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Student Travel Mode Choice: A Case Study of Students Attending the University of Texas at Austin

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Student Travel Mode Choice: A Case Study of Students Attending the University of Texas at Austin

by

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Student Travel Mode Choice: A Case Study of Students Attending the University of Texas at Austin

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The University of Texas at Austin, 2014

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In the last several years, student mode choice has increasingly become an important area of study. Findings from these studies can be applied to regional travel demand modeling efforts, campus planning efforts, and sustainability initiatives, among others. This paper presents an analysis of student mode choice at the University of Texas at Austin, using statistical and geographic information systems analysis, based on the University of Texas Parking and Transportation Services mode choice survey administered during the spring 2014 semester. Results showed that within this sample, more students take alternative modes than drive alone, though the proportion of students driving alone to campus remains substantial. Among other conclusions, analysis also indicated clustering of respondent residential locations, and drive alone hotspots in several zip codes primarily in south/southeast Austin. These results point to a geographic area where it may be beneficial to concentrate resources aimed at inducing drivers to switch to an alternative mode of transportation, in order to support UT's mobility and sustainability goals.

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Chapter 1: Introduction

This spring semester of 2014, University of Texas Parking and Transportation Services (PTS) administered its fourth travel mode survey to students, faculty, and staff at the University of Texas at Austin. Beginning in 2008, PTS has administered three previous travel mode surveys, publishing an executive summary of each, presenting faculty/staff and student responses together, and finding that the share of faculty/staff and students that typically drive to campus has increased each survey year. However, because the student group is of particular interest this paper will describe analysis undertaken for that cohort specifically, placing emphasis on the relationships between mode choice and where students live, the most significant motivating reasons for student mode choice, and where the university may have the greatest potential to induce student drivers to switch to an alternative mode.

In the fall of 2012, the University of Texas at Austin (UT) published its most recent master plan, and though the university is not expecting growth of the student population, it has made goals to improve the efficiency and coordination of the circulation network to support environmental goals as well as promote greater overall health through increased utilization of active modes of transportation: walking, cycling, and busing (p. 32, 37). The university has cited the importance of transportation demand management (TDM) within its overall mobility strategy and aims to improve the sustainability and quality of the campus through supporting and promoting the use of transportation mode alternatives to driving alone. Therefore, the plan states, “Traffic operations analysis should be integrated with campus design…[and] [e]very aspect of campus design should be considered from the point of view of people in motion” (UT, 2012, p. 112). With these goals in mind, analyses of student travel behaviors were undertaken, drawing on findings by previous studies of this kind.

Chapter 2: Review of Previous Research

Literature has informed this research effort on student mode choice. Research on the subject was conducted through an internet search of peer-reviewed journals as well as a review of the findings presented in previous PTS mode-choice survey executive summaries.

PREVIOUS PARKING AND TRANSPORTATION SERVICES MODE SURVEYS

Since 2008, University of Texas Parking and Transportation Services (PTS) has administered three previous travel mode surveys to all students, faculty, and staff at the University of Texas at Austin. These efforts were conducted in Fall 2008, via internet and face-to-face surveys (PTS, 2008, p. 1); in Fall 2009, via internet and paper surveys (PTS, 2009, p. 1); and in Spring 2012 via an online survey instrument (PTS, 2012, p. 1). The expressed purpose of the 2008 and 2009 surveys was to provide empirical data to contribute to campus planning efforts (PTS, 2008, p. 1; PTS 2009, p. 7), while the 2012 survey aimed to "identify opportunities for reducing parking demand and traffic congestion on and around campus" (PTS, 2012, p. 1). As a result of contributions to its design by a private engineering firm, the 2012 survey became the baseline for future survey analysis (PTS, 2012, p. 1) and thus, was the model for the spring 2014 survey analyzed in this report.

In 2008, the survey yielded 4,450 total responses, 61% of which were student responses. Results were published with students and faculty/staff responses presented together, and at that time 1,114 respondents (25%) took the bus as their primary mode of transportation, 540 (12%) indicated an "other" mode, and 350 (8%) said they drive. PTS issued 35,000 permits in 2008, the vast majority of which were to automobiles; thus, an 8% mode share for driving did not appear accurate. Therefore, PTS stated in the future they would work to design the survey so mode choice could be quantified more precisely. Beyond the mode breakdown, the number one reason people chose to drive alone was because of travel time, indicating this was the fastest way for them to get to campus. A secondary reason given was "inadequate, inconvenient public transportation" (PTS, 2008, p. 3). On the other hand, people chose to take transit largely because of convenience and cost. Finally, of interest, respondents indicated the largest obstacle to carpooling was the risk that one might need to leave for an emergency (PTS, 2008).

In 2009, the survey questions were expanded and refined, and PTS received 3,453 responses from paper surveys and internet responses. In this case, drive alone received the highest mode choice proportion at 35% and bus was second at 30%. The distribution of mode choice roughly corresponded to the number of days people drove to campus with 34% saying 0 days per week and 33% saying 5 days per week. Similar to the previous year, drivers cited travel time and/or less than ideal public transportation as their reason(s) for driving in the majority of cases. Bus-riders chose convenience and cost, though it is unclear whether travel time was offered as a choice. PTS also asked for respondents' residential zip code, finding the largest student, faculty, and staff populations lived in 78705 (West Campus) and 78741 (Riverside). Additionally, they asked about commute time and found that 65% of respondents reported a commute time of 20 minutes or less. Furthermore, in addition to asking how people got to campus, PTS was interested in knowing how people moved around campus once they had arrived, finding that though the campus spans about 400 acres, the most common way people circulate through campus is walking (PTS, 2009).

The 2012 survey was significantly different from the previous two, as a result of the contributions to the survey design by a private engineering firm. In addition to questionnaire language modifications, the 2012 survey was only offered online, which may have contributed to its lower response rate of 1,713 responses, roughly half the number from the previous survey. Findings for mode choice indicated that 46% of respondents drove alone to campus as their primary mode, with just 21% using public transportation; a substantial increase from 2009. Motivation choices for driving or taking an alternative mode were also expanded, but still, the largest percentage of drivers chose to drive because it was the fastest way to campus and the majority of those that took alternative modes did so because of high costs of driving/parking. Drivers were asked about factors that would induce them to switch modes; the top three responses included having a shuttle that connected campus to another area of town (17%), having showers in their building (16%), and getting help finding a person with whom to carpool (15%). PTS also asked, to those living within biking distance of less than 3 miles from campus, why those respondents did not bike, and the most cited reason was that biking was too dangerous (33%). Information was also gathered for respondents' age group (the majority were between 18 and 45 years old), and how far from campus the respondent lived, finding the majority of respondents, 65%, lived more than three miles away from campus. As previously mentioned, the 2012 survey became the model for the spring 2014 survey, which will be discussed in greater detail in the next chapter.

PEER REVIEWED STUDIES

An in-depth search of the UT library resource resulted in identification of several studies related to university student mode choice from other parts of the United States and around the world. These studies applied university student mode choice to several policy contexts including university sustainability (Delmelle & Delmelle, 2012), university and regional travel demand management and modeling (Eom et al., 2009), and transit network efficiency (Kamruzzaman et al., 2011). Several emphasized what factors contribute to the modes students choose when they make university-based and other types of trips, with a goal of understanding these motivations in order to create policy to induce drivers to switch to a more active mode of transportation, such as walking, biking, or taking transit.

Like PTS, many of the authors conducted independent survey efforts in order to obtain the data that served as the basis of their research. Numerous researchers, including Zhou (2012), Whalen et al. (2013), and others used an online questionnaire, while others, Klockner and Friedrichsmeier (2011) for example, asked respondents to fill out travel diaries for a specified period of time. Additionally, several of the surveys included incentives for participation, such as entrance into a prize drawing/lottery (Zhou, 2012; Klockner and Friedrichsmeier, 2011) to increase survey response rates. Finally, unlike various others, including the 2014 PTS survey, one group of researchers, Shannon et al. (2006), deliberately did not recruit respondents via email because of the lesser ability to predict response rates and the chance the email would go unseen, and instead chose to recruit through mailed letters. This method yielded a 48% response rate (p. 243), compared to response rates of 22% achieved by both Zhou (2012, p. 1018) and Whalen et al. (2013, p. 125).

Common analysis methods included descriptive analysis, statistical analysis in various forms, and spatial analysis using GIS. Zhou (2012) and Whalen et al. (2013) used descriptive analysis, spatial analysis, and multimodal logit models to show how mode choice is affected when a specific factor (e.g. travel time) changes, while Klockner and Friedrichsmeier (2011) performed multiple regression and tested a two-level travel mode choice model (p. 267). Kamruzzaman et al. (2011) used the travel diary responses of students at two universities in Northern Ireland to assess a demand responsive transport (DRT) service that connects the universities, by utilizing GIS to measure activity spaces of survey respondents. Delmelle and Delmelle (2012) also utilized GIS, using Network Analyst to compute network distance, as well as statistical analysis to interpret their data. Shannon et al. (2006) also employed descriptive and statistical analysis to make conclusions about surveys. All these analysis methods led to a variety of findings by the researchers.

Findings from these studies provide valuable insight into factors contributing to university student mode choice. For instance, Zhou (2012) found that students living alone or with their family were more likely to choose to drive alone when traveling to campus, and found that students who live more than 20 miles from campus, and almost all students living more than 40 miles from campus, commuted via driving alone (p. 1021). Eom et al. (2009) found that the personal vehicle is the primary mode for students living off campus (p. 148), though this group did not specify distance from campus. Finally, Whalen et al. (2012) and Kamruzzaman et al. (2011) both found that if a student owns a car he/she is more likely to use it instead of taking an alternative mode of transportation. These results prove relevant for understanding key variables associated with driving alone.

Likewise, these scholars identified contributing factors for students choosing an alternative mode of transportation. In fact, Khattak et al. (2011) found that, in addition to students exhibiting statistically significantly distinctive travel behavior compared to the general population, they also use alternative modes more often (p. 137, 141). Contrasting to the finding by Eom et al. (2009) that driving is the primary mode used by off-campus residents, that group discovered that walking is the primary mode for students who live on campus (p. 148). Particularly interesting was the finding by Zhou (2012) that having a transit pass is not only significant for transit travel, but also for carpooling, biking, and walking (p.1024); when one considers that these additional alternative modes do not necessarily rely on the possession of a transit pass, this insight is especially noteworthy. Zhou found that the utility of carpooling and telecommuting is slightly heightened as commute distance increases (p. 1024). On the other hand, Whalen et al. (2012) found the utility of cycling to be the lowest of all modes, suggesting that in spite of the "intrinsic value that cyclists place on their trip experience" (p. 133) other barriers to the selection of this mode may exist (p. 140). Lastly, Shannon et al. (2006) found travel time to be the most substantial obstacle to active commuting for university students and staff no matter how close to campus they might live (p. 249), which coincides with the most cited reason for driving alone by UT students and faculty in the previous PTS surveys being that it is the fastest way to get to campus.

Beyond presenting their findings, these studies suggested multiple applications where these results could be used to implement transportation policy and programs. Eom et al. (2009) applied their study of daily activity patterns of North Carolina State University Students as a "first step toward developing comprehensive models of activity-based travel behavior that will enhance other university and regional travel demand models" (p.141), while Whalen et al. (2013) used the observations resulting from their research to develop new transportation policies for McMaster University in Hamilton, Ontario, Canada (p. 133).

Furthermore, these studies suggested methods or areas of influence to encourage drivers to switch modes. These ranged from increasing parking fees (Shannon et al., 2006, p. 251); to transitioning from a yearly or semester parking pass to a more flexible daily parking pass (Whalen et al., 2012, p. 140); to reducing the travel time barrier, increasing the cost effectiveness of alternative transportation modes (Shannon et al. 2006, p. 250), increasing the "perceived behavioural control" associated with alternative modes (Klockner & Friedrichsmeier, 2011, p. 270), and promoting multimodal commuting among students (Zhou, 2012, p. 1027) to incite more preferred travel behavior (Whalen et al, 2012, p. 140). Finally, multiple studies (Zhou, 2012; Shannon et al., 2006) emphasized the important role a university transportation demand management (TDM) plan can play when working to implement these strategies. All these studies proved invaluable background for the current analysis of the 2014 PTS travel mode survey.

Chapter 3: Description of Data

The data used for this research was obtained from University of Texas Parking and Transportation Services in the form of table results from the spring 2014 travel mode survey. Details regarding the survey instrument, its administration, and data management are discussed in this section.

SAMPLE & RECRUITMENT

The intended sample for the PTS survey was all faculty, staff, and students at the University of Texas at Austin. PTS recruited respondents through an email with an explanation of and link to the survey, administered through SurveyMonkey. It is unknown how many students and staff/faculty observed this email however, because some email services may have filtered the email as spam, while other potential respondents had unsubscribed from PTS emails.

RESPONSE RATE

According to UT (2013) there are roughly 51,000 students, and roughly 24,000 faculty and staff at the university. The PTS survey received 3,151 responses from both groups combined, with 1,468 responses (46.6%) from those self-identified as a student. However, because of varying levels of survey completion, different subsample sizes were utilized for the various levels of analysis presented in this paper.

It should be noted that due to the survey administration method, it is unknown how, or whether, the results are representative of the university student population. Additionally, very little demographic information was collected from this survey. Age group information collected could be compared to population information, but the results are difficult to interpret as a result of multiple response options including the same age (18-**25** and **25**-35, for example). This gave respondents of those specific ages the opportunity to choose between one age group or the other, potentially resulting in a split, inconsistent with the actual university student age population distribution. A comparison of the student sample and population age distributions, based on UT's Office of Information Management and Analysis' Fall 2013 Statistical Handbook is shown in Table 1 below. A Chi-Square test was performed (df=4) resulting in a calculated Chi-Square value of 16.84 (at 95% level of confidence) indicating a rejection of the null hypothesis is appropriate, and that this sample and the university student population are significantly related in terms of age distribution.

	Sample: n=1265			Population: N=50,973	
	Count	Percent		Count	Percent
Under 18	4	0.3	Under 18	447	0.9
18-25	802	63.4	18-24	40,622	79.7
25-35	356	28.1	25-34	8,321	16.3
35-65	101	8.0	35-64	1,561	3.1
65+	2	0.2	65+	22	0.04

Table 1: Student Sample and University Population Age Distributions

SURVEY INSTRUMENT

The administered survey questionnaire contained 29 questions consisting of a combination of check box multiple response, multiple choice, and open-ended response types. Information was requested on several different topics including: university affiliation, schedule, primary mode choice, parking, UT transportation program familiarity, commute characteristics, mode choice motivating factors, residential location information, age, and any other comments or feedback for PTS. With the exception of the open-ended response questions regarding how many blocks away from campus a respondent typically parks and monthly parking costs, all questions that could have been answered with a numerical value (age, commute time, etc.) were presented as categorical ranges from which respondents could choose. A copy of the survey questions, question types, and available responses is provided in Appendix A.

DATA MANAGEMENT

To prepare the data for analysis; several data management tasks were undertaken. First, the raw data was sorted based on university affiliation and all records where a respondent self-identified as a student were selected. A separate sheet was then created, containing only the data of self-identified students; this sheet became the base data used for this research. Text-filled cells were then converted to binary notation where applicable; for example, when a respondent indicated his/her primary mode of travel to campus was the UT Shuttle, the response was recorded as "UT Shuttle," which was then changed to "1." This process was applied to numerous questions and responses.

Secondly, a coded mode choice field was created, compiling separate binary mode choice fields into one. Other multiple-choice questions were coded similarly; however, the mode code field is most applicable to the questions analyzed in this research. These mode codes are provided in Table 2 below. Based on responses in the "other" category, each response was either coded to an existing mode option (for example, "private car" as Mode Code 1: Drive alone) or led to the creation of additional mode codes to accommodate these responses. Those that specified a distinct mode choice in the "other" open ended response primarily indicated multimodal trips (drive then bus, etc.) or split modes (driving two days and busing three days, etc.). Additionally, several respondents indicated they were on-campus residents and therefore did not have to travel to campus. These responses were coded as such.

Mode	Code	n
Drive Alone	1	470
UT Shuttle	2	310
Bicycle	3	113
Walk	4	261
CapMetro Mainline	5	128
CapMetro Redline	6	16
Car Share	7	18
Carpool	8	35
Null	9	60
CapMetro Vanpool	10	1
Motorcycle / Scooter	11	24
Split	12	7
Multimodal	13	3
Pick up / Drop Off	14	3
On Campus Resident	15	17
CapMetro Rapid	16	2
TOTAL		1,468

Table 2: Mode Codes

In addition to coding responses, the location data was prepared for use in ArcGIS. This involved correcting zip codes and modifying addresses in Excel based on the provided location. Modifications to addresses were made to correct the spelling of streets or make them complete (changing "Guad" to "Guadalupe," for example); apartment numbers were also deleted where provided, as these were not necessary for the analysis. Zip Codes were modified to correct typing errors, and were added to addresses where enough locating information was provided in order to determine the correct zip code location.

After coding and modifying the data so it was ready for analysis, separate data sheets were created for each research question containing only the data needed to for that particular level of analysis, in order to simplify the analysis process. This made it possible to import only the data necessary to perform each analysis into the corresponding program where analysis was performed.

Chapter 4: Descriptive and Statistical Analyses and Discussion

To explore UT student mode choice a variety of methods were employed, including descriptive and statistical analysis using SPSS software. These analyses provided stand-alone insight into student travel behaviors and also helped refine the spatial analysis discussed in the next chapter.

DESCRIPTIVE ANALYSIS

Descriptive analysis was used to get an overall picture of the survey results from the 2014 PTS survey; the most important of which to this paper was mode choice distributions. Illustrated in Figure 1 below, roughly a third of students in the sample, who indicated a mode, drive alone as their primary mode to campus, while two thirds take an alternative mode, the most common of which is taking a UT Shuttle. Because the drive alone proportion is lower than that found by the past two surveys (35% in 2009 and 46% in 2012), this might indicate that the share of alternative mode use has increased over the years, but might also indicate that mode choice for students alone is simply distributed differently than when student and faculty/staff are represented together.

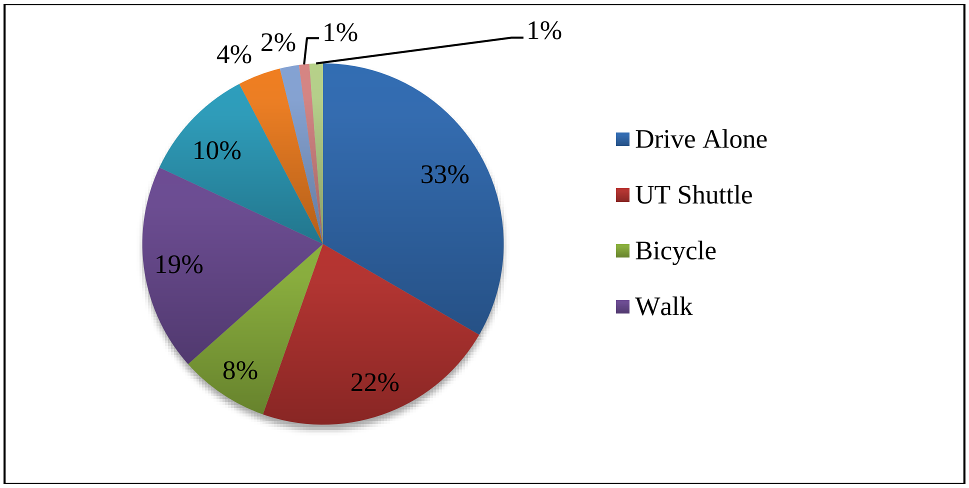

Figure 1: Mode Choice Summary (n = 1,408)

Another important variable for deeper levels of analysis discussed in later sections is residential distance from campus, shown in Figure 2 below. It is clear that the majority of respondents who chose to answer this question live further than three miles from campus, though this is less than the 65% found for all respondents in the 2012 survey. This potentially indicates a shortage of student housing nearer to campus or simply student preference.

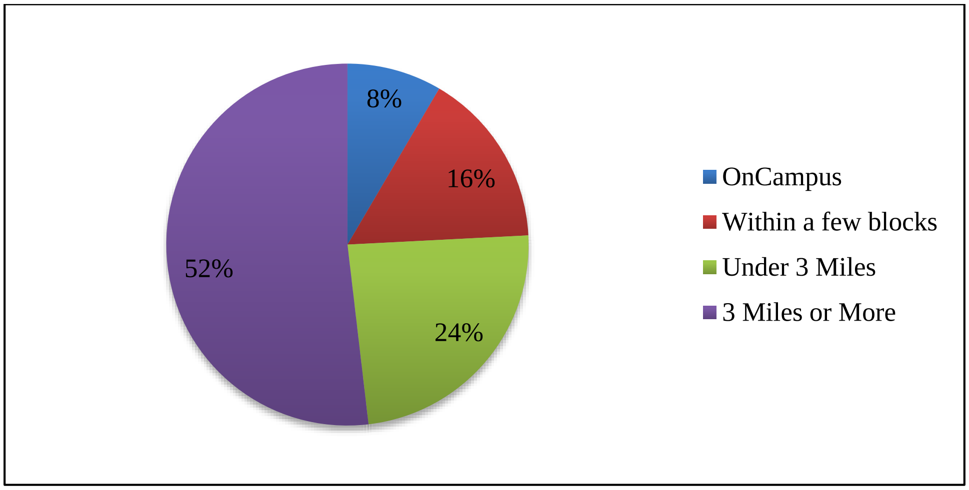

Figure 2: Residential Distance from Campus Summary (n = 1,265)

Though fewer respondents provided commute time information than other information, more than 325 respondents (or about 41% of individuals who gave this information) indicated a commute time to campus between 11 and 20 minutes (illustrated in Figure 3).

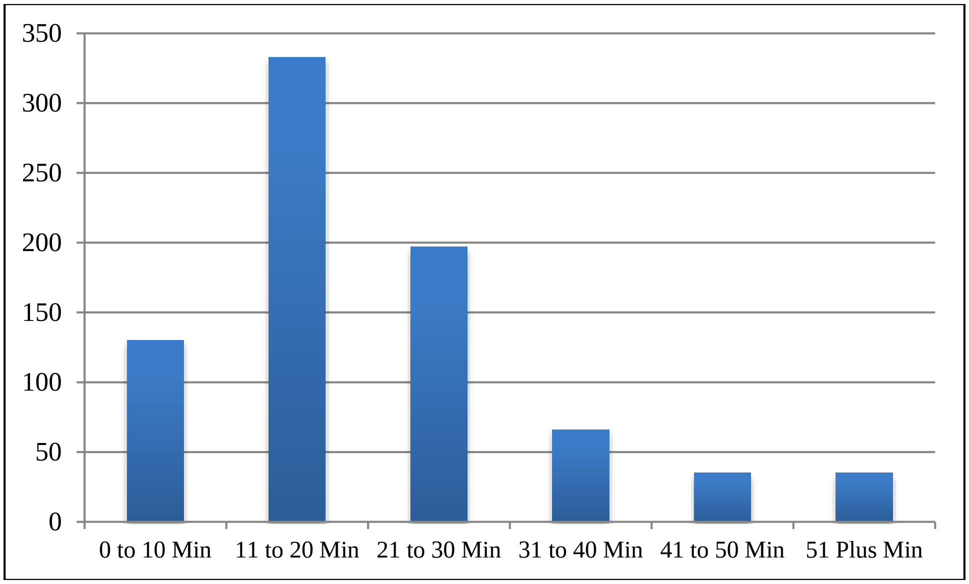

Figure 3: Commute Time Summary (n = 796)

Beyond analyzing each variable separately, valuable information could be gleaned when a classic Chi Square analysis or cross tabulations (crosstabs), of variables were generated. For example, a crosstab of mode choice versus age found that younger age groups have smaller proportions of drivers while these proportions were larger for older students, indicating a positive correlation between age and proportion of drivers. This aligns with Zhou's (2012) finding that "the older one is the fewer utilities public transit would provide to him or her" (p. 1025). Also interesting is the crosstab of age versus distance from campus, which shows that younger students tend to live closer to campus, leading to the question of whether this is because of preference, housing availability, or other factors. This bigger picture descriptive analysis helped refine the research questions and goals for the statistical and spatial analyses, examined in the following section and chapter.

STATISTICAL ANALYSIS

To carry out the statistical analysis portion of this research SPSS software was used. As mentioned above, for the majority of variables potentially associated with typical statistical analysis of this kind of data (age, commute time, etc.), respondents were asked to select a category or range of values, instead of entering a numeric value. As a result, these values became categorical and thus were not appropriate for means tests or regression analysis, like those performed in the reviewed studies.

However, one variable was collected as a numerical value and asked to all respondents regardless of mode choice; this was typical monthly parking cost. With this information, a means test was performed to identify whether these costs were significantly different among groups of different mode users, for those who responded to the question. After excluding those respondents who did not provide a dollar amount, and those that did not provide a mode choice, the sample size for this analysis was 579. Though a blank response might have indicated $0 in monthly parking (especially for those using alternative modes), and thus would have led to the inclusion of additional modes, the intentions of the respondents could not be determined, and thus, they were not included in the analysis.

Two ANOVA one-way tests were performed, one comparing driving alone to all other modes, and one comparing the mean costs among all modes. Results, shown in Tables 3 and 4 below, indicate that for both tests run, significant differences between groups exist.

ANOVA-Parking Cost					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	262838.874	1	262838.874	31.221	.000
Within Group	4857626.352	577	8418.763		
Total	5120465.227	578			

n=579

Table 3: Parking Costs ANOVA Output – Drive Alone vs. All Alternative Modes

ANOVA-Parking Cost					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	267666.105	3	89222.035	10.572	.000
Within Group	4852799.121	575	8439.651		
Total	5120465.227	578			

n=579

Table 4: Parking Cost ANOVA Output – All Modes Separate

Though the ANOVA tests indicate the difference between group means is significant, it does not indicate between which groups the significance exists. Therefore a multiple comparisons table was generated using the Turkey post-hoc test, which indicated that there are significant differences in parking costs between those that drive alone and those that take the UT shuttle, but that no other significant differences exists between any of the other groups. These results are shown in Table 5 below and indicate that taking the UT Shuttle results in substantially lower parking costs than driving alone. This is not surprising, but bolsters the evidence of one of the advantages of taking transit.

Multiple Comparisons: Parking Cost (Dependent Variable)						
Mode (I)	Mode (J)	Mean Difference (I-J)	Std. Error	Sig	95% Confidence Interval	
					Lower Bound	Upper Bound
Drive Alone	UT Shuttle	44.303*	8.044	.000	23.58	65.03
	CapMetro Redline	51.135	31.017	.352	-28.78	131.05
	CapMetro Redline	51.135	31.017	.352	-28.78	131.05
	Car Share	26.246	25.043	.721	-38.28	90.77
UT Shuttle	Drive Alone	-44.303*	8.044	.000	-65.03	-23.58
	CapMetro Redline	6.831	31.275	.996	-73.75	87.41
	Car Share	-18.057	25.362	.892	-83.40	47.29
CapMetro Redline	Drive Alone	-51.135	31.017	.352	-131.05	28.78
	UT Shuttle	-6.831	31.275	.996	-87.41	73.75
	Car Share	-24.889	39.250	.921	-126.02	76.24
Car Share	Drive Alone	-26.246	25.043	.721	-90.77	38.28
	UT Shuttle	18.057	25.362	.892	-47.29	83.40
	CapMetro Redline	24.889	39.250	.921	-76.24	126.02
* The mean difference is significant at the 0.05 level.						

Table 5: Parking Cost Multiple Comparisons

Chapter 5: Spatial Analysis and Discussion

To analyze the spatial patterns of student mode choice, several tools in ArcGIS software were employed, including the average nearest neighbor, hot spot, and network analyses tools. The average nearest neighbor and hot spot tools perform spatial analysis operations that produce results explaining a) whether there is significant clustering of student residential locations and b) where the most significant clustering exists. These tools start with a null hypothesis that the features in the dataset display a spatially random pattern, and then compute a p-value, which indicates the probability that the null hypothesis is true. Though one can visualize an overall pattern of features by seeing them on a map, these tools quantify the relationships and patterns, which can make it more straightforward to compare the patterns of different distributions (ESRI, 2013a). In this case, the different distributions being analyzed were groups of different mode users in the UT student population and their patterns of residential location. Network analysis was used to facilitate an exploration of the relationships between where students live and their campus destinations, as well as between residences and alternative mode facilities. Each of these levels of analysis will be reviewed in the following sections, while a geospatial data summary is provided in Appendix B.

NEAREST NEIGHBOR ANALYSIS

ArcGIS' Nearest Neighbor tool "calculates a nearest neighbor index based on the average distance from each feature to its nearest neighboring feature" (ESRI, 2013c), and provides a report containing five values: observed mean distance, expected mean distance, nearest neighbor index, z-score, and p-value. With a null hypothesis that the mapped features are randomly distributed, the z-score and p-value indicate whether to reject the null hypothesis. The nearest neighbor index, on the other hand, (calculated as the ratio of the observed mean distance to the expected mean distance) indicates whether the features demonstrate clustering or dispersion (ESRI, 2013c).

Residential location information provided in the PTS survey results was used to perform this analysis for all respondents, as well as individual modes with adequate representation: drive alone, UT shuttle, Capital Metro mainline, walk, bicycle, all non-shuttle transit, and motorcycle/scooter. Prior to running the average nearest neighbor analysis tool, it was necessary to geocode the location information respondents provided in the survey. Location information was coded based on level of detail (shown in Table 6 below), and because too many assumptions would have to be made to geocode levels three through six, only levels one and two (full street address, and cross streets) were used in this analysis.

ADDRESSDET_R	Level of Detail Code	n
Full street	1	369
Cross streets	2	567
Single street	3	172
Zip code	4	54
City	5	29
Neighborhood	6	27
Null	9	250
TOTAL		1,468

Table 6: Address Level of Detail Codes

A further limiting factor for this portion of the analysis was the malfunction of ArcGIS' national geocoder, leading to the use of an address locator based on the City of

Austin's streets shapefile. This made it impossible for ArcGIS to locate and geocode addresses and cross-streets that fell outside the perimeter of this shapefile, necessitating the exclusion of addresses provided for multiple non-Austin-resident students. In all, a sample of 908 was successfully geocoded for analysis, 14 were unmatched within Austin, and 17 were unmatched out of town. These geocoded addresses are presented in Figure 4 below, symbolized by mode choice.

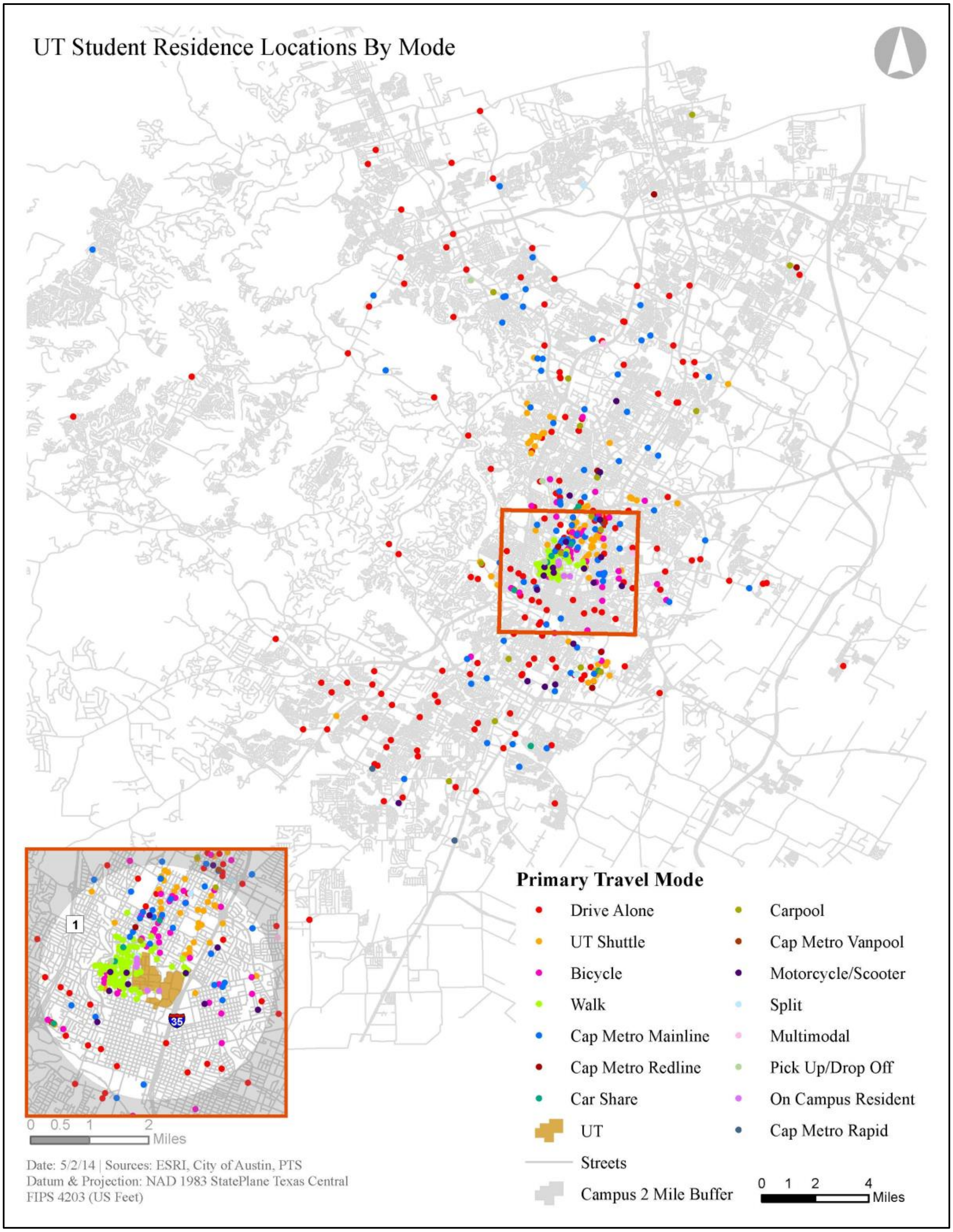

Figure 4: UT Student Residence Locations by Mode

The ArcGIS software provides an output for the average nearest neighbor analysis with an image like the example below in Figure 5, indicating to what level features are clustered, random, or dispersed.

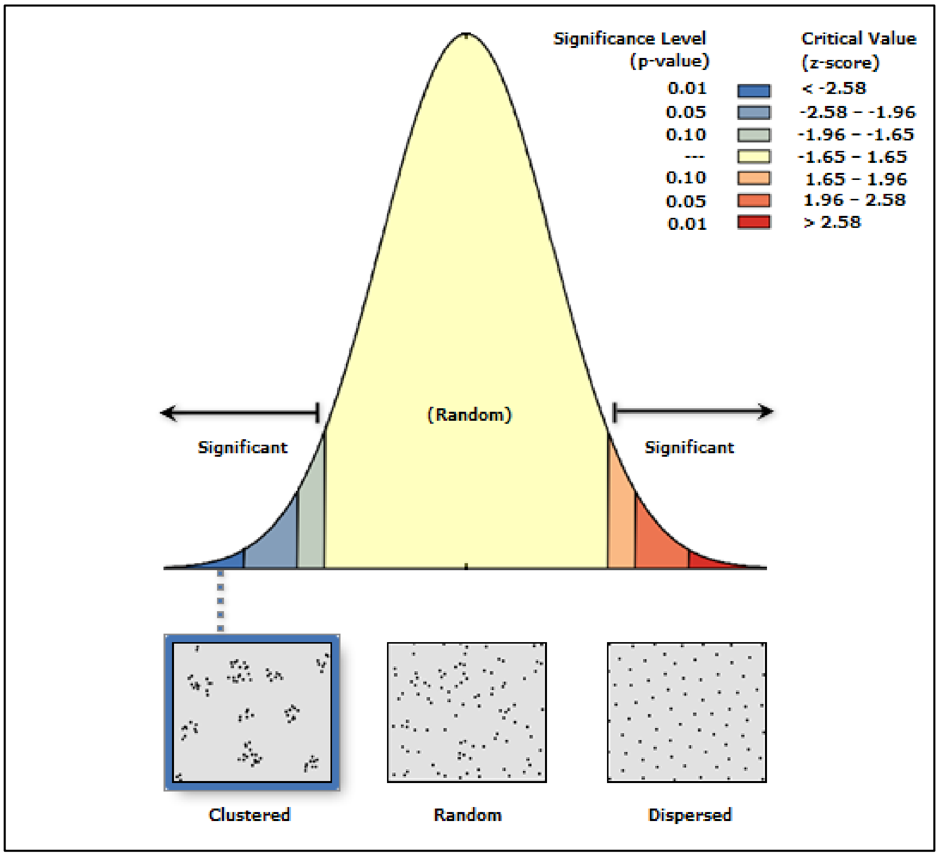

Figure 5: Sample Average Nearest Neighbor Analysis Output

Results, compiled in Table 7 below, indicate significant clustering of all groups except motorcycle/scooter riders, who in this sample, tended toward dispersion. The most highly significant clustering occurred for all students, while the next highest clustering significance occurred for UT Shuttle users, those that walk, and those that drive alone, in that order. Clustering for shuttle users might be expected because shuttle service is only available in particular areas, and thus it would follow that users of this service would tend to live in clusters around shuttle facilities. Likewise, clustering of walkers may be anticipated because walking as a mode of transportation to campus has likely the highest utility for students who live relatively close to the university. Though average nearest neighbor analysis cannot answer the questions raised regarding where clustering occurs, these relationships were explored using other tools, discussed below.

	n	Observed Mean Distance (ft)	Expected Mean Distance (ft)	Nearest Neighbor Ratio	z-score	p-value
All Modes	908	768.681300	2167.657591	0.354614	- 37.2043	0.000000
Drive Alone	269	2183.820209	4137.945076	0.527755	- 14.2560	0.000000
UT Shuttle	189	855.421462	2163.662739	0.395358	- 15.8179	0.000000
Cap Metro Mainline	105	3359.054602	4989.632678	0.673207	- 6.31399	0.000000
Walk	195	108.401887	253.353788	0.427868	-15.2450	0.000000
Bicycle	100	1181.671255	1907.032150	0.619639	- 7.1666	0.000000
Motorcycle/ Scooter	19	5873.545020	4328.016962	1.357098	2.9778	0.002903
All Non-Shuttle Transit	115	3662.447743	5632.725425	0.650209	- 7.0502	0.000000

Table 7: Average Nearest Neighbor Analysis Results

RESIDENTIAL HOT SPOT ANALYSIS

After determining there was significant clustering of student residences, hot spot Analysis was used to determine *where* the clustering was most significant. The hot spot Analysis tool is part of ArcGIS' Mapping Clusters toolset. These tools can be used for a variety of purposes, but one that is potentially most relevant to this study is pinpointing the location of clusters in order to look for potential causes of the clustering (ESRI, 2013b); in this case, the potential reasons student choose to drive alone or use an alternative mode of transportation. Similar to the average nearest neighbor tool, hot spot analysis provides z-scores and p-values measuring levels of statistical significance in order to indicate whether the rejection of the null hypothesis is appropriate. Additionally, this tool uses the Getis-Ord Gi* (pronounced G-i star) statistic which looks at each feature in the context of its neighboring features; designating a hot spot, not as the unit with the highest value, but one that has a high value and is surrounded by features that also have high values. Likewise, a unit with a low value, surrounded by other features with low values would be designated as a cold spot (ESRI, 2013d, 2013e).

Zip code was the unit of analysis selected for this portion of the analysis; while the sample was residential zip code counts (address detail level 4). This sample was chosen because more respondents provided zip codes than higher levels of address detail. In order for the tool to calculate hot spots, each zip code needed a neighbor. Therefore, zip code counts were only used for zip codes that had contained at least one geocoded address from the previous level of analysis. This ensured that each zip code had an adjacent neighbor, though it necessitated the exclusion of respondents that provided zip codes from outside the Austin area, including residents of Aledo, San Antonio, and Houston. This requirement for the tool, which influences the fixed distance used for the neighborhood search threshold, also contributed to the decision to only perform this analysis on two groups, all mode users and drive alone mode users. As a consequence of this decision, network analysis was selected as the analysis tool for alternative modes: bicycle, walk, UT Shuttle, and all non-shuttle transit); this analysis will be discussed in the following section.

The sample size for all student respondents was 1,165 for this level of analysis, and results indicate that, as may be expected, the most significant clustering of student residences occurred in central Austin zip codes surrounding UT's main campus. A map of these results, Figure 6, can be found below. Results indicate that student residences tend to cluster within six miles of campus. While the residential zip codes were statistically significant around UT's campus, none of the zip codes achieved the highest level of significance of over 2.58 standard deviations. Therefore, if UT is interested in encouraging students to live closer to campus in order to promote higher utility of alternative or active modes of transportation, this information could be useful.

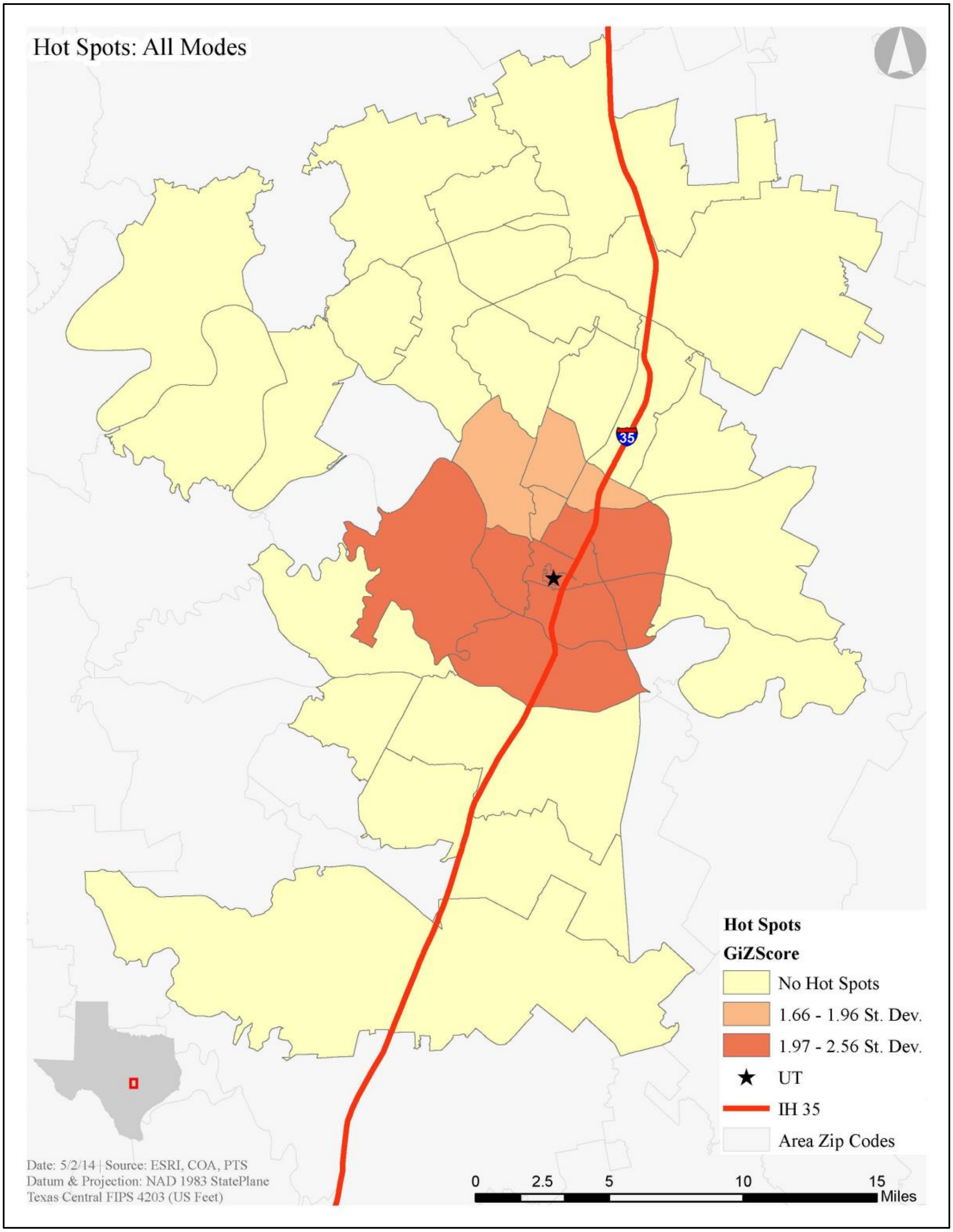

Figure 6: Hot Spots: All Modes

The hottest zip codes for drivers (n = 356), on the other hand, were concentrated south of campus, with the hottest zip codes being 78741, 78704, and 78701. Results for the most significant drive alone zip codes are listed in Table 8 below, while Figure 7 illustrates the results in map format. The hottest drive alone zip codes had a GiZ-Score of higher than 2.58 (indicating they are more than 2.58 standard deviations away from the mean) and a p-value of less than 0.01 (having a level of confidence of higher than 99%), signifying the most significant, non-random clustering of drivers.

Zip Code	Number of Drivers	GiZ-Score	GiP-Value
78741	**44**	**3.166896**	**0.001541**
78704	**17**	**2.822613**	**0.004763**
78701	**4**	**2.681638**	**0.007326**
78702	8	2.522834	0.011641
78703	19	2.410867	0.015915
78705	23	2.410867	0.015915
78722	2	2.410867	0.015915
78721	4	2.2156	0.026719
78744	6	2.176403	0.029525
78745	17	2.117166	0.034246

Table 8: Hottest Drive Alone Zip Codes

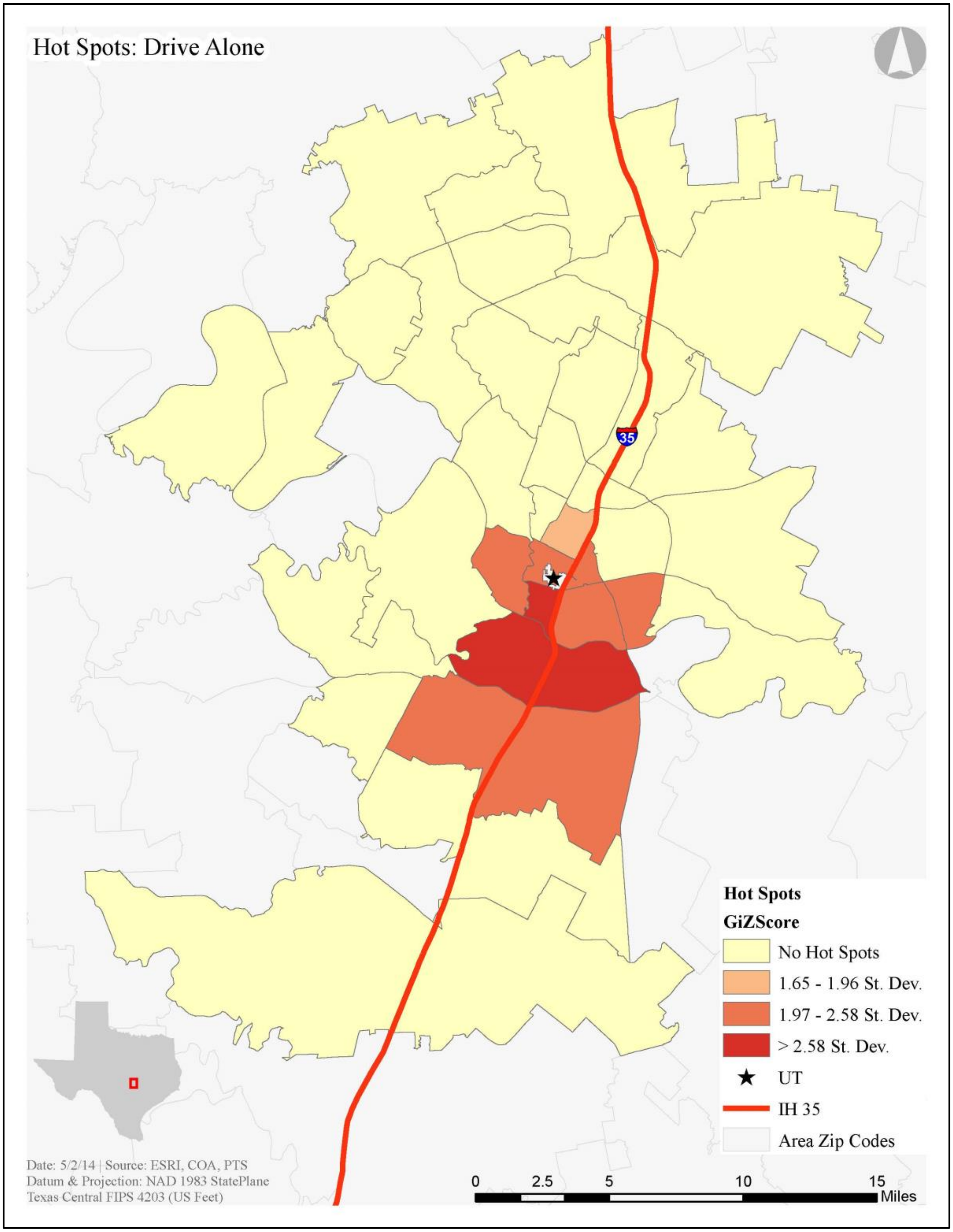

Figure 7: Drive Alone Hot Spots

Once the hottest drive alone zip code was identified, it became possible to infer reasons this spatial pattern exists, both from survey responses indicating various motivations for why each respondent chooses to drive, and based on the feasibility of using an alternative mode of transportation for trips to campus based on the zip code location. 78741 is located just southeast of downtown Austin, bound by IH 35 to the west, Lady Bird Lake to the north, US HWY 183 to the east and Ben White Blvd to the south. In addition to the physical barrier created by Lady Bird Lake, this zip code is further than three miles from campus, indicating both walking and bicycling to campus are less feasible for residents of this area. Furthermore, while eight Capital Metro routes intersect this zip code and travel to UT (four UT Shuttles, two local service routes, and two flyer routes) many of these routes have limited stops within, or provide limited coverage of, the zip code, indicating this might be a barrier for transit use as a resident's primary mode.

As to why respondents said they choose to drive alone as their primary mode to campus (shown in Figure 8 below), the majority in 78741 dwellers indicated that one of their motivations to drive alone is that it is the fastest way to get to campus. This might suggest that if transit efficiency were increased in between this area and campus, more students might choose that mode.

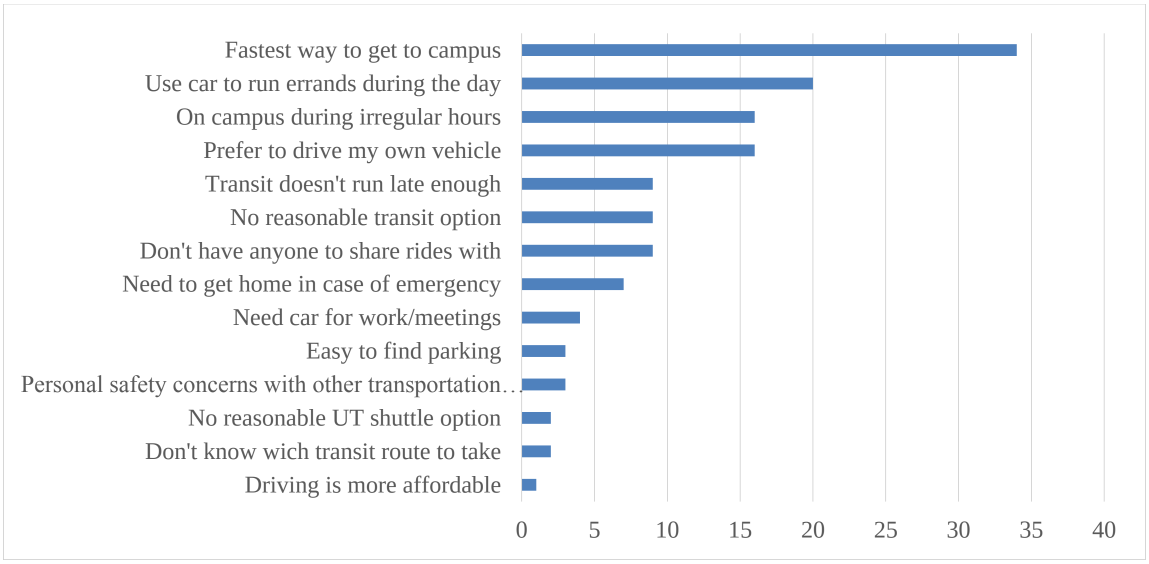

Figure 8: Motivations for Driving Alone by Hottest Driver Zip Code: 78741 (Multiple Response)

However, as illustrated in Figures 9 and 10 below, residents of all the hot spot zip codes, as well as just the residents of 78741, indicated the most support for switching modes through obtaining help finding a carpool/rideshare match. This might imply that the personal automobile would still be the preferred vehicle for travel. Still, representation for potential inducements of provision of a night safety shuttle covering a greater area and the establishment of a UT Shuttle connecting to a different area of town suggest some transit improvement could induce drivers to make a mode switch.

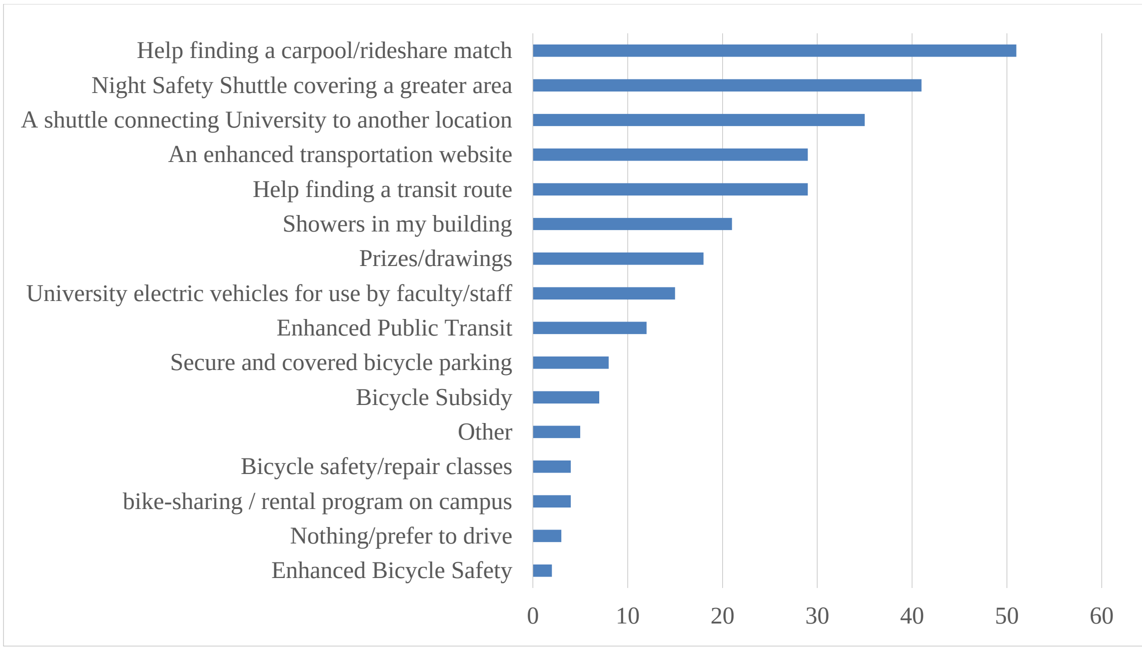

Figure 9: Potential Inducements to Motivate Drivers to Switch to an Alternative Mode (All Drive Alone Hot Spot Zip Codes) (Multiple Response)

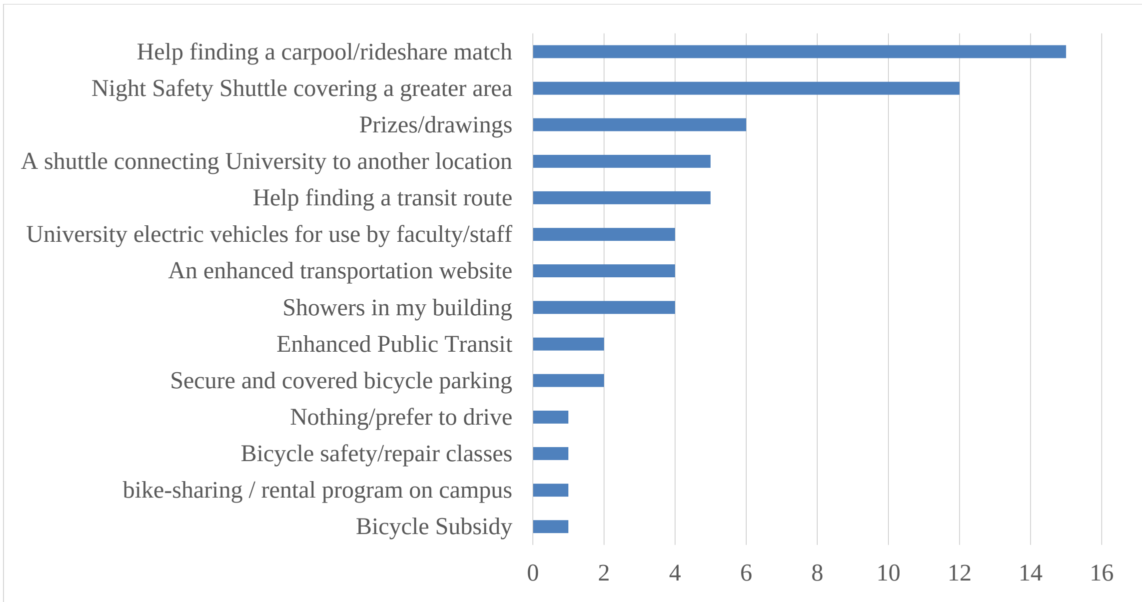

Figure 10: Potential Inducements to Motivate Drivers to Switch to an Alternative Mode (Hottest Drive Alone Zip: 78741) (Multiple Response)

NETWORK ANALYSIS

As previously mentioned, because it became apparent Hot Spot Analysis was not as readily appropriate for analyzing the spatial patterns of alternative mode users, network analysis was employed. This tool can be used for a variety of purposes including routing between two facilities, finding the nearest facility, and generating service areas, all using network distance instead of Euclidean distance. For this analysis service areas of various sizes were generated for points associated with alternative modes of transportation (addresses of students using alternative modes and bus stops). Then, the select by location function was used to determine how much of the alternative mode sample is covered by service areas for their chosen transportation mode. Because point shapefiles are most appropriate for this type of analysis, the geocoded addresses used for the average nearest neighbor analysis were also used for this level of analysis, while a dataset based on the City of Austin streets shapefile was used as the network for analysis.

The first groups of service areas were produced for shuttle user addresses and shuttle stops. Quarter-mile and half-mile service areas were generated for both shuttle addresses (n=189) and shuttle stops (n=187), and it was found that 33% of shuttle users live within a quarter-mile of a shuttle stop, while 48% live within a half-mile of a shuttle stop. However, it appeared a higher proportion of the shuttle addresses were close to shuttle routes, potentially indicating not all shuttle stops were coded as such; therefore, a select by location was conducted for shuttle routes intersecting shuttle user address service areas, finding that 91% of shuttle users live within a quarter-mile of a shuttle route and 93% live within a half-mile of a shuttle route. This large difference in service area coverage might be attributed, as mentioned above, to miscoded shuttle stops or, alternatively, to changes in route alignment or service (several respondents indicated that their shuttle service had recently been discontinued), not reflected in the shapefiles, which were last updated in 2012. Figures 11 and 12 illustrate the network analysis results for this mode group.

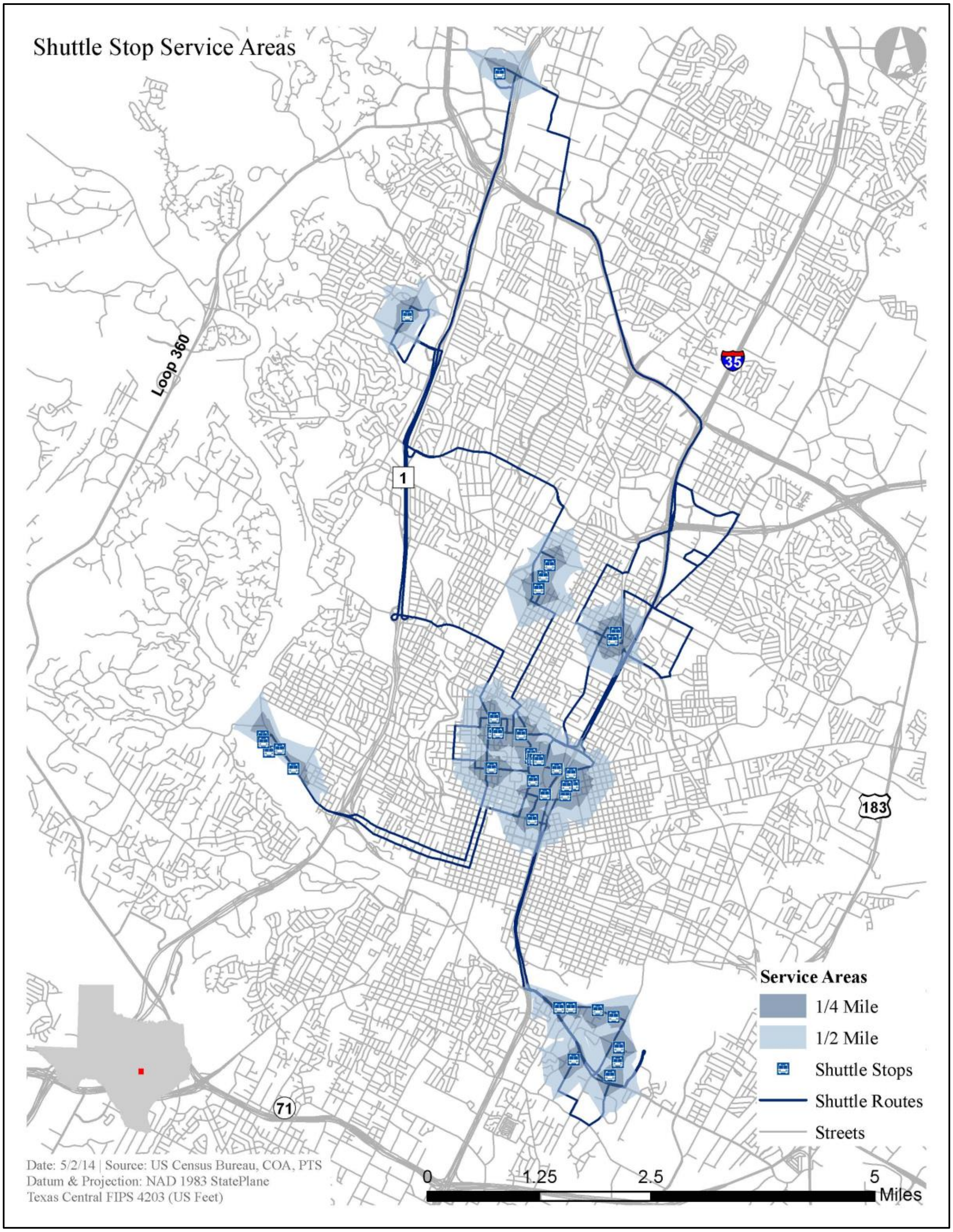

Figure 11: UT Shuttle Stop Service Areas

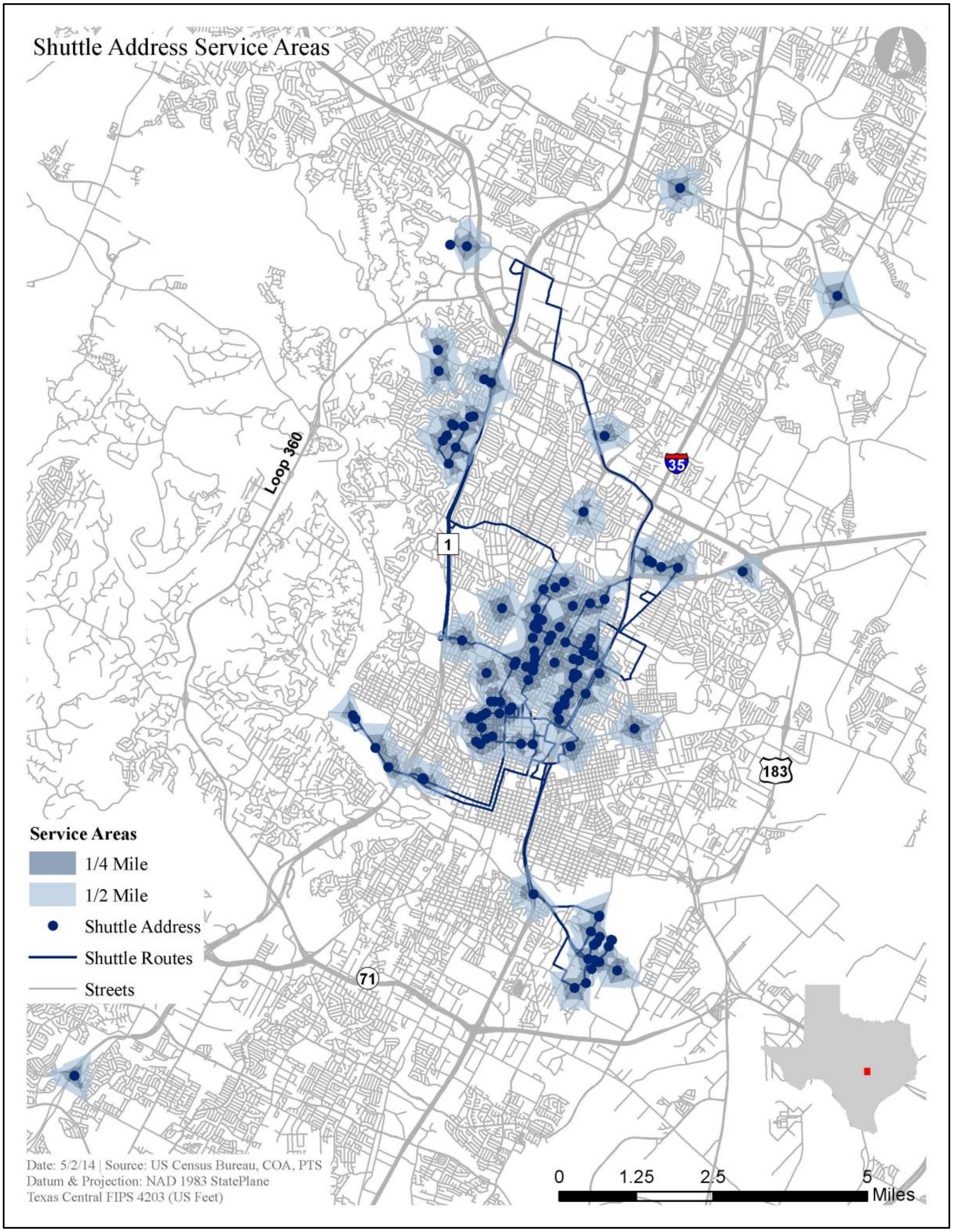

Figure 12: Shuttle Address Service Areas

After shuttle-users, non-shuttle-transit users (n=115) were assessed by generating quarter- and half-mile service areas for all non-shuttle-transit stops, and selecting by location the non-shuttle-transit user addresses that intersected these service areas. Findings from this analysis indicated that 82% of non-shuttle transit users live within a quarter-mile of a non-shuttle transit stop, while 85% live within a half-mile of the same. The quarter- and half-mile service areas were chosen for the transit analysis because they are commonly used as the perceived capture radii for transit stops, representing 5-minute and 10-minute walks. Results for this sub-sample are illustrated in Figure 13 below. Results from the network analysis for both shuttle and non-shuttle transit users indicated that to increase the share of student users of these modes, the university might encourage more students to live within a half mile of a transit/shuttle stop. This might be done with targeted advertising both to students at the university as well as through individual apartment complexes.

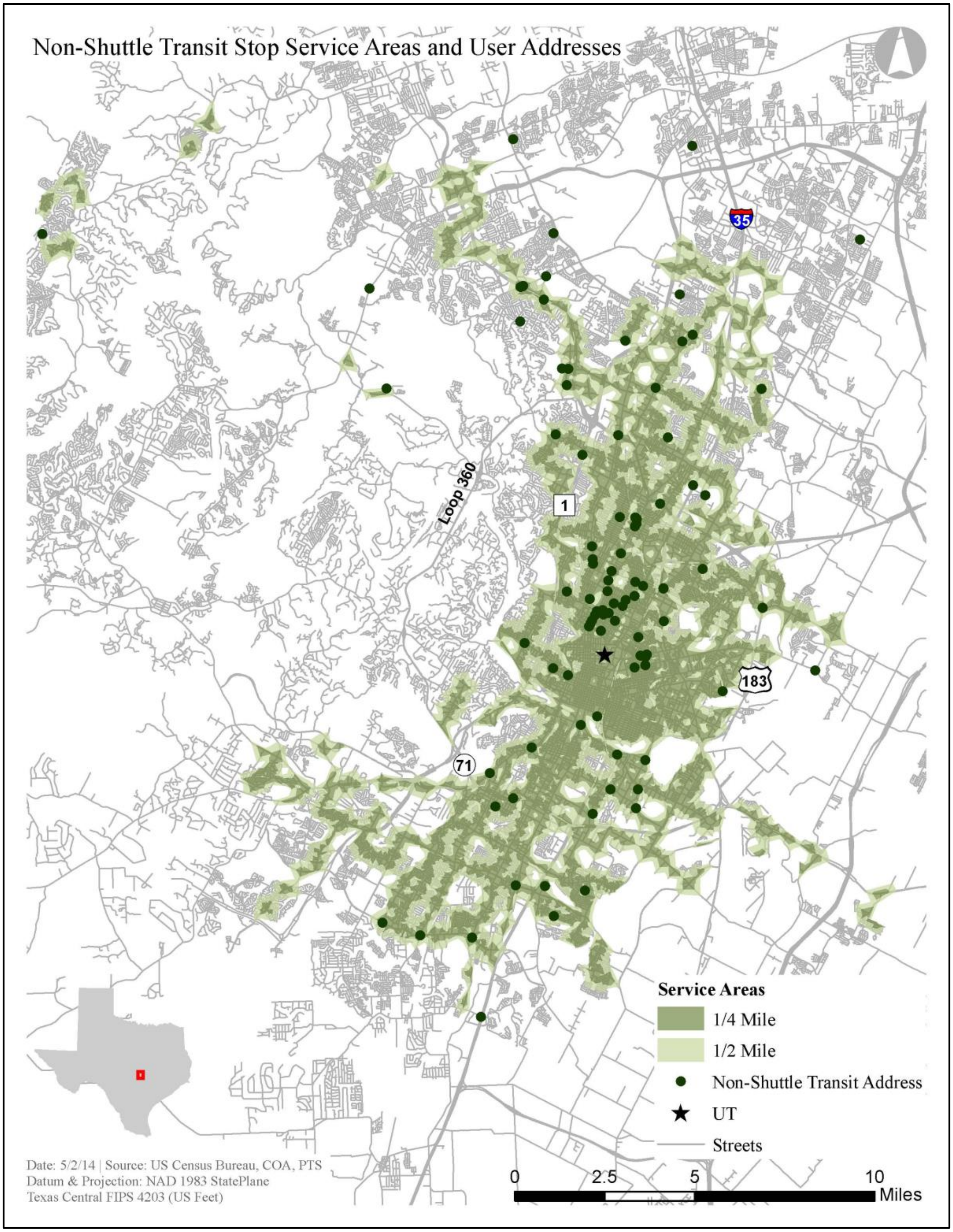

Figure 13: Non-Shuttle Transit Stop Services Areas and User Addresses

For walkers (n=194), the same quarter- and half-mile services areas were generated for walker addresses, but additional three-quarter-mile and one-mile services areas were also generated to see how many walking students within the sample live outside that 10-minute/half-mile distance. It was found that 64% of walkers live within a quarter-mile of campus, 93% live within a half-mile, 99.5% live within three-quarters of a mile, and 100% live within one mile. These results (illustrated in Figure 14 below) indicated the typical half-mile service area is appropriate for the vast majority of cases, as only 7% of sampled walkers lived outside that buffer. It also suggests that as more student housing is built within this radius, the walking mode could capture a larger proportion of students.

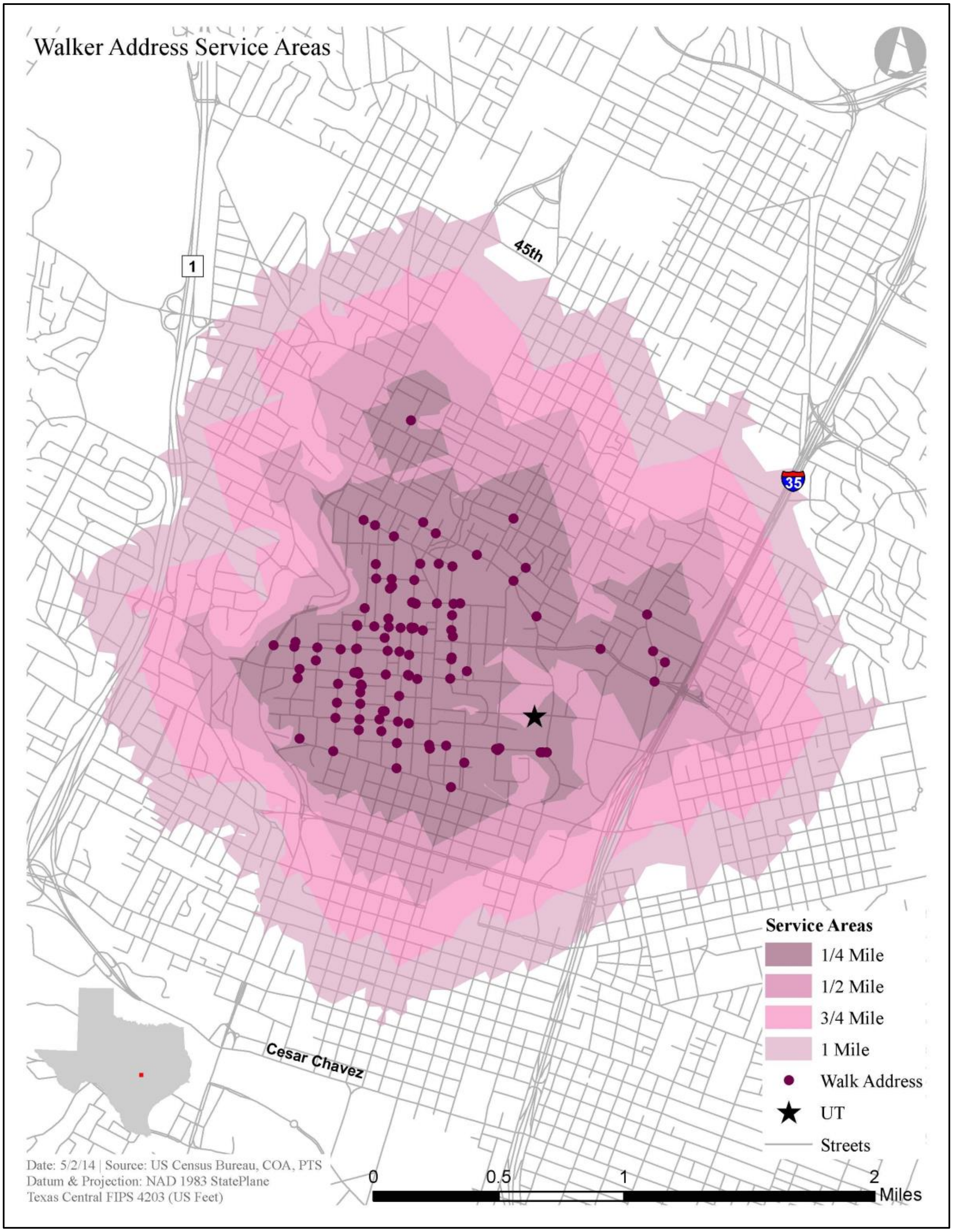

Figure 14: Walker Address Service Areas

Finally, one-mile, two-mile, and three-mile service areas were generated for bicyclist addresses (n=97). These service areas were chosen because the PTS survey characterized biking distance as within three miles of campus when asking why respondents who live within three miles of campus chose not to cycle to campus. Results indicated (illustrated in Figure 15, below) that 64% of cyclists live within 1 mile of campus, 81% live within 2 miles, and 92% live within 3 miles; leaving campus outside the 3-mile service area for 8% of cyclists, seven individuals.

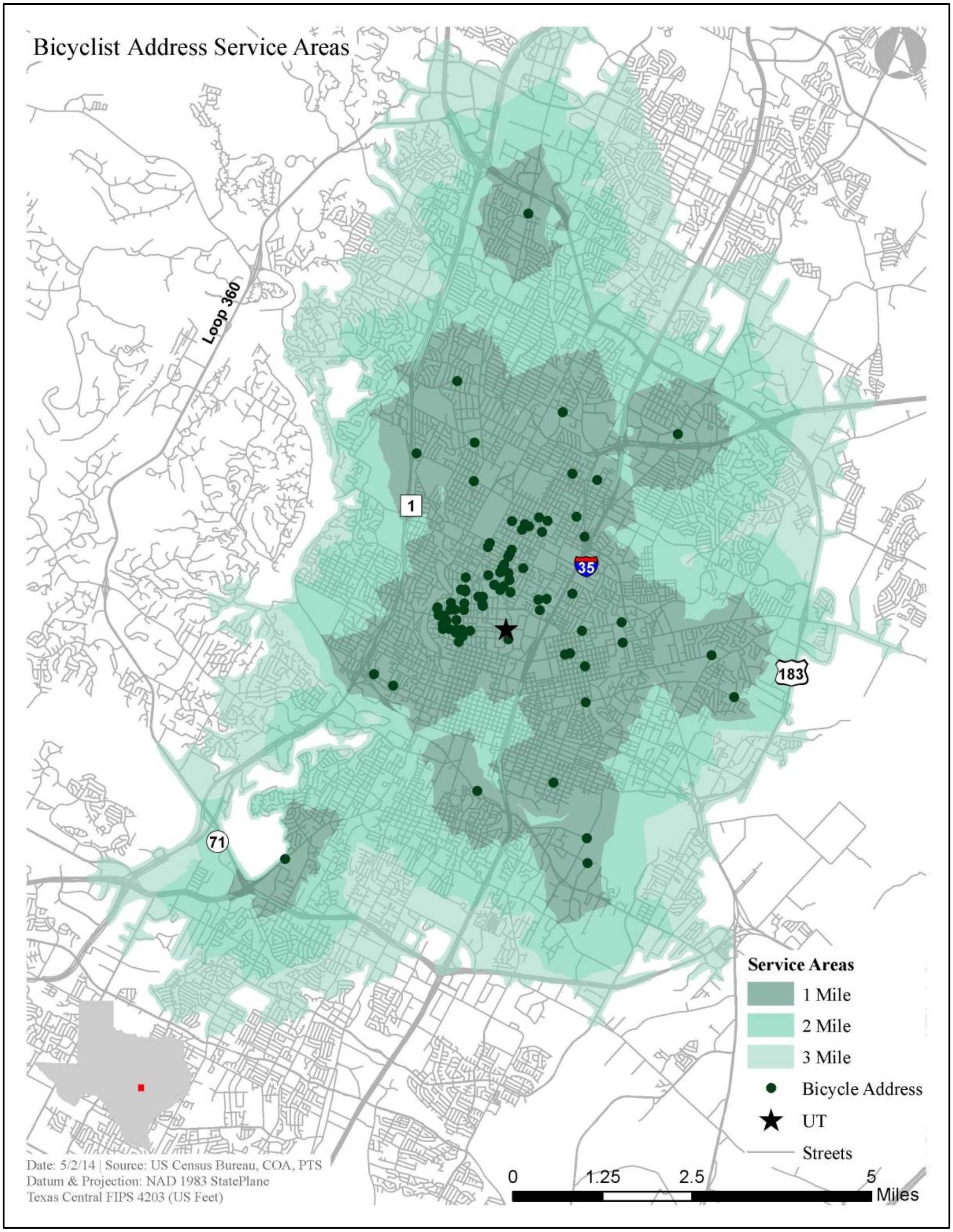

Figure 15: Bicyclist Address Service Areas

Though the proportion of respondents living beyond three miles from campus is small, this might indicate that under certain circumstances distance is not as important as other factors, or that these cyclists simply prefer this mode to others. Comparing this group's motivations for cycling to those who live within three miles of campus, 86% of these individuals cited enjoyment as a motivator, compared to 67% of cyclists that live within the 3-mile service area. Furthermore, 71% pointed to environmental, health, and financial concerns as reasons for cycling compared to 35%, 33%, and 42%, respectively of the other group citing these reasons. Below, Table 9 lists the mode choice motivation differences between the two groups.

	> 3 Miles from Campus	**Within 3 Miles of Campus**
Motivation		
Enjoyment of Biking or Walking	86%	67%
Environmental concerns	71%	35%
Health concerns	71%	33%
Financial concerns	71%	42%
Availability of Bike Parking	57%	41%
Enjoyment of taking transit	43%	6%
Difficulty finding parking	43%	32%
Availability of Shuttle	14%	15%
Kickstand Program	0%	2%
Zipcar @ University	0%	1%
Reserved Carpool Parking	0%	2%

Table 9: Motivator Comparison Between Cyclists Outside the 3-Mile Campus Service Area and Those Within (Multiple Response)

In General, alternate mode users cited several reasons for doing so, the top five of which were "availability of shuttle," "difficulty finding parking," "financial concerns/high cost of driving and parking," "enjoyment of walking or biking," and "environmental concerns." Though two of these reasons point to the disutility of driving experienced by this sample, two illustrate the positive utility of alternative modes, while the last suggests the power of ideological alignment (or "personal norms" (Klockner & Friedrichsmeier, 2011, p. 270)) on mode choice. The presence of "enjoyment of walking or biking" being among the top five motivators for both bicyclist and walker groups individually (top reason for cyclists and third highest for walkers) supports the finding by Whalen et al. (2012) that active mode users (cyclists in particular) feel their trip experience has inherent value (p. 133).

Chapter 6: Conclusion

This report has presented several levels of analysis of the data obtained by University of Texas (UT) Parking and Transportation Services (PTS) through their most recent travel mode survey, administered during the spring 2014 semester. These analyses were performed in the contexts of previous PTS surveys, previous peer-reviewed studies of university student travel behavior, and UT mobility and sustainability goals. Key findings include, but are not limited to, 1) the statistically significant parking cost differences between driving and other modes, 2) the presence of clustering of student residences, and 3) the identification of the zip code 78741 as the 'hottest' drive alone zip code, potentially pointing to an area where resource concentration might be most beneficial to induce drivers to switch to an alternative mode. Student drivers residing in the 'hottest' driving zip codes indicated that help finding a carpool/rideshare match and the provision of a night safety shuttle covering a larger area have the most potential to induce them to switch to an alternative mode. Therefore, concentrating resources in these areas might help decrease the share of drive alone travel to the university. Potential uses of resources could include more robust advertising of UT's current carpool program and development of a rideshare match application for UT students, faculty, and staff to help drivers find carpool contacts; and increased partnership activities with Capital Metro to provide the night safety shuttle.

In order to enhance the potential for analysis of future travel mode survey results, PTS might consider asking all mode users their motivations for using their mode of choice in a single question, instead of splitting drivers and alternative mode users. This would remedy the discrepancy between motivation option differences between the two groups. For example, while drivers were given the option of choosing to drive because it is the fastest way to campus, alternative mode users were not, though some wrote it in the open-ended response area as an "other" reason. Also, information that is naturally numeric (e.g., commute time, age, etc.) could be entered that way instead of through categorical choices, which would enable viable multiple regression analysis of the results. Furthermore, administering the survey through a UT email service from which students cannot unsubscribe might lead to increased response rates and an enhanced ability to predict response rates.

Drawing from the methods of previous studies reviewed, future research might include expanding the study to incorporate non-university related travel and/or the use of a travel diary as an information-gathering source. Finally, administering a travel behavior survey to all Austin area college and university students could spur a more comprehensive evaluation of mobility in Austin, the efficiency of implemented transportation policy and transportation facilities, and promote increased coordination between universities and the local and regional planning entities.

Appendix A: 2014 Parking and Transportation Services Mode Survey

Question	Type(s)	Response Options
How are you affiliated with the University? (Check all that apply).	Check Box Multiple Response (MR) Open Ended Response (OER)	Faculty Staff Student Other
If a student, what is your area of study?	OER	
If a staff or faculty member, do you work four 10-hour days or five 8-hour days?	Multiple Choice (MC) OER	Four 10-hour days Five 8-hour days None of the above (Please Explain)
If a staff or faculty member, do you have a flexible work schedule to avoid driving during peak morning traffic periods? (7-9 AM and 4-6PM)	MC	Yes No
If a staff or faculty member, do you telecommute?	MC	Yes No
Do you use your personal car for work-related travel during the workday (such as meetings, deliveries, etc.)?	MC	Yes No
Do you use your personal car for personal errands during the workday (i.e., running errands, lunch)?	MC	Yes No
What Days of the week do you travel to campus?	MR	Monday Tuesday Wednesday Thursday Friday Saturday

		Sunday
How do you arrive at campus on a typical day? (Note: choose which mode is the majority of your trip)	MC OER	Skateboard Car Share UT Shuttle Capital Metro Redline Drive Alone Carpool Capital Metro Mainline Bus Service Capital Metro Vanpool/ Green Ride Motorcycle, Motor-Scooter Walk Bicycle Other (Please Explain)
If you chose drive alone, do you own a hybrid vehicle?	MC	Yes No
How long is your commute? (one-way)	MC	0-10 Minutes 11-20 Minutes 21-30 Minutes 31-40 Minutes 41-50 Minutes 51 + Minutes
What time do you typically arrive on campus?	MC	Before 7AM 7AM – 8AM 8AM – 9AM 9AM – 10AM 10AM – 11AM 11AM – 12PM 12PM – 1PM 1PM – 2PM 2PM – 3PM 3PM – 4PM 4PM – 5PM 5PM – 6PM 6PM – 7PM 7PM – 8PM 8 PM – 9PM 9PM – 10PM After 10PM

What time do you typically Leave campus?	MC	Before 7AM 7AM – 8AM 8AM – 9AM 9AM – 10AM 10AM – 11AM 11AM – 12PM 12PM – 1PM 1PM – 2PM 2PM – 3PM 3PM – 4PM 4PM – 5PM 5PM – 6PM 6PM – 7PM 7PM – 8PM 8 PM – 9PM 9PM – 10PM After 10PM
Do you change modes of transportation when leaving campus? If yes, please list the different mode used on each day.	MC OER	Yes No Other Mode
If you drive and usually park in a garage or lot, where do you park?	MC	University Parking Garage or Lot Off-Campus Private Garage or Lot Off-Campus, On Street
Which Specific Garage, Lot or Off-campus Location Do You Most Frequently Use?	OER	
If you drive and park on-street, please indicate how many blocks away from campus your car is usually parked.	OER	
Do you currently have one of the following? (Choose all that apply)	MR OER	Faculty/Staff Parking Permit Student Parking Permit Evening Parking Permit Motorcycle Parking Permit Vendor Permit Do Not Have a Permit Other (Please Specify)
About how much do you typically spend per month on parking (permits, meter,	OER	

garage/lot charges, tickets) related to your travel to the University? Answer with a whole dollar amount.			
Which of the following University transportation services and incentives are you aware of and do you use any?	MC	Carpool Program Capital Metro Vanpool / Green Ride Program Texas Express E-Bus Zip Car Reserved Carpool Parking Telecommuting / Flex Work Hours UT Shuttle Capital Metro Mainline Program Bike UT Orange Bike Program The Kick Stand Bike Lockers	Aware of Program Use Program
If you typically drive alone to campus, what are your main reasons for doing so? (select all that apply)	MR OER	Fastest way to get to campus Easy to find parking Prefer to drive my own vehicle Driving is more affordable Need to transport children Use car to run errands during the day Need to get home in case of emergency No reasonable transit option Transit doesn't run late enough Don't know which transit route to take Personal safety concerns with other modes of transportation Don't have anyone to share rides with On campus during irregular hours Other (please specify)	
If you currently drive alone to campus, what would encourage you to use an alternative to driving alone? (select all that apply)	MR OER	Bicycle subsidy Help finding a carpool / rideshare match Help finding a public transit route Night Safety Shuttle covering a greater area Secure and covered bicycle parking	

		Bike-sharing / rental program on campus Bicycle safety / repair classes Showers in my building Enhanced transportation website University electric vehicles for use by faculty / staff Prizes / drawings Shuttle connecting university to another location (specify in “other” box below) Other inducement, please specify in box below Other
If you live within biking distance of campus (< 3 miles) and you do not currently bike to campus, what are the main reasons? (select all that apply)	MR OER	Too dangerous Too many hills Not enough bicycle lanes / paths connecting to campus Do not have a bike Do not want to purchase a bike / my bike was stolen Do not know how to ride a bike Do not know the bicycle route to campus Not enough secure bicycle parking on campus No long-term / overnight bicycle parking (covered and gated) No place to shower or change clothes Other, please specify
If you normally use an alternative transportation mode (not driving alone), what motivates or enables you to do so? (select all that apply)	MR OER	Availability of shuttle Availability of bike parking Kick Stand Program Environmental concerns Health concerns Financial concerns / high cost of driving and parking Difficulty finding parking Zipcar @ University Reserved carpool parking Enjoyment of biking or walking Enjoyment of taking transit Other, please specify

How far from campus do you live?	MC	On Campus Within a few blocks < 3 miles 3 miles or more
Where do you reside? (Address or Cross Streets)	OER	
What is the zip code of your current residence / home?	OER	
What is your age group?	MC	Under 18 18 – 25 25 – 35 35 – 45 45 – 55 55- 65 65 and older
Do you have any other comments of feedback on the transportation options available at the University?	OER	

Appendix B: Geospatial Data Summary—How Data Was Obtained, Who Produced the Data, and Summary of Metadata

Dataset	Website	Web Address	Organization	Original Projection	Date Last Modified
Cmta_stops	Cap Metro Geospatial Data	http://www.capmetro.org/datastats.aspx?id=129	Cap Metro	Lambert Conformal Conic	1/10/12
Cmta_fixed_routes	Cap Metro Geospatial Data	http://www.capmetro.org/datastats.aspx?id=129	Cap Metro	Lambert Conformal Conic	1/10/12
Cmta_service_area	Cap Metro Geospatial Data	http://www.capmetro.org/datastats.aspx?id=129	Cap Metro	Lambert Conformal Conic	1/10/12
Cmta_metrorail	Cap Metro Geospatial Data	http://www.capmetro.org/datastats.aspx?id=129	Cap Metro	Lambert Conformal Conic	4/5/07
Streets	City of Austin GIS Data Sets	ftp://ftp.ci.austin.tx.us/GIS-Data/Regional/coa_gis.html	City of Austin	NAD 1983 StatePlane Texas Central FIPS 4203 (US feet)	12/6/13
tl_2010_48_state10	U.S. Census TIGER/Line Shapefiles	http://www.census.gov/geo/maps-data/data/tiger-line.html	U.S. Census	None	Unavailable
USA_Zip_Code_Boundaries	ArcGIS	http://www.arcgis.com/home/item.html?id=8d2012a2016e484dafaac0451f9aea24	ESRI	None	7/19/13

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