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Texas A&M Transportation Institute

Improving the Amount and Availability of Pedestrian and Bicyclist Count Data in Texas

Technical Report 0-6927-R1

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

in cooperation with the
Federal Highway Administration and the
Texas Department of Transportation
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16. Abstract

The Texas Department of Transportation (TxDOT) currently has very limited count data on pedestrian and bicyclist usage of the transportation system. The first objective of this project was to recommend a count monitoring process for pedestrians and bicyclists that can be sustained statewide. The second objective was to develop a consolidated database of pedestrian and bicyclist counts from two pilot cities, as well as readily available pedestrian and bicyclist count data from other locations.

Researchers evaluated options for permanent and portable counter equipment, and recommended a combination of equipment and locations for both permanent and short-duration counts. Researchers then demonstrated the installation of both permanent and portable counter equipment in Austin and Houston. In an evaluation of crowdsourced data, researchers found that crowdsourced data represented a small (less than 1 percent at some locations) and biased portion of all pedestrian and bicyclist trips, varying widely by data source and location. Further study is needed to develop a systematic expansion process that can be used to estimate total pedestrian and bicyclist counts on different facility types from the crowdsourced data samples. Also, researchers developed a consolidated database that included 350 unique pedestrian and/or bicyclist count locations in 11 cities, of which 84 were permanent continuous count sites and 266 were short-duration (e.g., at least seven days) count sites. The database included a standardized data dictionary that is consistent with the Federal Highway Administration's *Traffic Monitoring Guide*, but also included additional attributes that were deemed necessary for TxDOT and other agency monitoring needs in Texas.

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CHAPTER 1. INTRODUCTION

PROBLEM STATEMENT

The Texas Department of Transportation (TxDOT) currently has very limited count data on pedestrian and bicyclist usage of the transportation system. This lack of pedestrian and bicyclist count data affects a number of areas in transportation, including safety, planning, design, and traffic operations.

PROJECT OBJECTIVES

The first objective of this project was to recommend a count monitoring process for pedestrians and bicyclists that can be sustained statewide. The second objective was to develop a consolidated database of pedestrian and bicyclist counts from the two pilot locations, as well as readily available pedestrian and bicyclist count data from other locations.

PILOT TEST LOCATIONS

Texas A&M Transportation Institute (TTI) researchers worked with TxDOT, metropolitan planning organization (MPO), and city staff in the Austin and Houston Districts to define high-priority count locations for pedestrians and bicyclists. Researchers evaluated options for permanent and portable counter equipment, and recommended a combination of equipment and locations for both permanent and short-duration counts. Researchers then demonstrated the installation of both permanent and portable counter equipment in Austin and Houston. These activities are described in detail in Chapters 4 and 5.

CROWDSOURCED DATA

To evaluate the potential for using crowdsourced data, TTI compared crowdsourced data to actual pedestrian and bicyclist counts at numerous locations. The crowdsourced data typically represent a small sample of pedestrian and bicyclist trips, and in particular, recreationally based trips. Also, the sample percentage of crowdsourced trips may not be similar for different types of pedestrian and bicyclist facilities, making it difficult to estimate total pedestrian and bicyclist counts. The crowdsourced data analysis is described in Chapter 6.

CONSOLIDATED DATABASE

To develop a consolidated database of pedestrian and bicyclist counts, researchers defined a standardized data dictionary that is consistent with the Federal Highway Administration's (FHWA's) *Traffic Monitoring Guide* (TMG). This standardized data dictionary provides a mechanism by which MPOs and local agencies can compile and submit count data into a single statewide pedestrian and bicyclist count database. These activities are summarized briefly in detail in Chapter 7.

CHAPTER 2. STATE OF THE PRACTICE: PEDESTRIAN AND BICYCLIST COUNT DATA

This chapter summarizes existing pedestrian and bicyclist count data collection practices in Texas (including those of TxDOT, MPOs, and local agencies). The researchers also identified existing practices in a few other leading state departments of transportation (DOTs) and FHWA.

INFORMATION GATHERING METHODS AND APPROACH

Researchers contacted public agency staff in all 25 MPO regions in Texas about their pedestrian and bicyclist data collection practices. In several regions, researchers gathered information from multiple agencies (i.e., MPO, city departments, and TxDOT district office). Figure 1 shows the information that researchers attempted to gather from all Texas public agencies who were collecting pedestrian and bicyclist data.

1. **Who is counting bikes and peds?**
    a. Regions/cities
    b. City department? Volunteers? etc.
2. **What are they Counting?**
    a. Bikes, peds, both?
    b. Matching with auto counts on nearby streets?
3. **Why are they counting?**
    a. What are the counts being used for?
    b. Are they tied to a plan (transportation plan, bike/ped plan, city plan)?
    c. Are they used for project selection?
4. **Who uses the counts?**
5. **How long have the count programs been occurring?**
    a. When did they first start?
6. **Where are the counts occurring?**
    a. Type of facilities?
7. **How are the counts being performed?**
    a. How many permanent counters do you have?
        i. Brand
        ii. Technology
        iii. Bike, Ped, or Both?
        iv. Directional?
        v. Of these, how many do you OWN?
    b. How many portable counters do you have?
        i. Brand
        ii. Technology
        iii. Bike, Ped, or Both?
        iv. Directional?
        v. Of these, how many do you OWN?
    c. How many temporary locations do you regularly count as part of a counting program?
        i. What is their rotation schedule (annually, biannually, etc.)?
    d. Are there any QA/QC efforts to clean the data once collected?
8. **How much does the counting program cost (approximately) and how is it paid for?**
9. **How would they rate their program overall?**
10. **What is their program's biggest need?**
11. **What do they see the state's role in counting?**
12. **What is being used to store data/generate reports (EcoVisio, custom database, excel)?**

Figure 1. Information Gathered from Agencies Collecting Pedestrian and Bicyclist Counts.

SUMMARY OF FINDINGS

Who Is Counting and Where?

Public agencies in eight metropolitan areas in Texas are systematically monitoring pedestrian and/or bicyclist volumes on a recurring basis. Of these eight areas, six areas have permanent counter installations, and all except for one (Brownsville) have portable equipment available for use in performing short-duration counts. Austin was the first area to begin counting in 2010; most other programs began between 2012 and 2014 with more beginning after 2014. A few areas (such as El Paso) plan to begin a systematic count program in the next year, and several areas are in the process of expanding their current program. Figure 2 illustrates the number of permanent monitoring locations and recurring short-duration (at least one week of data collection) monitoring locations at this time.

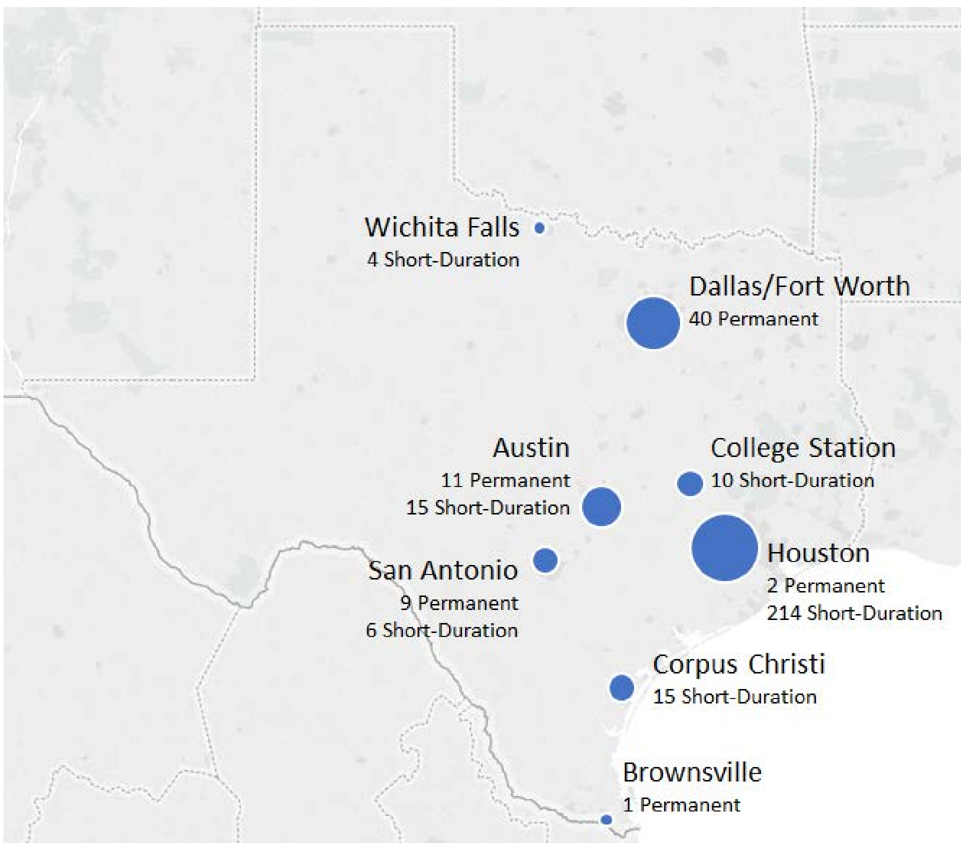


Figure 2. Pedestrian and Bicyclist Recurring Count Data Locations in Texas.

Note: Map shows number of functioning, recurring locations as of November 30, 2016.

Several areas have performed project counts on a one-time basis, but these locations are not included in Figure 2 because the data consistency and quality vary considerably. For example, some of these project-specific pedestrian and bicyclist counts were conducted for less than the duration recommended in FHWA's TMG. Houston is an exception, where agencies have conducted more than 160 one-time project counts that were longer than one week in duration (the TMG's minimum recommended duration for automated counts).

In most cases, counting efforts are performed either by the city or the MPO, though in larger areas, other entities (such as conservancy groups, utilities, and river authorities) may also be counting. In areas with multiple agency participation, there is generally some level of communication and coordination between entities or departments. TTI provides technical assistance in pedestrian and bicyclist counting in the Houston, El Paso, and College Station areas. The San Antonio area has expressed their desire for adding a volunteer element to their counting program to collect more detailed qualitative data.

TxDOT has not yet engaged in regular pedestrian or bicyclist counting anywhere in the state. The El Paso District of TxDOT did purchase permanent counter equipment in 2016, and TTI began performing counts for the district in 2017 (the City of El Paso does not engage in any regular counting activities at this time).

How Are the Data Being Used?

City and MPO officials, parks and recreation staff, and transportation planners and engineers primarily use the data to leverage additional funding for bicycle and pedestrian infrastructure. How areas approach the leveraging process varies among locations (e.g., Houston uses counts to validate previous expenditures; San Antonio uses counts to gain policy maker and private partner support).

Counts are also used in before-and-after studies to better understand facility usage over time and anticipate future need as neighborhoods develop or redevelop. Cities such as Austin are looking specifically at trend information (daily, seasonal, and weekly use) to understand commute or recreational patterns and the habits of their residents. In particular, Houston is looking at usage trends as key connections are made in the active transportation network.

Generally, pedestrian and bicyclist count data are loosely tied to some form of planning document (usually either a bicycle/pedestrian plan or an air quality plan) through new performance measures (i.e., count values or change in count values are the performance measures), goals, and objectives. However, in most cases, counting programs are so new that areas do not have enough count locations or trend information to provide substantial insight like traditional motor vehicle traffic counts can.

This lack of trend data impacts one other area: project selection. In all urban areas counting bicycle and pedestrian usage, none use the counts in the project selection process (though some like College Station and San Antonio have expressed an interest in using counts to prioritize projects).

How Are Counts Being Performed?

Counting efforts are being performed on a wide variety of facility types, including shared use paths, bike lanes, shoulders, sidewalks, other paths, unpaved facilities, and shared roadways. Most permanent count locations occur on shared use paths, whereas the recurring short-duration counts are on a wide range of facilities. In several areas (such as Austin, Corpus Christi, and San Antonio), the short-duration counts were focused more on bicyclists.

In nearly every case, permanent installations count both bicyclists and pedestrians separately, with most installations providing counts by direction. Agency staff seem to prefer permanent count locations over short-duration counts because of the resources required to collect short-duration counts (i.e., moving portable equipment every one or two weeks). However, it does not appear that any effort is being made to annualize (i.e., apply seasonal adjustment factors to compute annual averages) short duration recurring or one-time project counts. While Houston has a large number of one-time project count locations, the area is actively increasing the number of locations where recurring counts occur. This large number of one-time locations will give staff and researchers a snapshot of where bicycle and pedestrian use is occurring and where additional counting efforts are needed. Additionally, the one-time project counts provide a relative snapshot of the activity level in many different areas of the region, whereas recurring short-duration counts can provide year-to-year trends at fewer locations.

Urban areas generally attempt to count recurring locations on an annual basis; however, many have noted that due to resource constraints, counts are either sporadic or occur every other year. College Station, Houston, and Wichita Falls attempt to count many locations twice per year to give better seasonal information. Other locations, including San Antonio and Houston, also perform one-time counts as potential pedestrian and bicyclist projects arise. Note that there is likely a much higher number of one-time counts performed for specific projects. Most areas attempt to perform short-duration counts for two-week periods, though some (such as Corpus Christi) only count for one week per location.

Pedestrian and bicyclist counts are not usually matched with auto counts, primarily because the counts are not performed at the same time (due to the seasonal nature of pedestrian and bicyclist use). The Houston-Galveston Area Council and Corpus Christi do attempt some matching and the City of Austin does match counts when a large corridor bicycle improvement is planned.

Most areas perform some type of basic quality control and assurance on counts. This includes a basic visual review of the data, comparing to other sites with similar land use, or comparing to previous counts at the same site. Adjustments are made using best professional judgement or using simple averages of similar times and dates.

What Equipment Is Being Used?

Many cities and MPOs in Texas are using Eco-Counter products (total of 88 automated counters statewide) for both permanent and short-duration count locations. The most popular product is the Eco-Counter Multi (see Figure 3), which can count both bicyclists and pedestrians separately by travel direction. These counters use passive infrared sensors to count pedestrians and inductance loops in the pavement to count bicyclists. The counter also provides an option for a cellular modem that allows data to be transmitted to Eco-Counter's online data portal, Eco-Visio. Only one city (Brownsville) uses a different technology for their permanent counting, opting for Diamond Traffic's active infrared sensor (see Figure 4) that can only report pedestrian and bicyclist counts combined (but not separately).

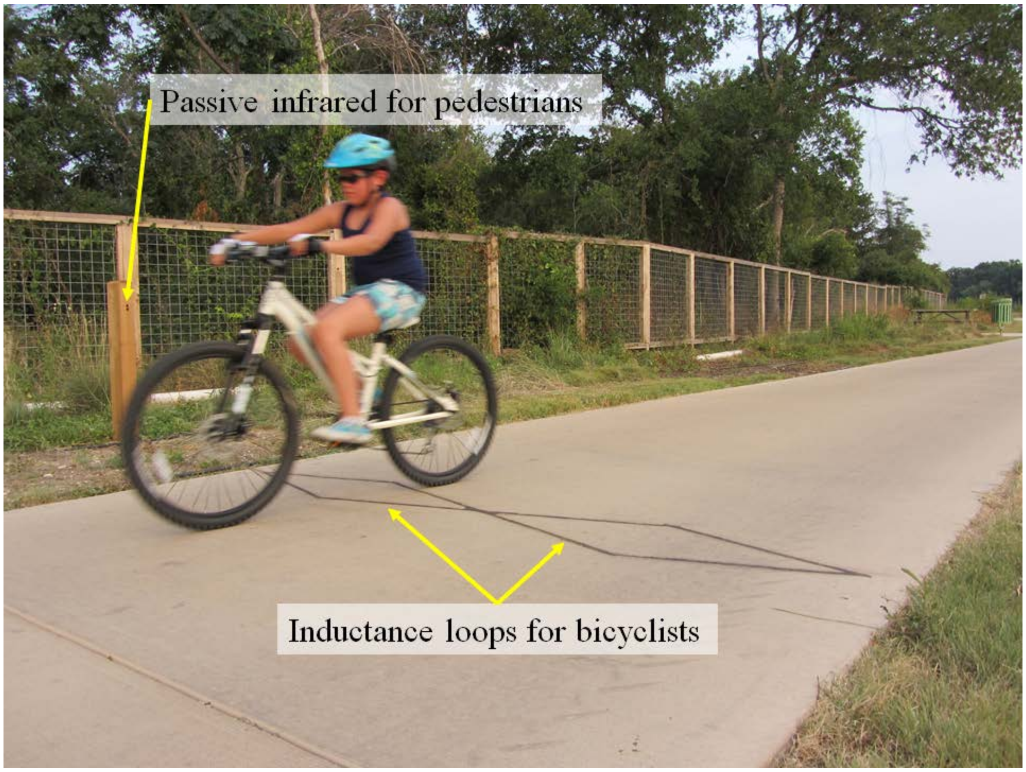


Figure 3. Eco-Counter Multi.

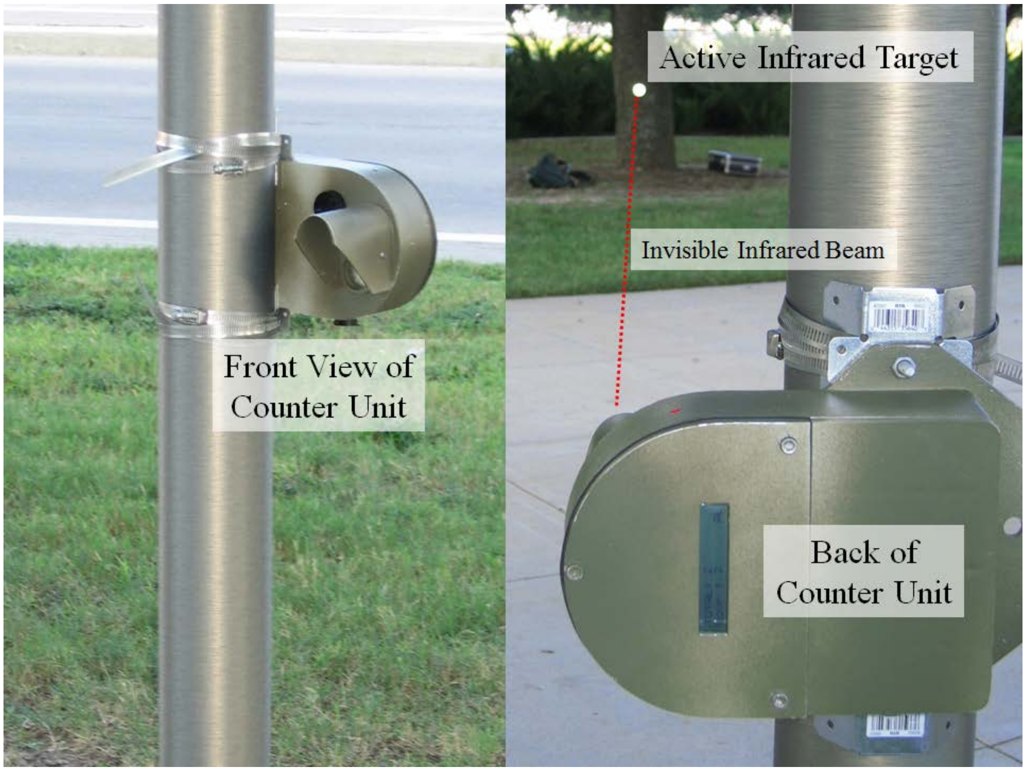


Figure 4. Diamond Traffic Trail Counter.

For short-duration counts, the mix of equipment is more diverse, though still largely dominated by Eco-Counter products with similar data structures. Many cities and MPOs use Eco Tubes (pneumatic tubes for bicycle-only counts, see Figure 5) or Eco Pyro (passive infrared for pedestrians, see Figure 6). The El Paso District of TxDOT also owns two Eco Citrix overhead counters for counting large groups of people in crowded areas. Eco-Counter products, while high quality, are also a more expensive option. For example, an Eco-Counter Pyro infrared counter costs about $4,400, whereas a TRAFx infrared trail counter costs about $900. This is the most representative comparison, as both counters are passive infrared and do not differentiate between bicyclists and pedestrians (the Pyro can measure user direction, whereas the TRAFx cannot). Data from Eco-Counter products are either uploaded to the Eco-Visio online tool or stored in Excel and Word files.

Figure 5. Eco-Counter Tubes.

Figure 6. Eco-Counter Pyro.

The second most popular (total of 23 automated counters statewide) product used is TRAFx's trail counter (see Figure 7), which is a simple passive infrared counter capable of counting both bicyclists and pedestrians (but not separately). The TRAFx counters are used by TTI and Houston. Corpus Christi also uses Jamar's TRAX pneumatic tubes for counting bicycles only.

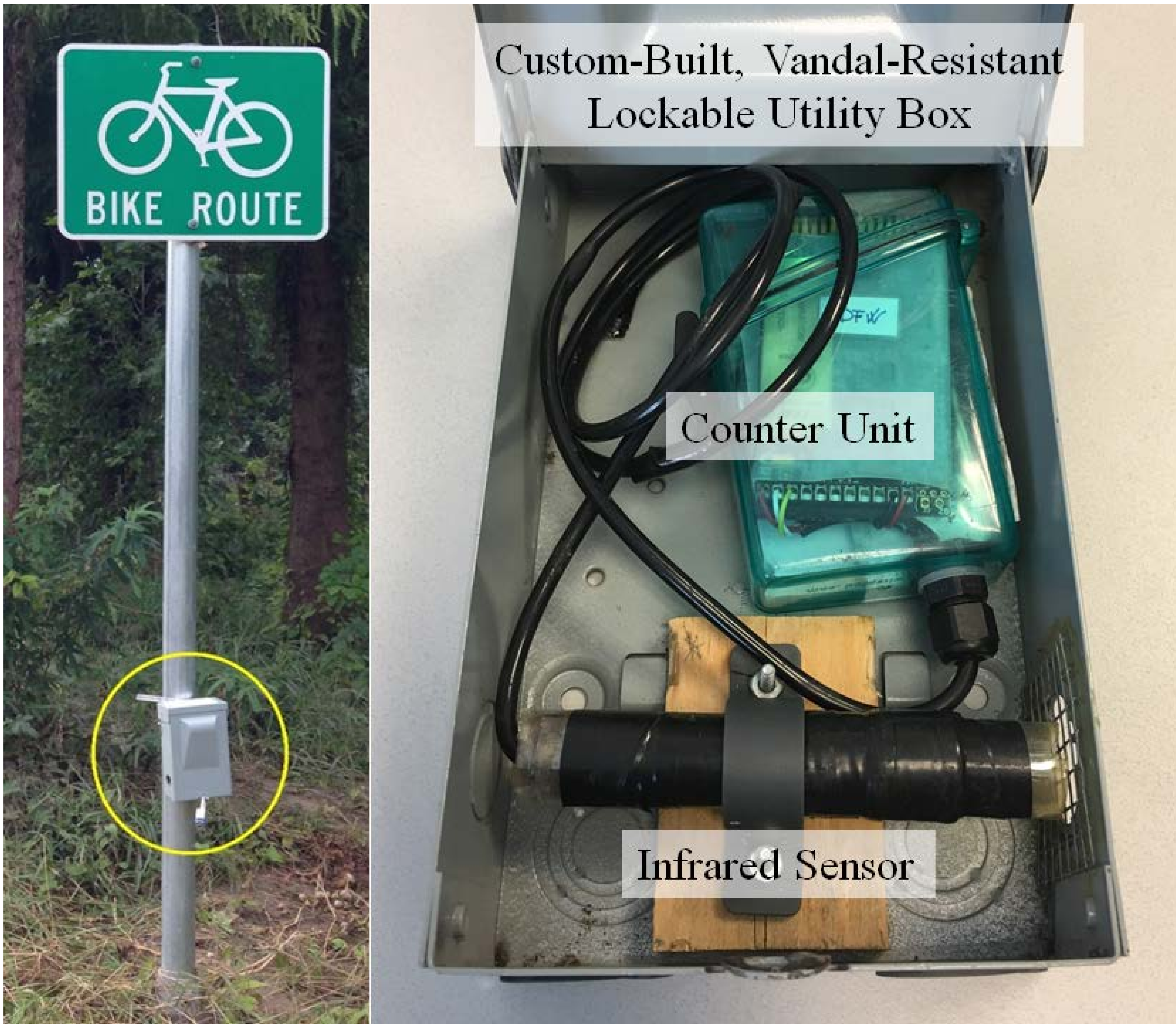


Figure 7. TRAFx Trail Counter in Customized Enclosure.

While all permanent counters in the state are owned by the managing agency, many portable counters are either shared between agencies or owned by TTI and loaned out to different users. Figure 8 shows how many permanent and portable automated counters are available in each urban area that is currently counting bicycles and pedestrians.

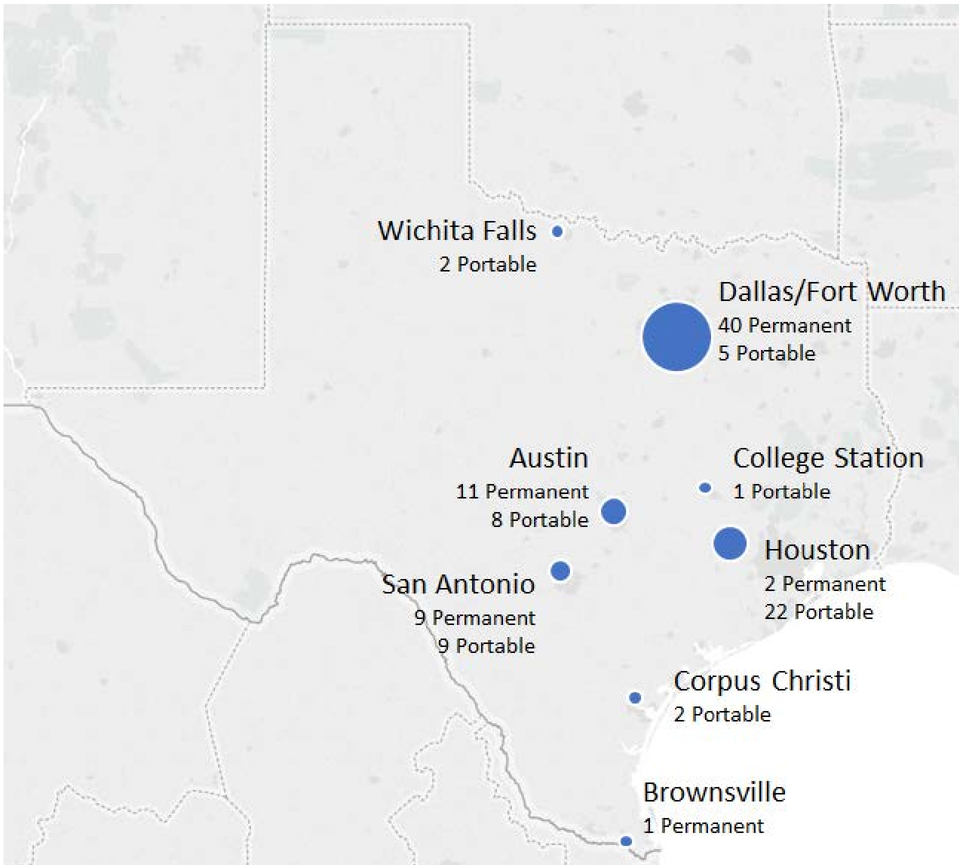


Figure 8. Pedestrian and Bicyclist Counting Equipment Available in Each Urban Area.

Note: Map shows number of automated counters available as of November 30, 2016.

What Are Other States and the FHWA Doing?

In the past several years, FHWA has taken an active role in developing and promoting technical guidance for pedestrian and bicyclist count data collection. The 2013 edition of FHWA's TMG included, for the first time, a chapter specifically devoted to nonmotorized traffic monitoring (*1*). FHWA also funded a follow-up effort on pedestrian counting (*2*). Finally, FHWA has been modifying their Travel Monitoring Analysis System (TMAS) to accept pedestrian and bicyclist count data (most state DOTs currently submit motor vehicle count data to TMAS on a monthly basis).

There are several other useful resources for pedestrian and bicyclist counting:

- Pedestrian and Bicycle Information Center (*3*).
- National Cooperative Highway Research Program (NCHRP) Report 797, *Guidebook on Pedestrian and Bicycle Volume Data Collection* (*4*).

Several state DOTs are also taking an active and leading role in pedestrian and bicyclist count data collection (beyond what MPOs and cities are doing in each state). Colorado DOT has numerous permanent (currently 16 stations statewide) and short-duration count locations across the state (*5*) and has integrated this pedestrian and bicyclist count data into their main traffic monitoring database. Washington State DOT has made similar progress, in terms of installing and maintaining permanent monitoring locations (currently 19 stations statewide) and short-duration count locations (*6*). The North Carolina DOT has contracted with the North Carolina State University to develop and maintain their statewide pedestrian and bicyclist counting program (*7*). At the end of 2017, their program includes 25 permanent count stations. Minnesota DOT has contracted with the University of Minnesota to develop their statewide pedestrian and bicyclist monitoring program. To date, several guidance documents and data collection manuals have been released (for example, see *8*).

The implementation path for these four state DOTs varied. Two of the four DOTs currently involve a university to aid in planning and implementation of a count program, and the four DOTs have differing involvement of local agencies and counter location emphasis (on-system versus off-system). Similar variation exists for which staffing group within each state DOT maintains the pedestrian and bicyclist count database (the traffic monitoring program versus the pedestrian and bicyclist program). Currently, it is difficult to draw clear conclusions except that implementation paths vary by agency and context.

Only a small portion of state DOTs (the early adopters) have gotten involved in pedestrian and bicyclist counting, and these state DOTs are in the early stages of establishing a formal monitoring program. But the initial uses are the same as here in Texas: justifying funding, documenting usage before and after new infrastructure is built, and monitoring trends over time. Of the few state DOTs that have gotten involved in pedestrian and bicyclist counting, they are cooperating closely with local agencies to collect data from locations where evidence of significant pedestrian and bicyclist activity exists, regardless of roadway jurisdiction or ownership. In several cases, the state DOT is serving a clearinghouse role for all data collected within the state, as well as providing technical guidance and assistance to ensure high-quality and consistency among local agency counting.

SURVEY CONCLUSIONS

Researchers developed the following conclusions from the information gathered:

- **Most pedestrian and bicyclist count programs are in very early stages**. Of those agencies who collect pedestrian and bicyclist data, most have been collecting for less than two to four years. Most of these agencies indicate that they would like to improve and expand their program, but lack the resources to do so (i.e., more counting equipment and more staff time to collect, review, and manage data).

- **Pedestrian and bicyclist count programs are most common in large metropolitan areas**. With a few exceptions (such as Brownsville, College Station, and Wichita Falls), the small and medium sized metropolitan areas were much less likely to have gathered pedestrian and bicyclist count data.

- **Most pedestrian and bicyclist count data are being gathered by city departments and MPOs.** To date, TxDOT has only been involved in pedestrian and bicyclist count data in one area (El Paso). In Houston and Dallas, the MPOs made the initial counter equipment purchases, but disbursed the equipment to other city or local entities. In several cities, the count data are being gathered by nontraditional entities (such as conservancies, utility districts, river authorities, parks department, etc.).

- **To improve their pedestrian and bicyclist count programs, cities and MPOs are asking for support from TxDOT in several areas**. One need mentioned was to provide a data clearinghouse with a uniform reporting standard. Cities and MPOs also asked for some type of peer exchange whereby best practices could be shared amongst agencies within Texas. Finally, several smaller MPOs asked about the possibility of TxDOT providing additional pedestrian and bicyclist counter equipment—either buying the equipment outright and providing to individual MPOs, or loaning the equipment on an as-needed basis to MPOs.

- **Most agencies are using the pedestrian and bicyclist counts to justify facility investments, monitor usage and trends, and inform overall decision-making.** As such, the pedestrian and bicyclist counts are typically for general informational purposes and not part of a formal business process, such as project ranking, funding formulas, or crash normalization factors. For these situations in which the pedestrian and bicyclist counts are not required for a business process, data collection resources are often very limited and a lower priority than other data that are required in explicitly defined business processes.

- **The majority of pedestrian and bicyclist counter equipment is from a single company, which helps reduce possible data integration burden for a statewide database**. The majority of permanent counter equipment being used in Texas is from Eco-Counter. Also, regardless of vendor, nearly all (60 of 63) of the permanent counters are located on shared use paths (as opposed to on-street bikeways or sidewalks). The next most commonly used equipment brand is TRAFx. Jamar and Diamond counters are also used, but each are used in only one city.

- **Several other state DOTs have taken an active role in pedestrian and bicyclist monitoring and provide an example for how TxDOT can develop a monitoring**

program at the statewide level. These state DOTs include Colorado, Minnesota, North Carolina, and Washington State.

- **FHWA has provided helpful guidance and continues to expand their role in assisting states and cities with pedestrian and bicyclist count procedures.** FHWA are modifying their TMAS to accept pedestrian and bicyclist count data.

CHAPTER 3. A SUCCESSFUL NONMOTORIZED DATA COLLECTION SYSTEM

This chapter provides an overview of a successful nonmotorized data collection system. Additional supporting details are providing in subsequent chapters.

COMPLEMENTARY ROLE OF PERMANENT CONTINUOUS COUNTERS AND SHORT-DURATION PORTABLE COUNTERS

Pedestrian and bicyclist counts can vary significantly by season, day of week, time of day, and even weather conditions. A successful pedestrian and bicyclist traffic monitoring program should account for this significant variability when establishing the number and type of count data collection sites. The FHWA TMG recommends the same overall monitoring program design as has been used for motor vehicle counts for more than 50 years:

- A modest number of permanent, continuously operating pedestrian and bicyclist count sites.
- A large number of short-duration pedestrian and bicyclist counts conducted using portable equipment.

As indicated in FHWA's TMG (*1*):

> The short duration counts provide the geographic coverage to understand traffic characteristics on individual roads, streets, shared use paths, and pedestrian facilities, as well as on specific segments of those facilities. They provide site-specific data on the time-of-day variation, can provide data on day-of-week variation in nonmotorized travel, but are mostly intended to provide current general traffic volume information throughout the larger monitored network. However, short duration counts cannot be directly used to provide many of the required data items desired by users. Statistics such as annual average traffic cannot be accurately measured during a short duration count. Instead, data collected during short duration counts are factored or adjusted to create these annual average estimates.
>
> The development of those factors requires the operation of at least a modest number of permanently operating traffic monitoring sites. Permanent data collection sites provide data on seasonal and day-of-week trends. Continuous count summaries also provide very precise measurements of changes in travel volumes and characteristics at a limited number of locations.

In summary, the continuous count sites provide extensive time coverage at a limited number of locations. The short-duration sites provide extensive geographic coverage for a limited time duration. When combined in a systematic manner, the continuous and short-duration count sites provide a more comprehensive picture of pedestrian and bicyclist traffic levels, patterns, and trends. Sections 4.4 and 4.5 of FHWA's TMG provides guidance and examples on combining continuous and short-duration counts in a pedestrian and bicyclist monitoring program.

In the pilot test phase of this research project, TTI used this basic approach of pairing continuous and short-duration counts. In Austin, TTI installed one permanent continuous pedestrian and bicyclist counter and conducted short-duration counts at nine locations. In Houston, TTI installed one permanent counter as part of this project, while five other permanent counters are being funded and installed by other Houston stakeholders. These permanent counters will be complemented by extensive short-duration counts that have and will continue to be conducted by several Houston stakeholder agencies. In addition, 24 counters were deployed in 22 locations to gather short duration count data over 10 days using TTI- and Houston Galveston Area Council (HGAC)-owned counting equipment in the Houston District.

TTI did not perform seasonal adjustments on the short-duration counts collected in this project. Late in this project, monthly adjustment factors were computed based on previously-installed permanent counters (see Chapter 8). These monthly adjustments will be applied to the short-duration counts in later phases of database development.

ORGANIZATIONAL MODELS FOR PEDESTRIAN AND BICYCLIST COUNT DATA COLLECTION—WHO DOES WHAT?

There are numerous public agencies and stakeholders that need or want pedestrian and bicyclist count data. In some cases, their data requirements are similar or overlapping. One of the key questions is: who does what? There is not a single easy answer, and who does what often depends on several contextual factors and criteria. This section discusses organization models (i.e., who does what) in more detail.

The traditional model for motor vehicle traffic monitoring has been a strong centralized control and administration. State DOTs have been the agency responsible for monitoring and reporting motorized vehicle traffic, and their efforts have focused on those highways that are state-maintained and carry the most traffic. Cities and MPOs have primarily relied on their state DOT for traffic counts where they are available, but will sometimes conduct their own limited counts where needed on a case-by-case basis. Recently, the increasing demand and requirements for more and better data is changing this strong central role of the state DOT in some states. Recognizing the difficulty and challenges, some state DOTs are cooperating more with cities and MPOs on data collection, whereby traffic monitoring is becoming a shared responsibility and cities and MPOs contribute to state DOT traffic monitoring efforts and to a statewide traffic data clearinghouse.

Conversely, nonmotorized traffic monitoring has largely been undertaken by cities and MPOs, with little involvement by state DOTs. Task 2 of this research project confirmed this trend in Texas, in that TxDOT had not yet engaged in any systematic nonmotorized traffic monitoring as of late 2016. This is partially due to the tendency for most pedestrian and bicyclist traffic to be on city streets, rather than on state highways. As with motorized traffic monitoring, however, some state DOTs are cooperating more with cities and MPOs on nonmotorized data collection. The role of these cooperating state DOTs varies. In some cases, the state DOT serves as a clearinghouse, compiling all available nonmotorized traffic counts within the state. In other cases, the state DOT maintains their own monitoring sites.

In Texas, the role of each agency (who does what?) is partly informed by the current situation; numerous cities, MPOs, and local authorities are already collecting nonmotorized count data for their own uses, whereas TxDOT has just started (through this research project) to consider collecting nonmotorized counts. Agency roles will also be determined by what is feasible given current and projected resources, staffing, and expertise. Agency roles will also be determined by compatibility with that agency's mission, goals, and objectives. Finally, the agency roles should be openly discussed, debated, and communicated, such that it is clear who is responsible for what role.

OTHER REPORTS ON BEST PRACTICES

Aside from the best practices included above, there are several other reports and guides that document best practices for pedestrian and bicyclist traffic monitoring:

- FHWA's 2016 *Traffic Monitoring Guide*, Chapter 4 Traffic Monitoring for Non-Motorized Traffic (*1*).
- NCHRP Report 797, *Guidebook on Pedestrian and Bicycle Volume Data Collection* (*4*).
- NCHRP Web-Only Document 229, *Methods and Technologies for Pedestrian and Bicycle Data Collection: Phase 2* (*9*).
- Report FHWA-HPL-16-026, *Exploring Pedestrian Counting Procedures: A Review and Compilation of Existing Procedures, Good Practices, and Recommendations* (*2*).
- North Central Texas Council of Governments Peer Exchange on Bicycle and Pedestrian Count Programs, Transportation Planning Capacity Building Peer Program (*10*).
- Alta Planning + Design, *Innovation in Bicycle and Pedestrian Counts: A Review of Emerging Technology* (*11*).

CHAPTER 4. CONSIDERATIONS FOR SELECTING EQUIPMENT AND SITES FOR PEDESTRIANS AND BICYCLISTS

This chapter describes important considerations that were used to select the pedestrian and bicyclist counter equipment and sites in the two pilot test locations.

CONSIDERATIONS FOR COUNTER EQUIPMENT

The concept for the pilot test is for TxDOT district staff to become familiar with counting equipment/technologies and day-to-day issues with documenting usage on nonmotorized facilities. Documenting use of nonmotorized facilities typically involves counting users, including cyclists, pedestrians, and other nonmotorized (skating, scooters, equestrian, etc.) users. Counting nonmotorized users is more difficult than counting motorized traffic. Nonmotorized users start and stop, do not follow regular paths, can be grouped tightly, and are typically not confined to a path, which can be challenging to count.

Several technologies can be used to count nonmotorized activity and all have advantages and disadvantages. This study used and built on several existing studies to merge and compare the information from the devices to assist engineers and planners to locate, design, build, operate, and maintain a more efficient nonmotorized transportation network.

A concise summary of these evaluations was presented in the TMG. Table 1 shows the technology, counter capability, duration, and cost.

Table 1. Traffic Monitoring Guide Summary of Technologies, Count Duration, and Cost.

1. What Are You Counting? / 2. How Long?	Technology	Bicyclists Only	Pedestrians Only	Pedestrians & Bicyclist Combined	Pedestrians & Bicyclist Separately	Cost
Permanent ↑	Inductance Loops[1]	●			◐	$$
	Magnetometer[2]	○				$-$$
	Pressure Sensor[2]	○	○	○	○	$$
	Radar Sensor	○	○	○		$-$$
	Seismic Sensor	○	○	○		$$
2. How Long?	Video Imaging: Automated	○	○	○	○	$-$$
	Infrared Sensor (Active or Passive)	○[3]	●	●	◐	$-$$
	Pneumatic Tubes	●			◐	$-$$
	Video Imaging: Manual	○	○	○	●	$-$$$
↓ Temporary/ Short Term	Manual Observers	●	●	●	●	$$-$$$

○ Indicates what is technologically possible.
● Indicates a common practice.
◐ Indicates a common practice, but must be combined with another technology to classify pedestrians and bicyclists separately.
$, $$, $$$: Indicates relative cost per data point.
[1] Typically requires a unique loop configuration separate from motor vehicle loops, especially in a traffic lane shared by bicyclists and motor vehicles.
[2] Permanent installation is typical for asphalt or concrete pavements; temporary installation is possible for unpaved, natural surface trails.
[3] Requires specific mounting configuration to avoid counting cars in main traffic lanes or counting pedestrians on the sidewalk.

From the literature and from practitioner experience, several trends have emerged:

- Passive infrared sensors are commonly used as a cost-effective technology for moderate to long term counts, but cannot differentiate between pedestrians and bicyclists.
- Inductance loops or piezoelectric strips are commonly used as a cost-effective technology for long-term counts of bicyclists.
- Manual and automated video data collection provides the most information and can be the most accurate, but can be cost-prohibitive for long periods of time.

Based on previous evaluations, literature review, and the information gathered in Task 2, past nonmotorized data collection in Texas has been limited to a select group of technologies and vendors. To be consistent with regional partners, a compatible set of technologies and vendors will be evaluated for purposes of this study to reduce the number of variables to control when comparing with historical data.

Based on previous research, existing permanent bicycle/pedestrian counter models were identified, equipment capabilities were evaluated, and life cycle costs were considered. To provide a good comparison between permanent/temporary data collection and crowdsourced data as a part of this study, both bicycle and pedestrian counts need to be assessed. Equipment that can measure small time increments (15 minutes), direction of travel, and separation of modes (bicyclists and pedestrians) is essential. Initial cost and life cycle costs of permanent counter equipment were also considered, including costs associated with power usage, communications, and reporting features (data format, vendor tools for analysis, and accuracy). Two permanent counters on the market meet the requirements of the study: 1) an integrated permanent monitoring solution for both pedestrians and bicyclists that has the ability to differentiate each mode separately, as well as distinguish travel direction; 2) have a proven track record (more than just two or three pilot tests) with multiple satisfied customers. Table 2 shows cost details for these two counters.

Table 2. Comparison of Life Cycle Costs for Two Permanent Counter Options.

Eco-Counter Loops	1	2	3	4	5	6	7	8	9	10	Total
Urban Post MULTI	$5,400										$5,400
Software Included	$0										
Cell Modem Fee	$420	$420	$420	$420	$420	$420	$420	$420	$420	$420	$4,200
Batteries (Modem)			$20		$20		$20		$20		$80
Batteries (ZELT inductive loop)			$80		$80		$80		$80		$320
Grand Total											$10,000

HI-TRAC Piezoelectric	1	2	3	4	5	6	7	8	9	10	Total
HI-TRAC CMU	$6,250										$6,250
Hi_Comm Software	$2,995										$2,995
Cell Modem Fee	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	$3,000
Batteries Modem				$40				$40			$80
Grand Total											$12,325

CONSIDERATIONS FOR PERMANENT COUNTER SITE SELECTION

Researchers considered various factors when selecting sites to install two additional permanent bicycle/pedestrian data counters. These factors include:

- Regions of the state.
- Urban/rural areas and land use.
- Facility type.
- Counter capabilities, costs, and consistency.
- Existing counts and other permanent counters in the area.

- Coordination with agency partners and user groups.
- Previous short duration counts.
- On or near TxDOT facility.

Region of the State

In the proposal, Austin and Houston were identified as pilot locations to install permanent and temporary count equipment to collect bicycle and pedestrian use data. Other regions were considered but ruled out due to logistics. Houston is a large urban area, with the city of Houston having a population of approximately 2.2 million and a regional population of 6.2 million. Austin is a medium sized urban area with a population of almost 900,000 and a regional population of 1.8 million.

Urban/Rural Areas and Land Use

Urban/rural areas and land use are interconnected characteristics affecting nonmotorized use. Adjacent land use is an important indicator of trip purpose which, in turn, influences time-of-day and day-of-week traffic patterns. Urban, suburban, and rural areas were evaluated. Since Texas is comprised of both large urban metropolitan areas and vast rural lands, count data in a range of area types is important for a successful statewide monitoring program.

Urban areas typically include a mix of commercial, residential, office, and mixed-use land development. Urban areas tend to exhibit a higher population density with a greater proportion of multifamily residences than single family structures compared with suburban and rural areas. Building types include multistory development using a majority of the buildable land. Suburban areas, located outside the city center, typically have lower population density with residential areas separated from commercial areas. Rural areas, located outside of urban and suburban areas, generally present sparse development patterns.

Facility Type

Facility type was also a consideration, because one can expect different comfort levels, user experience levels/abilities, and trip purposes associated with different facilities. Along with land use, facility type is another important variable that affects weekly and daily nonmotorized traffic trends. Therefore, understanding demand on various types of bicycle/pedestrian accommodations is important for a successful statewide monitoring program. The facility types considered were:

- Shared roadways.
- Shoulders.
- Designated bike lanes.
- Cycle tracks.

- Shared use paths.
- Sidewalks.

Existing Counts and Other Permanent Counters in the Area

Crowdsourced data will be compared with all bicycle/pedestrian data counts where the two data sources overlap: permanent, temporary, historical, and proposed counts. The location of existing permanent and temporary counts provides a background and progression of usage. The duration of the counts is important due to the variability in the nonmotorized data. Longer periods of time demonstrate the patterns related to growth, decline, seasonal and temporal patterns and help to differentiate those patterns from the large variability related to weather, security, and other issues that affect usage. Both the geographic area and time duration provide valuable information for evaluation and comparison of data sources. For these reasons, two years of bicycle/pedestrian crowdsourced data in each urban area were analyzed based on project locations selected for evaluation. Information about crowdsourced data is provided in Chapter 6 of this document.

Coordination

Researchers worked closely with TxDOT and its agency partners (including three MPOs and two cities) and user groups to ensure that a mix of bicycle and pedestrian accommodations would be considered. TxDOT district staff, users groups, and agency partners assisted TTI in determining the sites for installing permanent and temporary data collection equipment. The users groups consulted were comprised of bicycle clubs, the American Association of Retired Persons, and other local agencies.

Existing short duration counts were considered to optimize and extend the scope of coverage. The Strava heat map was used in the consideration of count locations. The proposed permanent counters were installed on or adjacent to TxDOT right-of-way.

CHAPTER 5. PILOT TESTS

This chapter describes the pilot tests that were conducted to assess pedestrian and bicyclist monitoring approaches in two TxDOT districts. The chapter includes the results of the short duration counter deployment, and then an overview of the permanent counter installation.

SHORT DURATION COUNTS

For the short duration counts, TTI deployed equipment in the Austin and Houston Districts. The equipment consisted of TRAFx infrared trail counters and Eco-Counter tube counters both which collected continuous data over two weekends and the weekdays in between. The TRAFx counters (Figure 9) were affixed inside an urban box (or a lockable metal utility/electrical box) for security and camouflage purposes and placed on a post, pole, tree or other structure (Figure 10) aimed away from the roadway and across the sidewalk or shared use path. Adjustable band clamps were used to hold it in the correct position, and a chain with a standard master key lock secured it.

Figure 9. TRAFx Trail Counter.

Figure 10. TRAFx Trail Counter Deployed and the Inside of the A/C Disconnect Box.

These TRAFx Infrared Trail Counters count people that pass the sensor, but cannot differentiate the travel mode (e.g., walking, jogging, skating, bicycling). Some features include:

- High quality infrared scope.
- Small size.
- Easy to install, hide, and secure.
- Large count capacity (millions of counts).
- Requires three alkaline AA batteries that last up to 4 years.
- Maximum range up to 20 ft.
- Operates in very cold and hot temperatures (−40°F to 131°F).
- Very low operating cost (about $1/year for batteries).

The way the TRAFx counters work is by detecting the thermal radiation that people emit. Like other trail counters, TRAFx counters undercount when people travel side-by-side or in tight groups. For this reason, one can expect estimates rather than absolutes. If the sidewalk is narrow and people travel in a single file and spaced apart (about 1.5 second gap between each person), a high accuracy of 95 to 100 percent can be expected. Orders of magnitude are important when considering bicycle/pedestrian count data. TTI used the manufactured defaults for counting, such as the sensitivity settings.

Four of Eco-Counter’s pneumatic tube counters were used to capture bicycle data (Figure 11). Pneumatic tube counters work by detecting the number of air pulses created by a set of bicycle tires rolling over hollow rubber tubes. These counters can be used on or off street and are able to distinguish between bicycles and motor vehicles, extract directional data and accurately count the number of bicyclists in a group. Deployment of the tube counter takes longer than the TRAFx counter mainly because it requires laying two tubes perpendicular to the flow of traffic, pulling the tube so that it remains straight, and securing the ends to the pavement surface. Some features include:

- Complete counting system contained in the unit (logger, sensor, and battery).
- Seamless transmission of data to Eco-Visio software using Bluetooth. Eco-Visio is the Eco-Counter online data analysis software.
- 10-year battery life.
- Bi-directional data.
- Waterproof and works in all weather conditions.
- Accurate to within ±3 percent.
- Two-year memory.

Figure 11. Stainless Steel Box that Houses the Tube Counter.

TTI deployed these counters in bike lanes or shoulders (Figure 12).

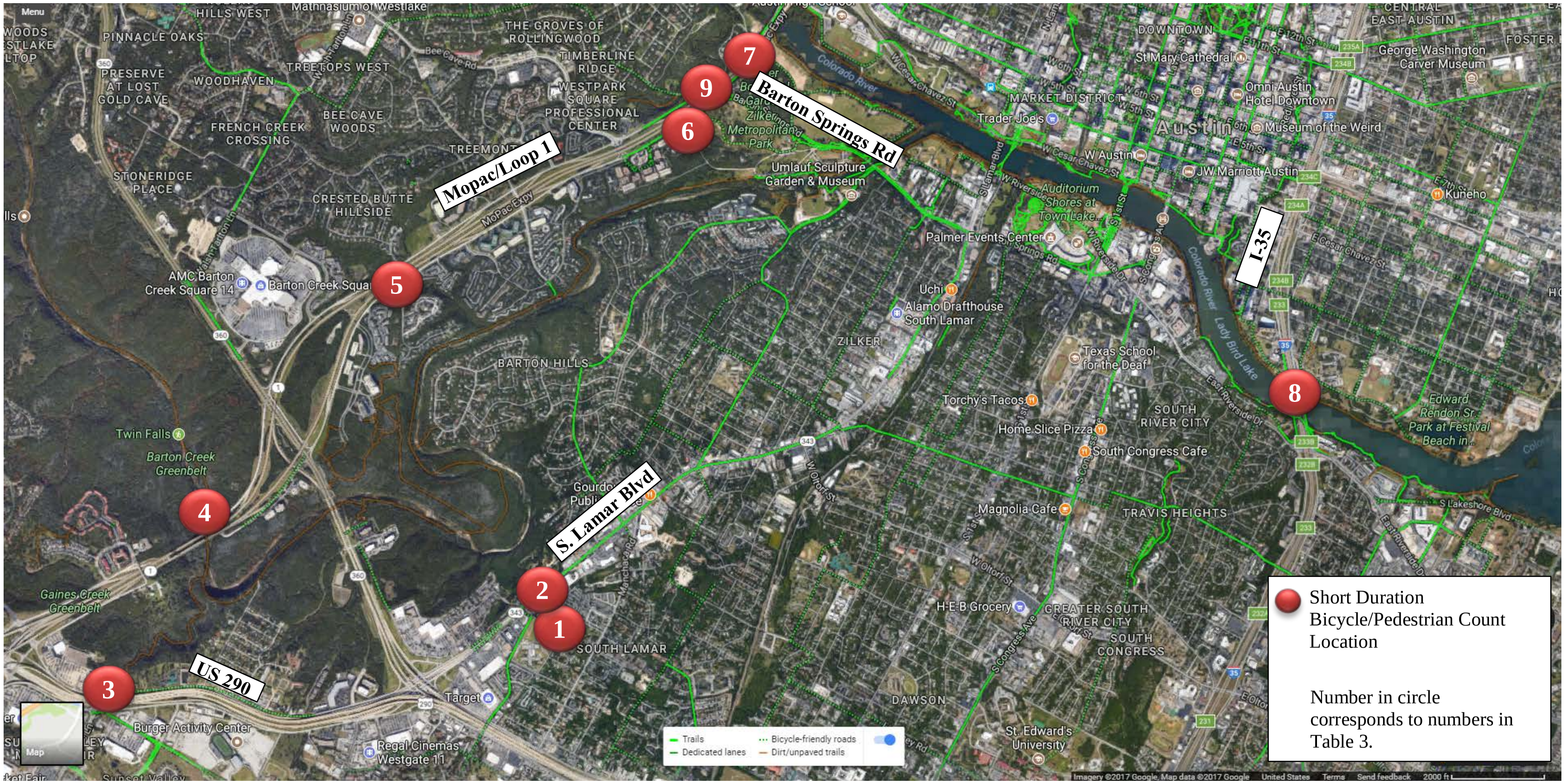
Figure 12. Eco-Counter Tube Counter.

The following sections detail the short duration count data collection in the Austin and Houston Districts.

Austin, Texas

Seventeen counters were deployed in nine locations to gather short duration count data over 10 days using TTI-owned counting equipment (see (Note: green lines represent bikeways designated in the Google Maps screenshot)

Figure 13 and Table 3). Both TRAFx Infrared Trail Counters and Eco-Counter tube counters were used at locations in southwest Austin as indicated in the table. All 17 counters were deployed on Thursday, May 4, 2017. A mixture of on-road and off-road locations were chosen, all of which were on or near TxDOT-owned roadways. Sidewalks, trails, and shared use paths as well as bike lanes and shoulders were included.



(Note: green lines represent bikeways designated in the Google Maps screenshot)

Figure 13. Austin District Short Duration Bicycle/Pedestrian Count Locations.

Table 3. Austin Short Duration Count Location Information.

#	Counter IDs	Location	Road Name	Section/ Intersection	Tubes	Infrared	Target User	Mount	Description
1	T1, T2	South Austin	Panther Trail	Keats Drive	0	2	Ped/bike combined	Utility Pole and tree	Sidewalk along Panther Trail
2	T3, T4, 8657, 8660	South Austin	South Lamar Boulevard	Westland Drive	2	2	Bike and ped/bike combined	Sign pole	On bike lane and sidewalk on both sides of roadway.
3	T5, T7	South Austin	US 290	Brodie Lane	0	2	Ped/bike combined	Guardrail and tree	Shared use path on Brodie Lane
4	T8, T9	Southwest Austin	Mopac	Barton Creek Greenbelt/ Violet Crown Trail	0	2	Ped/bike combined	Tree	North and south of Barton Creek on greenbelt trail
5	T10	South Austin	Mopac/Loop 1	Tuscan Terrace	0	1	Ped/bike combined	Light pole	Shared use path
6	T11, 8659	Southwest Austin	Mopac/Loop 1 East Service Road	South of Andrew Zilker Rd	1	1	Bicyclists and ped/bike combined	Sign pole	On sidewalk and bicycle lane
7	T12	South Central Austin	Mopac/Loop 1	Between Barton Springs Rd and Stratford Drive	0	1	Ped/bike combined	Sign pole	Shared use path adjacent and parallel to the mainlanes between Barton Springs Road and Stratford Drive
8	T13, T14	Downtown Austin	I-35 East and West Frontage Road	Colorado River	0	2	Ped/bike combined	Bridge railing/ barrier	On sidewalks that are separated from frontage roads.
9	8658	South Central Austin	Barton Springs Road	Under Mopac/Loop 1 east of Nature Center Drive	1	0	Bicyclists	Guardrail	Westbound bike lane

NOTE: Counter IDs with a T reflect the TrafX infrared counters. Counter IDs with a 4-digit number reflect the Eco-Counter tube counters.

The highest count location was recorded at the entrance to the Barton Creek Greenbelt at the Mopac Frontage Road south of Capital of Texas Highway/Loop 360. Over 12,000 people used that location during the 10-day deployment period. The average daily volume on the weekend is four times the average daily volume on the weekday. The bicycle/pedestrian bridge along I-35 at Lady Bird Lake was the second highest count location with over 8,500 people recorded and an average daily volume on the weekend (1,124 users) almost double the volume recorded on the weekday (672 users). The remaining count locations recorded significantly lower volumes. Table 4 shows the pedestrian and bicyclist count data at the top five short duration count locations.

Table 4. Top 5 Short Duration Count Locations and Results.

Counter ID	Location	Total Usage	Avg. Daily Usage	Avg. Daily Usage (Weekdays)	Avg. Daily Usage (Weekends)
T9	Barton Creek Greenbelt Trail	12,008	1,201	512	2,234
T14	I-35 Northbound Frontage Road at Colorado River (Lady Bird Lake)	8,527	853	672	1,124
T1	Eastbound Panther Trail at Keats Drive	1,891	189	202	170
T12	Two-Way Shared Use Path along MoPac Northbound Mainlanes North of Barton Springs Road	1,704	170	148	205
8657	Northbound South Lamar Boulevard at Westland Drive (bicyclists only)	1,613	161	167	153

Some of the other highlights include the following:

- Almost all locations reported larger daily average usage on the weekends rather than the weekdays.
- Over half the locations logged less usage on Tuesday, May 9, and/or Thursday, May 11, which were the only days in the deployment period with recorded precipitation.
- Most locations recorded an increase in volume in the morning and late evening hours.
- In locations where the tube counter was deployed, people bicycling against traffic were recorded. Almost a quarter of the 709 southbound South Lamar Boulevard bicyclists counted were recorded traveling in the northbound direction. Of the 110 bicyclists on the Mopac Northbound Frontage Road, over one-third were traveling southbound.

Table 5 provides the usage data for all of the short duration counters deployed in Austin for this project.

Table 5. Total and Average Usage of All Counters Deployed in Austin.

Counter ID	Location	Count Type	Facility Type	Total Usage	Average Daily Usage
T1	Eastbound Panther Trail at Keats Drive	Bike/ped combined	Sidewalk	1,891	189
T2	Westbound Panther Trail at Keats Drive	Bike/ped combined	Sidewalk	784	78
T3	Northbound Lamar at S of Westland	Bike/ped combined	Sidewalk	No data	No data
8657	Northbound Lamar at S of Westland	Bike only by direction	Bike Lane	1,613	161 (13% contraflow)
T4	Southbound Lamar at S of Westland	Bike/ped combined	Sidewalk	708	71
8660	Southbound Lamar at S of Westland	Bike only by direction	Bike Lane	709	71 (23% contraflow)
T5	Brodie Lane Trail at S of US 290 Eastbound Frontage Road	Bike/ped combined	Crushed Granite Shared Use Path	286	29
T7	US 290 Westbound Frontage Road at E of Brodie Ln	Bike/ped combined	Crushed Granite Sidepath	1,478	148
T8	Violet Crown Trail	Bike/ped combined	Wooded Trail	150	15
T9	Barton Creek Greenbelt Trail	Bike/ped combined	Wooded Trail	12,008	1,201
T10	Northbound MoPac Frontage Road at S of Tuscan Terrace	Bike/ped combined	Concrete Shared Use Path	482	48
T11	Northbound MoPac Frontage Road at S of Andrew Zilker Rd	Bike/ped combined	Sidewalk	631	63
8659	Northbound Mopac Frontage Road at S of Andrew Zilker Rd	Bike only by direction	Bike Lane	110	11 (35% contraflow)
T12	Northbound MoPac Frontage Road at N of Barton Springs Rd	Bike/ped combined	Concrete Shared Use Path	1,704	170
8658	Southbound MoPac Frontage Road (Barton Springs Road) at Nature Center Drive	Bike only by direction	Bike Lane	453	45 (5% contraflow)
T13	Southbound I-35 Frontage Road at Colorado River	Bike/ped combined	Bike/Ped Bridge	1,400	140
T14	Northbound I-35 Frontage Road at Colorado River	Bike/ped combined	Bike/Ped Bridge	8,527	853

Houston, Texas

HGAC, TxDOT Houston District, and the local agencies have conducted nearly 500 short duration counts starting in 2012. This research project has leveraged those resources and worked to incorporate those short duration counts into the statewide database (Task 5). In the past six months, 122 short duration counts were conducted in the area, and Table 6 shows the number of counts in each area and deployment dates. Most counts were conducted for 9 to 14 days, typically incorporating two weekends.

Table 6. Houston Area Short Duration Counts February through August 2017.

Deployment Area	Counts	Deploy Date	Retrieve Date
West Chase District	13	2/17/2017	3/6/2017
Sugarland	20	3/10/2017	3/28/2017
Tiger East West	20	4/7/2017	4/24/2017
League City	24	5/25/2017	6/7/2017
Energy Corridor District	7	5/10/2017	5/25/2017
Memorial Park Conservancy	19	7/27/2017	8/8/2017
Galveston (FM 3005 Seawall Boulevard)	19	8/9/2017	8/22/2017
Total Bicyclists and Pedestrians Counted	**122**		

Figure 14 shows a map of the Houston area and the general area of the short duration count deployments.

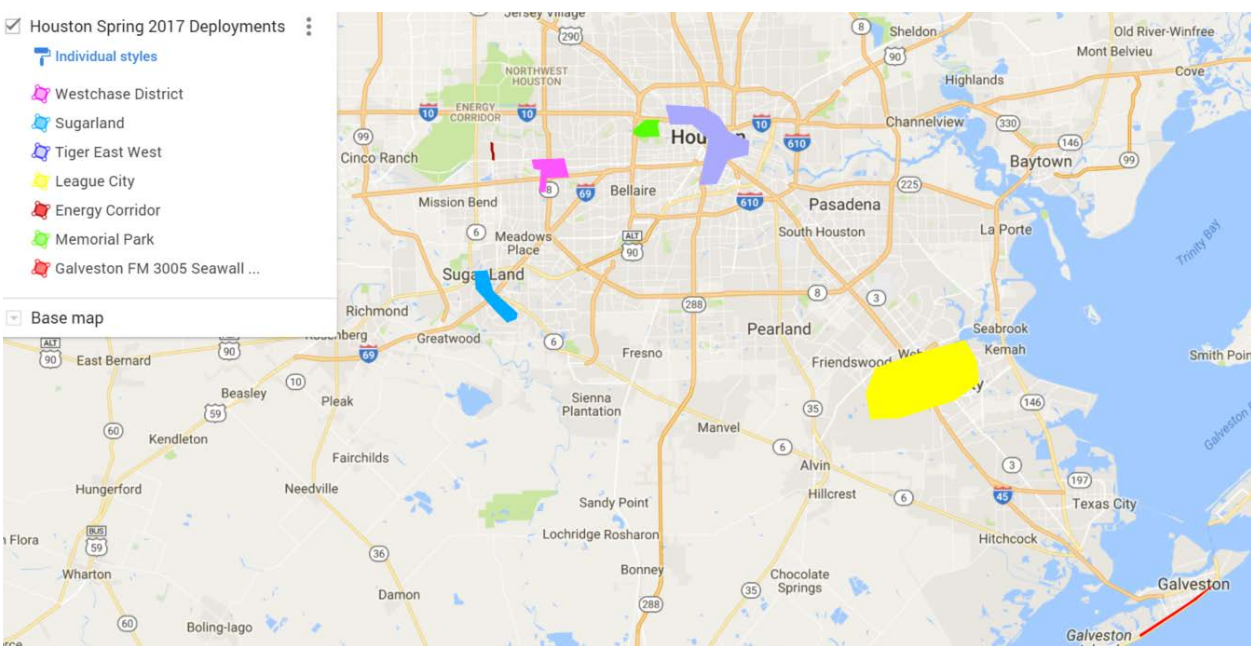


Figure 14. Houston Area Short Duration Count Map for Spring and Summer 2017.

PERMANENT COUNTERS

As part of this project, two Eco-Counter permanent counters were purchased, one for the Austin District and one for the Houston District. The Urban MULTI is the counting system that was purchased for the Austin District. The system monitors and differentiates between pedestrians and bicyclists. It combines the Eco-Counter PYRO sensor, a passive infrared sensor, with the ZELT, which is an inductive loop. The PYRO sensor is housed in Eco-Counter's Urban Post. A subsystem called Smart Connect analyzes the signal from both sensors to count and classify each user. The counting system can measure small time increments (15 minutes), direction of travel, and separation of modes (bicyclists and pedestrians). A ZELT count system housed in a ground box was purchased and installed in the Houston District. The ZELT system is an inductive loop system, which can measure bicyclists only and separate the bicyclists by direction, in 15-minute increments. Both systems are connected to the cloud-based platform via a Global System for Mobile (GSM) modem, which transmits the data at the end of each day.

Eco-Visio is the name of the visualization and count monitoring software developed by Eco-Counter. As seen in Figure 15, Eco-Visio is a cloud-based platform, and is interactive, and user friendly. The user can conduct various analyses and develop reports within the software. Graphs, charts, and tables can be easily exported and incorporated into documents and spreadsheets.

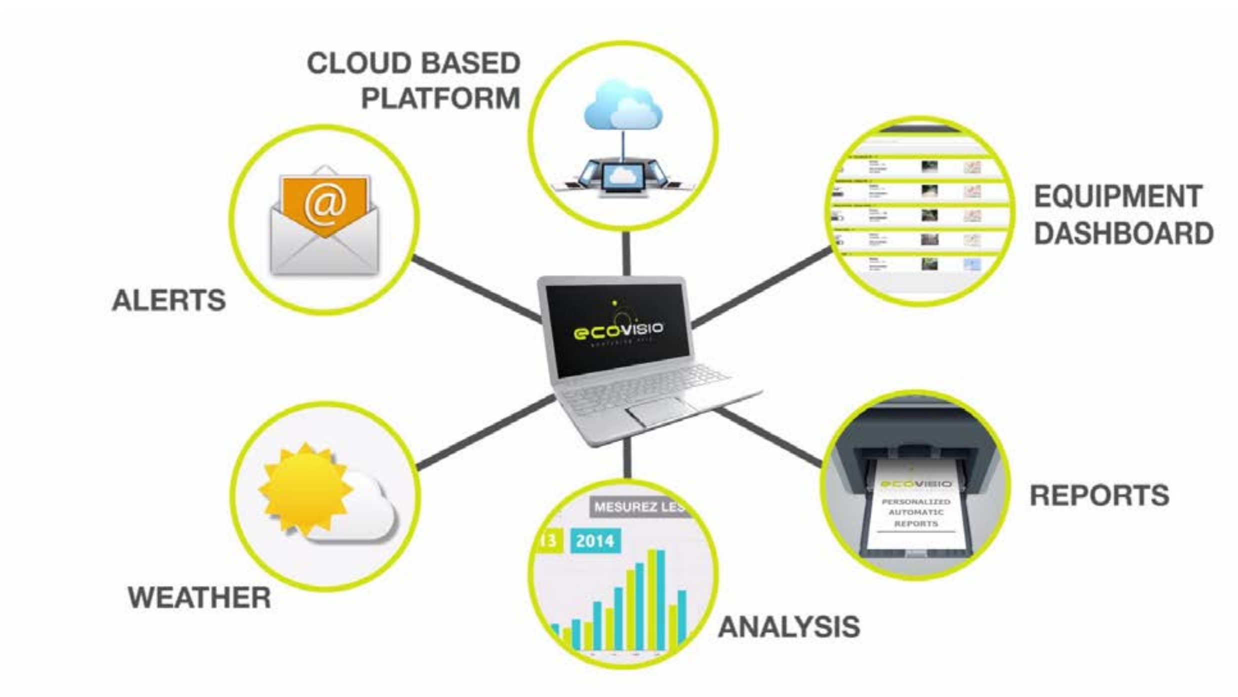


Figure 15. Eco-Visio Structure.

Austin Permanent Counter

One permanent counter was installed in the TxDOT Austin District in August 2017. It is located on the new South Mopac Expressway/Loop 1 bicycle/pedestrian bridge over Barton Creek (see Table 7 and Figure 16), which opened to the public in June 2017. The Eco-Urban MULTI system from Eco-Counter was installed with the assistance of the City of Austin. It counts and differentiates between bicyclists and pedestrians and captures the direction of travel. The system includes the PYRO (passive infrared) sensor and the ZELT inductive loop, which looks for the electromagnetic signature of bicycle wheels. The concrete was cut to install the loops and the pole was mounted in the bridge surface outside of the bridge railing.

Table 7. Austin Permanent Counter Location.

Location	Road Name	Section	Loops or Tubes	Infrared	Mount	Description	Users
Southwest Austin	Mopac/Loop 1 Ped/Bike Bridge	Loop 360 to US290/South-west Parkway	Loops	1	1 permanent post	North side of Barton Creek on bridge	Counts pedestrians and bicyclists by direction

Figure 16. Austin District Permanent Count Location Map.

Installation involved cutting diamond shaped pattern in the concrete where the loops were placed, placing the wires in the cuts, looping these wires eight times, connecting the wires to the counter that is housed in the metal post, testing the loops to ensure that the counter is working, using caulk to cover the wires and saw cuts, installing the metal post, and allowing the caulking material to cure.

Validation of the counter involved the help from a passing bicyclist who traversed the loops several times to ensure that the counter was registering correct data. The infrared counter was tested using TTI and City of Austin staff who were involved in the installation. The photos shown in Figure 17 illustrate some of these steps.

Figure 17. Example of Saw Cutting and Sealing Loops.

The City of Austin will be responsible for maintaining the counter and managing the data. They were involved in the decision concerning the exact location and assisted in the installation not only by being present to do the manual labor but also by providing equipment and materials needed. The operation of the counters is straightforward. Data are automatically sent via cell modem to the cloud on a nightly basis. Maintenance is also straightforward and involves changing the batteries and keeping insects away by using insecticide. There are a total of three batteries: a main computer battery with a 10-year life, a battery that powers the loops, which has a two-year lifespan, and a modem battery with a one-year lifespan. Additionally, there is fee for hosting/maintenance that covers the cost of sending the data via cell modem and hosting the data on the cloud data analysis site. See Table 8 for the breakdown of costs associated with the Eco-Counter MULTI. Photos of the installed counter are found in Figure 18 and Figure 19 looking northbound and southbound, respectively.

Table 8. Life Cycle Costs for MULTI Permanent Counter.

Eco-Counter Loops	1	2	3	4	5	6	7	8	9	10	Total
Urban Post MULTI	$5,400										$5,400
Software Included	$0										
GSM Fee	$420	$420	$420	$420	$420	$420	$420	$420	$420	$420	$4,200
Batteries (Modem)			$20		$20		$20		$20		$80
Batteries (ZELT inductive loop)			$80		$80		$80		$80		$320
Grand Total											$10,000

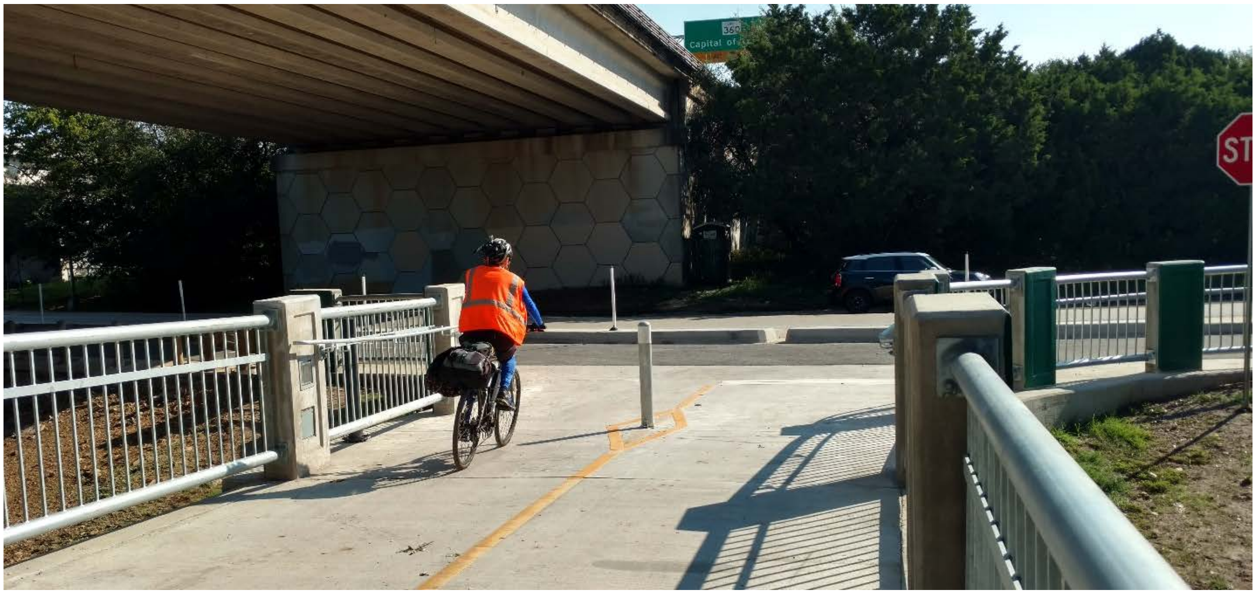


Figure 18. Northbound Bicyclist Passing the New Permanent Counter.

Figure 19. Southbound Bicyclist Passing the New Permanent Counter.

Count data were obtained a few days after installation of the counter and is shown in Table 9. From August 17, 2017, through August 26, 2017, 1,414 users were recorded with almost two-thirds traveling in the northbound direction. Also, bicyclists represented 62 percent of the users during this 10-day period. Figure 20 illustrates the average hourly bicycle and pedestrian volume data from this same time period and provides an example graph created using Eco-Visio software.

Table 9. Austin Permanent Counter Data Results, August 17, 2017, thru August 26, 2017.

Mopac/Loop 1 over Barton Creek Bicycle and Pedestrian Count Data					
Date	**Total Users**	**NB Pedestrians**	**SB Pedestrians**	**NB Bicyclists**	**SB Bicyclists**
Thu, Aug 17, 2017	126	22	32	51	21
Fri, Aug 18, 2017	101	25	17	38	21
Sat, Aug 19, 2017	256	57	25	113	61
Sun, Aug 20, 2017	212	35	25	98	54
Mon, Aug 21, 2017	141	44	14	49	34
Tue, Aug 22, 2017	116	26	11	49	30
Wed, Aug 23, 2017	135	23	13	62	37
Thu, Aug 24, 2017	114	38	12	44	20
Fri, Aug 25, 2017	125	33	18	44	30
Sat, Aug 26, 2017	88	39	29	13	7
TOTAL	**1,414**	**342**	**196**	**561**	**315**

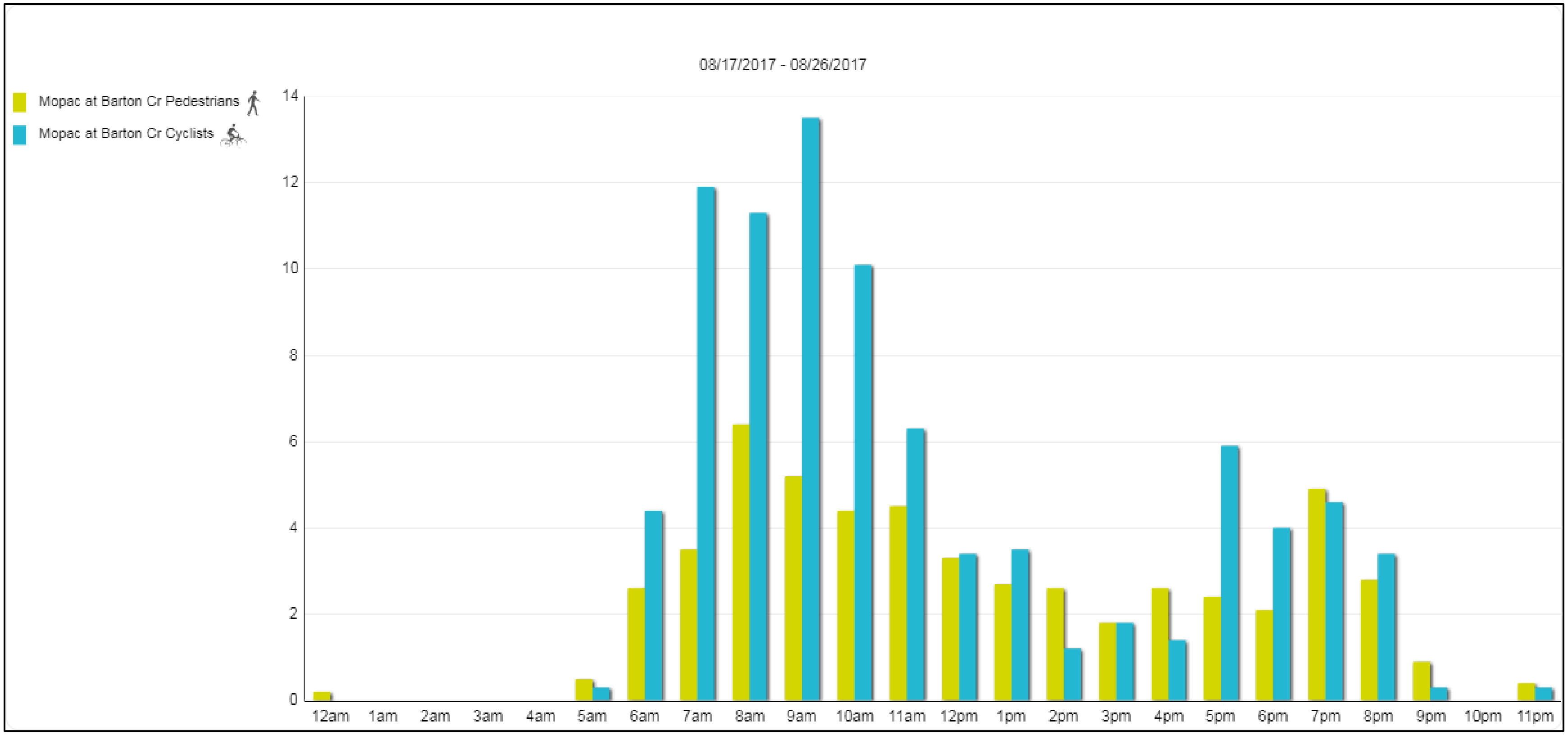


Figure 20. Average Hourly Pedestrian and Bicyclist Counts, Austin (Aug. 17-26, 2017).

Houston Permanent Counter

As part of this research project, an Eco-Counter ZELT was purchased for the Houston District. The Houston District worked with the City of Houston, the Midtown Management District (MMD), local agencies, and cycling groups to identify a location within the jurisdiction of MMD and discuss installation and maintenance. The MMD agreed to handle maintenance and approved the maintenance agreement at their September 12, 2017, board meeting. The counter was installed on October 27, 2017.

The counter was installed on a bike lane on Holman Street (at Spur 527), a newly reconstructed and reconfigured street (Figure 21 and Figure 22). The area surrounding the count location has been revitalized with new housing and streets. This location was also identified as a commuter route.

Figure 21. Houston District Spur 527 Permanent Bicyclist Counter Location.

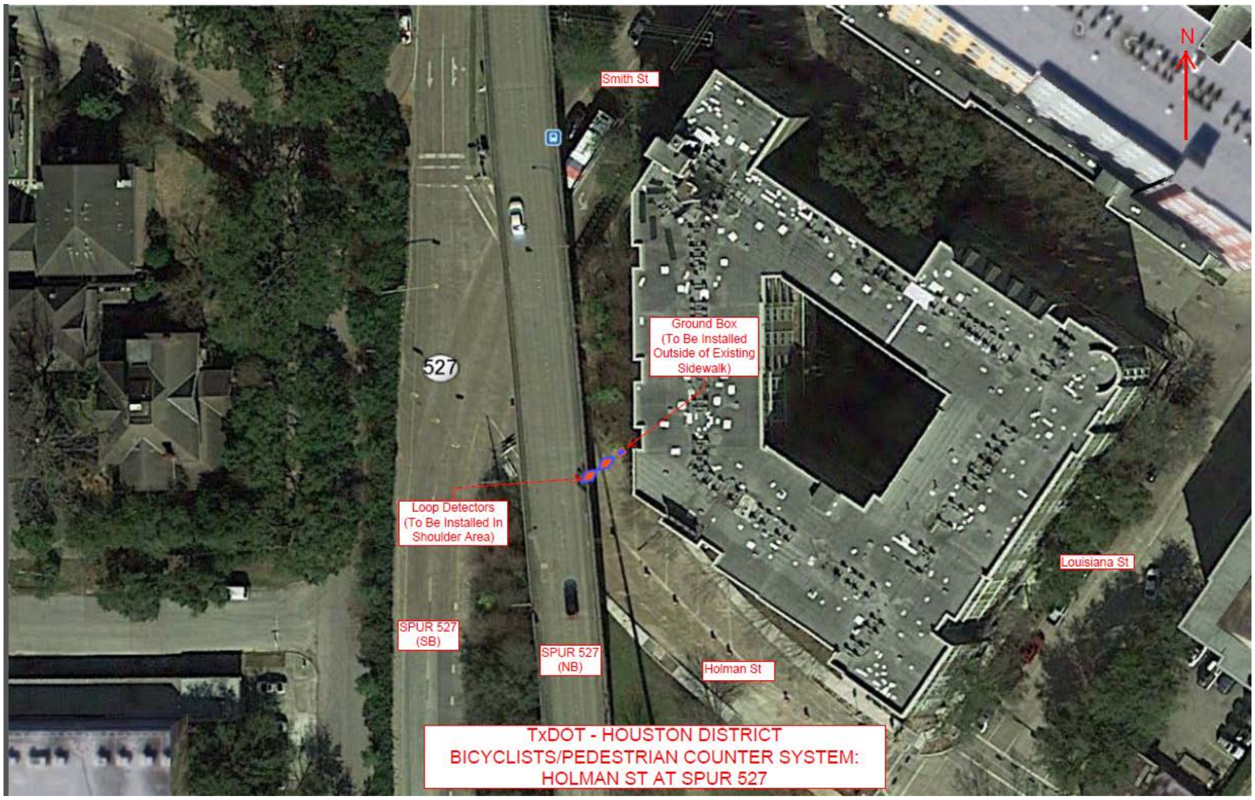


Figure 22. Detailed Spur 527 Location.

The ZELT Inductive Loops differentiate between travel directions in increments of 15 minutes. This location had the electronics installed in a ground box located outside the sidewalk. Data are stored in Eco-Counter's system called Eco-Visio, which is a cloud-based platform. The user can conduct various analyses and develop reports within the software.

Installation involves cutting a diamond-shaped pattern in the concrete where the loops were placed, placing the wires in the cuts, looping these wires eight times, connecting the wires to the counter that is located in a ground box, testing the loops to ensure that the counter is working, using caulk to cover the wires and saw cuts, installing the ground box, and allowing the caulking material to cure. Figure 22 illustrates the steps for installing the loops, and Figure 23 shows the ground box housing and actual counter equipment placed inside the ground box housing.

Like the Austin permanent counter, operation of the Houston District counter is straightforward. Data are automatically sent via cell modem to the cloud every evening. Maintenance involves changing the batteries and using insecticide. There are three batteries: a main computer battery with a 10-year life, a battery that powers the loops, which has a two-year lifespan, and a modem battery with a one-year lifespan. Additionally, the agency maintaining the equipment is responsible for the annual fee that covers the cost of sending the data via cell modem and hosting the data on the cloud data analysis site.

Figure 23. Installation and Equipment for Bicycle-Only Counting Equipment.

The permanent counter was installed on Friday, October 27, 2017. Table 10 shows the lifecycle cost breakdown for the ZELT.

In addition to the one permanent Eco-Counter, this research project has energized the region to install additional Eco-Counters. The TxDOT Houston District purchased four permanent Eco-Counters and one additional counter was purchased by the Memorial Park Conservancy. Figure 21 shows the existing and proposed locations of the new permanent eco-counters. One TxDOT counter was installed in August along BW 8 at Faust Lane, and the second was installed along Heights Boulevard under I-10. The two remaining TxDOT counters will be installed in late 2018, one in a suburban setting (FM 1488) and the other in a rural setting (FM 359). One additional counter was purchased by the Memorial Park Conservancy and was installed in August 2017 on the shared use path along Woodway Drive at I-610. Table 11 shows a matrix of the permanent counters that were installed in the Houston area as a result of the synergy of TxDOT research project 0-6927.

Table 10. Life Cycle Costs for ZELT Permanent Counter.

Eco-Counter Loops	1	2	3	4	5	6	7	8	9	10	Total
ZELT inductive loops	$4,245										$4,245
Software Included	$0										
GSM Fee	$420	$420	$420	$420	$420	$420	$420	$420	$420	$420	$4,200
Batteries (Modem)			$20		$20		$20		$20		$80
Batteries (ZELT inductive loop)			$80		$80		$80		$80		$320
Grand Total											$8,845

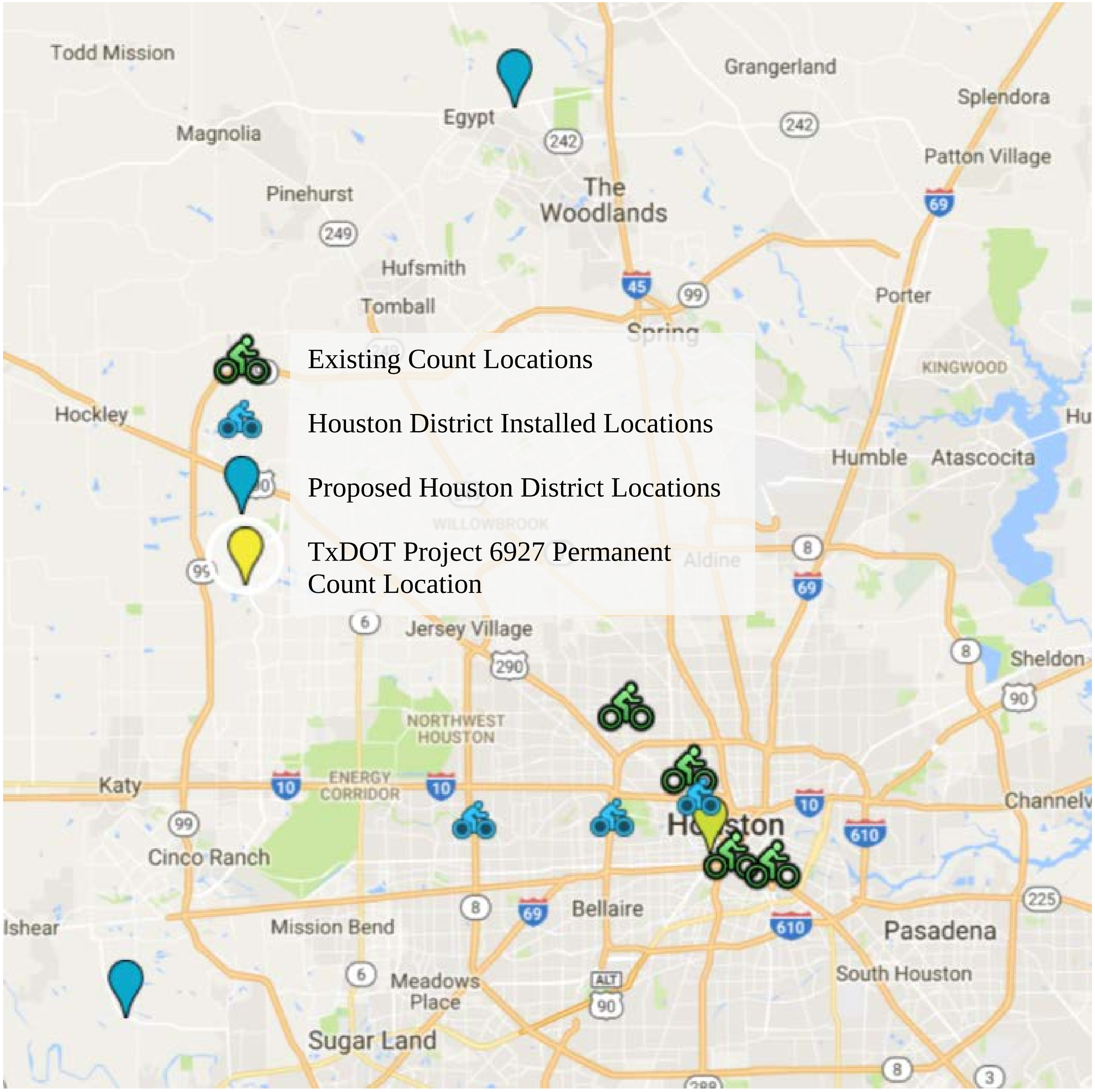


Figure 24. Permanent Nonmotorized Counters in Houston Area.

Table 11. Houston Permanent Counter Installations Resulting from TxDOT Project 0-6927.

Sponsor/Location	Part of Roadway	Equipment	Installation/ Status	Area Type
TxDOT Houston District FM 359 at North of FM 723	Signed shoulder route	ZELT inductive loops only	Jan. 2018	Rural
TxDOT Houston District BW8 Northbound Frontage Road at North of Faust Lane	Wide sidewalk	Urban Multi bicycle/pedestrian post with inductive loops	Sept. 2017	Suburban
TxDOT Houston District Heights at I-10 Westbound Frontage Road	Southbound bike lane and off-street bicycle/pedestrian facility	ZELT loops and Urban Multi bicycle/pedestrian post with inductive loops	Oct. 2017	Near Urban
TxDOT Research Project 6927 Holman at Spur 527/Bagby Street	Cycle track	ZELT loops only	Nov. 2017	Urban
TxDOT Houston District FM 1488 at Horseshoe Bend Drive	Signed shoulder route	ZELT loops only	To be installed	Urban Fringe
Memorial Park Conservancy Woodway Drive at I-610	Shared use path	Urban Multi Bicycle/Pedestrian post with loops	August 2017	Near Urban

CHAPTER 6. CROWDSOURCED PEDESTRIAN AND BICYCLIST DATA

Bicyclist and pedestrian counts that are not feasible to collect with field equipment might be estimated through smartphone apps and other online methods to leverage knowledge of networked communities, known as crowdsourcing. Crowdsourcing apps, such as Strava and Ride Report, have the potential of collecting data at any time and location that the apps are used. However, they are limited by the number of users and the target market for the apps.

Currently, Ride Report only reports bicycling data, and Strava includes walking, running, and hiking trips, in addition to bicycling trips. Full on-ground counts were compared with pedestrian and bicycling trips from these crowdsourcing apps where data were available. To date, use of these apps represents only a small portion of the population, which might significantly bias the results toward users interested and capable of participating.

This chapter describes the two sources of crowdsourced data acquired for this study: Strava Metro and Ride Report. Both are available from private firms, collected via users of the respective smartphone apps. Essentially, they use the global positioning system (GPS) of smartphones to record trip locations, times, and other characteristics, then aggregate individual trips along a transportation network. The resulting data provide traffic counts for broad geographies, representing trips of the respective app users in geographic information system data. However, each data source records bicycle trip data differently and reflects a distinctive set of participants.

In addition to this initial study of both data sources, researchers developed a method to scale crowdsourced data with additional data from the American Community Survey. The research method and scaling process for practitioners is described further in TTI report 0-6927-P6, *Guide for Seasonal Adjustment and Crowdsourced Data Scaling*.

CROWDSOURCED DATA SOURCE: RIDE REPORT IN AUSTIN, TEXAS

Ride Report is a provider of crowdsourced bicycle data that includes both traffic volumes and ratings. The app launched first in Portland, Oregon, and has also been working with the City of Austin, Texas, and others. As of mid-2018, it had not started in Houston, so no evaluation is possible in that city. When downloaded and authorized by the users, the smartphone app uses the on-board accelerometer in conjunction with the GPS to estimate trip mode automatically. Therefore, Ride Report theoretically records all trips taken by the user, though these proprietary algorithms were still under refinement as of a July 2016 interview with a TTI researcher. When the end of a bicycle trip is detected, the app automatically notifies the user to rate the ride on a scale with three levels. These ratings are a distinguishing feature of the service, but only bicycle volumes are the focus of this report.

The Austin Transportation Department has promoted the use of Ride Report through electronic media, yielding significant use that covers much but not all, of the city. Figure 25 shows the spatial extent of Ride Report trips from July 2016 through June 2017. The city's eight permanent bicycle counters are also included on this map to show the distribution of comparison sites.

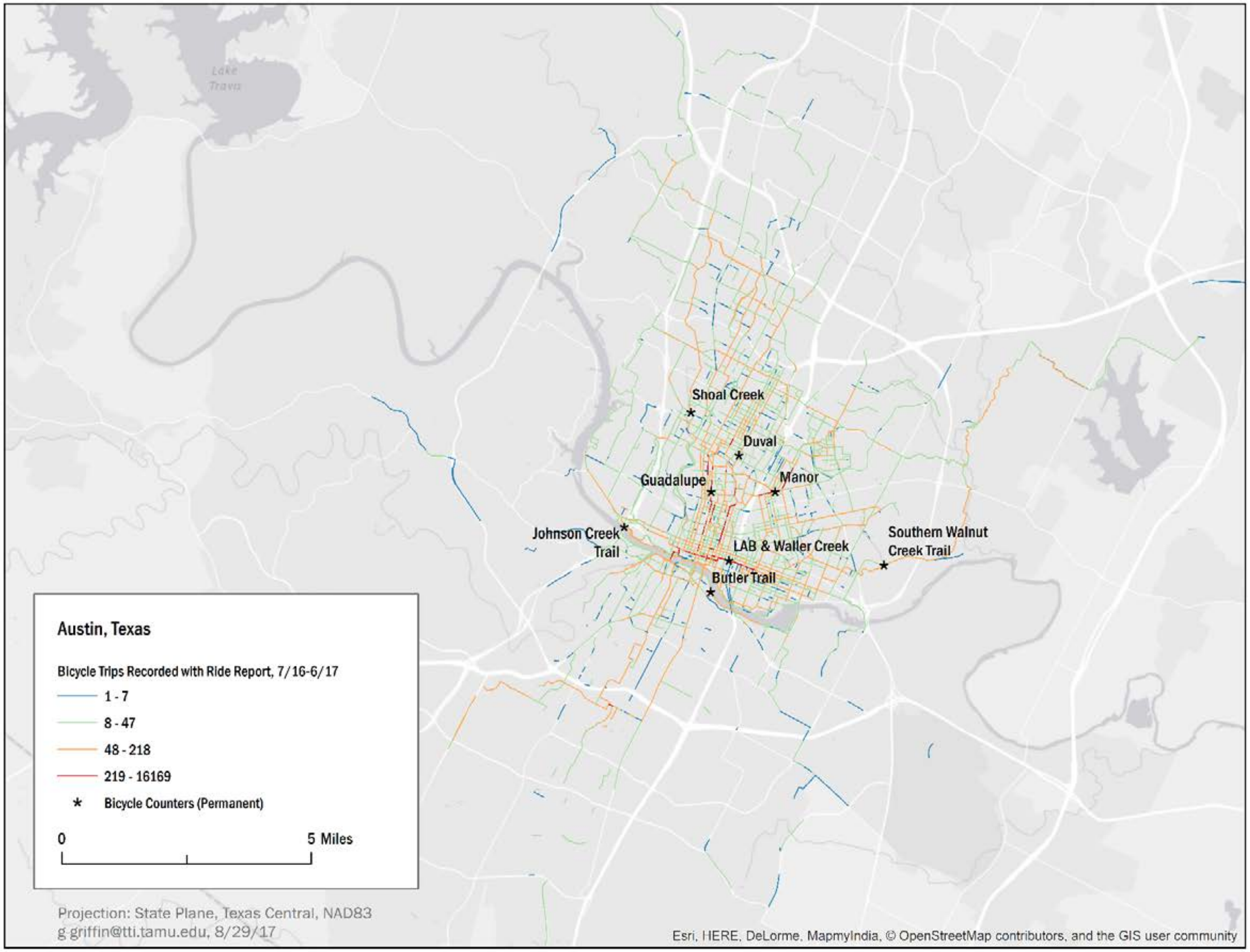


Figure 25. Bicycle Trips Recorded with Ride Report in Austin, June 2016–July 2017.

Ride Report includes a data dashboard for downloading the network results, in addition to descriptive statistics on the crowdsourcing contributors and their trips (Table 12). In July 2017, 154 people tracked bicycle trips using Ride Report, down from a peak of 262 users in November 2016. Gender information is available for contributors who link their Ride Report account with Facebook. Only 12 percent of users contributed this information—13 males and 6 females. The average trip taken with Ride Report was just over 3 miles, also consistent with national averages. These essential characteristics of Ride Report users in Austin suggest a small, but a roughly representative sample of the city's bicycling population.

Table 12. Descriptive Statistics of Ride Report Data in Austin.

	Austin
Contributors	
Count of contributors	154
Count providing gender as male	13
Count providing gender as female	6
Trips[1]	
Count of trips	48,090
Average Distance (miles)	3.2
Rated Good	92.0%

Note: [1] Trip characteristics include all time recorded, January 2016 through August 29, 2017. Ride Report currently provides statistics for several pre-selected time periods.

STRAVA VOLUMES IN AUSTIN AND HOUSTON, TEXAS

Strava Metro is the oldest and largest source of crowdsourced bicycle volumes currently available. The service is a business unit of Strava, which is a smartphone app and website that seeks to "enhance the experience of sport and connect millions of athletes from around the world." However, previous research has shown that Strava represents a sample of health-oriented contributors, and may not represent the broader bicyclist population.

The original plan for this study included purchasing a small area of crowdsourced data to overlay on-ground bicycle counts for comparison. However, during this research project, TxDOT acquired Strava Metro coverage for the entire state, expanding the available counter locations for comparison. Strava delivered data for the two pilot counties before the remainder of the state: Travis (Austin), and Harris (Houston). This enabled analysis of an entire year's worth of data, July 2016–June 2017, and comparison data in Austin was available for eight permanent counters, as well as Ride Report. As shown in Figure 26 and Figure 27, Strava Metro bicycle trips cover nearly every bicycle-accessible route in the counties and has much higher total use than Ride Report in Austin to date. However, Figure 28 and Figure 29 show that pedestrian trips recorded via Strava are more focused in certain areas of each city.

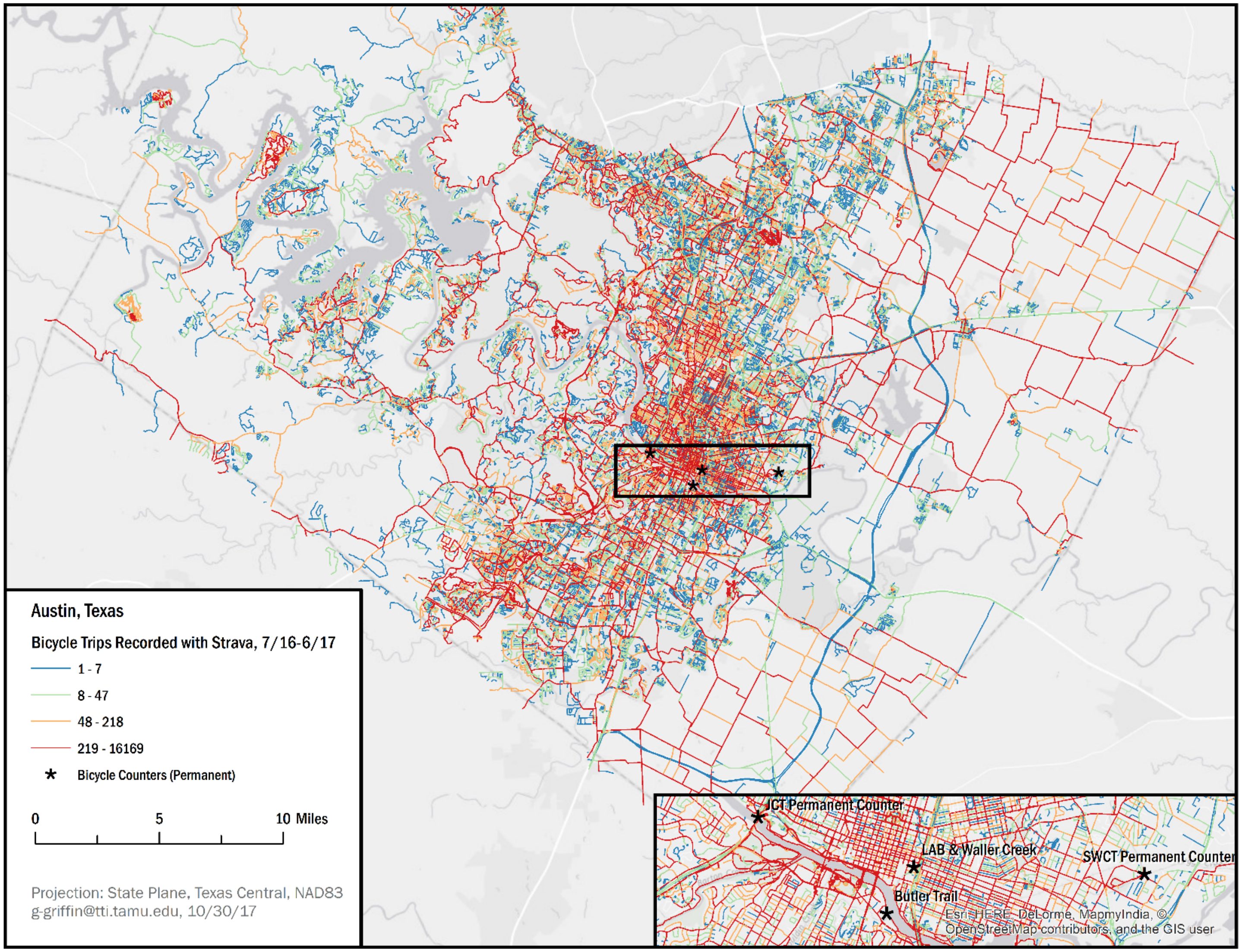


Figure 26. Bicycle Trips Recorded with Strava in Travis County, June 2016–July 2017.

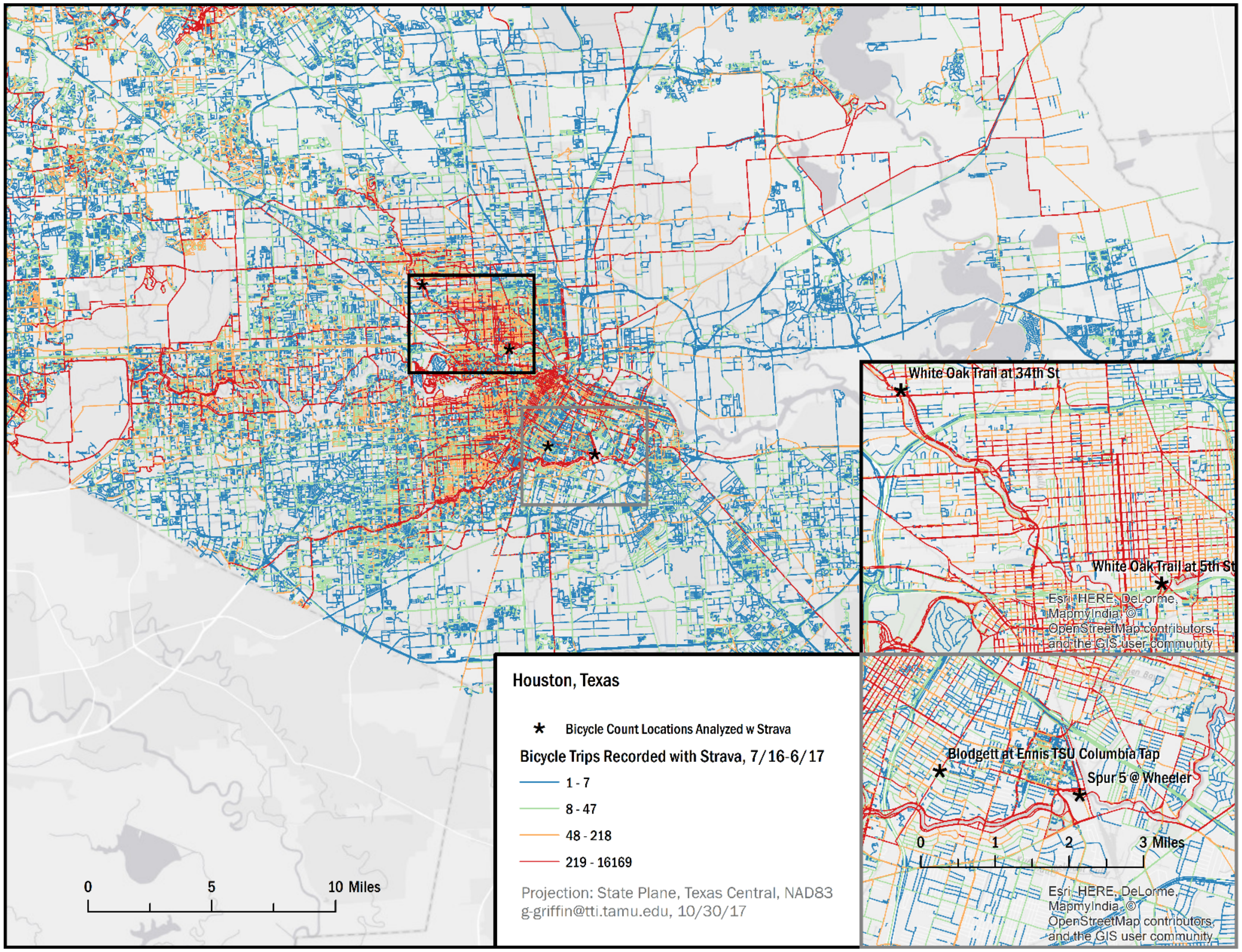


Figure 27. Bicycle Trips Recorded with Strava in Harris County, June 2016–July 2017.

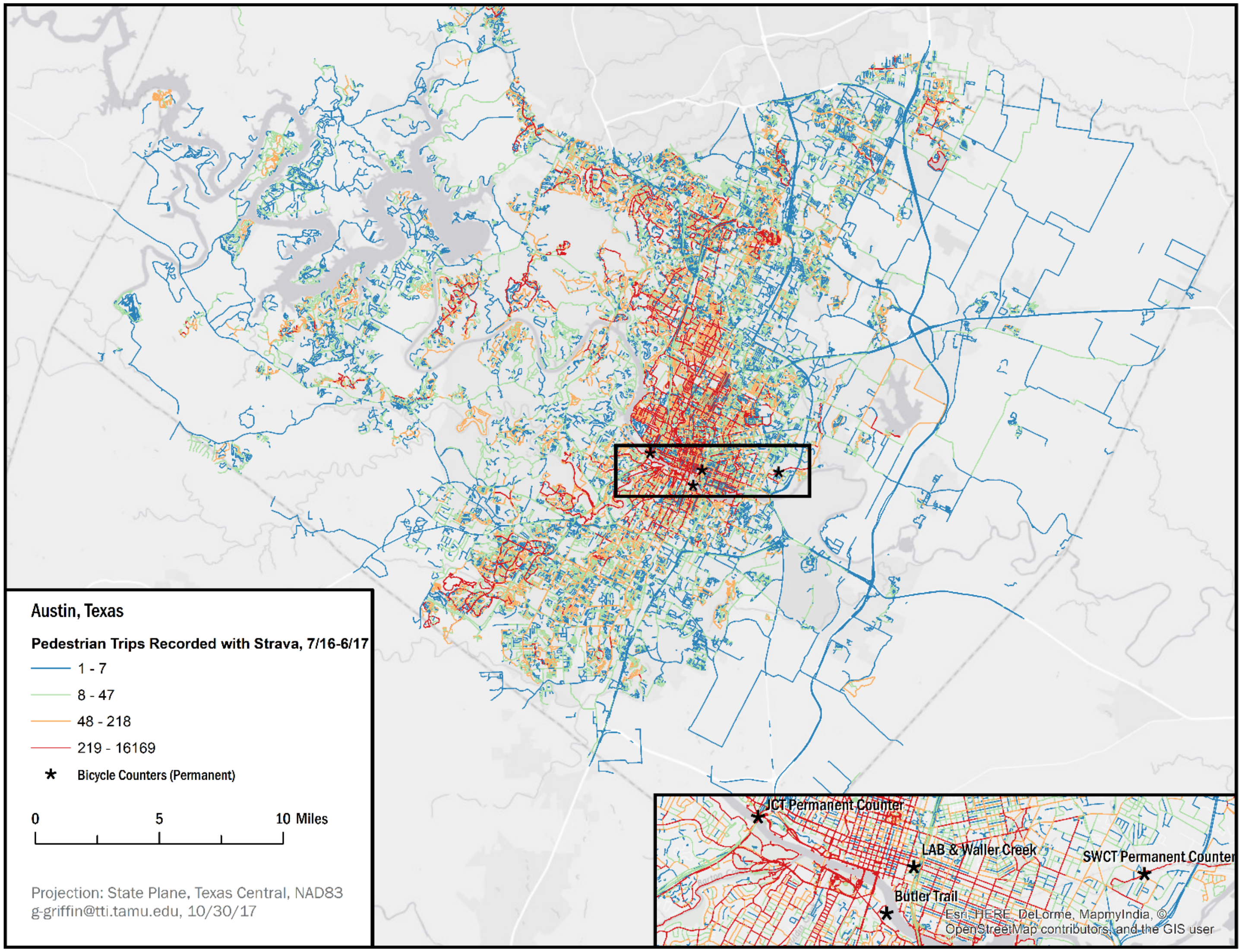


Figure 28. Strava Pedestrian Trips in Travis County, June 2016–July 2017.

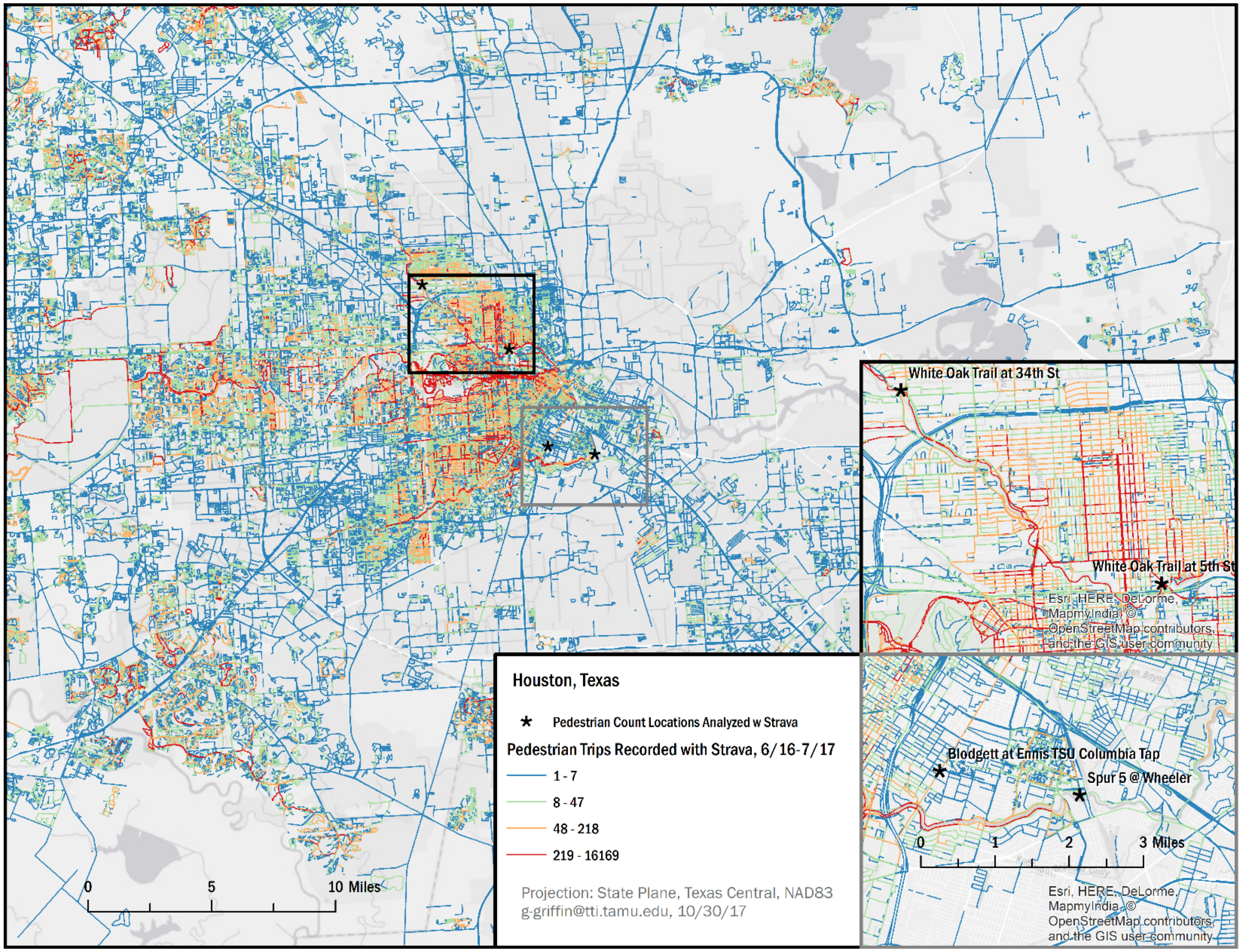


Figure 29. Strava Pedestrian Trips in Harris County, June 2016–July 2017.

Despite the overall larger population of Houston, the number of Strava users in the two cities is similar (Table 13). Two-thirds of Strava users are under the age of 45. Consistent with the voluntary use of the app (not automatic), and fitness orientation, the average trip is over 18 miles in Austin (six times that of Ride Report or national averages). The total number of trips taken in Austin is 18 percent greater, which may be related to some very frequent users. Strava users in Houston travel slightly farther, and faster on average, which may be related to flatter topography and intersection frequency. Additionally, because Strava users must manually deactivate the app at the end of a ride, it is possible that a small number of automobiles (i.e., those that were higher speed) are recorded as cycling or pedestrian activities, potentially increasing overall speed and distance averages on recorded routes.

Table 13. Summary of Strava Metro Data in Austin and Houston, July 2017.

	Austin	**Houston**
Contributors		
Count of contributors	18,414	17,774
Male[1]	81.9%	80.0%
Female[1]	18.1%	20.0%
Age 44 and under[1]	66.6%	67.8%
Age 45 and over[1]	33.3%	32.1%
Trips		
Count of trips	359,911	293,506
Commutes[2] (percent)	33.1%	21.6%
Median Distance (miles)	12.9	15.9
Average Distance (miles)	18.4	20.8
Median Time (hours)	1.3	1.4
Average Time (hours)	1.7	1.7
Median speed (mph)	9.8	11.3
Average speed (mph)	10.6	12.0

Notes:
[1] Percent of Strava users who offered gender or age. In Austin, 3,688 did not provide birthday (age), and 1125 omitted gender. In Houston, 3,965 contributors did not provide birthday (age), and 1,419 omitted gender.
[2] Strava identifies commutes "by an automated process that locates point-to-point cycling and pedestrian trips" where the origin and destination are greater than 1 km apart (Strava Metro Comprehensive User Guide, version 5.01). Researcher's anecdotal use of the app suggests not all commutes are automatically detected, though users can manually tag rides as commutes, which could increase accuracy of this detection.

Comparison of Crowdsourced Data Results to Permanent Counter Data

The eight permanent counting stations in Austin represent a range of bicycle facility types, but do not include rural sites or roadways with no bicycle facilities. They likely have higher volumes than average but provide useful variation for understanding the relationship between crowdsourced and complete bicycle counts. Table 14 provides details on the sites, which are mapped in Figure 26 and Figure 27.

Table 14. Permanent Count Locations.

Counter Name	Facility Type	Context	Dates Used
Austin Counters			
Butler Trail	Shared-Use Path	Central Business District	7/1/16–6/30/17
Duval	Bike Lane	Urban	7/1/16–6/30/17
Guadalupe	Protected Bike Lane	Urban	7/1/16–6/30/17
Johnson Creek Trail	Shared-Use Path	Urban	7/1/16–6/30/17
Lance Armstrong Bikeway (LAB) at Waller Creek	Shared-Use Path	Central Business District	7/1/16–6/30/17
Manor	Bike Lane	Urban	7/1/16–6/30/17
Shoal Creek	Shared-Use Path	Suburban	7/1/16–6/30/17
Southern Walnut Creek Trail	Shared-Use Path	Urban	7/1/16–6/30/17
Houston Counters			
Blodgett at Ennis TSU Columbia Tap	Shared Use Path	Urban	6/1/17–6/30/17
Spur 5 @ Wheeler	Shared Use Path	Urban	6/1/17–6/30/17
White Oak Trail at 34th St	Shared Use Path	Urban	6/1/17–6/30/17
White Oak Trail at 5th St	Shared Use Path	Urban	3/1/17–3/31/17

Selecting Strava Metro Trips and Monitoring Locations for Analysis

Strava Metro trips exist in almost every street and trail in both Harris and Travis Counties in Texas. However, high-quality full counts for comparison are rare. The following criteria were considered in determining which locations to use in this study:

1. Timing of counts match available Strava data.
2. All facility users should be accurately counted (minimal chances of avoiding the counter, etc.).
3. Maximize duration of available counts.
4. Long-term monitoring possible for later comparisons.

These criteria support use of available permanent monitoring stations as reference locations. Counts during 2016 were generally available to compare with the 2016 Strava data. The locations constrain facility users to be counted, for example, a bike lane user changing lanes to turn may miss a pneumatic tube. The duration is important to avoid complicating factors such as weather and special events—no temporal extrapolation or adjustment was needed. In addition, these locations are likely to remain in-place for later analysis—use of crowdsourcing services are likely to change over time.

Strava Metro data include counts separated by whether it was recorded as a commute, or all types of trips. This analysis includes all Strava trips with the comparison data, to most accurately reflect all trips recorded through each method. An intercept survey (stopping people on a path with one or more questions, or another mobile surveying app) would be required to evaluate the accuracy of trip purpose, as recorded through Strava Metro, or to record trip purpose for roadway users counted by stationary equipment.

Certain facility types are likely to attract different users. For instance, high-speed fitness-oriented bicyclists tend to choose routes with few intersections, wide shoulders, and hills, where available (*12*). Conversely, commuters and shoppers likely choose local streets to efficiently reach the destination. However, these trends do not represent all trips. Fitness cyclists certainly use local streets, and some commuters may have long highway rides as well. Shared-use paths may be used more often for recreation, but well-planned trails are used by a wide variety of users. Understanding the relationship between facility type, trip purpose, and use of crowdsourcing apps would require a specific study that incorporates trip purpose, such as an intercept survey. Given the available data, the next section describes the method to analyze crowdsourced counts with full traffic volumes.

Analysis Method

This study compares the crowdsourced data to complete counts following calculation methods used in the Transportation Research Board's *Guidebook on Pedestrian and Bicycle Volume Data Collection*, focusing on three key comparison statistics: average percent deviation, absolute percent difference, and Pearson's correlation coefficient (*4*). The average percent deviation shows the overall divergence of crowdsourced data from complete counts (Table 15). One disadvantage of this metric is that over- and under-counts can tend to cancel each other, which is eliminated by the absolute percent difference. Pearson's correlation coefficient shows the amount of linear correlation between the crowdsourced data and full counts. Ranging from −1 (complete divergence) to +1 (complete agreement), a positive Pearson's over 0.5 shows moderate correlation. A Pearson's closer to +1 would show the crowdsourced counts vary in proportion to the actual counts, suggesting an adjustment factor between a given crowdsourced data set and full counts may be appropriate to use.

Table 15. Percent Deviation for Bicycle Counters and Crowdsourced Counts.

Counter Name	Bicycle Counts, 7/16–6/17	Strava, 7/16–6/17	Ride Report, 7/16–6/17	Strava Percent Deviation	Ride Report Percent Deviation
Austin Counters					
Butler Trail	240,573	12,739	66	-94.70%	-99.97%
Duval	149,204	4,000	175	-97.32%	-99.88%
Guadalupe	183,911	7,293	241	-96.03%	-99.87%
Johnson Creek Trail	39,439	2,588	80	-93.44%	-99.80%
LAB at Waller Creek	378,966	15,142	417	-96.00%	-99.89%
Manor	105,163	7,145	330	-93.21%	-99.69%
Shoal Creek	58,809	10,709	62	-81.79%	-99.89%
Southern Walnut Creek Trail	110,941	13,960	160	-87.42%	-99.86%
Counter Name	**Bicycle Counts,** June 2017	**Strava,** June 2017		**Strava Percent Deviation**	
Houston Counters					
Blodgett at Ennis TSU Columbia Tap	3,101	102		-96.71%	
Spur 5 @ Wheeler	1,761	125		-92.90%	
White Oak Tr. at 34th St	6,227	1,188		-80.92%	
White Oak Tr. at 5th St	17,229*	1,306*		-92.42%	

Notes:
Ride Report was not available in Houston at the time of this study.
*March 2017 volumes used for this counter, as June 2017 was missing some data.

Looking at all eight Austin counter sites together in Table 15, Strava counts more closely approximate full counts than Ride Report in terms of the percent difference. However, despite the relatively low use of Ride Report, it has a slightly stronger linear correlation to the total counts, as represented by Pearson's *r* (see Table 17). In Houston, the higher correlation of Strava and full counts may be attributable to the more cohesive factor group—all four counting stations are shared-use paths in urban areas.

Crowdsourced pedestrian counts in this study are not consistent with full counts. Table 16 shows that the Strava Metro pedestrian counts are a small and inconsistent measure of actual counts, with only one user counted in May 2017 at Houston's Spur 5 site, and very high representation on the White Oak Trail at 5th Street. Pearson's *r* values in Table 17 show the Strava Metro pedestrian counts are not consistent with total pedestrian counts at the eight locations in this study. Although pedestrian volumes tracked via Strava in these locations are not proportional with total pedestrian counts, they may be useful for identifying base use levels (e.g., Do pedestrians use this facility at all?) or to determine which routes are used by fitness-oriented runners.

Table 16. Percent Deviation for Pedestrian Counters and Crowdsourced Counts.

Counter Name	**Pedestrian Counts,** 7/16–6/17	**Strava,** 7/16–6/17	**Strava Percent Deviation**
Austin Counters			
Butler Trail	1,382,046	729	-99.95%
Johnson Creek Trail	67,606	1,571	-97.68%
LAB at Waller Creek	525,850	1,747	-99.67%
Southern Walnut Creek Trail	25,781	525	-97.96%
Counter Name	**Pedestrian Counts,** May 2017	**Strava,** May 2017	**Strava Percent Deviation**
Houston Counters			
Blodgett at Ennis TSU Columbia Tap	3,570	12	-99.66%
Spur 5 @ Wheeler	692	1	-99.86%
White Oak Tr. at 34th St	407	56	-86.24%
White Oak Tr. at 5th St	1,713	208	-87.86%

Table 17. Evaluation Statistics for Bicycle and Pedestrian Crowdsourced Data.

	N	**APD**	**AAPD**	***r***
Bicycle				
Strava Bicycle (Austin)	8	-92.49%	92.49%	0.59
Ride Report Bicycle (Austin)	8	-99.86%	99.86%	0.61
Strava Bicycle (Houston)	4	-90.74%	90.74%	0.81
Pedestrian				
Strava Pedestrian (Austin)	4	-98.81%	98.81%	-0.21
Strava Pedestrian (Houston)	4	-93.40%	93.40%	-0.05

Figure 30 and Figure 31 show scatterplots of the crowdsourced information types and indicate a positive relationship with the full counts. The Ride Report values in Figure 30 have two outliers—Manor Road has a relatively high rate of Ride Report use, and users of the Butler Trail (the Lady Bird Lake Boardwalk) use Ride Report at a comparatively low rate. Removal of these two outliers produces a Pearson's r of 0.99, an interesting relationship worthy of further study with additional counters. Though the total number of sites analyzed in this study is not sufficient for city-wide factor group analysis, this suggests the automatic trip recording function of Ride Report may be useful for representing trips, despite its lower rates of use.

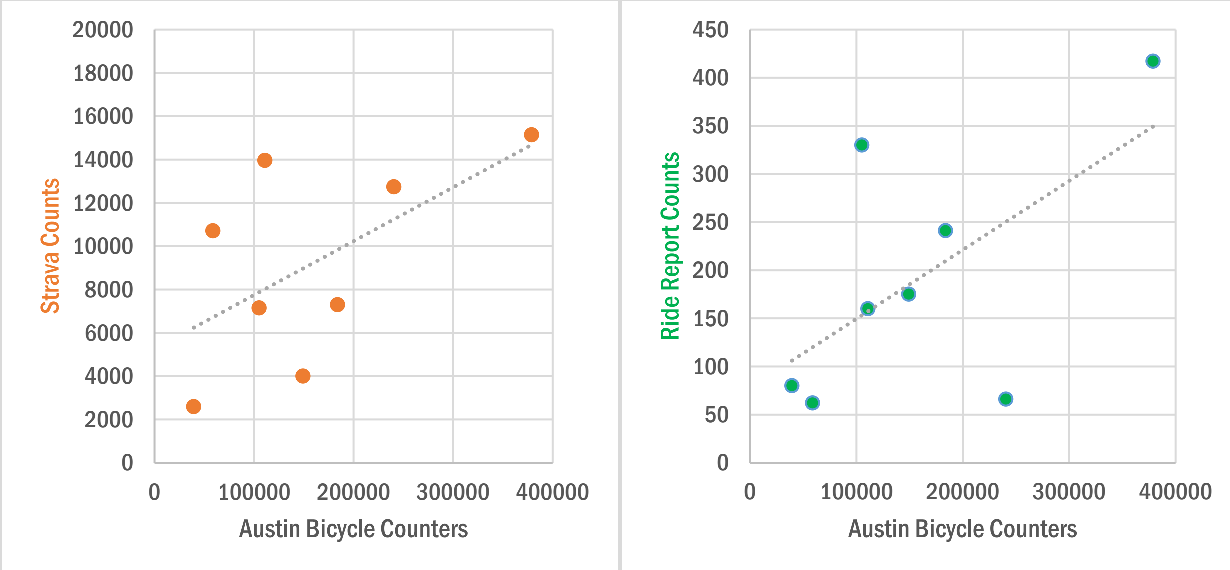


Figure 30. Comparison of Bicyclist Counts from Crowdsourced and Permanent Counters in Austin.

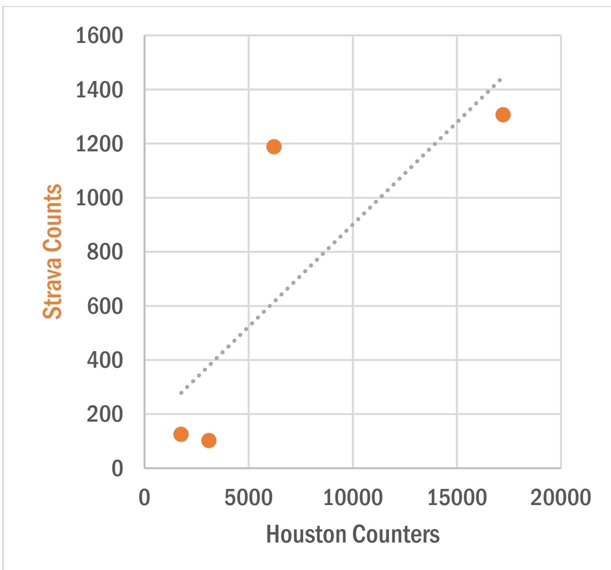


Figure 31. Comparison of Bicyclist Counts from Crowdsourced and Permanent Counters in Houston.

Pedestrian trips crowdsourced through Strava have a weaker relationship with full counts than the bicycle mode. Figure 32 shows plots of the counts at the same eight locations with the Strava pedestrian values, showing no significant correlation. Several factors may reasonably explain why crowdsourced bicycle counts are better predictors of actual counts than the crowdsourced pedestrian data. First, overall use of the Strava app is lower for pedestrian trips than bicycling. Second, the trip lengths are shorter for pedestrian versus bicycle trips, so the total area covered by each trip is more localized. Third and perhaps most significant is that there may be large differences in route choice between Strava pedestrian trips likely to be fitness-oriented runs and total pedestrian trips. Dog walking, for instance, is a very common pedestrian trip purpose, but is unlikely to be tracked using the Strava app. The next section briefly describes incorporation of additional data to build a statewide model of bicycle volume and how to apply it to expand a local crowdsourced count to estimate total volumes.

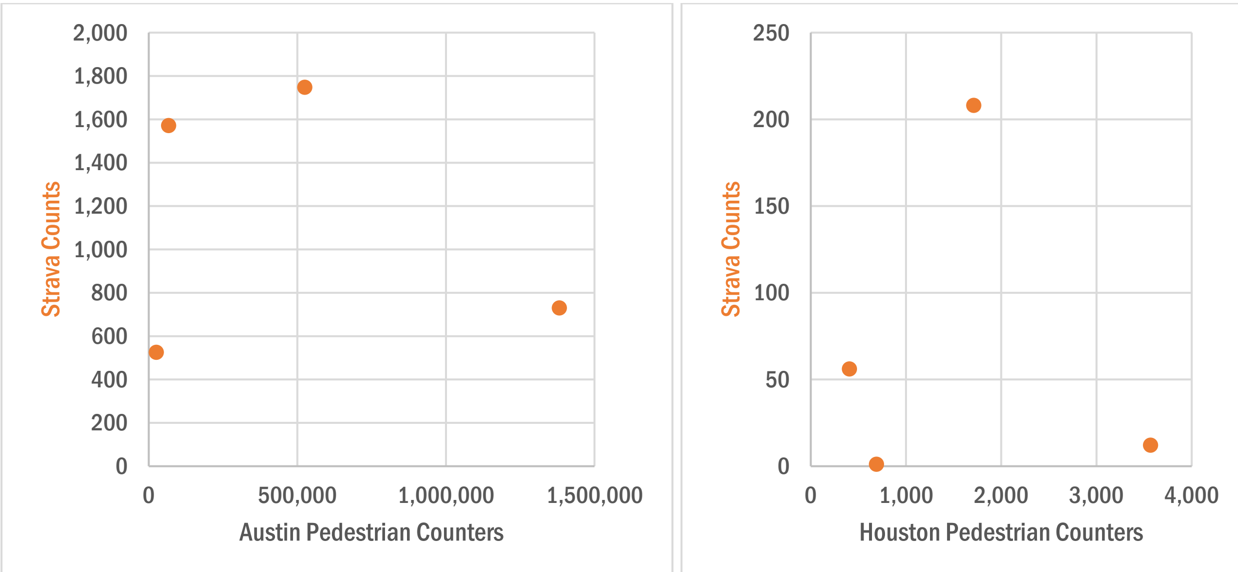


Figure 32. Pedestrian Count Scatterplots from Crowdsourced and Permanent Counters.

SCALING CROWDSOURCED DATA TO REPRESENT ALL TRIPS

The basic concept of scaling crowdsourced data to represent all trips is that if the crowdsourced counts of bicycle trips vary in proportion with the total bicycle trips counted at that location, then the crowdsourced count could be multiplied by a factor in other locations to estimate all trips in places where no full counts exist. Used this way, crowdsourced data could help provide reasonable count estimates with less resources than a statewide bicycle count.

Following the initial analysis above using only 12 bicycle count sites, researchers leveraged 153 total count sites with other data to improve the representativeness and accuracy of the scaling approach. TTI report 0-6927-P6, *Guide for Seasonal Adjustment and Crowdsourced Data Scaling*, provides additional background, methodology, and explanation of the variable selection process.

To better understand Strava usage in small urban and rural areas, TTI collected additional short-duration counts during late spring 2018 in small to mid-sized cities that were previously underrepresented in the count database, including Brownsville, Lubbock, Midland-Odessa, and Wichita Falls (see Figure 33 to Figure 36 for count locations). The spring 2018 counts are summarized in Table 18 through Table 21.

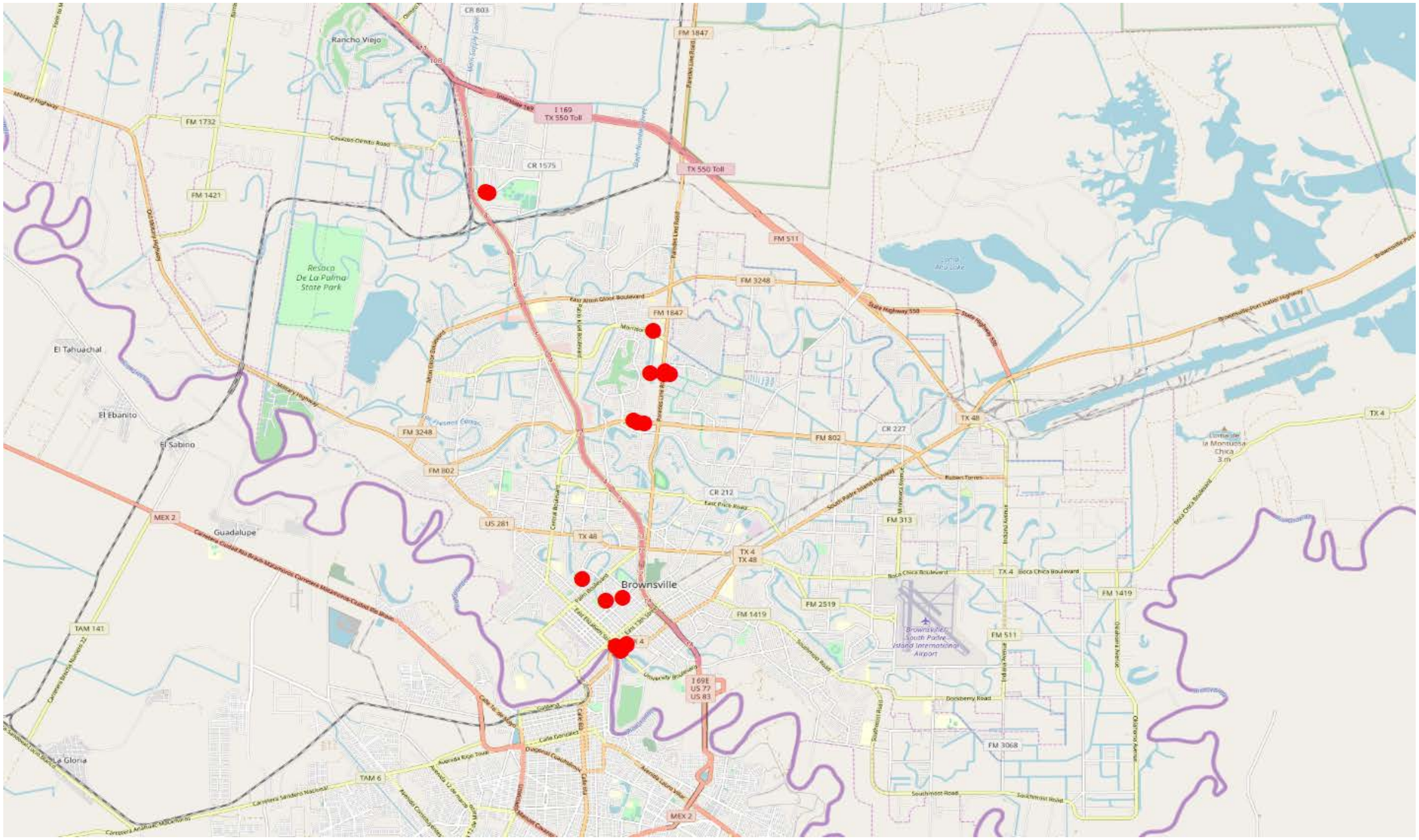


Figure 33. Spring 2018 Count Locations in Brownsville.

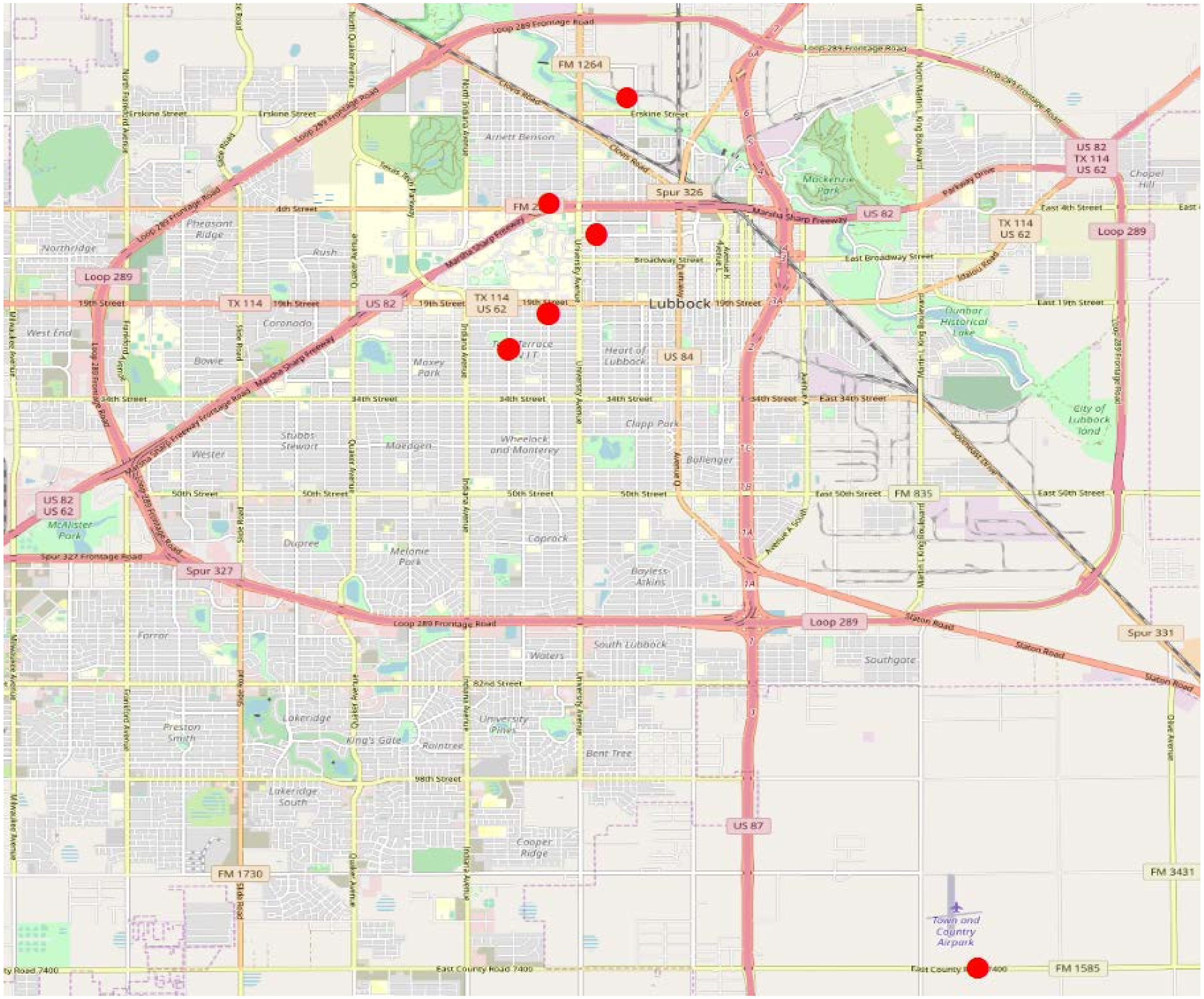


Figure 34. Spring 2018 Count Locations in Lubbock.

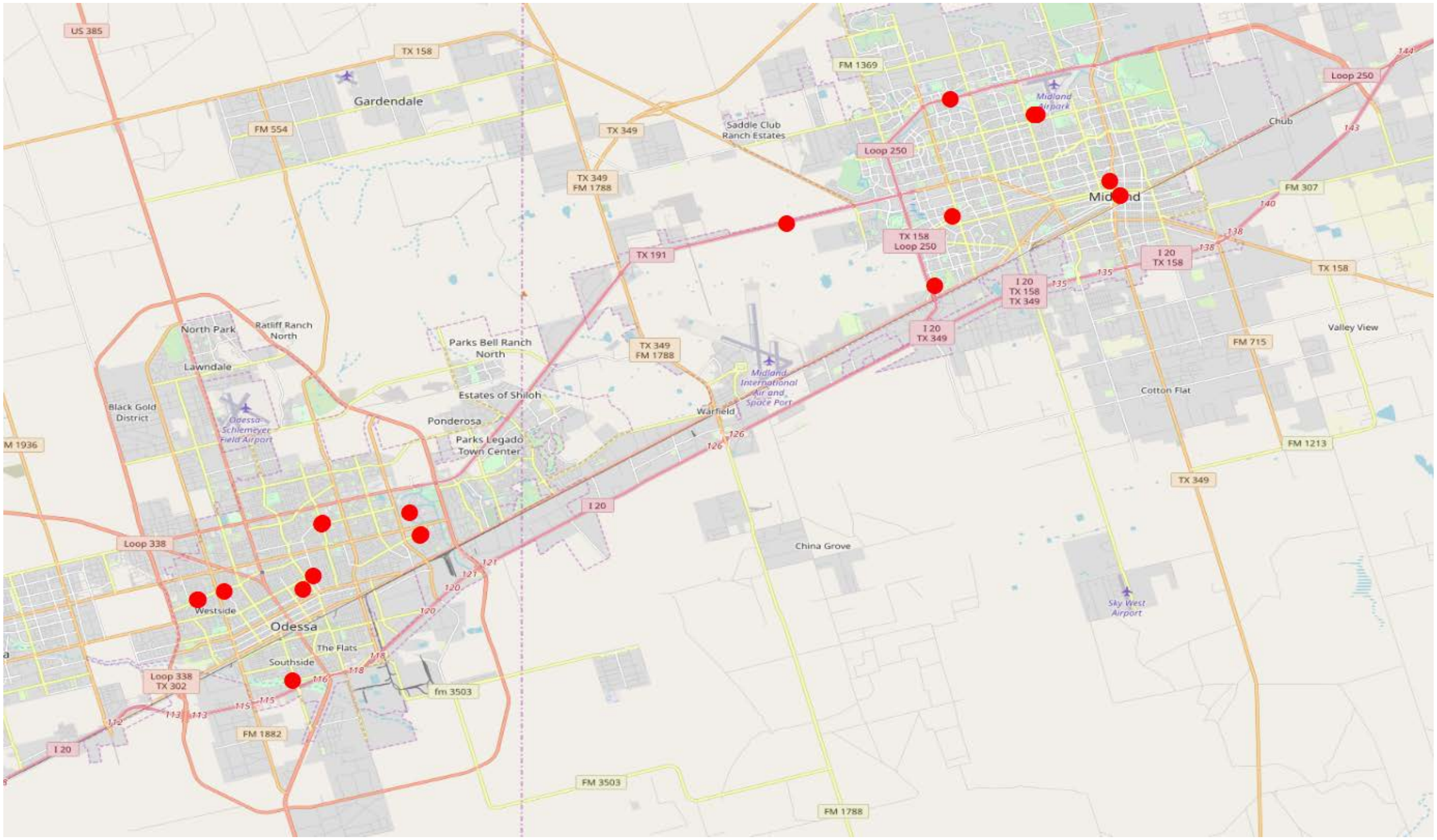


Figure 35. Spring 2018 Count Locations in Midland-Odessa.

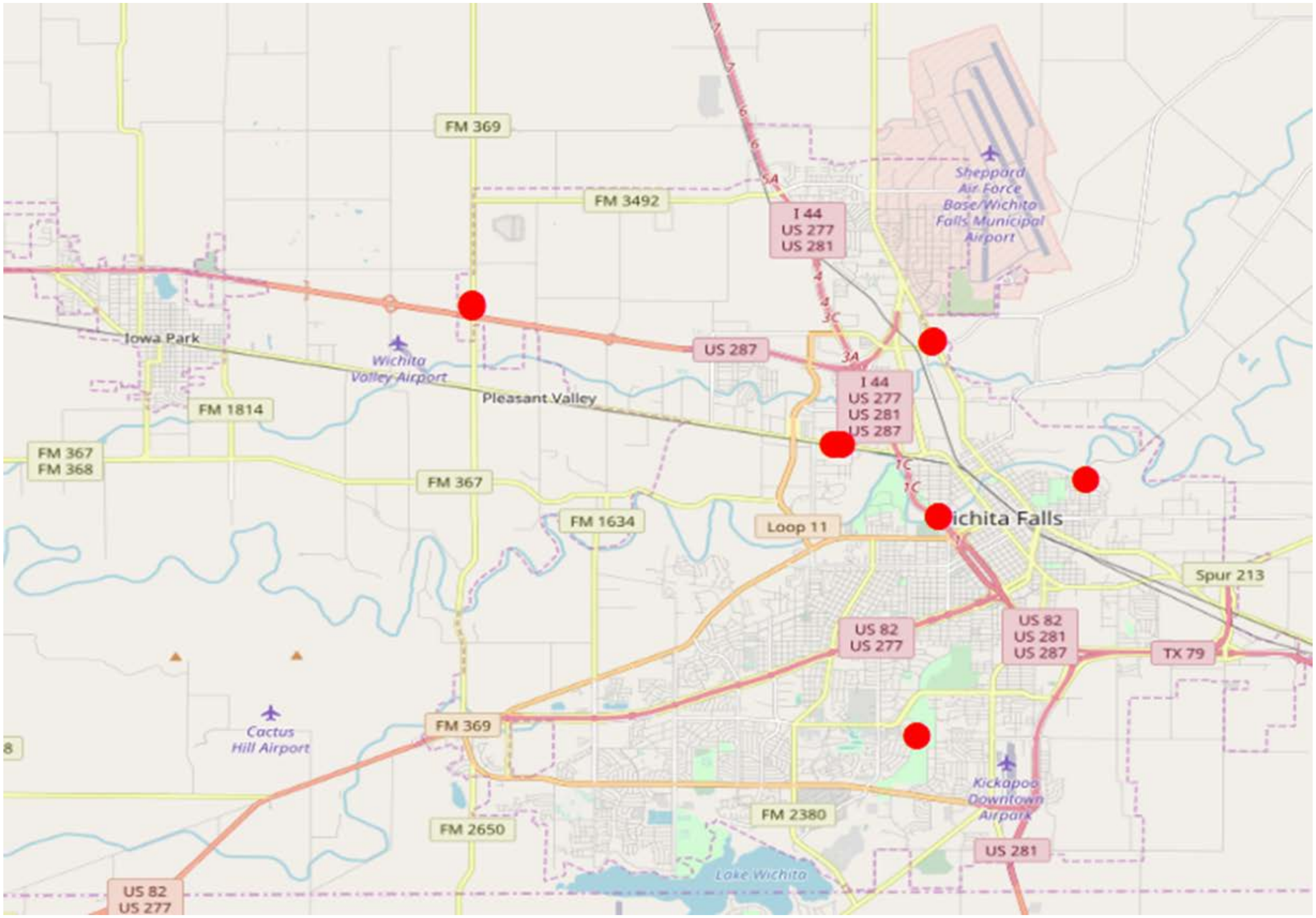


Figure 36. Spring 2018 Count Locations in Wichita Falls.

Table 18. Spring 2018 Count Summaries from Brownsville, Texas.

Location	Facility Type	User Type	Average Daily Traffic (7-day week)	Average Weekday Daily Traffic	Average Weekend Daily Traffic
Old Alice Road at N of Belvedere	Bicycle lane	Bicyclists only	22	20	24
FM 802 at W of Habana	Bicycle lane		6	6	6
Sports Park Blvd at W of Brownsville Sports Park	Bicycle lane		2	1	3
Elizabeth NB @ W International	Sidewalk	All pedestrians and bicyclists combined	963	947	986
Elizabeth SB @ W International	Sidewalk		N/A	N/A	N/A
University SB @ E International	Sidewalk		35	38	32
University NB @ E International	Sidewalk		64	62	67
International WB @ E of May	Sidewalk		460	496	414
International EB @ E of May	Sidewalk		210	202	219
Historic Battlefield H&BT @ N of 7th	Shared use path		N/A	N/A	N/A
Historic Battlefield H&BT @ S of E Ruben Torres	Shared use path		142	162	118
Historic Battlefield H&BT @ N of E Morrison	Shared use path		47	39	58
FM 1847 NB OST	Sidewalk		11	14	6
S Cameron Park OST	Shared use path		249	234	268
N Cameron Park OST	Shared use path		80	62	102

N/A = count data not available due to equipment malfunction.

Table 19. Spring 2018 Count Summaries from Lubbock, Texas.

Location	Facility Type	User Type	Average Daily Traffic (7-day week)	Average Weekday Daily Traffic	Average Weekend Daily Traffic
Flint Ave NB at N of 26th St	Bicycle lane	Bicyclists only	1	1	2
Flint Ave SB at N of 26th St	Bicycle lane		N/A	N/A	N/A
Boston Ave SB at S of 20th St	Bicycle lane		N/A	N/A	N/A
Boston Ave NB at S of 20th St	Bicycle lane		N/A	N/A	N/A
FM 1585 (130th St) at E of FM 2500	Bicycle lane		2	2	2
FM 1585 (130th St) at E of FM 2500	Bicycle lane		1	2	1
Flint Ave SB at N of 26th St	Sidewalk	All pedestrians and bicyclists combined	32	34	31
Flint Ave NB at N of 26th St	Sidewalk		N/A	N/A	N/A
Boston Ave NB at S of 20th St	Sidewalk		14	18	9
Boston Ave SB at S of 20th St	Sidewalk		16	13	3
Glenna Goodacre Blvd EB @ Ave X	Sidewalk		114	137	8
Glenna Goodacre Blvd Center @ Ave X	Sidewalk		21	23	17
Glenna Goodacre Blvd WB @ Ave X	Sidewalk		109	116	97
Boston Ave Bridge @82 Masha Sharp Fwy	Sidewalk		74	94	45
Canyon Lake Trail @ Cesar Chavez	Shared use path		32	34	31

N/A = count data not available due to equipment malfunction.

Table 20. Spring 2018 Count Summaries from Midland-Odessa, Texas.

Location	Facility Type	User Type	Average Daily Traffic (7-day week)	Average Weekday Daily Traffic	Average Weekend Daily Traffic
Michigan BL WB@ W of Marienfeld	Bicycle lane	Bicyclists only	1	1	1
Louisiana BL WB@ W of Marienfeld	Bicycle lane		N/A	N/A	N/A
Mid College Chaparral Creek Bike Lane South Side	Bicycle lane		12	10	16
SH 191 FR EB	Bicycle lane		1	0	1
Oakwood WB@ Sunnygrove	Bicycle lane		1	1	0
Maple NB @ 14th	Bicycle lane		1	1	1
Maple SB @ 14th	Bicycle lane		N/A	N/A	N/A
Maple EB @ Dawn	Bicycle lane		1	1	1
22nd WB BL @ Ventura	Bicycle lane		0	1	0
22nd EB BL @ Ventura	Bicycle lane		0	0	0
Wall St EB @ Loraine	Sidewalk	All pedestrians and bicyclists combined	315	352	250
Wall St WB @ Loraine	Sidewalk		48	46	50
Campus Bridge N of W Wadley Ave	Shared use path		60	58	63
Mid College Chaparral Creek Sidewalk South Side	Sidewalk		62	71	49
Loop 250 EB @ Midland Park Mall	Sidewalk		23	27	17
M Trail @ W of Midland Dr	Shared use path		24	30	16
Beal Parkway @ Beal Park (South Entrance)	Shared use path		N/A	N/A	N/A
UT PB Campus Walk	Shared use path		45	68	10
Center Ave @ 11 St Park Entrance	Sidewalk		20	22	16
San Jacinto Park @ 21St & Fly Ave	Shared use path		13	19	4
Monahans Draw West Monahan @ Kelley	Sidewalk		N/A	N/A	N/A
Monahans Draw East	Sidewalk		156	183	115

N/A = count data not available due to equipment malfunction.

Table 21. Spring 2018 Count Summaries from Wichita Falls, Texas.

Location	Facility Type	User Type	Average Daily Traffic (7-day week)	Average Weekday Daily Traffic	Average Weekend Daily Traffic
Wichita River Trail WB at E of Broad St/IH-44	Shared use path	Bicyclists only	19	22	14
Wichita River Trail EB at E of Broad St/IH-44	Shared use path		14	14	15
US 287 Bus at W of Ridgeway Dr	Bicycle lane		N/A	N/A	N/A
FM 369 NB @ SH 287	Bicycle lane		1	1	1
FM 369 SB @ SH287	Bicycle lane		1	0	2
Burkburnett Rd SB (SH 240) at N of Airport Dr	Bicycle lane		N/A	N/A	N/A
Burkburnett Rd SB (SH 240) at N of Airport Dr	Bicycle lane		3	3	3
Weeks Park Lane @ Granada	Sidewalk	All pedestrians and bicyclists combined	82	80	85
Wichita River Trail at E of River Rd.	Shared use path		23	21	25

N/A = count data not available due to equipment malfunction.

OVERVIEW: DEVELOPING FACTORS TO SCALE CROWDSOURCED BICYCLE VOLUMES

Researchers explored several different approaches to leverage crowdsourced data from Strava Metro to estimate bicycle volumes across the state, focusing on data that practitioners can regularly obtain and implement their own estimates. Therefore, researchers limited the data used to Strava Metro's standard data product, the Texas Department of Transportation's (TxDOT's) Roadway Inventory, and American Community Survey data. Researchers also kept to standard statistical analysis methods, focusing on linear regression.

Researchers found that functional classification, or the type of roadway or trail segment, is a key factor for estimating total use with crowdsourced data. This makes sense because Strava is marketed toward a recreation/fitness-oriented user base, and researchers expected these users to more often choose off-street paths based on previous research. Therefore, researchers expected Strava data to represent a relatively smaller proportion of users on urban arterial streets, where bicyclists may ride more often for work or shopping, rather than recreational trips logged using Strava. Researchers included functional classification (called CLAZZ in Open Street Map or FUN-SYS in TxDOT's Road-Highway Inventory Network [RHiNO] data) to characterize the type of infrastructure on a given segment in the models. Researchers found that the model using the Open Street Map classification (also used in the Strava Metro product) had a lower mean absolute percentage error (29 percent versus 38 percent for RHiNO). Therefore, researchers decided to use the CLAZZ variable instead of FUN-SYS as the roadway functional classification variable.

Income plays a role in the proportion of bicyclists logging trips on Strava, though it is less important in the model than Strava activity or functional classification. Preliminary model testing showed the number of households with income more than $200,000 a year was positively associated to the number of bicycle trips recorded on Strava.

Functional class of infrastructure, Strava activity, and household income form the basis of the model to estimate total bicycle trip volumes, which is described in the next section. Interested readers can find additional detail on model development in associated project report 0-6927-P6.

STEPS TO ESTIMATE BICYCLE TRAFFIC WITH CROWDSOURCED DATA

This section describes how to estimate total bicycle traffic, by combining crowdsourced counts from Strava Metro with functional classification and nearby household income. This example uses data from the Walnut Creek Trail North of Jain Lane in Austin, Texas. The input data for the estimate includes the annual number of bicyclist activities logged via Strava in both directions (TACTCNT = 16,271), the density of households with more than $200,000 income in the given block group ($\text{Household Density}_i = 0$), and the functional classification ($CLAZZ_i$= Cycleway, which is equivalent to a shared use path).

Step 1 – Record Annual Daily Strava Bicyclist Activities

TxDOT has access to Strava Metro data starting in summer 2016, and later, subject to annual contract review, viewable on a web-based interface,[1] or with geospatial datasets for analysis in geographic information system (GIS) software. Strava activity data are available through Strava's Dataviewer[1] and in GIS shapefiles. In the Strava Dataviewer, data are displayed as annual roll-ups of activities, i.e. the total Strava activities are pooled for a given point or linear segment during the entire year. In GIS shapefiles, Strava provides activity count data at different geographies (streets, intersections, areas), and time periods (i.e. annual, monthly, hourly), described further in the current Strava Metro Comprehensive User Guide that is provided with the company's data deliveries. In Strava data, segments are referred to as edges and are assigned a unique identifier. In our example, the edge ID of Walnut Creek Trail is 1644966. The bicyclist activity for the Strava edges can be found in the following files:

- Annual roll-up: texas_201607_201706_ride_rollup_total.csv
- Monthly roll-up: texas_201607_201706_ride_rollup_month_2016_7_total.shp
- Weekday of Month roll-up: texas_201607_201706_ride_rollup_month_2016_7_weekday.shp
- Weekend of Month roll-up: texas_201607_201706_ride_rollup_month_2016_7_weekend.shp

Strava activity are available for both directions of travel (total activity count, TACTCNT), for default direction of travel (activity count, ACTCNT) and for reverse direction of travel (reverse activity count, RACTCNT). Strava does not report the name of the travel direction. The default direction can be identified by using the arrow symbols in ArcGIS.

[1] July 2016–June 2017 Strava Metro data viewable at http://metro-static.strava.com/dataView/TEXAS/201607_201706/RIDE/#5/31.215/-101.239

After selecting the Strava segment (edge) for analysis, review Strava activities on nearby links to check for accuracy problems. Previous research showed that Strava data "had some routes that were double- or triple-counted because of GPS assignment errors" (Wang et al. 2017). If adjacent segments inexplicably change volumes, use the volume that most closely matches the other nearby links.

If using the annual roll-up data, then divide the total activity counts (TACTCNT) by 365 to estimate average daily Strava bicycle traffic (AADB Strava). If monthly, then divide TACTCNT by 30 or the actual number of days in the recorded month. If weekly, then divide TACTCNT by 7 to estimate daily traffic. Finally, round to the nearest integer.

In this case, 16,271 Strava trips were found on our example segment of the Southern Walnut Creek Trail in Austin, resulting in an average annual daily Strava bicyclist estimate of 45.

$$AADB\ Strava_{Walnut\ Creek} = \frac{Annual\ TACTCNT_{Walnut\ Creek}}{365} = 44.57 = 45$$

Step 2 – Identify Segment Functional Classification and Select Equation

Each of the seven functional classifications in Open Street Map (OSM) has a different relationship to total use, given Strava activities and the number of nearby households with annual income over $200,000.

Functional Classification (CLAZZ in Strava Metro's network data from Open Street Map)

Highway, primary (15)	$AADB_i = 63 \times (\exp(AADB\ Strava_i))^{0.038}(\exp(\text{Household} > \ 200\text{K}_{\ i}))^{0.002}$
Highway, secondary (21)	$AADB_i = 13 \times (\exp(AADB\ Strava_i))^{0.038}(\exp(\text{Household} > \ 200\text{K}_{\ i}))^{0.002}$
Highway, tertiary (31)	$AADB_i = 22 \times (\exp(AADB\ Strava_i))^{0.038}(\exp(\text{Household} > \ 200\text{K}_{\ i}))^{0.002}$
Highway, residential (32)	$AADB_i = 17 \times (\exp(AADB\ Strava_i))^{0.038}(\exp(\text{Household} > \ 200\text{K}_{\ i}))^{0.002}$
Highway, path (72)	$AADB_i = 72 \times (\exp(AADB\ Strava_i))^{0.038}(\exp(\text{Household} > \ 200\text{K}_{\ i}))^{0.002}$
Cycleway (81)	$AADB_i = 62 \times (\exp(AADB\ Strava_i))^{0.038}(\exp(\text{Household} > \ 200\text{K}_{\ i}))^{0.002}$
Footway (91)	$AADB_i = 28 \times (\exp(AADB\ Strava_i))^{0.038}(\exp(\text{Household} > \ 200\text{K}_{\ i}))^{0.002}$

Definitions and examples of these and other CLAZZ functional classes in OSM can be found here: https://wiki.openstreetmap.org/wiki/Key:highway.

Since the Walnut Creek example is a Cycleway, researchers chose the following equation:

$$AADB_{Walnut\ Creek} = 62 \times (\exp(AADB\ Strava_{Walnut\ Creek}))^{0.038} \times$$

$$(\exp(\text{Household} > \ 200\text{K}_{\ Walnut\ Creek}))^{0.002}$$

Step 3 – Plug in Values to Excel

Insert the daily count of Strava trips (45), and the number of high-income households (0), and the equation becomes:

$$AADB_{Walnut\ Creek} = 62 \times (\exp(45))^{0.038}(\exp(0))^{0.002}$$

To write this equation in Excel, enter the following in a spreadsheet cell:

=62*(EXP(45)^0.038)*(EXP(0)^0.002)

Average Annual Daily Bicyclist traffic at Walnut Creek = 343

The results show that the predicted number of bicycles on this segment is equal to 343. Calculation of lower and upper prediction intervals for AADB are 272 and 412 respectively. Additional detail on prediction interval calculation is provided in Appendix B of associated research report 0-6927-P6. Note that the observed counts are 304 at this trail, indicating that the AADB model predicted the ground count at this location relatively accurately.

Step 4 – Review Results

Finally, review these results against local knowledge and reasonableness. There are several reasons why this model might over-or-under predict bicycle traffic. Strava use itself may be particularly high or low in a certain area. It might over-estimate such if a major event took place during the Strava sampling period; or under-estimate if Strava use is particularly low. Researchers expect higher fluctuations in rural areas with lower overall Strava use, as compared with urban areas.

Changes in segment classification over time, such as upgrading a street from a tertiary to secondary segment, could significantly impact bicycle traffic estimation values. Similarly, any errors in the classification will expand error of the traffic estimate. High-income households have a relatively minor, yet statistically significant, role in scaling Strava activities to estimate totals. However, there may be bicyclist count areas that do not respond to residential income in a predictable manner, such as bicycling loops in large parks. Use of the route in the park may be rather homogenous, but nearby residential income could skew traffic estimates when they do not, in practice, impact bicycling rates.

This traffic estimation technique is designed to work even with zero Strava activities, since the input data used counts at some low-activity-bicycling locations throughout the state. Table 22 can be used to review against estimates with low Strava activity levels.

Table 22. Estimated Daily Annualized Bicyclist Counts for Low Strava Sample Sizes by OSM Roadway Class.

Strava Sample Counts	Highway, primary (15)	Highway, secondary (21)	Highway, tertiary (31)	Highway, residential (32)	Highway, path (72)	Cycleway (81)	Footway (91)
0	63	13	22	17	72	63	28
5	76	16	26	21	87	76	34
10	92	19	32	26	105	92	41
20	134	29	46	37	153	135	59

SUMMARY AND CAVEATS OF USING AADB ESTIMATION MODELS

To develop the AADB models, researchers have used the ground counts collected from 100 count stations. The ground counts were mainly collected from urban areas and shared use paths. Moreover, as indicated earlier, Strava uses Open Street Map (OSM) as the basemap. OSM classifies the roadways into 22 categories or CLAZZ (Appendix B of associated research report 0-6927-P6). The sites used in this study only represent 7 CLAZZ categories. Although the model goodness of fit measures are within acceptable range (i.e. 29% error margin, and 70% accuracy level), the researchers suggest that the practitioners take caution when implementing these models to estimate the bicycle counts on: 1) rural highway segments; 2) CLAZZs that are not included in this study; and 3) analyzed road segments located in an area with a high proportion of high-income residents. Appendix B of associated research report 0-6927-P6 provides further guidelines on how the AADB model can be used to estimate the AADB counts for the roadway functional classes that were not included in the modelling process.

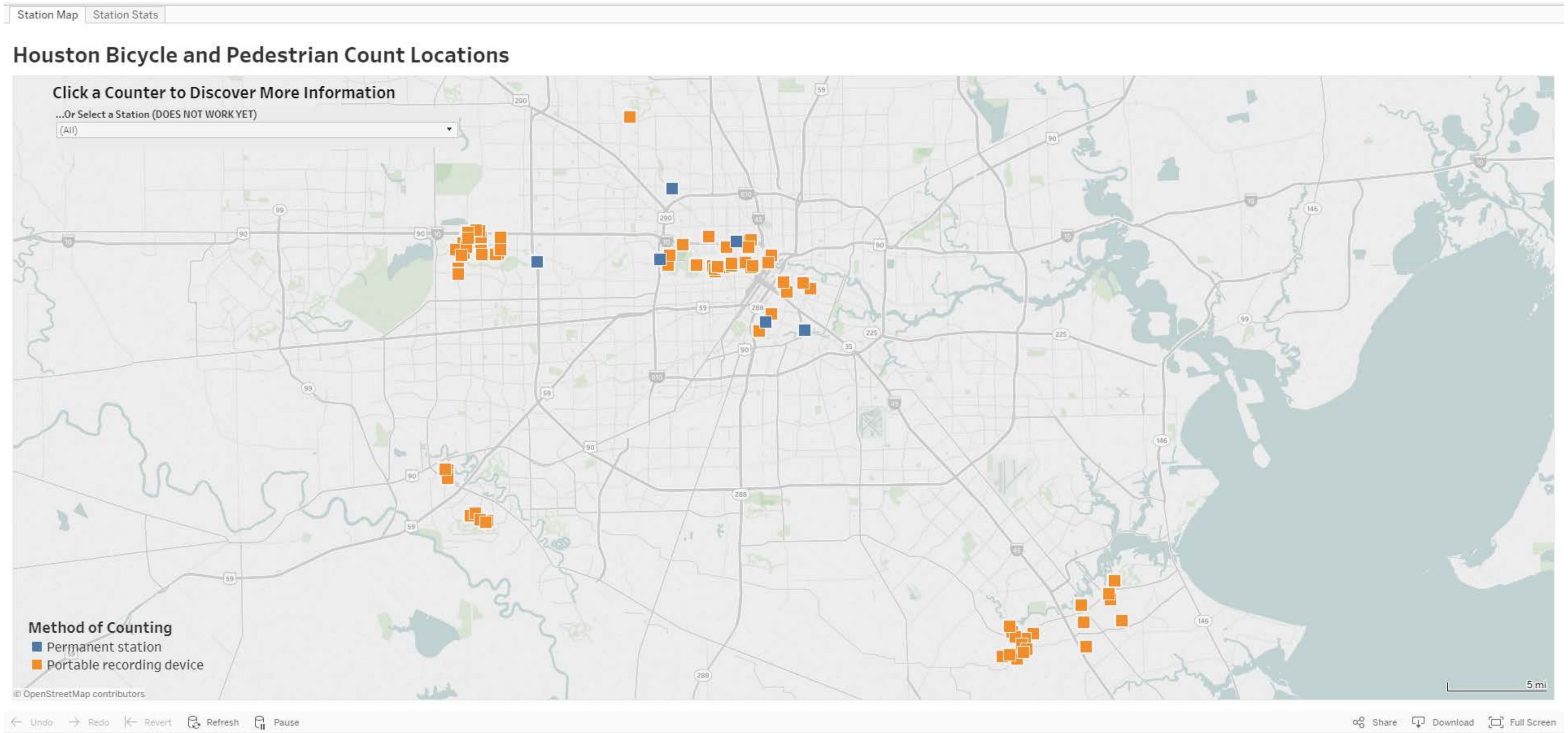
CHAPTER 7. PEDESTRIAN AND BICYCLIST DATABASE

One of the two primary objectives of this project was to develop a consolidated database of pedestrian and bicyclist counts from the two pilot cities, as well as readily available pedestrian and bicyclist count data from other locations in Texas and four small and mid-sized cities collected as part of this research. This chapter briefly summarizes the development of this database. Separate technical documentation on the database is contained in TxDOT report 0-6927-P7 and includes details on the data dictionary and basic analytic features in the database and is available upon request.

Researchers developed a consolidated database that included 350 unique pedestrian/bicyclist count locations in 11 cities, of which 84 were permanent continuous count sites and 266 were short-duration (e.g., at least seven days) count sites. TTI also defined a standardized data dictionary that was consistent with FHWA's TMG, but included additional attributes that were deemed necessary for TxDOT monitoring needs. The data dictionary also includes attributes that describe the count location and supporting information about the actual pedestrian and bicyclist counts. A total of 63 attributes (28 are required, 35 are optional) are defined for each count location, and 17 attributes (10 are required, 7 are optional) are defined for the count data.

The database includes an interface that provides several basic analytic functions that can be used to easily summarize and visualize the count data. Figure 37 shows the map-based home screen for the database interface (zoomed in to Houston for this example). Figure 38 shows several charts and statistics provided to the user after a specific count location is selected. These count station and site details include:

- Basic count location statistics (upper left section of display).
- Daily or sub-daily count values for the selected location (upper right section of display).
- Day-of-week count averages for the selected location (lower left section of display).
- Time-of-day count average for the selected location (lower right section of display).



(Note: zoomed to Houston for example)

Figure 37. Map-Based Home Screen Display for Statewide Database.

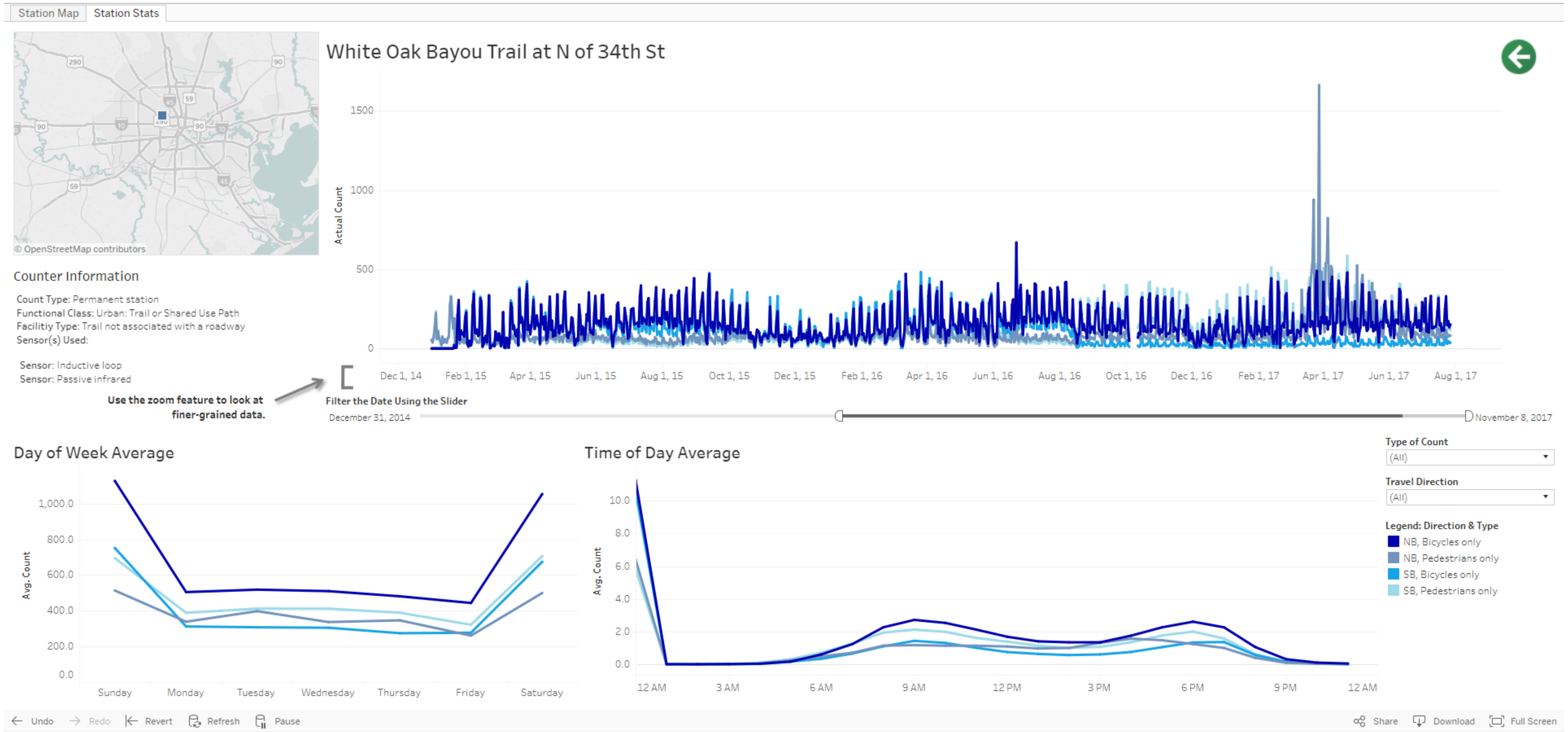


Figure 38. Interface Display for Selected Pedestrian and Bicyclist Count Location.

CHAPTER 8. SEASONAL ADJUSTMENT FACTORS

Seasonal adjustment factors are used to process short-duration traffic counts to more accurately estimate annual average daily traffic (AADT), one of the most common traffic count statistics. For example, if bicyclist counts are collected during a month when fewer bicyclists are riding, the collected bicyclist counts should be adjusted up to better represent annual average bicycling levels. Similarly, if pedestrian counts are collected during a month when more people are walking, these collected pedestrian counts should be adjusted down to better represent annual average walking levels. Traffic count analysts routinely use seasonal adjustment factors to annualize motor vehicle counts, as recommended in the Federal Highway Administration's Traffic Monitoring Guide (TMG) (FHWA 2016).

Researchers developed pedestrian and bicyclist seasonal adjustment factors using the methods outlined in the 2016 edition of the TMG. For non-motorized traffic, these methods are detailed in pages 4-25 through 4-32 (Section 4.4). The factor development methods for non-motorized traffic are very similar to those for motorized traffic detailed on pages 3-16 through 3-30 (Section 3.2.1). In general, the method is outlined as follows:

1. **Create a summary of traffic count patterns from continuous counters:** Develop month-of-year, day-of-week, and time-of-day summary charts.
2. **Identify distinct traffic patterns:** Examine charts to identify which continuous counters are most similar or dissimilar.
3. **Classify continuous counters into unique factor groups:** Combine continuous counter locations into unique factor groups.
4. **Calculate average adjustment factors from each factor group:** Calculate average adjustment factors that can be applied to short-duration counts.

In Step 1, researchers created numerous charts to display pedestrian and bicyclist count patterns separately by time-of-day, day-of-week, and month-of-year (see Appendix A in associated research report 0-6927-P6). These charts were created for all 17 permanent counters that had at least one full calendar year of complete and valid count data.

In Steps 2 and 3, researchers examined the pedestrian and bicyclist count patterns for each available count location, and classified each location into one of these factor groups as listed in the 2016 TMG:

- Commuter and work/school-based trips: typically have the highest peaks in the morning and evening.
- Recreation/utilitarian: may peak only once daily or be evenly distributed throughout the day.
- Mixed trip purposes (both commuter and recreation/utilitarian): have varying levels of these two different trip purposes, or may include other miscellaneous trip purposes.

TTI's preliminary analysis identified the following number of permanent counter locations in each factor group:

- Commuter and work/school-based trips: one location for pedestrians, one different location for bicyclists.
- Recreation/utilitarian: five locations for pedestrians, two locations for bicyclists.
- Mixed trip purposes: 11 locations for pedestrians, 10 locations for bicyclists.

Since the statewide pedestrian and bicyclist count database currently includes only short-duration counts of at least seven days (including at least one day of each day of the week), the seasonal adjustment would only need to account for the month of year and not the day of week. Therefore, researchers further analyzed the preliminary factor groups by examining the month-of-year patterns. In looking at these seasonal patterns, researchers concluded that the month-of-year patterns were quite similar, even among different factor groups (Figure 39). To simplify the seasonal adjustment process, TTI combined all analyzed permanent count locations in the three factor groups to create month-of-year count adjustment factors (Figure 40).

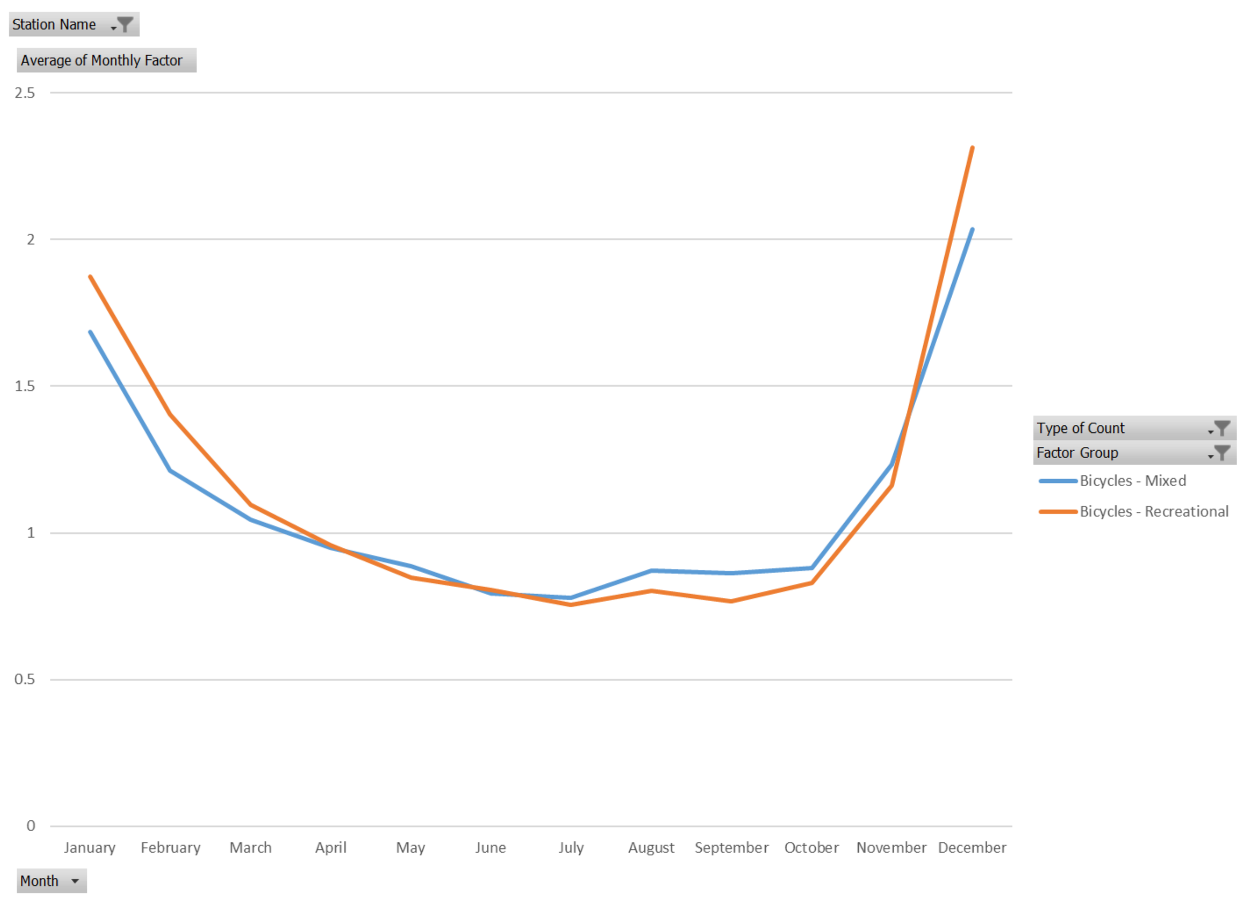


Figure 39. Chart Illustrating Similar Seasonal Patterns for Different Factor Groups.

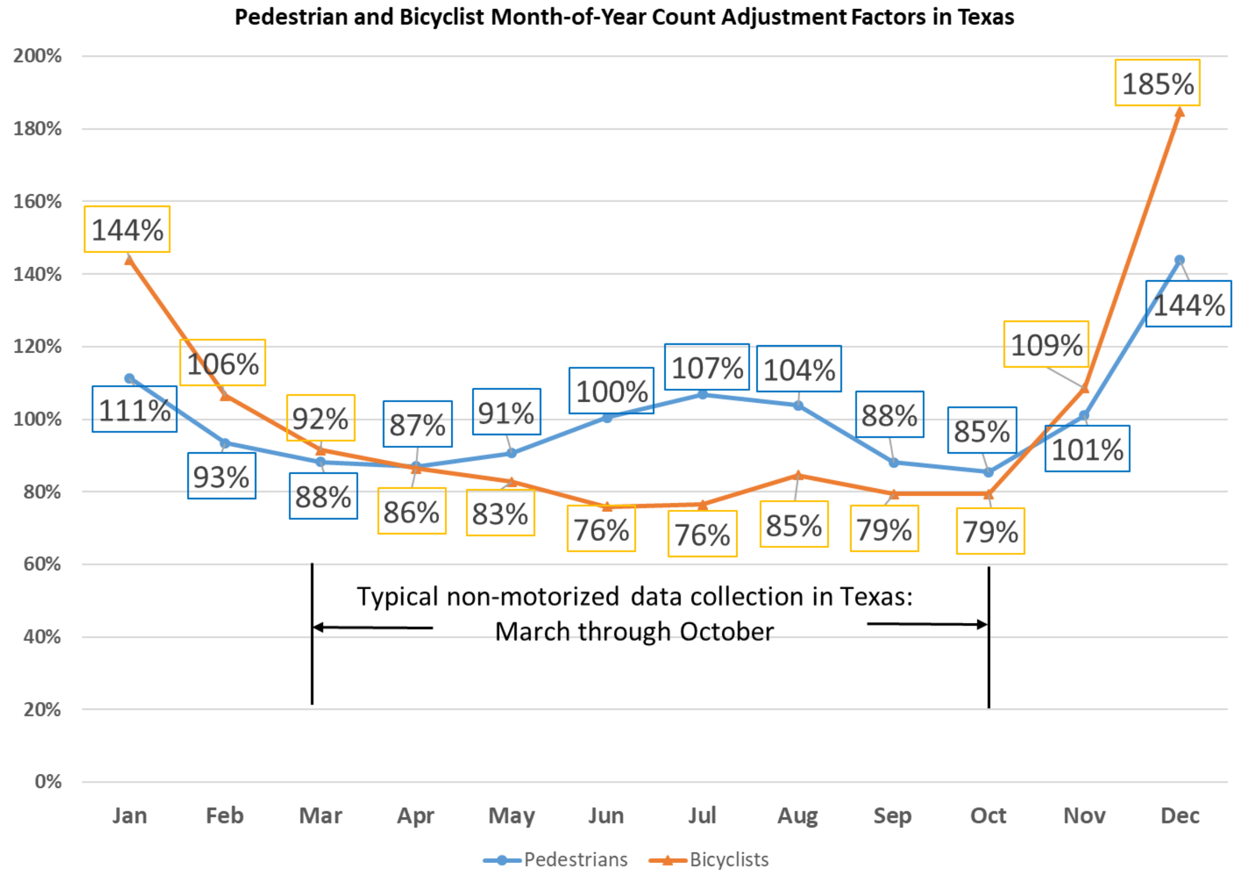


Figure 40. Month-of-Year Count Adjustment Factors for Short-Duration Counts.

To apply these adjustment factors, the seven-day average daily traffic (ADT) volume is multiplied by the factor corresponding to the travel mode and month of short-duration counts. For example, if a seven-day ADT in July for pedestrians is 100 persons, then the annualized ADT (or AADT) is 100×107 percent, or 107 pedestrians. Similarly, if a seven-day ADT in April for bicyclists is 50, then the AADT is 50×86 percent, or 43 bicyclists.

CHAPTER 9. CONCLUSIONS AND RECOMMENDATIONS

OVERALL MONITORING PROGRAM RECOMMENDATIONS

Previous sections in this report identified several elements that contribute to a successful nonmotorized traffic monitoring program:

- Complementing a modest number of permanent, continuous monitoring sites with a larger number of short-duration sites (using portable equipment). The continuous count sites provide extensive time coverage at a limited number of locations, while the short-duration sites provide extensive geographic coverage for a limited time duration.
- Cooperation, coordination, and communication between state (TxDOT) and local agencies to clearly define who does what for nonmotorized traffic monitoring.
- Understanding the role of crowdsourced data in nonmotorized traffic monitoring.

Based on the findings of this research project, TTI recommends the following roles for TxDOT in nonmotorized traffic monitoring:

- **Establishing and maintaining a statewide data clearinghouse:** This research project is already pursuing this objective by gathering and compiling readily available nonmotorized count data, but further efforts are necessary to fully implement this statewide data clearinghouse function. TxDOT should procure an enterprise-level data clearinghouse that provides flexibility for various data reporting and management functions. TxDOT should also formalize procedures and agreements with local agencies to routinely upload their nonmotorized count data, with quality control a joint responsibility.

- **Supplemental monitoring on high-priority state highways:** Numerous local agencies are already collecting nonmotorized count data for their own uses on mostly local streets and shared use paths. Therefore, TxDOT should focus any additional efforts on supplemental monitoring of high-priority state highways that are not currently being monitored by these local agencies. Ideally, these state highway-based monitoring systems would be maintained by local entities, TxDOT district staff, or the TxDOT traffic monitoring staff who maintain motorized traffic equipment. The TxDOT Bicycle and Pedestrian Program (within the Public Transportation Division) currently has insufficient staff and resources to maintain these supplemental monitoring sites on state highways.

- **Facilitating coordination and sharing best practices:** TxDOT should facilitate coordination among the local agencies and TxDOT districts, such that best practices can be shared among these groups. Some best practices have been identified and shared through this research project, but there is benefit to having ongoing communication and coordination among those agencies within Texas that are monitoring nonmotorized traffic. The Colorado DOT created a Traffic Data Committee, which met monthly to share information about their plans and practices.

- **Expediting counter deployment by local agencies and TxDOT districts:** Some local agencies or TxDOT districts have technical or financial difficulty purchasing and/or installing nonmotorized counter equipment. TxDOT should work to expedite counter deployment, so that these agencies can then provide their local data to TxDOT's statewide data clearinghouse. TxDOT can expedite counter deployment by: 1) providing small grants to purchase equipment; 2) buying and installing permanent counters, then transferring operations and maintenance responsibilities to local entities or districts; and 3) loaning portable counter equipment that can be borrowed for up to one month. One condition of these purchase grants or loaner equipment could be that the agency must submit their collected data to TxDOT's statewide data clearinghouse.

SPECIFIC DATA COLLECTION RECOMMENDATIONS

Short-duration counts revealed details about how people move about the area on foot or by bicycle. Collecting a week or more of data can prove valuable in answering questions about where people walk and bicycle which in turn will guide transportation project development.

One such example pertains to walking and bicycling along I-35. The Mobility35 Project is a major effort where congestion, safety, and other concerns along I-35 are being addressed through various projects. Bicycle and pedestrian accommodations are included in the Mobility35 Project; however, very little data about how people walk and bicycle along and across the highway exist. As part of this research project, bicycle and pedestrian data were collected on the shared use paths/bridges adjacent to the northbound and southbound frontage roads across Lady Bird Lake. The counter along the southbound frontage road recorded 1,400 users during the deployment period while the one adjacent to the northbound frontage road recorded over 8,500 users. Understanding the reason for this large difference may help agencies develop projects that improve accommodations, connections, and/or safety concerns for pedestrians and bicyclists.

Based on the short-duration counter deployment and the permanent counter installation, the following recommendations should guide future nonmotorized data collection efforts:

- Leverage partnerships with local agencies to access materials, labor, and equipment for installation of permanent counters; to operate and maintain permanent counters; and, additional funds to purchase more counters. Coordinating with the City of Austin proved helpful in borrowing a blower and water containers for the concrete saw work, purchasing plywood to cover caulk for curing, and setting up the work zone. In addition, working with partners in Houston resulted in the acquisition of additional permanent counters.

- For maximizing short-duration count data, deploy equipment every two weeks to capture at least two weekends and an entire week in between. To do this, deploy on Thursday, pick up 13 days later on Wednesday, download data, and re-deploy on Thursday.
- Short-duration counts are highly variable, and caution should be exercised when attempting to expand or factor data. Count data should be expressed as weekday averages and weekend averages. Using a total sum of counts over multiple days is problematic when comparing locations that have differing deployment durations.
- Understand the advantages and disadvantages of short-duration counter equipment. For example, advantages of TRAFx counters are that they are inexpensive and easy to deploy and pick up. Disadvantages are that they only detect a total number of users (pedestrians and bicyclists combined) and directional information is not recorded.
- Different equipment options have different limitations or challenges. One limitation of infrared counters is that they must be aimed away from motor vehicles or moving vegetation. As a result, site location needs to be carefully chosen. Install infrared counters on a post or pole between the bicycle/pedestrian facility and the roadway travel lanes, aiming away from traffic to a fence or other fixed structure.
- Invest in permanent counters that provide maximum data collection possibilities. Knowing the count data for each mode separately and by direction will prove useful for understanding variability and facility usage, in developing and refining seasonal adjustment factors, and in applying expansion factors for crowdsourced data. Install these counters in locations that provide a regional perspective about walking and bicycling.

CROWDSOURCED DATA FINDINGS

Crowdsourced bicycling data, such as those from Strava and Ride Report used in this study, can be useful when coupled with local counts. Pedestrian trips are not commonly logged using crowdsourcing platforms and were found to poorly represent actual total use. This report presented an approach to calculating an adjustment factor to expand crowdsourced bicycling trips to estimate total bicycle traffic volume for individual locations. The following are key findings of this study for crowdsourced bicycling data:

- Crowdsourced bicycle volumes represented a small fraction of all trips, varying widely by data source and monitoring site. For example, Strava counts were found to vary from 0 to 63 percent of total bike traffic among 100 count sites across Texas. This variation in sample percentage makes it challenging to expand Strava counts at other locations where total counts of bike traffic do not exist.

- Although the accuracy of the model to scale crowdsourced data to estimate total bicyclist counts is within acceptable range, the researchers suggest that the practitioners take caution when implementing these models to estimate the bicycle counts on: 1) rural highway segments; 2) CLAZZs that are not included in this study; and 3) analyzed road segments located in an area with a high proportion of high-income residents.
- As advancements in crowdsourcing methods continue and technology changes, the utility of these approaches for calculating and utilizing crowdsourced data in transportation planning will be affected as well.

SEASONAL ADJUSTMENT OF SHORT-DURATION COUNTS

Seasonal adjustment factors are used to process short-duration traffic counts to more accurately estimate annual average daily traffic (AADT), one of the most common traffic count statistics. Traffic count analysts routinely use seasonal adjustment factors to annualize motor vehicle counts, as recommended in the Federal Highway Administration's Traffic Monitoring Guide (TMG) (FHWA 2016).

In this project, researchers developed pedestrian and bicyclist seasonal adjustment factors using the methods outlined in the 2016 edition of the TMG. In analyzing the seasonal patterns, researchers concluded that the month-of-year patterns were quite similar, even among different factor groups. To simplify the seasonal adjustment process, TTI combined all analyzed permanent count locations in the three factor groups to create month-of-year count adjustment factors. TTI recommends that all short-duration pedestrian and bicyclist count data be seasonally adjusted using the adjustment factors presented in Chapter 8 of this report.

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