

# IMPROVING ACCESS TO TRANSIT USING ROAD SAFETY AUDITS: FOUR CASE STUDIES



U.S. Department of Transportation  
Federal Highway Administration



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**Technical Documentation Page**

<b>1. Report No.</b> FHWA-SA-16-120	<b>2. Government Accession No.</b>	<b>3. Recipient's Catalog No.</b>
<b>4. Title and Subtitle</b>  Improving Access to Transit Using Road Safety Audits: Four Case Studies		<b>5. Report Date</b> October 2016
		<b>6. Performing Organization Code</b>
<b>7. Author(s)</b>  Elissa Goughnour, Javier Revilla, and Corey Pitts		<b>8. Performing Organization Report No.</b>
<b>9. Performing Organization Name and Address</b>  Vanasse Hangen Brustlin, Inc. 8300 Boone Boulevard, Suite 700 Vienna, VA 22182-2626		<b>10. Work Unit No. (TRAIS)</b>
		<b>11. Contract or Grant No.</b>
<b>12. Sponsoring Agency Name and Address</b>  Federal Highway Administration Office of Safety 1200 New Jersey Ave. S.E. Washington, DC 20590		<b>13. Type of Report and Period Covered</b>  Final Report October 2016
		<b>14. Sponsoring Agency Code</b>

**15. 1 Supplementary Notes**

The Federal Highway Administration Office of Safety sponsored the study of the Transit Road Safety Audits reported in this document. The Task Manager for this report was Rebecca Crowe (FHWA Office of Safety). Cynthia Chagnon-Mackenzie provided graphic design and Meg Bryson and Kevin Keeley provided research and content review. Cover photos: Elissa Goughnour and Dan Nabors.

**16. Abstract**

Road Safety Audits (RSAs) are a formal safety performance examination of an existing or future roadway or off-road facility and are conducted by an independent, experienced, multidisciplinary team. This case study document provides a review of the RSA process and four case study examples of RSAs that had a demonstrated interest in improving transit safety. The case studies include photographs, a project background, and key RSA findings and suggestions. These case studies will help Federal, State, Tribal, and local agencies better understand conditions that affect transit access and how to effectively address safety in the RSA process.

<b>17. Key Words</b>  Road safety audit, transit, roadway design, safety		<b>18. Distribution Statement</b>  No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161.	
<b>19. Security Classif. (of this report)</b>  Unclassified	<b>20. Security Classif. (of this page)</b>  Unclassified	<b>21. No. of Pages</b>  56	<b>22. Price</b>

## ACKNOWLEDGMENT

Development of this report required input from transportation agencies at the Federal, State, and local levels. The Federal Highway Administration (FHWA) and the authors greatly appreciate the cooperation of the North Carolina Department of Transportation; the City of Asheville, North Carolina; Orange County, Florida; the Central Florida Regional Transportation Authority; the Florida Department of Transportation; MetroPlan Orlando; the City of Springfield, Oregon; Sun Tran; and the City of Tucson, Arizona.

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## Purpose

The purpose of this report is to help Federal, State, Tribal, and local agencies understand conditions that affect the safety of pedestrians, cyclists and transit users; address road safety issues; and identify opportunities for improvement through the Road Safety Audit (RSA) process.

The Federal Highway Administration (FHWA) sponsored four Transit Access RSAs through the Mayor's Challenge, an initiative from the U.S. Department of Transportation's Secretary of Transportation, to demonstrate the benefits of using the RSA process to reduce pedestrian and cyclist fatalities, injuries, and crashes in urban areas.<sup>1</sup> This report describes the background of how to conduct RSAs, the benefits and costs of performing RSAs, and how to incorporate transit safety into the RSA process. A synthesis of the findings from each Transit Access RSA is provided, and identifies lessons learned about challenges and opportunities facing communities as they seek to improve the safety of transit riders during all phases of their trip.



*The locations selected for the Transit Access RSAs were urban and suburban areas and focused on safety concerns facing transit users accessing transit facilities (Photo Credit: Dan Nabors).*

## Background

An RSA is an effective tool for proactively improving roadway safety. FHWA defines an RSA as a “formal safety performance evaluation of an existing or future road or intersection by an independent, multidisciplinary team.” The primary focus of an RSA is safety, while working within the context of other aspects such as mobility, access, surrounding land use, and aesthetics. An RSA is

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<sup>1</sup> U.S. Department of Transportation. Mayor's Challenge for Safety People, Safer Streets. Available: <https://www.transportation.gov/mayors-challenge>.

conducted by a team that is independent of the design and operation of the facility, and can address safety through a thorough review of roadway, traffic, transit, environmental, and human factors conditions. By using an unbiased and multidisciplinary team to perform a comprehensive review and an evaluation of geometric, operational, and human factors-related safety issues for a given study area, RSAs make sure that safety is adequately considered. The RSA team is typically composed of at least three members having expertise in road safety, traffic operations, and roadway design. Other potential team members may have a background in enforcement, emergency medical services, maintenance, human factors analysis, transportation planning, pedestrian safety, bicyclist safety, or any other discipline deemed relevant to the context of the evaluation.

RSAs can be performed at any stage in a project's life:

- **A Pre-Construction RSA (*planning and design stages*)** examines a road prior to construction. This may occur at the project planning, feasibility, or project development stage or could occur during the design stage, beginning with preliminary design stage and ending with final design stage. An RSA at this stage identifies potential safety issues before crashes occur. The earlier an agency conducts a Pre-Construction RSA, the greater potential it has to effectively mitigate possible safety concerns. For example, a planning stage RSA can examine a system of roads before a specific project has been identified for project development, design, and construction. The RSA team assesses the transportation system at the earliest point to identify, evaluate, prioritize, and program projects and activities that would considerably enhance traveler safety, in the context of and in collaboration with other multimodal transportation investments.
- **Construction RSAs (*work zone, changes in design during construction, and preopening*)** examine temporary traffic management plans associated with construction or other roadwork and changes in design during construction. Construction RSAs can also be conducted after construction is completed, but before the roadway is opened to traffic.
- **A Post-Construction or Operational RSA (*existing road*)** examines a currently operating road and is usually conducted to address a demonstrated crash problem.

# Responsibilities

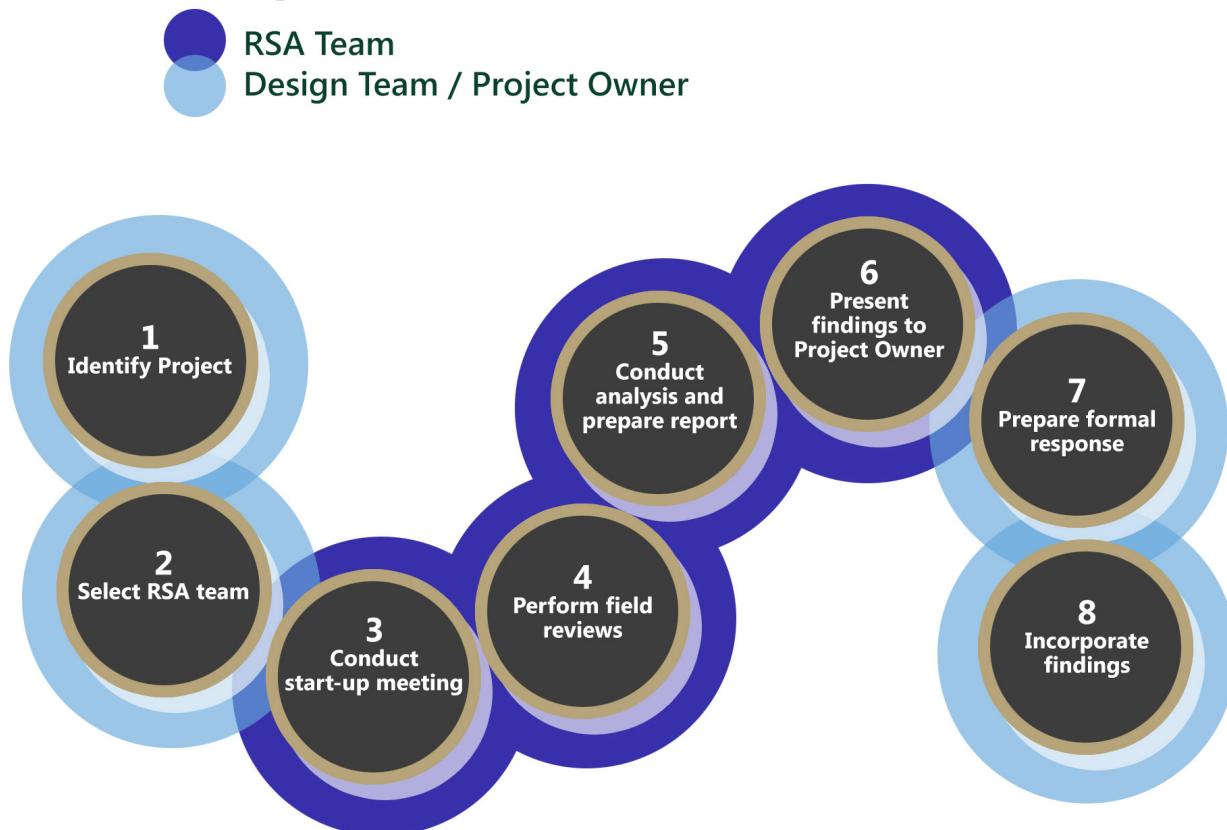


Figure 1: Typical Eight-step RSA Process (Source: FHWA).

## Eight Steps of an RSA

The eight steps of an RSA, shown in Figure 1, follow the procedures outlined in the FHWA *Road Safety Audit Guidelines* document.<sup>2</sup>

The **RSA Projects** in this case study project were pre-selected (Step 1) and the **RSA Teams** (Step 2) were interdisciplinary, typically including engineering, planning, enforcement staff from various levels of government to include Federal, State, municipal, and metropolitan planning organizations (MPOs).

All meetings and site visits for the RSAs in the case studies project were conducted over two- or three-day periods. The RSAs typically began with a **start-up meeting** (Step 3) attended by the Project Owner and/or Design Team (hereafter referred to as the Owner) and the RSA team:

- The Owner described concerns regarding the roads and intersections to be assessed, why the sites had been chosen for an RSA, and any constraints or limitations. Typically, the reasons for the RSA site selection centered on high-profile crashes or public safety concerns.

<sup>2</sup> Federal Highway Administration. FHWA *Road Safety Audit Guidelines*. FHWA-SA-06-06. Available: [http://safety.fhwa.dot.gov/rsa/guidelines/documents/FHWA\\_SA\\_06\\_06.pdf](http://safety.fhwa.dot.gov/rsa/guidelines/documents/FHWA_SA_06_06.pdf).

- The multidisciplinary RSA team then described the RSA process. This included an overview of the RSA process with examples of typical safety issues and potential measures to address them.
- This step may include discussion of additional issues, such as planned roadway improvements.

Following the start-up meeting and a preliminary review of the design or site documentation, the RSA team conducted a **field review** (Step 4). The purpose of the field review was to observe geometric and operating conditions. The RSA team observed site characteristics such as road geometry, sight distances, clear zones, drainage, signing, lighting, and barriers; traffic characteristics such as typical speeds and mix of road users and vehicles; surrounding land uses including traffic and pedestrian generators; and link points to the adjacent transportation network. The RSA team also considered human factors issues, including road and intersection “readability,” sign location and sequencing, and older-driver limitations. The RSA team conducted field reviews under a variety of environmental conditions, such as daytime and nighttime, and operational conditions, such as peak and off-peak times.

The team conducted the **RSA analysis** (Step 5) in a setting in which all team members reviewed available background information, such as traffic volumes and collision data, in light of the observations made in the field. Based on this review, the RSA team identified and prioritized safety issues, including features that could contribute to a higher frequency and/or severity of crashes. For each safety issue, the RSA team generated a list of possible measures to mitigate the crash potential and/or severity of a potential crash.

At the end of the analysis session, the Owner and the RSA team reconvened for a **preliminary findings meeting** (Step 6). In presenting the preliminary findings verbally in a meeting, the RSA team gave the Owner an opportunity to ask questions and seek clarification on the RSA findings, and provided a useful forum for the Owner to suggest additional or alternative mitigation measures in conjunction with the RSA team. The discussion provided practical information that was subsequently used to write the RSA report.

In the weeks following the on-site portion of the RSA, the RSA team wrote and issued the **RSA report** (also part of Step 6) to the Owner. The RSA documented the findings of the RSA and consisted of a prioritized listing and description of the safety issues identified—illustrated using photographs taken during the site visit—and suggestions for improvements.

The Owner was encouraged to write a brief **response letter** (Step 7) containing a point-by-point response to each of the safety issues identified in the RSA report. In the eight-step RSA process, the response letter identifies the action(s) to be taken, or explains why no action would be taken. The formal response letter is an important “closure” document for the RSA. As a final step, the Owner was encouraged to use the **RSA findings** to identify and implement safety improvements when policy, resources, and funding permit (Step 8).

## **RSAs: Benefits and Costs**

### **RSA Benefits**

The primary benefits of RSAs are the reduction of crashes and associated crash costs as road safety is improved. The US Department of Transportation estimates the costs of automotive crashes as:<sup>3</sup>

- \$9,400,000 for a traffic fatality (category K).
- \$5,574,200 for a critical injury (category A1).
- \$2,500,400 for a severe injury (category A2).
- \$987,000 for a serious injury (category B1).
- \$441,800 for a moderate injury (category B2).
- \$28,200 for a minor injury (category C).
- \$18,374 for property damage only (PDO).<sup>4</sup>

Other benefits of RSAs include reduced life-cycle project costs due to crash reduction, and the development of good safety engineering and design practices, including consideration of the surrounding land use and development in combination with potential multimodal safety issues and integrating human factors issues in the design, operations, and maintenance of roads. Additional benefits may include enhanced traveler experience and access management, reduced travel delay and travel time, and improved travel reliability.

In 2012, FHWA sponsored a study of nine RSA programs and five RSA projects illustrating the benefits of RSAs. The project documented key strategies underpinning the success of the nine RSA programs, as well as the quantitative safety benefits of specific improvements implemented through the five specific RSA projects. The FHWA report *Road Safety Audits: An Evaluation of RSA Programs and Projects* (FHWA-SA-12-037) provides the results of this study. In order to build support for conducting RSAs and implementing RSA programs, practitioners are encouraged to refer to this FHWA report along with other local and regional studies that document the successes in implementing RSAs.

### **RSA Costs**

Three main factors contribute to the cost of an RSA:

- RSA team costs.
- Design team and Owner costs.
- Costs of design changes or enhancements.

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<sup>3</sup> U.S. Department of Transportation, Memorandum to Secretarial Officers and Modal Administrators from Polly Trottenberg, Under Secretary for Policy, February 28, 2013.

<sup>4</sup> Derived from comparison of 2001 and 2015 fatality costs using the Federal Highway Administration. Crash Cost Estimates by Maximum Police-Reported Injury Severity Within Selected Crash Geometries (FHWA-HRT-05-051). Available: <https://www.fhwa.dot.gov/publications/research/safety/05051/05051.pdf>

The *RSA team costs* reflect the size of the team and the time required for the RSA, which in turn depend on the complexity of the RSA project. RSA teams are typically composed of three to four persons, although they can be larger when multiple owners are involved.

Opening and closing meetings, site visits, and RSA analysis sessions are typically conducted in a two- or three-day period for each RSA. Prior to and following the on-site portion of the RSA, time is required for analysis (such as analysis of collision records, and research on applicable design standards or mitigation measures) along with writing the RSA report.

The *design team and owner costs* reflect the time required for staff to attend the start-up and preliminary findings meetings, and to subsequently read the RSA report and respond to its findings. In addition, staff time is required to compile project or site materials for the RSA team.

The final cost component entails those costs resulting from *design changes or enhancements*, which reflect the number and complexity of the issues identified during the RSA.

## Principles of Transit Safety

The primary goal of transit providers is to enhance citizens' mobility, accessibility, and economic well-being through the development and management of public transport services that are comprehensive, affordable, efficient, reliable, safe, and environmentally sound.<sup>5</sup> The physical safety of transit passengers while using and accessing transit facilities is crucial to the success of the transit system. Every transit passenger must travel some distance, whether it is driving and then walking from a park and ride lot, or walking and bicycling a longer distance to the transit stop. A general rule-of-thumb regarding the distances people are willing to travel to a transit stop is as follows:<sup>6,7</sup>

- People are willing to walk up to  $\frac{1}{4}$  mile to access Local Bus transit.
- People are willing to walk up to  $\frac{1}{2}$  mile to access BRT or Rail transit.
- People are willing to bike between 1-3 miles to access Rail transit.

Figure 2 illustrates an example of a bus stop and bus corridor catchment area. Within these catchment areas, it is important to identify routes that people use to walk, bike, or drive to transit facilities and identify and address the safety risks to transit users.

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5 Federal Transit Administration. Region 5 Mission Statement. Available:

<https://www.transit.dot.gov/about/regional-offices/region-5/mission-statement>.

6 U.S. Government Publishing Office. Federal Transit Administration Final Policy Statement on the Eligibility of Pedestrian and Bicycle Improvements Under Federal Transit Law (Docket No: FTA-2009-0052). Federal Register Volume 76, No. 161. Available: <https://www.gpo.gov/fdsys/pkg/FR-2011-08-19/pdf/2011-21273.pdf>.

7 Federal Highway Administration. Pedestrian Safety Guide for Transit Agencies. Available: [http://safety.fhwa.dot.gov/ped\\_bike/ped\\_transguide/ped\\_transguide/transit\\_guide.pdf](http://safety.fhwa.dot.gov/ped_bike/ped_transguide/ped_transguide/transit_guide.pdf).



Figure 2. Example of bus stop and bus corridor catchment area (Map data: ©Google).

### ***Transit Safety Considerations***

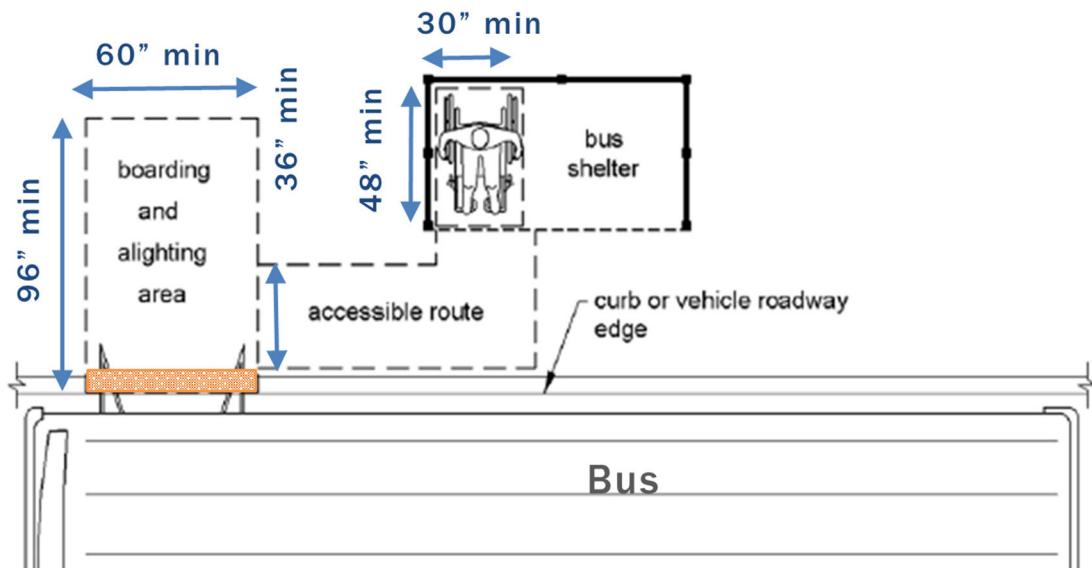
Understanding and properly identifying safety issues at transit facilities that affect transit riders is essential to finding an appropriate solution. In order for transit to be viable for users, the following needs should be considered:<sup>8</sup>

- *Access to and from the transit stop* – From the transit stop, transit users need to have access to destinations such as places of business, schools, and healthcare facilities. This access should be provided through unobstructed accessible routes and crossing measures. For pedestrians and cyclists, this access can be provided through sidewalks, bike lanes, shared use paths, and in some instances a wide shoulder.
- *Continuous facilities* – bicycle and pedestrian facilities to transit facilities should be continuous and avoid abrupt changes and gaps in facilities.
- *Crossing measures* – Crossing measures such as crosswalks, signs, and signals that provide adequate time for pedestrians to cross the street should be provided to help users access transit facilities.

<sup>8</sup> Federal Highway Administration. A Resident's Guide for Creating Safer Communities for Walking and Biking. Available: [http://safety.fhwa.dot.gov/ped\\_bike/ped\\_cmnty/ped\\_walkguide/residents\\_guide2014\\_final.pdf](http://safety.fhwa.dot.gov/ped_bike/ped_cmnty/ped_walkguide/residents_guide2014_final.pdf).

At the transit facility, there are other measures that should be considered:<sup>9</sup>

- *Accessible transit stops* – transit stops should include ramps, landing pads, and connections to accessible routes. Figure 3 illustrates some of the Americans with Disabilities Act (ADA) standards for bus stops.
- *Lighting* – transit stop lighting provides riders with a sense of personal safety when using transit during dark conditions. It also helps to alert drivers of transit facilities and transit riders, and helps transit operators see waiting riders.
- *Transit stop amenities* – transit stop amenities are important components to help attract transit riders. It is important to note what amenities are in use, how they are designed, and what could be improved upon. Amenities can include features such as seating, shelters, trash receptacles, and bicycle racks.
- *Location of transit stops* – the location of transit stops can have a significant impact on traffic operation and safety for transit riders, transit operators, and other drivers. Transit stops placed prior to a signal can use the red phase for boarding and alighting. However, some transit agencies have noted that with riders exiting the rear of the transit vehicle, this stop placement can encourage mid-block crossings. Placing the transit stop after the signal can cause other vehicles to unexpectedly and abruptly stop after driving through the signal and can impede traffic operations, but can encourage pedestrians exiting the transit vehicle at the rear to cross at the intersection. Other transit stop considerations include whether to use pull-outs, median stops, or dedicated transit lanes for exiting passengers. Each option should be reviewed to determine the impact on traffic flow, safety, and rider behavior.



**Figure 3. ADA Standards for bus stop boarding & alighting area and shelters (Source: US Access Board).**

<sup>9</sup> Federal Highway Administration. Pedestrian Safety Guide for Transit Agencies. Available: [http://safety.fhwa.dot.gov/ped\\_bike/ped\\_transit/ped\\_transguide/transit\\_guide.pdf](http://safety.fhwa.dot.gov/ped_bike/ped_transit/ped_transguide/transit_guide.pdf).

## **How to Incorporate Transit into the RSA Process**

Incorporating a transit access focus to the RSA process is unique due to the complexity of facility ownership. In many instances, transit agencies are responsible for providing local service to the community and operate on roadways maintained by the locality or state department of transportation. Furthermore, lighting and intersection traffic signals may be maintained by the locality. The transit agency may work with the locality to solicit input, but the transit agency is ultimately responsible for planning routes, operating service, and selecting/maintaining transit stop locations. The transit agency must work with the owner of the roadway (often a State or local agency or private entity) to install the transit stops and any associated amenities. It is imperative that these agencies work together during the RSA process to address safety concerns related to transit use and access.

When considering conducting a transit access focused RSA, the following areas should receive particular attention.

- **Participants:** Every RSA should seek to involve participants from a variety of backgrounds and specialties. The RSA team should include the agencies that own and maintain the roadway, traffic specialists, safety specialists, and first responders. Due to the complexity of the relationship between transit, State, and local agencies, representatives from each should be included in the RSA. Additionally, transit operators can provide unique perspectives of the transit facilities and behaviors of roadway drivers and transit riders.
- **Focus:** Transit Access RSAs are not solely limited to the transit stops; they should also consider the routes that riders take to and from the transit facilities. The FHWA *Pedestrian Road Safety Audit Guidelines and Prompt Lists* and *Bicycle Road Safety Audit Guidelines and Prompt Lists* can help to provide unique insights on safety concerns facing pedestrians and cyclists.<sup>10,11</sup>
- **Field Review:** During the RSA, teams are encouraged to experience the facilities in a variety of conditions by conducting field reviews during both dark and light conditions and using a variety of modes such as driving, walking, and biking through the study area. In addition, during a Transit Access RSA, teams should also try to experience the study area by riding the transit vehicle to view first hand driver behavior in response to transit vehicles and challenges facing transit riders. In some instances, the transit agency may be able to provide a vehicle for the RSA team. In other instances, the RSA team may have to ride through the facility on a vehicle operating on its standard route.

## **Transit Users in the RSA Process**

### **RSA Project Selection**

This case study effort included four Transit Access RSAs in different regions of the country with crashes involving pedestrians and bicyclists, as shown in Table 1. Each RSA followed the standard

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10 Federal Highway Administration. *Pedestrian Road Safety Audit Guidelines and Prompt Lists*. FHWA-SA-07-007. Available: <http://www.pedbikeinfo.org/cms/downloads/PedRSA.reduced.pdf>.

11 Federal Highway Administration. *Bicycle Road Safety Audit Guidelines and Prompt Lists*. FHWA-SA-12-018. Available: [http://safety.fhwa.dot.gov/ped\\_bike/tools\\_solve/fhwasa12018/](http://safety.fhwa.dot.gov/ped_bike/tools_solve/fhwasa12018/).

eight-step RSA process documented by FHWA. Each of the RSA teams selected study area sites based on combinations of the following criteria:

- High crash frequency involving transit users.
- Existing multimodal concerns.
- Locations with high transit ridership.
- Planning for alternative transit modes.

A more detailed report of these four RSAs is included in Appendix A.

**Table 1: Case Study RSAs.**

Host Agency	Location	Facility Type and Project Stage	Area of Study
City of Asheville, North Carolina	Four locations on Patton Avenue: three urban intersections and three suburban intersections.	Existing multi-lane road and multi-lane divided highway.	Patton Avenue: ~2.0 miles Transit Stops: 12
Orange County, Florida	Three locations at varying intersections throughout Orlando, Florida: West Colonial Drive at North Pine Hills Road, Econlockhatchee Trail at Valencia College Lane, and two intersections in the Florida Mall area.	Existing urban, multi-lane highway and urban intersections with heavy transit use.	Urban intersections with approximately 16 transit stops and two super stops.
City of Springfield, Oregon	Four locations on Main Street Corridor: four urban/suburban intersections.	Existing and planning level on urban/suburban two-lane road	Approximately 5 miles Transit Stops: 12
City of Tucson, Arizona	Ronstadt Transit Center and surrounding area.	Urban transit center with multi-modal transit.	Transit center and the surrounding area, approximately 17.5 acres.

### ***How Transit Safety was Incorporated into the RSA Process***

RSAs were conducted on existing facilities based on a variety of factors, including crash frequency, transit ridership, bicycle and pedestrian use, and future transit changes (Step 1 in the RSA process). RSA teams consisted of the typical participants such as persons with expertise in road safety, traffic operations, road design, and law enforcement (Step 2). Other RSA team members also had expertise critical to understanding conditions affecting transit users, such as members from departments of planning and transportation, transit agencies, and other groups and organizations. The transit operators provided unique insights into transit rider safety and transit operation.

During the start-up meeting (Step 3) and the RSA analysis workshop (Step 5), the RSA team reviewed and discussed crash data, including contributing factors, and conditions during the time of the crash. The start-up meeting also included a discussion of the transit modes and routes within the study area. The RSA team reviewed these conditions in the field (Step 4). Furthermore, during each

RSA, several team members who were very familiar with the locations relayed their knowledge and experience to the RSA team.

Later, during the RSA analysis workshop (Step 5), the team discussed these conditions in more detail. The objective of this review was to discuss the analysis results and compare them with conditions observed in the field. Based on this analysis, the RSA team considered conditions critical to the safety of pedestrians, bicyclists, and transit users and suggested countermeasures that may reduce the risk to all users.

The RSAs helped bring attention to safety issues affecting transit users by highlighting the effects of design and maintenance practices and by bringing together a multidisciplinary and multimodal group of safety professionals to clarify issues that may not have been adequately understood previously. Furthermore, through the RSAs conducted as part of this study, the RSA teams discussed positive measures, challenges, and opportunities for advancement of pedestrian and transit safety. The following section describes these in further detail.

### ***Positive Measures***

The RSAs included in this report demonstrated many of the positive measures implemented to address safety near transit facilities. Some of these positive measures include a general commitment to safety, encouragement of multimodal transportation choices through policies and engineering, and strong collaboration between agencies.

*Commitment to safety.* The RSAs demonstrated that agencies are seeking specific measures to address the safety of transit users. This interest has been driven in part by a high crash frequency in the vicinity of transit stops, particularly among bicyclists and pedestrians who may be traveling to or from a transit facility. The City of Springfield, Oregon, in conjunction with Lane Transit District (LTD), proactively addressed pedestrian safety by installing a series of rectangular rapid flashing beacons (RRFBs) and pedestrian refuge islands along Main Street near transit stops.

*Encouragement of multimodal transportation choices.* Local agencies in the study areas demonstrated a desire to create a multimodal culture. For example, the City of Tucson has cultivated a strong multimodal culture; people were found to be walking, cycling, and taking mass transit (bus and streetcar) in addition to driving. Numerous organizations provided support in creating a multimodal environment, such as the Downtown Tucson Partnership, which provided improved landscaping, maintenance, marketing, and economic development opportunities to the downtown area. Similarly, the City of Springfield has encouraged and embraced a multimodal environment through their policies and infrastructure including shared use paths, sidewalks, bike lanes, and attractive and convenient transit services.

*Collaboration with transit agencies and other organizations.* Transit agencies and other organizations in the study areas contribute heavily to the culture of creating safer roadways for multimodal users. For example, the Florida Department of Transportation developed a Complete Streets policy

to address safety and serve the transportation needs of transit users, including pedestrians, cyclists, and transit riders. In Asheville, the City of Asheville and NCDOT worked together to relocate transit stops to the far end of an intersection to encourage rear alighting pedestrians to use crosswalks. In Tucson, collaboration among transit agencies has led to the implementation of safety measures including upgraded traffic signals that include transit signal priority, accessible pedestrian routes to transit facilities, security provided by law enforcement and privately staff retained by the Downtown Tucson Partnership, promotion of a multimodal culture, and improved street lighting, among others.

## ***Challenges***

The RSAs included in this report demonstrated several challenges that agencies face when addressing the safety of pedestrians, cyclists, and transit users. Some of these challenges include the difficulty in relating crash data to transit vehicles and facilities, understanding the conditions for non-motorized users accessing transit facilities, and driver and pedestrian behavior.

*Understanding the problem.* It can be difficult for transit agencies to understand the risks facing transit users as they travel to and from the transit facility. For each of the RSAs conducted, the host agency provided pedestrian, bicyclist, and transit-related crash data and in many cases included access to police reports with more detailed crash narratives. However, for pedestrian and bicycle crashes, it was unclear if any involved transit riders traveling to or from a transit facility. Additionally, only a small portion of pedestrian and bicycle crashes are typically reported.<sup>12</sup>

Detailed crash data can help identify crash trends, such as age and location, and can help assess overall trends and contributing factors to crashes. This data may help target not only higher-risk groups, but also higher-risk locations or transit user behavioral trends.

*Understanding conditions affecting transit users.* Pedestrians, bicyclists, and transit users face unique challenges when utilizing facilities designed primarily for personal motor vehicles. The following section identifies some of the most common issues facing transit users:

- *ADA compliance.* The RSA teams noted many instances where marked and unmarked crossings were not ADA compliant and were lacking ramps and/or detectible warning strips and signalized intersections lacked accessible pedestrian signals. It is important to ensure ADA compliance so that all individuals are able to access transit facilities. For example, the RSA performed in the City of Springfield, Oregon, noted that many marked and unmarked crossings did not meet ADA standards, even though there is a large population of older or disabled individuals to the east of the downtown area. Figure 4 shows an unmarked crosswalk that is not ADA compliant.

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<sup>12</sup> Pedestrian and Bicycle Information Center. Pedestrian and Bicyclist Crash Statistics. Available: [http://www.pedbikeinfo.org/data/factsheet\\_crash.cfm](http://www.pedbikeinfo.org/data/factsheet_crash.cfm).

Regarding the construction of transportation facilities by public entities, any new facility or station to be used in providing public transportation services must be “readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs.” (49 CFR Part 37.41). If an existing structure is altered, the altered portions must be made “readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs” to the “maximum extent feasible”. The definition of “maximum extent feasible” means that the regulations must be followed unless “the nature of an existing facility makes it impossible to comply fully with applicable accessibility standards” and that any portion of the facility that can be made accessible, shall be. If it is not possible to make a portion of the facility accessible to individuals with certain disabilities, it should still be made accessible to individuals with other types of disabilities (49 CFR Part 37.43).



**Figure 4. Example of ramp at an unmarked crosswalk on Main Street in the City of Springfield, Oregon**  
**(Photo Credit: Elissa Goughnour).**

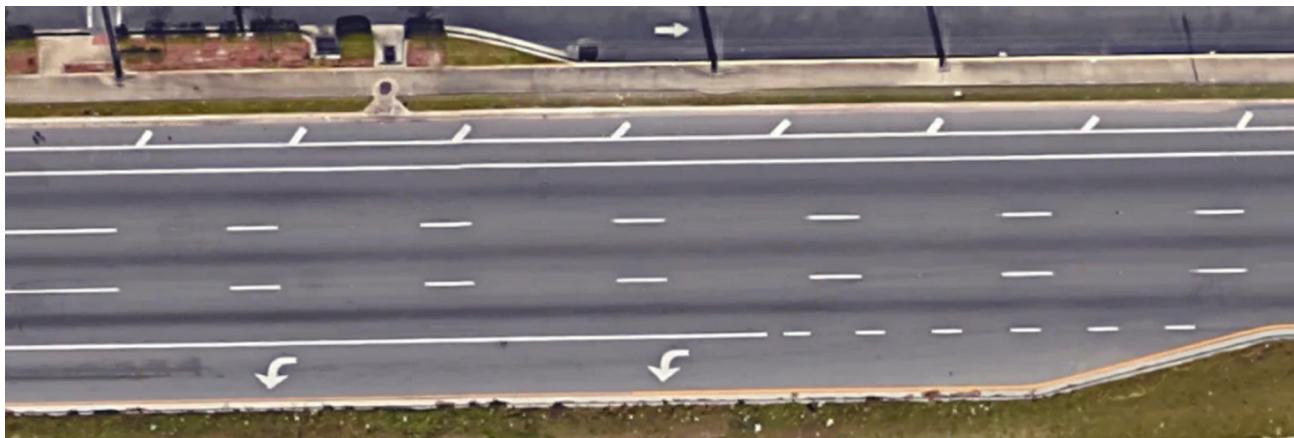
- *Pedestrian marked and unmarked crossings.* Pedestrian crossings, whether marked or unmarked, create a conflict point between motorized and non-motorized users. The RSAs in this report noted many locations with inadequate pavement markings or signage to provide drivers with warning or indication of pedestrian crossings. For example, in the City of Asheville, North Carolina, the RSA team noted that none of the intersections analyzed by the RSA team, outside the downtown area, have crosswalks or pedestrian signals. At signalized intersections without pedestrian signals, it can be difficult for pedestrians and cyclists to know when to cross. In particular, with split signal phasing pedestrians can end up stuck in the middle of the roadway when the signal phase changes. Additionally, the yielding rate for turning vehicles to pedestrians was low. This issue may be exacerbated at unmarked crossings.

In the eastern portion of Springfield, Oregon study area, where higher population of older residents was noted, evaluating pedestrian crossing measures is even more important. According to the FHWA report, *Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines*, older pedestrians are more at risk than younger pedestrians on virtually all types of crosswalks.<sup>13</sup> Some of the possible reasons that older pedestrians are at greater risk are that, in comparison to younger pedestrian, they are more likely to have:

- » Slower walking speeds (and thus greater exposure time).
- » Visual and/or hearing impairments.
- » Difficulty in judging the distance and speed of oncoming traffic.
- » Difficulty keeping track of vehicles coming from different directions, including turning vehicles.
- » Reduced reaction speed or inability to avoid a collision under emergency conditions.
- *Conflicts between motorists and pedestrians, cyclists, and transit users.* Throughout the process of evaluating RSA sites, conflicts between turning vehicles and non-motorized users were observed by the RSA teams. Even while wearing highly visible safety vests, the RSA team noticed many drivers who did not yield to crossing RSA team members. In Orlando, Florida, the RSA team observed many instances in which drivers disregarded crossing pedestrians and cyclists during the green phase and while making right turns on red.
- *Pavement markings.* The use of pavement markings on roadways to alert drivers of non-motorized users plays a significant role in creating cohesive multimodal environment. During the RSAs, the team members noted many instances of faded and/or incomplete pavement markings. In some instances, the markings were present but could have been used in a more effective format. For example, in Orlando, Florida, the RSA team noted that pavement markings are present and in good conditions in all the study areas. However, in one of the focus areas, a buffer was provided between the bike lane and the curb as shown in Figure 5, rather than a buffer between the bike lane and travel lanes where it would provide the greatest benefit for cyclists. In this area, drivers were also using the bike lane and buffer as a right- turn lane possibly due to the lack of bike lane pavement markings and the available width which allows the buffer and bike lane to function as a full travel lane.

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<sup>13</sup> Federal Highway Administration. Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines. FHWA-HRT-04-100. Available: <https://www.fhwa.dot.gov/publications/research/safety/04100/04100.pdf>.



**Figure 5.** West Colonial Drive, east of the Pine Hills Road intersection, with a buffer between the bicycle lane and the curb (Map data: ©Google).

- *Pedestrian behavior.* During all of the RSAs, the teams observed pedestrians crossing mid-block, and crossing against the pedestrian signal designation. According to the National Highway Traffic Safety Administration, the majority (71 percent) of fatal pedestrian crashes occur outside of intersections.<sup>14</sup> In the City of Springfield, Oregon, the RSA team witnessed many pedestrians crossing Main Street at unmarked crossings or mid-block crossings. While unmarked crossings are legal crossing locations, drivers may not expect pedestrians to cross Main Street outside of the marked crosswalk locations due to the high vehicle speeds and long crossing distance. In Orlando, Florida, the RSA team noted pedestrians crossing mid-block on wide multi-lane roadways. Mid-block crossings were also a source of pedestrian crashes—four of the study area crashes involved pedestrians crossing mid-block, and two of those resulted in fatalities. Some members of the RSA team anecdotally noted that in some locations pedestrians have expressed their opinion that it is safer to cross away from the crosswalk. It is important for communities to examine pedestrian behavior and pathways in order to create safer and more convenient facilities for them. Frequent mid-block crossings may indicate that driver needs have been prioritized over pedestrian needs.

## *Opportunities*

In response to the issues identified during each of the RSAs, a variety of opportunities were identified. Some of these opportunities included improving ADA compliance, evaluating the need for pedestrian crossing measures, implementing corridor access management techniques, and increased separation of modes.

<sup>14</sup> National Highway Traffic Safety Administration. Traffic Safety Facts: Pedestrians 2014 (DOT HS 812 270). Available: <https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812270>.

*ADA compliance.* It is important to ensure ADA compliance so that all individuals can access transit facilities. Agencies should continue evaluating transit stops locations and pedestrian access to transit facilities, and ensure compliance with ADA access requirements for bus boarding and alighting areas. This is particularly important in areas with an aging population or populations with mobility challenges.

*Pedestrian crossing measures.* Agencies should evaluate pedestrian routes to transit stops and identify appropriate locations for crosswalks and pedestrian signals. These measures are particularly important in locations with wide roadway crossings that are more difficult for pedestrians to cross. According to FHWA, “On many roadways, particularly multilane and high-speed crossing locations, more substantial improvements often are needed for safer pedestrian crossings, such as providing raised medians, installing traffic signals (with pedestrian signals) when warranted, implementing speed-reducing measures, and/or other practices.”<sup>15</sup> For multilane (four or more lanes) roadways with a raised median and an AADT greater than 15,000 vehicles per day, the study concluded that marked crosswalks should be combined with other pedestrian facility enhancements, such as pedestrian signals. Installing marked crosswalks alone has not proven to be sufficient in reducing pedestrian crashes.

Consider implementing measures to reduce conflicts between pedestrians and vehicles. Some of the measures discussed include pedestrian hybrid beacons, rectangular rapid flashing beacons (RRFBs) and raised crosswalks/intersections. Other measures to reduce risks for crossing pedestrians include the following:

- Pedestrian crossing warning signs to warn motorists of an upcoming crosswalk and identify the crosswalk location, specifically in locations that are more challenging to identify.
- Leading Pedestrian Interval (LPI) to let waiting pedestrians begin to cross at signalized intersections prior to vehicles. This helps improve visibility of crossing pedestrians and can reduce conflicts with turning vehicles.
- Signage to help bring attention to crossing pedestrians. These can include blackout Yield to Pedestrian signs and pedestrian hybrid beacons, shown in Figure 6.
- High-visibility crosswalk pavement markings at intersections to draw the driver’s awareness to the crossing.

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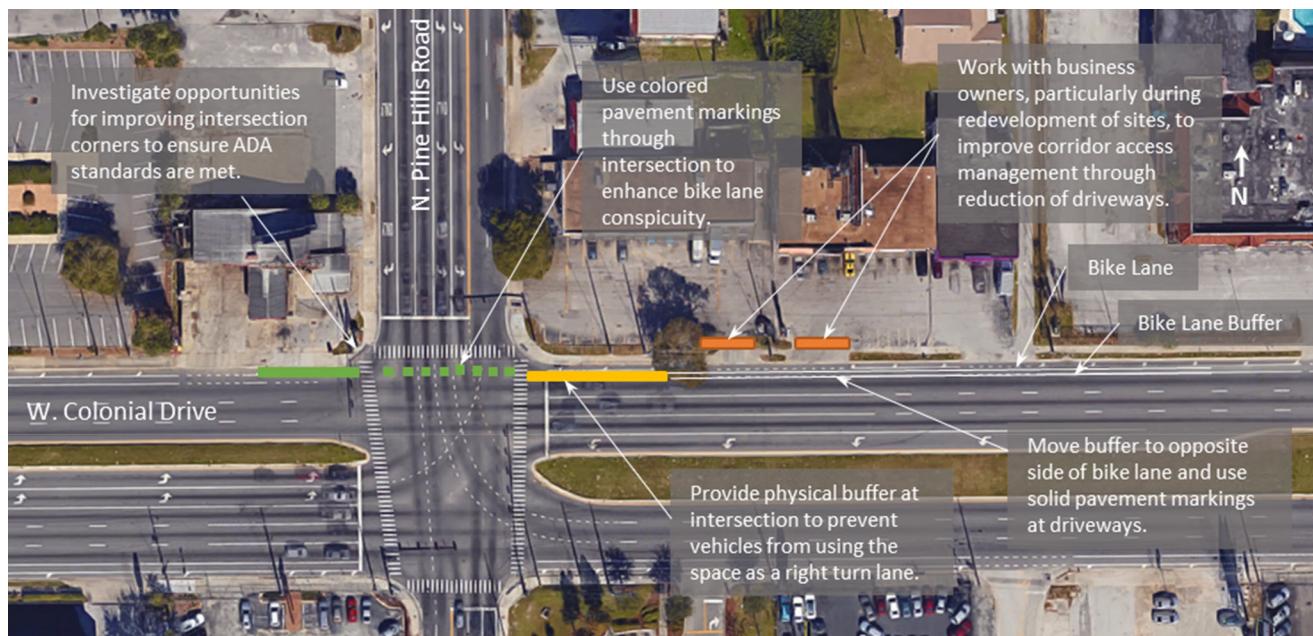
<sup>15</sup> Federal Highway Administration. Safety Effects of Marked versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines. FHWA-HRT-04-100. Available: <https://www.fhwa.dot.gov/publications/research/safety/04100/04100.pdf>.



**Figure 6.** On left: Blackout Yield to Pedestrian sign (Source: Orange Traffic).  
On right: pedestrian hybrid beacon (Source: FHWA).

*Corridor access management.* A higher number of driveway access points along a corridor increases the crash risk for all users, as was observed in the RSA study areas. Corridor access management can be implemented by combining driveways and reducing the number of entrances onto the roadway, thereby reducing the number of potential conflict points. Modifications to the number of access points could be accomplished during changes in land use and redevelopment.

*Increased separation of modes.* Consider alternatives to provide physical separation of motorized vehicles from bicyclists and pedestrians. In Orlando, Florida, at the intersection of West Colonial Drive and North Pine Hills Road, drivers were using the bike lane and buffer as a right turn lane and were also encroaching on crossing pedestrians in the crosswalk. Moving the buffer so that it is placed between the bike and travel lanes would provide bicyclists additional separation from motorized vehicles. Additionally, at intersections, a physical barrier in the buffer could be used to prevent vehicles from using this space as a turn lane and would reduce the pedestrian crossing distance. As shown in the example in Figure 7, alternative designs that provide additional protection to non-motorized users are recommended.

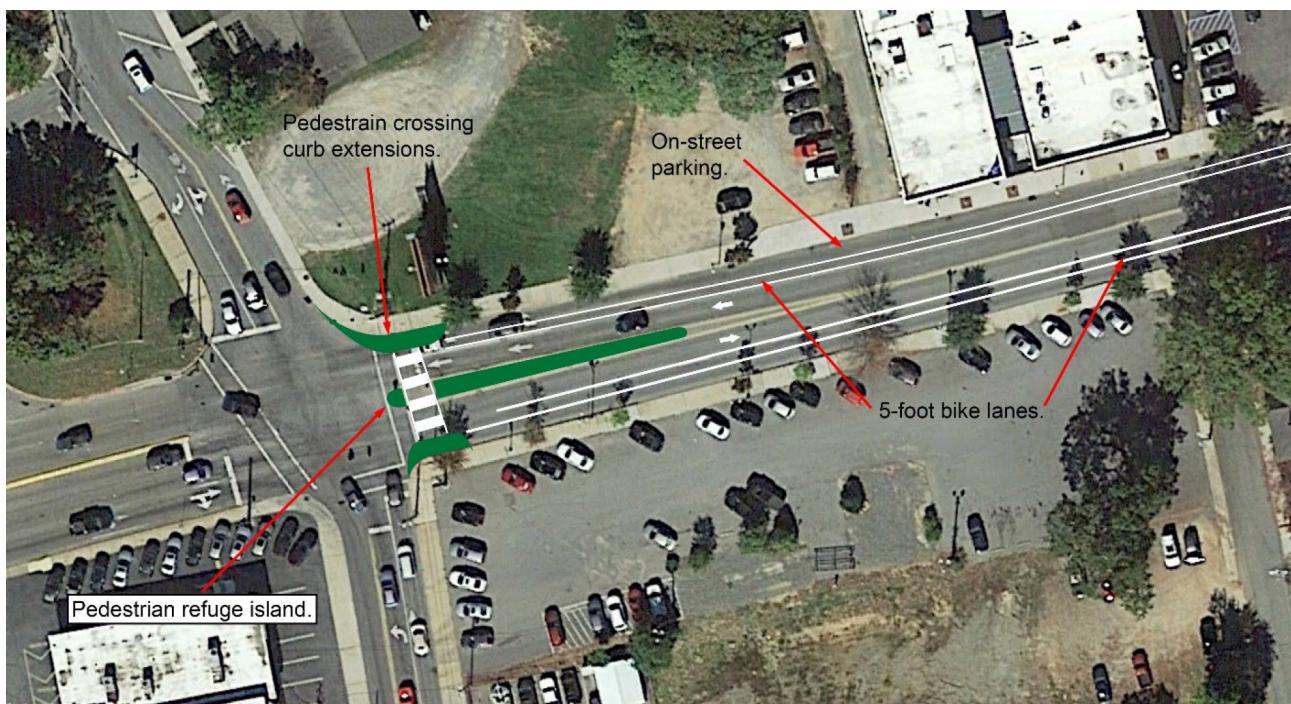


**Figure 7.** Focus area in the Orlando, FL area (West Colonial Drive and North Pine Hills Road) showing possible intersection improvements (Map data: ©Google).

Road diets are an effective way to reduce speeds and in some instances can provide space for an increased separation of modes. Road diets are FHWA-proven safety countermeasures that reallocate space from travel lanes to provide safety improvements such as two-way left-turn lanes, medians, or dedicated space for bicycles and pedestrians.<sup>16</sup> The primary goals of a road diet are “enhanced safety, mobility and access for all road users and a ‘complete streets’ environment to accommodate a variety of transportation modes.”<sup>17</sup>

Figure 8 shows how a road diet could be implemented on Patton Avenue in the City of Asheville, starting at the entrance to the city. At Clingman Avenue, one traffic lane could be removed to allow for on-street parking and a bike lane as displayed in. This would provide several benefits:

- A narrower cross-section would make it easier for pedestrians to cross Patton Avenue.
- Space could be provided for a designated bike lane and on-street parking.
- Narrowing of the roadway would provide traffic calming and could potentially reduce the frequency/severity of crashes.
- Pedestrian refuge island at the intersection with Clingman Avenue provides a refuge for pedestrians as well as indications to drivers of the change in roadway conditions from suburban to urban.
- Designate bus-pullout bays could be used to minimize traffic disruption on Patton Avenue.



**Figure 8. Patton Avenue road diet concept diagram (Map data: ©Google).**

<sup>16</sup> Federal Highway Administration. Proven Safety Countermeasures. Available: <http://safety.fhwa.dot.gov/provencountermeasures/>.

<sup>17</sup> Federal Highway Administration. Road Diets (Roadway Reconfiguration). Available: [http://safety.fhwa.dot.gov/road\\_diets/](http://safety.fhwa.dot.gov/road_diets/).

*Intersection geometric modifications.* Intersection modifications can provide opportunities for improvements that benefit all roadway users. Some of the potential benefits include improved sight distance, reduced crossing distance, and speed modifications.

In addition, alternative intersection designs, such as roundabouts, could facilitate pedestrian crossings, reduce potential conflicts within the intersection, and improve traffic flow. The intersection of Florida Mall Avenue and August Lane is an example of an intersection that could benefit from this type of treatment. Figure 9 shows a conceptual diagram of changes that could be made to the intersection along with a diagram of a mini-roundabout provided by FHWA.

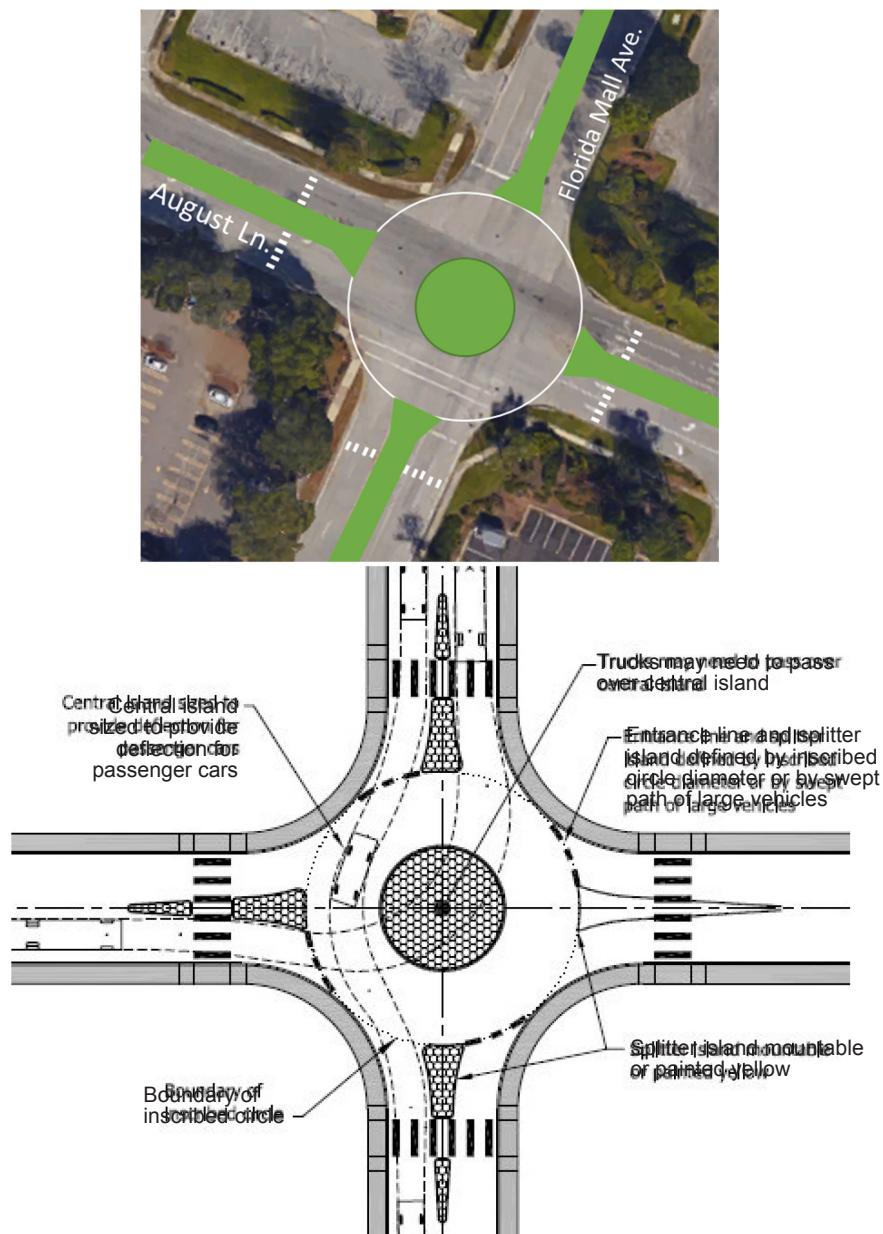


Figure 9. Alternative intersection design option. On top: mini-roundabout intersection conceptual diagram from Florida Mall location in Orlando, Florida. On bottom: mini-roundabout diagram (Map data: ©Google; Graphic source: FHWA).

## Conclusions and Recommendations

The purpose of this document is to help Federal, State, Tribal, and local agencies:

1. Understand conditions that affect the safety of transit riders.
2. Apply the RSA process to address these conditions.

RSA teams conducted four RSAs at locations with a high frequency of crashes, high transit ridership, or at locations where planning for changes to transit service are underway.

The RSA locations included urban and suburban areas with transit facilities and included a multidisciplinary team of planners, engineers, transit managers and operators, and law enforcement. This multidisciplinary perspective and experience of transit personnel was critical to defining approaches to improving transit rider safety using the 4-E approach to safety.

RSA teams identified existing countermeasures or those under review that may improve the safety of transit users. These include the promotion of multimodal and complete streets environments, implementing innovative crossing measures, and a history of collaboration among agencies to address safety and transit planning.

A lack of detailed data is a key issue inhibiting a fuller understanding of the factors that affect the safety of transit riders. This includes detailed pedestrian and bicyclist crash data, transit incident reports, and an understanding of origins and destinations of transit riders.

During the RSAs, the RSA team concluded that certain conditions appear to present challenges to transit users. These were:

- Lack of ADA compliant accessible routes and transit stops.
- Driver behavior and lack of yielding to pedestrians at marked and unmarked crosswalks.
- Lack of pedestrian crossing measures along routes to transit stops, including pedestrian signals and crosswalks.
- Pedestrian mid-block crossings due to wanting to use the most direct route or intentionally crossing away from intersections due to safety concerns.

RSA teams suggested a variety of potential countermeasures to address these issues. Some of these suggested countermeasures included improving ADA compliance, evaluating the need for pedestrian crossing measures, implementing corridor access management techniques, and increased separation of modes.

As the case studies in this document demonstrate, RSAs can be a useful tool in addressing transit safety. Collaboration among city, state, and transit agencies is key to that success.

# APPENDIX A: TRANSIT ACCESS ROAD SAFETY AUDIT CASE STUDIES

## RSA CASE STUDY NO. 1—RONSTADT TRANSIT CENTER AND SURROUNDING AREA, TUCSON, ARIZONA

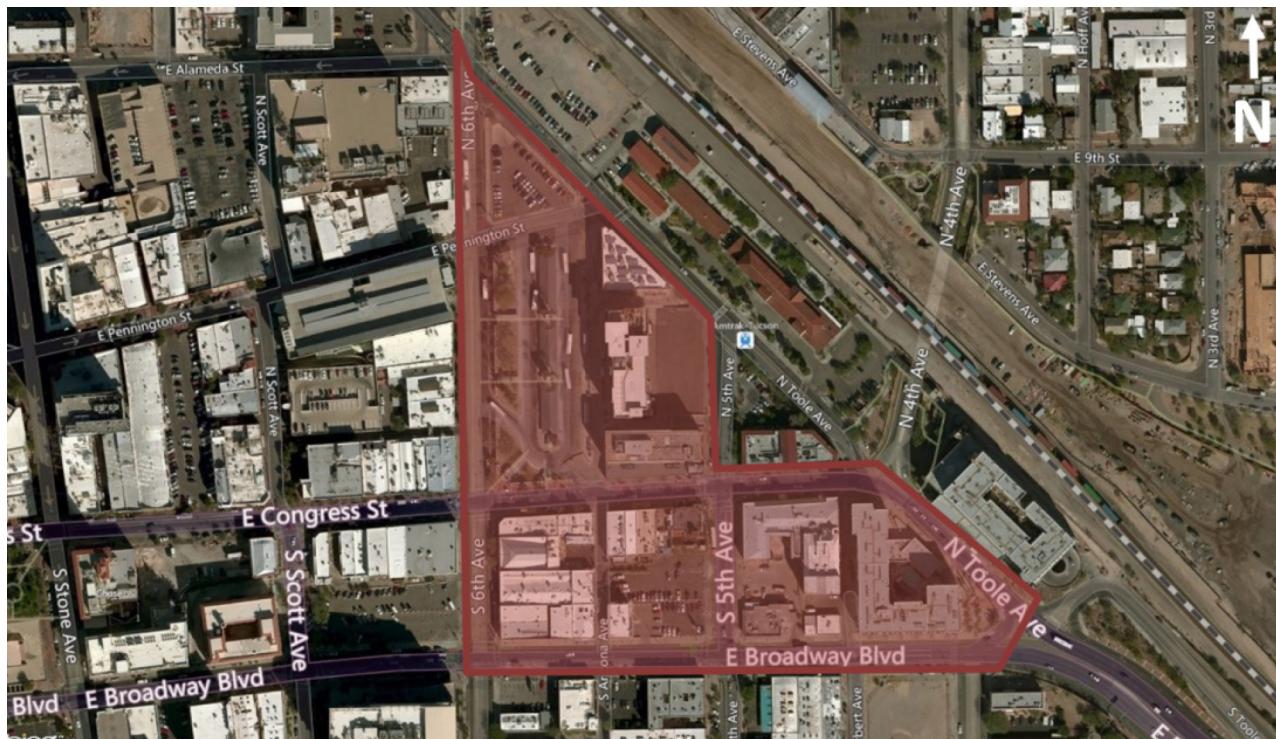
Project Overview	
Project Location:	The Ronstadt Transit Center and surrounding area, including five intersections in the vicinity of the transit center.
Project Environment:	Urban
Project Design Stage:	Existing roadway
Project Owner(s):	Sun Tran and the City of Tucson, Arizona
RSA Overview	
Date of RSA:	March 29-31, 2016
RSA Stage(s):	Transit Access RSA of existing roads and transit facilities
RSA Team:	Representatives from the City of Tucson, Pima Association of Governments, Sun Tran, the Tucson Police Department, and VHB.

### Project Background

The purpose of this study was to complete a transit road safety audit (RSA) for Sun Tran and the City of Tucson, Arizona. Tucson was one of four cities selected for RSA assistance as part of the Mayor’s Challenge, an initiative from the Department of Transportation Secretary to improve pedestrian and bicyclist safety in urban areas.<sup>18</sup> The City of Tucson wanted to conduct an RSA to document some of the challenges to pedestrian and bike safety, including incidents involving pedestrians and transit vehicles and multimodal interactions around the Ronstadt Transit Center.

The Ronstadt Transit Center is Sun Tran’s largest transit center, served by 27 different routes (14 local and 13 express). The transit center serves over 100 buses an hour during peak hours. The transit center is located in downtown Tucson, just west of the Amtrak Station, between East Pennington Street, North 6th Avenue, East Congress Street, and North Toole Avenue. The study area for this RSA includes the Ronstadt Transit Center and the surrounding streets. The triangular study area is framed by North Toole Avenue to the north and east, 6th Avenue to the west, and East Broadway Boulevard to the south (Figure A- 1). The study area did not include an assessment of conditions along North Toole Avenue between North 6th Avenue and North 4th Avenue, North 5th Avenue north of East Congress Street, and South Arizona Avenue.

<sup>18</sup> U.S. Department of Transportation. Mayor’s Challenge for Safety People, Safer Streets. Available: <https://www.transportation.gov/mayors-challenge>.



**Figure A-1: Aerial image of the RSA study area for the Ronstadt Transit Center and surrounding area  
(Map data: Microsoft® Bing™).**

## Key RSA Findings and Suggestions

Upon completing the data analysis and field observations, the RSA team identified a number of issues and suggestions. The following presents a summary that highlights several main points.

Overarching Safety Issues, Ronstadt Transit Center and Surrounding Areas	
Concerns/ Issues	Examples of Suggested Actions
<b>Automobiles and Transit.</b> The transit center is not open to general traffic, and includes signage at the entrances indicating such. The RSA Team noted on numerous occasions drivers entering the transit center.	<b>Signage.</b> Installing more conspicuous “Do Not Enter, Authorized Vehicles Only” would likely help compliance and reduce the number of private vehicles driving into the transit center. This could include utilizing larger signs, more conspicuous signs, or identifying locations and sign positioning that is more noticeable. These locations would need to consider the turning movements and dimensions of the buses traveling into the center as well.
<b>Street Closures.</b> Another contributing factor observed during the RSA was the closure of the western left of the intersection of East Pennington Street and North Toole Avenue. Drivers missed the “Road Closed” sign and by the time they realized they could not continue they use the transit center loop to turn around.	<b>Geometric Changes.</b> Consider removing parking along Congress Street and/or Broadway Boulevard to eliminate violations that interfere with streetcars. The removal of parking could provide opportunities for expanded sidewalks or other outdoor space for public or commercial uses.
<b>Street Parking.</b> The RSA Team also discussed the interactions of parked vehicles and the streetcar. Currently, some blocks along the streetcar route provide on-street parking. If a vehicle is improperly parked, it can impede the streetcar from continuing along the track. This situation requires the streetcar to wait for the offending vehicle to be moved or towed.	<b>Signal Phasing.</b> Consider shortening the cycle length of pedestrian signals to 60 seconds at these locations where traffic volumes do not warrant a longer cycle length. This should result in better compliance from pedestrians waiting to cross the street. Also, the city should consider making the pedestrian intervals automatic and not require the use of buttons at some of the signals. The shorter cycle length will mean that special additional turn arrows are not desirable for the downtown signal system.
<b>Pedestrian Crossings.</b> The RSA team noted that pedestrians cross against the “Do Not Walk” indication at intersections with lower traffic volumes.	

**Focus Area #1: Toole Avenue/East Alameda Street/North 6th Avenue**
**Concerns / Issues**

**Restricted Sight Distance.** Intersection geometry and building placement combine to create challenging sight lines for vehicles attempting to turn left from North 6th Avenue to East Alameda Street and drivers turning left from northbound North Toole Avenue to southbound North 6th Avenue. It is particularly difficult for drivers turning left to see pedestrians waiting on the corner to cross East Alameda Street and North 6th Avenue.

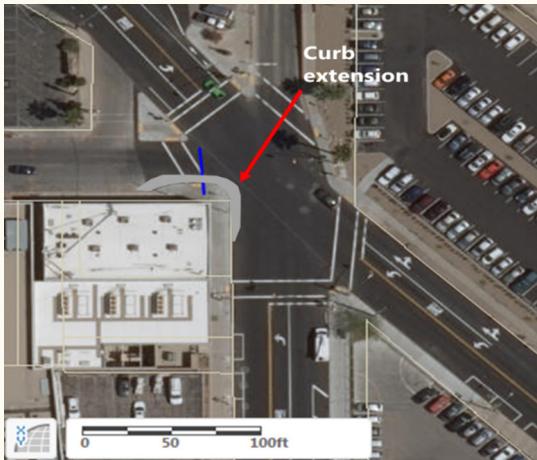


**Top Photo:** Sight lines of turning traffic from westbound East Toole Avenue to North 6th Avenue. **Bottom Photo:** Signage designed to alert pedestrian to watch for turning vehicles (Photo credit: Dan Nabors).

**Confusing Pedestrian Signs.** Signage has been installed, alerting both drivers and pedestrians to watch for each other when turning or crossing the street. The signage intended for pedestrians is a black and white sign informing them to "Watch for Turning Traffic". This message was considered confusing to pedestrians because it is not a typical application of the sign.

**Examples of Suggested Actions**

**Curb Extension.** Reduce the pedestrian crossing distance and improve visibility of pedestrians at the intersection by extending the existing curb extension on East Alameda Street and adding a curb extension on the southwest corner of the intersection along North 6th Avenue. Any reconfiguration of the curb line should consider future bicycle infrastructure designs that may be installed along East Alameda Street.



**Above:** diagram showing the curb extensions on East Alameda Street and North 6th Avenue (Map data: Microsoft® Bing™).

**Modify Pedestrian Warning.** Replace existing black and white "WATCH FOR TURNING TRAFFIC" signage with yellow warning sign and consider alternative warning methods such as adding pavement marking warnings for pedestrians to watch for turning vehicles.



**MUTCD R10-15 sign TURNING VEHICLES [YIELD] TO [PEDESTRIAN]** at the East Toole Avenue and North Avenue intersection (Photo credit: Dan Nabors).

**Focus Area #1: Toole Avenue/East Alameda Street/North 6th Avenue (cont.)****Concerns/ Issues**

**Atypical Traffic Signalization.** The City utilizes a flashing yellow arrow to alert drivers to make the left turn cautiously, and look for pedestrians. This indication is given for northbound drivers at the same time the opposing drivers are seeing a red indication. This type of application is atypical of standard industry practices, and is not applied anywhere else in Tucson. This could create a situation where left turning vehicles seeing a flashing yellow arrow do not expect to encounter opposing traffic.

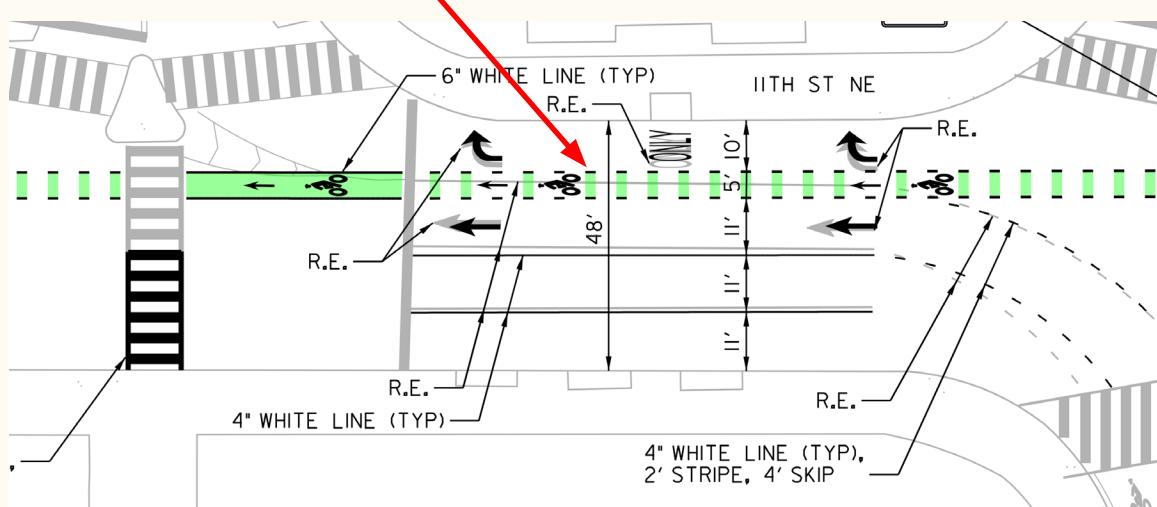
**Bike Lane Intersection Conflicts.** There are bike lanes along the western leg of East Toole Avenue that transition to shared lane markings to the east of North 6th Avenue. The size and geometry of the intersection create a situation where it is not clear how cyclists should travel through the intersection. "Watch for Turning Traffic". This message was considered confusing to pedestrians because it is not a typical application of the sign.

**Examples of Suggested Actions**

**Signal Modification.** Replace the non-standard flashing yellow arrow with a green ball and supplement the traffic signal with the appropriate static or illuminated signage R10-15 alerting drivers to the presence of pedestrians.

**Signal Phasing.** Return the signal to a two-phase operation, with Mayor and Council approval, to allow for the improvement in the overall pedestrian movement throughout the entire downtown area.

**Pavement Markings.** Consider using green transition markings to indicate to cyclists how they should travel through the intersection and transition from the bike lane to the shared lane markings. The green bike lane pavement markings have interim approval in the Manual of Uniform Traffic Control Devices and as such, approval must be requested by FHWA prior to implementation.<sup>19,20</sup>

**Transition Markings**

*Above: An example of the dashed bicycle lane and green pavement markings that could be considered in transition areas (Source: VHB).*

19 Federal Highway Administration. Manual of Uniform Traffic Control Devices: Interim Approval for Optional Use of Green Colored Pavement for Bike Lanes (IA-14). April 15, 2011. Available: [http://mutcd.fhwa.dot.gov/resources/interim\\_approval/ia14/](http://mutcd.fhwa.dot.gov/resources/interim_approval/ia14/).

20 Federal Highway Administration. Manual of Uniform Traffic Control Devices: Interim Approvals Issued by FHWA. Available: [http://mutcd.fhwa.dot.gov/res-interim\\_approvals.htm](http://mutcd.fhwa.dot.gov/res-interim_approvals.htm).

**Focus Area #2: North 6th Avenue and East Pennington Street****Concerns/ Issues**

**Temporary Limited Access.** The “Road Closed” signage warning drivers about the closure of East Pennington Street was not visible to vehicles attempting to turn right from North 6th Avenue onto East Pennington Street.

**Confusing Vehicle Signage.** There was an overhead warning sign mounted to the signal mast arm over northbound North 6th Avenue alerting drivers that the “Lane Ends Merge Right”. The lane does not end, but instead becomes a left-turn only lane. The existing signage is not clear to drivers.

**Limited Sight Distance.** When buses are parked along North 6th Avenue near the intersections with East Pennington Street, they block sight lines of the southeast corner for approaching northbound vehicles. This makes it challenging for both pedestrians and vehicles to see each other.

**Cyclist Behavior.** Northbound cyclists were observed squeezing between queuing vehicles and parked buses, which could be risky.

**Examples of Suggested Actions**

**Limited Access Signage.** Place a “No Right Turn, Except Buses” sign at the southeast corner of the intersection of North 6th Avenue and East Pennington Street. The sign should be located so that it is visible to traffic traveling northbound along North 6th Avenue.

**Diagrammatic Signage.** Consider replacing the overhead signs warning about the lane ending with a lane diagrammatic sign to more clearly communicate the lane geometry.

**Bus Bay Alignment.** Consider pulling the bus parking area back from the intersection of North 6th Avenue and East Pennington Street to provide better sight lines for pedestrians and approaching vehicles.

**Pavement Markings.** Consider shifting the shared lane markings along North 6th Avenue from the right edge to the center of the lane.



*Example of a shared-lane marking placed in the center of the lane (Photo credit: Dan Nabors).*

### Focus Area #3: North 6th Avenue and East Congress Street

#### Concerns/ Issues

**Unmarked Lanes.** The lane striping used along East Congress Street approaching North 6th Avenue does not clearly indicate that the curb lane is a bus only lane. This was noted as part of the general observations for the study.

**Limited Sight Distance.** Approximately 150 feet north of the intersection is a bus-only exit for the transit center. Exiting buses have poor sight lines of approaching traffic.

**Mid-block Pedestrian Crossings.** Pedestrians were observed crossing North 6th Avenue mid-block between East Congress Street and East Pennington Street. This area is planned for redevelopment, likely increasing pedestrian activity. There is currently no mid-block crossing here.



*Above: View looking south along North 6th Avenue from behind the stop bar at the bus exit (Photo credit: Dan Nabors).*



*Above: Bus only lane along East Congress Street uses broken lane markings with "Bus Only" and red curbpaint as opposed to the hatched pavement markings found along North 6th Avenue (Photo credit: Dan Nabors).*

#### Examples of Suggested Actions

**Pavement Markings.** Consider applying hatched pavements markings across the Bus Only lane along East Congress Street. Adding lane use markings at the intersection will also more clearly inform drivers of which lane they should be using.

**Turning Sight Distance Improvements.** Consider removing at least two parking spaces along North 6th Avenue just south of the exit from the transit center. This can be done on a temporary basis to identify how many spaces should be removed to improve sight lines for buses.

**Mid-block Pedestrian Crossing Improvements.** Consider adding a mid-block crossing on North 6th Avenue as part of the redevelopment of the transit center.



*Above: Suggested pavement marking changes along Congress Street (Map data: Microsoft® Bing™).*



*Above: Example of hatched pavement markings in bus only lane along North 6th Avenue (Photo credit: Dan Nabors).*

**Focus Area #4: East Broadway Boulevard and South 5th Avenue****Concerns/ Issues****Right Turning Vehicle and Streetcar Conflicts.**

Vehicles turning right from eastbound Broadway onto southbound South 5th Avenue from the through lane as the streetcar receives its advance signal have resulted in collisions. Additionally, vehicles attempting to turn right on red from northbound South 5th Avenue to eastbound East Broadway Boulevard while the streetcar/bus is stopped have poor sight lines of approaching traffic.

**Roadway Alignment.** Vehicles turning left from southbound South 5th Avenue to eastbound East Broadway Boulevard exit a single turn lane into multiple receiving lanes.

**Potential Left-Turn/Transit Conflicts.** The streetcar has a turnaround along South 5th Avenue that provides the ability to short-turn streetcars if there is an incident blocking the tracks further down the line. The tracks transition from the southbound through lane across the left-turn lane. If there is a left turning vehicle stopped at the stop bar it blocks the streetcar from advancing.

**Long Crossing Distance.** There was a higher number of crashes involving vehicles and pedestrians noted at this intersection. The crossing distance across the eastern leg of the intersection is wider, resulting in longer pedestrian crossing times.

**High Speed Traffic.** The additional travel lane on East Broadway Boulevard east of South 5th Avenue, and the change in building setbacks and heights results in vehicles increasing speed as they pass through the intersection. This change in speed impacts vehicles leaving downtown as they approach Aviation Highway.

**Driver Behavior.** Drivers were observed to use the streetcar/bus-only lane approaching the intersection from the west.

**Examples of Suggested Actions**

**Blackout Illuminated Signage.** Install an electronic “No Right Turn on Red” sign across East Broadway Boulevard and northbound South 5th Avenue that illuminates when the streetcar is stopped.

**Skip Lines.** Consider adding dotted line markings to extend the South 5th Avenue southbound left turn lane line markings through the intersection.



*Example of dotted line markings to extend the left-turn lane line markings into the intersection (Source: MUTCD).*

**Intersection Modifications.** Pull the stop bar back for the southbound left turn lane, and avoid adjusting the signal phasing to provide priority LEFT ARROW to the streetcar. Consider the possibility of an early GREEN priority.

**Sidewalk Extensions.** Bulb-out the southeast corner of the intersection to reduce the pedestrian crossing distance, add a short LPI and narrow the three travel lanes to two.

**Road Diet.** To address the long crossing distance, high speeds, and driver behavior, implement a road diet on Broadway from 5th Avenue to 4th Avenue. Reduce the street cross-section to include two general purpose lanes and a bus lane. The repurposed lane can be converted to provide parking, a bike lane, or an expanded sidewalk. This should include relocating the bus stop to the new curb line and pulling it back west from the intersection to improve sight lines. Additionally, the bike lane should be placed in between the new bus lane and the curb to further separate cyclists from the vehicular travel lanes and to avoid busses stopping in the bike lanes at transit stops.

**Enforcement.** Increase enforcement efforts at the end of the travel lane/beginning of the bus-only lane to encourage motorists to merge into the adjacent travel lane

### Focus Area #5: East Congress Street and 5th Avenue

#### Concerns/ Issues

**Stop Bar Placement.** The northbound left turn lane stop bar crosses the Sun Link tracks.

**Gaps in Streetcar Tracks.** There were incidents involving cyclists whose bike wheels became trapped in the tracks at the split in the streetcar tracks. Due to their smaller wheel size, it is more difficult for cyclists to traverse roadway elements that may not pose a hazard to other roadway users with larger wheels.



*Left turn lane stop bar currently crosses the streetcar tracks, blocking the streetcar if vehicles are pulled forward (Photo credit: Dan Nabors).*



*Streetcar track split can present challenges for bicycles attempting to turn left and cross over the multiple tracks (Photo credit: Dan Nabors).*

#### Examples of Suggested Actions

**Pavement Markings.** Shift the stop bar for the northbound left from South 5th Avenue back 25 feet.

**Bicycle Safety Measures.** Consider adding a two-stage left turn queue block for bikes turning left from East Congress Street onto South 5th Avenue so that cyclists can completely avoid crossing the tracks or cross them at a 90 degree angle, allowing them to cross without trapping their wheels in the tracks.



*Example of relocating the stop bar and providing a two-stage left turn queue box for cyclists (Photo credit: Dan Nabors; Map data: ©Google).*

## RSA #1 Conclusions

This Transit Access RSA focused on addressing some of the safety challenges related to transit use, particularly for pedestrians and cyclists, in the vicinity of Ronstadt Transit Center in Tucson, Arizona. The transit center is located in downtown Tucson, and is the area's busiest center in terms of bus activity. The transit center is also located along Tucson's streetcar line, which connects the University of Arizona to downtown and Mercado.

Crash data for the study area was provided by the City and included crashes for the past six years involving a bus, pedestrian, or bicyclist. This resulted in 76 total crashes, with the majority focused around the intersection of East Broadway Boulevard and South 5th Avenue. There were no serious injuries or fatalities reported.

The study area included many positive findings including: a quality transit system, strong multimodal culture, and numerous efforts to promote and revitalize the downtown area. Despite the many positive attributes observed, there were also some identified safety concerns. The study area is located in an urban setting with a high level of multimodal activity resulting in many interactions between motorized vehicles and pedestrians or bikes, and transit vehicles (both bus and streetcar) and all users. At some intersections, roadway geometry creates reduced sight distance, awkward turning angles, or long crossing distances. Some of the recommendations involve improving pedestrian crossings by extending the curb to shorten the crossing distance, or considering a leading pedestrian interval. Other improvements propose applying consistent pavement markings around the transit center to reduce confusion for all users. Changing the parking zones around the transit center would improve sight lines for both pedestrians, vehicles, and buses. Applying traffic calming measures to locations where the design currently cues drivers to speed up will improve conditions for pedestrians and cyclists. Lastly, pavement marking and signage improvements are proposed at specific locations to improve operations for the streetcar and bus.

Following this RSA, the City will need to work with its partner agencies (AZDOT, Sun Tran, and others) to identify those recommendations that are higher priority. The area around the transit center is planned for some significant changes in the future and the issues and countermeasures identified as part of this RSA should be considered as future development projects are proposed and designed. Tying improvements to other larger efforts, where feasible, will improve safety and convenience for all users and result in a more consistent and cohesive design.

## RSA CASE STUDY NO. 2— MAIN STREET CORRIDOR, SPRINGFIELD, OREGON

Project Overview	
Project Location:	Four locations: One urban area surrounding the Springfield Transit Center and three suburban areas, Main Street from 17th Street to 23rd Street, Main Street from 41st Street to 42nd Street, and Main Street from 54th Street to 58th Street.
Project Environment:	Suburban and Urban
Project Design Stage:	Existing roadway and planning stage
Project Owner(s):	City of Springfield, Oregon
RSA Overview	
Date of RSA:	April 13-14, 2016
RSA Stage(s):	Transit access RSA of existing roads and transit facilities
RSA Team:	Representatives from the City of Springfield, Lane Transit District (LTD), Oregon Department of Transportation (ODOT), and VHB.

### Project Background

In April 2016, the City of Springfield, Oregon, conducted a dual-focus Road Safety Audit (RSA) on the Main Street Corridor to look at locations with existing transit-related safety concerns and evaluate the impact of potential changes to the transit network. The City and the Lane Transit District (LTD) are currently undergoing planning efforts related to a possible extension to their Bus Rapid Transit (BRT) network that would extend BRT service from the Springfield Bus Terminal to the east along Main Street. Springfield was one of four cities selected for a Transit access RSA as part of the Mayor's Challenge, an initiative of the U.S. Department of Transportation to improve pedestrian and bicyclist safety in urban areas.<sup>21</sup>

<sup>21</sup> U.S. Department of Transportation. Mayor's Challenge for Safety People, Safer Streets. Available: <https://www.transportation.gov/mayors-challenge>.

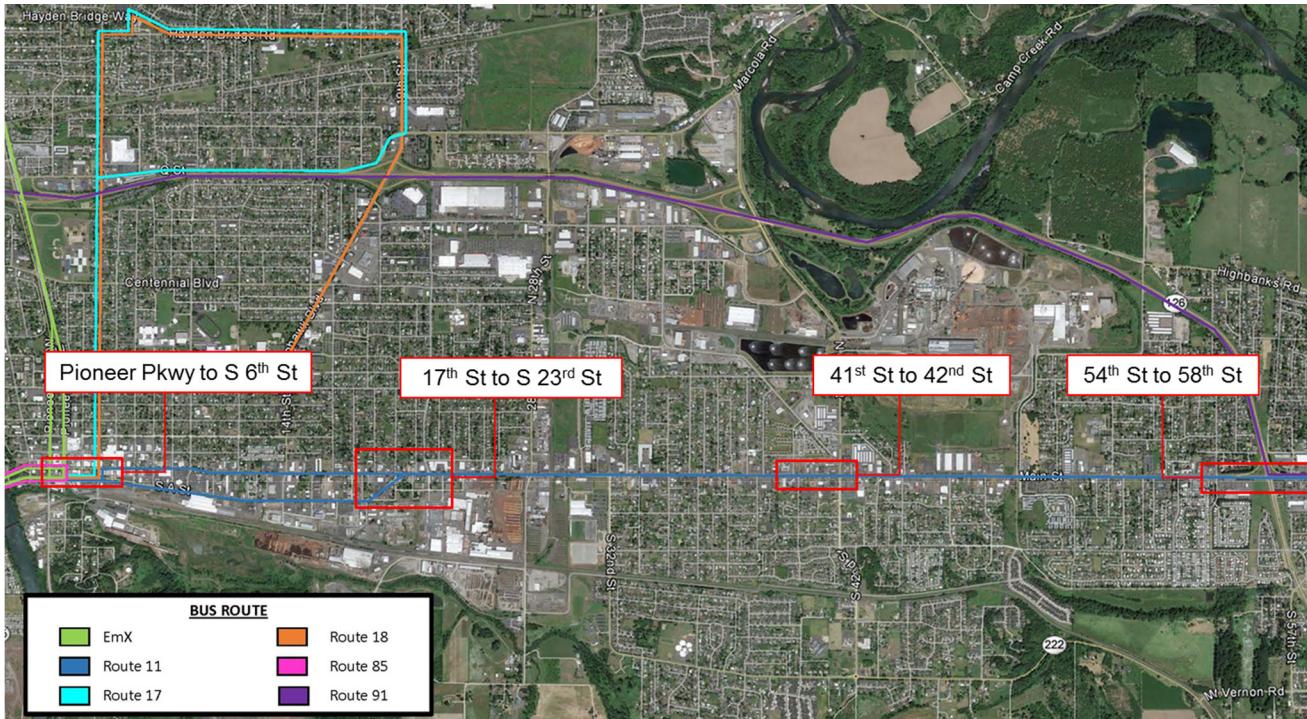


Figure A-2: State Route 7 Study Area (Source: ©Google Maps).

## RSA Overview

The RSA team reviewed an approximately 4.8-mile portion of Main Street and South A Street between Pioneer Parkway and 58th Street. As shown in Figure A-2, the RSA team identified four focus areas along Main Street based on one or more of the following factors: crash history, existing multimodal safety concerns, and proposed BRT routing and station locations. The four focus areas include the following:

- Focus Area 1: Main Street and South A Street from Pioneer Parkway to 5th Street.
- Focus Area 2: Main Street from 17th to 23rd Street.
- Focus Area 3: Main Street from 41st Street to 42nd Street.
- Focus Area 4: Main Street from 54th Street to 58th Street.

## Key RSA Findings and Suggestions

After completing the RSA field review, the RSA team developed a list of overarching and site specific issues as part of the RSA process.

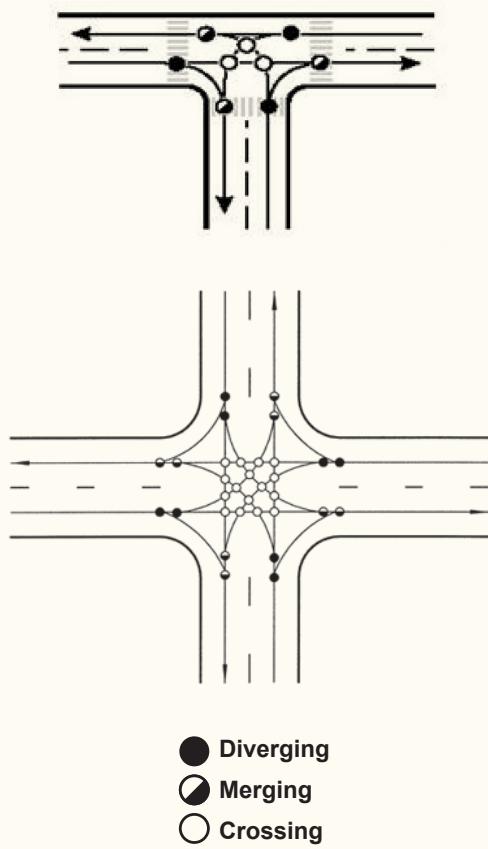
### Overarching Safety Issues, Main Street Corridor, Springfield, Oregon

Concerns / Issues	Examples of Suggested Actions
<p><b>ADA compliance and accommodations for older pedestrians.</b> The RSA team noted many instances where marked and unmarked crossings were not ADA compliant and were lacking ramps or detectable warning strips. It was also discussed that to the east of the downtown area, there is a large population of older and/or disabled individuals. It is important to ensure ADA compliance so that all individuals are able to access transit facilities.</p>	<p><b>Ensure that pedestrian routes and crossings are ADA compliant.</b> This is particularly important in areas with an aging population or populations with mobility challenges. The city should review pedestrian routes and develop or update a Transition Plan for addressing the necessary changes to bring the routes up to current ADA standards.</p>
	<p><b>Evaluate bus stop locations.</b> Continue evaluating bus stop locations and types – such as near-side or far-side, curb or bus-bay, etc. – based on crash risk and pedestrian desire lines and behavior. Review both crash records and LTD logged incidences.</p>
<p><b>Example of ramp at an unmarked crosswalk on Main Street (Photo credit: Elissa Goughnour).</b></p>	<p><b>Continue and enhance education efforts.</b> Many people may be unaware that unmarked crossings are legal crossings. However, according to the same FHWA study referenced above, “On multilane roads with traffic volumes greater than 12,000 vehicles per day, having a marked crosswalk was associated with a higher pedestrian crash rate (after controlling for other site factors) compared to an unmarked crosswalk.”<sup>2</sup> Education efforts can help education both drivers and pedestrians on pedestrian-related laws but also safe crossing techniques. Similarly, education efforts are needed to educate cyclists about wrong-way riding, sidewalk riding, and mid-block crossings.</p>
<p><b>Unmarked crossings and mid-block crossings.</b> The RSA team witnessed many pedestrians crossing at unmarked crossings or mid-block crossings. While unmarked crossings are legal crossing locations, drivers may not expect pedestrians to cross Main Street outside of the marked crosswalk locations due to the high speeds and wide crossing distance.</p>	<p><b>Bike lane maintenance.</b> Ensure that the bike lane is swept regularly and is free of debris. Also, during the next paving cycle, inspect to make sure there is a smooth transition between the pavement and gutter pan, so that cyclists can use the full width of the bike lane, and also to help ensure that the road drains properly and does not pool in the bike lane.</p>
<p><b>Bicyclist behavior.</b> The RSA team noted many instances of wrong-way and sidewalk riding despite the presence of bike lanes. Bicyclists may have a relatively low bike comfort level due to proximity to the travel lane, pavement quality, speed differential between bikes and the neighboring motor vehicles, debris in the bike lane, poor drainage, and the rough transition between the pavement and gutter pan.</p>	<p><b>Lighting.</b> Review/add lighting on eastern portion of corridor, particularly at intersections, transit stops, and certain pedestrian crossings. During the nighttime field review, the RSA team noted that while street lighting was present, these locations were either unlit or the lighting did not effectively light the area.</p>
<p><b>Lighting.</b> During dark conditions, it was difficult to identify pedestrian crossings, particularly on the eastern portion of the study area.</p>	

### Overarching Safety Issues, Main Street Corridor, Springfield, Oregon

#### Concerns/ Issues

**Corridor access.** There are many roadway access points, particularly on the eastern end of Main Street. A four-leg intersection has 32 conflict points and a three-leg intersection has nine conflict points. Each roadway access point (i.e. driveway, commercial entrance, etc.) has many potential conflict points which increase the crash risk for all roadway users. Additionally, with so many entrances into the roadway there are many opportunities for slower moving vehicles to enter or exit the roadway, leading to a speed differential with faster moving vehicles continuing straight along the road.



**Conflict points for three and four-leg intersections**  
(source: FHWA).

#### Examples of Suggested Actions



**A competition was used in Nevada for educational messaging. This image is one of the winners of the competition and was displayed at bus shelters (source: LasVegas NOW).**

**Continue to evaluate crossing locations.** The city should continue to review pedestrian crossing locations to evaluate whether a marked crosswalk is needed and if additional crossing countermeasures are necessary. During the RSA, the team witnessed many students crossing South A Street near the Academy of Arts and Academics, at the intersection of 6th Street and South A Street. If a marked crosswalk is added at this intersection, then additional crossing countermeasures should be considered, such as a Pedestrian Hybrid Beacon, RRFB, or reconfiguring the road to two lanes until after the intersection and installing curb extensions. Alternatively, the city could try to install measures to deter crossings at this location, such as using vegetation or fencing, and encouraging students to cross at the signalized intersection at 5th and South A Street.

### Overarching Safety Issues, Main Street Corridor, Springfield, Oregon

Concerns / Issues	Examples of Suggested Actions
<p><b>Lighting.</b> During the nighttime field review, the RSA team noted that while street lighting was present, certain intersections, transit stops, and pedestrian crossings were either unlit or the lighting did not effectively light the area.</p>	<p><b>Corridor access management.</b> There are two primary ways that corridor access management could be implemented throughout the study area. First by combining driveways and reducing the amount of entrances onto the roadway, thereby reducing the number of potential conflict points. Modifications to the number of access points could be accomplished during changes in land use and redevelopment.</p>
<p><b>Conflicts between right turning vehicles and pedestrian and bicyclists.</b> As indicated by the crash report descriptions and as witnessed during the field reviews, there are numerous conflicts between turning vehicles, particularly right turning vehicles, and crossing pedestrians and cyclists.</p>	<p><b>The second way is by reallocating space from wide travel lanes to provide buffered bike lane.</b> Currently, the widening of South A Street from two lanes to three lanes at 4th Street, and the lack of unsignalized intersections between 5th Street and Main Street, encourages faster speeds. Also, the wide cross-section and open feel on Main Street also encourages higher speeds. Reallocating space through a road diet could provide a variety of safety benefits along both roads.</p>
<p><b>Glare at dawn and dusk.</b> Main Street and South A Street are primarily oriented in an east-west direction. As a result, sun glare can reduce driver visibility, particularly their visibility of traffic signals. Signal backplates are a proven countermeasure to improve signal conspicuity and can assist drivers during periods of high glare such as at dawn and dusk.<sup>22</sup> As retroreflective backplates were present throughout the study area, the city should continue to investigate additional measures to mitigate this concern.</p>	<p><b>Pedestrian Crossing Measures.</b> Consider implementing measures to reduce conflicts between pedestrians and vehicles and/or reduce pedestrian crossing distance. In addition to the measures discussed, such as curb extensions, median refuge islands, and road diets, there are other measures to reduce risk for crossing pedestrians.</p>
<p><b>Rear-end collisions at bus stop locations.</b> The Lane Transit District noted that rear end collisions involving vehicles hitting stopped transit buses are relatively common. These crashes could be due to speed, distraction, or congestion.</p>	<p><b>Continued Countermeasure Education.</b> Several education efforts are underway regarding some of the new countermeasures, such as the rectangular rapid flash beacon. Those education measures should be continued to ensure that a broader audience is reached.</p>
<p><b>Lack of understanding of pedestrian crossing treatments.</b> Some members of the RSA team noted that they felt drivers were initially confused about how to respond to the rectangular rapid flash beacons on Main Street.</p>	
<p><b>High speeds on South A Street.</b> The RSA team noted that drivers seemed to travel at high speeds on South A Street, particularly after the road widens to three lanes east of the intersection with 5th Street.</p>	

## RSA #2 Conclusions

This Transit Access RSA focused on the Main Street corridor in Springfield, Oregon from Pioneer Parkway to 58th Street. The city and LTD are currently undergoing planning efforts related to a possible extension to their Bus Rapid Transit (BRT) network that would extend BRT service from the Springfield Bus Terminal to the east along Main Street. The purpose of this RSA was to investigate current safety concerns related to transit stops and access, and also possible changes associated with converting the bus routes to BRT.

<sup>22</sup> Federal Highway Administration. Field Guide for Inspecting Signalized Intersections to Reduce Red-Light Running. FHWA-SA-05-008. Available: [http://safety.fhwa.dot.gov/intersection/conventional/signalized/rllr/rllr\\_05fieldguide/](http://safety.fhwa.dot.gov/intersection/conventional/signalized/rllr/rllr_05fieldguide/).

There were several positive features including coordination between agencies, proactive efforts to address safety through transit stop location, installation of pedestrian crossing measures, lighting and sign clutter studies. LTD has also worked to provide attractive transit stop amenities with seating and transit shelters.

Many of the safety concerns at each of the focus areas were common to the entire study area. Some of the safety concerns included ADA compliance and accommodations for older pedestrians, unmarked and mid-block crossings, motorists yielding behavior to crossing pedestrians and bicycles, bicyclist riding behavior, and numerous roadway access points.

Some of the identified countermeasures include reviewing accessible routes to transit facilities develop a plan for ADA compliance; implementing corridor access management and a road diet; increase visibility of pedestrian crossings through high visibility crosswalks, LPI, and intersection signage; also increasing pedestrian and bicycle education.

## RSA CASE STUDY NO. 3—ORLANDO, FLORIDA

Project Overview	
Project Location:	Urban intersections with approximately 16 transit stops and two super stops. The study area includes the Florida Mall and surrounding area, including the highest use transit Super Stop.
Project Environment:	Suburban and Urban
Project Design Stage:	Existing roadway
Project Owner(s):	Florida Department of Transportation (FDOT)
RSA Overview	
Date of RSA:	May 23-24, 2016
RSA Stage(s):	Transit access RSA of existing roads and transit facilities
RSA Team:	Representatives from Orange County, Central Florida Regional Transportation Authority, MetroPlan Orlando, Orange County Neighborhood Preservations & Revitalization, the Florida Department of Transportation, and VHB.

### Project Background

Nationally, pedestrian fatalities rose in 2015 by 9.5 percent, despite a decrease in the number of motor vehicle crash fatalities on US roadways during the same period according to the National Highway Traffic Safety Administration<sup>23</sup>. Pedestrian fatalities accounted for over fifteen percent of total motor vehicle fatalities nationwide during the same year.

In Florida, there were 628 pedestrian and bicyclist fatalities in 2015, making up almost twelve percent of the nationwide total. In order to address non-motorized fatalities and injuries, agencies throughout Florida have made a concerted effort to focus on pedestrian and bicycle safety. In May 2016, Orange County and the Central Florida Regional Transportation Authority (LYNX), with assistance from the Florida Department of Transportation (FDOT) and MetroPlan Orlando, conducted a Transit Road Safety Audit (RSA) to proactively address safety at transit stops throughout Orange County, FL within the Orlando metropolitan area. Orange County was one of four communities selected for Transit access RSA assistance as part of the Mayor’s Challenge, an initiative of the U.S. Department of Transportation to improve pedestrian and bicyclist safety in urban areas.

### RSA Overview

The RSA conducted reviews of the following three study areas:

- Focus Area 1: West Colonial Drive & North Pine Hills Road.
- Focus Area 2: Econlockhatchee Trail & Valencia College Lane.
- Focus Area 3: Florida Mall (specifically the intersections of West Sand Lake Road & South Orange Blossom Trail and Summer Day Lane & West Sand Lake Road).

<sup>23</sup> National Highway Traffic Safety Administration. Facility Analysis Reporting System (FARS). Available: <http://www-fars.nhtsa.dot.gov/Main/index.aspx>.

As shown in Figure A-3, the study areas are all located within unincorporated Orange County in the Orlando metropolitan area. The three focus areas were identified based on potential risk due to exposure and transit stops with the highest ridership, leading to high pedestrian and bike activity.

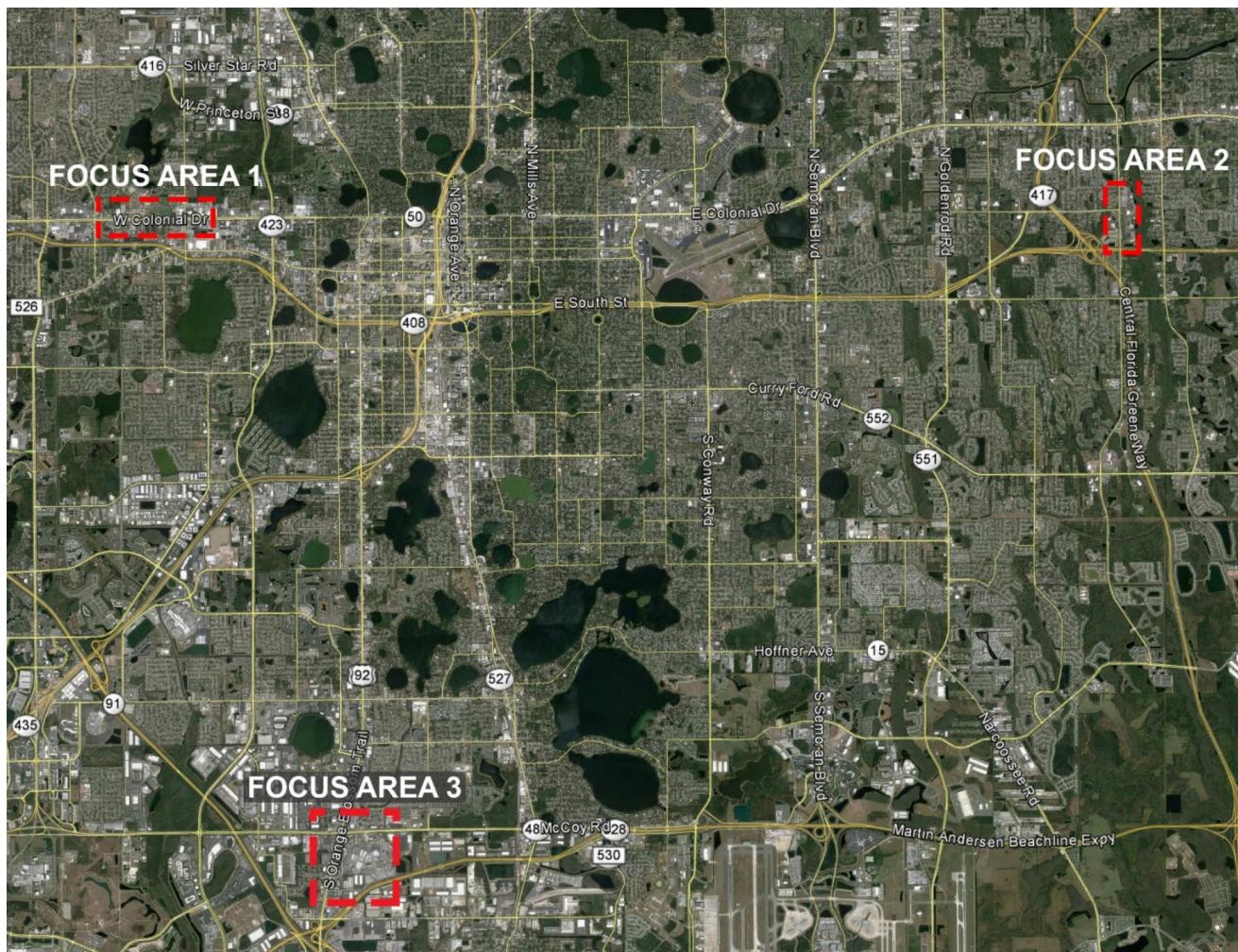


Figure A- 3. Transit Access RSA focus areas in the greater Orlando metropolitan area (Map data: ©Google).

## Key RSA Findings and Suggestions

After completing the RSA field review, the RSA team developed a list of overarching and site specific issues as part of the RSA process.

Overarching Safety Issues, Orlando, Florida	
Concerns/ Issues	Examples of Suggested Actions
<p><b>Bicyclist behavior.</b> The RSA team noted many instances of wrong-way and sidewalk riding. This could be attributed to a relatively low bike comfort level from the proximity to travel lane as none of the bike lanes were buffered, speed differential between cyclists and motorists, and maintenance/debris.</p> <p><b>Pedestrian crossing behavior.</b> Throughout the focus areas, the RSA team noted pedestrians crossing mid-block on wide multi-lane roadways. Mid-block crossings were also a source of pedestrian crashes – four of the study area crashes involved pedestrians crossing mid-block and two of those resulted in fatalities. Some members of the RSA team received feedback that pedestrians feel unsafe crossing at the intersections and so would rather cross away from it.</p> <p><b>Conflicts between right turning vehicles and pedestrians/bikes.</b> There were numerous conflicts between turning vehicles and bicyclists and pedestrians. The RSA team viewed vehicles disregarding crossing pedestrians and cyclists during both the green phase and while making right-turns on red.</p> <p><b>Pavement Markings.</b> There were several instances where pavement markings could be improved to help provide additional positive guidance to roadway users. There was a gap in pavement markings on West Colonial Drive that appeared to be related to recent paving as the pavement markings not being applied all the way to the paving join. On West Colonial Drive, there was a lack of cyclist and arrow pavement markings to denote the space as a bike lane versus a shoulder. Bike lanes were dashed at most driveways instead of just at the intersections, which could indicate a lower level of caution for drivers pulling out of driveways. The buffer was provided between the bike lanes and the curbs, rather than the bike lane and through lane where it could be used to provide additional separation between modes. Some of the crosswalk pavement markings were faded.</p>	<p><b>Education.</b> Provide education targeting pedestrians and cyclists. Education should be provided on the risks associated with sidewalk riding, mid-block crossing safety and bicycle laws.</p> <p><b>Bicycle and pedestrian facility evaluation.</b> Evaluate placement of bicycle and pedestrian facilities to ensure that they are located on desirable routes and that they are ADA complaint. For example, ensure that bicycle facilities are located where they provide access to attractions and also are locateddesigned so that bicyclists will feel comfortable using them. Route evaluation is of particular concern in relation to transit stops so that riders have access to the stop and to nearby destinations.</p> <p><b>Improve pavement markings.</b> Extend all roadway pavement markings on West Colonial Drive so that they are continuous and start at the paving joint. Reapply faded pavement markings and install crosswalks on all legs of the intersections as necessary to provide access between transit stops. Modify bicycle lane pavement markings on West Colonial Drive so that the buffer is located in between the bike lane and the travel lane. Provide solid bike lane edgelines at driveway entrances, and place additional cyclist and arrow pavement markings so that drivers do not confuse the bike lane with a shoulder or additional travel lane.</p>

**Focus Area #1: West Colonial Drive and North Pine Hills Road**

Concerns/ Issues	Examples of Suggested Actions
<p><b>Drivers using bike lane and buffer as a right turn lane.</b> The RSA team watched drivers on the westbound approach encroach on the bicycle lane and use it as a right turn lane. Additionally, there were conflicts between vehicles turning right from the bike lane and vehicles turning right from the travel lane.</p>	<p><b>Increased separation of modes at the intersection.</b> Along this corridor, the bicycle lane buffer was provided between the bike lane and the curb. If the buffer was moved to the other side, it would provide bicyclists additional space from motorized vehicles. Additionally, at the intersection, a physical barrier could be used to prevent vehicles from using this space as a turn lane.</p>
<p><b>Lack of yielding to pedestrians and bikes in crosswalk.</b> As was apparent by the crash reports and time spent in the field, many right-turning drivers did not yield to pedestrian and cyclists crossing at the intersection.</p>	<p><b>Modify signal operations.</b> Consider signal options to reduce the potential for conflict between right-turning vehicles and pedestrians/cyclists. Implementing a leading pedestrian interval (LPI) would allow pedestrians and cyclists crossing at the intersection to begin crossing before motorized vehicles, making them more visible to motorists. Additionally, the complimentary measure of restricting right-turns by installing a no-right-turn-on-red sign would increase the effectiveness of the LPI and would further reduce potential conflicts.</p>
<p><b>Bus stop placement.</b> Bus stops at this location were placed away from the intersection due to signal spacing. If a transit rider needed to cross the road, quite often they would try to cross mid-block.</p>	<p><b>Review transit stop placement and accessible routes.</b> Review transit stop placement to ensure that stops are in desirable locations and encourage crossing at protected locations. Also, evaluate the routes to access these stops and create a plan to bring those routes up to current ADA standards through the ongoing implementation of the County's adopted ADA Transition Plan.</p>
<p><b>Lack of accessible routes to transit stops.</b> The routes leading to transit stops near this intersection were not ADA compliant. Despite the presence of a sidewalk, it was difficult to access some of the transit stops as the RSA team noted vegetation and debris blocking the sidewalk and non-ADA compliant ramps.</p>	<p><b>Crossing pavement markings.</b> In order to encourage pedestrians and cyclists to cross at the intersection, pedestrian and bicycle facilities need to be enhanced to provide more direct access between destinations, to improve awareness and visibility of pedestrian and bicycle crossings. Install high-visibility crosswalks on all legs of the intersection and consider using colored pavement markings in bike lanes through the intersection.</p>
<p><b>Pedestrian behavior.</b> As mentioned in the overarching issues, pedestrians throughout the study area were crossing mid-block on high-speed multi-lane arterials rather than at controlled intersection crossings.</p>	<p><b>Corridor access management.</b> Build upon the existing corridor access management measures of the landscaped median by reducing the frequency of driveway access. On the northeast corner of the intersection, there are four driveway access locations. The driveways could be condensed down to two, which would reduce the crash risk and provide space to move the transit stop closer to the intersection.</p>
<p><b>Bicycle lane pavement markings.</b> There was also a lack of cyclist and arrow pavement markings in the bike lanes on West Colonial Drive. Additionally, it was noted that the bike lane pavement markings were dashed at driveway entrances.</p>	<p><b>Debris and vegetation growth.</b> Sidewalks and roadway should be inspected to ensure they are free of debris and clear for cyclist and pedestrian use. Vegetation should also be trimmed and maintained in order to improve sight distance and user ability of sidewalks and bike lanes.</p>
<p><b>Large number of driveway entrances in close proximity.</b> The more driveway entrances along a corridor, the higher the number of potential conflict points and risk for a crash for motorized and non-motorized vehicles alike. Additionally, the high frequency of driveways can pose issues when trying to place transit stops.</p>	
<p><b>Debris on road.</b> Debris on the road and sidewalks can be difficult for cyclists to avoid or maintain traction.</p>	

**Focus Area #2: Econlockhatchee Trail and Valencia College Lane****Concerns/ Issues****Examples of Suggested Actions**

**Continuous right turn lane.** Northbound on Econlockhatchee Trail, there is a continuous right turn lane. The turn lane is effectively 1,700 feet long on Econ Trail. As this long continuous lane is located on the right side of the bike lane there is the potential for cyclists to have faster moving motorized vehicles on both the right and left side.

**Long crossing distance on Econlockhatchee Trail.** Pedestrians and cyclists have a long crossing distance on Econlockhatchee Trail. The wide roadway promotes higher vehicle speeds and with large crossing distances, non-motorized users are at a higher risk of conflict with motorized vehicles.

**Large intersection radii.** The large corner radii at the intersection of Econlockhatchee Trail and Valencia College Lane encourage higher speed turning movements and higher risk conflicts with crossing pedestrians and cyclists.

**Stop bar placement and sight distance.** The stop bar on the westbound intersection approach, for vehicles leaving the college, is placed too far back for adequate sight distance.

**Lighting.** The northern portion of this focus area is well-lit with new LED street lights. However, south of Valencia College, the street lights are discontinued. It may be difficult for driver's eyes to adjust to the change in lighting during dark conditions, which can pose a higher risk to cyclists in the bike lanes at risk.

**Reallocate space.** Better define the necessary length for the right turn lanes providing access to the Valencia College property. Consider using the remaining space to provide a buffer to the bike lane.

**Reduce crossing distance.** Investigate opportunities to reduce crossing distances through reducing curb radii and installing curb extensions/islands.

**Modify stop bar placement.** Modify stop bar placement on the westbound approach to ensure adequate sight distance.

**Add/modify street lighting.** Investigate the potential for continuing street lighting to the south on Econlockhatchee Trail.

**Focus Area #3: Florida Mall Area****Concerns/ Issues**

**Right slip lane/island design.** The design of islands at the intersection of Orange Blossom Trail and West Sand Lake Road have large radii that promote high-speed right turns. This presents a risk to pedestrians crossing from the island over to the intersection corner and for vehicles merging from the right turn lane turns into the through lanes.

**Lack of warning/visibility of pedestrian crossings.** There were no signs (in advance or at the crosswalk) warning motorists of the pedestrian crossings in the northbound and southbound directions. Additionally, at the southeast corner and the northwest corners it is difficult to see waiting/crossing pedestrians.

**Lack of pedestrian accommodations at Sand Lake Road and Summer Day Lane.** There are no pedestrian accommodations (pedestrian signal and pavement markings) along western leg of Sand Lake Road and Summer Day Lane. The RSA team witnessed many pedestrians crossing along this leg of the intersection in order to travel from the mall over to the transit stop on the north side of Sand Lake Road.

**Confusion at Florida Mall Ave intersections and wide crossings.** A LYNX Super-Stop is located on Florida Mall Avenue between Sun Life Path and August Lane. At the intersection with August Lane and Florida Mall Avenue many motorists were confused about who had the right-of-way. The intersection is two-way stop controlled with stop signs on Florida Mall Avenue as are three other mall entrances. There is only one entrance that is four-way stop-controlled.

**Examples of Suggested Actions**

**Modify right slip lane/island design.** Evaluate the potential to redesign the right slip lane islands to provide right turning vehicles with a better view of crossing pedestrians, cyclists, and on-coming vehicles.

**Provide better visibility and warning of crossing pedestrians.** Ensure that drivers approaching the intersection have an unobstructed view of waiting pedestrians. Also due to the high speeds of right turning vehicles, provide pedestrian warning signs in advance of the intersection (W11-2) and on both sides of the crosswalk (W11-2 and W16-7P).



**W11-2 and W16-7P (Source: MUTCD).**

**Florida Mall Avenue intersection improvements.** With the pedestrian activity accessing the mall and Super-Stop, the intersections should incorporate elements to help reduce crossing distances, such as curb extensions and median refuge islands. With the confusion among drivers about right of way, additional wayfinding signs could provide additional guidance to drivers. Another option could include investigating alternate intersection designs. A roundabout would facilitate pedestrian crossings, reduce potential conflicts within the intersection, and improve traffic flow in and out of the mall.

**Accessible routes.** Work with business owners to encourage and determine the feasibility of adding accessible paths to their businesses. A separate pathway would provide direct access for pedestrians rather than requiring them to use the driveway alongside motorized vehicles.

### Focus Area #3: Florida Mall Area (cont.)

#### Concerns / Issues

**Long crossing distances.** At the August Lane and Florida Mall Avenue intersection, pedestrians traveling to and from the mall and the Super-Stop have long crossing distances ranging from approximately 90 to 100 feet.

**Lack of accessible paths from bus stop to neighboring destinations.** There were pathways worn into the grass, indicating the path that pedestrians travel from the transit stop to neighboring destinations.



**Pathway leading to the shopping center on the northwest corner of West Sand Lake Drive and Summer Day Lane intersection (Photo credit: Elissa Goughnour).**

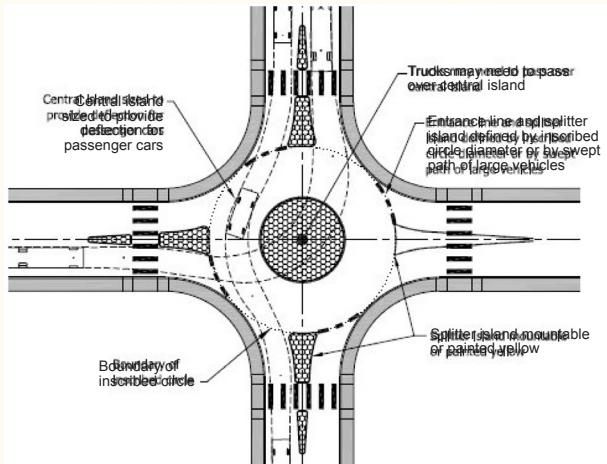


**A wheelchair user accessing the same shopping center by using the driveway (Photo credit: Elissa Goughnour).**

#### Examples of Suggested Actions



**Alternative intersection design option. Mini-roundabout intersection conceptual diagram (Map data: ©Google).**



**Mini-roundabout diagram (Source: FHWA).**

## RSA #3 Conclusions

This Transit Access RSA focused on three locations in unincorporated Orange County within the Orlando, Florida, metropolitan area. Orange County and LYNX have been working to improve safety for transit users and used this RSA to investigate transit stops with the highest ridership where safety has not been recently addressed through other projects. The purpose of this RSA was to investigate current safety concerns related to non-motorized access to transit stops.

There were several positive features, including coordination between agencies, proactive efforts to address safety, incorporating/adopting Complete Streets measures, dedicated bicycle and pedestrian facilities, and the presence of corridor access management measures. LYNX has also worked to provide attractive transit stop amenities including seating, trash receptacles, and lighted shelters.

There were some area-wide safety concerns present, such as the conflicts between turning vehicles and crossing pedestrians and cyclists and mid-block crossings. Some of the issues at each of the specific focus areas included wide crossings, transit stop location, high driveway density, ADA compliance, and lack of pedestrian crossing treatments.

Some of the identified countermeasures include reviewing accessible routes to transit facilities and developing a plan for ADA compliance, implementing corridor access management measures, reallocating space to narrow crossings and provide buffered bicycle lanes, and providing pedestrian crossing measures.

## RSA CASE STUDY NO. 4— ASHEVILLE, NORTH CAROLINA

Project Overview	
Project Location:	Four locations: One urban area surrounding the Springfield Transit Center and three suburban areas, Main Street from 17th Street to 23rd Street, Main Street from 41st Street to 42nd Street, and Main Street from 54th Street to 58th Street.
Project Environment:	Suburban and Urban
Project Design Stage:	Existing roadway
Project Owner(s):	City of Asheville, North Carolina and North Carolina Department of Transportation (NCDOT)
RSA Overview	
Date of RSA:	August 2-4, 2016
RSA Stage(s):	Transit access RSA of existing roads and transit facilities
RSA Team:	Representatives from the City of Asheville Planning, Transportation, Transit, and Special Projects, Asheville Police, North Carolina Department of Transportation, Accessible Design for the Blind, and VHB.

### Project Background

The purpose of this study was to complete a Transit Access RSA in Asheville, North Carolina. Asheville is one of four cities selected for RSA assistance as part of the Mayor’s Challenge, and initiative from the Department of Transportation Secretary to improve pedestrian and bicyclist safety in urban areas.<sup>24</sup> The City of Asheville wanted to conduct an RSA to document some of the challenges to transit stop access.

### RSA Overview

The subject intersections are all located on the Patton Avenue corridor, which runs from downtown Asheville due west until it merges with Smokey Park Highway, see Figure A- 4. Patton Avenue is a major corridor for the area with multiple commercial businesses along the perimeter. The study area varies from urban to suburban and starts at the intersection with Coxe Avenue and ends west at the intersection with Haywood Road. The RSA team identified five transit stops along Patton Avenue based on one or more of the following factors: crash history, existing multimodal safety concerns, intersection design, and pedestrian and bike usage. The study areas include the following:

- Study Area 1: Patton Avenue from Coxe Avenue to Asheland Avenue.
- Study Area 2: Patton Avenue and Pearl Street.
- Study Area 3: Patton Avenue and Florida Avenue.
- Study Area 4: Patton Avenue and New Leicester Highway.
- Study Area 5: Patton Avenue and Haywood Road.

<sup>24</sup> U.S. Department of Transportation. Mayor’s Challenge for Safety People, Safer Streets. Available: <https://www.transportation.gov/mayors-challenge>.

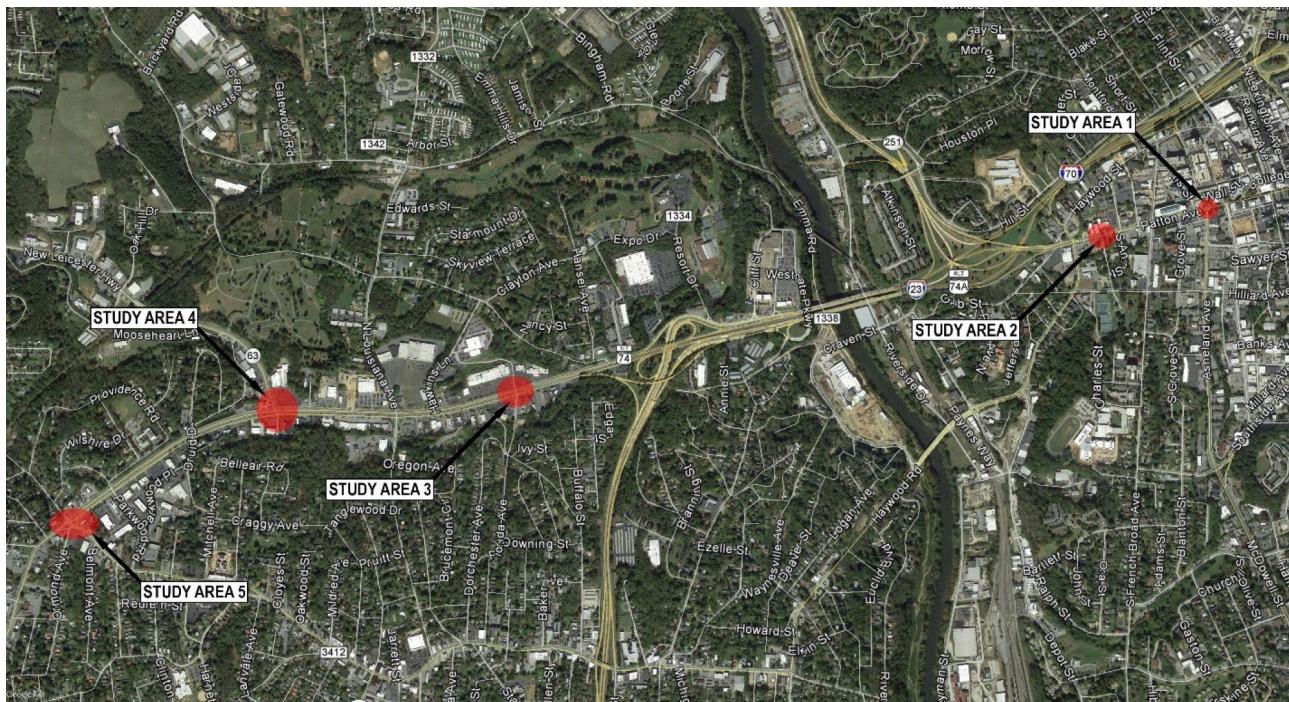


Figure A- 4. Transit Access RSA study areas for Asheville, North Carolina (Map data: ©Google).

## Key RSA Findings and Suggestions

After completing the RSA field review, the RSA team developed a list of overarching and site specific issues as part of the RSA process.

### Detailed Issues: Downtown Asheville, Patton Avenue from Coxe Avenue to Asheland Avenue and Patton Avenue at Pearl Street

Concerns/ Issues	Examples of Suggested Actions
<p><b>Pedestrian signal phasing.</b> The RSA team noted that pedestrian behavior, when waiting for the appropriate phase to cross, has reduced compliance due to longer wait times. Also noted that pedestrian phasing coincides with traffic signal phasing creating a greater chance of conflict areas between a pedestrians and vehicles turning onto Patton Avenue.</p>	<p><b>Pedestrian Crossing Measures.</b> The City should review signal timing and ability for pedestrians to call the signal during non-peak hours by using the push button. Additionally, use pedestrian counts to determine if certain intersections warrant modified pedestrian phases.</p>
<p><b>Unmarked crossings and mid-block crossings.</b> The RSA team witnessed many pedestrians crossing at unmarked crossings, mid-block crossings, and/or crossing against the pedestrian signal. While unmarked crossings are legal crossing locations, drivers may not expect pedestrians to cross Main Street outside of the marked crosswalk locations due to the high speeds and wide crossing distance.</p>	<p><b>Continue and enhance education efforts.</b> Many people may be unaware that unmarked crossings are legal crossings. Education efforts can help educate both drivers and pedestrians on pedestrian-related laws but also safe crossing techniques. Similarly, efforts are needed to educate cyclists about wrong-way riding, sidewalk riding, and mid-block crossings.</p>
<p><b>Driver speed and yield behavior.</b> The RSA team noted driver behavior when approaching an intersection with a pedestrian present, that little or no attempt was made to yield to pedestrians. In addition, driver speeds were higher than the posted speed limit of 20 mph.</p>	<p><b>Speed reduction through road diet.</b> Road diets are a FHWA proven safety countermeasure that reallocate space from travel lanes to provide safety improvements such as two-way left-turn lanes, medians, or dedicated space for bicycles and pedestrians.<sup>25</sup> The primary goals of a road diet are, “Enhanced safety, mobility and access for all road users and a “complete streets” environment to accommodate a variety of transportation modes.”<sup>26</sup> Currently, the wide four-lane undivided roadway on Patton Avenue encourages higher speeds. Reallocating space through a road diet could provide a variety of safety benefits along the corridor.</p>



*Image shows an example of pedestrians crossing outside of the crosswalk (Photo credit: Elissa Goughnour).*

<sup>25</sup> Federal Highway Administration. Proven Safety Countermeasures. Available: <http://safety.fhwa.dot.gov/provencountermeasures/>.

<sup>26</sup> Federal Highway Administration. Road Diets (Roadway Reconfiguration). Available: [http://safety.fhwa.dot.gov/road\\_diets/](http://safety.fhwa.dot.gov/road_diets/).

**Detailed Issues: Downtown Asheville, Patton Avenue from Coxe Avenue to Asheland Avenue and Patton Avenue at Pearl Street (cont.)**

Concerns/ Issues	Examples of Suggested Actions
<p><b>ADA compliance.</b> The RSA team noted many instances where marked and unmarked crossings were not ADA compliant and were lacking ramps or detectable warning strips. It is important to ensure ADA compliance so that all individuals are able to access transit facilities.</p> <p><b>Intersection Lighting.</b> The nighttime field review identified reduced lighting at the intersections due to increased foliage. In some instances, street lights were out as well as reduced lighting from traditional bulbs when compared to LED lighting present in other parts of the corridor.</p>  <p><i>Image shows reduced lighting at the intersection of Patton and Asheland Avenues. The intersecting road (Asheland Avenue) is highlighted within the red box, and is not visible to drivers due to reduced intersection street lighting (Photo credit: Elissa Goughnour).</i></p>	<p><b>Ensure ADA compliance.</b> Continue evaluating transit stops locations and pedestrian access to transit facilities. Ensure compliance with ADA access requirements for bus boarding and alighting areas.<sup>27</sup> Work with business owners to develop a plan for implementing measures, such as installing ramps, if features prohibit installation by the city and state (such as underground vaults in the downtown area of Asheville).</p> <p><b>Lighting.</b> Review/add lighting at intersections, transit stops, and certain pedestrian crossings. During the nighttime review, the RSA team noted that LED lighting on Asheland Avenue is obscured by an overgrown tree, which should be trimmed to maximize lighting. The downtown corridor of Patton Avenue utilizes older yellow street lighting that is not as effective as LED lighting. The city should consider replacing or retrofitting the existing lighting with LED lights, in addition to replacing bulbs that are burnt out to ensure proper lighting on the corridor.</p>

<sup>27</sup> US Department of Justice, Civil Rights Division. 2010 ADA Standards for Accessibility Design. Available: <https://www.ada.govregs2010/2010ADASTandards/2010ADASTandards.htm>

**Detailed Issues: Suburban Asheville, Patton Avenue at Florida Avenue, Patton Avenue at New Leicester Highway, and Patton Avenue at Haywood Road**

**Concerns/ Issues**

**Pedestrian crossing widths.** Patton Avenue expands from two lanes to three lanes in each direction with additional turn lanes at each intersection. This creates a greater crossing width for pedestrians, increasing time needed to safely navigate across.

**Yielding behavior of right turning vehicles.** During the field review the RSA team witnessed numerous instances where turning vehicles, particularly those turning right, did not yield to crossing pedestrians and cyclists.

**Lack of crosswalks and pedestrian signals/pedestrian phasing.** None of the intersections analyzed by the RSA team, outside the downtown area, have crosswalks or pedestrian signals. It can be difficult for pedestrians and cyclists crossing in the unmarked crosswalk, to know when to cross and at times. With split phasing, pedestrians could end up in the middle of the roadway when the signal phase changes. Additionally, the yielding rate for turning vehicles to pedestrians was low. Even while wearing vests, the RSA team noticed many drivers who did not yield to crossing RSA team members.

**Vegetation growth.** In several locations the vegetation was overgrown, encroaching on the sidewalk and obscuring sight distance for drivers.

**Obscured crosswalk visibility.** The RSA team identified two specific locations where pedestrians are not visible to drivers when attempting to cross. The first location is at the southeast corner of Haywood Road and Patton Avenue. A marked crosswalk is located in the middle of the right-turn slip lane. Drivers turning right from Haywood Road onto Patton Avenue cannot see waiting/crossing pedestrians due to the location of street trees and vehicles parked on the periphery of the dry cleaning parking lot.

**Connectivity of accessible routes to transit stops.** The RSA team noted that transit stops in several locations do not have adequate accessible routes. In particular, the intersection of Patton Avenue with Haywood Road has a refuge island with no pedestrian access. The island acts as a barrier for pedestrians to navigate across Haywood Road.

**Examples of Suggested Actions**

**Pedestrian crossing measures.** Crosswalks and pedestrian signals should be installed at all legs of the study area intersections due to the amount of pedestrian activity and location of transit stops and transit rider destinations. This is particularly important in locations with wide roadway crossings that are more difficult for pedestrians to cross. For multilane (four or more lanes) roadways with a raised median and an AADT greater than 15 thousand, marked crosswalks should be combined with other pedestrian facility enhancements, such as pedestrian signals.

**Modify intersection geometry.** Consider changing the geometry of the intersection of Patton Avenue with Haywood Road. The road currently functions as a five-leg intersection with Ormond Avenue connecting in the middle of the right turn slip lane on the southwest corner. Intersecting at this location can result in confusion among drivers and the potential for high speed conflicts due to the large intersection radii and combination of traffic controls, including the traffic signal, a one-way stop on Ormond Avenue, and a yield where the right turn and Ormond Avenue combines with Haywood Road.

**Vegetation growth.** Vegetation should be trimmed and maintained in order to improve the sight distance, such as at the intersection of Patton Avenue and Haywood Road and at the intersection of Patton and Florida Avenues.

**Accessible routes.** Connectivity of accessible routes to transit stops is essential when evaluating transit rider safety. Consider reviewing transit rider origins and destinations and evaluating accessible routes in those areas. During the RSA, it was clear that pedestrians are in need of an accessible route along the southern side of Patton Avenue at the intersection with Haywood Road. Additionally, it is also important to work with business and property owners to evaluate the possibility of adding accessible routes to their properties. Even if an accessible route is provided along the road, transit riders still need to access destinations.

**Detailed Issues: Suburban Asheville, Patton Avenue at Florida Avenue, Patton Avenue at New Leicester Highway, and Patton Avenue at Haywood Road (cont.)**

Concerns/ Issues	Examples of Suggested Actions
<p><b>High turning volumes at New Leicester Highway.</b> The RSA team noted high right turn volumes from Patton Avenue to New Leicester Highway and high left turning volumes from New Leicester Highway onto Patton Avenue. On average, approximately half the volume on Patton Avenue originates from or turns onto New Leicester Highway. These high turning volumes have resulted in long vehicle queues and subsequent crashes just north of the intersection from northbound vehicles attempting to turn left into parking lots and intersecting roads.</p>	<p><b>Corridor access management.</b> Throughout this portion of the study area, Patton Avenue had a high number of access points, thereby increasing the crash risk for all road users. Between New Leicester Highway and Florida Avenue, the majority of the access points were on the southern side of Patton Avenue. Corridor access management can be implemented by combining driveways and reducing the amount of entrances onto the roadway, thereby reducing the number of potential conflict points. Modifications to the number of access points could be accomplished during changes in land use and redevelopment, such as the redevelopment planned for the southwest corner of Patton and Florida Avenue.</p>
<p>The high turning volumes and intersection crashes have made it necessary for NCDOT to look at alternate methods to accommodate traffic, such as adding in additional turn lanes, which in turns lengthens the pedestrian crossing distance. Additionally, the heavy turning movements with multiple turn lanes can pose a multiple threat to crossing pedestrians where one vehicle may stop but the vehicle in the next lane may not.</p>	<p><b>Drainage on Patton Avenue.</b> Roadway drainage facilities should be inspected to ensure they are free of debris and operating properly. NCDOT is already reviewing stormwater management plans and flood plain analysis for the Patton Avenue corridor to determine implications for future drainage improvements.</p>
<p><b>Numerous roadway conflict points.</b> There are many roadway conflict points, particularly on the southwest corner of Patton Avenue and Haywood Road, where Ormond Avenue intersects the channelized right-turn lane. Additionally, there are many roadway access points on Patton Avenue spread throughout the corridor. A four-leg intersection has 32 conflict points and a three-leg intersection has nine conflict points.</p>	
<p><b>Drainage on Patton Avenue.</b> During the RSA field review the team witnessed large amounts of pooling water on Patton Avenue, likely due to poor drainage.</p>	

## RSA #4 Conclusions

This Transit Access RSA focused on five locations in Asheville, North Carolina. The city of Asheville and NCDOT have been working to improve safety for transit users and used this RSA to investigate transit stop rider safety on a primary corridor through the city. The purpose of this RSA was to investigate current safety concerns related to non-motorized access to transit stops.

There were several positive features, including coordination between agencies, proactive efforts to address transit stop safety, and upgraded pavement markings and street lighting. There were two distinct area types in the RSA study area; a downtown area and a more suburban area. The first three focus areas were in the downtown area. Some of the specific issues in this area included ADA compliance, turning vehicle yielding behavior, and pedestrian mid-block crossings. Some of the potential countermeasures included improving ADA compliance, implementing a road diet, and pedestrian crossing measures such as the LPI.

The remaining three focus areas were in a more suburban area west of the downtown area. Some of the specific issues in this area included lack of pedestrian crossing measures, vehicular speeds, numerous access points, and yielding behavior of right turning vehicles. Some of the potential countermeasures included corridor access management, modifying intersection geometry, and implementing a variety of pedestrian crossing measures.





