and cyclists so as to encourage walking and biking on campus. To do so, we conducted an audit to evaluate the walkability and bikeability, both objectively and subjectively, on the main campus of the University of North Texas (UNT) in Denton, TX. Following the audit, we mapped the standardized scores of walkability and bikeability in a geographic information system (GIS) to illustrate the current infrastructure quality and to propose recommendations to increase on-campus walking and biking. Upon examining the data collected, we argue that UNT has the potential to become a more walkable and bikeable campus. It should be noted that although this is a cross-sectional analysis of a campus, its recommendations are still adaptable for campuses across the United States, as colleges and universities possess significant walking and biking infrastructure. This study recommends changing the aims of planning and government funding to reembrace this tradition, enhancing the convenience of individuals' walking and biking.

Walkability and Bikeability

The capacity of physical spaces to provide residents opportunities to walk and bike is a critical measure of the convenience and quality of a community in urban planning (Ewing, Handy, Brownson, Clemente, & Winston, 2006). This capability also determines the willingness of residents to go outside their homes and use walking and biking facilities (Cervero & Kockelman, 1997; Saelens, Sallis, & Frank, 2003). Walkability is measurable by how safe it is for people to walk from one place to the other (Moudon et al., 2006; Shay, Spoon, & Khattak, 2003). A walkable neighborhood can be further characterized by the socialization amongst neighbors that enhances the physical, mental, and spiritual health of people in the community (Moudon et al., 2006). Banerjee, Mente, Miller, and Anand's (2010) definition of walkability focuses on the features of a certain place that encourage people to walk. They also emphasize the capacity of the place to make walking safe and accessible. Similar to the concept of walkability, which is characterized by characteristics ranging from safety to attractiveness, bikeability can be evaluated using comparable factors. It is argued that both activities can be done to serve multiple but similar purposes—leisure, recreation, exercise, transportation to work and shopping (Saelens et al., 2003), and can be characterized by several environmental and non-environmental features.

Transforming walkability and bikeability to observable measures is somewhat challenging, as the measurement needs to embed physical indicators and subjective attitudes of users. Well known built-environment studies consist of four types of measurements that are suitable for different aims: survey, GIS, audit, and observation (Maghelal & Capp, 2011). GIS and audit measurements often contain objective variables that can be replicated in other studies. On the other hand, the data collected by observation are normally limited to the particular analysis only, while survey instruments can capture subjective data better (Maghelal & Capp, 2011).

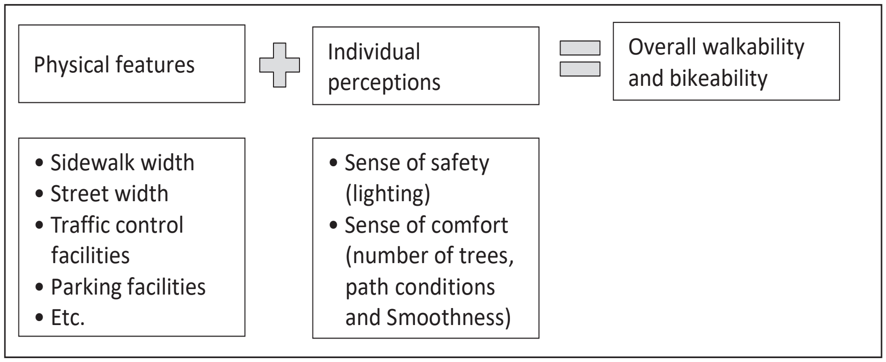
GIS tools are recommended to measure the objective aspect of walkability (Maghelal & Capp, 2011). But current walkability indexes that embrace both objective and subjective measures often use surveys and audits rather than GIS methods (e.g., Bradshaw, 1993; Fort Collins, 1996; Wellar, 2003; Dannenberg, 2004; Saelens et al., 2003). These surveys and audits can capture the standardized measures well, but may fall short of studying specific cases with less-standardized characteristics (Maghelal & Capp, 2011). Hence, a combination of both audits and GIS can be a good measure of built-environment related to walking and probably biking. The following studies are good examples of how both concepts can be measured.

Shay et al. (2003) generalize five infrastructural factors of walkability. The first is pedestrian facility, which includes sidewalks and trails, crosswalks, and other street treatments. A second component of walkability is accessibility and convenience, which includes proximity to multiple destinations. The third factor is connectivity, measured by short block lengths of 400–600 feet, a grid pattern with many intersections and few cul-de-sacs, and efficiency to destinations. Fourth is the aesthetic aspect of walkability involving a pleasant atmosphere, attractive architecture, landscaping and street trees throughout the streetscape. The last factor is traffic calming or street safety, which can be operationalized as street designs limiting vehicle speed (curb extensions, street narrowing, tree canopies, on-street parking, etc.) and street lighting.

Most of these environmental factors affect bikability as well. Pedestrians and cyclists share many sidewalks and trails, and cyclists are sensitive to sloping terrain, path and route information, and sidewalk also (Rodríguez & Joo, 2004). Even though cyclists have higher mobility compared to pedestrians, their ability on daily commutes to travel long distances is significantly less than automobiles (see National Household Travel Survey 2009 data) and they are influenced by similar built-environment factors, even if not to the same degree. Although the built environment that encourages walking and biking may vary a little, the barriers for both are very similar (Rodríguez & Joo, 2004).

Ewing et al. (2006) evaluate these concepts subjectively by analyzing the qualities and individual perceptions of physical features. They believe that urban design qualities may be assessed with a degree of objectivity by outside observers. Accordingly, safety and attractiveness

Figure 1. Conceptual Framework



are for them the major elements determining walkability and bikeability. Evaluating the walkability and bikeability of a street can be viewed as the attempt to answer the question: to what extent can a certain street be safe and attractive for people to walk and bike? Ewing et al. (2006) used physical features and individual reactions to measure the walkability and analyze people's walking behavior. Using this framework and other theoretical approaches (e.g., Leslie et al., 2005), this study reviews the quality of a walking and biking environment by analyzing both physical features and individual perceptions of a community. Figure 1 illustrates the conceptual approach this study takes toward assessment of walkability and bikeability on campus.

Research Design

In contrast with residential communities in the United States, university campuses are characterized by higher density and less automobile transportation generally. Even when students, faculty members, staff and residents commute by automobile they frequently bike and walk for their last miles on campus. Thus, a campus can provide us more opportunities of multi-modality including walking and biking in a relatively smaller area. We assessed UNT's residential campus located about 29 miles north of Dallas, TX in a semi-urban setting. Its enrollment of over 36,000 students has rapidly increased in recent years, which creates higher demand for walking and biking facilities. These characteristics make UNT a good study area for a few reasons. First, the distance from the well-developed Dallas downtown makes it a self-governed system managing the walking and biking facilities. Second, its location in a populated metropolis attracts students and employees who create a significant demand of on-campus walkability and bikeability. Finally, the tension between rapid growth and limited campus area lends this study a practical import that is applicable to other areas encountering similar challenges.

As the student population of UNT and in Denton continues to grow, assessment of sidewalks and bike paths is more imperative than ever. Therefore this study maps this information analytically. A three-step data collection was carried out to examine campus walkability and bikeability. We first geo-coded all sidewalks, pedestrian trails, and bikeable roads using a recent aerial image of the campus. Next, we conducted a comprehensive audit that included multiple measures of biking and walking paths. All the measures in the audit were assigned values in the third step to develop a ranking for each segment.

The audit was generated from the existing tools that were selected based on whether they fit in the research framework. That is, the audit should capture the most critical elements that may affect walkability and bikeability applicable to a campus context. For example, a campus can have more restrictions to automobiles and attract more pedestrians and biking, compared to a residential community. But the functions of the buildings on campus might be less diverse than those in a non-university downtown area. Thus, the audit tool should not be as comprehensive as those applicable to all-type communities (e.g. with mixed land uses), but can address the needs of on-campus students and employees. Five audits were selected that could be adapted for campus setting that matched criteria of: (1) simplicity of content and adaptability, (2) ease of use and understanding for non-expert users, and (3) addressed several criteria that can support walking and biking (e.g., safety, convenience, built environment). A combination of varied elements of each

Table 1. Comparing the Four Audits

Audit	Strength/Weakness		Items Used	Items Not Used (Reasons)
SPACES	S	Reliable, simple to use, somewhat comprehensive	Walking/biking path: type, location, material, condition, permanent obstructions; On-road path: type, condition, lanes, parking restriction signs, kurb type, traffic control devices, crossings and aids, streetlights, lighting coverage, destinations, car parking at destination, bike parking, driveway crossovers, garden and verge maintenance, trees number and height, cleanliness, type of views, alike building design; Overall segment: attractiveness, walking/biking difficulty, path continuity, neighborhood legibility	Type of buildings/features; Predominant buildings/features (lack of variance in research area); Slope, other routes, surveillance (lack of variance)t
	W	Some key items missed		
Pedestrian and Bicycle Information Center	S	Distinguishable bikeability and walkability	Bikeability: sharing road with motor vehicles, problems of off-road path, problems of path surface, problems of intersections; Walkability: barriers to walk, problems to cross streets, easiness to follow safety rules	Bikeability: driver behaviors (long period observation), easiness to bike (duplicated with SPACES), rider's personal safety activities and self-description (low inter-rater reliability); Walkability: driver behaviors, pleasure to walk (random event, e.g., scary dogs), self-rating the neighborhood (subjective)
	W	Not research-based; over-simplified for general resident usage; lack of clear units of analysis		
WABSA	S	Distinguishable bikeability and walkability, practical guide	Bikeability: number of lanes, speed limit, pavement condition, presence of a curb, rough railroad crossing, storm drain grate; Walkability: sidewalk/path continuity, material, curb ramps	Bikeability: average traffic (long period observation), on-road lane width (duplicated), location factors (duplicated or not applicable); Walkability: average traffic, speed limit, number of lanes, lighting, isolated problem spots (all duplicated)
	W	Lack of measures other than safety		
PEDS	S	Simple to use, well organized	Pedestrian facility: types, material, condition, obstruction, buffer between road and path, path distance from curb, sidewalk width, continuity, connectivity; Road attributes: conditions, number of lanes, speed limit, traffic control devices, crosswalks, bicycle facilities; Walking/cycling environment: lighting, amenities, trees shading, cleanliness/maintenance	Environment items (lack of variance or duplicated); Road attributes: on/off-street parking (duplicated), med-hi volume driveways and crossing aids (lack of variance); Walking/cycling environment: wayfinding aids (lack of variance), degree of enclosure (low inter-rater reliability), power line (lack of variance), building design and height (low inter-rater reliability), building setbacks (inconsistent within one segment)
	W	Lack of reliability and external validity test		

audit were used in designing an audit that encompassed all the indicators of the walking and biking environment and was easy to use for a campus setting.

The first audit selected was the Systematic Pedestrian and Cycling Environmental Scan (SPACES) conducted by Pikora, Bull, and Jamrozik (2000). This audit is used to evaluate the academic built environment that is suitable for biking and walking. Along with its ease of use and application, it reported high the inter- and intra-rater reliability (Day, Boarnet, Alfonzo, & Forsyth, 2006). However, SPACES may fall short in its over-simplification in an all-type community setting (Day et al., 2006; Boarnet, Day, Alfonzo, Forsyth, & Oakes, 2006). We therefore made changes based on other campus-specific audit tools while retaining its major structure (see Table 1 for detailed comparison of the audits).

The second audit was the self-evaluated checklists created by the Pedestrian and Bicycle Information Center in the National Highway Traffic Safety Administration. These lists help residents assess their community's walkability and bikeability, and report problems to local authorities. This audit is designed for residents who would like to evaluate their own community and report certain disadvantages of walking and biking facilities. Therefore, we only selected some items that are critical to campus walkability and bikeability and were not included in the SPACES tool.

The third audit is the walking and bicycling suitability assessment (WABSA) project, conducted by the University of North Carolina at Chapel Hill. This audit provides a guide for community members who would like to participate in building and making improvements to a walkable-bikeable neighborhood. So it aims at multiple-level users, including interest groups, organizations, and active individuals. Its instruction theoretically illustrates whether and how walking and biking networks are connected. However, the audit tool itself is too general to incorporate many important factors other than safety issues (School of Public Health, 2002). Thus, our selection from this audit was to measure the safety for pedestrians and cyclists.

The University of Maryland developed the Pedestrian Environment Data Scan (PEDS) audit, that offers us several valuable measures, such as path obstructions, sidewalk width, traffic control devices, crossing aids, and bicycle facilities. This audit is part of a research project used mainly in the Montgomery County, Maryland with a high social and geographic diversity (About the Project). Although it may lack external validty that can be applied elsewhere, the PEDS audit questions can capture many elements in the SPACES but are organized for easier data collection. Consequently, we treated it as a reference to reorganize some audit items we used from other tools to balance the reliability and ease of use.

Besides these four audits applied to our study, we also reviewed the Irvine-Minnesota Inventory (Day et al., 2006; and Boarnet et al., 2006), but decided not to use it. This inventory is one of the most comprehensive audits evaluating the built environment. Boarnet et al. (2006) also tested the geographic and inter-rater reliability of the inventory in California and Minnesota and found positive results in most of its audit items. However, a paper version of the Irvine-Minnesota Inventory may require at least 20 minutes per segment, in addition to the time for training or other administrative tasks (Boarnet et al., 2006, p. 156). Such a time-consuming audit can hamper the willingness of a university with tight budgets to conduct the study like this, limiting its application to the largest audience. Thus, we applied the Irvine-Minnesota Inventory as a reference to reevaluate our audit and double-check if anything important was missed. The following sections discuss the methodology used for the study of walkable and bikeable infrastructure at UNT, including the boundaries of the study area (Figure 2), the geocoding process, how we conducted the audit, and the way we assign weights to the audit items in detail.

Step 1: Geocoding segments

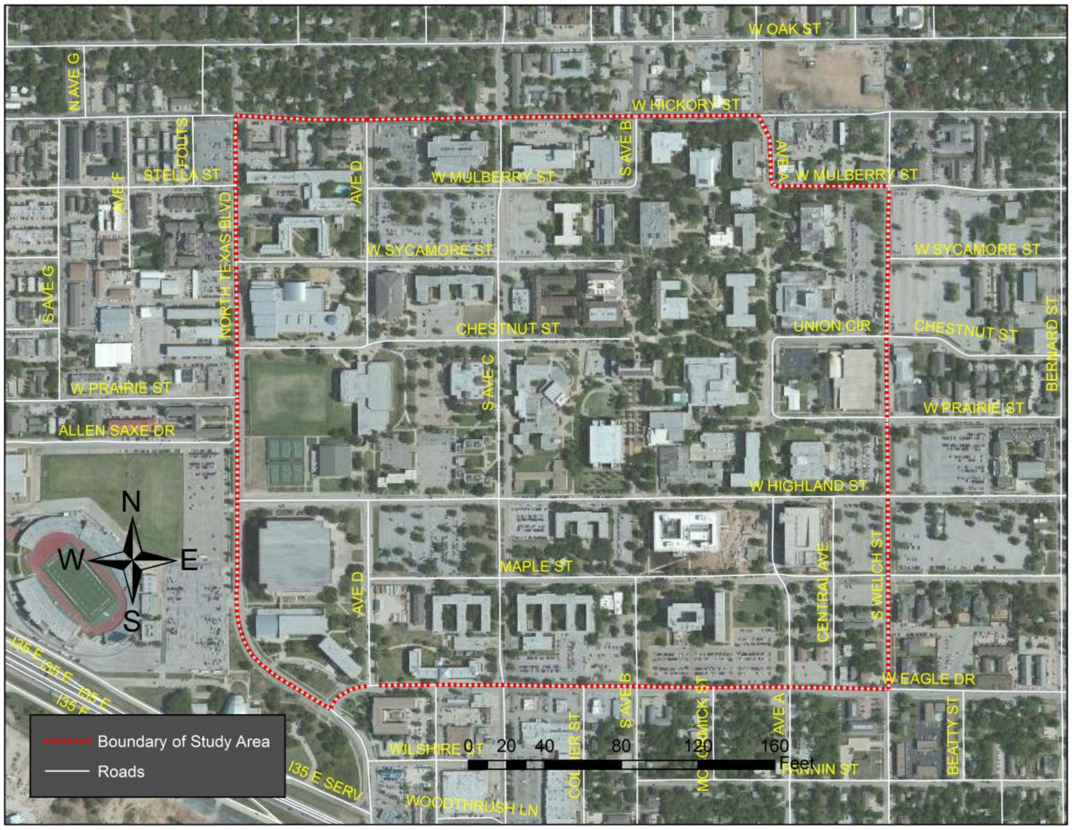
The auditors separated into three groups: one group defined all the segments from the aerial image, while the other two double-checked the built-environment features by walking through all the segments. ArcGIS shapefiles were created to represent the segments of the network (Figure 3).

Step 2: Auditing

The audit items selected were driven by a pretest observation of the study area, which determined what data could be observed and obtained. The reasons why certain items were not included in our audit in Table 2 help illustrate our selection criteria. This process can be a limitation if the audit were to be applied to another campus that differs significantly from UNT, such as those in urban settings. Nevertheless, a study such as this can help use the implications to assess and improve the built-environment in the campus setting around the country, with only a few modifications, according to the specific geographic characteristics.

After compiling the audit tool, groups of two of the authors were assigned to collect data from two out of the

Figure 2. Study Area In University of North Texas



three sections in the study area identified in Figure 3. Hence, every segment was evaluated by four individual authors. After the first-round audit, all the segments with inconsistent observations were reviewed and re-audited to eliminate differences. Finally, all six audits were compared and after consistency was achieved they were incorporated into one outcome.

Step 3: Weighing items and options

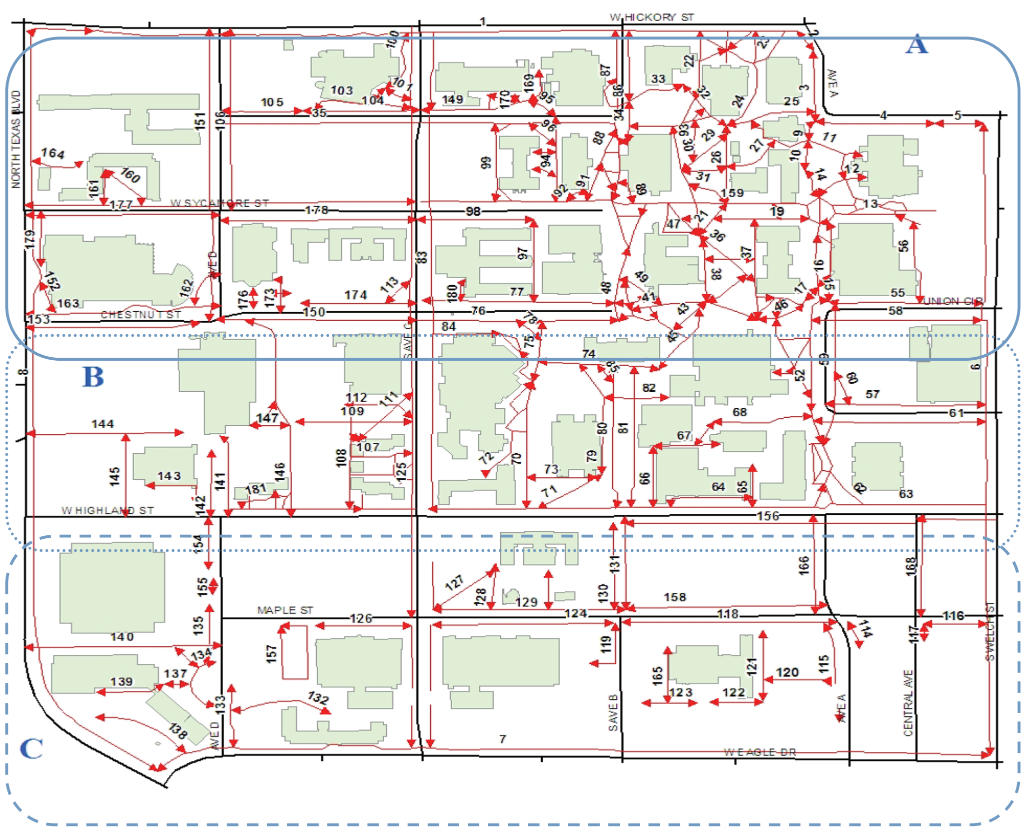
The physical and subjective measures or the questions of walkability and bikeability were incorporated into two final scores for every segment. This step provided us with a clear-cut result illustrating the walkability and bikeability of each segment. As each measure is not equally important to pedestrians or cyclists, and may influence walking and biking differently, we assigned different weights to each measure of walkability and bikeability.

The means of creating these values was a survey distributed to each author. Two questionnaires were created representing perspectives from pedestrians and cyclists, respectively. All the questions and items were assessed with five scales. The questions and the options are evaluated independently, which means that the importance of a question does not influence the goodness of the options in this question. Once the scores were assigned, a "weights" column represented the final weight for each option automatically. These weights are utilized to calculate the walkability and bikeability scores for each segment, as an average of all the option values. Lastly, two maps were created using ArcGIS to illustrate the goodness of walking and biking of all the segments.

Results and Discussion

We found some patterns from the maps shown in Figures 4 and 5. (1) The best paths are clustered in the northeast part of campus, which is the oldest part of the university. Most of the buildings there were constructed a decade ago, when walking was the major transportation in town (Taaffe, Gauthier, & O'Kelly, 1996). This part of campus is still where most students attend classes, and automobile-

Figure 3. Segment and Section Definitions



dominated travel mode is highly limited. (2) The worst walking and biking paths are along the main roads across and around the campus. Motorized traffic is the prevailing mode of transportation on-campus. So it would be hard to walk or bike across campus and around certain areas. (3) Another pattern is that the bikeability and walkability of UNT campus are generally similar with bikeability being only slightly better. This may indicate that the reasons for people to bike and walk are similar, but biking has higher accessibility and speed than walking. Cyclists can be less critical of longer distances and sharing roads with automobiles.

We also found advantages and challenges to the campus with respect to walkability and bikeability (Appendix A). The three advantages are, respectively: (1) Most path locations, materials, and conditions are good. Sixty-eight percent of path widths are more than 3 m from a curb. While only a small portion (18%) of walk-bike paths are close to curbs, this raises a safety issue due to their proximity to automotive traffic (Schneider, Ryznar, & Khattak, 2004). A great majority of paths have good conditions and are made of continuous concrete, which promote walking and biking experiences and convenience. (2) It was noticeable that the university paid attention to the pleasure of walking and biking. About 93% of merges are well maintained, and 79% of paths have one or more trees per house block, providing adequate shade for walkers and bikers in the summer. Trees can also help absorb noise and clean the air. (3) A majority of segments are free from potential harms: 73% of off-road paths and 53% of on-road paths have no obstructions at all; vehicle parking restriction signs are presented in most of the segments, keeping pedestrians and cyclists away from the chaotic automobile traffic.

Nevertheless, we also discovered some aspects of walking and biking facilities that needed to be enhanced on the campus. (1) More than half of the segments have no bike facilities. Bike parking facilities were especially inadequate on campus. This might result in more illegal parking on campus, increasing the probability of conflict with pedestrians and lower students' willingness to bike. (2) More than 80% of footpaths were shared with bikes

Figure 4. Walkability Map of the University North Texas (UNT)

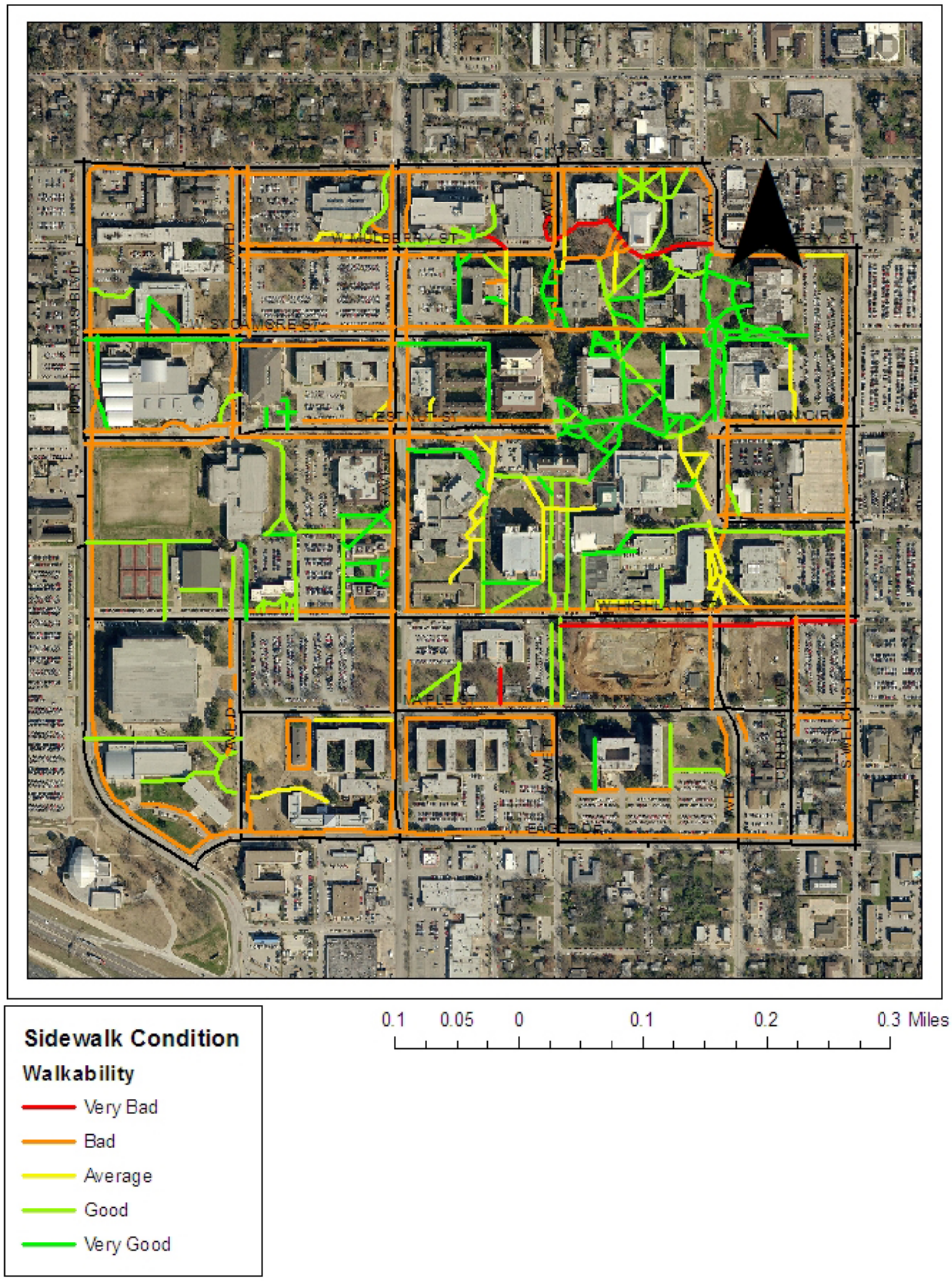
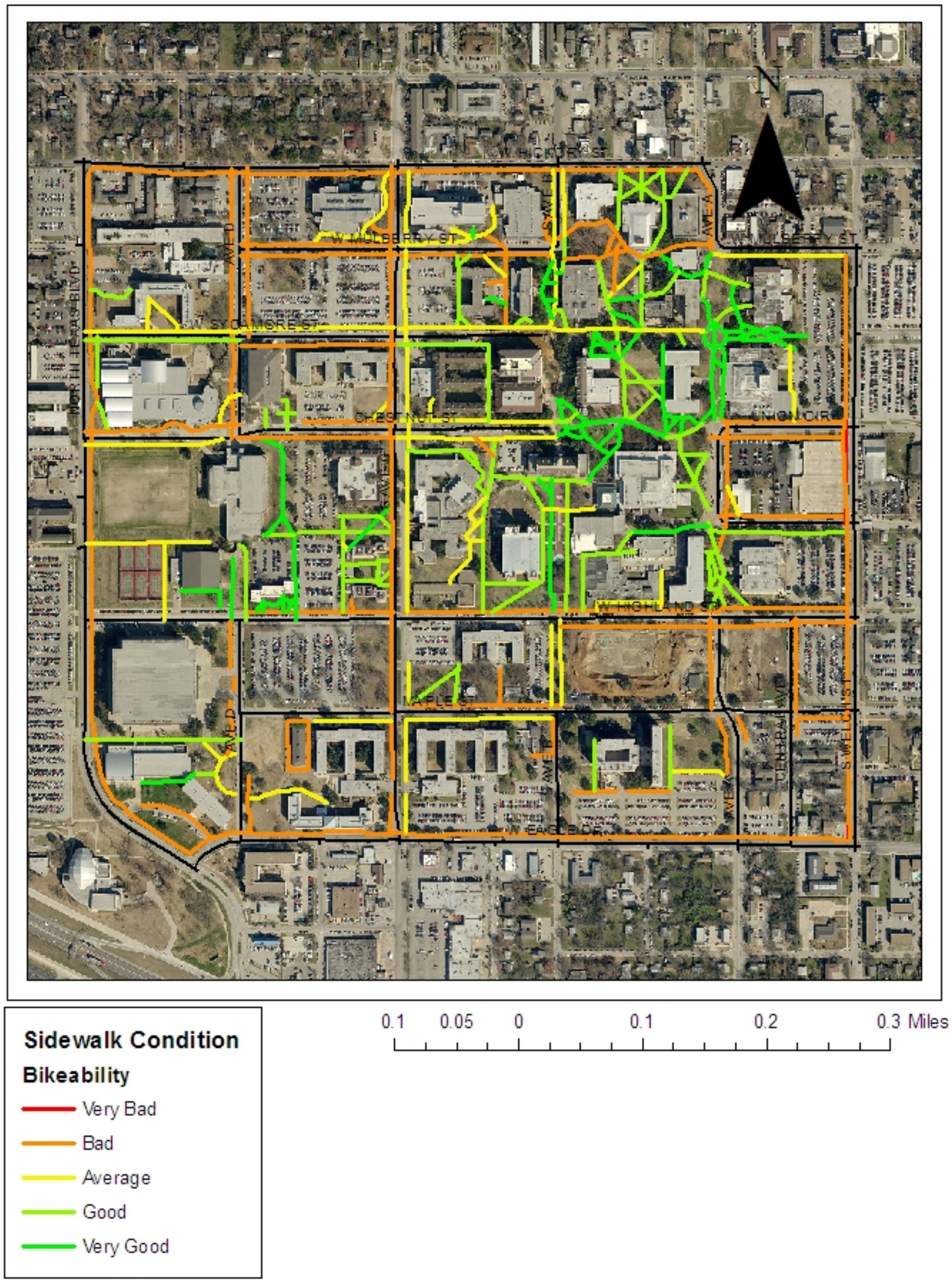


Figure 5. Bikeability Map of the University North Texas (UNT)



but failed to have adequate markings on them. To make things worse, 76% of paths were less than 8 feet in width but cyclists and pedestrians share the path. (3) Some areas were dangerous for both pedestrians and cyclists after sunset because of inadequate lighting. This problem may increase the possibility of traffic accidents and hamper the perception of safety. (4) Traffic controls rely heavily on stop signs (49%) or no control at all (12%). Mandatory traffic control devices, such as traffic signals (10%) and speed bumps (12%) on the campus, might be required to enforce safe speeds for automobiles. (5) A noticeable amount of the road segments on the campus have inadequate crosswalks (35% had none). Missing crosswalks could lead to pedestrian-vehicular conflict resulting from unawareness of pedestrian usage by drivers.

Conclusion and Recommendations

This study assessed the existing walking and biking infrastructure in a campus setting and evaluated its suitability to walk and bike. As a campus with sufficient need for walking and biking by its patrons, this study provides an audit tool and recommendations that enhance the walking and biking experience across university campuses in the United States.

Based on the outcomes of our analysis, we believe the UNT campus houses a well-maintained and smooth environment for pedestrians and cyclists in general. However, lack of adequate lighting and shared routes lower the safety levels. More bicycle parking facilities might be necessary in order to increase convenience and attract cyclists. The sidewalks classified as "footpaths only" reported higher scores of walkability compared with shared routes, indicating that shared routes can increase potential conflicts between pedestrians and cyclists. Another interesting finding is that most of the segments that gained high scores are located in the oldest area and have well-developed walking route network.

Some recommendations could be generated from previous literature that aim to create a walking- and biking-friendly campus. First, it may be helpful to establish a biking and pedestrian committee to assess the needs and issues that pedestrians and cyclists on campus face. The voice of the committee should be heard by the administrative agencies before and during the transportation plan making for campus. The committee should involve the stakeholders (i.e., students, faculty and staff, local residents, etc.) with real demands for the facilities and services. In addition, user surveys can be a good tool to collect public opinions.

Second, promotional offers could be useful to attract biking or walking as major modes of travel on campus. For instance, brochures offering special discounts at local bike stores could be a good way to stimulate biking. Creating a comprehensive transportation network might also encourage communication with other modes of transportation, such as public transit and reduction in auto usage on campus.

The third recommendation is related to education. Safety classes and materials can educate pedestrians and cyclists how to share the road effectively. The idea of green transportation can be embedded in them so that walking and biking might become the preferred mode of travel on campus over driving. A university website encouraging green transportation and elimination of private automobiles could help increase walking and biking on campus.

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References

About the project. Planing and Physical Activity. University of North Carolina. Retrieved from http://planningandactivity.unc.edu/About_the_ProjectNT.htm

Ball, K., Bauman, A., Leslie, E., & Owen, N. (2001). Perceived environmental aesthetics and convenience and company are associated with walking for exercise among Australian adults. *Preventive Medicine, 33*, 434–440.

Banerjee, A. T., Mente, A., Miller, R., & Anand, S. (2010). *Perceptions of walkability attributes on the Six Nations Reserve in Ontario: A pilot study*, Heart and Stroke Foundation of Ontario.

Boarnet, M. G., Day, K., Alfonzo, M., Forsyth, A., & Oakes, M. (2006). The Irvine–Minnesota Inventory to Measure Built Environments: Reliability Tests. *American Journal of Preventive Medicine, 30*(2), 153–159.

Bradshaw, C. (1993). *Creating and using a rating system for neighborhood walkability: Towards an agenda for "local heroes."* Paper presented at the 14th International Pedestrian Conference, Boulder, CO.

Cervero, R., & Kockelman, K. M. (1997). Travel demand and the 3Ds: Density, diversity, and design. *Transportation Research-D, 2*, 199–219. doi: 10.1016/S1361-9209(97)00009-6

Dannenberg, A. (2004). *Assessing the walkability of the workplace: A new audit*. Presented at the 4th National Congress of Pedestrian Advocates, America Walks.

Day, K., Boarnet, M., Alfonzo, M., & Forsyth, A. (2006). The Irvine–Minnesota Inventory to Measure Built Environments: Development. *American Journal of Preventive Medicine, 30*(2), 144–152.

Ewing, R., Clemente, O., Handy, S., Brownson, R. C., & Winston, E. (2006). Identifying and measuring urban design qualities related to walkability. *Journal of Physical Activity and Health, 3*(Suppl.), S223–S240.

City of Fort Collins. (2002). *Pedestrian level-of-service*. Fort Collins, CO.

Hoehner, C. M., Brennan Ramirez, L. K., Elliott, M. B., Handy, S. L., & Brownson, R. C. (1994). Perceived and objective environmental measures and physical activity among urban adults. *Transportation Research Record*, No. 1466, Transportation Research Board, National Research Councils, Washington DC, 63–70.

Humpel, N., Marshall, A. L., Leslie, E., Bauman, A., & Owen, N. (2004). Changes in neighborhood walking are related to changes in perceptions of environmental attributes. *Annals of Behavioral Medicine, 27*(1), 60–67.

Leslie, E., Saelens, B., Frank, L., Owen, N., Bauman, A., Coffee, N., & Hugo, G. (2005). Resident's perceptions of walkability attributes in objectively different neighborhoods: A pilot study. *Health and Place, 11*, 227–236.

Maghelal, P. K. & Capp, C. J. (2011). Walkability: A review of existing pedestrian indices. *URISA Journal, 23*(2), 5–19.

McCracken, M., Jiles, R., & Blanck, H. M. (2007). Health behaviors of the young adult U.S. population: Behavioral risk factor surveillance system, 2003. *Preventing Chronic Disease, 4*(2), 1–15.

Moudon, A. V., Lee, C., Cheadle, A. D., Garvin, C., Johnson, D., Schmid, T. L., Weathers, R. D. & Lin, L. (2006). Operational definitions of walkable neighborhood: Theoretical and empirical insights. *Journal of Physical Activity and Health*, Suppl. 1, S99–S117.

Pikora, T., Bull, F., & Jamrozik, K. (2000). *Pedestrian and Cycling Environmental Scan (SPACES) Instrument*. School of Population Health, The University of Western Australia.

Rodríguez, D. A., & Joo, J. (2004). The relationship between non-motorized mode choice and the local physical environment. *Transportation Research. Part D: Transport and Environment, 9*(2), 151–173.

Saelens, B., Sallis, J., & Frank, L. (2003). Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures. *Annuals of Behavioral Medicine, 25*, 80–91.

Schneider, R. R., Ryznar, M., & Khattak, A. (2004). An accident waiting to happen: A spatial approach to proactive pedestrian planning. *Accident Analysis and Prevention, 36*, 193–211.

School of Public Health, Department of Health Behavior and Health Education, the University of North Carolina at Chapel Hill. 2002

Shafer, C. S., Lee, B., Turner, S. & Hughart, M. (1999). *Evaluation of bicycle and pedestrian facilities: User satisfaction and perceptions on three shared use trails in Texas*, Texas Transportation Institute, The Texas A&M University System, College Station, Texas.

Shay, E. & Khattak, A. J. (2012). Household travel decision chains: Residential environment, automobile ownership, trips and mode choice. *International Journal of Sustainable Transportation, 6*, 88–110.

Shay, E., Spoon, S., & Khattak, A. (2003). *Walkable environments and walking activity. Walk, don't walk: A resource for planners and engineers*. Final Report for Seed Grant Submitted to: Southeastern Transportation Center University of Tennessee Knoxville, Tennessee.

Taaffe, E. J., Gauthier, H. L., & O'Kelly,M. E. (1996) *Geography of Transportation*, Prentice-Hall Inc., New Jersey.

The South Yorkshire Local Transport Plan (SYLTP). (2006) Partnership. Chapter 8. Walking, Cycling and Smarter Travel Choices. *Second Local Transportation Plan 2006–2011*, South Yorkshire Joint Secretariat, Website: http://www.southyorks

.gov.uk/embedded_object.asp?id=531

U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. (2016). *Finding a balance*. Retrieved from http://www.cdc.gov/healthyweight/calories/index.html

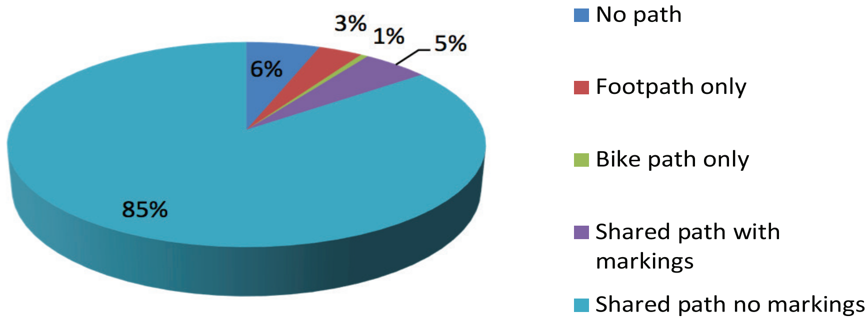
U.S. Department of Health and Human Services, Centers for Disease Control and Prevention. (2003). *Physical activity and good nutrition: Essential elements to prevent chronic diseases and obesity*.

U.S. Department of Health and Human Services, Public Health Service, Office of the Surgeon General. (2001). *The Surgeon General's call to action to prevent and decrease overweight and obesity, 2001*, Rockville, MD.

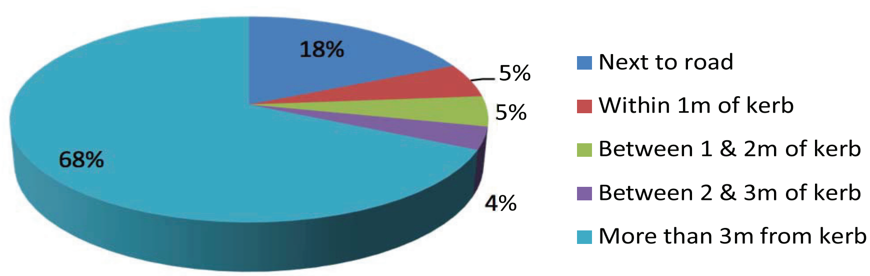
Wellar, B. (2003). *Walking Security Index pilot study*. Report submitted to the Mobility and Area Traffic Management Branch Traffic and Parking Operations Division Transportation, Utilities, and Public Works City of Ottawa. Retrieved from the City of Ottawa website: http://ottawa.ca/calendar/ottawa/citycouncil/ttc/2003/02-05/WSI-Annex1.htm

Appendix A
Results

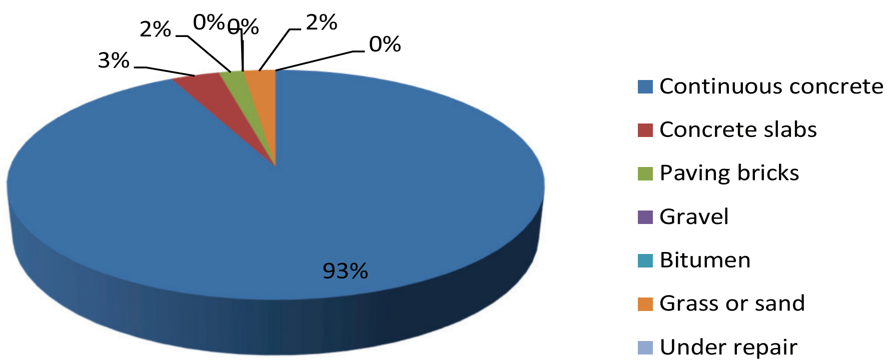
1. Type of Path



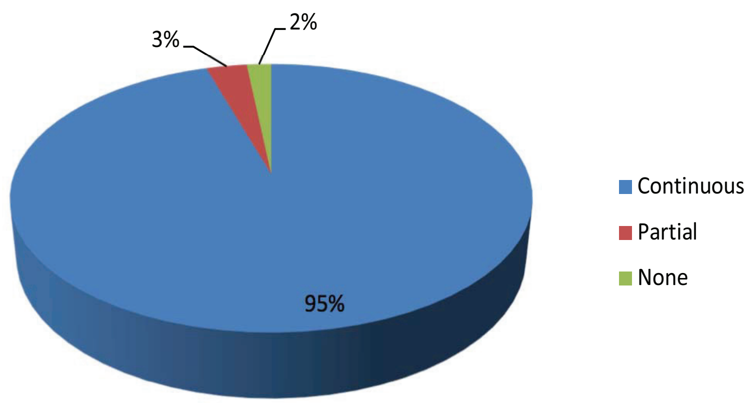
2. Path Location



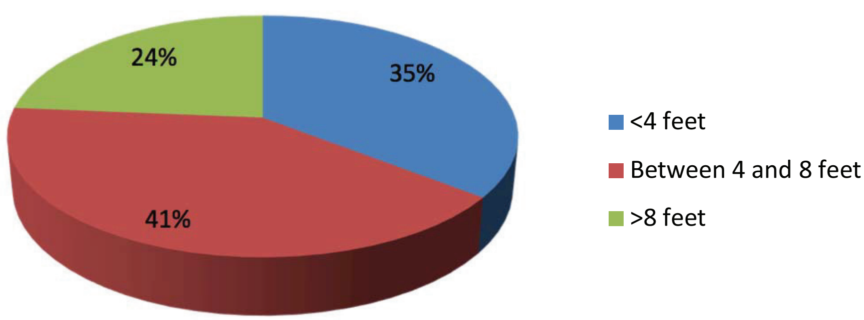
3. Path Material



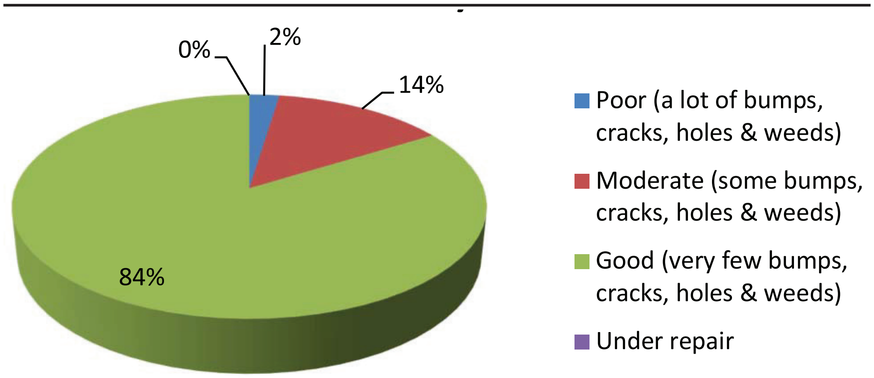
4. Sidewalk or Path



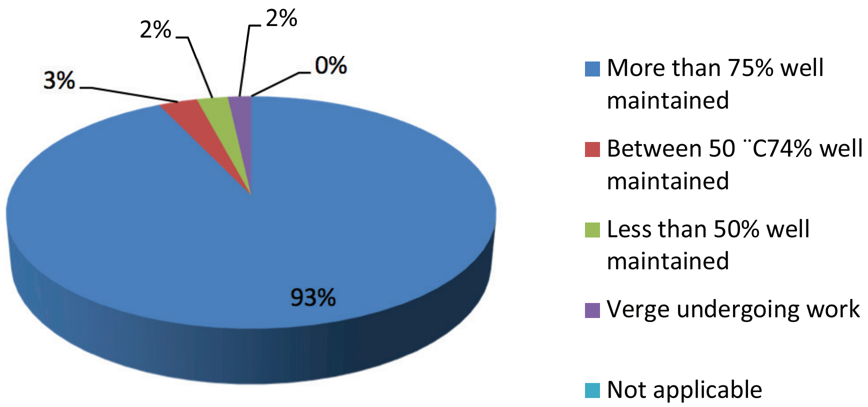
5. Sidewalk or Path Width



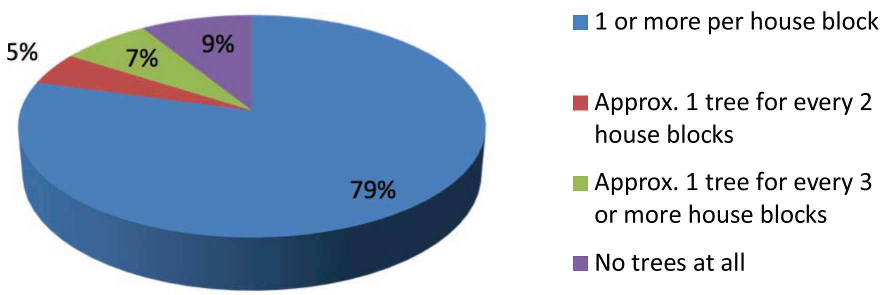
6. Path Condition and Smoothness (Off-Road)



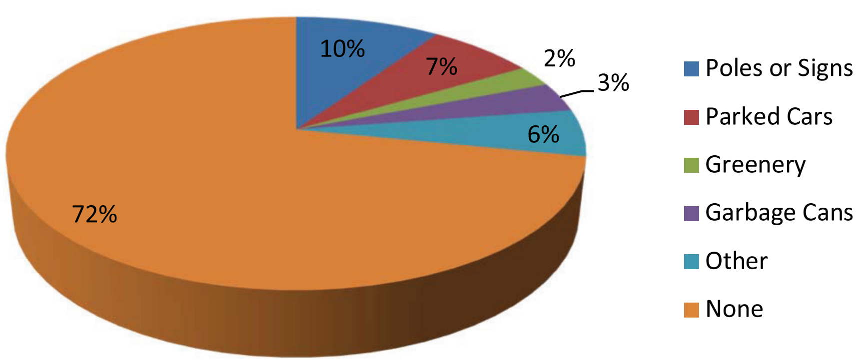
7. Verge Maintainance



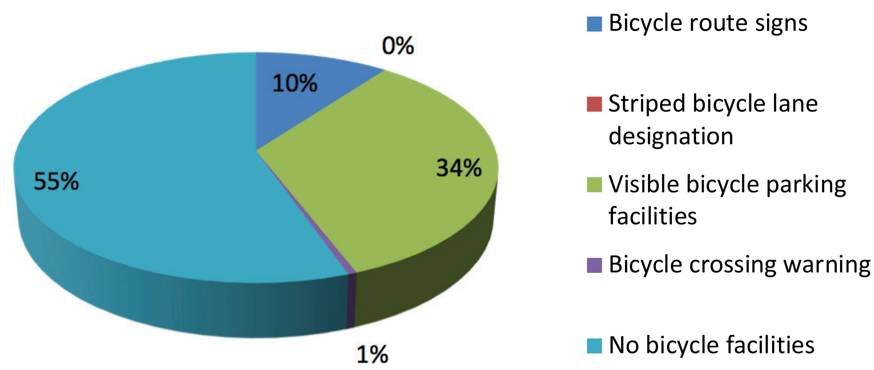
8. Number of Verge Trees



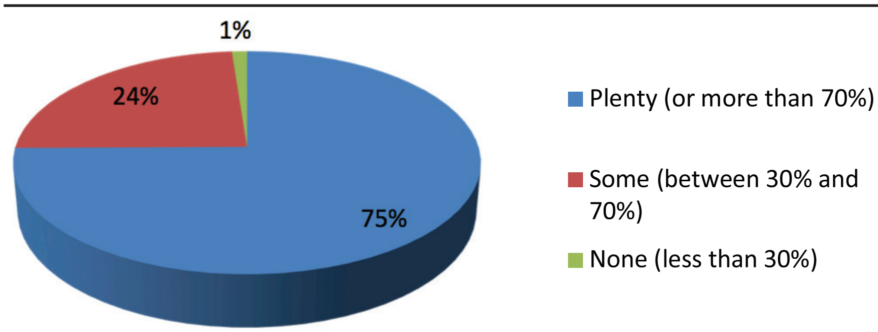
9. Path Obstructions (Off-Road)



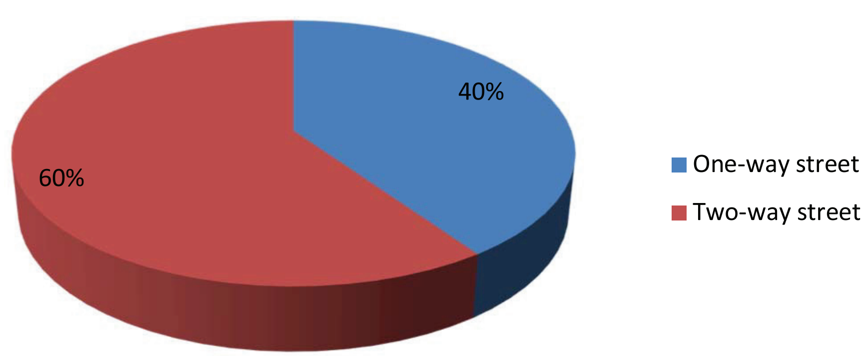
10. Bicycle Facilities (Off-Road)



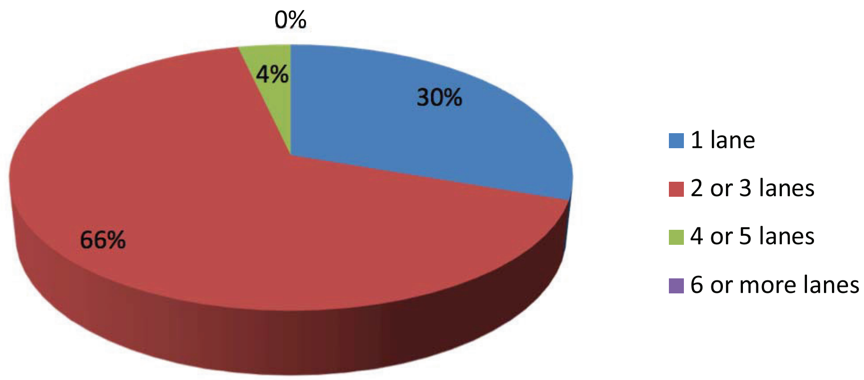
11. Adequate Lighting (Off-Road)



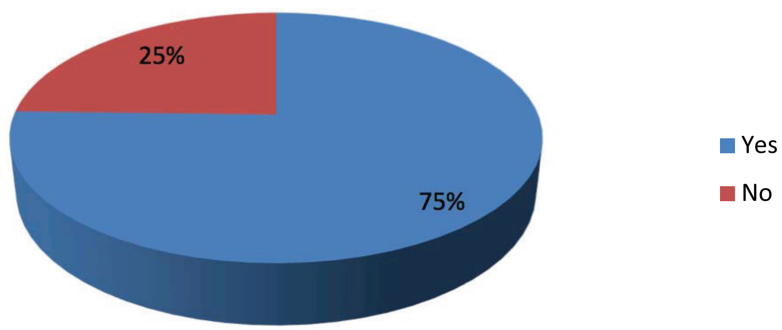
12. Direction of the Road



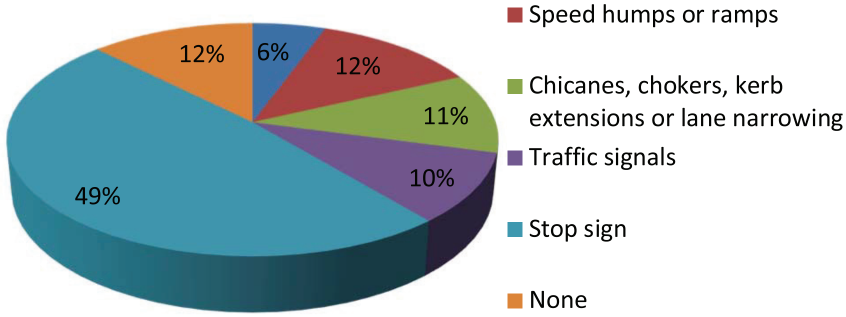
13. Number of Lanes on Road (In Total)



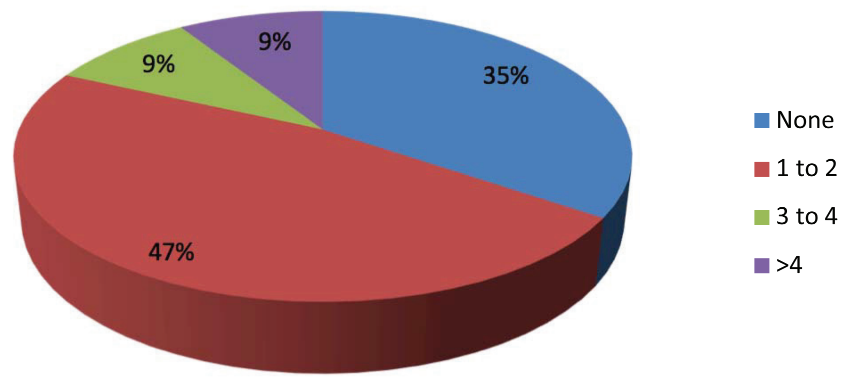
14. Vehicle Parking Restriction Signs Presents



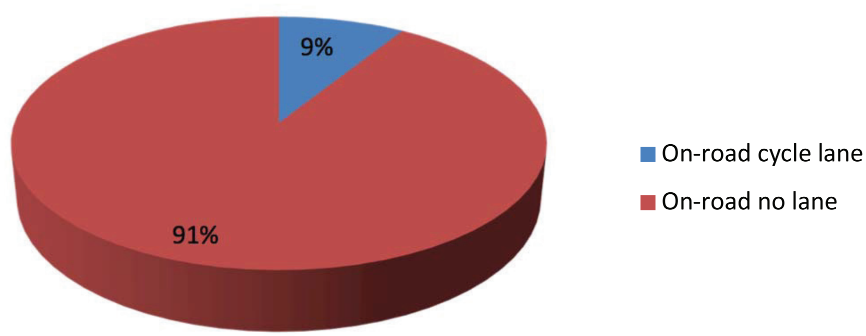
15. Trafic Control Devices



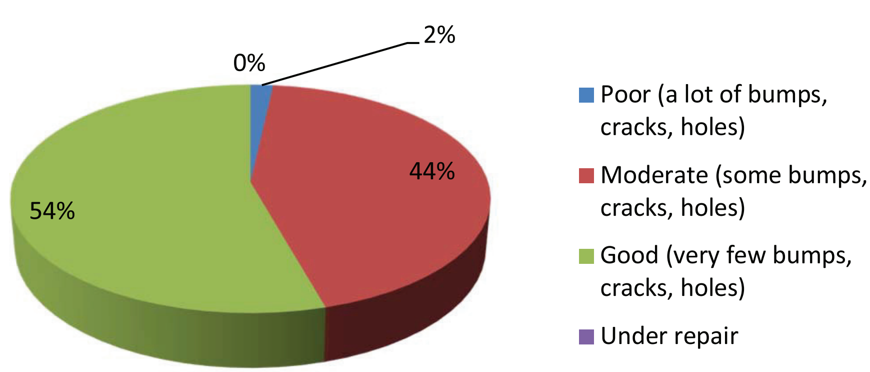
16. Crosswalks



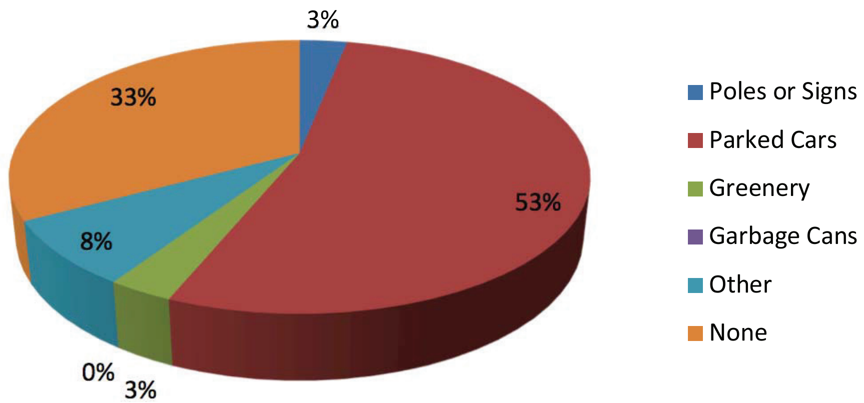
17. Cycling Path Type



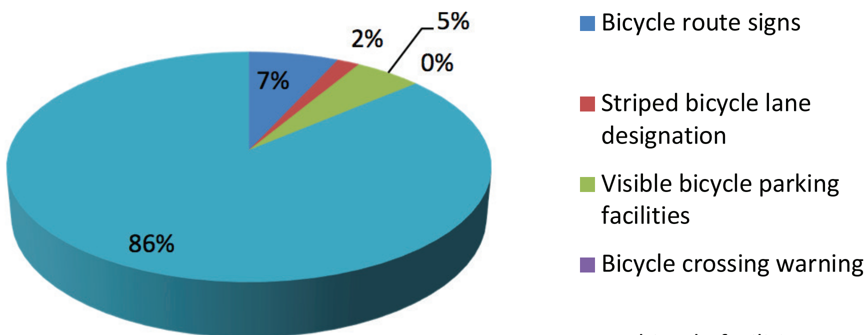
16. Road Condition (On-Road)



19. Path Obstructions (On-Roard)



20. Bicycle Facilities (On-Roard)



21. Adequate Lighting (On-Roard)