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Abstract

This report contains six chapters that document the activities related to counting bicycles and pedestrians, modeling techniques for non-motorized demand, and developing a non-motorized counting plan for the HGAC region. The chapter titles and brief summary include:

1. PEDESTRIAN AND BICYCLIST MONITORING -- EQUIPMENT AND METHODS – A literature review of the state of the art and state of the practice on counting technologies, describing the strengths weaknesses and challenges of counting bicycles and pedestrians.
2. COUNTING EQUIPMENT – GUIDANCE AND INSTALLATION – Two permanent counting stations were installed and guidance on placement, settings and best practices for portable pedestrian and bicycle (non-motorized) counters were provided. A bike classification scheme was developed to more accurately count bikes using pneumatic tube counters. Draft interlocal agreements were developed addressing deployment, operation, and maintenance responsibilities for both the permanent and short term use devices and may be used for interagency loan and use of the temporary count equipment.
3. DEVELOP PEDESTRIAN AND BICYCLE COUNTING PLAN – Existing count locations and counts were gathered and summarized to use as the basis of the non-motorized count plan. A concept of permanent and short term counts, similar to what is done for motorized traffic was developed to sample and apply factors to the short term counts.
4. DATA COLLECTION AND REPORTING STRUCTURE – A conceptual level data repository with a list of elements was developed based on literature and desire to develop bike and pedestrian indices.
5. PEDESTRIAN AND BICYCLE DEMAND ESTIMATION – A model was developed from household travel survey data to estimate current demand. Indices based on roadway, and traffic characteristics were calculated and gaps between supply and demand were shown graphically with maps.

Key Words
Bicycle Counting, Pedestrian Counting, Bicycle Classification, Pedestrian Classification, Non-Motorized Counting, Non-Motorized Classification, Bicycle and Pedestrian Travel Demand Estimation, Non-Motorized Travel Demand Estimation

HGAC PEDESTRIAN-BICYCLIST COUNTING AND DEMAND STUDY

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DISCLAIMER

This research was performed in cooperation with the Houston-Galveston Area Council (H-GAC). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the H-GAC. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The research engineer in charge of the project was Robert J. Benz, P.E. # . 85382

The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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TABLE OF CONTENTS

Page

DISCLAIMER .... **v**
ACKNOWLEDGMENTS .... **vi**
TABLE OF CONTENTS .... **vii**
List of Figures .... **ix**
List of Tables .... **x**
Chapter 1: PEDESTRIAN AND BICYCLIST MONITORING EQUIPMENT AND METHODS **1**
INTRODUCTION 1
MONITORING EQUIPMENT AND TECHNOLOGY 2
Overview and Challenges 2
Inductance Loop Detectors 3
Infrared Sensors 6
Magnetometers 11
Pneumatic Tubes 11
Pressure and Acoustic Sensors 12
Video Image Processing 14
Chapter 2: Counting Equipment Guidance and Installation **17**
Chapter 3: Develop Pedestrian and BicycleCounting Plan **21**
Existing Non-Motorized Transportation System Counts 21
Project Agency and Advocacy Input 23
Methodology 23
Count Location Criteria 24
Permanent Count Location Considerations 26
Development of a Draft Count Plan 28
Chapter 4. Data Collection and Reporting Structure **31**
Statement of the Problem 31
Existing Counts 32
Database Needs 33
Database Elements 33
Adjustment Factors 35
Chapter 5: Modeling Regional Non-Motorized Travelin H-GAC Area **37**
Literature Review 37
Nation-Wide Walking and Biking Modeling Effort Guidebook on Methods to Estimate Non-Motorized Travel (1) 37

Guidelines for Analysis of Investments in Bicycle Facilities (2) 39
Estimating Bicycling and Walking for Planning and Project Development (3) 40
H-GAC Area-wide Walking and Biking Modeling Effort 40
Methodology 41
Non-Motorized Travel Current Demand 42
Non-Motorized Travel Supply 46
Bicycle Travel Supply 46
Recommendation for Improving the Friendliness of Roadway to Bicycling Travel 50
Pedestrian Travel Supply 52
Recommendation for Improving Walking Supply 56
Interaction between Demand and Supply 56
Pedestrian Travel Demand and Supply 63
Integration with Super Neighborhoods 63
Case Study 67
Pedestrian Project 67
Bicycle Project 69
Case Study Recommendations 71
Conclusion 71
Limitations and Future Research 72
Chapter 6: Project Summary 71
Chapter 1. Pedestrian and Bicyclist Monitoring -- Equipment 71
and Methods 71
Chapter 2. Counting Equipment – Guidance and Installation 72
Chapter 3. Develop Pedestrian and Bicycle Counting Plan 73
Chapter 4. Data Collection and Reporting Structure 74
Chapter 5. Pedestrian and Bicycle Demand Estimation 75
Conclusions and Next Steps 75
References 77
Appendix A 78
Appendix B 3
Appendix C 3
Appendix D 4
Appendix E 3
Appendix F 3

LIST OF FIGURES

Page

Figure 1-1. Examples of Inductance Loop Detector Shapes for Bicyclist Counting. 7

Figure 1-2. Example of Passive Infrared Sensor Combined with Inductance Loop Detectors 9

Figure 1-3. Different Types of Infrared Counters for Non-Motorized Traffic. 10

Figure 1-4. Typical Configuration for Passive Infrared Sensor. 10

Figure 1-5. Example of Pneumatic Tube Configuration for Counting Directional Bicyclist Traffic. 12

Figure 1-6. Examples of Pressure Sensors on Natural (a) and Paved (b) Surfaces 13

Figure 1-7. Example of Video Image Processing for Tracking and Counting Non-Motorized Traffic. 14

Figure 3-1. Existing Harris County ITE National Bicycle and Pedestrians Documentation 22

Figure 3-2. Existing and Proposed Bike and Pedestrian Count Locations. 29

Figure 5-1. Current Demand for Non-Motorized Travel in H-GAC Area. 43

Figure 5-2. Current Demand for Walking Travel in H-GAC Area. 44

Figure 5-3. Current Demand for Biking Travel in H-GAC Area. 45

Figure 5-4. Bicycle Compatibility Index for the H-GAC Area. 51

Figure 5-5. Pedestrian Friendliness Index for the H-GAC Area. 53

Figure 5-6. Pedestrian Friendliness Index for the Harris County. 54

Figure 5-7. Supply and Demand for Bicycle Travel in H-GAC Area. 58

Figure 5-8. Supply and Demand for Bicycle Travel in Harris County. 59

Figure 5-9. Supply and Demand for Bicycle Travel in Houston Downtown Area. 60

Figure 5-10. High, Medium and Low Level of Undersupplied Road Sections for Bicycle Travel in H-GAC Region 62

Figure 5-11. High, Medium, and Low Level of Undersupplied TAZ for Pedestrian Travel .... in H-GAC Region. 64

Figure 5-12. Undersupplied Bike Travel Road Sections in the Super Neighborhoods. 67

Figure 5-13. Undersupplied Pedestrian Travel TAZs in the Super Neighborhoods. 68

Figure 5-14. Proposed Sidewalk Project Location. 69

Figure 5-15. Proposed Bicycle Project Location. 70

LIST OF TABLES

Page

Table 1-1. Bicyclist and Pedestrian Monitoring Technologies. 4

Table 1-2. Overview of Automatic, Commercially-Available Pedestrian and Bicyclist Counters. 5

Table 3-1. Bicycle Count Matrix Based on Lane Miles of Facility Type and Area Type. 24

Table 3-2. List of Existing and Proposed Count Locations. 26

Table 5-1. Indicators of Pedestrian and Bicycle Travel Demand. 41

Table 5-2. Bicycle Compatibility Index (BCI) Model, (in English units). 46

Table 5-3. Speed Assumptions Made for BCI Calculation. 48

Table 5-4. Area Values for BCI Calculation. 48

Table 5-5. Adjustment Factors for BCI Calculation. 49

Table 5-6. Undersupplied Road (BCI>5.3 and Non Motor Trips>1000) 61

Table 5-7. Indicators and Variables Chosen for Final Composite Indicator. 65

Table 5-8. Top 25 Biking and Walking Friendly Neighborhoods in H-GAC Area. 66

Table 5-9. Calculation Procedure of TAZ 2490. 69

Table 5-10. BCI Calculation Procedure. 70

CHAPTER 1: PEDESTRIAN AND BICYCLIST MONITORING EQUIPMENT AND METHODS

INTRODUCTION

This report summarizes the state-of-the-practice for pedestrian and bicyclist monitoring equipment and methods. The information gathered in this chapter will inform subsequent chapters in this project:

- Chapter 2 – Counting Equipment Guidance and Installation
- Chapter 3 – Develop Pedestrian and Bicyclist Counting Plan
- Chapter 4 – Data Collection and Reporting Structure

A literature search and review was performed to establish the state of the practice. An extensive list of resources is compiled in Appendix A. These resources were used to develop this report.

In general, pedestrian and bicyclist monitoring is an emerging practice and definitive guidance is not well established. Even though both of these modes preceded the automobile, the monitoring of non-motorized traffic has not been systematic or widespread in the US and, even today, is not nearly as comprehensive as motorized traffic monitoring.

One of the key differences in state-of-the-practice between non-motorized and motorized traffic monitoring is the scale of data collection. Most non-motorized data collection programs have a much smaller number of monitoring locations, and these limited location samples may not accurately represent the entire geographic area of interest. In many cases, the non-motorized monitoring locations have been chosen based on highest usage levels or strategic areas of facility improvement. Given limited data collection resources and specific data uses, these site selection criteria may be appropriate. However, one should recognize that location samples may be accurate use indicators at each specific location, but may represent a biased estimate of use levels and trends for a city or state. More research is needed to identify statistically-representative site selection criteria.

Another key difference is that non-motorized traffic will typically have higher use levels on lower functional class roads and streets, simply because of the more pleasant environment of lower speeds and volumes of motorized traffic. Conversely, motorized traffic monitoring focuses on the higher functional class roads as these roads provide the quickest and most direct route for motorized traffic.

Finally, the last key difference in current practice is a tendency to use very short duration counts (i.e., as short as 2 hours) for non-motorized traffic monitoring, primarily because of the perceived difficulty of automatically counting pedestrians and bicyclists (as well as the desire to collect gender and bicycle helmet use). Although this practice is not prohibited, data users must recognize that these very short-duration counts can introduce significant overall error when non-motorized traffic use is low and inherently variable.

MONITORING EQUIPMENT AND TECHNOLOGY

This section describes the various technologies that are commonly used to count non-motorized (i.e., bicyclists and pedestrians) traffic volumes at fixed locations. The discussion differentiates between those technologies best suited to count bicyclists versus those best suited to count pedestrians. The discussion also identifies those technologies that are ideal for short-duration (i.e., portable) count locations and those that are ideal for continuous (i.e., permanent) count locations. This section does not address technologies that collect other attributes of non-motorized travel, such as the use of GPS-enabled mobile devices for trip traces or the use of Bluetooth-enabled devices for origin-destination or travel time.

Overview and Challenges

Many of the basic technologies used to count bicyclists and pedestrians are similar to that used to count cars and trucks; however, the design/configuration of the sensors and the signal processing algorithms are often quite different. Therefore, separate equipment typically is used to monitor non-motorized traffic.

There are a few technological challenges to non-motorized traffic monitoring:

- Pedestrians and bicyclists are less confined to fixed lanes or paths of travel than motor vehicles, and they sometimes make unpredictable movements. Pedestrians take shortcuts off the sidewalk or cross streets at unmarked crossing locations. Bicyclists sometimes ride on sidewalks or travel outside designated bikeways. They may stop in front of a sensor to talk, wait, or even to examine the sensor. These actions make it difficult to place or aim sensors and may decrease the accuracy of the sensor equipment.
- Pedestrians and bicyclists sometimes travel in closely-spaced groups, and some sensors have difficulty differentiating between individuals within the group. In these cases, a group with multiple persons will be counted as one person, and the sensor will underestimate the actual counts.

Despite these challenges, there are several technologies that can be used to accurately count non-motorized traffic. The growing demand for automatic bicyclist and pedestrian counters has brought about improvements in equipment accuracy and capabilities. Increased competition in this marketplace and collective experience with existing products will continue to drive improvements to automatic bicyclist and pedestrian counters.

Table 1-1 summarizes the technologies for counting bicyclists and pedestrians, various attributes of each technology, and their strengths and weaknesses. Table 1-2 summarizes specific commercially-available counters for bicyclists and pedestrians.

Inductance Loop Detectors

Inductance loop detectors operate by circulating a low alternating electrical current through a formed wire coil embedded in the pavement. The alternating current creates an electromagnetic field above the formed wire coil, and a conductive object (e.g., car, truck, bike) passing through the electromagnetic field will disrupt the field by a measurable amount. If this disruption meets predetermined criteria, then detection occurs and an object is counted by a data logger or computer controller.

Inductance loop detectors do not require the presence of ferrous (i.e., iron, steel) bicycle frames; however, large conductive objects (like a car or truck) are more likely to meet the predetermined "disruption" criteria than smaller conductive or non-ferrous objects (like a motorcycle or bicycle). The sensitivity of an inductance loop can be changed to better detect motorcycles or bicycles, but the increased sensitivity often results in over counting for cars and trucks. For this reason, most agencies typically use dedicated loop detectors for counting bicycles rather than trying to use existing loop detectors to count cars, trucks, and bicycles.

Loop detectors are commonly used to detect the presence of motor vehicles at or near intersections for the purposes of traffic signal control. In some cases, these loop detectors may detect the presence of bicycles. However, the location and configuration of these intersection-based loop detectors are often not ideal for counting purposes, both for motor vehicles and bicycles.

The preferred counting location is at mid-block or other locations where bicycles are free-flowing and/or not likely to stop. Ideally, loop detectors for bicycle counting are placed in lane positions primarily used by bicycles. If the loop detectors are placed in lanes shared by motorized traffic and bicycles, then special algorithms will be necessary to distinguish the bicycles from the motorized traffic.

Inductance loop detectors are capable of measuring the direction of bicyclist travel using at least two possible options:

1. Installing an inductance loop within each directional travel "lane" and assuming that all (or a certain percentage) bicyclists in that "lane" are traveling in the specified direction (e.g., shared-use path or directional bike lane).

Table 1-1. Bicyclist and Pedestrian Monitoring Technologies.

Technology	Typical Applications	Strengths	Weaknesses
Inductance Loop	Permanent counts Bicyclists only	Accurate when properly installed and configured Uses traditional motor vehicle counting technology	Capable of counting bicyclists only Requires saw cuts in existing pavement
Infrared – Active	Short-term or permanent counts Bicyclists and pedestrians combined	Relatively portable Low profile, unobtrusive appearance	Cannot distinguish between bicyclists and pedestrians unless combined with another bicycle detection technology Very difficult to use for bike lanes and shared lanes
Infrared – Passive	Short-term or permanent counts Bicyclists and pedestrians combined	Very portable with easy setup Low profile, unobtrusive appearance	Cannot distinguish between bicyclists and pedestrians unless combined with another bicycle detection technology Difficult to use for bike lanes and shared lanes, requires careful site selection and configuration
Magnetometer	Permanent counts Bicyclists only	May be possible to use existing motor vehicle sensors	
Pneumatic Tube	Short-term counts Bicyclists only	Relatively portable, low-cost Uses traditional motor vehicle counting technology	Capable of counting bicyclists only Tube and nails to attach may pose hazard to bicyclists
Pressure / Acoustic	Permanent counts Bicyclists and pedestrians separately Typically unpaved trails or paths	Some equipment able to distinguish bicyclists and pedestrians	Expensive/disruptive for installation under asphalt or concrete pavement
Video Imaging - Automated	Short-term or permanent counts Bicyclists and pedestrians separately	Potential accuracy in dense, high-traffic areas	Typically more expensive for exclusive installations Algorithm development still maturing
Video Imaging – Manual Reduction	Short-term counts Bicyclists and pedestrians separately	Can be lower cost when existing video cameras are already installed	Limited to short-term use Manual video reduction is labor-intensive
Manual Observer	Short-term counts Bicyclists and pedestrians separately	Very portable	Expensive and possibly inaccurate for longer duration counts

Table 1-2. Overview of Automatic, Commercially-Available Pedestrian and Bicyclist Counters.

Company and Product Name	Technology	Required surface type	Cost per counter (US $)[1]	Battery life (months)	Trail user type[2]	Remote data retrieval	Directional monitoring[3]	Time intervals[4]
EcoCounter: Pyro	Passive Infrared	Any	$2,350	120	No	Optional GSM[5]	Yes	Yes
TRAFx: Infrared Trail Counter	Passive Infrared	Any	$748[6]	36	No	No	No	Yes
Diamond Traffic: TTC-4420	Active Infrared	Any	$499	12-15	No	No	No	Yes
Cuesta Systems: RS501, TS601	Active Infrared	Any	RS501: $650 TS601: $825[7]	12-18	No	No	No	RS 501: No TS 601: Yes
Ivan Technologies: Trail Counter	Active Infrared	Any	~$1,500	~12	No	No	No	Yes
TrailMaster: TM 1550	Active Infrared	Any	$360 - $460	8- 12	No	No	No	Yes
TRAFx Mountain Bike Counter	Geomagnetic	Buried on or beside trail	$748[6]	8	Bicyclists only	No	No	Yes
Miovision: Scout	Video	Any	$3,950[8]	72 hrs	Yes	No	Yes	Yes
Diamond Traffic: TT-41/Pegasus	Inductance Loop	Paved asphalt or concrete	TT-41: $369 Peg.: $1,800	TT-41: 18 Peg.: 1[9]	Bicyclists only	No	TT-41: No Peg.: Yes	TT-41: No Peg.: Yes
EcoCounter ZELT	Inductance Loop	Paved asphalt, concrete, or stabilized trail	$2,200-$2,950	12	Bicyclists only	Optional GSM[6]	Yes	Yes
EcoCounter TUBE	Pneumatic Tube	Any firm surface	$2,225-$2,650	120	Bicyclists only	Optional GSM[6]	Yes	Yes
Trail Counters: RBBP7	RadioBeam™	Any	$1,900-$5,600	12-24	Yes	N/A	Yes	Yes

Notes:
1. Estimated cost as of August 2011.
2. Ability to automatically differentiate between bicycling, walking, and equestrian trail users.
3. Ability to separately count users in each travel direction.
4. Ability to summarize trail counts by defined time intervals (e.g., 15 minutes for each day of monitoring).
5. Requires cell network subscription and modem for each detector.
6. Package of 3 counters with accessories cost $2,245. Additional counters cost $395 to $525.
7. Cuesta TS601 requires a TS625 data download accessory (can be used across multiple counters).
8. Equipment cost does not include cost of video analysis. Analysis cost is variable depending on volume and study complexity. Ranges from $11 to $60 per hour.
9. Battery life is one month, so permanent inductance loop applications require a direct AC power source.

2. Installing two inductance loops in series, such that direction can be inferred from the timing of detection events for each loop.

The first option is the most commonly used practice to date. For the second option, some data loggers or controller equipment may not be capable of interpreting signals from a paired inductance loop sequence.

The most important variables in accurate bike detection via a loop detector are:

- Loop configuration: Several different wire patterns have been used for counting bicycles, including quadrupole, diagonal quadrupole (also called Type D), chevron, and elongated diamond patterns (see Figure 1-1).
- Detector circuit sensitivity: The sensitivity should be high enough to detect non-ferrous bicycle frames but not so high as to detect motor vehicles in adjacent lanes.
- Bicycle position over the loop: Pavement stencils may be used to indicate optimal (i.e., most accurate) bicycle position over the loop detector, which is typically directly over the saw cut for the wire coil.
- Bicycle size and composition: A large steel frame is more likely to disrupt the loop detector's field than a smaller non-steel frame, but the threshold amount of ferrous metal is not a known quantity and varies based on the above three and other variables.

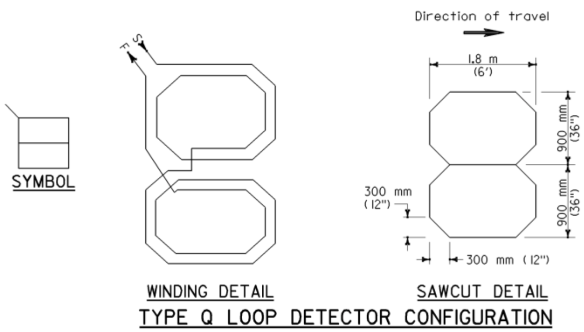
Infrared Sensors

Infrared sensors operate by identifying a changing heat differential in the detection area. If the heat differential and pattern meets pre-defined criteria, then a detection and/or count is registered. There are two types of infrared sensors that can be easily distinguished:

- Active infrared sensors use a signal transmitter on one side of the detection area and a receiver or target on the other side.
- Passive infrared sensors use a signal transmitter only on one side of the detection area.

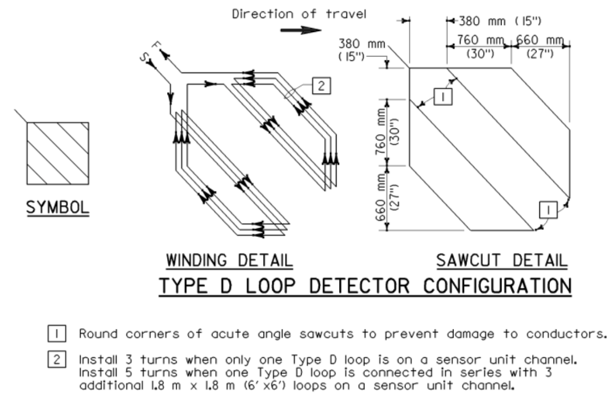
Active infrared sensors have a narrower cone/zone of detection than passive infrared sensors. However, installation of active infrared sensors can be more challenging than passive infrared sensors. The transmitter and receiver parts of an active infrared sensor must be aligned properly, and requires a vertical mounting location on both sides of the detection area with a clear line of sight between. A passive infrared sensor only requires a single vertical mounting location on one side of the detection area. However, accuracy is improved when the passive infrared sensor is pointed toward a wall, building face, dense vegetation, or similar background.

Quadrupole Shape: Schematic



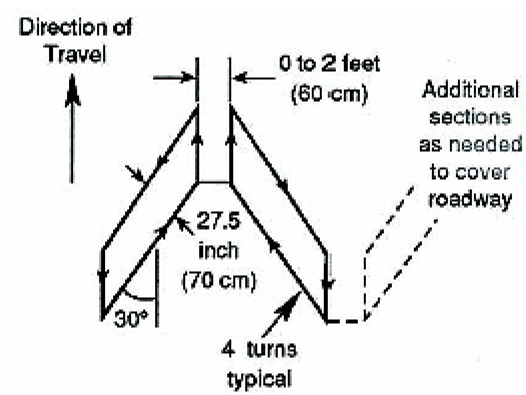
Source: Caltrans Standard Plan ES-5B, 2002

Diagonal Quadrapole Shape: Schematic



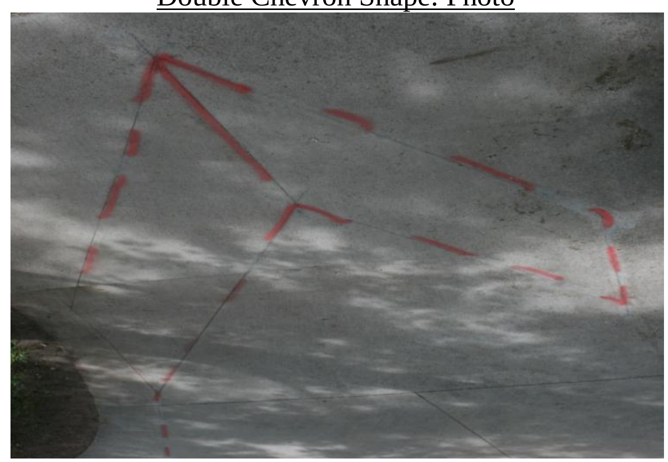
Source: Caltrans Standard Plan ES-5B, 2002

Double Chevron Shape: Schematic



Source: Traffic Detector Handbook, May 2006

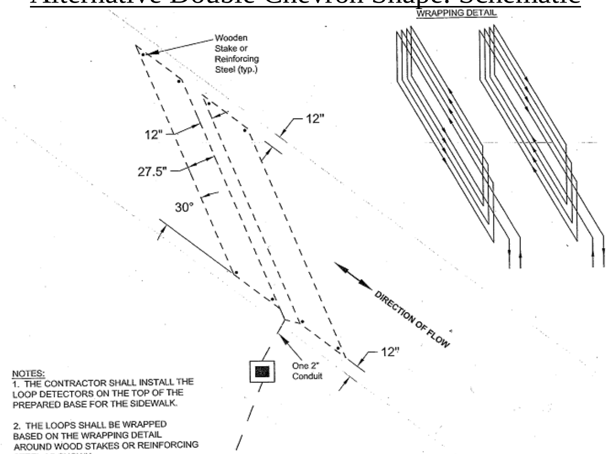
Double Chevron Shape: Photo



Source: S. Turner, Texas Transportation Institute

Figure 1-1. Examples of Inductance Loop Detector Shapes for Bicyclist Counting.

Alternative Double Chevron Shape: Schematic

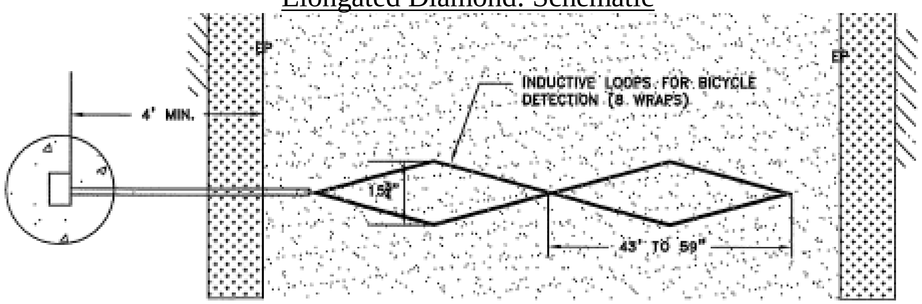


Source: J. Bunker, City of Boulder

Alternative Double Chevron Shape: Photo

Source: S. Turner, Texas Transportation Institute

Elongated Diamond: Schematic



Source: Marin County NTPP Specifications Sheet, 2009

Elongated Diamond: Photo

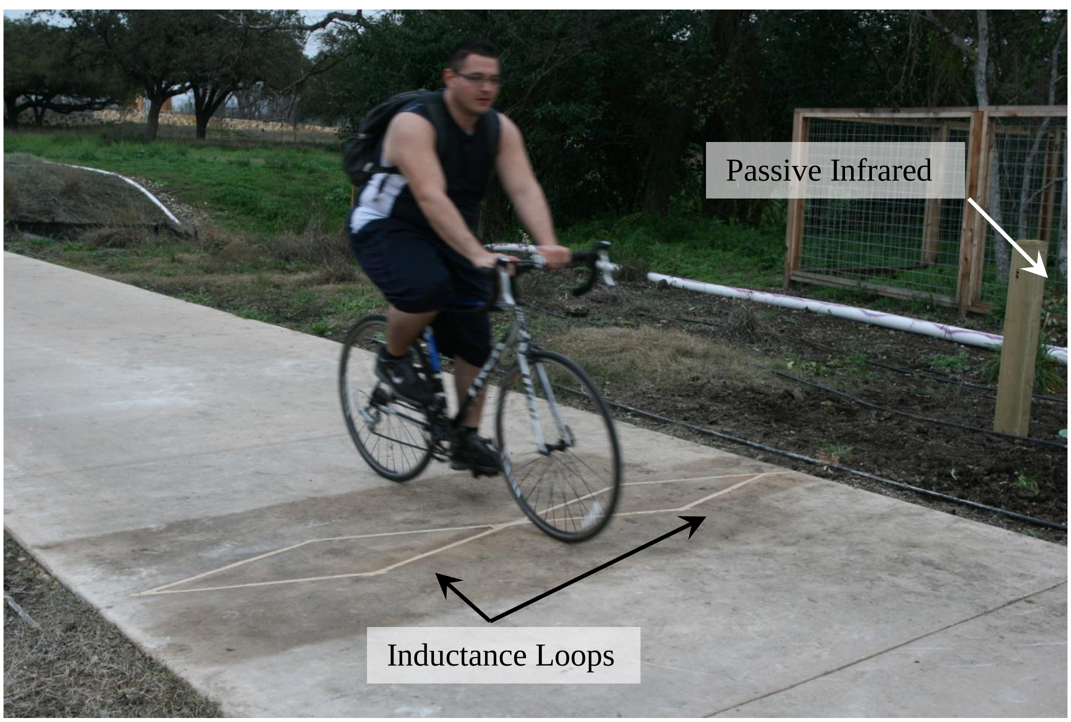
Source: S. Turner, Texas Transportation Institute

Figure 1-1. Examples of Inductance Loop Detector Shapes for Bicyclist Counting (Cont.)

Most infrared sensors perform best in areas where the travel area is constrained and/or the detection area is well defined. Because of the basic operating principle, infrared sensors sometimes cannot distinguish multiple persons in a group (i.e., side-by-side or closely spaced front-to-back). Also, infrared sensors cannot differentiate between bicyclists and pedestrians; therefore, if separate counts are required, infrared sensors must be paired with another technology able to accurately count bicycles. For example, Figure 1-2 shows a permanent monitoring location that combines a passive infrared sensor with inductance loop detectors.

Most infrared sensors have a small profile and form factor (see Figure 1-3 for several examples). For portable applications, infrared sensors can be enclosed in a small vandal-resistant, lockable box and attached to an existing utility pole, fence post, or tree. For permanent applications, infrared sensors are often enclosed within wooden fence or other vertical posts.

Figure 1-4 shows a typical configuration for using a passive infrared sensor. This example shows an ideal location: 1) primarily used by pedestrians and bicyclists only, 2) the travel area is constrained with the detector pointing across the sidewalk away from the street; and 3) the detection area is well defined in a position where pedestrians and bicyclists will be traveling perpendicular to the sensor.



Source: S. Turner, Texas Transportation Institute

Figure 1-2. Example of Passive Infrared Sensor Combined with Inductance Loop Detectors.

(Equipment shown in a temporary controlled testing configuration)

Source: S. Turner, Texas Transportation Institute

Figure 1-3. Different Types of Infrared Counters for Non-Motorized Traffic.

Source: S. Turner, Texas Transportation Institute

Figure 1-4. Typical Configuration for Passive Infrared Sensor.

Magnetometers

Magnetometers operate by detecting a change in the normal magnetic field of the Earth caused by a ferrous metal object (e.g., bicycle frame or components). It may be possible to use existing motorized traffic magnetometers for counting bicyclists; however, the installation and configuration may not be optimal for accurate bicyclist counting. According to the Third Edition (October 2006) of the *Traffic Detector Handbook*, "Magnetometers are sensitive enough to detect bicycles passing across a four-foot span when the electronics unit is connected to two sensor probes buried six inches deep and spaced three feet apart." The shallow placement of magnetometers will result in more accurate bicyclist counts but could over count motor vehicles, as the detector might distinguish between changes in sections of the vehicle (e.g., engine block, axles, transmission) as multiple vehicles.

Magnetometers designed for motorized traffic may be capable of detecting bicycle frames made of non-ferrous materials (e.g., aluminum, carbon fiber, titanium), but are not designed or optimized for this purpose. There are commercially-available magnetometers specifically designed for bicycle detection and counting.

Another drawback to the use of existing magnetometers for the detection of bicycles is increased equipment needs. For example, a thirty-foot detection area for automobiles would require five magnetometers and one electronic data logger. The same thirty-foot detection area would require ten magnetometers and four to five data loggers to detect bicycles.

Pneumatic Tubes

Pneumatic tubes are a low-cost, portable approach for counting bicyclists only. Pneumatic tubes operate by using an air switch to detect short burst(s) of air from a passing vehicle, motorized or non-motorized. The data logger then uses various pre-defined criteria (e.g., axle spacing, etc.) to determine whether a valid vehicle type has passed over the tubes. The technology has been used to count cars and trucks for several decades, so most public agencies either have the equipment or are familiar with the technology. Pneumatic tubes have been combined with infrared sensors at locations where both bicyclist and pedestrian counts are desired.

As with other traditional motorized traffic monitoring technology, the optimal placement and configuration of pneumatic tubes for counting bicyclists will be different than that for cars and trucks. Ideally, the placement of pneumatic tubes for bicycles should adequately cover the bicycle travel path while not being exposed to excessive passage by motor vehicles. When counting bikes in a bike or shared lane, passage and activation by motorized traffic may be unavoidable. In these cases, the data logger criteria should be capable of ignoring typical motor vehicle axle spacing. If direction of bicyclist travel is desired, a pair of pneumatic tubes can be placed (see Figure 1-5), and travel direction can be inferred from the timing of detection events at each tube.

Source: J. Parks, Kittelson & Associates, Inc.

Figure 1-5. Example of Pneumatic Tube Configuration for Counting Directional Bicyclist Traffic.

Bicyclist safety is a concern when pneumatic tubes are installed with pavement nails or other metal fixtures. The nails or metal fixtures could dislodge from the pavement and puncture a bicycle tire or create a road hazard for bicyclists.

Pressure and Acoustic Sensors

Pressure sensors operate by detecting changes in force (i.e., weight), much like an electronic bathroom scale. Acoustic sensors operate by detecting the passage of sound waves caused by feet, bicycle tires, or other non-motorized wheels. As with other monitoring technologies, pre-defined criteria are used to determine a valid detection and therefore a valid user to be counted.

Both pressure and acoustic sensors require the sensor element to be placed underneath or very near the detection area. Pressure and acoustic sensors are most common on unpaved trails or paths (Figure 1-6), where burial of the sensor element is typically low-cost and minimally disruptive. However, pressure sensors have been used (more commonly in Western Europe) at

(a) Pressure sensor on natural surface trail

(b) Pressure sensor on paved surface

Source: J.F. Rheault, Eco-Counter

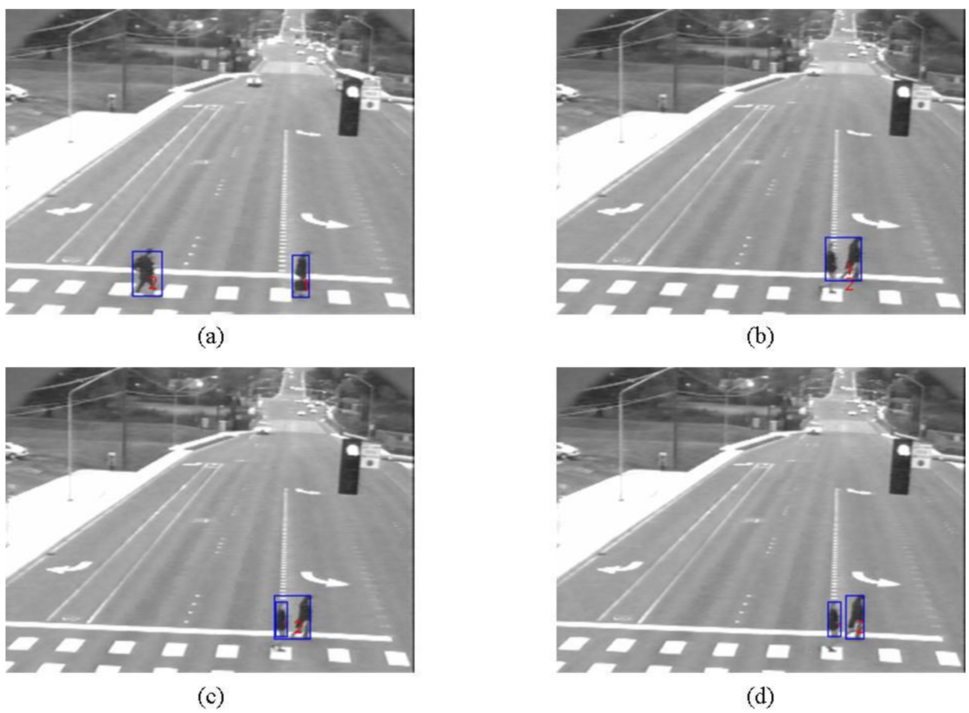
Figure 1-6. Examples of Pressure Sensors on Natural (a) and Paved (b) Surfaces.

curbside pedestrian signal waiting areas, as a supplement to or replacement of a pedestrian crosswalk push button.

Some models of pressure and acoustic sensors are capable of detecting the difference between pedestrians and bicyclists. Placement and size of the pressure sensors (also known as pressure mats) can be used to gather directional information. When installed properly, pressure and acoustic sensors can serve as permanent continuous counters.

Video Image Processing

Video image processing operates by using sophisticated visual pattern recognition to identify (and sometimes track) a pedestrian or bicyclist traveling through a video camera's field-of-view (see Figure 1-7). The critical element for accurate bicyclist and pedestrian counting is the pattern recognition algorithms and software. Because of the commercial demand for detecting and counting motorized traffic, this software has been extensively refined by manufacturers and vendors. Some research and development for bicyclist and pedestrian-specific algorithms has been conducted at the university level; however, much of this university research has not been incorporated into existing commercially-available products.



Source: Malinovskiy, Zheng, and Wang, 2009[1]

Figure 1-7. Example of Video Image Processing for Tracking and Counting Non-Motorized Traffic.

Video image processing has the capability to distinguish pedestrians and/or bicyclists traveling in a group or cluster. The technology also has the capability to distinguish direction of travel and potentially track the non-motorized traffic through the field-of-view. Again, these capabilities are dependent on the level of algorithm development of the commercial products.

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[1] Malinovskiy, Y., Zheng, J. and Wang, Y. (2009), Model-Free Video Detection and Tracking of Pedestrians and Bicyclists. *Computer-Aided Civil and Infrastructure Engineering*, Volume 24: pp. 157–168.

Weather and lighting may reduce the accuracy of this technology. Finally, video image processing typically has the highest equipment costs.

In some cities, pedestrian and bicyclist counts are manually reduced by viewing recorded video from intersection control or surveillance cameras. This manual approach is practical and low-cost for periodic short-term counts, but is not sustainable for continuous monitoring purposes. This approach eliminates equipment installation (and corresponding traffic control), but also requires a low-cost labor force to manually review the video. Several companies offer a portable video recording unit as well as data reduction services. Finally, the recorded video may be useful to other agencies or departments that wish to study bicyclist and pedestrian behavior (e.g., in response to safety issues or concerns).

Manual Observers

A low-technology approach for counting pedestrians and bicyclists is to position human observers, who tally the non-motorized users passing through the monitoring location. Various parameters and instructions for this technique are described in more detail at the National Bicycle and Pedestrian Documentation Project website, http://bikepeddocumentation.org/. Standardized data collection forms and survey questionnaires are also available at this website.

The use of manual observers is relatively low-cost and very portable. Manual observers can also gather addition information about bicyclists and pedestrians, such as helmet use, gender, relative age, and various behavior types. However, manual observers are limited to relatively short periods of data collection (i.e., several hours) and can sometimes be error-prone.

Emerging Technologies

The commercial marketplace for non-motorized traffic monitoring is still maturing, and several companies are still working to adapt their motorized traffic monitoring technology to accurately count bicyclists and pedestrians. For example, several companies are working to adapt their existing video image processing products to accurately count bicyclists and pedestrians. However, there are several companies (some based in non-US countries) that have been successfully selling their non-motorized traffic monitoring equipment for more than a decade. An increased demand for non-motorized traffic monitoring data will provide incentives to existing companies outside the US as well as other companies that want to develop non-motorized traffic monitoring products.

Mobile devices with GPS and/or Bluetooth capabilities also provide a means to monitor small samples of bicyclist and pedestrian traffic. Several cities are evaluating or using these technologies to gather route choice, origin-destination, and travel time data (e.g., San Francisco, Austin, and Monterey). However, these technologies do not yet have the capability to count the total volumes of bicyclist and pedestrians.

CHAPTER 2: COUNTING EQUIPMENT GUIDANCE AND INSTALLATION

The purpose of Chapter 2 was to assist H-GAC with evaluation and determination of best practices when using bicycle and pedestrian count equipment. In addition, specifications and procedures for equipment and use of equipment were documented. Specifically, the Texas A&M Transportation Institute (TTI) served as an advisor to H-GAC staff by performing the following activities:

- Advise H-GAC staff regarding the ideal mix of permanent versus temporary (or moveable) bicycle and pedestrian counters considering budget constraints and research objectives.
  - The initial recommendation is that H-GAC staff procure pedestrian and bicycle counting equipment including: one to three permanent counters and two to four temporary counters.
  - The counter numbers may be adjusted depending on cost and availability of local government partners that agree to install and maintain permanent counters.
- Advise H-GAC staff regarding technical specifications and capabilities of counters based on previous research and experience.
- Oversee the installation of an initial set of permanent counters and set up of data collection mechanisms including (modems, cell network, etc.).
- Provide guidance for use of temporary (movable) counters.

Based on the methodology described in Chapter 3 and the available project budget, a mix of permanent and short duration equipment may be desired. While the project budget allows for a limited amount of count equipment to be purchased, the collection of non-motorized transportation data has been identified as an important planning activity. The Federal Highway Administration (FHWA) *Traffic Monitoring Guide Update* provides the following justification:

> *"The prevailing practice for collecting short-duration non-motorized traffic data has been to focus on targeted locations where activity levels and professional interest are the highest. Although this non-random site selection may not yield a statistically-representative regional estimate, it provides a more efficient use of limited data collection resources (e.g., random samples are likely to result in many locations with little to no non-motorized use)"*.

In previously documented work (see Chapter 1) and ongoing monitoring of the traffic counting market, TTI reviewed the available products and advised HGAC to procure a mixture of permanent and short duration counters. It is estimated that the most efficient use of funds is to procure two permanent bike and pedestrian counters. In addition, TTI recommends developing procedures and parameters to utilize existing pneumatic tube traffic counters for bicycles to conduct short term counts.

The two permanent counters will be the start of a system to develop adjustment factors based on area and facility type as outlined in Chapter 3. The short term counts would be conducted using a combination of: 1) loaning out portable pedestrian counters and 2) providing procedures, settings, and vehicle classification schemes that can be used with existing agency and consultants' vehicle tube count equipment. As part of this project, three pedestrian counters were purchased with the intent to loan the units out to local agencies to conduct counts in their jurisdictions. The bicycle counts would be conducted by agencies and consultants using H-GACs recommended procedures, vehicle classification schemes, and settings.

The purchase of two permanent pedestrian/bicycle counters expended most of the funds set aside for equipment procurement for this project. The Eco Counters Multi Urban Post count bikes and pedestrians separately and have the ability to distinguish flow by direction. Aggregated data is sent via cell modem to internet-based cloud storage where it can be downloaded for analysis, archival, or analyzed online with vendor supplied analysis and graphing tools. The two permanent counters could be considered the beginning of a starter counting system that will mature in time as resources become available to add locations to the system.

In addition to the two Eco Counters, three TRAFx Infrared Trail counters were also procured by H-GAC for temporary pedestrian counts. These counters were tested and modifications were made to make them more suitable for installation in the urban environment. The counters have a long battery life (over a year) and count bidirectional pedestrians at a moderate cost. Testing and modification to the enclosure was made in order to secure the equipment and allow for a variety of mounting capabilities such as on street lights, sign poles, trees, or other fixtures.

The use of automatic pneumatic tube counts was selected for bicycle counts as they were proven to be effective in counting bicycles and in the region there are several private and public agencies that currently utilize this equipment for vehicle traffic counts. By utilizing the existing fleet of equipment and modifying some features and functions, this same counting equipment can be used to count activity on bicycle facilities. Tube counters were examined closely for the bike counting application since several agencies and organizations already had equipment and their technicians familiar with their use. The ultimate goal would be to institutionalize the process of counting non-motorized facility use by various agencies in the region on a programmatic basis. The concept is that when a vehicle traffic count is being scheduled or conducted on a facility with a bike lane, an additional counter or a bike count can be set up so that both bikes and cars are counted. This minimizes the cost of counting the non-motorized facility. A project-based bike count program, while useful and serving a purpose could more easily be subject to a line item budget cut. An institutionalization process may not require additional time and could easily be absorbed within existing schedules and with the use of existing resources as there would be no incremental cost to buy or maintain specialized equipment. Once personnel become accustomed to counting non-motorized facilities it is envisioned that non-motorized counts could become routine.

Draft language for an interlocal agreement for the deployment and use of permanent and short term counters was provided and modified through H-GAC and local agency legal departments, as shown in Appendix B. The agreements addressed deployment, operational, and maintenance responsibilities for both the permanent and short term use devices. The permanent count equipment agreement indicated that H-GAC would purchase the equipment and the City of Houston would install and maintain. The agreement for the loan of the portable count equipment provides roles and responsibilities for the use of the equipment. An example of these documents is provided in the Appendix C of this memorandum. TTI researchers coordinated and assisted in the installation of the initial deployment of permanent count equipment on January 22, 2013 at the MKT/SP-Rails to Trails in the Heights at 5 ½ street and another at White Oak Bayou Trail at 34^{th} street and TC Jester.

Guidance on the deployment and use of the pedestrian counters is presented in Appendix D of this document. The pedestrian tip sheet provides suggestions on count location siting, equipment mounting, and collection of the pedestrian data. A companion tip sheet for the settings, location and deployment for bicycle counters is shown in Appendix E of this technical memorandum. These tip sheets provide the user with guidance on recommended settings to optimize setups to obtain the most accurate counts. Location is critical in counter deployment and factors such as facility, background, and area or lanes are included in these tip sheets. Additionally, references to areas in the user manual provide interpretation on some of the most common deployments. This memo does not include scheduling, inventory lists, and spare parts to maintain. There have, however, been discussions on how to efficiently manage the counter inventory using spreadsheets and outlook calendars to schedule and track the equipment.

CHAPTER 3: DEVELOP PEDESTRIAN AND BICYCLE COUNTING PLAN

Bike and pedestrian counts are vital to the planning process. Counts reflect the usage of existing facilities and can provide insight into the areas and types of bicycle and pedestrian facilities that are most desired. These counts are also used to provide a feedback loop for planning model calibration and validation. Bike and pedestrian counts can also be used for trend analysis to determine seasonal, temporal, and types of facilities most utilized. All of these uses for bicycle and pedestrian activity data provide guidance on where and how to invest in the transportation infrastructure.

The purpose of Chapter 3 was to develop a pedestrian and bicycle count program plan. This plan guides a logical framework of count locations sited based on various important criteria. The Federal Highway Administration (FHWA) provides some guidance in the *Traffic Monitoring Guide* [1]. In the *Traffic Monitoring Guide*, count locations should be distributed by area type, facility type and trip purpose. Some of the count location criteria include:

- Counts in key pedestrian and bicyclist activity areas or corridors (downtowns, near schools, parks, and other non-motorized traffic generators.);
- Representative count locations in urban, suburban, and rural locations;
- Counts in key corridors that can be used to gauge the impacts of future improvements;
- Count locations where counts have been conducted historically; and
- Count locations where bicyclist and pedestrian collision numbers are high.

The objectives of this chapter were to:

- Identify the existing count locations,
- Solicit input from agencies and bike groups on additional count locations,
- Determine a framework and criteria to develop a count program, and
- Develop a draft count plan for consideration.

EXISTING NON-MOTORIZED TRANSPORTATION SYSTEM COUNTS

Some, but very few, bicycle and pedestrian counts have been done in the Houston region, but these counts were done infrequently and on a volunteer basis. The most significant efforts have included:

- 2005 - Institute of Transportation Engineers' (ITE) National Bicycle and Pedestrian Documentation Project;
- 2009 - ITE's National Bicycle and Pedestrian Documentation Project; and
- 2009-2012 - City of Houston (COH) short term bike counts.

The ITE National Bicycle and Pedestrian Documentation Project counts were two hour manual counts. At some of the count locations pedestrians and bicyclists were also surveyed regarding characteristics of activity. Machine and/or video counts were done by Harris County, the Energy Corridor District, and the City of Houston which were included in the documentation projects. These longer duration counts provide time of day and day of week usage for the facilities. There were a total of 28 count locations. Most counts were AM and PM counts or all day multiday machine counts. Data was collected from various sources and several interviews were conducted to determine location, type of counts, and duration. Latitude and Longitude locations were obtained for each location and the locations were plotted and are shown in Figure 3-1 and a corresponding list is supplied in Appendix F. Several counts were conducted in about the same locations as shown, but there may have been different names on datasheets, tube counts, and/or an intercept survey.

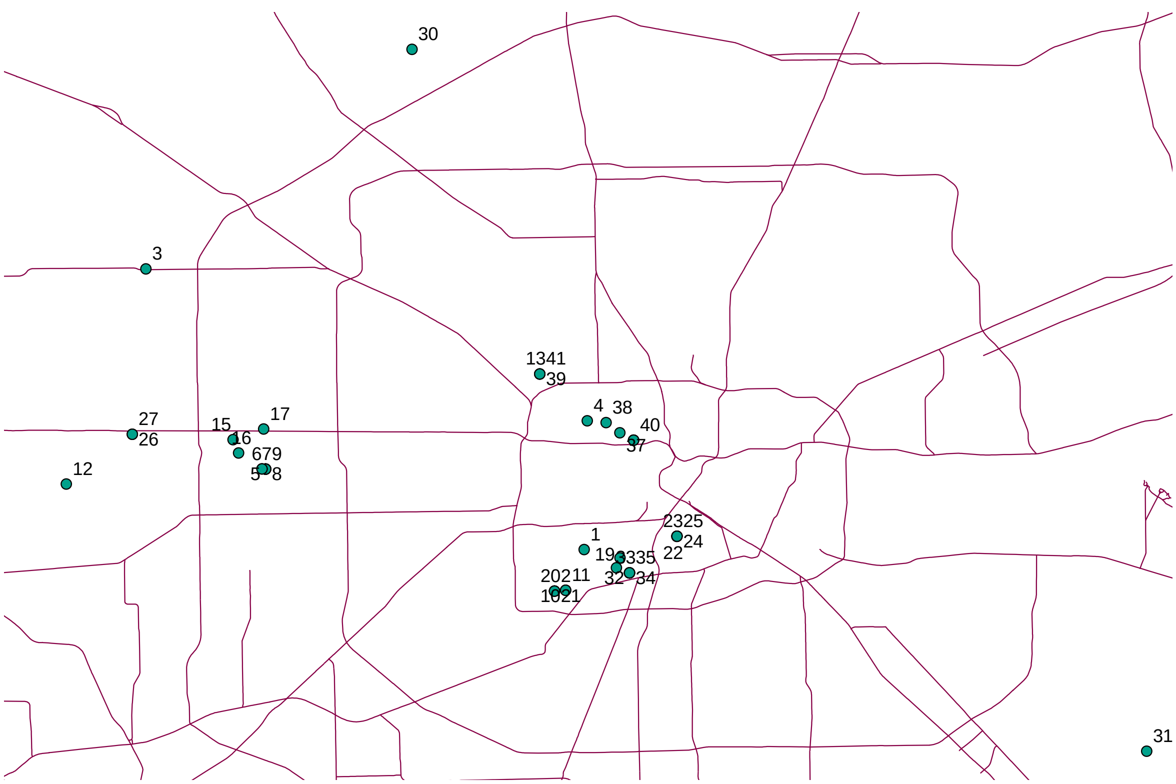


Figure 3-1. Existing Harris County ITE National Bicycle and Pedestrian Documentation.

PROJECT AGENCY AND ADVOCACY INPUT

The existing count map was presented to the H-GAC Bicycle and Pedestrian Subcommittee for review and comment. In addition, the non-motorized demand estimates from the Chapter 5 modeling effort were reviewed by that subcommittee as well. Input on locations where there is perceived or actual bicycle and/or pedestrian demand was sought to test equipment and to submit as potential locations for inclusion in an enhanced regional non-motorized count program. Both agency representatives and citizen advocates provided potential count locations for consideration.

Methodology

To plan and operate any transportation facility efficiently and effectively requires good data. Basic information required for the facilities includes:

- Location,
- Function,
- Capacity,
- Condition, and
- Facility use.

The first four items are inventory items that vary in degree of implementation in the Houston region. The focus of this chapter is to determine system use or to determine how much and how often the bicycle and pedestrian facilities are being used. Other questions can also be answered such as: which facilities are used most (on street vs. trails); what function facilities serve (recreation, commute, or utility); and when the facilities are being used (morning or evening, weekday or weekend; summer or winter).

The bicycle and pedestrians count program was modeled after the vehicular count program, which uses factors from permanent count locations to adjust a sampling of short duration traffic counts by:

- Time of day,
- Day of week (and day to day use due to environmental or weather factors), and
- Month and season.

This system of sampling and use of adjustment factors is a logical method to be used to monitor bicycle and pedestrian infrastructure. A program of bicycle and pedestrian counts would be conducted at a set of permanent and temporary count locations. The permanent count locations would be used to factor the temporary locations. A matrix or set of groups would be developed based on area and facility types as shown in Table 3-1. This table is based on the existing mileage by facility type provided by HGAC. Similar tables could be developed on a sub-regional or jurisdiction level. A similar table could be developed for pedestrian facilities; however no pedestrian data was available for this chapter.

Table 3-1. Bicycle Count Matrix Based on Lane Miles of Facility Type and Area Type.

Area Type	Bike Lane	Shared Path or Trail	Share the Road Sign	Signed Shoulder	Signed Share the Roadway	Total
CBD	0.0	5.2	0.0	0.0	7.4	12.6
Urban Intense	55.4	104.3	0.0	0.0	93.4	253.0
Urban Residential	120.5	754.7	1.3	2.1	64.8	943.5
Suburban Residential	42.7	922.4	11.0	25.4	6.2	1,007.7
Rural	18.0	118.4	153.7	54.8	0.0	344.9
Total	236.6	1,905.0	166.0	82.3	171.8	2,561.7

From the literature and the basic non-motorized travel demand model presented in Chapter 5, a series of count criteria was developed with the underlying focus based on transportation (or utility) trips as opposed to exercise trips. The transportation trips might include destinations such as work, school, or social. Utility trips include destinations such as stores, appointments, friends, and other activities such as going to sporting game or practice and parks. The count location criteria proposed were as follows.

Count Location Criteria

The proposed bike and pedestrian count locations may be based on the following criteria:

Commuter or Utility Routes

Non recreational routes are preferred since transportation funds are used for these facilities. Areas around employment centers, retail, etc. should be favored.

Geographically Disbursed Throughout Region

Some consideration was given to distributing the sites geographically to provide a cross section of users.

Non-Motorized Demand and Supply

The maps developed in Chapter 5 were utilized to identify high demand locations which would provide some feedback on the model's relevance.

Existing Count Locations

An inventory of existing count locations were developed and plotted. Locations with high utilization were considered based on meeting other criteria in this list.

Non-University or CBD

While there is higher demand for bike and pedestrian facilities, the facilities are not typical due to the restrictions on parking and population characteristics.

Mix of Facility Types (bike lanes, trails, etc.)

Some attempt was made to get a cross section of facility types. It was initially envisioned that the number of count locations per facility type would be based on a percentage of the lane miles of each type of facility. However it was found that certain types of facilities were underutilized potentially due to retrofit implementations or locations that do not have the recommended lane width, poor pavement quality and other substandard design elements.

One Location Per Route

Some routes could be considered for multiple locations but due to limited resources only one location was selected. Typically the location with the highest volume and with the most relevance meeting multiple criteria was selected.

Minimum Distance and Connectivity

Very short facilities that are not connected with other facilities were given less consideration since the likelihood of the facility being used as a commute or utility trip were limited. A distance of four miles for bike routes and one mile for pedestrian routes was used. The distance is based on the assumed distance a typical person would use a given type of facility.

Detection Technology Criteria

Specific site location was based in criteria that produced the best results from a given count technology. Infrared pedestrian detector needs to be aimed toward pedestrians with no movement in the background (shoot away from roadway). In addition, a pedestrian detector needs a location to mount the box (i.e. a light post works well). For bike and pedestrian detection, areas of free flow are most desired. Areas at intersections where someone would stop would not produce accurate counts.

Permanent Count Location Considerations

Most car and truck traffic monitoring programs include multiple adjustment factor groups that represent different roadway functional classes, traffic volume levels, and urbanization level. Permanent count locations are used to develop these adjustment factors. Each adjustment factor group is designed to represent a unique traffic pattern and its variations. Following this same model non-motorized permanent count locations will belong to an adjustment factor group that is proposed in Table 3-2. Ideally each of these factor groups will include one or more permanent count locations.

Table 3-2. List of Existing and Proposed Count Locations.

	Name	Description	Location	Existing/Proposed
1	1013 Nicholson	Heights	Houston	Existing
2	7th street	Heights to Yale	Houston	Existing
3	Bayou walking Trail N of Epps Island Elem	S of Silent Wood Ln	Harris	Existing
4	Bertner	Pressler	Houston	Existing
5	Braes Bayou	Stella Link & Buffalo Spwy	Houston	Existing
6	Braeswood	Braesmont	Houston	Existing
7	Brays	Linkwood	Houston	Existing
8	Brays Bayou	Castlewood	Houston	Existing
9	Cambridge	Wyndale	Houston	Existing
10	Columbia Tap Trail	TSU	Houston	Existing
11	Dairy Ashford	IH 10	Houston	Existing
12	FM 529	Hudson Oaks Dr	Harris	Existing
13	Heights Blvd	16th street	Houston	Existing
14	Moursund	Bertner	Houston	Existing
15	Myer Park Bike Trial	NW Houston	Harris	Existing
16	TC Jester	34th street	Houston	Permanent
17	Terry Hersey Park	Sport Park Trail	Houston	Existing
18	Terry Hersey Park	Dairy Ashford	Houston	Existing
19	Terry Hershey	Dairy Ashford	Houston	Existing
20	Terry Hershey Park	Memorial	Houston	Existing
21	Terry Hershey Park	Eldridge	Houston	Existing
22	MKT Trail	5 1/2 St at bridge	Houston	Permanent
23	Heights Trail	Heights Bike Trl W of Main	Houston	Proposed
24	34th street	W of Shepherd Garden Crest	Houston	Proposed
25	Belfort	W of Alcott Elem (Crestmont)	Houston	Proposed
26	Briar Forest	Wilcrest	Houston	Proposed
27	Brooks Street	Bluebonnet	Fort Bend	Proposed

Table 3-2. List of Existing and Proposed Count Locations. (Cont.)

28	Calhoun Rd	N of OST	Houston	Proposed
29	Cambridge Connection	Under Construction	Houston	Proposed
30	Cavalcade	East of Hirsch	Houston	Proposed
31	Chimney Rock	N of Memorial	Houston	Proposed
32	Columbia Tap North	Clay Street	Houston	Proposed
33	Columbia Tap South	Palmer Street	Houston	Proposed
34	Country Club Boulevard	Sugar Land	Fort Bend	Proposed
35	E Cross Timbers	Jenson Drive	Houston	Proposed
36	Fairway	W of Telephone south of 610	Houston	Proposed
37	FM 2920	Bridgestone Lane	Harris	Proposed
38	George Bush	Fry and Highland knolls	Harris	Proposed
39	Hickory Trail	Armand Bayou N of Running Springs Dr near Armand Bayou Elementary School	Harris	Proposed
40	Highland Knolls	Peek Road	Harris	Proposed
41	Highland Knolls	East of Fry Road	Harris	Proposed
42	Kempwood	West of Campbell	Houston	Proposed
43	Kirby	University	Houston	Proposed
44	Lakeside Drive	S of Red Bluff N of Humble Dr near elementary school	Harris	Proposed
45	Main Street	Lakeview	Fort Bend	Proposed
46	N Caesar Chavez Blvd 67th St	S of Sherman N of Harrisburg	Houston	Proposed
47	River View or Lakeside Estates	At Chevy Chase	Houston	Proposed
48	W Lake Houston Pkwy	N of Oakwood Forest Dr	Houston	Proposed
49	Wakefield 38th street	Alba	Houston	Proposed
50	Wilcrest	Brandon	Houston	Proposed

Note: These locations are a starting point and as facilities are identified outside the central part of the region others will be added.

A preliminary analysis of bicyclist and pedestrian traffic count data indicates that adjacent land use and trip purpose play an important role in determining the traffic patterns and variations. In particular, there are three basic types of trip purposes that can significantly impact traffic patterns:

1. Commuting-based trips – these trips exhibit sharp peaks in the morning and evening (and sometimes mid-day), and are relatively consistent across all weekdays and little to no weekend trips.
2. Recreation, exercise, and sports trips – these trips are the most common on weekends, but these patterns can also occur on recreational trails on weekdays typically during non-business hours before or after typical commute patterns.
3. Utilitarian trips – these trips can have a multiple patterns based on the population and land use but tend not to be distributed more evenly throughout the day with

wider/longer AM and PM peaks than the AM and PM commuting peaks. In addition, weekends are as common as weekdays. Trips such as shopping, personal business, school, church, doctor or visiting friends are examples of utilitarian trips.

In reality, most permanent monitoring locations will have a mix of commuting, recreational, and utilitarian trips represented in the counts. For HGAC permanent monitoring locations, we are recommending that sites be selected that are believed to be primarily either commuting or recreational in characteristic. For example, if two permanent monitoring locations will be installed in the first phase of deployment, we would recommend that one of the permanent locations should be on a facility believed to be used primarily for commuting trips; and the other is placed on a facility at a location where trips are believed to be recreational. Subsequent permanent locations should “fill in the gaps” and could provide counts on facilities considered to carry a mixture of commuting, recreational, and utilitarian trips.

When selecting these first two monitoring locations, the following criteria should be used:

- One location should be located on a facility in a location with trips perceived as primarily commuting, and one location should be located with primarily recreational trips.
- There should be consistent and fairly high use. Selection should not necessarily be for the absolute highest use location, but a location with a combination of consistent and moderately high use.
- The monitoring locations should be representative and typical of many other locations, as the traffic patterns at these permanent locations will be used to annualize counts from numerous other locations.
- The locations could be chosen in an area that will receive infrastructure investments or redevelopment to encourage bicycling and walking (i.e., strategically located to support a future before-after study).

Development of a Draft Count Plan

The above criteria were used to develop a draft count plan that was presented to the Bicycle and Pedestrian Subcommittee for review and comment. No comments were received during or after the meeting. Figure 3-2 and Table 3-2 show the proposed short term count locations for the H-GAC region. The majority of the count locations are within Harris County. The locations were based on non-motorized network that was available and recommendations from agencies. There are likely other facilities in other counties and those should be added as locations are identified and as non-motorized networks are inventoried.

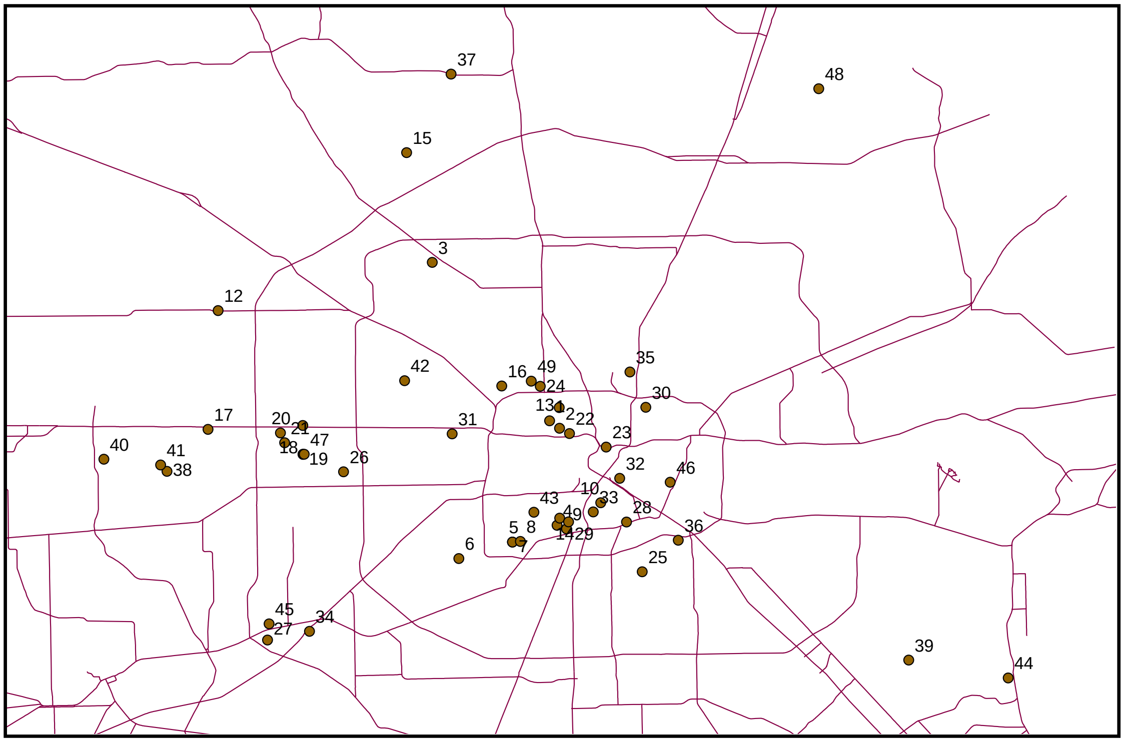


Figure 3-2. Existing and Proposed Bike and Pedestrian Count Locations.

Non-motorized facilities should be counted periodically as needs arise for specific study purposes. Periodic count for planning and monitoring of facilities should be done at least every three years and ideally in the spring and fall. Some facilities may have higher traffic in the summer so knowing the facility is critical to determine the average and peak usage of the facility.

When using automatic count equipment, seven day counts provide a more complete picture of the facility use. It is typically not feasible to collect survey data for more than a couple of hours and using the data from the automatic counter a data collection plan can be devised to collect the information by trip purpose.

Two permanent count locations were selected by HGAC and the City of Houston that were thought to represent a commuting and a recreational pattern. The MKT at 5 ½ Street and White Oak Bayou at 34th street had been locations that had been counted using tube counters periodically in the past several years. Both facilities will eventually be connected and there is interest in determining if the much larger route significantly increases the volume at both count locations.

This plan should be periodically reviewed and updated to reflect the growth and changes to the use of facilities in the region.

CHAPTER 4. DATA COLLECTION AND REPORTING STRUCTURE

STATEMENT OF THE PROBLEM

Chapter 4, Data Collection and Reporting Structure of the Pedestrian-Bicycle Counting and Demand Estimation Study documents a framework for collection and documentation of pedestrian and bicycle count data based on national standards, including the National Bicycle and Pedestrian Documentation Project.

Currently little pedestrian and bicycle count data has been collected. The information that was collected was only available in paper form in a series of folders and binders held by a retired county employee. The information was not kept in a central repository for agency members to see or use. The goal of this project is to collect and use non-motorized traffic counts for planning and monitoring of projects. To make the data collected more useful, it will need to be stored in an accessible format and retained so that trends, model calibration and validation can be conducted as well as other planning and engineering work. This chapter will document the data elements that will need to be captured and stored.

The reporting structure will enable H-GAC staff to utilize pedestrian and bicycle count data from outside data collection efforts (e. g., volunteer spot counts) and integrate it with ongoing count data collected through both permanent and temporary counters deployed throughout the region. This memorandum includes a summary of:

- Previous non-motorized counting efforts in the region and to ensure that other counts (i.e., those undertaken by the City of Houston and/or Houston Parks Board) are incorporated into data collection and consolidation efforts.
- Investigate data storage needs including data aggregation levels, data types, and data descriptions;
- Investigate existing data warehouse tools and off-the-shelf products; and
- Develop methods to extrapolate spot count data into daily/annual use estimates based on data collected through permanent count locations.

The information in this chapter memo is based largely on guidance provided by the FHWA Traffic Monitoring Guide and the standard for the National Bicycle and Pedestrian Documentation Project (NBPD). NBPD suggests that information gathered in the region should be collected, reported and stored in the local, regional and national database to provide a better understanding of the characteristics and use of local facilities.

A regional database should be established to backup and archive the online data from the permanent counters and to provide a repository for temporary (spot- or limited-duration) bicycle and pedestrian counts. This database should also provide storage for the raw data files from various count sources. The database will assist in the analysis and modeling of non-motorized facilities. A phased implementation of a system of regular bicycle and pedestrian counts and monitoring sites in the eight county H-GAC Transportation Management Area will give HGAC and local government adequate data to:

- Understand usage of pedestrian and bicyclist facilities in a variety of regional development contexts.
- Adjust calculations on estimated air quality benefits of pedestrian and bicyclist facilities based on data collected in the region on facility usage.
- Estimate demand or usage of planned or proposed pedestrian and bicyclist facilities for project evaluation and selection purposes.

Existing Counts

Only a few non-motorized transportation counts have been conducted in the Houston region. The locations (and data) of the existing counts have been collected, assembled in a spreadsheet, mapped and documented in Chapter 3 of this project. Those locations have been submitted to the National Pedestrian and Bicycle Documentation Project. The City of Houston, the Energy Corridor District, and Harris County Public Infrastructure Department all participated in the National Pedestrian and Bicycle Documentation Project counts in 2005 and 2010. The Houston Parks Department also completed manual counts on walking trails in Herman and Memorial Park several years ago but no data was provided.

Local jurisdictions and agencies should be encouraged to collect and submit data to be included in a regional database for a variety of reasons.

- Regular counts on non-motorized facilities will more consistently provide documentation of the demand, use, and benefits of the investment in these active modes of transportation.
- Non-motorized counts can provide information to validate and calibrate travel demand and air quality models.
- A regional database will provide a framework for the documentation process and help move the state-of-the-practice forward.
- Data can be shared to help better understand the characteristics of these non-motorized modes.
- The better the understanding of the characteristics that make a facility successful and well utilized will provide planners and engineers the information to guide future transportation investment.
- More data will also provide better insight into regional adjustment factors which can be developed over time with enough input from the agencies.

Database Needs

There is a need for a central repository or data warehouse for non-motorized traffic data. Regional transportation models and a newly developed non-motorized travel demand model will use this data for validation and calibration and other regional planning efforts. The database can be used to quantify existing use characteristics, development of regional adjustment factors, and usage trend analysis. This repository should be both a database and storage for traffic, pedestrian, and bicycle count files. The database can be used for ease of access and the storage will allow future data analysis and/or back up of the raw data files. The data warehouse should have the flexibility to store data to be used locally and for submission to the *Bicycle and Pedestrian Documentation Project* or what is proposed to be a federal data submission process.

An internet search for traffic count (vehicle, bike/pedestrian) databases indicated that most agencies have a database that was developed in-house, by a consultant, or was vendor specific. An off-the-shelf software or online software for traffic data storage was not identified. The non-motorized count technology is still an emerging field, but as it matures a data warehouse option may become commercially available. As a start, some agencies have vehicular traffic volume databases that could be modified to incorporate non-motorized traffic.

A data warehouse including non-motorized traffic data should have the capability of accommodating these types of data:

- Pedestrian and bicycle volume data
- Raw and summarized volume and travel survey data
- Temporary station and permanent count station data
- Data in minimum 5 minute intervals, with ability to aggregate to 15 minute, hourly, daily, weekly, monthly and yearly count data
- Raw data files with standard metadata convention to detail agency, date, location, and other factors listed in the Traffic Monitoring Guide (TMG) and this tech memo
- Storage and reporting of automatic, manual, and intercept travel survey data
- Data description elements

Data warehouse elements are detailed in Chapter 7 of the Traffic Monitoring Guide. The highlights are provided below.

Database Elements

Nationally, practitioners are gathering data from across the nation to understand what characteristics influence the use of bicycle and pedestrian facilities. When pedestrian and bicycle counts are collected, reduced and analyzed, several elements should be included in the resulting data file. These elements can be used to help analysts track usage patterns over time and allow other agencies to mine the data to develop adjustment factors (by time of day, day of week, and season), as well as develop estimates of use based on facility type, land use, and other demographic characteristics.

The *Traffic Monitoring Guide* (TMG) provided by FHWA is intended for state highway agencies to provide good practice and to improve the quality, availability, and reduce the cost of data collection. The TMG supplies temporal data to understand the differences between short term and continuous count locations. One of the main sources of information is the Highway Performance Monitoring System (HPMS) data. The TMG provides a framework for short term and in the most recent update has included a chapter on non-motorized traffic data. Chapter 7 of the TMG provides a specific format for data elements to be included in a national database. There are many critical and optional data fields which should be included in the database if available. In general, the data elements include:

- Latitude
- Longitude
- Direction of Route
- Direction of Travel
- Facility Type
- Type of Sensor
- Weather Information
- Date and Time
- Count Interval

Other items that should be considered for local use are:

- Agency that conducted count
- Agency Reference File Number - if applicable
- Location Description – local name of facility and nearest cross street
- Street Address
- Facility Type (side walk, off street trail, bike lane, etc.)
- Adjacent Facility Type (major collector, arterial, frontage road, etc.)
- Average Daily Traffic (ADT) or 24 hour count of the non-motorized facility
- Count Description - (monitoring, special study, special event)

- Traffic Generators – (pedestrian traffic counted on sidewalk 100 yards from the ABC Youth Baseball complex)
- Condition – typical, construction, holiday, special event, etc.
- User Type - group of users that are reflected by the data (recreational, commuting, utility, hybrid)
- Local Facility Type (bike lane, shared lane, shared use path, other)
- Land Use Characteristics (person density, intersection density, land use density, etc.)

Adjustment Factors

Adjustment factors are used to extrapolate estimates of daily, monthly, and/or annual user counts based on counts done during any period of a day, a month, or a year. Over time local permanent traffic counters will be used to develop local adjustment factors based on facility type, area type, day, month, and year. The development and application of adjustment factors are best achieved with local data; however, there is currently a lack of local data in the system. With the installation of the permanent counters along the MKT and White Oak Bayou, these local factors can be used within a year or so to adjust counts along other similar trails in areas with similar demographics. Not all counts in the Houston area can be normalized with factors generated from these two permanent count stations. Additional permanent count locations based on demographics and facility type will be needed to accurately adjust those counts. Through engineering judgment, week long counts may be able to be normalized using these local factors but with a higher degree of error.

Existing methods for extrapolating spot counts using local factors were identified in the ITE Manual of Transportation Engineering Studies and in the Bicycle and Pedestrian Documentation project. The procedures are best described at the National Bicycle and Pedestrian Documentation Project (NBPDP) that allows for an average of counts to be used to provide an estimate of day, month, and year count. More information can be found here: http://bikepeddocumentation.org/. These factors shown in the NBPDP are only available for multi-use paths and higher density pedestrian and entertainment areas. These are only estimates and there is no substitute for actual data. All facilities are highly variable due to local users, seasonal factors, and the use of the facility. Once local factors are available, the same methodology would be used to extrapolate temporary counts for planning purposes.

CHAPTER 5: MODELING REGIONAL NON-MOTORIZED TRAVEL IN H-GAC AREA

Chapter 5 is divided into three general sections. The first section reviews the researches and practices in the non-motorized demand estimation. The second section documents the development of a framework for estimating the demand and the ranking procedure of an area or road linked to non-motorized travel. The last section gives examples of how to use the developed framework to evaluate the non-motorized improvement projects.

LITERATURE REVIEW

When it comes to the investment decision for walking and biking facilities, identification of the most suitable location is of great interest to the planning organizations and decision makers. However, despite the importance, to date there has not been an established set of techniques or procedures to estimate the demand for walking and biking. The goal of this review is to focus on the major efforts in non-motorized demand modeling. Instead of reviewing a broad range of research, this review introduces a few national level efforts that have summarized most of the works in the field. In addition, this study also looks at recent local efforts to estimate the demand for walking and biking in the H-GAC area.

Nation-Wide Walking and Biking Modeling Effort Guidebook on Methods to Estimate Non-Motorized Travel (1)

There have been numerous efforts to model walking and biking demand over the years. The 1999 FHWA report gives a comprehensive review on the subject. The report categorized the demand modeling effort into five major methods, namely 1) comparison studies, 2) aggregate behavior studies, 3) sketch plan methods, 4) discrete choice models, and 5) regional travel models. In the report, biking and walking demand were collectively referred in terms of modeling effort, although the differences between the two non-motorized transportation modes were briefly introduced. This research report evaluated these methods by five factors that include ease of use, data requirements, accuracy, sensitivity to design factors, and widely used.

The five major demand methods and their evaluation by the chapter are summarized below.

1. The comparison studies use the observed results on walking or bicycling rate change to predict the change in another area assuming all other influencing factors are roughly the same between the two situations.
2. The aggregate behavior studies apply the relationship of travel behavior characteristics for an aggregate population to predict mode split for non-motorized modes. Both of these two methods are relatively easy to use and have relatively low

data requirement, it is believed the methods had low explanatory power, hence produce low accuracy results.

3. A sketch plan method is a step forward in terms of the estimation method. It applies the easy-to-collect data (such as census and land use data) to estimate the non-motorized travel (NMT) at the facility level. The report concludes that this method tends to be relatively simple to understand and apply, and could have reasonable results if the variables selected carefully. However, the disadvantages are that 1) the limited local data and general assumptions about behavior may hinder the precision of the results and 2) the transferability of model to another geographic area may be questionable due to the local conditions. The discrete choice model and regional travel model are comprehensive modeling efforts. Both methods require collection of extensive data.
4. A discrete choice model predicts the likeliness of a choice (mode, route, and time) as a function of variables including factors describing a facility improvement or policy changes. Discrete choice models are widely used by the modelers to predict auto vs. non-auto mode choice. The limitation of the model is the identification and applying of influencing factors in the modeling effort. The transferability of the model can also be limited.
5. Regional travel model, also known as the four-step travel demand model, uses the land use conditions, transportation network characteristics, along with the human behavior models to predict future travel patterns. The models have been traditionally used to predict auto and transit trips. Many planning organizations have been modifying the models to integrate biking and walking facility and to predict the biking and walking trips. However, due to the large amount of data required, including the inventory of existing biking and walking facilities and land use factors not included in the auto trips modeling, it has not become a widely used method.

This chapter concludes that biking and walking demand modeling is an evolving field and creative thought is needed in the real world. Three areas of future research were identified by the report:

- Development of a manual for bicycle and pedestrian sketch-planning. The report concludes that such a manual would help the practitioners to easily yet effectively estimate the demand even without the resources and expertise.
- Further research on factors influencing non-motorized travel behavior. Research on identification of influencing factors, how these factors interact, and how to incorporate these factors into the models would be helpful to improve the modeling techniques.

- Integration of bicycle and pedestrian considerations into mainstream transportation models and planning. The report suggested that the inclusion would put biking and walking on more equal status with the motorized modes.

Guidelines for Analysis of Investments in Bicycle Facilities (2)

The National Cooperative Highway Research Program (NCHRP) project 07-14 also reviewed the effort on estimating bicycling demand and characterized the work into two major approaches which are 1) the models that establish a relationship between the amount of bicycling and the influencing factors including demographic, policy, land use, facilities environment, and etc. and 2) the approach use an established census commute-to-work share, combined with other data, to provide an area specific baseline of bicycle usage. This chapter found that most of the past work follows the first kind of approach.

The chapter reports that these two approaches are completely different ways of approaching the problem: the first approach relies on the assumption that the relationships between demand and identified influencing factors will be stable over time and transferable from place to place, the second one relies more directly on what is known to be true about demand in a given area. One limitation of the second approach is that it does not directly relate demand to changes in the underlying environment. However, the chapter believes that "it is more accurate to base predictions on known facts than on theoretical and possibly unproven relationships", especially within the short to medium forecasting time frames.

This chapter also reviewed the five methods evaluated in the 1999 FHWA report. However, this report has different viewpoints about the evaluation. This chapter believes that the sketch planning method could be rather accurate and yield comparative level of estimation as the more comprehensive modeling efforts. It suggests the method is especially useful for the planners to do a risk analysis since the degree of accuracy can be known. The chapter does not suggest the discrete choice and regional travel models are appropriate for modeling bicycle travel because of the "unobservable" factors playing a greater role in determining bicycle travel than in auto or transit travel.

The chapter used the sketch planning method developed for the Twin Cities area as an example to illustrate that 1) factors such as local attitudes and perhaps history play a substantial role in choosing bicycle travel, and 2) although the range of estimation by different methods can be large in relative terms, the difference is small in absolute terms. The conclusion was that the decision based on the demand estimation for major investments of walking and biking infrastructure is generally sound despite of somewhat less accurate estimation.

Estimating Bicycling and Walking for Planning and Project Development (3)

One research effort still in progress is the NCHRP project 08-78. This study can be viewed as one of the follow up studies to the 1999 FHWA study to develop a manual for the practitioners to easily yet effectively estimate the demand.

The objective of the research is to prepare a guidebook for practitioners on estimating and forecasting bicycling and walking activity. The guidebook will include transferrable methods for practitioners working on regional-, corridor-, and project-level analysis to estimate and forecast bicycling and walking activity in relation to transportation infrastructure characteristics, land use, topography, weather/climate, and socio-demographic characteristics.

An interim report documenting primary results from several chapters has been submitted. The research project is expected to be done by the first half of 2013.

H-GAC Area-wide Walking and Biking Modeling Effort

The 2010 Pedestrian and Bicycle Special District Study was based on the 2004 study to "identify districts where there are significant opportunities to replace vehicle trips with pedestrian or bicycle trips and to improve pedestrian and bicycle safety."(*4*)

The study identified destinations or attractors for biking and walking and assigned a one-half mile radius, a compromised distance for both walking and biking, to form the area of analysis (district) for each destination point. The values of a series of indicators (as seen in Table 5-1) originally identified to be correlated to the likeliness of biking and walking in the 2004 study were collected for each district. A score was calculated for each district based on these values. These districts were then grouped into super neighborhoods due to the close vicinity with each other. Top 25 districts with the highest score were identified. It was found that high scoring districts are concentrated in urbanized areas within the city of Houston where population and employment densities are high, mixed land uses are found, and transit access is widespread.

The method used by the study can be viewed as the first approach described by the NCHRP 07-14, which links the usage of walking and biking to a series of infrastructure and land use factors. Although the study considered many influencing factors, no existing collected counts or household survey data was used to verify the findings. As stated by the report, the study was intended to serve as a starting point for further study and investment for biking and walking projects in the H-GAC area, rather than suggesting investment for the high scoring areas only.

Table 5-1. Indicators of Pedestrian and Bicycle Travel Demand.

Indicator/Variable	Description	Rationale	Data Source
Population Density	Total population within district	Higher population density is associated with increased rates of walking and bicycling	2000 Census (Block Group Level Data)
Children	Percent of persons age 5-17	School-aged children tend to walk and bicycle more than adults	
Older Persons	Percent of persons age 65 and older	Older persons tend to be more dependent on non-motorized transportation options when compared to working adults	
Income (per capita)	Percent of persons in lowest income quintile	Low income rates are associated with low rates of automobile ownership and greater dependence on non-motorized transportation. Per capita is used over household income because household size can skew income factors	
Home-Work Distance	Number of workers with a commute to work that is less than 10 minutes	People with short commute times or distances are more likely to walk or bicycle to work	
Existing Walking Rates	Percent of people who walk to work	High walking rates demonstrate an existing desire and willingness to walk for transportation	
Existing Bicycling Rates	Percent of people who bicycle to work	High bicycling rates demonstrate an existing desire and willingness to bicycle for transportation	
Employment	Number of jobs within the district	Jobs are significant trip attractors for all modes of travel and are important	H-GAC Land Use Database
Diversity of Land Uses	Percentage of land not categorized as the predominant land use within the district	A mix of land uses (demonstrated as the lack of one dominant land use in the area) is associated with higher rates of pedestrian and bicycle travel	
Destination Type	Category of destination type (i.e. school, office, retail center, park)	Certain land uses/types of destinations may be more attractive for pedestrians and bicyclists when compared to others [2]	
Presence of Other Destinations	Count of other destination points within district	Clusters of destinations within a compact area tend to encourage walking and bicycling trips	
Number of Pedestrian Crashes	Count of pedestrian crashes within district	Indicates heavy use and/or safety issues that need to be addressed	TxDOT Crash Record Information System (2003-2008)
Number of Bicyclist Crashes	Count of bicyclist crashes within district	Indicates heavy use and/or safety issues that need to be addressed	
Street Density	Ratio of streets to land area	Smaller street blocks and more street miles per square mile are more supportive of bicycling and walking	H-GAC StarMap
Number of Transit Stops	Count of transit stops within district	Walking and bicycling are commonly combined with transit for trips	Houston METRO, Island Transit, Fort Bend County Transit

METHODOLOGY

Modeling non-motorized travel in the H-GAC area involves four modeling components: 1) estimation of current demand, 2) estimation of current supply, 3) interaction between current demand and supply, and 4) overlapping with super neighborhoods, which is the latent demand. This report addresses each of the four aspects of the modeling work respectively.

Non-Motorized Travel Current Demand

The data used for estimating current demand comes from the H-GAC regional transportation study 2008 household survey conducted by travel survey group of the Texas A&M Transportation Institute (TTI). The 2008 H-GAC household survey obtained data and information on 5,807 households randomly selected in Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller Counties. The survey data were processed and expanded to prepare estimates of travel by pre-defined trip purposes.

There are nine different trip purposes used in H-GAC, they are:

- Home Based work (HBW),
- Home Based Non-Work (HBNW) Retail,
- Home Based Non-Work (HBNW) Airport,
- Home Based Non-Work (HBNW) Other,
- Home Based Non-Work (HBNW) / Non-Home Based (NHB) Education (K to 12) – School Bus only,
- Home Based Non-Work (HBNW) / Non-Home Based (NHB) Education (K to 12) – by other,
- Home Based Non-Work (HBNW) Education (Post Secondary),
- Non-Home Based Work (NHBW),
- Non-Home Based Other (NHBO).

Stratified trip rates were developed based on the estimated number of trips and number of households for each trip purpose by worker stratification. Trip rates were developed for person, motorized, walk and bike trips. Small stratified sampling surveys typically produce results that are not always consistent with logic or rational. A manual smoothing process was done to reduce what is referred to as sampling noise. This smoothing process is based on professional judgement in combination with statistical data from the survey. In all cases, the results are constrained to produce the same total estimates of travel for each trip purpose.

The resulting walk and bike trip rates for all trip purposes were obtained from the H-GAC survey results. The summation of these trips by each Traffic Analysis Zone (TAZ) constitutes the demand of the non-motorized travel. A geographic information system (GIS) application was used to join the walk, bike, and the sum of the walk and bike (non-motorized) trips to a TAZ GIS map. The current demand of non-motorized travel by TAZ for the H-GAC area is shown in Figures 5-1, 5-2 and 5-3.

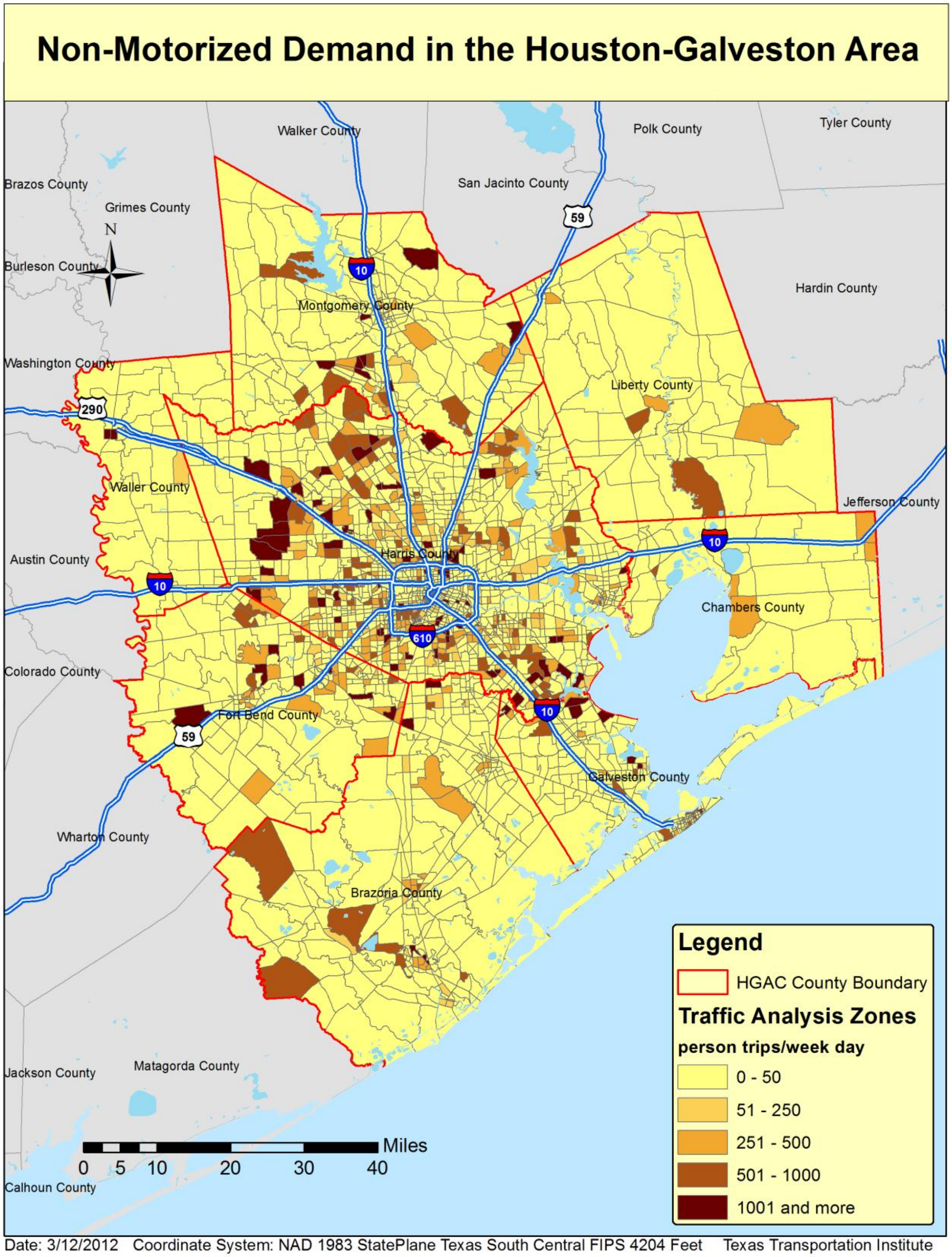


Figure 5-1. Current Demand for Non-Motorized Travel in H-GAC Area.

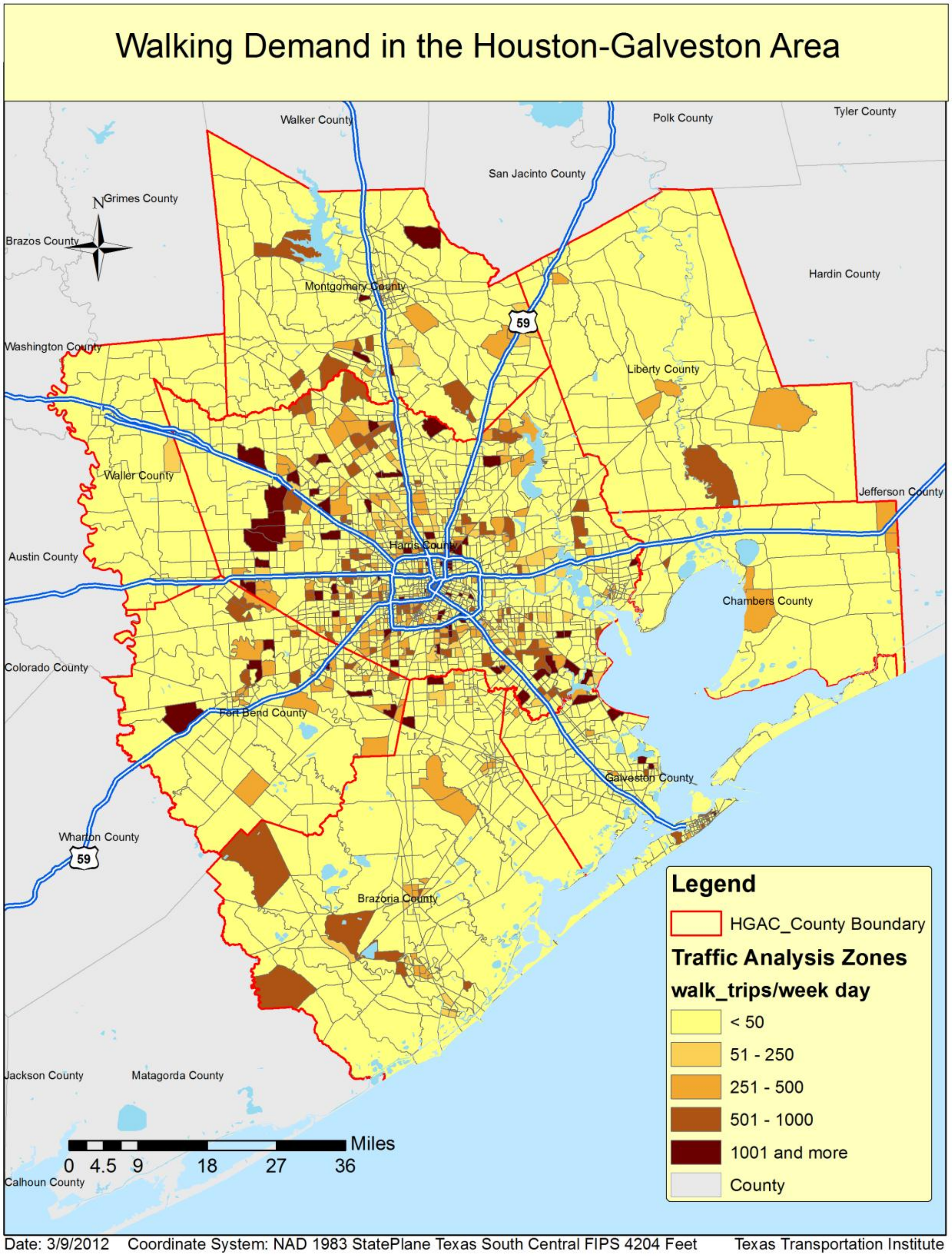


Figure 5-2. Current Demand for Walking Travel in H-GAC Area.

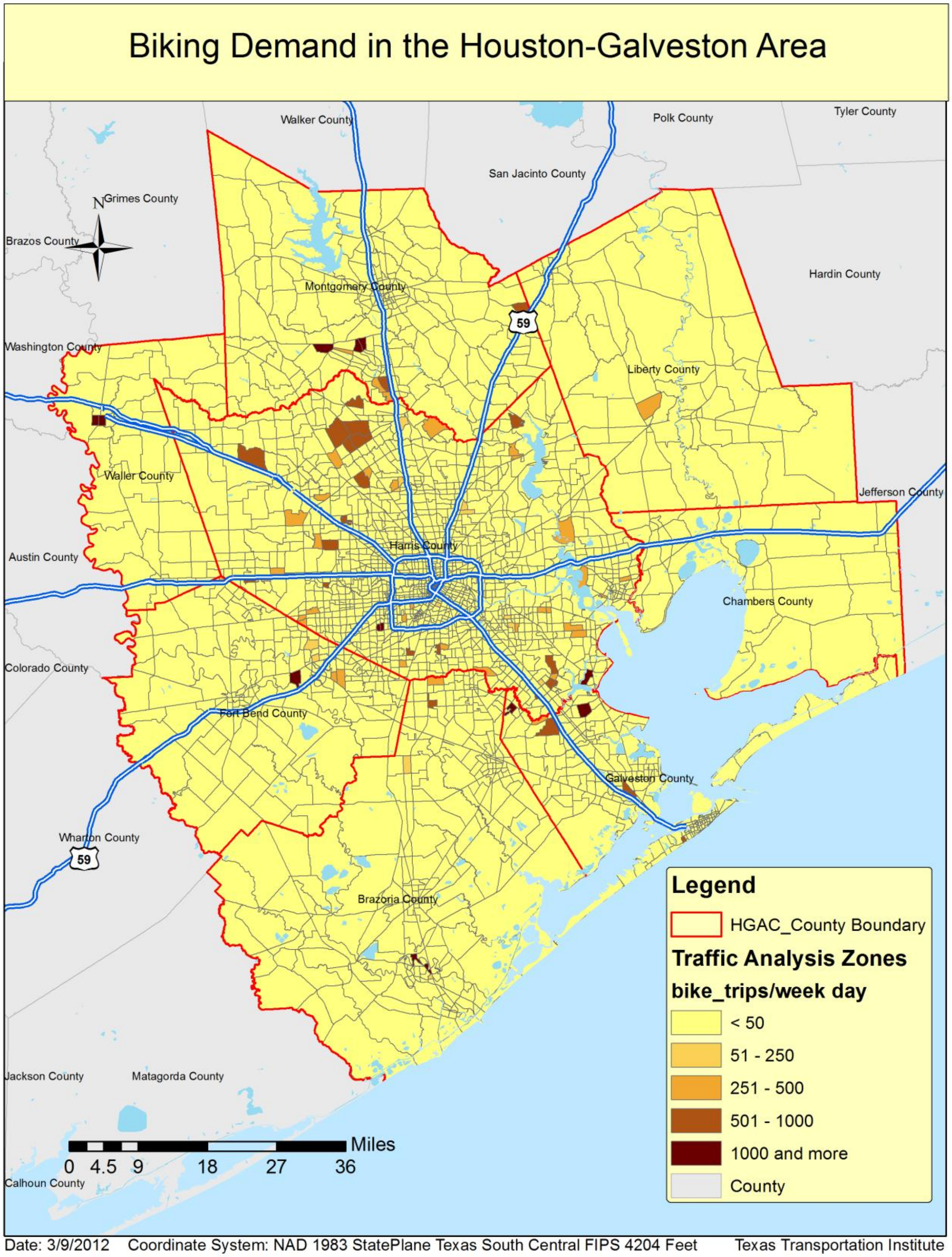


Figure 5-3. Current Demand for Biking Travel in H-GAC Area.

Non-Motorized Travel Supply

The supply of non-motorized travel can be modeled by creating the indicators that reflect the compatibility of the road network to the non-motorized travel. It can be separated by bicycle travel supply and pedestrian travel supply.

Bicycle Travel Supply

The Federal Highway Administration's Bicycle Compatibility Index (BCI) was used to model the road network supply for bicycle travel (5). The BCI was developed to indicate the compatibility of the roadway to bicycle travel. It incorporates variables that bicyclists typically use to assess the "bicycle friendliness" of a roadway, such as curb lane width, traffic volume, and vehicle speeds. The BCI model can be used for operational evaluation, design and planning applications. The formula and variables of the model are listed in Table 5-2.

Table 5-2. Bicycle Compatibility Index (BCI) Model, (in English units).

BCI = 3.67 - 0.966**BL** - 0.125**BLW** - 0.152**CLW** + 0.002**CLV** + 0.0004**OLV** + 0.035**SPD** + 0.506**PKG** - 0.264**AREA** + **AF** where:	
BL = presence of a bicycle lane or paved shoulder > 3.0 ft *no = 0* *yes = 1* **BLW** = bicycle lane (or paved shoulder) width *ft (to the nearest tenth)* **CLW** = curb lane width *ft (to the nearest tenth)* **CLV** = curb lane volume *vph in one direction* **OLV** = other lane(s) volume -same direction *vph* **SPD** = 85th percentile speed of traffic *mi/h*	**PKG** = presence of a parking lane with more than 30 percent occupancy *no = 0* *yes = 1* **AREA** = type of roadside development *residential = 1* *other type = 0* **AF** = $f_t + f_p + f_{rt}$ where: f_t= adjustment factor for truck volumes (*see below*) f_p = adjustment factor for parking turnover (*see below*) f_{rt} = adjustment factor for right-turn volumes (*see below*)

Adjustment Factors

Hourly Curb Lane Large Truck Volume[1]	(f_t)	**Parking Time Limit (min)**	f_p
> 120	0.5	< 15	0.6
60 - 119	0.4	16 - 30	0.5
30-59	0.3	31 - 60	0.4
20-29	0.2	61 - 120	0.3
10-19	0.1	121 - 240	0.2
< 10	0.0	241- 480	0.1
Hourly Right-Turn Volume[2]	f_{rt}		
> 270	0.1		
< 270	0.0		

1 Large trucks are defined as all vehicles with six or more tires.
2 Includes total number of right turns into driveways or minor intersections along a roadway segment.

Although some road facilities are perceived unsafe or unfriendly to bicycle travel, it is often seen that bicyclists ride not only the bike lanes but also all classes of road facilities except for freeways. For this reason, the BCI was calculated for the entire road network of the H-GAC area. Two road network layers were integrated for the H-GAC area to form the entire bicycle supply network: the bike lane network and the road network. A GIS application was used to integrate the two road networks. The bike lanes and vehicle travel road network were joined based on the recorded location of bike lane facilities. It should be noted that the bike lane network is not the most current information. Additional efforts are needed to update the inventory of the bike lanes in the H-GAC area.

The BCI calculation for the entire road network is introduced below.

- Bike Lane (no unit): The bike lane was coded 1 if the street had a bike lane and 0 if it didn’t. The BCI values for streets with bike lanes were received from H-GAC, all the other streets that did not have a bike lane were coded as 0 for the BCI.
- Bike Lane width (Feet): Due to lack of detailed data, the bike lane width was coded as 4 feet wide for all streets with a bike lane.
- Curb Lane width (Feet): Due to lack of detailed data, curb lane width was coded as 12 feet wide for all functional classes 9-13, and 11 feet for all other non-freeway functional classes.
- Curb Lane Volume (vehicle per hour): The curb lane volume was calculated by 1) dividing the total daily traffic volume from 2010 (bi-direction) by 2 and by the number of lanes to obtain the daily volume per lane per direction, and 2) by dividing the daily volume per lane per direction by 12 to obtain the peak hour volume per lane per direction. The assumption is that the peak hour volume accounts for 12% of the daily volume.
- Non-Curb Lane Volume (vehicle per hour): The non-curb lanes volume was obtained by subtracting the curb lane volume from the total hourly volume per direction.
- Speed Limit: To determine the speed limits, the speed limit data from the traffic demand modeling network is referred. But the data is incomplete. For the roadway links that do not have speed limit records, assumptions are made on the basis of functional classes. Table 5-3 lists the speed limit assumptions in this project. Since freeway and High Occupancy Vehicle lanes will be finally taken out from the analysis, assumptions are only made for Facility Type 9 – 19 (excluding 18), 90 and 91.

Table 5-3. Speed Assumptions Made for BCI Calculation.

Facility Type	Description	Speed Limit
9	Principal Arterial with some Grade Separations	50
10	Principal Arterial – Divided	50
11	Principal Arterial – Undivided	50
12	Other Arterial – Divided	45
13	Other Arterial – Undivided	45
15	One-way Pair	50(FUNC 12) 45(FUNC 5) 35(DOWNTOWN)
16	Major Collector	40
17	Minor Collector	40
18	Ferry	-
19	Saturated Arterial	40(FUNC 5) 50(FUNC 12)
90	'Smart' Streets	45
91	'Express' Street	45

- Parking (no unit): The parking variable is the presence of a parking lane with more than 30 percent occupancy. For this project, the parking value was uniformly set to 0 because the road facilities in the travel demand model network do not typically include the road facilities with functional class lower than collector. Therefore, parking facilities typically do not exist on the roads with the functional class of collector or higher.
- Area (no unit): The area variable was calculated by assigning the value 1 for the links that are in the residential area type and values 0 for the links that are not in the residential area. Table 5-4 lists the values used for this project.

Table 5-4. Area Values for BCI Calculation.

Area Type	Description	Area Value
1	Central Business District (CBD)	0
2	Urban Intense	1
3	Urban Residential	1
4	Suburban Residential	1
5	Rural	0

These values were plugged into the BCI formula resulting in a 2.3 BCI, which is LOS B.

- Adjustment Factors (no unit): The adjustment factors were assigned based on the functional class of the highway, with high traffic lanes given the score 1.1, and other values assigned a score of 0.9. The reason for this is that highways have high truck volume as well as no parking, but also no right turn facilities. For other major arterial roads, the parking time and large truck volume are not as high, but there are right turn lanes. Table 5-5 lists the values used for this project.

Table 5-5. Adjustment Factors for BCI Calculation.

Facility Type	Description	AF
1	Radial Freeway without Frontage Roads	1.1
2	Radial Freeway with Frontage Roads	1.1
3	Circumferential Freeway without Frontage Roads	1.1
4	Circumferential Freeway with Frontage Roads	1.1
5	Radial Toll way without Frontage Roads	1.1
6	Radial Toll way with Frontage Roads	1.1
7	Circumferential Toll way without Frontage Roads	1.1
8	Circumferential Toll way with Frontage Roads	1.1
9	Principal Arterial with some Grade Separations	0.9
10	Principal Arterial – Divided	0.9
11	Principal Arterial – Undivided	0.9
12	Other Arterial – Divided	0.9
13	Other Arterial – Undivided	0.9
14	One-way Facility	0.9
15	One-way Pair	0.9
16	Major Collector	0.9
17	Minor Collector	0.9
18	Ferry	0.9
19	Saturated Arterial	0.9
20	HOV Lane (High Occupancy Vehicle)	1.1
21	HOV Ramp to Park & Ride/Transit Center (PNR/TC)	1.1
26	PNR/TC access to Roadway	1.1
27	HOV Slip Ramp	1.1
29	HOV Ramp	1.1
30	Guideway / Rail	1.1
40	HOT Lane (High Occupancy Toll)	1.1
41	HOT Ramp to PNR/TC	1.1
47	HOT Slip Ramp	1.1
49	HOT Ramp	1.1
50	Freeway Frontage Road	1.1
51	Tollway Frontage Road	1.1
52	Freeway Ramp	1.1
53	Freeway Direct Connector Ramp	1.1
60	Diamond Lane (non-barrier separated HOV)	1.1
90	‘Smart’ Streets	0.9
91	‘Express’ Street	0.9

After the BCI was calculated for the entire integrated road network, the road facilities were further classified by the level of service using the range established by FHWA *(I)*. The higher the BCI value, the lower the LOS is. Figure 5-4 shows the BCI and the associated LOS for the road network. It should be noted that this road network was originally developed for the motorized travel demand modeling. Therefore, most of the lower functional class roads, for example collectors and local streets, were not included in this road network. Although Figure 5-4 shows no roadway link has LOS A or B, it does not preclude that some of lower function class roads do not have a higher LOS. In fact, the pedestrians and cyclists tend to choose lower function class roads for safety and aesthetic reasons. However, since the lower function class roads were not included in the network, the BCI and LOS were not calculated for these roads.

Recommendation for Improving the Friendliness of Roadway to Bicycling Travel

The BCI formulation suggests that the existence of bike lane (or paved shoulder), bike lane width, and curb lane width are three factors positively related to the friendliness of the roadway to the bicycle travel. Vehicular volume and speed also significantly impact the BCI and parallel routes in congested corridors are the most desired method to accommodate bicycles. Most residential streets do not have bike lanes; however residential streets can make excellent facilities due to the lower traffic volumes and speeds.

Out of the three factors, the existence of bike lane (or paved shoulder) is obviously the most significant factor in improving the BCI. For the roadway where no designated bike lane is available, the wider the curb lane the friendlier the roadway is to bicycle travel. However, these roadways without bike lanes would, most likely, not be able to make level of service A or B. Potentially a modification to the BCI calculation based on roadway functional class would more accurately represent the true bicycle friendliness of the collector and residential streets, which are not included in the modeling network.

According to the LOS range established by FHWA, a road link with BCI less than 1.5 and 2.3 would be a LOS A and B respectively. A hypothetic case is described to illustrate a scenario which would be a LOS B:

A two lane collector with a bike lane is located in a residential area with the speed limit of 35 mph and curb lane with of 12 ft. The curb lane volume of the street is about 400 VPH and other lane volume 500 VPH. The hourly curb lane large truck volume is below 10 and hourly right-turn volume is below 270. No parking is allowed on this street. The respective values of the variables are listed below:

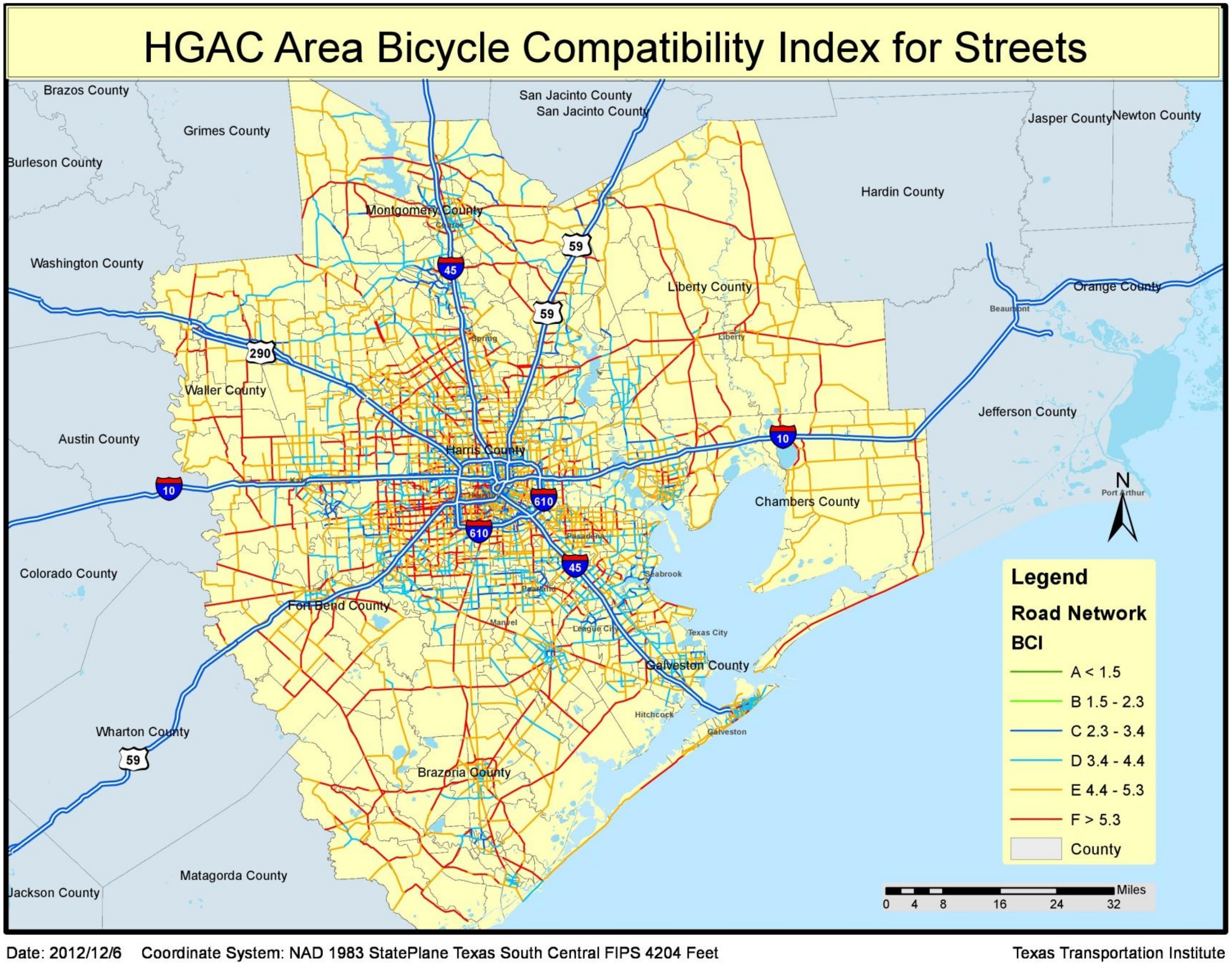


Figure 5-4. Bicycle Compatibility Index for the H-GAC Area.

- BL =1
- BLW=4
- CLW=12
- CLV=400
- OLV=400
- SPD=35
- PKG=0
- Area=1
- AF=0

Plugging these values into the BCI formula, the resulting BCI would be 2.3, which is LOS B.

For a street to be at LOS A, the traffic volume for the curb lane and the other lane need to be lower than 200 VPH which is rather rare for any collector and up functional class roads.

The FHWA BCI was developed in late 1990s. There have been many questions and debates as for how well the BCI represents the friendliness of a roadway to bicycle travel. Many new efforts have been put into develop a friendliness index more suitable for the specific region or area. In the case of this study, it may be of interest that a bicycle friendliness index could be developed using a regional scale to differentiate the roadways that are now clustered in the LOS C, D and F for the H-GAC region. This additional study would help identify the factors that are important to bicycle travel and the degree of the significance to the bicycle travel in the context of the H-GAC region.

Pedestrian Travel Supply

The pedestrian travel supply for the H-GAC region was modeled by creating the pedestrian friendliness index (PFI) for all TAZs in the area. Since no sidewalk inventory or other walking facility data was available for the H-GAC area, a method was developed to estimate the PFI for a TAZ. The method uses variables such as population density, retail density, and intersection density to model the friendliness of a TAZ. The details of the variables and steps used to calculate PFI are explained below. The PFI by TAZ for the H-GAC region is shown in Figure 5-5 and the PFI by TAZs for Harris County is shown in Figure 5-6.

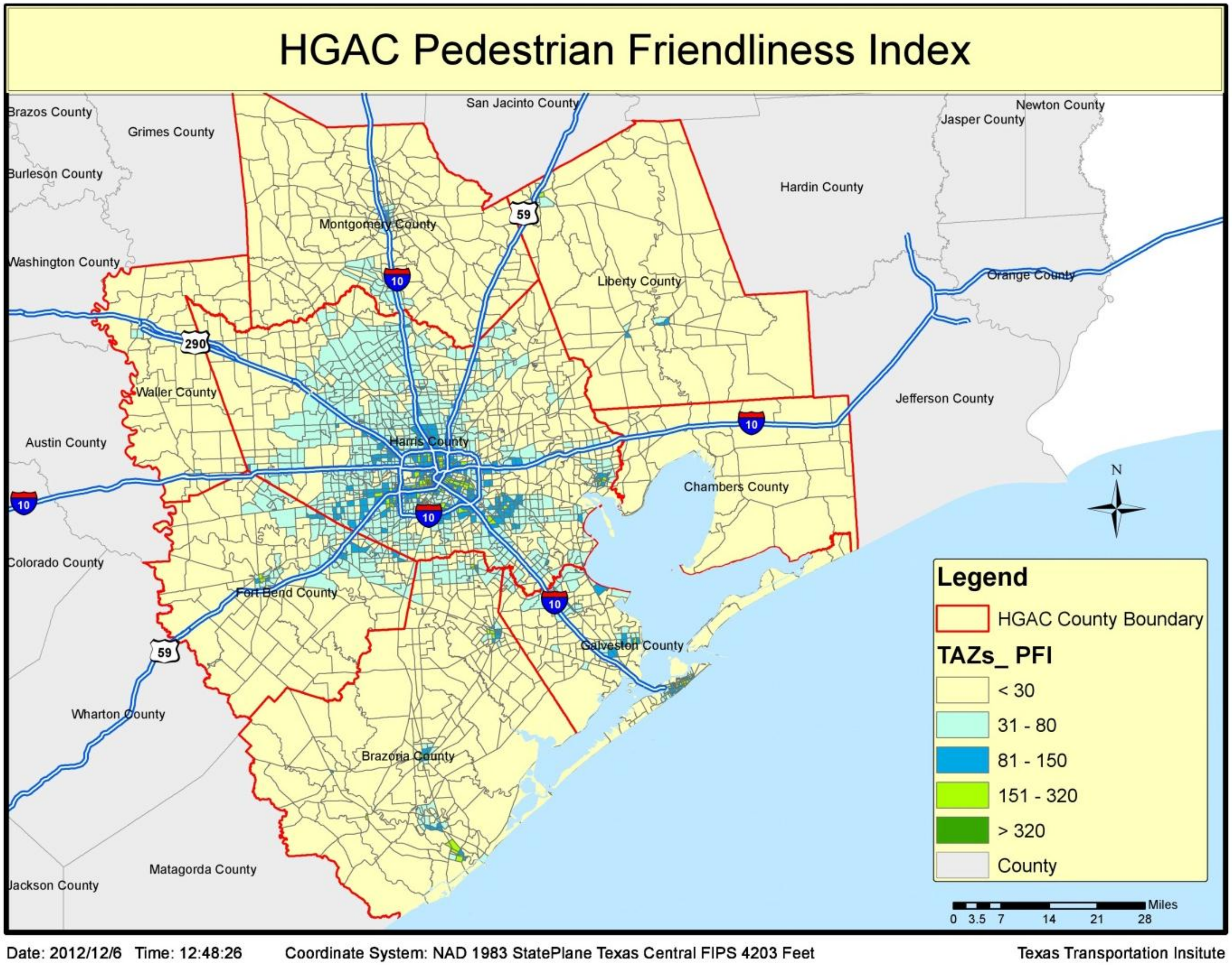


Figure 5-5. Pedestrian Friendliness Index for the H-GAC Area.

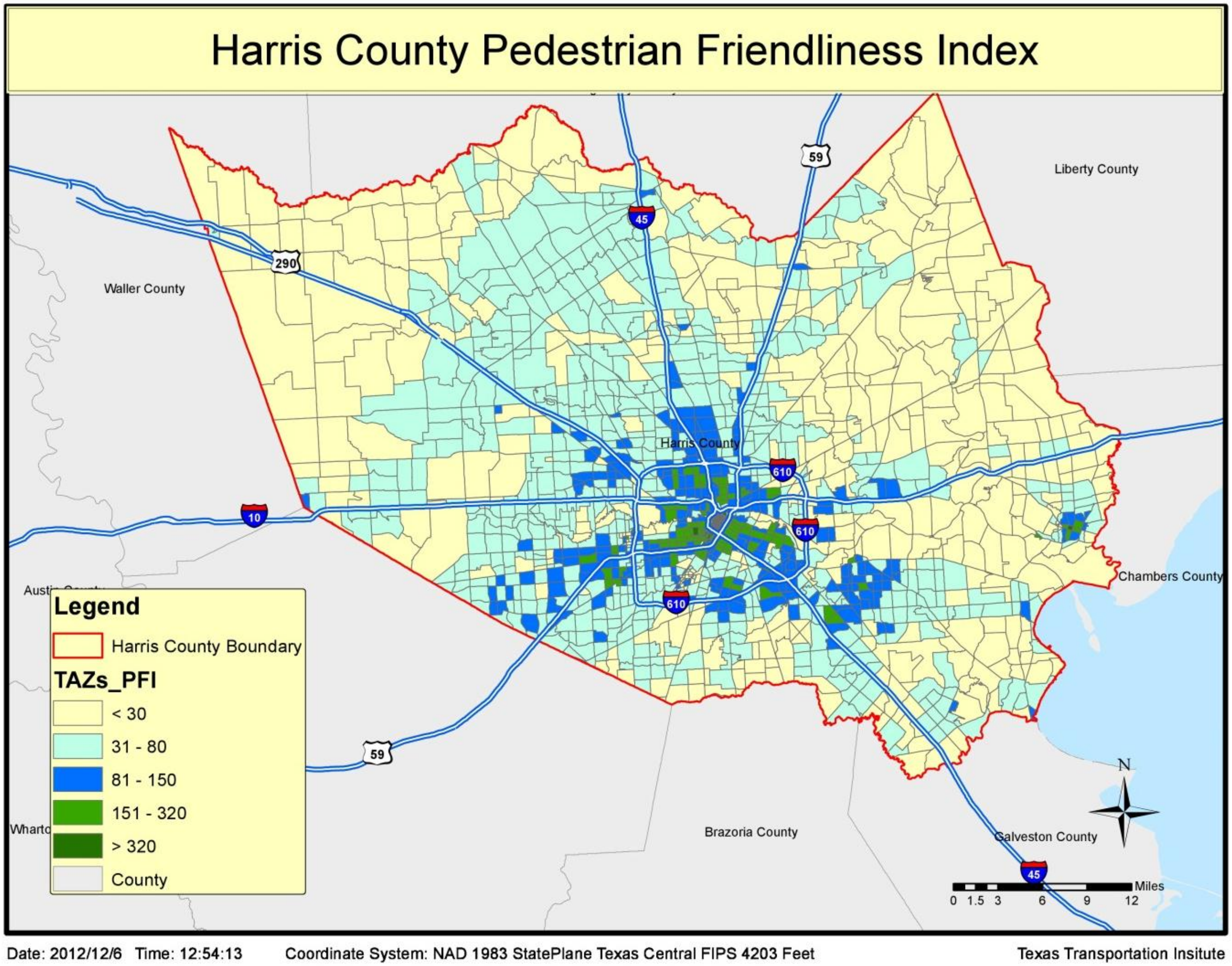


Figure 5-6. Pedestrian Friendliness Index for the Harris County.

Population density is a straightforward estimate of population in the year 2010 per square mile (POPpMI), and was calculated by dividing the 2010 population estimate per TAZ by the number of acres in the TAZ, then multiplying by 640 acres in a square mile. The average population density in the region for 2010 is 2955.2 per square mile.

Retail density was used as a TAZ-level proxy for distance to a store, calculated as commercial land use parcels per square mile (COMpMi). The H-GAC model used H-GAC area parcel level land use data. The average commercial parcel density in the region is 77.7commercial land parcels per square mile.

Intersection density was computed as the number of roadway intersections per square mile (INTpMI). This variable has a strong relationship to walking mode choice, and is also relatively challenging to calculate at the regional scale. The average intersection density for the region was 79.4 intersections per square mile. For comparison, this figure is less dense than Los Angeles, CA (150 intersections/square mile), but more than the CAMPO region (Austin, TX) (43.2 intersections/square mile).

Following are the steps undertaken:

1. Prepare pedestrian network

   A complete street network of the eight-county region was obtained from the H-GAC that was updated. Since this study concerns the pedestrian network, segments not generally accessible by foot were removed, including interstate main lanes and freeway ramps, for example.

2. Identify street intersections

   In order to automate the calculation of street intersection density, a step-by-step procedure was developed to generate street intersections. It outputs an ESRI point feature class containing the intersections of the network. The output point file was refined by removing nodes that are not pedestrian-accessible street intersections, such as freeway main lanes not coded in the H-GAC dataset, and airport access roads.

3. Calculate intersection density

   The number of intersections was summed by the TAZ using the “Spatial Join” Tool in ArcGIS tool box. Intersection density was then computed by dividing the number of intersections in a TAZ by the number of acres in the TAZ, multiplying by 640 acres in a square mile.

4. Estimating the Pedestrian Friendliness Index

In order to normalize the three variables to an index value, the maximum value in each of the TAZ records in the 5-county dataset was divided by 100. The average of these values was then computed for each TAZ as the Pedestrian Friendliness Index (PFI). Following Ewing and Cervero's meta-analysis (*5*), this estimation method is relatively simple to calculate, yet may be a powerful estimation of pedestrian mode choice.

Recommendation for Improving Walking Supply

The PFI developed in this study is a rather rough estimation of the pedestrian friendliness of an area. The three densities used to estimate PFI are indications of pedestrian walking supply. It should be noted that the method of estimating PFI does not suggest that the way to increase the walking friendliness of an area is to build high rise buildings (increase population density) and concentrate all retails (increase retail density) and cut the streets shorter (intersection density). In fact, it would be rather unsafe to have those high densities without sidewalks and other walking facilities.

A more accurate estimation of walking supply would need an inventory of the sidewalks and the condition of the sidewalks in the area. Currently, no such information is available. For future work, it is recommended that the remote sensing technology be applied on the regional aerial map to obtain the extensively time consuming information.

Interaction between Demand and Supply

Sketch planning procedures were developed to model the interaction between the demand and supply for bicycle and pedestrian travel respectively.

Bicycle Travel Demand and Supply

The total bicycle trips by TAZ which is the output of the travel survey were used as the demand for the bicycle travel. The BCI was used as the indicator of bicycle travel supply for the road facilities.

A GIS procedure was used to illustrate the interaction of bicycle travel demand and supply in the region and also identify the links that are undersupplied for bicycle travel. The steps are described below:

- Using colors to represent the Level of Service (supply) for the road links (as in Figure 7);
- Using thickness to represent the non-motorized demand of the road links; and

- Filtering the links that are with the color of LOS F as well as thicker than a threshold level (1000 trips/day was used for this project).

The assumptions made for these procedures are:

- The bicycle demand is evenly distributed within the TAZ. Therefore, the thickness of the road links are the same within the same TAZ;
- The road links that are in LOS F are considered undersupplied for bicycle travel and further ranked for the level of undersupply with high, medium and low.

Figures 5-7, 5-8 and 5-9 illustrate the demand and supply in the H-GAC region, Harris County, and downtown Houston area respectively. The road sections that are undersupplied (LOS F) with over 1000 non-motorized trip demand per day were further ranked with high, medium and low using 2000 and 1500 trips/day as thresholds. Table 5-6 and Figure 5-10 respectively list and illustrate these undersupplied road links on map.

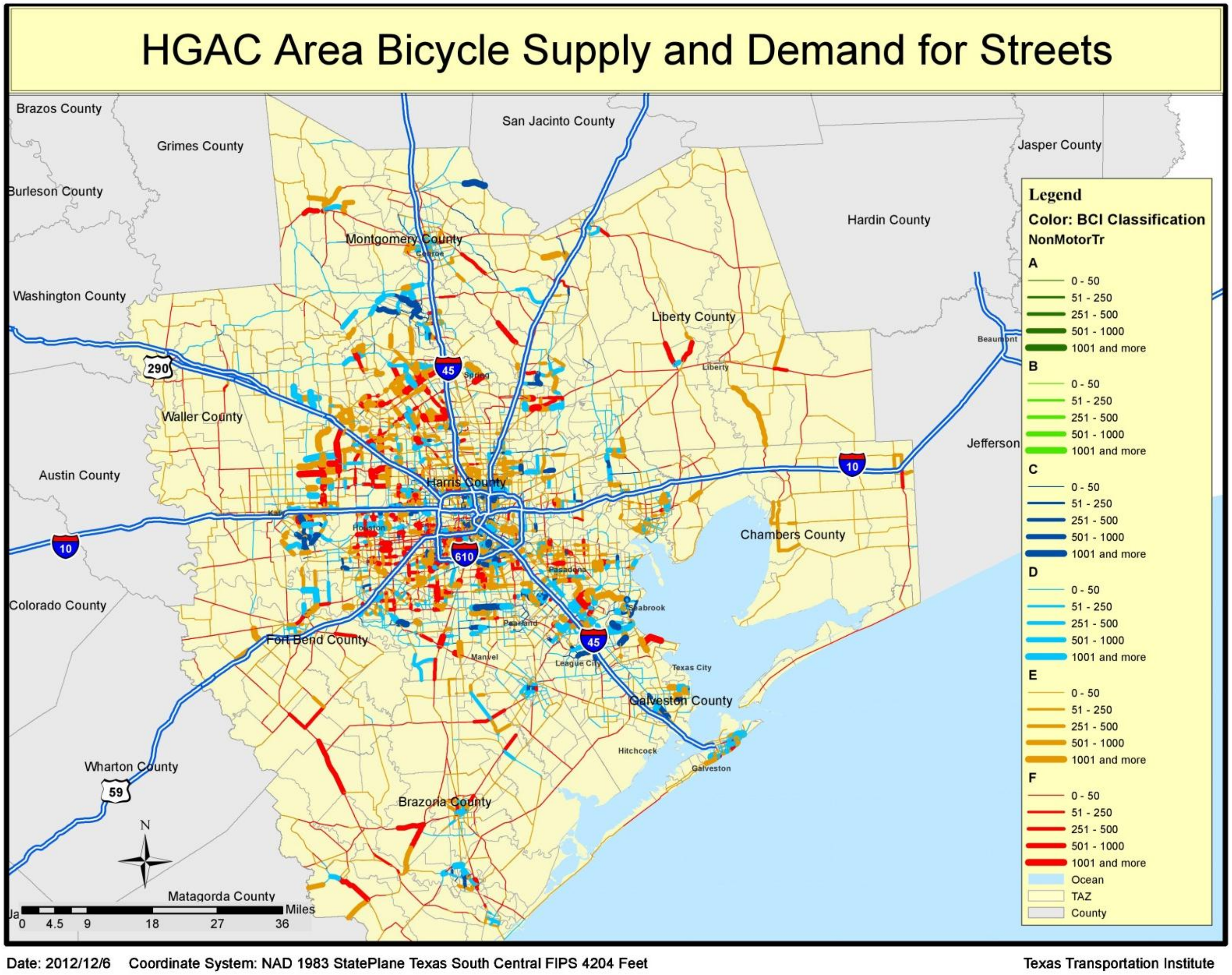
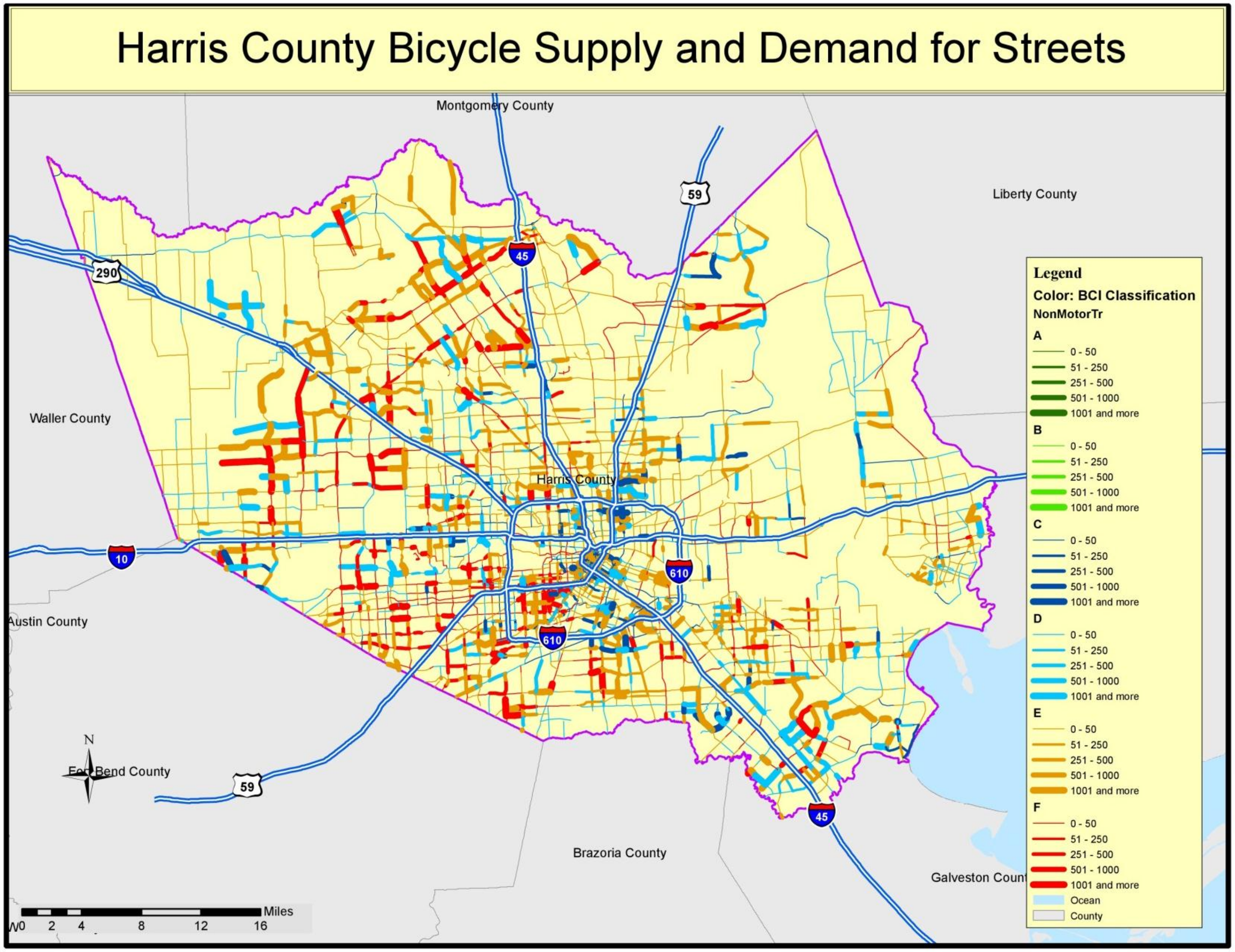


Figure 5-7. Supply and Demand for Bicycle Travel in H-GAC Area.



Date: 2012/12/6 Coordinate System: NAD 1983 StatePlane Texas South Central FIPS 4204 Feet Texas Transportation Institute

Figure 5-8. Supply and Demand for Bicycle Travel in Harris County.

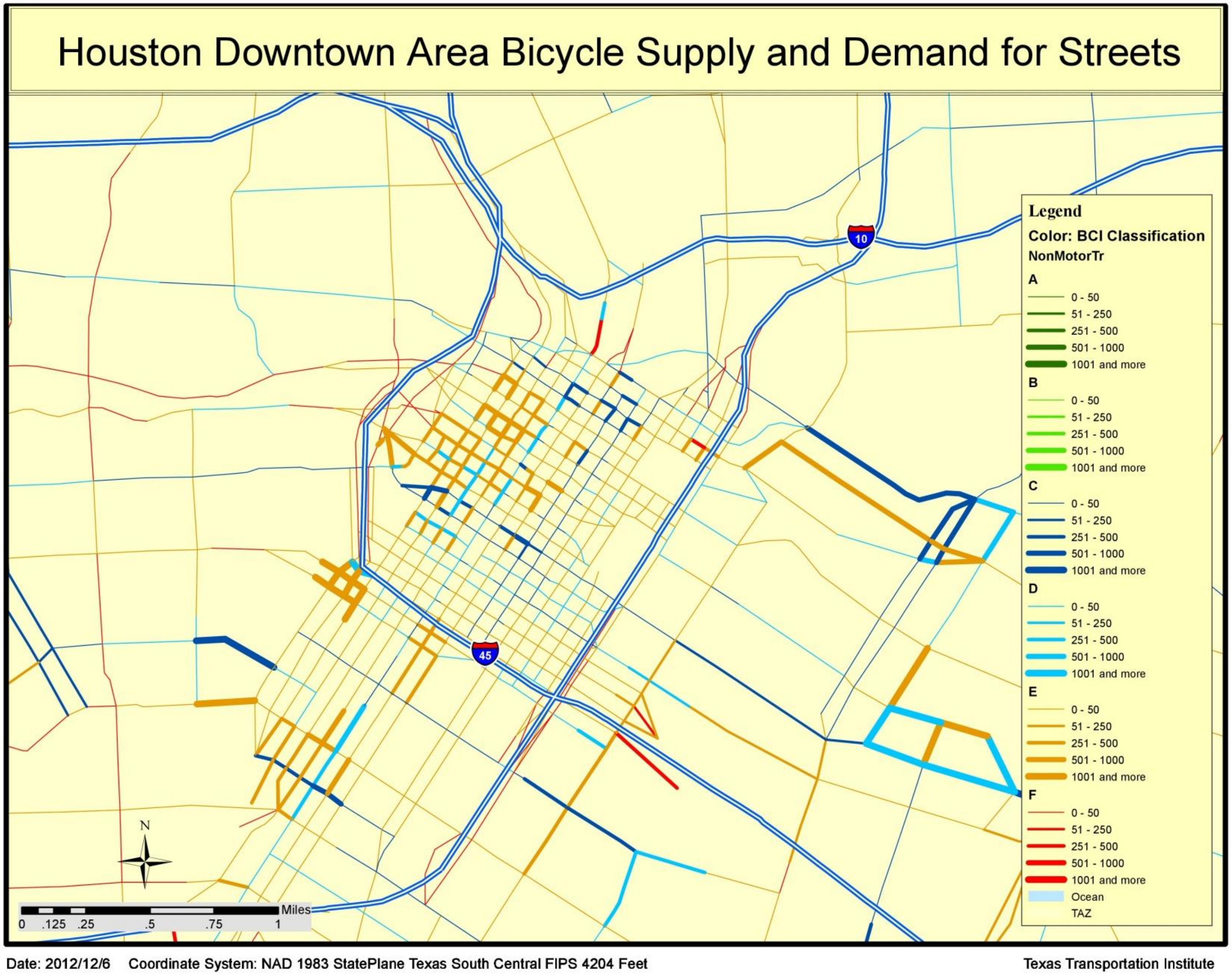


Figure 5-9. Supply and Demand for Bicycle Travel in Houston Downtown Area.

Table 5-6. Undersupplied Road (BCI>5.3 and Non Motor Trips>1000) Sections in Harris County.

Non-Motor Trips	Street Name	Start - End	Area Type	Total Miles
High	SH 6	OLD AIRLINE/CR 48 - LOUISIANA	5	4.56
High	FM 2351	BLACKHAWK BLVD - FM 2351	3	1.74
High	ELLA BLVD	34TH - KINLEY LN	3	1.76
High	EL DORADO	WOODBOURNE DR - SPACE CENTER BLVD	3	1.60
High	SPACE CENTER BLVD	FM 2351 - EL DORADO	3	8.40
High	FM 646	SH 146 - 27TH ST	4	9.74
High	SHEPHERD N	FORTY THIRD W - 34TH	3	4.14
Medium	ATASCOCITA RD	CONTINENTAL PKWY - WILL CLAYTON PKWY	4	2.34
Medium	WILLIAMS TRACE	S PARKWAY BLVD - SUGAR CREEK	3	1.47
Medium	FM 1960	NORTHWEST FWY - N ELDRIDGE PKWY	4	4.14
Medium	JONES	WEST RD - VILLAGE GREEN DR	4	6.84
Medium	KUYKENDAHL	ELLA BLVD -	3	5.22
Medium	WILL CLAYTON PKWY	ATASCOCITA RD - RALSTON RD	4	3.68
Medium	VETERANS MEM	W RICHEY - SPEARS RD	3	2.46
Medium	AIRPORT BLVD	SCOTT - LEITRIM WAY	3	1.88
Medium	FM 521	SH 6 - CR101	4	7.86
Medium	CULLEN	AIRPORT BLVD - WEST OREM	3	5.64
Medium	FM 1960	POSSUM PARK RD - Loop 184	4	10.84
Medium	JONES	WINDFERN - TRAIL RIDGE DR	4	13.38
Medium	SPEARS	ANTOINE DR - RANKIN RD W	3	8.68
Medium	TRESCHWIG RD	BIRNAM WOOD BLVD - CYPRESSWOOD DR	3	4.64
Low	FM 1488	SH 159 - FM 1887	4	0.20
Low	RICHMOND AVE	CUMMINS - EDLOE	2	0.90
Low	STUEBNER-AIRLINE	FIVE FORKS DR - LOUETTA RD	3	5.34
Low	BS 288B	PECAN ST - STRATTON RIDGE RD	4	3.36
Low	FM 521/ALMEDA	WEST OREM - MONTICELLO DR	3	2.40
Low	KUYKENDAHL	SPRING CYPRESS RD - BRIDGEVIEW LN	4	3.66
Low	FM 2090	US 59 -	5	0.48
Low	MASON RD	PARK TREE LN - HIGHLAND KNOLLS	3	2.00
Low	FM 529	GREENHOUSE - BARKER CYPRESS RD	3	4.96
Low	SH 99 FRONTAGE RD	KINGSLAND - GRAND RESERVE DR	3	0.87
Low	SPENCER HWY	UNDERWOOD - VALLEY BROOK DR	4	3.48
Low	LOUETTA	FIRESIDE DR - KUYKENDAHL	3	3.18
Low	SH 249	FALLBROOK - OLD BAMMEL N HOUSTON RD	3	2.17
Low	N HOUSTON-R0SSLYN	SH 249 - SILENT WOOD LN	3	1.08
Low	SH 99 FRONTAGE RD	KINGSLAND - W GRAND PKWY	3	0.88
Low	WILLOWBEND	CHIMNEY ROCK RD - MANHATTAN DR	3	0.42
Low	FUQUA	HIRAM CLARKE - CAMPDEN HILL RD	3	2.32
Low	WESTHEIMER	ELDRIDGE - DAIRY ASHFORD	3	8.64
Low	BECKENDORF/LITTLE YORK W	PEEK RD - FRY RD	4 and 3	12.87
Low	W LITTLE YORK	BRITTMORE - ENCLAVE VISTA LN	3	9.84
Low	LOUETTA	STUEBNER-AIRLINE - T C JESTER	3	8.94
Low	LOUETTA	SH 249 - GETTYSBURG DR	3	7.74
Low	HARWIN/ALIEF CLODINE	KIRKWOOD - WILCREST DR	3	4.00
Low	ANDERSON	S POST OAK - HIRAM CLARKE	3	4.52
Low	BARKER - CYPRESS RD	TUCKERTON RD - W LITTLE YORK RD	4 and 3	17.48
Low	BELLAIRE BLVD	KIRKWOOD - WILCREST DR	3	7.92
Low	BRAESWOOD S	CHIMNEY ROCK - W IH 610 S	3	4.16
Low	ELDRIDGE	W LITTLE YORK - TANNER	3	5.10
Low	FRY RD	FM 529 - CLAY RD	3 and 4	27.28
Low	FRY RD	MORTON RD - SAUMS RD	3	8.08
Low	S POST OAK	HEATHERBROOK DR - ANDERSON RD	3	6.60
Low	SH 159	AUSTIN ST - SHEPARD ST	4	5.52
Low	W BELLFORT	CHIMNEY ROCK RD - BALMFORTH LN	3	7.28

*** Area Types**
1: Central Business District; 2: Urban Intense; 3:Urban Residential; 4: Suburban Residential; 5: Rural
*__Non Motor Trips (trips perday):__
Low: 1000-1500; Medium: 1500 – 2000; High: 2000 and more

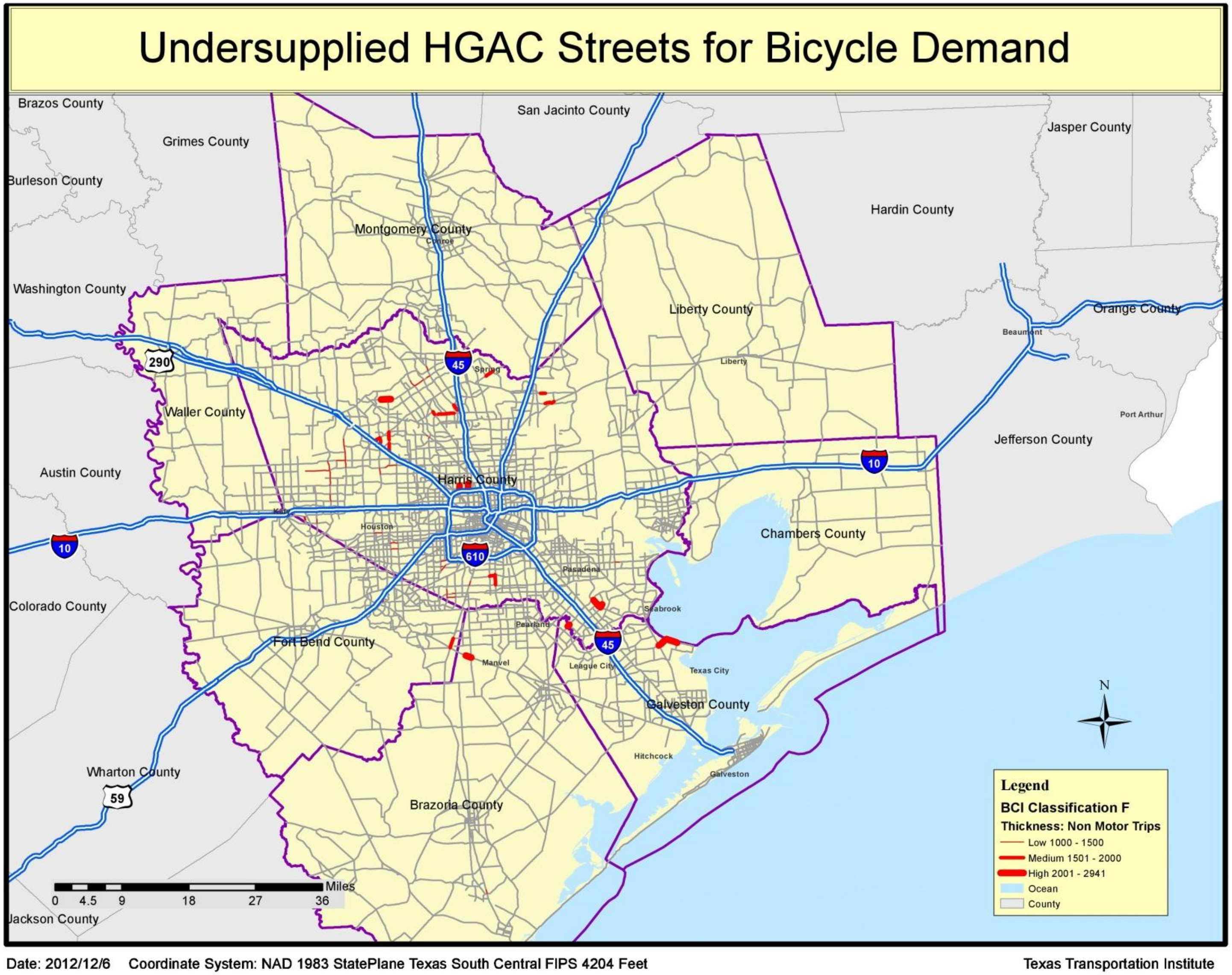


Figure 5- 10. High, Medium and Low Level of Undersupplied Road Sections for Bicycle Travel in H-GAC Region.

Pedestrian Travel Demand and Supply

The total walking trips by TAZ was used as the demand for the pedestrian travel. The PFI was used as the indicator of pedestrian travel supply for the road facilities. A mathematic relation was used to model the interaction of demand and supply for pedestrian travel. Equation below illustrates the relationship:

Equation 1

$$\frac{Demand}{Supply} = \frac{trips/day}{PFI}$$

Using the numbers of pedestrian trips per day divided by the PFI indicates the severity of the demand over supply for pedestrian travel. Due to the different units used for the demand and supply in Equation 1, the ratio is not exactly the times of demand over supply but nevertheless represent the degree of difference between the two values. Since there are 0 values of PFI for some TAZs, 1 was uniformly added to all TAZs on the PFI to avoid an infinity value. Figure 5-11 shows the results of three levels (high, medium, and low) of demand over supply for the pedestrian travel.

Integration with Super Neighborhoods

As far as bicycling or walking demand is concerned, there are two essential parts that should be viewed at the same time. One is the existing demand, which is relatively easy to observe and identify, while the other is the latent or potential demand for bicycling or walking, currently being fulfilled by automobile traveling. The latter is more difficult to identify, yet of greater significance for planning purpose. Potential demand for bicycle, pedestrian travel will convert into real usage of facilities, and reduce automobile travel, once they are accommodated properly with good level of service.

In June 2003, The Houston-Galveston Area Council selected the Walter P. Moore Bicycle and Pedestrian Study Team (WPM Study Team) to perform a study to identify districts where there are significant opportunities to replace vehicle trips with pedestrian or bicycle trips and to improve pedestrian and bicycle safety.

This study used activities centers that are likely to generate or attract bicycle and pedestrian trips and create circles around these centers to delineate study districts. The study area radii are different due to different traveling mode—biking or walking. A scoring system is developed to objectively identify a large number of districts, which consists of a group of indicators believed to represent the potential for biking and walking. The study approach and methodology was updated in 2010, including the choice of indicators.

The indicators and variables chosen for final composite indicators are shown in Table 5-7.

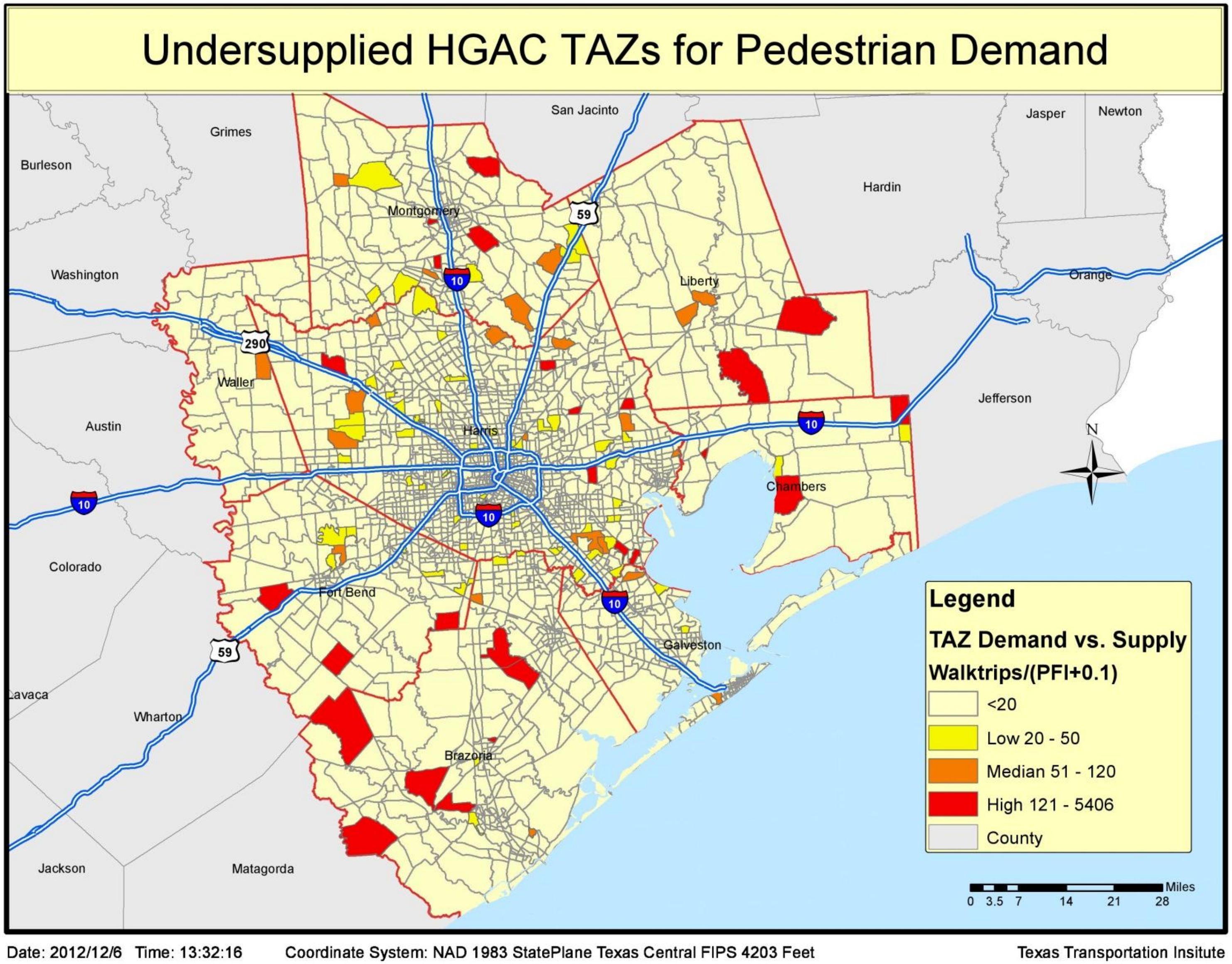


Figure 5-11. High, Medium, and Low Level of Undersupplied TAZ for Pedestrian Travel in H-GAC Region.

Table 5-7. Indicators and Variables Chosen for Final Composite Indicator.

Indicator	Variable	Weight
Population Indicator		
Population	Total population (not including prison population). All districts are equal size so this is equivalent to population density [1/4]	3
Children	Number of persons age 5-17 of center divided by total number of persons in the district [1/4]	2
Elderly	Number of persons age 65 and over, divided by total number of persons in the district [1/4]	2
Low-income households	Number of households in lowest 20 percent of all households in region, divided by total number of households in region, divided by total number of households in the district [1/4]	3
Employment and Activity Indicator		
K-12 Education employment **Total trip attractions**	Number of jobs classified as Lower Education (corrected for HISD headquarters) [1/2]	2
Total trip attractions	Log of Total trip attractions (from transportation modeling) [1/2]	3
Higher education enrollment	Log of number of higher education students enrolled (full and part time) [1/2]	2
Land Use Indicators		
Land-use diversity	Measure of number of different land use types and the proportional area distribution of land use types [1/2]	1
Employment diversity	Measure of the number of different employment job categories and their numerical distribution(lack of dominance of any one category) [1/2]	2
Balance of households and employment	Measure of how close the ratio of households-to-jobs is to 50:50 [1/2]	2
Travel Indicators		
Existing bicycling	Number of persons reporting bicycle as mode of transportation to work [1/2]	1
Existing walking	Number of persons reporting walk as mode of transportation to work [1/2]	1
Short (work) trips	Number of workers reporting a trip to work of 10 minutes or less, divided by the total number of workers not including work-at-home [1/2]	2
Other Indicators		
Transit access	Log of number of bus stops [1/2]	2
Bicycle crashes	Number of bicycle crashes reported in 1999 [2]	1
Pedestrian crashes	Number of pedestrian crashes reported in 1999 [1/2]	1

The newly identified 585 top-ranking districts with greatest demand for pedestrian and bicycle infrastructure investments are combined together due to their nature of clustering. Districts are assigned to Super Neighborhoods (for the City of Houston), or incorporated places (outside the City of Houston) based on their center. The following Table 5-8 shows the top 25 districts grouped by Neighborhood.

Table 5-8. Top 25 Biking and Walking Friendly Neighborhoods in H-GAC Area.

Rank	Neighborhood	District Top Score	Top District Score Rank
1	DOWNTOWN	44.4	1
2	GULFTON	40.6	24
3	MIDTOWN	39.4	44
4	NEARTOWN – MONTROSE	37.9	65
5	SHARPSTON	35.5	122
6	NORTHSIDE VILLAGE	33.3	192
7	GREENWAY/UPPER KIRBY AREA	32.5	212
8	WOODLAKE / BRIARMEADOW	32.4	213
9	UNIVERSITY PLACE	31.9	231
10	GREATER UPTOWN	31.8	234
11	MEMORIAL	31.5	244
12	GREATER THIRD WARD	31.1	271
13	FOURTH WARD	30.7	285
14	BINZ	30.6	290
15	SECOND WARD	30.2	315
16	CLEAR LAKE	30.2	321
17	GALVESTON	29.7	362
18	PECAN PARK	29.3	407
19	AFTON OAKS / RIVER OAKS AREA	29.1	431
20	GREATER HEIGHTS	28.9	466
21	WEST UNIVERSITY PLACE	28.8	507
22	MAGNOLIA PARK	28.7	510
23	GREATER EASTWOOD	28.7	511
24	GREATER FONDREN SOUTHWEST	28.4	575
25	GREATER FIFTH WARD	28.3	585

To enrich the bicycle and pedestrian demand estimation with future potential demand, the result of identified super neighborhoods are overlaid with the identified undersupplied TAZs and road links. The following maps (Figures 5-12 and 5-13) show the overlaying result of super neighborhoods.

As shown in the Figure 5-12, areas within super neighborhoods are considered to have the social/economical characteristics and built environment that would have potentially growing non-motorized trips. The links showed as red within super neighborhood areas are road links that have limited service accommodating the existing non-motorized travel activities. With growing demand, these road links may face more challenges in the future and should be considered as priority in transportation improvement projects and long range transportation plans.

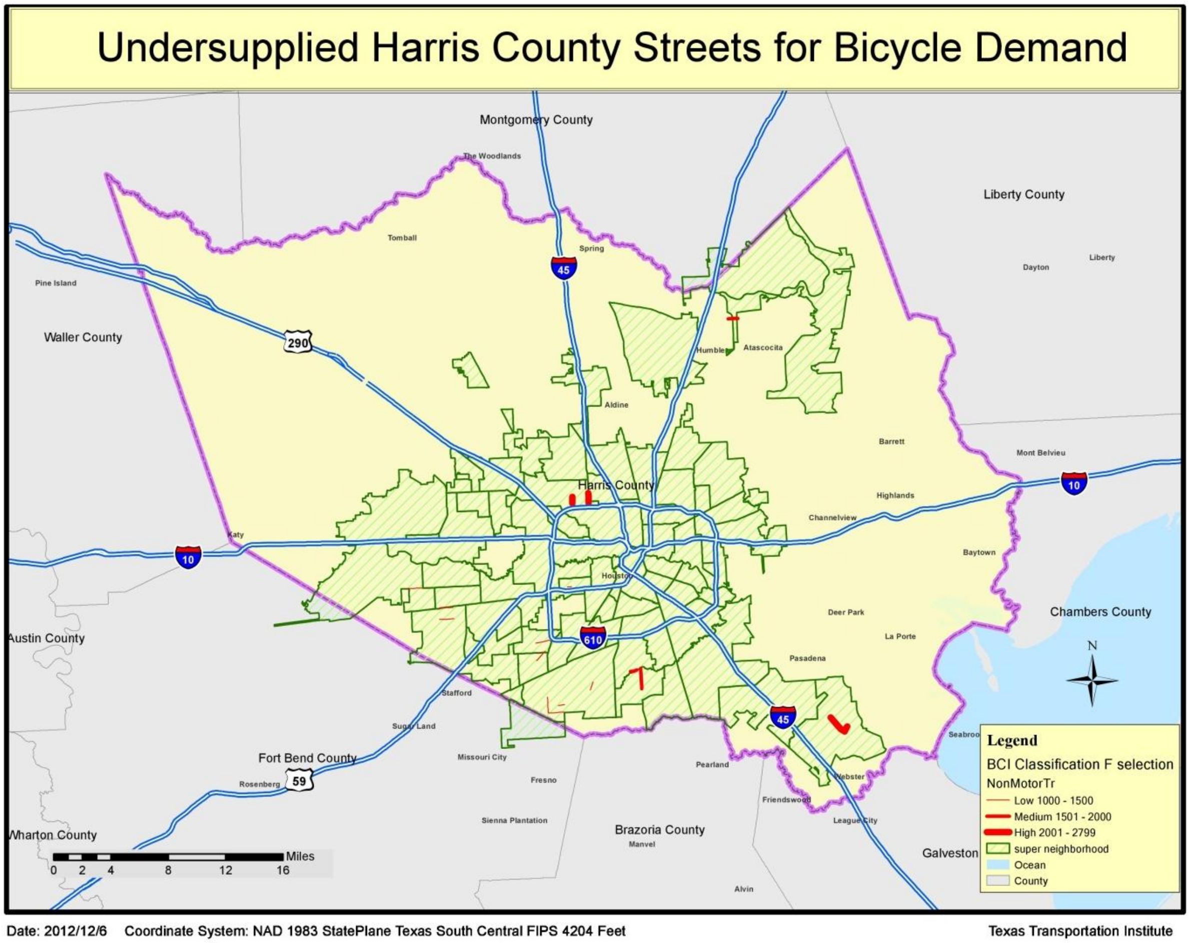


Figure 5-12. Undersupplied Bike Travel Road Sections in the Super Neighborhoods.

Figure 5-13 shows the identified undersupplied traffic analysis zones (TAZs) for pedestrian demand within super neighborhoods. The TAZs shown are those with limited supply of pedestrian facility yet have relatively higher existing demand for pedestrian travel and potential of future demand for pedestrian travel. These identified areas may receive more attention in long range transportation planning and transportation improvement projects.

Case Study

Two projects were selected from the previously proposed bike and pedestrian improvement project list to illustrate how the procedure works.

Pedestrian Project

The case study is located in the City of Conroe, and the proposed project is to construct 5' concrete sidewalks with curbs and ADA ramps on SH 75/Frazier from N. Loop 336 to Gladstell Rd. The total length of construction is 3 miles and the estimated cost is $1,000,000. Figure 5-14 shows a map of the project location.

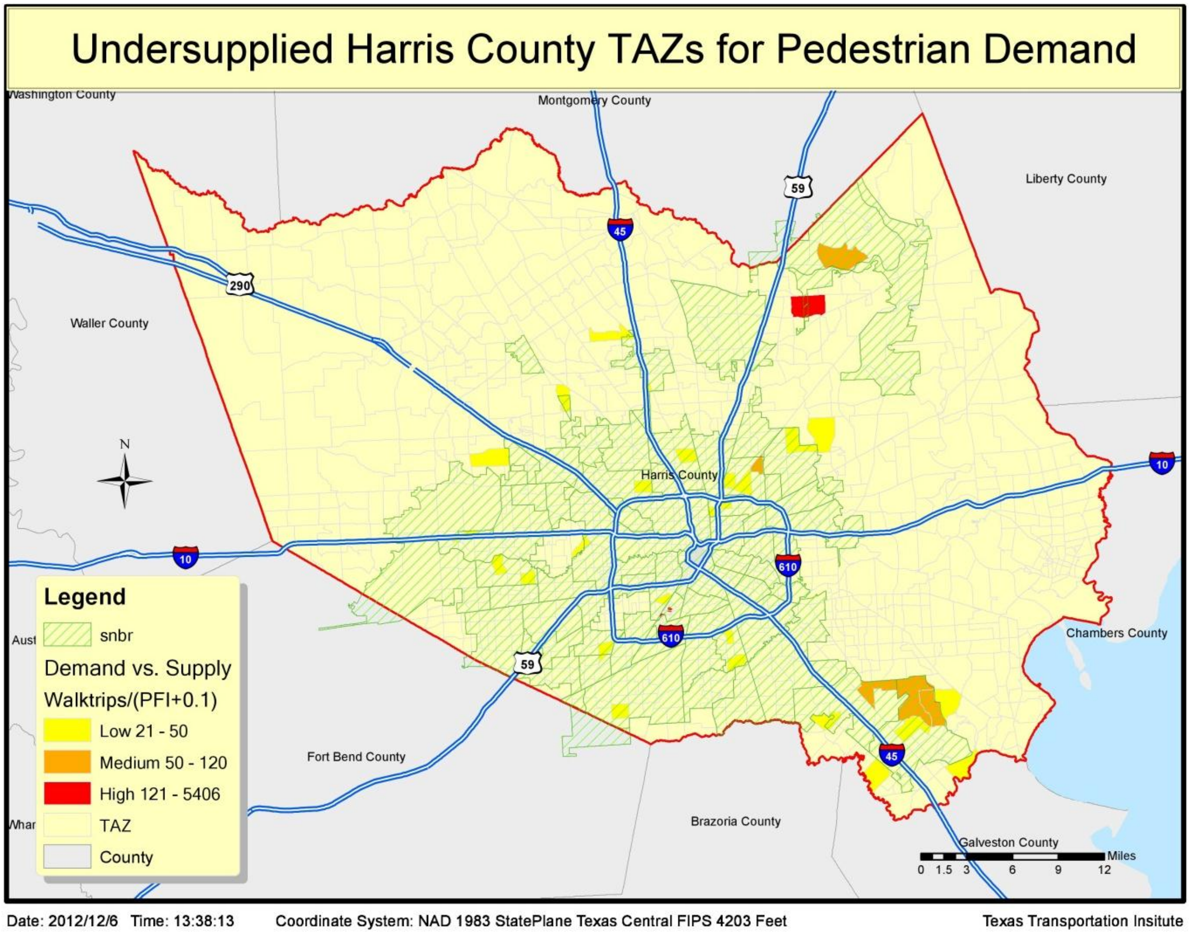


Figure 5-13. Undersupplied Pedestrian Travel TAZs in the Super Neighborhoods.

The case study used the pedestrian friendliness index developed in the above methodology and the pedestrian demand in the target area to identify the need of pedestrian travel and the necessity of facility improvement to accommodate the potential needs.

The calculation of pedestrian friendliness index, as discussed in previous passages, involves intersection density, population density and commercial density. Table 5-8 summarizes the process of calculation for the target traffic analysis zone where the project road is located.

The calculated PFI for the target TAZ is 64.47, as shown in Figure 5-14, the PFI is not within the lowest category of PFI. Also, the number of non-motorized trips in this TAZ is 0 per weekday, according to the survey data. Therefore, the facility for walking trips within the target TAZ is not severely undersupplied based on the analysis.

Table 5-9. Calculation Procedure of TAZ 2490.

TAZ Number	Intersection density	Population Density	Commercial Density	Normalized Intersection density	Normalized Pop density	Normalized Commercial density	PFI
2490	61.817	5121.570	80.363	61.817	51.216	80.363	64.47

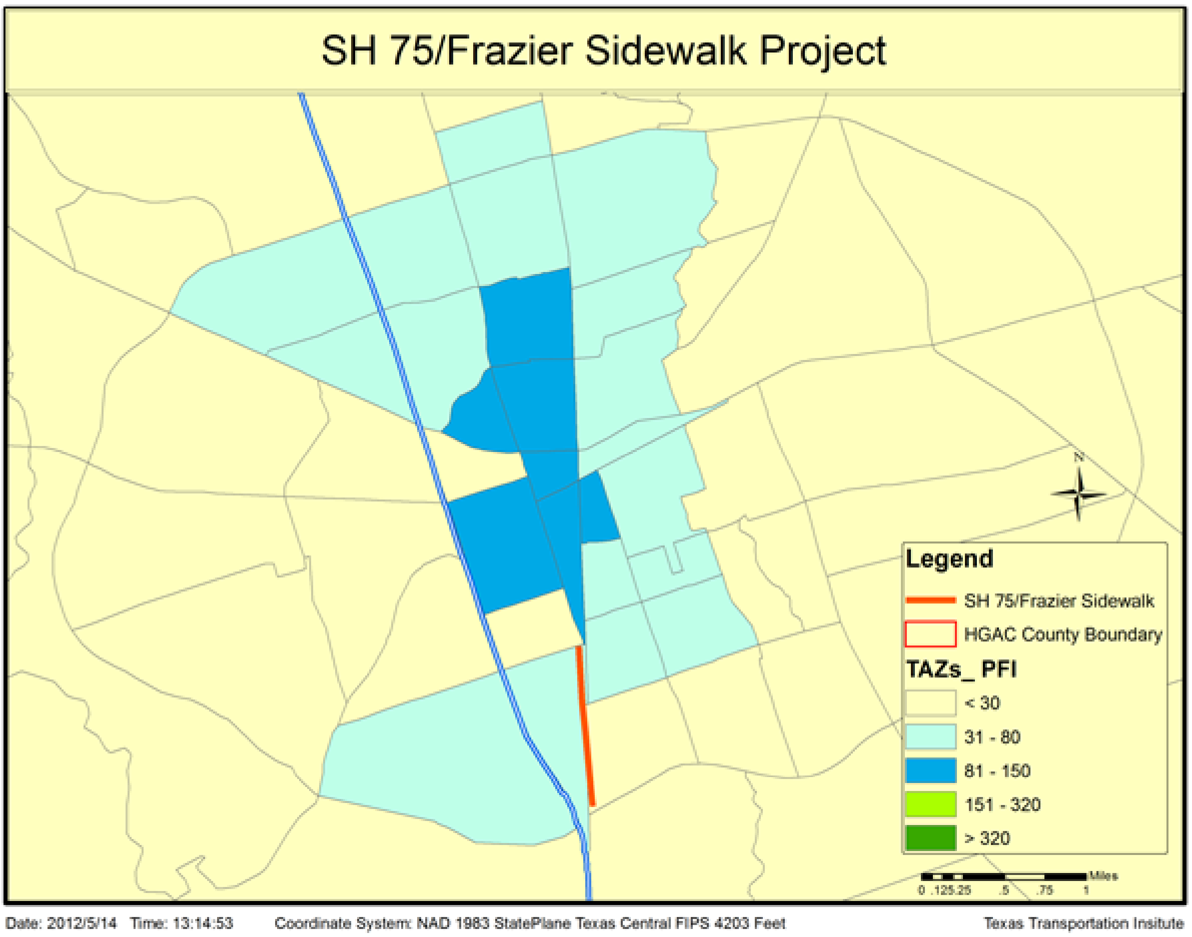


Figure 5-14. Proposed Sidewalk Project Location.

Bicycle Project

The case study is located in the City of Galveston. The proposed project is to resurface outside lanes along 19th and 27th streets and install bike lane striping and signage. The target road links start from Seawall Boulevard to Post Office Street on 19th street and to Ball Street on 27th street. The lengths of target road links are 1 mile on 19th Street and 1.3 miles on 27th Street. The proposed project estimated a total cost of $750,000. Since the 27th street was not included in the GIS road network for H-GAC, further analysis was not conducted for the street. Figure 5-15 shows the 19th street location of the project.

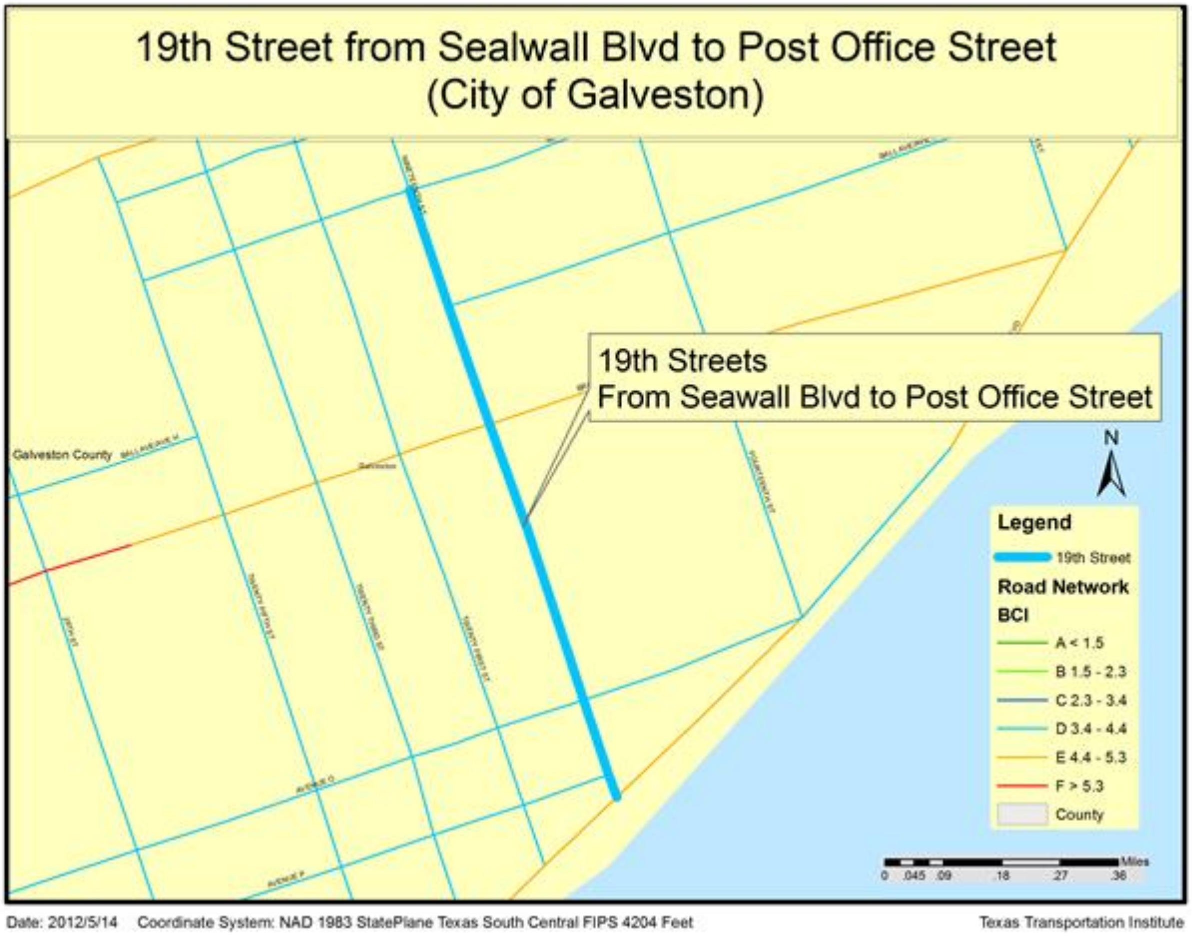


Figure 5-15. Proposed Bicycle Project Location.

The Bicycle Compatibility Index is used to identify the bicycle supply of the target road links. As discussed in the previous passages, the calculation of BCI involves a list of variables including the existence of bike lanes, the traffic volume, lane width, etc. Also, to analyze the biking demand, the bicycle trips per week day from survey data are applied. Table 9 describes the calculation procedure for Bicycle Compatibility Index.

Table 5-10. BCI Calculation Procedure.

LINK_ID	COUNT06	BikeLane	PKG	BLW	AREA	CLW	AF	SPD	CLV	OLV	BCI	BCICategory
14835-14836	4072	0	0	0	1	11	0.9	30	170	0	4.024	D
14829-14831	1612	0	0	0	1	11	0.9	30	67	0	3.818	D
14836-15362	4620	0	0	0	1	11	0.9	30	192	0	4.068	D
14839-15362	5272	0	0	0	1	11	0.9	30	220	0	4.124	D
14831-14833	3900	0	0	0	1	11	0.9	30	162	0	4.008	D
14833-14835	3052	0	0	0	1	11	0.9	30	127	0	3.938	D

The calculated BCI for the target road link is within Category D, which is not the worst case category F. The bike trips within the target TAZ is also 0. It shows little current bike travel in this target TAZ area. The facilities for biking in this area are not severely undersupplied given the existing need. Therefore, the case project will not be recommended as top priority for implementation.

Case Study Recommendations

While the model provided good results, a more accurate method would be to obtain real world data in place of the survey data. For more accurate results, an inventory of the existing and proposed facility, motor vehicle counts and bicycle and pedestrian counts are necessary. The calculations for BCI (supply) should be compared to the actual and the projected demand of the facility to estimate the needs for the improvement.

Conclusion

As bicycling and pedestrian activity continues to evolve in the H-GAC region, the needs for identifying the most inadequate biking and walking location with the highest demand for investment purpose become increasingly important. However, no established guidelines and procedures for modeling the non-motorized travel exist to date. This study developed a framework to identify the areas and roadway sections where the gaps exist in term of demand and supply for biking and walking. The method to estimate the components of the framework can be updated and depend on the data available. For example, the household travel survey data was used to estimate the current demand for non-motorized travel in this study. However, the actual counts of non-motorized trips which are more accurate than the sampling data from the survey can be used if the data is available. Assumptions were made for the bike facility; an inventory of facilities would improve the accuracy of the model.

For pedestrian travel, the analysis is area (TAZ) based. This is because pedestrians tend to be active in a vicinity area instead of just on a single roadway link. For the urban areas, the size of the TAZs can be as small as a few blocks. However, the size of TAZs can be much bigger for the rural areas. This study set up the procedure to identify the most inadequate TAZs for the pedestrian travel. Most likely the identified TAZs are those urban TAZs or in a residential area where the walking demands are high.

For bicycle travel, the analysis is roadway link based. This is because bicycles use the paved roadways similar to motorized vehicles. The Bicycle Compatibility Index (BCI) developed by FHWA to describe the friendliness of roadway to bicycle travel is also link based. The identified inadequate roadway links for bicycle travel are not necessarily the most poorly-supplied roadway links in the entire H-GAC area but the most poorly-supplied roadway links in TAZs where the demands are high.

The procedures developed can also be integrated into the H-GAC Regional Travel Demand Model with additional inventory of the walking and biking infrastructure. The sketch model developed for the study can be validated and calibrated once enough data can be collected from counters installed for the project.

Limitations and Future Research

The methodology developed for this project is at the sketch planning level in that it is relatively simple to understand and apply; however, the accuracy of the model results is dependent on the accuracy of the input data.

For the analysis of the current demand, the estimation used the data directly from the travel survey. Although 5807 households in the region were surveyed, the sample size for stratified household size and income group may be small. Also, the data was from the most recent 2008 travel survey. The information could be outdated, especially for non-motorized travel which appears to be experiencing an increase in recent years with high gas prices. The travel survey is designed to estimate typical weekday travel. Using the travel survey data as the estimation for current demand only considered the demand of typical weekday utilitarian biking and walking trips. Other methods need to be used to estimate non-motorized demand on weekends and for recreational trips which may account for a significant portion of total non-motorized travel demand. Validation of this survey data using bicycle and pedestrian count data would also greatly improve the model.

For the bicycle supply analysis, several road inventory variables have significantly effects on the BCI value, for example existence of bike lane and bike lane width. At this time, the inventory of bike facilities in the H-GAC region is incomplete. In addition, it may be of more interest that an H-GAC regional bicycle friendliness index could be developed using a regional scale to differentiate the roadways that are now clustered in the LOS C, D and F under the current FHWA BCI. This future study would help identify the factors that are important to bicycle travel and the degree of the significance in the context of H-GAC region.

A more accurate estimation of walking supply would need an inventory of the sidewalks and the condition of the sidewalks in the area. Currently, no such information is available. For future work, it is recommended that the remote sensing technology be applied on the regional aerial map to obtain the extensive time consuming information.

The validation analysis is missing in the study because not enough data was collected to perform the analysis at the time the model was developed. The validation and calibration process using the collected data would also enhance the accuracy of the model.

CHAPTER 6: PROJECT SUMMARY

Chapter 6 provides a summary of the previous five project chapters as listed below. Included herein is a short description of work activity completed for each chapter. The objective of the study was to develop a plan for phased implementation of a system of regular pedestrian and bicycle counting and monitoring sites in the eight county H-GAC Transportation Management Area that will give H-GAC and local governments adequate data to:

- Understand usage of pedestrian and bicyclist facilities in a variety of regional development contexts;
- adjust calculations on estimated air quality benefits of pedestrian and bicyclist facilities based on data collected in the region on facility usage; and
- estimate demand or usage of planned or proposed pedestrian and bicyclist facilities for project evaluation and selection purposes.

Listed below is a summary of the previous five chapters of the project:

- Chapter 1. Pedestrian and Bicyclist Monitoring – Equipment and Methods
- Chapter 2. Counting Equipment – Guidance and Installation
- Chapter 3. Develop Pedestrian and Bicycle Counting Plan
- Chapter 4. Data Collection and Reporting Structure
- Chapter 5. Pedestrian and Bicycle Demand Estimation

CHAPTER 1. PEDESTRIAN AND BICYCLIST MONITORING -- EQUIPMENT AND METHODS

In this chapter, researchers summarized the state-of-the-practice for pedestrian and bicyclist monitoring (counting) equipment and methods. Below is a list of the equipment and technologies used to count non-motorized traffic:

- Inductance Loop
- Infrared–Active
- Infrared–Passive
- Magnetometer
- Pneumatic Tube
- Pressure/Acoustic

- Video Imaging-Automated
- Video Imaging-Manual Reduction
- Other Emerging Technologies

In general, pedestrian and bicycle monitoring is an emerging practice and definitive guidance is not well established. Non-motorized traffic monitoring has not typically been conducted on a systematic or comprehensive basis as compared to vehicular traffic monitoring, in part because of the following:

- There are a smaller number of monitoring locations.
- There are no clear criteria available for a representative site selection.
- Non-motorized traffic typically has higher use levels on lower functional class roads and streets, so the use is distributed more over the greater transportation network.
- The general practice of using short duration counts due to the perceived difficulty of automatically counting pedestrians and bicyclists can introduce significant error due to the low volume and inherently variable nature of non-motorized traffic.

Other challenges in monitoring non-motorized traffic are that bicyclists and pedestrians do not stay in a fixed lane, they have unpredictable movements, and they may regularly travel in closely spaced groups.

CHAPTER 2. COUNTING EQUIPMENT – GUIDANCE AND INSTALLATION

The results of Chapter 2 provided H-GAC with guidance on potential deployment for a mix of permanent versus temporary (or moveable) bicycle and pedestrian counting technologies, including selections when considering budget constraints and research objectives. TTI recommended:

- two permanent count locations;
- three portable pedestrian counters which can be moved throughout the region; and
- procedures, classification scheme, and traffic counter settings for standard pneumatic tube traffic counters to count bicyclists.

TTI also provided in-field supervision of the installation of the two permanent counters and the setup of data collection mechanisms including connecting loop detectors, achieving communications via the cellular network, and host website configuration. The two permanent counters, ("Eco Counters Multi Urban Post") count bikes and pedestrians separately and have the ability to distinguish flow by direction and transmit the data using a cell modem.

Three portable TRAFx Infrared Trail Counters were also procured by H-GAC for conducting short-duration pedestrian counts. These counters were tested and modifications were made to make them more suitable for installation in an urban environment. Metal installation housings were assembled to provide a secure platform that could be locked and mounted using large diameter (size range from 3 to 36 inch) hose clamps. The use of automatic pneumatic tube counts was selected for bicycle counts as they were proven to be effective in counting bicycles, and several private and public agencies in the region currently utilize this equipment for vehicle traffic counts. In addition, a bicycle classification scheme, deployment and setup procedures, and recommendations for tube counter settings were developed.

Draft language for an interlocal agreement for the deployment and use of permanent and short term counters was provided and modified through H-GAC and local agency legal departments. The agreements addressed deployment, operation, and maintenance responsibilities for both the permanent and short term use devices and may be used for interagency loan and use of the temporary count equipment.

TTI researchers coordinated and assisted in the installation of the initial deployment of permanent count equipment on January 22, 2013 at: 1) the MKT/SP-Rails to Trails in the Houston Heights at 5 ½ Street and 2) at the White Oak Bayou Trail at 34th Street and TC Jester Blvd.

Guidance on the deployment and use of the pedestrian counters was developed and presented as a "Pedestrian Tip Sheet". The tip sheet provides suggestions on selecting count locations, mounting equipment, and collecting and processing of pedestrian data. A companion "Bicycle Tip Sheet" was developed to suggest settings, locations, and deployment instructions for bicycle counters. These tip sheets provide user recommendations for settings to optimize count setups to obtain the most accurate counts. Location is critical in counter deployment and factors to consider (such as facility, background, and area or lanes) are included in the tip sheets.

CHAPTER 3. DEVELOP PEDESTRIAN AND BICYCLE COUNTING PLAN

The purpose of Chapter 3 was to develop a pedestrian and bicycle count program plan. This plan guides a logical framework of count location sites based on various criteria. The Federal Highway Administration (FHWA) provides some guidance in the *Traffic Monitoring Guide* [1]. Count locations should be distributed by area type, facility type, and trip purpose. Some of the count location criteria include:

- counts in key pedestrian and bicyclist activity areas or corridors (downtowns, near schools, parks, and other non-motorized traffic generators.);
- representative count locations in urban, suburban, and rural locations;
- counts in key corridors that can be used to gauge the impact of future improvements;

- count locations where counts have been conducted historically; and
- count locations where bicyclist and pedestrian collision numbers are high.

The objectives of this chapter were to:

- identify the existing count locations;
- solicit input from agencies and bike groups on additional count locations;
- determine a framework and criteria to develop a count program; and
- develop a draft count plan for consideration.

Very few bicycle and pedestrian counts have been completed in the Houston region, and these counts were done primarily on a volunteer basis. The most significant count efforts have included:

- 2005 - Institute of Transportation Engineers' (ITE) National Bicycle and Pedestrian Documentation Project;
- 2009 - ITE's National Bicycle and Pedestrian Documentation Project; and
- 2009-2012 - City of Houston (COH) short term bike counts.

The count locations from each of these efforts were identified, latitude and longitude locations documented, and the locations plotted. From these existing count locations, the criteria developed in Chapter 3 and the demand estimation work in Chapter 5, a set of proposed count locations was developed. The proposed count locations were prepared in graphical format and presented to the Bicycle and Pedestrian Subcommittee for review and consideration.

CHAPTER 4. DATA COLLECTION AND REPORTING STRUCTURE

The reporting structure will enable H-GAC staff to utilize pedestrian and bicycle count data from outside data collection efforts (e. g., volunteer spot counts) and integrate it with ongoing count data collected through both permanent and temporary counters deployed throughout the region. Chapter 4 included:

- a summary of previous non-motorized count efforts in the region to ensure that other counts (i.e., those undertaken by the City of Houston and/or Houston Parks Board) are incorporated into data collection and consolidation effort;
- an investigation of data storage needs including data aggregation levels, data types, and data descriptions;
- an investigation of existing data warehouse tools and off-the-shelf products; and

- a methodology to extrapolate spot count data into daily/annual use estimates based on data collected through permanent count locations.

Existing counts were gathered from various agencies and from two major efforts including the 2005 and 2010 Bicycle and Pedestrian Documentation Project. The count locations were identified and plotted on a map. A literature and internet search was conducted to determine if existing off-the-shelf or data warehouse tools were available. The review indicated that most agencies build their own software and databases or use private-sector proprietary software. While any pedestrian and bicycle count information is useful, optimally there would be a seamless dataset for all transportation data to aid in planning activities and transportation and air quality model development, calibration, and validation. The most common data types and aggregation levels were identified along with other characteristics that will allow the inclusion of data into national reporting efforts and databases. The *Transportation Monitoring Guide* was identified as a primary resource to identify data standards and formats. Existing methods for extrapolating spot counts using local factors were identified in the ITE Manual of Transportation Engineering Studies and in the Bicycle and Pedestrian Documentation project.

CHAPTER 5. PEDESTRIAN AND BICYCLE DEMAND ESTIMATION

Chapter 5 developed an overall framework to identify the areas and roadway sections where gaps exist with respect to demand and supply for biking and walking in the H-GAC region. The framework is established to be adaptive so that the methods to estimate the components of the framework can be updated depending on the data availability.

The chapter also developed methods to estimate the current demand and supply of non-motorized travel in the region using the detailed GIS data available. The household travel survey data was used to estimate the current demand for biking and walking. The chapter also estimated the suitability of roadway sections for biking based on the Bicycle Compatibility Index (BCI) developed by FHWA. The Pedestrian Friendliness Index (PFI) of an area was estimated based on a highly correlated land use factor: an aggregate of population density, retail density, and intersection density.

The chapter combined the findings from H-GAC's Special Districts Study which identified the districts where there are significant opportunities to replace vehicle trips with pedestrian or bicycle trips. The result of the combination was that the chapter identified the areas and roadway sections that are not only currently in need for improvements but also with high potential for more non-motorized travel once improvements are made.

Conclusions and Next Steps

This study provides a foundation upon which H-GAC and other regional agencies can collect data that can be used to analyze investments in non-motorized transportation facilities.

The methods and procedures will need to be used, refined, and institutionalized to develop a base knowledge of non-motorized activity in the Houston region. Over time, with a concerted effort to understanding which facilities are utilized and the characteristics that drive that use, sound reasoning on where and what type of facilities should be deployed with the limited resources available.

Several items were identified as gaps in the process that could be addressed in the future as resources become available. These items include:

- a regional inventory of bike and pedestrian facilities;
- a speed limit inventory as an estimate of operating speed for BCI;
- a list of sub-regional count locations (to be revised on a periodic basis);
- a workshop to instruct interested agencies and groups on how to deploy both bike and pedestrian counters;
- a regional traffic database that would include motorized and non-motorized information on traffic volumes;
- calibration and validation of the non-motorized travel demand model using counts;
- a study of highly utilized facilities (including common characteristics, facility type, land use, demographics, or other factors);
- a study of non-utilized facilities (common characteristics); and
- a benefit cost analysis based on actual use and source of funding of the facilities.

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APPENDIX A

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APPENDIX B

Permanent Counter Interlocal Agreement Template

HOUSTON-GALVESTON AREA COUNCIL
INTERLOCAL AGREEMENT FOR
PEDESTRIAN-BICYCLIST PERMANENT COUNTERS

AGREEMENT

This Interlocal Agreement is made and entered into this ____ day of _____________, 2012, by and between the Houston-Galveston Area Council, hereinafter referred to as "H-GAC", having its principal place of business at 3555 Timmons Lane, Suite 120, Houston, Texas 77027 and the City of Houston, hereinafter referred to as the "City", having its principal place of business at 901 Bagby, Houston, Texas 77002.

BACKGROUND

In the 8-county H-GAC Transportation Management Area, there is a lack of current reliable data on pedestrian and bicyclist travel, creating a significant challenge when conducting cost-benefit analyses for projects, documenting air quality benefits, and prioritizing projects for funding. H-GAC contracted with the Texas Transportation Institute ("TTI") to conduct a "Pedestrian and Bicyclist Counting and Demand Estimation Study" ("Study") to develop a plan and phased implementation of a system of regular pedestrian and bicyclist counting and monitoring sites in the region. Through consistent data collection of bicyclist and pedestrian counts, local governments will more fully understand the usage of bicyclists and pedestrians and will be able to better estimate demand or usage of planned or proposed pedestrian and bicyclist facilities for project evaluation and selection purposes.

The TTI team recommends the installation of two permanent pedestrian-bicyclist counter stations at two separate locations within the limits of the City. The counter stations will have the capacity to automatically count bicycles and pedestrians by direction in fifteen minute intervals while transmitting the data collected to a central host via cell modem. Data will be collected and transmitted twenty-four hours a day, seven days a week.

RECITALS

A. It is to the mutual benefit of the City and H-GAC that two permanent pedestrian-bicyclist counters are installed at these two locations within the City right-of-way:
   a. Directly north of 34^{th} Street on the shared-use path along TC Jester Boulevard
   b. On the shared-use path MKT Bike Trail within the Heights neighborhood, within proximity of Clark's Hardwood Lumber Co. located at 700 East 5^{th} ½ Street, Houston, TX 77007

B. The data collected from each of the counters will be accessible by the City and by H-GAC through the online software, and will allow the City and H-GAC to:

   a. Collect, analyze, and understand usage of pedestrian and bicyclists facilities;
   b. Estimate demand or usage of planned or proposed pedestrian and bicyclist facilities for planning purposes, and project evaluation and selection purposes; and
   c. Estimate air quality benefits of pedestrian and bicyclist facilities based on data collected on facility usage.

NOW THEREFORE, for and in consideration of the mutual covenants, agreements, and benefits to the parties herein named, it is agreed as follows:

TERMS

I. Upon execution of this Agreement, H-GAC will purchase the two permanent counters. Upon receiving the two purchased counters, the City shall install counter equipment at the two designated locations described in Exhibit A, maintain the counter stations throughout the life of the equipment (ten plus years), and share the data with H-GAC through the online software.

II. H-GAC shall purchase the permanent counters from a vendor capable of supplying the equipment necessary to perform the continuous bi-directional pedestrian and bicyclist counts.

III. Upon receiving counter equipment, H-GAC, TTI and the City will coordinate on proper installation of the counter stations and equipment.

IV. TTI will oversee the installation of the counter stations, and will assist in the set up of the initial data collection for the City and H-GAC to use with the counters.

V. The City shall provide staff to install the two counter stations. Installation includes but is not limited to:

   a. Installation of a galvanized steel 5.5 inch diameter post into the ground along the trail, that will hold the data collection equipment;
   b. Installation of pedestrian counter equipment with a lens that will be placed in the metal post in order to transmit pedestrian count data;
   c. Saw cuts in the concrete to install the loop detector wire and sealant necessary for bicycle detection; and
   d. Installation of pull boxes that will connect the loop detector wire (two 16 inches by 60 inches) with the counter equipment.

VI. The City will maintain and ensure proper operation of the counters from installation through the life of the counter equipment. Maintenance and operation includes but not limited to:

   a. Pedestrian counter lens cleaning twice a year to ensure accurate pedestrian counts;
   b. Yearly battery checks or battery replacements for the two counter stations;
   c. Monthly field visits to ensure debris does not impede the proper operation of the counters;
   d. Monthly field visits to check that the equipment is functioning properly and to address and fix any potential equipment problems due to vandalism, flooding, or other disruptions;
   e. Monthly payments to the cell modem provider of approximately $40 per counter to ensure proper data transfer to the cell modem after the first two years of free data/storage collection for the equipment;
   f. Manual yearly counts at the locations to ensure proper calibration of the counter equipment at each counter station location; and
   g. Coordination with the commercial vendor of the counter equipment if any equipment malfunctions within the equipment two-year warranty period.

VII. The City and H-GAC will have unlimited access to the online database of pedestrian and bicyclist count data collected using the two permanent counter stations.

VIII. This agreement will be evaluated every two years (from the date the agreement is signed) to ensure proper coordination between H-GAC and the City.

   a. This agreement may be terminated by any of the following conditions:

b. By mutual agreement and consent of both parties.
c. By any party, upon failure of the other party to fulfill the obligations as set forth herein.

The termination of this agreement shall extinguish all rights, duties, obligations, and liabilities of H-GAC and the City under this agreement. If the potential termination of this agreement is due to the failure of any party to fulfill its contractual obligations as set forth herein, the party alleging the breach will notify the other party that possible breach of contract has occurred.

IX. If the City decides to no longer maintain or utilize the permanent counters, or if the City decides to remove the counters, it is the responsibility of the City to physically remove the counter equipment without disrupting activity on the pedestrian-bicyclist facility, and return the equipment to H-GAC.

X. If the City needs to relocate the permanent counters due to construction or other circumstances, the new location should be mutually agreed upon by both the City and H-GAC and should be on a facility that is used for commuting or other transportation related purposes.

XI. It is expressly understood and agreed that the City has the available staff and capacity to satisfy its obligations under this Agreement.

XII. Any changes in the agreement provisions or obligations of the parties hereto shall be enacted by written amendment executed by both the City and H-GAC.

XIII. All notices required or permitted shall be in writing and shall be deemed delivered when actually received or, if earlier, on the third day following deposit in a United States Postal Service Post Office or receptacle with proper postage affixed addressed to the other party at the address prescribed below or at such other address as each party may prescribe by written notice from time-to-time.

City of Houston:	City of Houston 901 Bagby, Houston, Texas 77002 Houston, Texas 77002 Attention: Joe Turner
H-GAC:	Houston-Galveston Area Council P.O. Box 22777 Houston, Texas 77227 Attention: Jack Steele, H-GAC Executive Director

Either party may designate a different address by giving the other party ten days written notice.

XIV. The Parties agree that this Agreement contains all of the terms and conditions of the understanding of the parties relating to the subject matter hereof. All prior negotiations, discussions, correspondence and preliminary understandings between the parties and others relating hereto are superseded by this Agreement.

This instrument, in duplicate originals, has been executed by the parties hereto as follows:

BY_________________________DATE__________

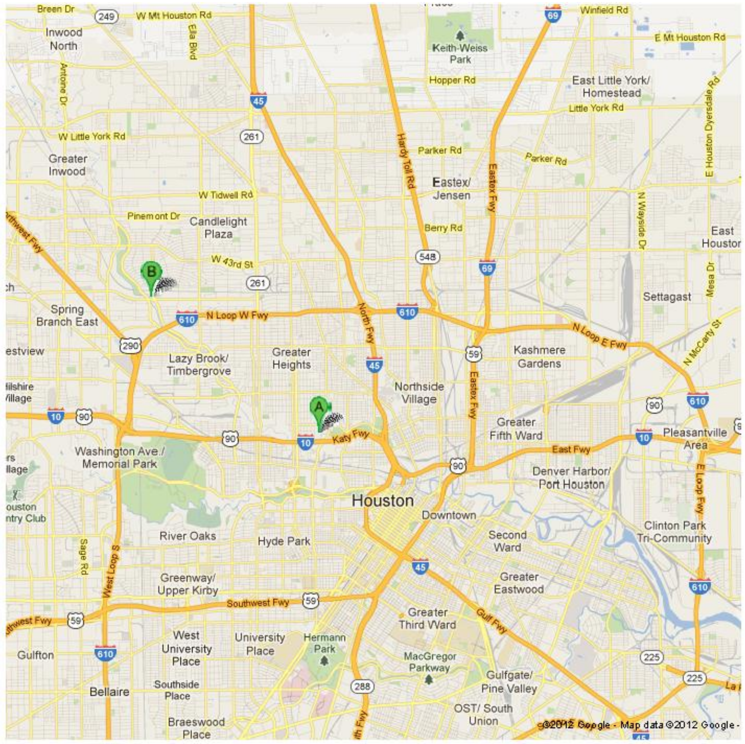
City of Houston

BY_________________________DATE__________

Jack Steele, Executive Director, Houston-Galveston Area Council a political subdivision of the State of Texas

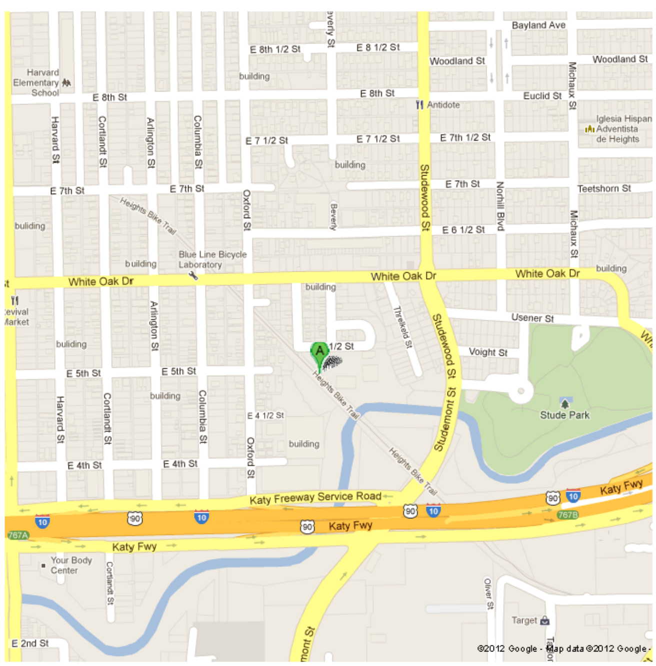
EXHIBIT A

Permanent counter installation locations at points A and B on the map:



Permanent counter installation location A

On the shared-use MKT Bike Trail within the Heights neighborhood, in proximity of Clark's Hardwood Lumber Co. located at 700 East 5th ½ Street, Houston, TX 77007



Permanent counter installation location B

Directly north of 34th Street on the shared-use path west of East TC Jester Boulevard

APPENDIX C

Temporary Counter Interlocal Loan Agreement Template

(Subject to change as needed upon direct coordination with jurisdictions)

HOUSTON-GALVESTON AREA COUNCIL
LOAN OF BICYCLE AND PEDESTRIAN
MONITORING EQUIPMENT AGREEMENT

1. **PARTIES.** This agreement is made and entered into this ____ day of ____________, 201_, by and between the Houston-Galveston Area Council, hereinafter referred to as "H-GAC", having its principal place of business at 3555 Timmons Lane, Suite 120, Houston, Texas 77027 and _________(person), of ______________(organization), who must be an authorized representative of a governmental jurisdiction or transportation provider, hereinafter referred to as the "Borrower".

   LOAN OF EQUIPMENT. For and in consideration of the covenants and agreements hereinafter contained, to be kept and performed by Borrower, H-GAC has loaned and does hereby loan to borrower the personal property known and described as follows: __________________(EQUIPMENT LIST) hereinafter designated as "equipment", to have and to hold the same unto Borrower for the period of _________________(# of WEEKS) weeks commencing from ___________________________(DATE).

2. **DELIVERY AND RETURN OF PROPERTY.** Borrower shall pick up the equipment at H-GAC's place of business, 3555 Timmons Lane, Suite 120, Houston, Texas 77027, or at another location agreed to by both parties. At the end of the term, Borrower shall return equipment to H-GAC in as good condition as exists at the commencement of the term, reasonable wear and tear in respect thereto expected.

3. **PAYMENT AND LATE FEES.** No payment is required for use of the equipment within the period stated in this agreement. Late fees will be charged to Borrower if the equipment is not returned within this period under the following schedule: $20 per calendar day.

4. **DAMAGES.** If the Borrower damages, or loses possession of the equipment at any time, full costs of repair or replacement, shipping and late fees will be due to H-GAC.

5. **REPOSSESSION.** If Borrower shall lose possession of the equipment or any interest therein, or if Borrower defaults in any of the covenants, conditions or provisions of this agreement, it is agreed that H-GAC may immediately and without notice take possession of the equipment whereinsoever found and to remove and keep or dispose of the same and any unpaid late fees shall at once become due and payable.

6. **LOCATION AND USE.** Borrower shall use equipment only in Harris, Montgomery, Liberty, Chambers, Galveston, Brazoria, Fort Bend, and Waller Counties in Texas except as may be permitted by H-GAC by consent thereto in writing. Borrower shall provide HGAC with date, location of equipment deployment, and electronic data from the count locations.

7. **INDEMNIFICATION OF OWNER.** Borrower shall and does hereby agree to protect and save Owner harmless against any and all losses or damage to equipment by fire, flood, explosion, hurricane, wind or theft and Borrower shall and does hereby assume all liability to any person whomsoever arising from the location, condition or use of equipment, and shall indemnify Owner of and from all liability, claim and demand whatsoever arising from the location, condition, or use of equipment whether in operation or not, and growing out of any cause, and from every other

liability, claim and demand whatsoever during the term of this Loan or arising while equipment is in the possession of Borrower.

8. **TIME OF ESSENSE.** Time is the essence of this agreement.

9.

10. **NO ASSIGNMENT.** Neither this Loan and agreement nor any right or interest thereunder shall be assigned by Borrower in any respect whatsoever.

11. **CHOICE OF LAW.** This Loan and agreement shall be deemed to have been executed and entered into in the State of Texas and shall be construed, enforced and performed in accordance with the laws thereof.

12. **EXCLUSION OF ORAL STATEMENTS.** This instrument contains all of the agreements of the parties. No oral or other statements shall be binding on either of the parties hereto.

BY_________________________DATE__________

Borrower

____

Title

BY_________________________DATE__________

Houston-Galveston Area Council

____

Title

APPENDIX D

Pedestrian Count Tip Sheet Using TRAFx Trail Counters

H-GAC TRAFx Infrared Pedestrian Counter Deployment Tip Sheet

The following document is a brief summary of things to consider or remember when selecting pedestrian count locations and conducting pedestrian counts with the TRAFx infrared trail counter. This sheet is meant to be a reminder after reading:

- TRAFx Manual
- Infrared Trail Counter Instructions *(For Generation II and III)*

Urban Environment Site Selection

1. Choose activity areas (near parks, schools, businesses; but where you are NOT counting the circulating traffic). Site should be several hundred feet from an entrance which reduces the number of pedestrians counted coming from and going to a parking lot.
2. Areas where pedestrians are spread out or in single file line provide the most accurate counts. One to two second gaps between users is optimal.
3. Select locations that are on the regional count map or notify H-GAC of new locations that are desired.
4. Face away from roadway traffic (need static background).
5. Select a shaded area or an area without sun shining directly into the lens (orient primarily N/S).
6. Look for shaded areas without a lot of vegetation that will blow in the wind. Typically movement beyond 10 meters or 30 feet is OK.
7. Point sensor at a downward angle toward the ground to provide a static background.
8. Use a sturdy mounting platform such as a sign pole or tree, see Figure 0-1.

Figure 0-1. Examples of Pedestrian Counter Strapped to No Parking Sign and Tree

Before You Leave the Office

1. Review counter manual and be certain to understand the settings and other parameters that will affect the data.

2. Review your Field Check List
    - Personal Safety Equipment (Vest, Hard hat, Steel Toe shoes)
    - Counters
    - Bands
    - Drill and hex bits for tightening bands
    - TRAFx Manual
3. Check Desiccant Packets to ensure the color indicator shows a dry packet.
4. Set counter to hourly data collection
5. Maps and count location description sheets

Equipment Setup

Detection Zone Size – Increases in diameter as distance from the sensor

Distance from IR scope to trail	2m (6.5 ft.)	4m (13 ft.)	6m (20 ft.)
Diameter of detection zone	0.3m (1 ft.)	0.7m (2.3 ft.)	1.0m (3.3 ft.)

Equipment checklist	Deployment checklist
✓ TRAFx manual ✓ Spare batteries for counter ✓ Counters, dock, etc. ✓ Screws or worm drive straps and screw or drill driver for mounting boxes ✓ Saw, axe or clippers to trim back vegetation in scope's field of view (to about 6 meters) ✓ GPS, flagging, large umbrella or tarp if raining, map, camera, compass, clipboard, tape measure, etc.	✓ Three dots engraved on cable pointing skywards? ✓ IR scope shaded from direct sun? ✓ No possible moving vegetation (branches, shrubs, long grasses) in the scope field of view to 6 meters away? ✓ Desiccant pack inside case for moisture control? ✓ Lid properly closed with nothing sticking out; seal clean? ✓ Well hidden? Secure location? ✓ Launched counter with G3 Dock in Shuttle Mode? ✓ Counter's **Status LED** blinking 4x per second after disconnect? ✓ Verify time and do a 10 repetition test walking past the counter with a 3 second gap.

Counters Settings

Period Setting- Period of collection = event/time stamp, hourly and 24 hour. There is a maximum of 32,000 events per period with a 14,000 maximum number of periods total count capacity of 448,000,000.

000	Events (Time stamps each activation - 14,000 max)
001	Hourly (maximum of 32,000 events/hour)
024	Daily Totals (maximum of 32,000 events/day)

Delay Setting – (Time is measured in 50 milliseconds increments)

025 = 1.25 second delay
030 = 1.50 second delay (30*50ms = 1500ms)
035 = 1.75 second delay
040 = 2.00 second delay (40*50ms = 2000ms)
050 = 2.50 second delay
060 = 3.00 second delay
080 = 4.00 second delay
100 = 5.00 second delay

Refer to TRAFx Infrared Trail Counter instructions

Data Retrieval

Data can be retrieved in the field or the units can be brought in after data collection. Follow procedures in the TRAFx Manual to retrieve data. Check counter after the first 24 hours to ensure you have data, and be sure to restart counter.

QAQC/ Data Storage

Once data is collected and retrieved, a series of quality control checks should be conducted to ensure accuracy of the count. Import the data into a spread sheet and use pivot tables and charts to check:

- Deployment Day Test
- Day of Week Plots
- Time of Day Plots
- Reasonableness of Data – High/Low

Once data has been through agency QAQC checks, a copy of the data should be sent to H-GAC to be included in a region non-motorized count database.

Data should include:

- TRAFx Electronic Data File
- Meta Data
    - Count location – general description of the count area and the land use and activity and area around the count location.
    - Latitude and Longitude Coordinates
    - Count Conditions – Typical, Special Event, Commuting, Recreation, Mixed, etc.

APPENDIX E

Bike Count Tip Sheet Using Time Mark Tube Counters

HGAC Bicycle Pneumatic Tube Counter Tip Sheet

Pneumatic tubes or road tubes can be used to count bicycle traffic. Typical vehicle counters are used with some special settings to conduct off and on street bike counts. This tip sheet documents site selection and settings for the Time Mark traffic counter. In addition it will cover user types and best practices.

User Types and Best Practices

Bicycle volume counts are typically conducted for 24 hours a day for seven days a week. An extra seven days of counts should be conducted if any inclement weather or special events occur during the original time period. Time of day variations provide an insight to the types of riders. Recreational riders tend to be in the early morning, evening, and on weekends and holidays. Commuting riders tend to be during the weekday morning and afternoon peak periods. Utility trips can be any time of day or day of week, as they are typically quick shopping trips or short errands.

There are several bicycle rider types:

- A (Advanced) – Experienced riders who can operate under most traffic conditions
- B (Basic Bicyclists) – Casual riders including adults and teenagers who are less confident of their ability to operate in traffic without special provisions for bicycles
- C (Children) – Pre-teen riders whose roadway use is initially monitored by parents

Many times a facility caters to the trip type or rider type. Almost all riders feel comfortable on a multi-use trail and typically only the advanced riders feel comfortable on a bike lane on a major arterial.

Site Selection

The site selection should be based on what is needed for the type of study being conducted. Some counts are done for operations and others for planning purposes. Count location should be based on the group of riders targeted for the count (recreational, commuting, utility), and sites should be in a level tangent area to avoid turns and stopping on the road tubes.

Urban Site Location

There are several urban bike facility types:

- Trail / Multi Use Path
- Bike Lane and Cycle Tracks
- Shared Lane "Sharrows" (mixed traffic - bikes and motor vehicles)

The data recording setups are slightly different if you are counting mixed traffic versus only bikes. In all cases you should determine a location on a level straight away. Ideally, bicycles should be counted separately from motor vehicles. So if you are counting on a street with a bicycle lane, have one set of tubes on the bike lane and one set across all lanes. This cannot be done on a Shared Lane facility.

Development of Bike Classification and Axle Spacing

Initial tests using the standard FHWA 13 functional class showed that bicycles were underrepresented. The research team developed a bicycle and classification and axle spacing by measuring several different bicycle types. A classification of 30 to 48 inches was found to be the most representative.

Table 1. Bicycle Axle Spacing (Wheel Base) for Traffic Count Classification

Bike Type	Wheel Base	Wheel Size
Mountain Bike	42	26
Small Road Bike Orange	41	25
Road Bike 27"	43	27
Kid Mountain	39	24
Road Bike	41	25
Child Bike 20"	34	20
Child Bike 20"	35	20
Child Bike 12"	20	12
Tandem Curser	67	26

Time Mark Traffic Counter Settings

There are two locations where settings need to be adjusted. The first is in the counter equipment hardware (counter box). When you have the VIAS software running and are connected to the counter, you should see the screen depicted in Figure 1. On this screen SELECT the “Counter Setup” button on the left, you should then see the screen shown in Figure 2. On this screen, SELECT the “Advanced” button on the right side of the screen. The Advanced Counter Settings dialogue box will appear (as shown in Figures 3 and 4).

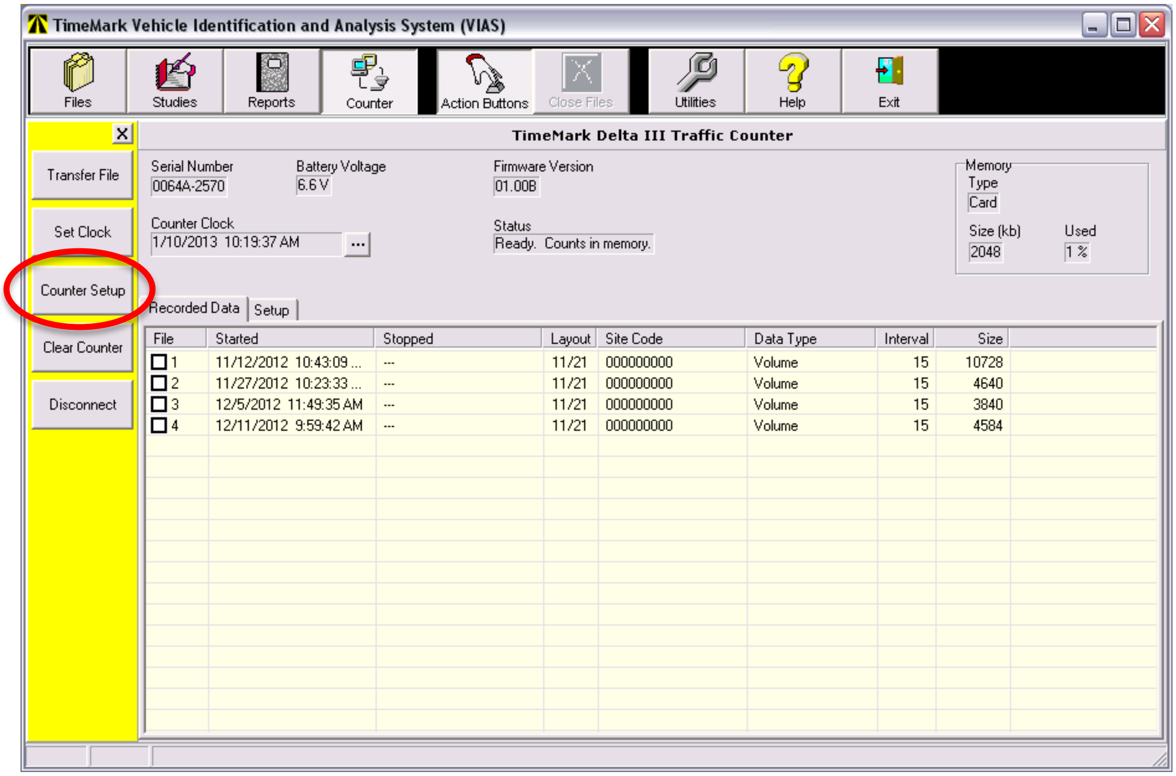


Figure 0-1. TimeMark VIAS Hardware Settings

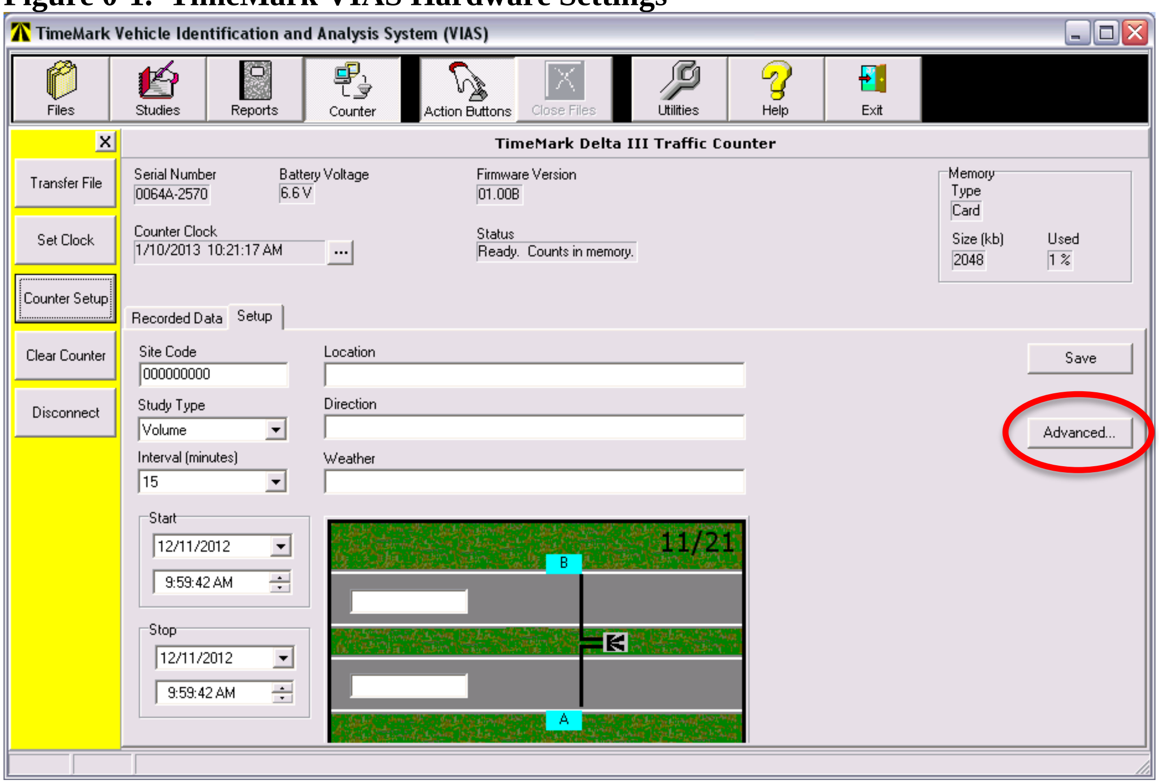


Figure 0-2. TimeMark VIAS Hardware Settings

The counter hardware settings shown in Figure 3 are used for bicycle counts only (not motor vehicles):

- Dead Time = 20
- Sensitivity/Threshold = 15

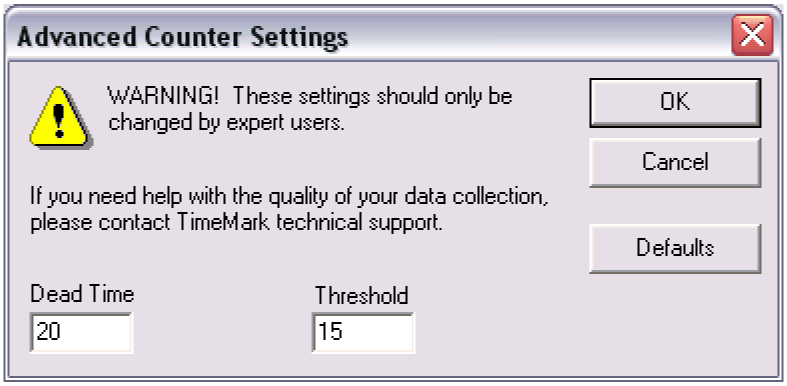


Figure 0-3. TimeMark Hardware Advanced Counter Settings for Bicycle Setup

These settings are changed by connecting to the counter and changing settings on the counter itself. Normally, we use different settings as shown in Figure 4 for counting typical motor vehicles on roads; these settings are:

- Dead Time = 10
- Sensitivity/Threshold = 30

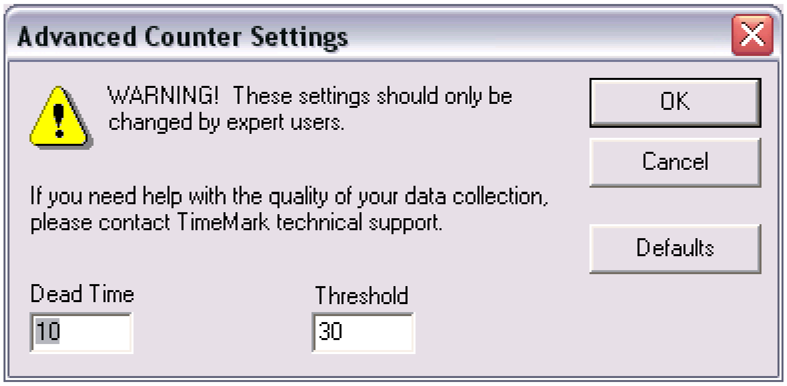


Figure 0-4. TimeMark Hardware Advanced Counter Settings for Vehicle Counts

Note that these settings are based on the Delta III Classifiers – the newer NT versions do not allow a numeric value of 1-100 to be used for Threshold/Sensitivity. Instead, a value from 1-5 is used, and this does not allow for a full range of adjustment. The normal sensitivity for motor vehicles with the NT is "1 - High". Also, note that if these bike hardware settings are used on a typical roadway to count motor vehicles, the counts will likely be very high due to double-counting caused by a lower sensitivity threshold and longer dead time such that extra (double) hits are not excluded.

The tube setup for bicycle counts always has a six foot spacing for tube pairs. When using a 2-tube setup, Setup 51 is used, and the A & B tubes go across a bike lane or sometimes across a bike lane and vehicle lane. Setup 67 can also be used utilized to collect more robust data for certain lane configurations. In this setup, four tubes are used; tubes A & C extend across the bike lane and tubes B & D extend across the bike lane and vehicle lane(s). Using tubes of equal length is very important because of the shorter time between pulses (caused by shorter axle spacing and close proximity of the bike lane to the counter box). Make sure to have all tube pairs (A & C and/or B & D) identical in length within 2 inches. Generally, shorter tubes are preferred for bikes, as it is thought that the weaker bike air pulse may get lost along a long tube; however, observation has shown this is not much of a problem for tubes up to 50 feet in length.

When downloading and processing the data, use certain system settings found in VIAS under Utilities – System Settings – Analysis as shown in Figure 5. Standard layout is:

- Min Speed = 5 mph
- Max Speed = 100 mph
- Max Accel/Decel = 5 mph/s
- Software Dead Time = 10 Ms.

These default settings work well for vehicles and for the most part they are sufficient for bicycles, particularly if you are counting mixed traffic. If you are trying to count a bicycle only lane, a slight adjustment of these settings may work a little better. The adjusted bicycle settings as shown in Figure 6 follow:

- Min Speed = 5 mph
- Max Speed = 50 mph
- Max Accel/Decel = 5 mph/s
- Software Dead Time = 40 Ms.

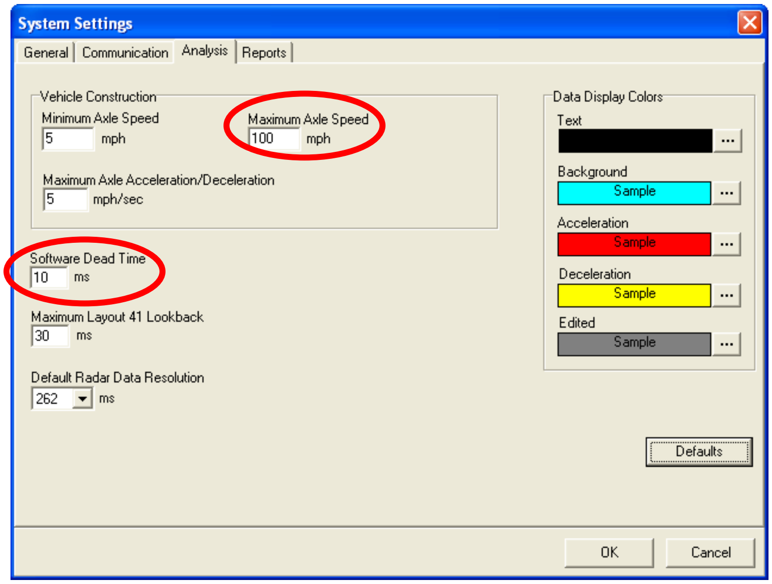


Figure 0-5. Time Mark VIAS Traffic Counter Download Typical System Settings for Counting Motor Vehicle Traffic.

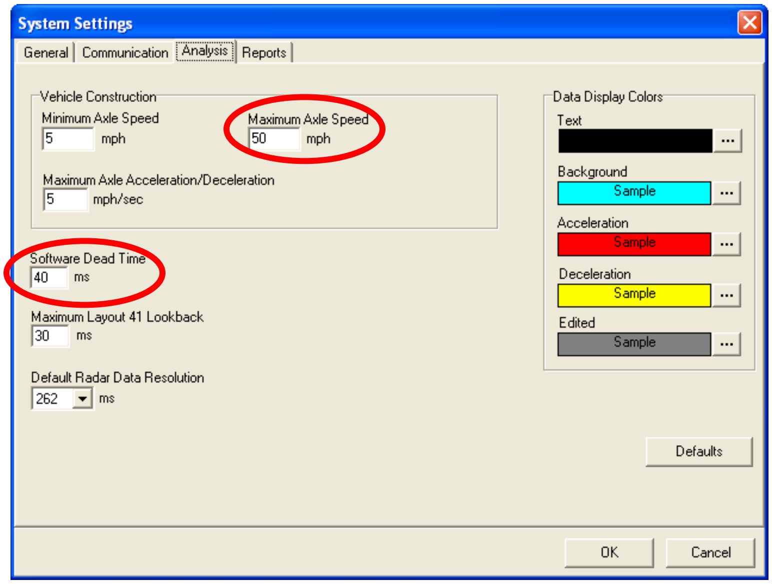


Figure 0-6. Time Mark VIAS Traffic Counter Download Typical System Settings for Counting Motor Vehicle Traffic.

It is a good idea to check the settings before going in the field to limit the exposure from a traffic safety perspective but to also ensure the settings are correct for the bike counters. It is also helpful to use some blue painters tape to label that counter as a bike counter so that when crews are deploying equipment the correct counter can be used for the correct type of count.
Using a one foot of stretch per 10 foot of tube length between securing devices is recommended.

Data Retrieval

Data can be retrieved in the field or the units can be brought in after data collection. Follow the procedures in the Time Mark Manual to retrieve data. Once the data is downloaded and saved, it will need to be processed as a classification count using a specific classification scheme developed specifically for bicycle counts.

After a few trial tests, we settled on a classification scheme called “TTI – Bikes (30)”, which has 4 classes (bikes, cars, motorcycles, and pickups). Each class is defined by axle spacing as shown in the screenshot Figure 7.

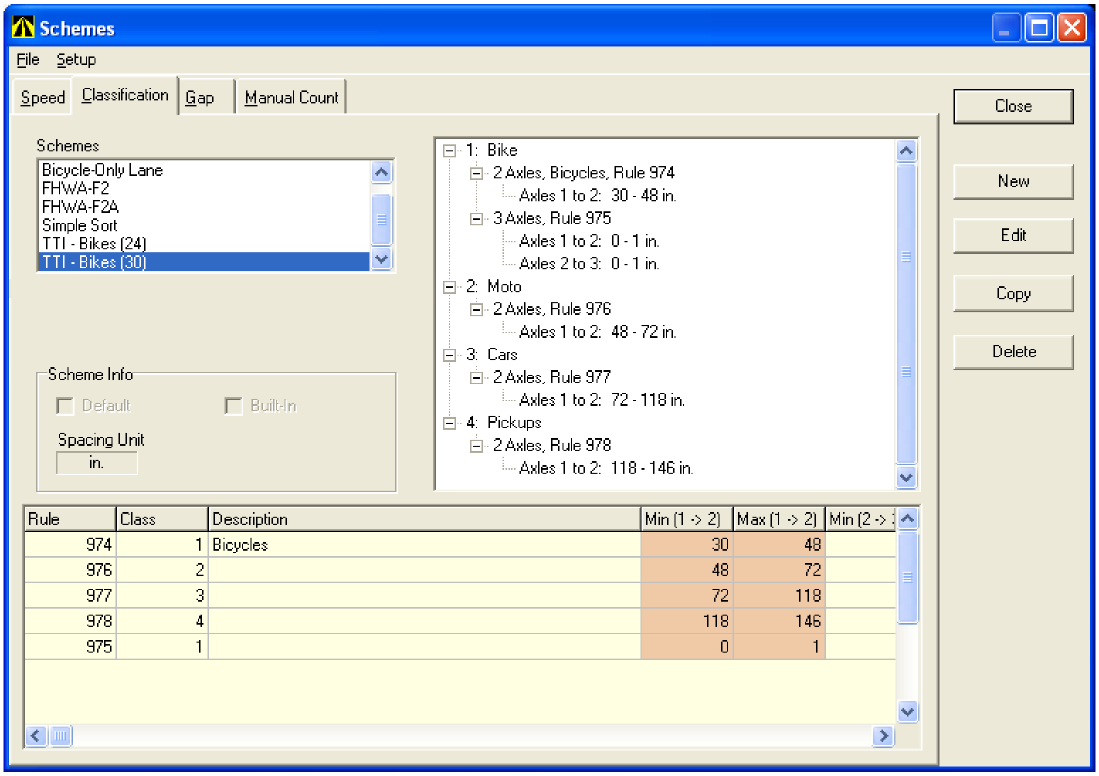


Figure 0-7. Time Mark VIAS Software Settings for TTI Bikes (30), Bicycle Classification Scheme.

This classification scheme must be created in VIAS the first time that it is to be used. Under Schemes – Classification, SELECT the "New" button, and add the various vehicle classes and axle rules to match what is shown in Figure 7. The four vehicle types and all axle rules shown in Figure 7 should be used exactly as shown. The 3 axle bicycle rule helps with a software requirement in VIAS so that the software does not exclude vehicles.

QAQC/ Data Storage

Once data is collected and retrieved a series of quality control checks should be conducted to ensure accuracy of the count. Import the data into a spreadsheet and use pivot tables and charts to check:

- Day of Week Plots
- Time of Day Plots
- Reasonableness of Data – High/Low

Once data has been through agency QAQC checks, a copy of the data should be sent to HGAC to be included in a region non-motorized count database.

Data should include:

- CSV Time Mark Electronic Data File (VIAS Export - Default Volume Format)
- Meta Data
    - Count Location – general description of the count area and the land use and activity and area around the count location.
    - Latitude and Longitude Coordinates
    - Key Map Page and Square
    - Direction of Travel by Tube
    - Type of Facility (bike lane, shared use path, other)
    - Adjacent traffic lane counts (always helpful)
    - Count Conditions – Typical, Special Event, Commuting, Recreation, Mixed, etc.
- Time Mark Count File Information
    - Start of Count Date; August 9, 2012
    - Start of Count Time; 14:15
    - Sensor Layout; 51
    - Location; Heights Blvd. Bike Lane - North of 17th Street
    - Direction; Northbound
    - Weather; Clear and Hot

APPENDIX F

List of Existing Non-Motorized Counts

	Name	Description	Location	Count Type	Date Counts Performed
1	Kirby	University	Houston	Manual	5/13/05
2	Braes Bayou	Stella Link & Buffalo Speedway	Houston	Manual	5/13/05
3	FM 529	Hudson Oaks Dr	Harris County	Manual	5/13/05
4	TC Jester Park	White Oak Bayou Trail	Houston	Manual	5/12/05
5	Terry Hershey Park	E of Dairy Ashford	Houston	4-day Tube	5/11/05
6	Terry Hershey Park	E of Dairy Ashford	Houston	4-day Tube	5/15/05
7	Terry Hershey Park	E of Dairy Ashford	Houston	4-day Tube	5/19/05
8	Terry Hershey Park	E of Dairy Ashford	Houston	Manual	5/12/05
9	Terry Hershey Park	E of Dairy Ashford	Houston	Manual	10/27/05
10	Brays Bayou	Castlewood	Houston	Manual	10/29/05
11	Brays Bayou	Castlewood	Houston	Manual	10/31/05
12	George Bush	Fry and Highland knolls	Harris County	Manual	10/22/05
13	E TC Jester	34th	Houston	7-day tube	5/13/10 - 5/19/10
14	White Oak	Frazier	Houston	7-day tube	5/13/10 - 5/23/10
15	Terry Hershey Park	Memorial	Houston	Video	5/19/10 - 5/20/10
16	Terry Hershey Park	Eldridge	Houston	Video	5/19/10 - 5/20/10
17	Dairy Ashford	IH 10 WB FR	Houston	Video	5/19/10 - 5/20/10
18	Bertner	Pressler	Houston	Manual	5/17/10
19	Moursund	Bertner	Houston	Manual	5/18/10
20	Brays	Link wood	Houston	Manual	5/21/10
21	Brays	Link wood	Houston	Survey	5/21/10
22	Columbia Tap Trail	Wheeler	Houston	Manual	5/19/10
23	Columbia Tap Trail	TSU	Houston	Manual	5/19/10
24	Columbia Tap Trail	TSU	Houston	Survey	5/19/10
25	Columbia Tap Trail	TSU	Houston	Survey	5/19/10
26	Terry Hersey Park	Sport Park Trail	Houston	Manual	5/18/10
27	Terry Hersey Park	Sport Park Trail	Houston	Manual	5/18/10
28	Terry Hersey Park	Dairy Ashford	Houston	Manual	5/14/10
29	Terry Hersey Park	Dairy Ashford	Houston	Manual	5/14/10
30	Myer Park	By baseball field on trail	Harris County	7-day Tube	5/17/10 - 5/23/10
31	Bay Area Park	T intersection bike & sidewalk	Harris County	7-day Tube	5/3/10 - 5/9/10
32	Cambridge	Wyndale	Houston	Manual	5/14/10
33	Cambridge	Wyndale	Houston	Manual	5/14/10
34	Cambridge	Wyndale	Houston	Survey	5/14/10
35	Cambridge	Wyndale	Houston	Survey	5/14/10
36	White Oak	Frazier	Houston	7-day Tube	5/19/10 - 5/20/10
37	7th street	Heights to Yale	Houston	7-day Tube	10/20/11-10/26/11
38	1013 Nicholson	1013 Nicholson	Houston	7-day Tube	10/20/11-10/26/11
39	TC Jester	34th	Houston	7-day Tube	10/20/11-10/26/11
40	White Oak	at bridge	Houston	7-day Tube	10/20/11-10/26/11
41	TC Jester	34th street	Houston	7-day Tube	5/13/10 - 5/24/10

Note: These counts represent counts conducted prior to 2012 and some counts were conducted as testing of equipment that was not included in this list.