Final Report

INTEGRATING TRANSIT INTO TRADITIONAL NEIGHBORHOOD DESIGN POLICIES - THE INFLUENCE OF LANE WIDTH ON BUS SAFETY

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Integrating Transit into Traditional Neighborhood Design Policies - The Influence of Lane Width on Bus Safety

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16. Abstract

Recently, there has been a move to use complete streets principles in promoting livable communities and traditional neighborhood design (TND) to encourage non-motorized modes of transportation and multimodalism. One of the measures that is being adopted to encourage pedestrian oriented design is the reduction of vehicular lane width from a conventional 12 feet to as narrow as 9 feet. The reduction of traveled lane width to 9 feet poses safety concerns to transit vehicles. Narrow lanes may lead to transit vehicles encroaching into adjacent lanes which in turn may result in sideswipe collisions. This project was initiated by the Transit Office of the Florida Department of Transportation (FDOT) to determine the influence of lane width on the overall safety of transit vehicles. The research employed five methods to investigate whether there is a significant relationship between lane widths and bus vehicle safety. The five methods employed were: (1) Questionnaire Survey; (2) Statewide Bus Crash Analysis; (3) Transit Agencies Incident Reporting Analysis; (4) Field Observational Study; and (5) Physical Constraints Analysis. All five study methods consistently suggest a strong relationship between lane width and bus vehicle safety. The results suggest that the narrower the lane width, the higher the likelihood of having bus sideswipe and mirror crashes. The results indicate that narrow lane widths, especially lane widths of 10 feet and narrower are overrepresented in the occurrences of bus sideswipe crashes. Based on the results of this study, it is recommended that 12-foot wide lanes be provided as practical as possible for roadways located on transit routes.

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EXECUTIVE SUMMARY

Recently, there has been national support for complete streets principles in promoting livable communities and traditional neighborhood design (TND) to encourage non-motorized modes of transportation and multimodalism. One of the measures that is being adopted to encourage pedestrian oriented design is the reduction of vehicular lane width from a conventional 12 feet to as narrow as 9 feet. Narrowing lane width is done in order to provide more space for pedestrians and cyclists within the right-of-way, to reduce operating speed, to calm traffic, and to discourage non-local traffic from using roadways located within livable communities. As a matter of economizing, many state and local governments are looking at ways to better accommodate their traveling public by maximizing current roadway widths without having to purchase additional right-of-way for wider roads. Although the narrowing lanes may help to achieve these goals, the reduction of traveled lane width to 9 feet poses safety concerns to transit vehicles. The standard mirror-to-mirror bus width is approximately 10.5 feet compared to passenger vehicles which are 8 feet wide (mirror-to-mirror). Narrow lanes may lead to transit vehicles encroaching into adjacent lanes which in turn may result in minor equipment loss and in worst case scenarios, sideswipe collisions The purpose of this project is to investigate the effects of narrow lane widths on transit vehicles and to determine how the competing strategies may be employed together to provide a bicycle and pedestrian friendly environment which also accommodates safe and convenient transit operations.

This project was sponsored by the Transit Office of the Florida Department of Transportation (FDOT) to determine the influence of lane width on the safety of transit vehicles. So far, the research team has conducted a comprehensive analysis of the influence of lane width on transit vehicle safety using a combination of methods. Each method was geared towards investigating whether there is a significant relationship between lane widths and bus safety. The five methods employed were: (1) Questionnaire Survey; (2) Statewide Bus Crash Analysis; (3) Transit Agencies Incident Reporting Analysis; (4) Field Observational Study; and (5) Physical Constraints Analysis.

Transit safety and operational officials have firsthand experience with factors that influence the safety of transit vehicles. The firsthand experience shared through the interviews was gained from daily operations and maintenance of transit vehicles. It was therefore important to gather their perspectives of the influence of tight roadway geometry including lane width and turning radii on the safety of buses. The survey revealed that most streets that are known to have lane width related collisions have lane widths of 11 feet or less. The survey also revealed a relationship between tight turning geometry and lane width. Most of the intersections that were categorized as having tight turning geometry and most prone to bus crashes were found to have lane widths of less than or equal to 11 feet. It should be noted that lane width dimensions reported in the survey study are average lane widths based on the curb-to-curb width divided by number of lanes. The actual lane width based on the distance between pavement markers is normally narrower. A follow-up phone conversation with several agencies revealed that most of the sideswipe collisions take place on the roadways located in older parts of the cities surveyed. Older parts of cities are generally known to have relatively narrower lanes due to limited right-of-way.

The survey also sought to determine the cost of replacing mirrors as it is indicative of the presence of mirror collisions which is rarely reported to law enforcement officers. It was found that transit agencies spent up to $800 per mirror replacement for new coaches which are equipped with power mirrors. Larger agencies spend a substantial amount of funds on mirror replacements. Miami-Dade Transit Agency for example spent $178,556.15 on labor cost just for mirror replacement from year 2004 to year 2008 which is equivalent to $35,711 per year.

A statewide analysis of bus related crashes was conducted. The analysis utilized the statewide crash database maintained by the Florida Department of Transportation and the Florida Department of Highway Safety and Motor Vehicles (FDHSMV). Merging the statewide crash database with the FDOT Roadway Characteristics Inventory (RCI) database provided the possibility of conducting a comprehensive analysis to determine the relationship between safety and other roadway geometric and traffic attributes and their interactions with lane width. An algorithm was developed by using the STATA statistical software for the purpose of determining the number of crashes in roadway segment with similar geometric and traffic characteristics. A list of the top ten segments with the highest frequency of sideswipe crashes was reviewed to determine what they have in common. Only one roadway segment in the top ten was found to have 12-foot wide lanes, i.e., Union Street in the city of Jacksonville. Further investigation revealed that this segment is a one-way four-lane roadway located adjacent to the transit plaza where most of the buses change routes. The remaining nine segments had average lane widths ranging from 9 feet to 11 feet. Seven out of ten were found to be 10 feet wide or narrower. The research team analyzed statewide bus crashes using the Poisson Regression Model. The preliminary results indicate the negative relationship between number of crashes on a segment and the lane width, suggesting that the decrease in lane width is likely to increase the frequency of crash occurrence. Apart from lane width, the results of the Poisson Regression analysis indicate that the average annual traffic volume, posted speed limit, and median width have influence on occurrence of bus sideswipe crashes.

Most of the sideswipe and mirror crashes involving buses are not reported to law enforcement officers. Furthermore, only a small portion of a few crash reports (by law enforcement officers) involving sideswipe and mirror strikes are archived in the FDHSMV and FDOT crash depository. This is because the FDOT crash database contains crashes that are reported in long forms only. In Tallahassee for example, only 5.7% of the bus sideswipe and mirror crashes archived by StarMetro had attached long forms. Crashes that are reported in the short form and driver exchange form are not logged in the FDOT Crash Analysis Reporting (CAR) system. This analysis used data from three transit agencies – StarMetro (in Tallahassee), Jacksonville Transit Authority, and Miami-Dade Transit Authority. The average width of the roadways that had sideswipe and mirror collisions was found to be 10.55 feet. An inferential statistical test to determine whether there was a significant difference between the lane widths of roadways where crashes occurred and all roadways on transit routes was conducted. A one-tail two-sample *t*-test revealed a significant difference exists with a *p*-value of less than 0.001. The results strongly suggest that sideswipe and mirror crashes occur predominantly on narrow roadways.

A comparative analysis was performed using data from the three transit agencies. This analysis compared the percentage of each lane width on transit routes for three agencies – StarMetro, Jacksonville Transit Authority, and Miami-Dade Transit Authority. The analysis revealed that only 1.56% of the roadways used by transit routes are 9 feet while 67.49% of the roadways on transit routes were found to be 12 feet wide. The percentages of 10-foot and 11-foot wide roadways on transit routes were found to be 3.89% and 27.05%, respectively. This reinforces the anecdotal information that many transit agencies avoid roadways with narrow lane widths, often rerouting to parallel or adjacent facilities with wider lanes to safely accommodate buses.

Despite the fact that there are only 1.56% of the roadways on transit routes which were 9 feet wide, they represented about 23.22% of the sideswipe and mirror collisions. Overrepresentation in sideswipe and mirror crashes was also observed on 10-foot wide roadways. Ten-foot wide roadways accounted for 24.64% of all sideswipe and mirror collisions. On the other hand, the results indicate that 12-foot wide roadways accounted for only 26.07% of sideswipe and mirror crashes while they represent over 67% of the transit routes network. The ratio of the percentage of crashes to the percentage of roadways used by buses for each lane width category showed overrepresentation of lane width related crash occurrences for roadways with 9 and 10-foot wide lane and underrepresentation for roadways with 12-foot wide lanes. Further analysis indicated that narrow lanes have higher rate of bus sideswipe crashes per miles traveled.

Data collection for the field observational study involved collecting bus movements by videotaping. The number of times the bus encroaches another lane was recorded. The field observational study revealed the following:

1. Narrower lanes make it difficult for bus and heavy vehicle drivers to position their vehicle completely within their lane.
2. Buses fail to maintain their lanes when maneuvering tight horizontal curves on narrow lanes.
3. The passing maneuver between two opposing buses on 10-foot, 2-way, 2-lane roadways was hard to perform. One bus had to stop to give room for another bus to pass.
4. Buses were encroaching on an adjacent lane whenever performing right turning maneuvers onto a street with narrower lanes. The encroachment during a turning maneuver could be a function of receiving lane width as well as the corner radii.
5. Field observation also revealed a problem with location of bus stops. Most of the bus stops were located close to the intersections where in most cases the lanes were narrow. One of the reasons for the reduction of lane width at intersections was to allow for the addition of exclusive left-turn lanes by repainting the existing roadway surface. This forces buses to encroach on adjacent lanes, causing potential for mirror collisions.

A physical constraints analysis was conducted to determine the minimum space requirements for buses to operate safely without encroaching into an adjacent lane. It was assumed that streets will be designed using complete streets design principles. Two main requirements were considered: adhering to 3-foot clearance for bicyclists (Florida Statute 316.083) and maintaining the bus including its mirrors in the same lane without encroaching into the adjacent lane. The results of this analysis indicate that a minimum of 11.25 feet and 11.75 feet for the outside lane is required for curbed roadways and roadways without curb and gutter, respectively, to meet these requirements. However, a 12-foot wide outside lane is recommended for all bus routes. The physical constraints analysis suggests a minimum lane width of 11 feet for the inside lane for four-lane, two-way roadways (both curbed and uncurbed). Minimum space requirements for roadways with on-street parking are the same as for the streets with curb and gutter.

In summary, this research project employed five different study methods to determine the influence of lane width on bus safety. The study considered sideswipe and mirror crashes as they are predominantly caused by narrow lane geometry. All five studies consistently suggest a strong relationship between lane width and bus safety. The results suggest that the narrower the lane width, the higher the likelihood of having bus sideswipe and mirror crashes. The results also indicate that locations with tight turning geometry were associated with narrow lane widths. It is important to note that although this relationship was identified, the severity of the crashes were minor and did not result in any fatalities.

The report also recommends potential solutions for accessing and operating transit in or around TND communities to ensure the safety of pedestrians, bicyclists and transit vehicles. In TND communities, the narrow lanes are typically recommended for the local, neighborhood streets where buses typically do not travel. A recommended concept is presented to illustrate how buses can utilize the major roadway facilities with wider lanes at the perimeter of the TND neighborhood and still provide safe and convenient access to transit for residents.

The last chapter discusses the need for coordination between local and state governments and transit agencies to determine how the reduction of lanes in their communities may affect a specific transit route. If notified, transit agencies may be able to reroute to avoid the use of the facilities with narrower lanes.

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1 INTRODUCTION

This project is sponsored by the Transit Office of the Florida Department of Transportation (FDOT). The project is aimed at determining the influence of lane width on the overall safety of transit vehicles and to identify solutions in providing transit services in Traditional Neighborhood Design. The following sections provide a narrative of the background and project objectives.

1.1 Background

Across the United States, a great deal of attention is being focused on creating more livable communities, as well as implementing smart growth, transit-oriented and generally more sustainable communities. The importance of adopting traditional neighborhood designs (TND) was further heightened by the US House of Representatives Bill 5951 entitled *Safe and Complete Streets Act of 2008* and the US Senate Bill 2686 entitled *Complete Streets Act of 2008*. Both bills called for transportation agencies to develop and adopt policies which will ensure that Complete Streets principles are adhered to when designing transportation facilities.

One of the measures that is being adopted to encourage pedestrian oriented design is reduction of vehicular lane width from a conventional 12 feet to 9 feet. Narrowing lane width is done in order to provide more space for pedestrians and cyclists within the right-of-way, to reduce operating speed – traffic calming, and to discourage non-local traffic from using roadways located within livable communities. As a matter of economizing, many state and local governments are looking at ways to better accommodate their traveling public by maximizing current roadway widths without having to purchase additional right-of-way for wider roads. Although the narrowing lanes may help to achieve these goals, the reduction of traveled lane width to 9 feet poses safety concerns to transit vehicles. The standard bus mirror-to-mirror width is approximately 10.5 feet, compared to passenger vehicles which are 8 feet wide (mirror-to-mirror). Narrow lanes may lead to transit vehicles encroaching adjacent lanes which in turn may result in minor equipment loss and in worst case scenarios, sideswipe collisions. Clearly, it is geometrically difficult for buses to maintain their lanes especially along curved roadway sections with narrow lanes. Bus accidents are likely to discourage the use of public transportation hence forcing passengers to return to dependency on automobile mode of transportation which in turn will reduce pedestrian activity. It is important that livable communities be designed in such a way that all energy efficient modes of transportation including pedestrians, cycling, and transit work in harmony to enhance livability and sustainability.

1.2 Research Objective

The main objective of this research was to evaluate geometric factors such as lane width and turning radii and their influence on the overall safety of transit vehicles. The outcome of this study would be used by transportation officials from local to state level in determining how best livable communities should be designed to integrate transit on livable communities. It is important that both transit and non-motorized modes of transportation function in harmony to promote sustainable transportation in traditional neighborhoods.

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2 LITERATURE REVIEW

A survey of the published literature was conducted through various literature search sources. The search revealed paucity of literature on the relationship between transit vehicles and lane width. However, there was plenty of literature on the influence of lane width on general highway safety. Most of the studies were conducted using general vehicular population data which is predominantly passenger cars. Literature review is summarized in the following sections.

2.1 Lane Width Design Guidelines

The standards used by FDOT for lane width design are described in the *FDOT Plans Preparation Manual (2009)*. Table 2.1 depicts the Florida's design criteria for resurfacing, restoration, and rehabilitation (RRR) projects of urban roadways with curb and gutter. Minimum lane widths of 9 feet and 10 feet are required for left-turn and through lanes, respectively. For a through lane, a minimum requirement is raised to 11 feet if truck percentage exceeds 10%. The same lane width requirements for through and turn lanes are specified for roadways without curb and gutter as well.

Table 2.1. FDOT Minimum Lane Width Requirements

Facility Type	Design Year AADT	Design Speed (mph)	Minimum Thru Lane (ft.)	Minimum Turn Lane (ft.)	Minimum Parking Lane (ft.)
Urban Multilane or Two-Lane with Curb and Gutter	ALL	ALL	10_1	9_1	7_3
Urban Multilane Without Curb and Gutter	ALL	ALL	10_1	9_1	6_3

1. 11 ft. if Trucks are >10% of Design Year Traffic.
2. 10 ft. for 2 Way Left Turn Lanes.
3. A minimum width of 7 ft. measured from face of curb may be left in place. Otherwise provide 8 ft. minimum, measured from face of curb.

Table 2.2 shows FDOT lane width requirements for new construction projects. The lane width requirements are based on facility type (freeway, arterial, or collector road), type of lane (through or auxiliary), average annual daily traffic, and posted speed limit. FDOT standards specify the lane widths of 12 feet and 11 feet for urban arterials and collector roadways, respectively. Twelve-foot wide lanes are desired for both arterial and collector roadways if the truck percentage is significant (>10%).

Table 2.2. FDOT Lane Width Standards for New Construction Projects

LANE WIDTHS (FEET)							
FACILITY		THROUGH OR TRAVEL	AUXILIARY			
TYPE	AREA		SPEED CHANGE	TURNING (LT/RT/MED)	PASSING	CLIMBING
FREEWAY	Rural	12	12	----	----	12
	Urban	12	12	----	----	12
ARTERIAL	Rural	12	12	12	12	12
	Urban	12 [1]	12 [1]	12 [1,4]	12 [1]	12
COLLECTOR	Rural	12 [6]	11 [2]	11 [2,4]	11 [2,5]	12
	Urban	11 [3]	11 [3]	11 [3,4]	11 [3]	12

1. 11 ft. permitted on non-FIHS/SIS roads if one of these conditions exist:
   a. R/W and existing conditions are stringent controls
   b. Facility operates on interrupted flow conditions
   c. Design speed 40 mph or less
   d. Intersection capacity not adversely affected
   e. Truck volume 10% or less
2. 12 ft. lanes for all 2-lane rural.
3. 12 ft. lanes in industrial areas when R/W is available.
4. With severe R/W controls, 10 ft. turning lanes may be used where design speeds are 40 mph or less and the intersection is controlled by traffic signals. Median turn lanes shall not exceed 15 ft.
5. 12 ft. when truck volume more than 10%.
6. 11 ft. for low volume AADT.

2.2 Lane Width and Crash Data Analysis

Narrow lanes are presumed by many engineers to have an adverse effect on highway safety. The link between lane width and safety is woven of two principal strands (Hauer, 2000). First, the wider the lane the larger will be the average separation between vehicles moving in adjacent lanes. This may provide a wider buffer to absorb the small random deviations of vehicles from their intended path. The second strand in the link between safety and lane width is that a wider lane may provide more room for correction in near-accident circumstances.

There are at least forty different crash categories as presented in the Florida traffic crash report (Appendix A). It is likely that narrow lanes by themselves may lead to crashes that would not otherwise occur. Such collisions would most likely include sideswipe collisions. Other crash types closely related to lane width include motor vehicles hitting fixed objects including signs, utility poles, and other roadside features. The National Cooperative Highway Research Program

(NCHRP) Report 330, prepared by Harwood (1990) pointed out that although many agencies that have implemented narrower lanes reported no adverse traffic operational or safety problems, other agencies reported some specific problems including: increases in sideswipe crashes, straddling of lane lines, particularly by trucks and buses, and turning problems at intersections, particularly for trucks and buses. The same study indicated that although lane narrowing provides additional space to relieve traffic congestion or address specific accident patterns, narrower lanes may result in increases in some specific accident types, such as same-direction sideswipe collisions.

A study that was conducted by DeLuca (1985) in Miami-Dade on Interstate 95 investigated the effect of lane narrowing on the roadway accident profile. The study observed a significant increase in sideswipe crashes with the decrease in lane width. Another study conducted by Zegeer *et al.* (1981) found that wide lanes had accident rates 10 to 39% lower than those on narrow lanes. Wide shoulders up to 9 feet wide were also associated with lower accident rates. The study observed that heavy vehicles overtaking other heavy vehicles remain centered in their lanes only when lanes were 12 feet wide or wider. Studying the effects of lane width on trucks, Joshua and Garber (1990) found that lane width has the greatest effect on the probability of a truck accident and that the probability for a truck accident increases as lane width decreases.

A Federal Highway Administration (FHWA) study by Zegeer *et al.* (1987) quantified the effects of lane width, shoulder width, and shoulder type on highway crash experience based on an analysis of data for nearly 5,000 miles of two-lane highways from seven states. An accident prediction model was developed and used to determine the expected effects of lane and shoulder widening improvements on related accidents. The study found that lane widening of 1 foot will be expected to reduce related accidents by 12 percent. Widening lanes by 2 feet, 3 feet, and 4 feet resulted in reducing related accident types by 23%, 32%, and 40%, respectively. Although the study by Zegeer *et al.* did not mention the base lane width, the study considered single vehicle fixed objects, rollover, and run-off-the-road accidents and multi-vehicle head-on, opposite and same direction sideswipe to be associated with lane width. Another lane widening study was conducted by Goldstine (1991) using 25 projects in New Mexico. Goldstine found a significant crash rate reduction for before and after comparisons on most of the roads.

Hadi *et al.* (1995) developed several regression models to quantify the safety effects of different cross-section design elements on various highway types in Florida. Based on the developed regression models, significant relationships were found between lane width and crashes for undivided highways and urban freeways. Based on categorical representation of lane width, for two-lane rural, two-lane urban, four-lane urban undivided, and urban freeways, widening lane width up to 13 feet, 12 feet, 13 feet, and 13 feet, respectively, was found to decrease crash rates as shown in Figure 2.4.

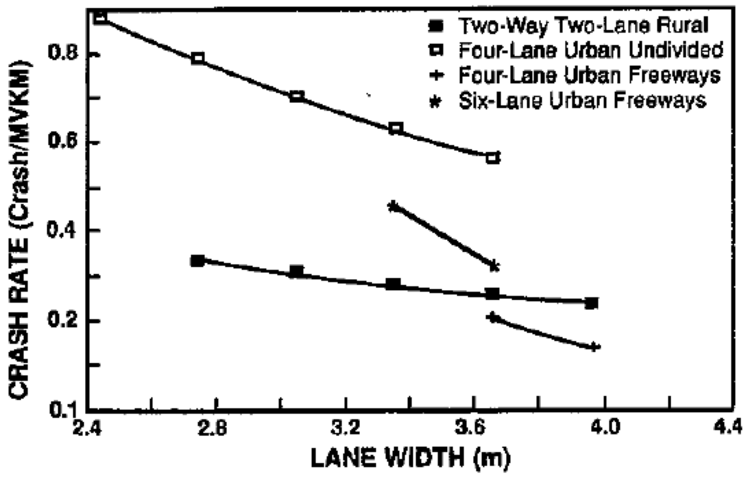

Figure 2.4. Effect of lane width on midblock crash rates (Hadi *et al.*, 1995)

Figure 2.5 illustrates the relationship between accidents per million vehicle miles traveled on two-lane non-intersection rural roadways as illustrated by Hauer (2000). According to Figure 2.5, lane width widening results in a decrease in non-intersection accidents.

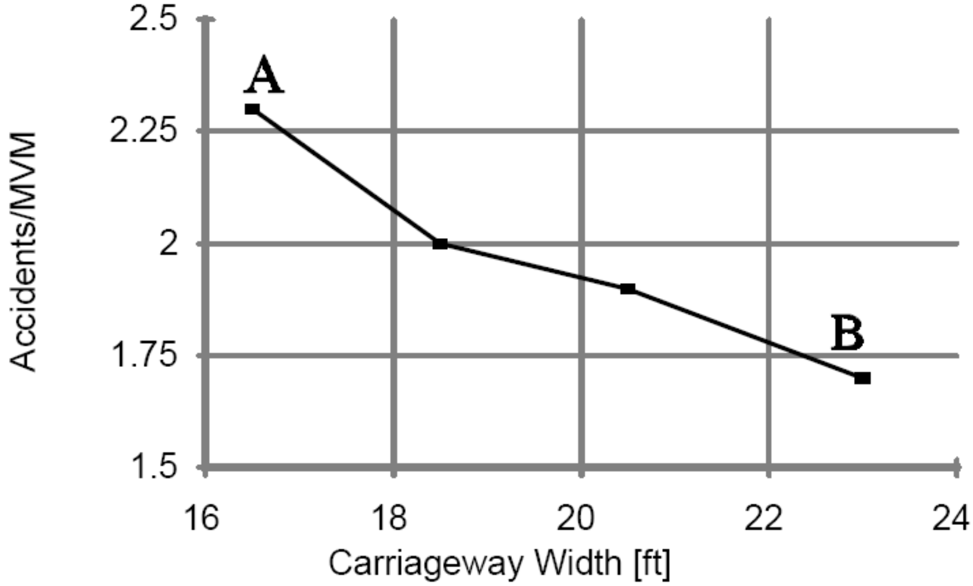

Figure 2.5. Relationship between lane width and non-intersection accidents (Hauer, 2000)

The results of the study by Dart and Mann (1970) show the same trend as observed by Hauer (2000). Figure 2.6 presents the relationship between the accident rate per million vehicle miles traveled based on the study that was performed by Dart and Mann (1970) for rural highways in Louisiana. The graph indicates a higher crash rate for narrow roadways.

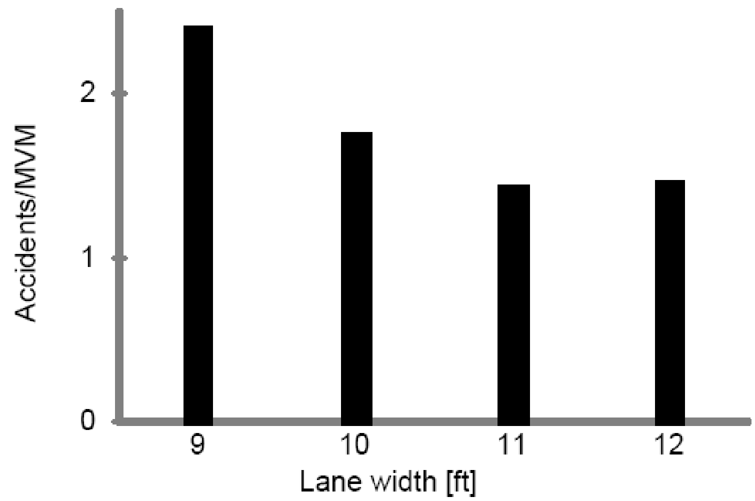

Figure 2.6. Relationship between accident rate and lane width for rural roadways (Dart and Mann, 1970)

According to the 1996 Guidelines for the Location and Design of Bus Stops prepared by the Transit Cooperative Research Program - TCRP Report 19, a traffic lane used by buses should be no narrower than 12 feet in width because the maximum bus width (including mirrors) is about 10.5 feet. TCRP Report 19 proposes a desired curb lane width of 14 feet.

2.3 Literature on Lane Encroachments

A NCHRP Project 3-38(5) by Harwood (1990) studied the influence of street width on urban arterials using roadside videotaping. The analysis of the field observations found that, for all vehicle types, unforced encroachment rates were more frequent for sites with narrower lanes than for sites with 12-foot lanes. Unforced encroachment rates on tangent sites with narrower lanes were four times higher than on tangent sites with 12-foot lanes. The unforced encroachment rates on horizontal curves with narrower lanes were found to be about 2.5 times higher than for tangent sections with narrower lanes. NCHRP 3-38 provides the following guidelines among many others for reallocation of street width on urban arterials;

- Curb lanes should usually be wider than other lanes by 1 to 2 feet to provide allowance for a gutter and for greater use of the curb lanes by heavy vehicles.
- Lane widths less than 10 feet should be used cautiously and only in situations in which it can be demonstrated that increases in accident rates are unlikely.

A study by Harkey *et al.* (1996) investigated lane encroachments of the vehicles on the outside lane for different designs of bicycle facilities in the state of Florida. The percentage of motor vehicles encroaching into the adjacent left lane when passing a bicyclist was much higher on bicycle shared facilities (22.3%) compared to paved shoulder and dedicated bicycle lane facilities (3.4% and 8.9%, respectively).

2.4 Literature on Combination of Lane Width and Other Factors

Traffic collisions are caused by a combination of factors. Zegeer *et al*. (1981) conducted a safety analysis using approximately 17,000 records in Kentucky representing 41,072 miles. Figure 2.7 shows the findings of the study on the relationship between the accident rate and average daily traffic for 2-way 2-lane roadway for various lane widths. The results suggest higher occurrences of opposite direction accidents for narrow roadways compared to wider roadways. Zegeer *et al*. (1981) also analyzed the combined effect of lane width and shoulder width on highway safety. The results suggest a decrease in accident rate as the lane width and shoulder width increase as depicted in Figure 2.8.

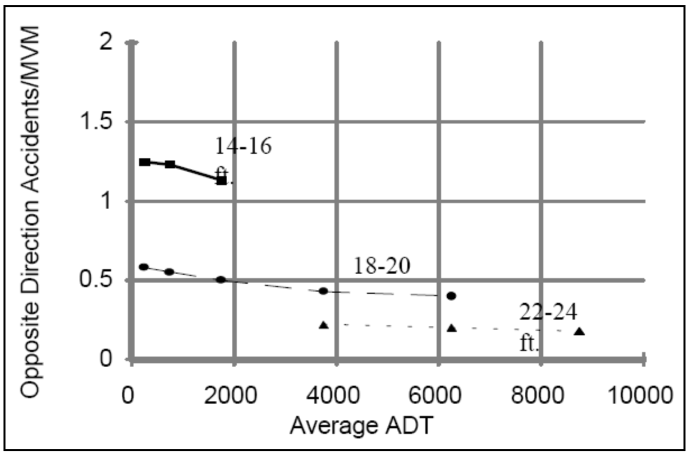

Figure 2.7. Relationship between opposite direction collisions versus AADT for different lane width categories (Zegeer *et al*., 1981)

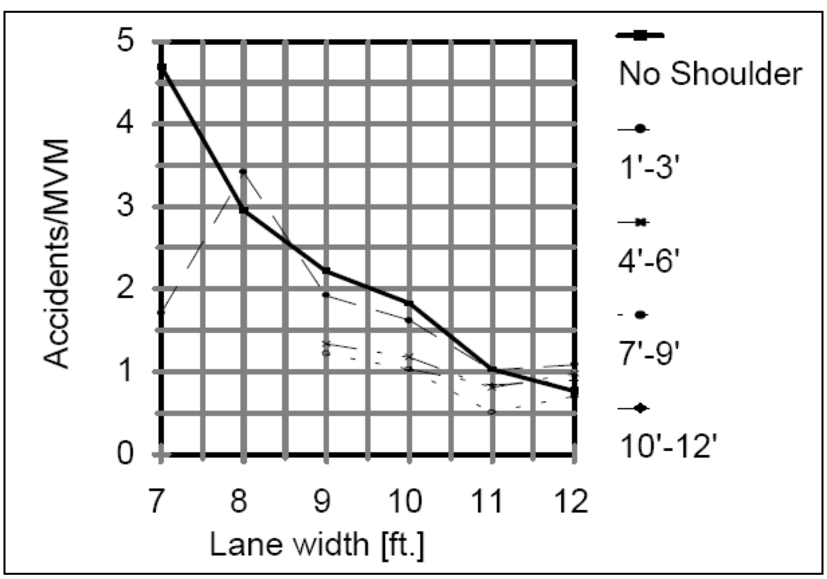

Figure 2.8. A combined influence of lane width and shoulder width on crash occurrences (Zegeer *et al*., 1981)

2.5 Florida Law on Motorist and Bicycle Lateral Clearance

According to the American Association of State Highway and Transportation Officials (AASHTO) Guide for the Development of Bicycle Facilities (1999), an operating space of 4 feet is assumed as the minimum width for any facility designed for exclusive or preferential use by bicyclists. The guide proposes a more desirable operating space of 5 feet where motor vehicle traffic volumes, motor vehicle or bicyclist speed, and a mix of truck and bus volumes are increased. Florida Statute 316.083 states that a driver overtaking a bicycle must maintain a horizontal clearance of at least 3 feet. Three feet is a minimum safe lateral separation for passing a cyclist under typical urban conditions. According to this statute, when the passing vehicle is large, towing a trailer, or traveling at much higher speed, greater lateral clearance is needed. A study that was conducted in Florida by Harkey *et al*. (1996) to evaluate the safety of different types of bicycle facilities using an observational comparative analysis revealed that motorists preferred at least 5.5 feet of horizontal separation from bicycles. The study also observed a vehicular lateral change of position to the left of 2.4 feet and 1.0 foot for shared bicycle facilities and dedicated bicycle facilities, respectively when passing bicyclists.

Consider an illustration of a shared bicycle facility on a 14-foot wide curb lane (Figure 2.9). Each strip represents one foot of pavement. The Department of Transportation's Manual of Uniform Minimum Standards (Florida Greenbook, 2007) recommends an outside lane width of 14 feet as the minimum width that allows passenger cars to safely pass bicyclists within a single lane, i.e., without the need for passing motorists to use part of the adjacent lane. According to the Florida Bicycle Association (2009), the minimum requirements are derived as follows:

- A cyclist is defined as being 2.5 feet wide with a minimum operating space of 4 feet. This includes the minimum safe distance from the edge of useable pavement (2 feet).
- The legal minimum passing clearance for an overtaking vehicle is 3 feet.
- A typical passenger vehicle is 5.5-feet (car) to 7-feet (sport utility vehicle [SUV]) wide.

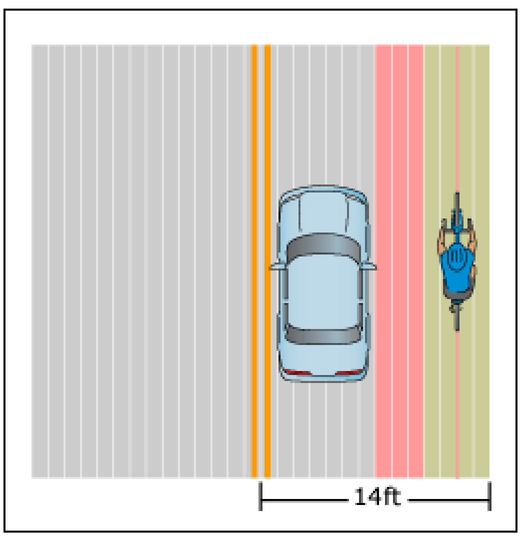

Figure 2.9. Bicycle lateral clearance as described by Florida Bicycle Association (2007)

Clearly, the minimum standards do not take into consideration buses and other heavy vehicles which are much wider than typical passenger cars. According to the Florida Bicycle Association, the minimum lane width requirements do not account for commercial vehicles and utility trailers which are wider than passenger vehicles. The Florida Bicycle Association suggests that heavy vehicles (buses and trucks) must use part of another lane to pass safely. Figure 2.10 illustrates how a bus would not be able to maintain the 3-foot clearance from bicycle requirement unless it encroaches into an adjacent lane, given a 14-foot wide curb lane.

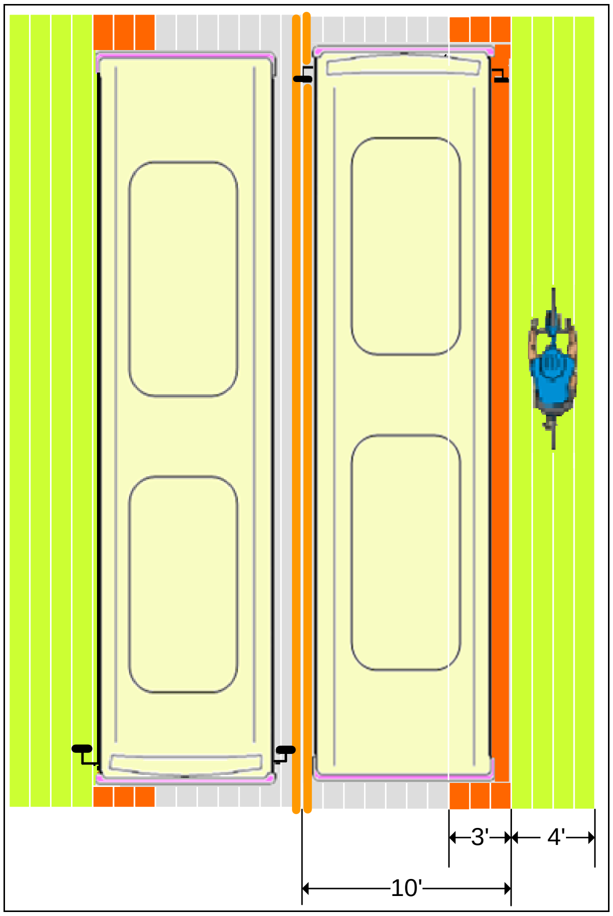

Figure 2.10. Buses not able to maintain a 3-foot clearance law from the bicycle for a 14-foot wide curb lane

3 RESEARCH APPROACH

Most of the research approaches for analysis of roadway safety in relation to design features were found to be based on general traffic (both passenger and heavy vehicle traffic). A few studies looked into the influence of lane width on the safety of trucks. None of the research of this nature was found to be specifically focused on bus safety. The research team conducted a thorough analysis of the influence of lane width on transit vehicle safety using a combination of analyses. Each analysis type was geared towards investigating whether there is a significant relationship between lane widths and bus safety. The following specific methods were considered.

3.1 Questionnaire Survey

Transit safety and operational officials have firsthand experience with factors that influence transit vehicle safety. It was therefore important to gather their perspectives of the influence of tight roadway geometry including lane width and turning radius on the safety of buses. The contact information of transit safety and operational officials compiled by the Center for Urban Transportation Research (CUTR) at the University of South Florida (USF) was used as a preliminary list of contacts for sending the surveys.

3.2 Statewide Bus Crash Analysis

A statewide analysis of bus related crashes was conducted to investigate the general trend of bus safety in relation to lane width. This analysis utilized the statewide crash database maintained by the Florida Department of Transportation (FDOT) and the Florida Department of Highway Safety and Motor Vehicles (FDHSMV). Merging the statewide crash database with the FDOT Roadway Characteristics Inventory (RCI) database provided the possibility of conducting a comprehensive analysis to determine the relationship between safety and other roadway geometric and traffic attributes and their interactions with lane width.

3.3 Transit Agencies Incident Reporting Analysis

Most of the sideswipe and mirror accidents involving buses are not reported to law enforcement officers. Furthermore, only a small portion of a few crash reports involving sideswipe and mirror strikes are archived in the FDHSMV and FDOT crash depository. This is because the FDOT crash database contains crashes that are reported in long forms only. Any crashes which are reported in the short form and driver exchange form are not found in the FDOT Crash Analysis Report (CAR) system. Different law enforcement agencies might have varied criteria for reporting traffic crashes using long forms. The policy of the Florida Highway Patrol for reporting a crash in long forms is appended (Appendix B). Clearly, most sideswipe and mirror crashes would not qualify to be reported in the long forms based on the criteria shown in Appendix B. Transit agencies however, maintain their own databases that contain all incidents that occur when transit vehicles are in operation. Bus operators are required to report any incidents including bus collisions with other vehicles and fixed objects. This untapped source was used as it contains most of the mirror-to-mirror collisions and sideswipe crashes that are related to lane width.

3.4 Field Observational Study

Traffic crashes are generally caused by traffic conflicts. Lane width related crashes would generally be caused by one or more vehicles not being able to maintain their lanes. Clearly, large size vehicles including buses and trucks are more prone to encroaching into other lanes if the lane width is insufficient. A lane encroachment field study was conducted to determine the lane encroachment behavior of buses at selected locations. The field observational study intended on establishing the relationship between lane width and lane encroachment.

3.5 Physical Constraints Analysis

Physical constraints analysis considered the space requirements of buses and the interaction between buses and other modes of transportation, particularly bicycles. Two main requirements were considered: adhering to a 3-foot clearance for bicyclists (Florida Statute 316.083) and maintaining the bus including its mirrors in the same lane without encroaching into the adjacent lane.

4 QUESTIONNAIRE SURVEY

The purpose of the survey reported herein was to determine the perception of the transit agencies on the influence of tight roadway geometrics, particularly lane width and turning radius on transit bus safety. Tight turning geometry is a factor of the number of receiving lanes, turning angle, and lane width at an intersection. The survey was conducted using questionnaires which were emailed to all transit agencies in Florida during the month of December 2008. The personnel targeted to respond to the survey questionnaires were transit agencies' operations and safety managers.

4.1 Questionnaire Design

The survey questionnaire was designed to guide a transit official such as the safety and/or operations manager to provide the agency's experience as it relates to roadway geometrics. The questionnaire consisted of 12 questions, which were formulated to allow responders to share their experience in a manner that did not require them to collect additional data. Eight questions required general answers while the remaining four called for specific information. Specific information included the narrowest lane width used by standard buses, streets which do not have bus routes because of tight geometry, streets that are more prone to or have the potential of having bus accidents related to lane width, and names of intersections that have tight geometry and known to have accidents related to tight turning geometry. A blank questionnaire is shown in Appendix C.

4.2 Survey Results

The completed questionnaires were either emailed or faxed back to the researchers between December 2008 and January 2009. The survey questionnaires were sent to all transit agencies in the state of Florida. Twelve agencies responded to the questionnaire. Appendix D presents a summary of responses for each question. The following sections discuss the responses of the survey for questions that were posed.

4.2.1 Roadway geometrics critical to transit vehicle safety

The mirror-to-mirror width of a standard bus is approximately 10.5 feet while that of a standard sports utility vehicle (SUV) is about 8-foot wide (mirror-to-mirror). Narrow lanes may lead to transit vehicles encroaching into adjacent lanes which in turn may result in sideswipe collisions. Clearly, it is geometrically difficult for buses to maintain their lanes especially along curved roadway sections with narrow lanes. The question was asked to determine the roadway geometrics that the transit agencies' perceive to be critical to transit vehicle safety. All responders mentioned lane width as a critical roadway factor for bus safety. Five agencies reported tight turning radius as another issue for bus accidents. Other roadway features that were mentioned at least once include roadway curvature, tree encroachments, and poor location of shelters.

4.2.2 Safety experience on narrow lanes compared to wider lanes

Preliminary phone interviews with transit agencies indicated problems with mirror accidents. A question was designed to investigate whether transit agencies experience more sideswipe, mirror strikes, and hitting objects accidents on narrow roadways compared to wider streets. Responders raised concerns about narrow lanes. The agencies pointed out in the survey that there are generally more sideswipe, mirror strikes, and hitting roadside objects on narrow streets compared to wider streets. However, the agencies reported that most accidents involving buses hitting roadside objects such as signs and curbs are caused by mainly tight turning geometry. Only one agency, SunTran located in Melbourne, Florida, indicated that they do not have consistent problems with narrow lanes or tight turning geometry. The agency however, reported problems with sideswipe crashes on SR 520 in Cocoa due to reduced lane width during construction. SunTran also reported problems on tight curvature on Banana River Drive towards SR 520 in Merritt Island.

4.2.3 Roadways that are avoided because of tight geometry

Transit agencies tend to avoid narrow streets for the safety of their vehicles. Some of these streets are located in areas which are conducive to and have potential for transit patronage. One of the questions in the survey intended to solicit whether there are streets that are avoided based on tight geometry such as inadequate lane width and tight turning radius. A list of street segments avoided by the transit agencies are listed in Table 4.1. Field review indicated that only one street segment (Madeline Avenue in Daytona) was found to be 12 feet wide. A follow-up phone interview revealed that the street was recently widened from 10-foot to 12-foot wide lanes and is now safe for buses. The interview revealed, however, that there are other streets in Daytona such as 8th Street and 6th Street between Nova Street and Derbyshire Avenue that buses operate only one way because the other side of the streets has tree canopies (due to poor maintenance) which constantly cause bus mirror strikes. All other streets that were reported to be avoided by transit agencies have the average width that ranged between 9 to 11 feet.

4.2.4 Roadways which are prone to or are known to have lane width related crashes

The lane widths of the streets which were reported to be prone to sideswipe accidents ranged mostly between 9 to 11 feet (Table 4.2). The streets with lane widths less or equal to 11 feet accounted for more than 90 percent of the roadways reported to be prone to or are known to have lane width related crashes as shown in Figure 4.1. The results indicate that all but one roadway segments reported as either more prone to or have higher occurrence of sideswipe or/and mirror collisions are less than 12 feet wide. A site visit to the Mathews Bridge in Jacksonville indicated that although the lane width is 12 feet, the bridge is two-lane in each direction with no shoulder (raised curb design). It was also found that vehicles travel at speeds higher than 60 mph as they cross the bridge and the bridge has a vertical curve. Although Mathews Bridge is 12 feet wide, it feels much narrower due to the operating traffic and roadway geometric conditions. Miami-Dade Transit Authority listed a segment of the newly constructed I-95 expressway, from SR 112 to Golden Glades to be prone to sideswipe and mirror crashes. This segment was recently restriped from five 12-foot lanes to six 11-foot lanes to allow implementation of high occupancy toll (HOT) lanes in Miami-Dade. It appears that wherever high speed facilities are used by buses, the perceived influence of lane width and curvature on sideswipe collisions become more pronounced.

Table 4.1. Narrow Streets Avoided by Transit Agencies

Transit Name	County or City	Street(s) Avoided	Width (ft)
JTA	Duval	College St	10
PSTA	St. Petersburg	N.E. Coachman Rd	10
		Some streets in the Old N.E. in St. Petersburg	-
Pasco County Public Transportation	Pasco	From Delmar St to MLK Ave	10
Miami-Dade Transit	Miami	2nd St, Miami Beach	10
		N.E. 10 Ave (traffic circles)	10
		Coral Way (traffic circles)	11
HART	Tampa	Part of Florida Ave	11
		Part of Nebraska Ave	11
		Part of Columbus Blvd	10
Lee Tran	Lee	Bay St	9.5
		Second St	10
		Matanza Bridge (old San Carlos)	11
		Estero Blvd	11
RTS (Gainesville)	Gainesville	Woodlawn St Between Museum and Stadium Road	11
SunTran	Ocala	N.E. 2nd Ave and 25th S.E. Ave	-
		N.E. 3rd St	9
		Old Blichton Rd	11
VOTRAN	Daytona	Madeline Ave	12
		N John Anderson Dr	11
		Derbyshire Ave	11
StarMetro	Tallahassee	Part of Gaines St	9
LYNX	Orlando	Robinson St in downtown Orlando	10
		Fullers Cross Rd in Ocoee/Winter Garden	9
Manatee County Area Transit	Manatee	Did not mention roads	-

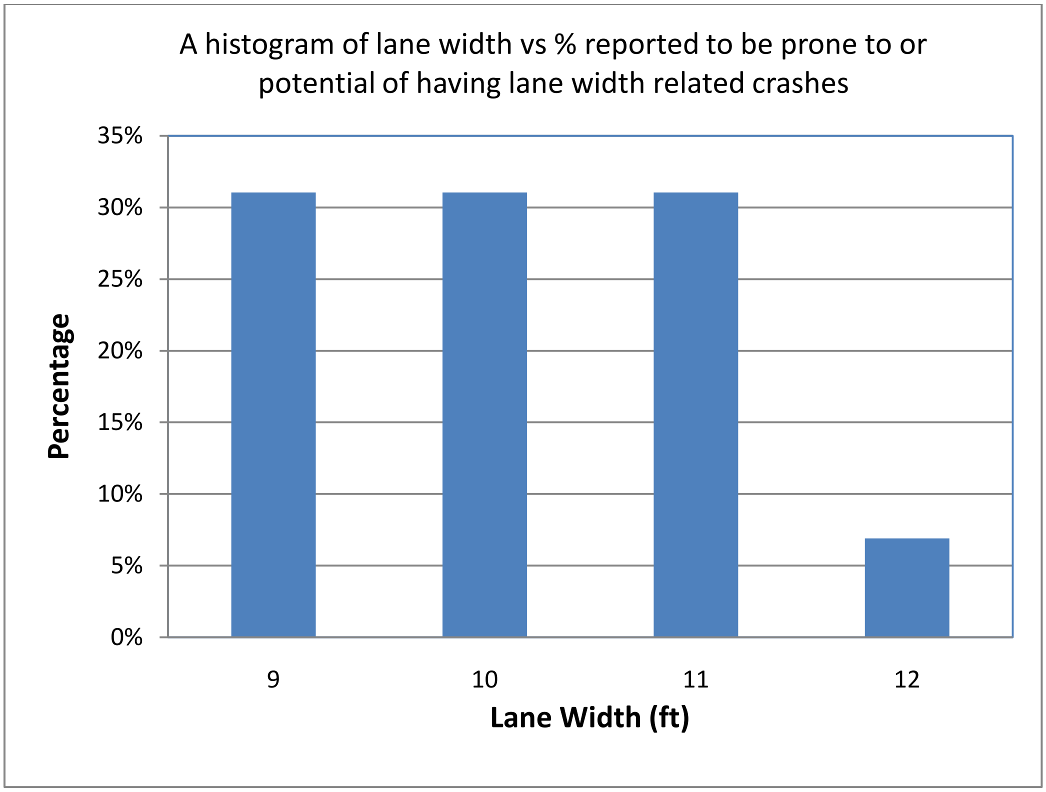

Figure 4.1. A histogram of lane width versus percentage of roadways prone to lane width related crashes

4.2.5 Intersections with tight turning geometry and potential to causing bus collisions

Buses face difficulties in maneuvering turning movements due to wider and longer dimensions compared to smaller vehicle types. A typical standard bus is about 40 feet long while personal automobiles are 14 feet and 18 feet long for compact cars and sport utility vehicles (SUV), respectively. Buses are also about 2 feet wider than a typical SUV. A question was formulated to determine the intersections that transit agencies perceive to have tight geometry for bus turning maneuvers. The list of intersections listed by transit agencies is shown in Table 4.3. The research team collected several roadway variables including the average lane width, number of lanes before the turn, number of receiving lanes after the turn, number of lanes for the receiving/turning direction, the presence of one-way streets, and whether the roadway has a divided or undivided median. Most of the intersections that were categorized as having tight turning geometry and most prone to causing bus crashes were found to have lane widths of less than or equal to 11 feet. Only two intersections, US1 & Ridge Boulevard in Daytona and Manatee Avenue & 14th Street in Manatee County were found to be 12 feet wide. This observation suggests a correlation between tightness of turning maneuvers and lane width. Further investigation revealed that the two intersections with 12-foot wide lanes had buses turning into one receiving lane. It is possible that tight turning curbs coupled with only one receiving lane might cause potential for buses to hit roadside objects. At one of the two intersections, Manatee Avenue & 14th Street in Manatee County, the receiving lane is undivided causing a potential for collision with vehicles on the opposing direction.

Table 4.2. Street Segments which are Prone to or Have Higher Lane Width Related Bus Crashes

Transit Agency	County or City	Street	From	To	Average Lane Width (ft)	Posted Speed Limit (mph)	Urban or Suburban *
JTA	Duval	Beaver St	Edgewood Dr	Liberty St	9	30	Urban
		Forsyth St	Stuart St	Liberty St	10	30	Urban
		Matthews Bridge			12	45 - 50	Urban
PSTA	St Petersburg	22nd Ave S	30th St S	16th St S	10	40	Urban
		9th St S	62nd Ave S	45th Ave S	11	35	Urban
		4th St S	45th Ave S	Pinellas Point Dr S	11	-	Suburban
Pasco County Public Transportation	Pasco	Moog Rd	Grand Blvd	US Hwy 19	9.5	30	Suburban
		Main St	US Hwy 19	Madison	9	25	Urban
		MLK Ave	Roosevelt Ave	5th St	-	-	Urban
Miami-Dade Transit	Miami	Washington Ave	5th St	Lincoln Rd	10	-	Urban
		95 Express Lanes	NB 112 Entrance Ramp	Golden Glades	11	55	Urban
		Flagler Street (downtown)	NW 1st Ave	Biscayne Blvd	11	30	Urban
HART	Hillsborough	Nebraska Ave	Downtown	Bearss Ave	9	35	Urban
		Florida Ave	Downtown	Bearss Ave	10	40	Urban
		Columbus Dr	Dale Mabry Hwy	40th Street	9	30	Urban
Lee Tran	Lee	Country Club Blvd	Veterans St	Palm Tree St	9.5	40	Urban
		Bay St	First St	Monroe St	9.5	30	Urban
		Second St	Monroe St	Lee St	10	30	Urban
RTS (Gainesville)	Gainesville	N Main St	NE 8 Ave	NE 16 Ave	11	30	Urban
		11th St	6th St	9th Rd	11	-	Urban
SunTran	Ocala	Old Blichton Rd	NW 16th St	Hwy 27	11.5	-	Suburban
		NE 2nd Ave			11	-	Suburban
VOTRAN	Daytona	Eighth St	Nova St	Derbyshire St	11	30	Suburban
		Sixth St	Nova St	Derbyshire St	10	30	Suburban
		Second Ave	Beach St	US 1	11	25	Urban
StarMetro	Tallahassee	Pullen Rd	Old Bainbridge Rd	Monroe St	10	30	Suburban
		Tennessee St	Adams St	Dewey	10.5	30	Urban
		Gaines St	Monroe St	Woodward Ave	10	30	Urban
LYNX	Orlando	Robinson St	Maguire St	Orange Ave	9	30 - 35	Urban
		Fullers Cross Rd	Ocoee/Apopka Rd	Lakewood Ave	9	45	Suburban
Manatee County Area Transit	Manatee	14 St**					
		US 41**					
		9 St**					

* Sections with curb and gutter were assumed to have urban design while those without curb and gutter were designated as suburban
** Segment limits were not provided

Table 4.3. Intersections with Tight Geometry and are Known for or Have the Potential for Bus Collisions

Transit Name	County or City	Intersection	Lane Width (ft)	# of Sending Lanes	# of Receiving Lanes	Divided (Y/N)	Urban or Suburban *
JTA	Duval	Jefferson St & Water St	10.5	2	2	Y	Urban
		Ocean St & State St	8	4	4	N	Urban
		Beaver St & Market St	9	2	1	N	Urban
PSTA	St Petersburg	Pierce St & N Fort Harrison Ave (Clearwater)	11.5	1	1	N	Urban
		Druid Rd & Martin Luther King Ave (Clearwater)	11.5	2	1	N	Urban
		Drew Rd & Hampton St (Clearwater)	10	2	1	Y	Urban
Pasco County Public Transportation	Pasco	Main St & Madison Ave	10	2	1	N	Urban
		Grand Blvd & Gulf Dr	10	2	1	N	Suburban
		Pretty Pond to entrance to Wal-Mart Super Center (Zephyrhills)	11	1	2	Y	Suburban
Miami-Dade Transit	Miami	41st St & Collins Ave WB	11	3	1	N	Urban
		193rd St & Collins Ave (U-Turn)	11	2	3	Y	Urban
		NW 2nd St & 1st Court (Downtown Miami)	10.5	1	1	N	Urban
HART	Hillsborough	Too many to list					Urban
Lee Tran	Lee	MLK Blvd & Hendry St	10.5	2	1	N	Urban
		Jackson St & MLK Blvd	10.5	1	1	N	Urban
		Mohawk Ave & Chiquita Blvd (Cape Coral)	9	2	2	Y	Suburban
VOTRAN	Daytona	LPGA & US1	11	1	2	Y	Suburban
		Big Tree & US1	11	2	2	Y	Urban
		US1 & Ridge Blvd	12	2	1	Y	Urban
StarMetro	Tallahassee	St. Augustine St & Copeland St	10	2	1	N	Urban
		Palmer St & Martin Luther King Blvd	11.5	1	1	N	Urban
		Martin Luther King Blvd & Osceola St	11	1	1	N	Urban
LYNX	Orlando	17-92 & Minnesota Ave	9.5	2	1	N	Urban
Manatee County Area Transit	Manatee	Manatee Ave & 14 St	12	3	2	N	Urban
		US 41 & 53 Ave	10.5	4	2	N	Urban
		Manatee Ave & 9 St	11	3	2	N	Urban

* Sections with curb and gutter were assumed to have urban design while those without curb and gutter were designated as suburban

4.2.6 Cost of mirror replacement

The cost of replacing mirrors could give an indication of the presence of lane width related crashes. Most sideswipe crashes involving vans and trucks and crashes involving buses hitting fixed objects result in mirror damage. The cost that agencies incur in replacing mirrors was sought. The research team could not obtain a uniform format of data on this particular question in the survey. However, some agencies provided valuable information which is worth sharing. For example, Miami-Dade Transit Agency spent $178,556.15 on labor cost just for mirror replacement from year 2004 to year 2008. This is an average of $44,639 per year for labor direct cost only. Hillsborough Area Regional Transit (HART) in Tampa spent $41,421.37 in the first nine months of year 2007 for mirror replacement, an average of $4,600 per month. HART indicated that eight to twelve mirrors are replaced per month. Lynx (in Orlando) spends 300 to 800 dollars per mirror replacement on material alone depending on the type of mirror. According to Lynx officials, new coaches are equipped with power mirrors which cost about 800 dollars per replacement. The Jacksonville Transit Authority replaced 63 mirrors in year 2008 alone. A phone conversation with several transit agencies indicated that more mirrors are being repaired than the ones being replaced. Clearly the cost of repairing mirrors and the transit vehicle downtime due to repair need could be reduced by avoiding having narrow lanes on transit routes. Although agencies indicated that most of mirror replacement is caused by mirror strike accidents, there might be other causes of mirror replacements that were beyond the scope of this study. A mathematical expression of the relationship between cost of mirror replacements and fleet size could not be established due to insufficient data.

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5 STATEWIDE BUS CRASHES ANALYSIS

5.1 Data Collection

Statewide bus crash data were obtained from an electronic database for five years from 2003 to 2007. In total, 4608 bus crashes were archived in the FDOT CAR system over the five years study period. Sideswipe and hitting fixed objects accounted for 19.75% of all bus crashes (910 crashes). Only 15 crashes involved buses hitting fixed objects while 895 crashes were classified as sideswipe crashes.

5.1.1 Crash analysis reporting (CAR) database

Law enforcement agencies report the traffic crashes on the Florida Traffic Crash Report form. A sample crash report is appended (Appendix A). The Florida Department of Highway Safety and Motor Vehicles (DHSMV) assembles the paper forms, warehouses the data, and for crashes on state maintained roadways, supplies crash data to FDOT. FDOT safety office has personnel responsible for entering the data in an electronic database (Crash Analysis Reporting (CAR) System). The location of each crash is linearly referenced to the FDOT roadway system using the milepost system indexed by the roadway identification number (Roadway ID).

5.1.2 Roadway characteristics inventory (RCI) database

The FDOT statistics office maintains an electronic inventory of the state roadway system referred to as the Roadway Characteristics Inventory (RCI). This database consists of hundreds of roadway attributes that are essential in highway safety modeling. Roadway traffic and geometrics and traffic data were obtained from the RCI database. Roadway geometric characteristics data included information such as horizontal curves, shoulder width, lane width, and number of lanes while traffic data consist of the average annual daily traffic and posted speed limit. It should be noted that RCI data represents surface width which could be used to calculate the average lane width and not individual lane width. The RCI data is also associated to a specific roadway segment by milepost system through the roadway identification number (Roadway ID).

5.2 Data Analysis

5.2.1 Merging CAR and RCI databases

Data from CAR and RCI database were merged using roadway ID as a key identifier. Merging of the two databases made it possible for a comprehensive examination of statewide data using data from both the crash reports and the FDOT roadway inventory. Two types of analyses – high crash site ranking and crash modeling were performed. The two analyses are discussed next.

5.2.2 Crash data ranking analysis

Traffic crashes have been used as a direct measure of highway safety. If an unusually high number of crashes occur at a location, it is probable that something associated with the roadway design or traffic operation is unsafe. Ranking of locations with the highest frequency provides a means of thoroughly examining geometric and traffic characteristics of the high frequency crash locations. In order to determine the locations with similar characteristics, roadway segmentation was performed. The roadways were divided into segments defined by any change in the geometric and/or roadway variables (e.g., a new section would be identified when the lane changes from 10 to 11 feet, or when Average Annual Daily Traffic (AADT) changes from 10,000 to 15,000). Therefore, each highway segment is uniform with respect to all the possible geometric and traffic attributes recorded by the FDOT database. A statistical software (STATA) was used to determine the frequency of crashes for each segment. Ten locations with the highest bus sideswipe crash frequencies were identified. Table 5.1 shows a list of the top ten locations in the State of Florida with high sideswipe crashes.

Table 5.1. Segments with the Highest Frequency of Sideswipe Crashes (Year 2003 to Year 2007)

Roadway ID	Crash Frequency	State Road Number	Street Name	City	Begin Milepost	End Milepost	Average Lane Width
87037000	11	SR 907	Alton Rd	Miami	1.1	2.583	9
12010000	9	SR 45	Cleveland Ave	Fort Myers	21.027	23.421	10
87140000	9	SR 7	NW 7th Ave	Miami	5.649	10.714	9
15150000	8	SR 55	34th St N	St. Petersburg	8.078	8.907	10
72080101	8	SR 15	Union Street	Jacksonville	0.282	1.024	12
72150000	8	SR 115	Norwood Ave	Jacksonville	0.72	1.9	9
86200000	8	SR 858	Hallandale Beach Blvd	Miami	3.63	5.429	11
87060000	8	SR A1A	Collins Ave	Miami	4.535	5.472	10
86020000	7	SR 5	US 1/SR5/Federal Hwy	Fort Lauderdale	0	15.325	10
87060000	7	SR A1A	Collins Ave	Miami	5.649	6.669	11

A list of the top ten segments with the highest frequency of sideswipe crashes was reviewed to determine what they have in common. Only one roadway segment in the top ten was found to be 12 feet wide, i.e., Union Street in the city of Jacksonville. Further investigation revealed that this segment is a one-way four-lane roadway located adjacent to the transit plaza where most of the buses change routes. The remaining nine segments had lane widths ranging from 9 feet to 11 feet. Seven out of ten were found to be 10 feet wide or narrower.

Table 5.2 shows some attributes of interest for the top ten high-sideswipe crash locations in the state. The results indicate that all ten sites are designated to be either urban minor or urban principal arterials. Nine out of the ten segments have urban design – curb and gutter. A site review using FDOT video logs revealed that the segments which have paved shoulders have on-street parking which might have contributed to the high frequency of sideswipe crashes. Typically, the presence of a shoulder enables vehicles to swerve to the right and avoid sideswipe crashes. The posted speed limits for all ten segments ranged between 20 to 45 mph. Most bus routes are located on roadways with speed limits less than or equal to 45 mph. The review of crash reports revealed that these crashes involved a bus and vehicles moving in the same direction.

Table 5.2. Selected Variables for Segments with the Highest Frequency of Sideswipe Crashes (Year 2003 to Year 2007)

Roadway ID	87037000	12010000	87140000	15150000	72080101	72150000	86200000	87060000	86020000	87060000
Ranking	1	2	3	4	5	6	7	8	9	10
Street name	Alton Rd	Cleveland Ave	NW 7th Ave	34th St N	Union Street	Norwood Ave	Hallandale Beach Blvd	Collins Ave	US 1/SR5/Federal Hwy	Collins Ave
City	Miami Beach	Fort Myers	Miami	St. Petersburg	Jacksonville	Jacksonville	Miami	Miami Beach	Fort Lauderdale	Miami Beach
Route ID	SR 907	SR 45	SR 7	SR 55	SR 139	SR 117	SR 858	SR A1A	SR 5	SR A1A
Number of lanes	4	6	6	6	4*	4	6	4	6	3*
Roadway functional class	Urban minor arterial	Urban principal arterial	Urban minor arterial	Urban principal arterial-other	Urban principal arterial-other	Urban minor arterial	Urban principal arterial-other	Urban principal arterial-other	Urban principal arterial-other	Urban principal arterial-other
Shoulder type	Paved**	Curb and gutter	Curb and gutter	Curb and gutter	Curb and gutter	Curb and gutter	Curb and gutter	Curb and gutter	Curb and gutter	Paved**
Median width (ft)	4	10	11	16	0	0	35	0	27	0
Curbed	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Divided	Yes	Yes-painted	Yes-painted	Yes	No	No	Yes	No	Yes	No
1 or 2 way	2-way	2-way	2-way	2-way	1-way	2-way	2-way	2-way	2-way	1-way
Speed Limit (mph)	20	40	40	45	35	30	40	30	45	30
AADT	39,000	52,500	37,500	45,500	26,500	17,300	34,000	25,500	50,000	35,000

* One-way street
**Classified as paved but FDOT video logs show on-street parking with curb and gutter

5.2.3 Crash data modeling

Crash modeling involves the use of stochastic techniques to explain the relationship between pertinent variables that influence crash occurrence. In this case, we have crash frequency for the study period of five years (2003 to 2007). The Poisson regression model was used to model the relationship between crash frequency and specific geometric and traffic variables. Poisson regression model was employed because Poisson distribution approximates rare-event count data, such as crash occurrence. The Poisson Regression Model is well described by Washington et al. (2003). Consider the number of crashes occurring per year at various segments. In a Poisson regression model, the probability of segments having y_i crashes per year where y_i is a non-negative integer is given by

$$P(y_i) = \frac{Exp(-\gamma_i)\gamma_i^{y_i}}{y_i!}$$

Where $P(y_i)$ is the probability of segment I having y_i crashes per year and γ_i is the Poisson parameter for segment *i*, which is equal to the expected number of crashes per year at segment *i*, E[y_i].

Twelve variables from RCI and CAR databases were used in the model. Crash frequency was the only independent variable. Continuous dependent variables included AADT, segment length, median width, and shoulder width. Lane width was divided into four categories i.e., 9 feet, 10 feet, 10 feet, 11 feet, and 12 feet. Any lane width less than 9 feet was categorized as 9 feet while any lane width greater than 12 feet was grouped with 12-foot lanes. Lane widths were rounded to the nearest integer. Other discrete variables included weather, the presence of curve, pavement conditions, speed, day of the week, and distance from the intersection. Segment length was assumed to be the exposure variable. Table 5.3 shows metadata of model variables. The results of the Poisson regression model are shown in Table 5.4 and discussed next.

Table 5.3. Metadata of the Poisson Model Variables

Variable	Categories
Lighting	Daylight = 0, otherwise = 1
Weather	Clear = 0, otherwise = 1
Pavement conditions	Dry = 0, otherwise = 1
Posted speed limit	15 to 35 mph = 0, 40 to 70 mph = 2
Day of week	Weekend = 0, weekday = 1
Distance from intersection	250 feet from intersection = 0, otherwise = 1
Degree of curve	Tangent segment = 0, curved segment = 1

Table 5.4. Parameter Estimates of the Poisson Regression Estimated on the Crash Data

Poisson regression	Number of obs = 511			
	LR chi2(10) = 475.57			
	Prob > chi2 = 0.0000			
Log likelihood = -1163.6695	Pseudo R2 = 0.1697			
Crashes	Coefficient	Std. Err.	z	P>z
AADT	2.39E-06	1.24E-06	1.93	0.054
Lane width	-0.30843	0.037494	-8.23	0
Median width	-0.03035	0.003499	-8.67	0
Shoulder width	-0.0058	0.010866	-0.53	0.593
Weather	0.028569	0.080423	0.36	0.722
Degree of curve	0.058273	0.117691	0.5	0.621
Pavement conditions	0.005127	0.178409	0.03	0.977
Posted speed limit	-0.78554	0.076557	-10.26	0
Day of week	0.04566	0.08381	0.54	0.586
Distance from intersection	-0.0547	0.116504	-0.47	0.639
Constant	4.116439	0.414781	9.92	0
Segment length	(exposure)			

5.2.4 Average annual daily traffic

The probability of crash occurrences increases with an increase in traffic volume. The model predicts higher number of crashes per segment as AADT increases. However, based on 95% level of significance (alpha = 0.05), the influence of AADT on bus sideswipe crash occurrence was not significant (*p*-value=0.054).

5.2.5 Lane width

Wider lanes provide larger separation between vehicles moving in adjacent lanes. Wider lanes also allow for motorists to stay in their lanes instead of encroaching adjacent lanes when they have small deviations from their intended paths. Nowhere is room for error correction important than when two heavy vehicles travel on adjacent lanes. The lane width of 12 feet was kept as a control. The results in Table 5.4 show that a decrease in the lane width from 12 feet increases the likelihood of crash frequencies. The *p*-value (*p*-value <0.001) suggest a strong relationship between crash frequency and roadway lane width.

5.2.6 Shoulder width

The presence of adequate shoulder width allows vehicles to swerve away from a sideswipe conflict and hence reducing the occurrences of sideswipe collisions. The negative coefficient for shoulder width suggests that the smaller the shoulder width, the higher the probability of a bus sideswipe crash occurrence. However, based on the observed *p*-value of 0.593, there is no significant evidence that the occurrence of bus sideswipe crashes was influenced by shoulder width.

5.2.7 Weather

Generally, if all other variables remain constant, cloudy, wet, or foggy weather increases the possibility of sideswipe collisions as it affects visibility and friction properties of the pavement. The results show that cloudy, rainy, or foggy weather increases the chance of getting involved in a bus sideswipe collision. However, the data indicate that the influence of weather on bus sideswipe crashes is insignificant.

5.2.8 Horizontal curvature

Negotiating curves requires more attention than driving on a straight section of the road. Generally, drivers adjust their lane positioning as they negotiate a sharp horizontal curve. The results show that a presence of a horizontal curve increases the probability of bus sideswipe crashes. The results however indicate that the horizontal curve is not a significant factor in predicting bus sideswipe crashes (*p*-value=0.621). It should be noted however that the analysis did not consider the severity of the horizontal curve. Only the presence of the horizontal curvature versus a straight section was considered.

5.2.9 Road surface conditions

The results suggest that wet and slippery surfaces have a higher likelihood of causing bus sideswipe crashes compared to dry pavement surfaces. The observed *p*-value (*p*-value = 0.977) however, suggest an insignificant difference between dry and wet/slippery surface.

5.2.10 Speed

Higher speeds are generally associated with higher crash occurrences. The model results suggest the opposite for bus sideswipe crashes. The results indicate that there is a higher probability of bus sideswipe crash involvement on roadways with speed limits ranging from 15 mph to 35 mph than streets with posted speed limits of 40 mph or higher. It is possible that the results are due to the fact that most bus routes operate on roadways which have posted speed limits lower than 40 mph.

5.2.11 Day of week

Typically, there are more buses in service during weekdays than weekends. The results suggest that there is a higher likelihood of bus sideswipe crashes in weekdays than weekends. However based on the *p*-value, the influence of day of the week on bus sideswipe crash occurrence is not significant.

5.2.12 Distance from intersection

Generally, more crashes occur at intersections than on midblock sections. The results suggest that there is an increased influence on crash occurrence near the intersection area. Based on statewide data, the results do not suggest a significant influence of intersection area on sideswipe crashes.

6 TRANSIT AGENCIES INCIDENT REPORT ANALYSIS

Transit agencies maintain records of all incidents that occur when transit vehicles are in service. This study employed hardcopies of incident reports archived locally at the transit agencies' offices. While the crash report completed by police officers is identical throughout the state, there is no standard transit agencies incident reporting system throughout the state. Each agency has its own format of the incident report form. At a minimum, the collision incident report would include the following attributes;

- Crash location: name of the street and the nearby crossing street
- Type of collision
- Accident photograph (if available)
- Collision summary description

Other attributes such as a collision diagram, video, and law enforcement crash report were also included if available. The incidence reports were reviewed to determine the percentage of crashes that are reported by law enforcement officers. The review indicated that 79.3% of sideswipe and mirror crashes were not reported by law enforcement officers. Only 5.7% of the bus sideswipe and mirror crashes were found to have attached long forms completed by law enforcement officers. Eight percent of the sideswipe and mirror crashes were reported in the short form while 6.9% of the same category of crashes were reported using a driver exchange form. This finding suggests that about 94% of sideswipe and mirror crashes are not reported in the FDOT CAR system since the database consists of crash records that are reported on the standard long form only.

6.1 Agency Selection

It was not feasible to collect data from all transit agencies in the state due to the nature of the local transit agency incident reports. Some of the agencies contacted were willing to allow the research team to analyze data at the data repository sites but did not allow making copies due to liability issues. Three agencies were therefore chosen for this particular analysis. The three selected agencies were StarMetro in Tallahassee, Jacksonville Transit Authority (JTA) in Jacksonville, and Miami-Dade Transit Authority in Miami.

6.2 Data Collection

The first step of data collection for this particular analysis involved a thorough review of the agencies' incident reports. Any incident that occurs when the transit vehicle is in service whether it is a traffic crash, theft or verbal dispute has to be reported in an incident report. First, the reports were reviewed to identify those that involve traffic crashes with other vehicles or with fixed objects. Second, the reports were further screened to obtain only sideswipe and hitting fixed objects crashes. Lastly, further examination was done to discard any sideswipe and hitting fixed object crashes that were perceived to have been caused by factors other than lane width.

The second step of data collection involved determination of lane width. Most of the roadways in transit routes are not maintained by FDOT. It was therefore not possible to retrieve lane width information from the RCI database. The research team conducted field lane width measurements at most locations where sideswipe and hitting fixed objects occurred in Tallahassee and Jacksonville. Due to time limitations, the research team requested the Miami-Dade public works traffic engineer to provide lane width data for the streets in question. The public works traffic engineer provided lane width data gathered from as-built drawings.

Apart from collecting lane width information, other pertinent information such as AADT, the presence or absence of curb, and median type (divided or undivided) were collected. AADT for Tallahassee streets were obtained from a web based database (www.talgov.org under public works/traffic counts) while AADT from Jacksonville and Miami were obtained from traffic concurrency reports and FDOT GIS database. Lastly, GIS data from all transit agencies in the state were collected for conducting a spatial analysis. In particular, transit routes GIS shapefiles from the transit agencies were collected. Transit route GIS databases were used to compute the proportion of each lane width category on the transit routes.

6.3 Data Analysis

Several analyses were conducted to determine if bus sideswipe and hitting fixed objects crashes occur on narrower roadways. These analyses included descriptive statistics, inferential statistical tests, and a comparative analysis. The lane width was rounded to the nearest integer. All roadways with an average lane width of less than 9 feet were assigned a 9-foot lane width while all lane roadways with an average lane width greater than 12 feet were assumed to be 12 feet wide.

6.3.1 Descriptive statistics

A 95% confidence interval for the mean lane width of the streets that had bus sideswipe and bus hitting fixed objects was computed (Table 6.1). Roadways with such types of crashes related to lane width were found to have a mean lane width of 10.6 feet and a 95% confidence interval of 10.4 feet to 10.7 feet. The results suggest that stochastically, there is a 95% chance that crashes involving bus sideswipe and bus hitting fixed objects would take place on roadways which are narrower than 10.7 feet (approximately 11 feet). It is clear from the results presented in Table 6.1 that most sideswipe crashes that involve buses take place on roadways which are narrower than 11 feet.

Table 6.1. Summary of Descriptive Statistics

Statistics parameter	Value
Mean (ft)	10.550
Standard deviation (ft)	1.113
95% Confidence interval for mean (ft)	10.399 to 10.701
Sample size	211

6.3.2 Inferential statistical tests

An extremely useful application of statistics is in comparing different samples or groups. In this case, a set of average widths of the roadways on transit routes is compared with a sample of roadway within transit routes that had collisions involving bus sideswipe and bus hitting fixed objects. An inferential statistical test to determine whether there is a significant difference between the lane widths of roadways where crashes occurred and all roadways on transit routes was conducted. A one-tailed two-sample *t*-test was used to determine whether sideswipe crashes occur predominantly on narrower lanes. The results are summarized in Table 6.2. The average lane width of roadways that had sideswipe and mirror collisions was found to be 10.55 feet while the mean lane width for the general transit routes was 11.51 feet. Based on the estimate of the difference, the results suggest that roadway lanes which had lane width-related bus collisions are narrower by about 1 foot (0.96 foot) compared to the overall population of lanes on transit routes. A one-tail two-sample *t*-test revealed that a significant difference exists with a *p*-value of less than 0.001. The results strongly suggest that sideswipe and mirror crashes occur predominantly on narrow roadways.

Table 6.2. Two-Sample t-Test Results for Comparing Lane Widths of Roadways with Sideswipe and Mirror Crashes with All Roadways on Transit Routes

Dataset	Mean Lane Width	Standard Deviation	Standard Error Mean
Roadways with sideswipe crashes	10.55	1.11	0.08
All roadways on transit routes	11.51	0.70	0.02
Estimate of the difference = -0.96 One-tail *t*-Value = -12.24 *P*-Value <0.001 Degrees of freedom = 231			

6.3.3 A comparative analysis

A comparative analysis was performed using data from the transit agencies. This particular analysis divided the lane width into four categories i.e., 9 feet, 10 feet, 11 feet, and 12 feet. The proportion of each category on transit routes was computed. The proportion of lane width-related crashes for each category was then calculated (Table 6.3). The analysis revealed that only 1.56% of the roadways used by transit routes are 9 feet while 67.49% of the roadways on transit routes were found to be 12 feet wide. The percentages of 10 feet and 11 feet wide roadways on transit routes were found to be 3.89% and 27.05%, respectively. Despite the fact that there are only 1.56% of the roadways on transit routes which were 9 feet wide, they represented over 23.22% of the sideswipe and mirror collisions.

Table 6.3. Comparative Analysis Results

Lane Width (ft)	Transit Routes (miles)	% Transit Lanes	# Crashes	% Crashes
9'	324	1.56	49	23.22
10'	805	3.89	52	24.64
11'	5599	27.05	55	26.07
12'	13969	67.49	55	26.07
Total	20697	100.00	211	100.00

Overrepresentation in sideswipe and mirror crashes were also observed for 10-foot wide roadways. Ten foot wide roadways accounted for 24.64% of all sideswipe and mirror collisions.

On the other hand, the results indicate that 12-foot wide roadways account for only 26.07% of sideswipe and mirror crashes while they represent about 67.49% of the transit routes network. The results of the comparative analysis are graphically presented in Figure 6.1.

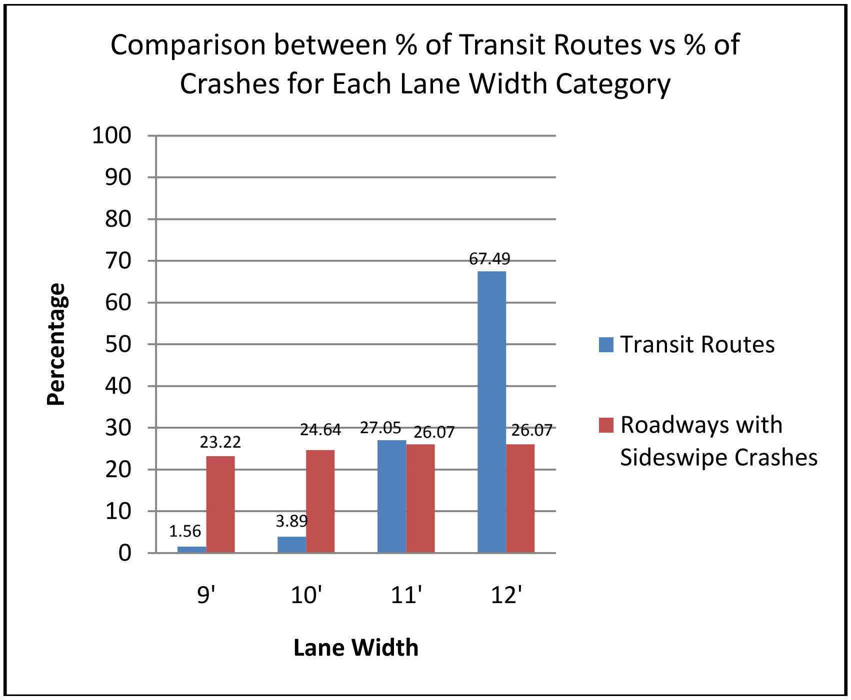

Figure 6.1. Comparative analysis of lane width for roadways on transit routes versus roadways with sideswipe and mirror collisions

6.3.4 Overrepresentation analysis

The results of the comparative analysis were used to determine sideswipe and mirror crash overrepresentation ratios for each lane width category. The overrepresentation ratio for each lane width category was computed as the proportion of crashes in each lane width category divided by the proportion of roadways on transit routes for the same lane width category. The ratio of the percentage of crashes to the percentage of roadways used for each lane width category is depicted in Figure 6.2. The results suggest higher overrepresentation for 9-foot and 10-foot wide lane roadways and underrepresentation for 12-foot wide lane roadways. Sideswipe and mirror crashes on roadways with 9-foot wide lanes were found to be proportionally overrepresented by the ratio of 14.88 while streets with 12-foot wide lanes were underrepresented by the ratio of 0.39.

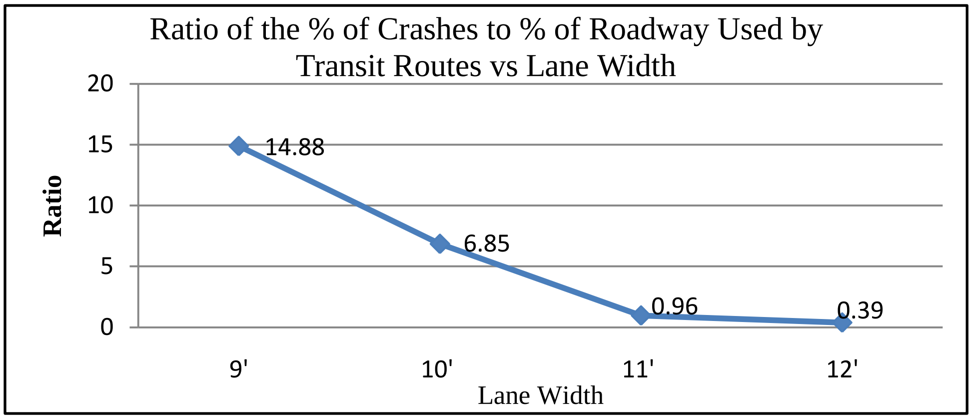

Figure 6.2. Ratio of the percentage of crashes to the percentage of roadways used by transit routes versus lane width

An additional analysis was conducted to include exposure data. The exposure data used was the bus miles traveled for each lane width category. The bus miles traveled were calculated based on the number of bus passes for each segment which were computed from productivity and schedule data obtained from transit agencies. Table 6.4 summarizes the results of this analysis. Roadways with average lane width of 9-foot or narrower were found to have higher number of sideswipe crashes per million buses per mile (15.82) while roadways with average lane widths of 12 or higher were found to have the lowest rate (0.44 sideswipe crashes per million buses per mile). It was observed that narrower road segments tend to be shorter while segments with standard lane widths (12-foot or wider) are longer hence causing narrower roadways to have higher bus sideswipe crash rates and wider roadways to have lower rates. The results in Tables 6.3 and 6.4 are in agreement, suggesting a strong relationship between lane width and bus sideswipe and mirror strike crashes.

Table 6.4. Overrepresentation Based on Number of Sideswipe Crashes per Million Buses per Mile

Lane Width (ft)	Average Bus Miles Traveled per Day (Mile buses per day)	Number of Sideswipe Crashes	Number of Sideswipe Crashes per Million Buses per Mile
9'	3,096.3	49	15.82
10'	35,934.3	52	1.45
11'	64,070.4	55	0.86
12'	124,801.1	55	0.44
Total	227,902.2	211	0.93

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7 FIELD OBSERVATION OF ROADWAY WITH NARROW LANES

A field observational study was conducted to determine lane encroachment characteristics at sites with different lane widths. Bus movements were collected by videotaping which were later reviewed in the office. Videotapes were used to examine lane encroachments and other tight geometry effects on bus operations.

7.1 Roadside videotaping

Field observations by videotape were conducted at five sites including one site with narrow lanes at the intersection. Two sites had 10-foot lane widths and the other three sites had 8-foot lanes. The sites were Tennessee (section between Copeland Street and Macomb Street, and between Duval Street and Bronough Street), Palmetto Drive (section between Woodward Street and Chieftain Way), and Jefferson Street (section between Copeland Street and Woodward Street, and between Macomb Street and Copeland Street). All selected sites were located in Tallahassee.

7.2 Results of field observational study

Table 7.1 summarizes lane encroachments by buses as observed in the field. The number of times the bus encroaches another lane was recorded. The field observational study revealed the following:

- Narrower lanes make it difficult for bus and heavy vehicle drivers to position their vehicle completely within their lane.
- Buses fail to maintain their lanes when maneuvering tight horizontal curves on narrow lanes.
- The passing maneuver between two opposing buses on 10-foot, two-way, two-lane roadways was hard to perform. One bus had to stop to give room for another bus to pass.
- Buses were encroaching an adjacent lane whenever performing right turning maneuver onto a street with narrower lanes.
- Field observation also revealed a problem with location of bus stops. Most of the bus stops were located close to the intersections where in most cases the lanes were narrow. One of the reasons for the reduction of lane width at intersections was to allow for the addition of exclusive left-turn lanes by repainting the existing roadway surface. This forces buses to encroach adjacent lanes, causing potential of mirror collisions.

Table 7.1. Field Observational Study Results

Road	Road Section Between	Lane Width	Divided/ Undivided	Curbed	Number of Observations	Total Bus Encroachments
Jefferson St	Macomb St and Copeland St	10	Undivided	Yes	10	5
Jefferson St	Copeland St and Woodward St	8	Undivided	Yes	23	22
Palmetto Dr	Woodward St and Chieftain Way	11	Undivided	Yes	21	5
Tennessee St	Duval St and Bronough St	8.7	Undivided*	Yes	16	12
Tennessee St	Copeland St and Macomb St	8.5	Divided	Yes	16	11

*Has two-way, left-turn (TWLT) lane

Figures 7.1 to 7.6 show some of the snapshots of lane encroachments at different locations.

Figure 7.1. Narrow lane forces a bus to encroach the adjacent lane at the intersection between Jefferson Street and Woodward Street in Tallahassee. (8.4-foot wide left-turn lane)

Figure 7.2. Narrow lane forces a bus to encroach the adjacent lane on Tennessee Street near Macomb Street in Tallahassee. (8.7-foot wide lane)

Figure 7.3. Narrow lane forces a bus mirror to encroach the adjacent lane at the section of Palmetto Drive in Tallahassee. (10-foot wide lane)

Figure 7.4. Narrow lane on a tight horizontal curve forces a bus to encroach the adjacent lane on Palmetto Drive in Tallahassee. (10-foot wide lane)

Figure 7.5. Tight turning radius followed by a narrow lane at intersection between Palmetto Drive and Chieftain Way in Tallahassee forces a bus to encroach the adjacent lane. The bus has to wait for the absence of vehicles on the adjacent lane for it to maneuver a right turning movement. (10-foot wide lane)

Figure 7.6. An 8 feet on-street bus bay on Nebraska Avenue in Tampa with the bus encroaching to the adjacent lane

7.3 Remarks

The field observations suggest a major safety problem related to narrower lanes. Encroachments observed were made with bus drivers without being forced by action of other vehicles ahead of them. Narrower lane widths force the encroachment to occur automatically as a driver performs a driving task. However, no collisions were observed during the field observational study.

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8 PHYSICAL CONSTRAINTS ANALYSIS

8.1 Complete Streets Design Principles

A complete street is a road that is designed to be safe for drivers, bicyclists, transit vehicles, and pedestrians of all ages and abilities (Laplante and McCann, 2008). Complete streets focuses more on road users and is about making multimodal accommodation routine so that multimodal roads do not require extra funds or extra time to achieve. In conducting the physical constraints analysis, it was assumed that roadways would be designed with dedicated bike lanes.

8.2 Physical Space Requirements

Physical constraints analysis was conducted to determine the minimum space requirements for buses to operate safely without encroaching into an adjacent lane. It was assumed that streets would be designed using complete streets design principles. To adhere with complete streets design principles, facilities for all modes of transportation including bicycles and pedestrians should be considered in any design. Figure 8.1 depicts the FDOT Greenbook minimum requirements for bicycle lanes on urban (curb and gutter) and suburban (open channel drainage) typical sections. According to the FDOT Greenbook, the minimum bicycle space requirement for an urban design is 5 feet (from motorists' lane to face of curb). A bicycle lane width of 4 feet (from motorists' lane to beginning of shoulder) is required for suburban design. Four scenarios were considered next.

8.2.1 Curbed streets (two-lane, two-way undivided)

Consider Figure 8.1(a). The minimum bike space is 5 feet (4 feet of pavement and 1 foot from the edge of pavement to face of curb). AASHTO assumes a minimum bicyclist width of 30 inches (2.5 feet) as shown in Figure 8.2. The following steps were followed in deriving the minimum lane width requirements for a bus to safely travel in its lane without encroaching into an adjacent lane and violating Florida law requiring 3 feet of clearance to the bicyclist. The results of the physical constraints analysis for a two-lane, two-way undivided curbed street is graphically presented in Figure 8.3(a).

- Assume that bicyclists ride in the center of the bicycle space (2.5 feet from face of curb and 2.5 feet from the edge of motorists' lane).
- This leaves only 1.25 feet lateral clearance between the bicyclist and the edge of vehicular lane.
- To maintain a 3 foot clearance from side of bus to bicyclist, an additional 1.75 feet is required.
- The width of a standard bus is 102 inches (8.5 feet), and a mirror-to-mirror width is approximately 10.5 feet.
- The distance from the face of the curb to the left (drivers side) mirror of the bus in feet is calculated as

$$A + B + C + D + E = F$$

- A minimum outside lane width for the bus (including drivers side mirror) to barely stay in its lane is given as

$$F - G = H$$

- Providing a minimum clearance (L) for mirrors, the minimum lane width becomes H + L = J, or 12.0 ft. as shown in Figure 8.3(a).

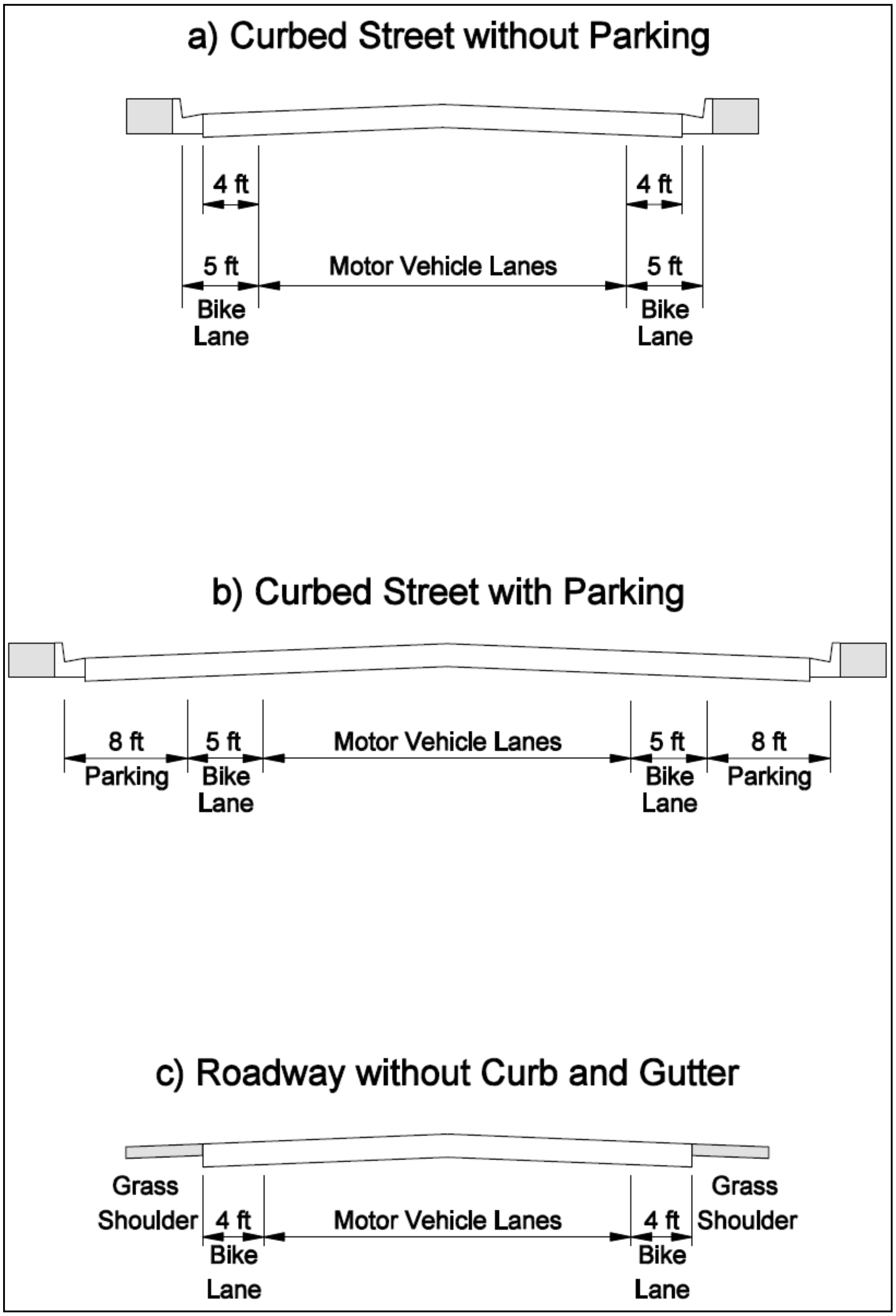


Figure 8.1. Minimum widths for bike lanes (FDOT Greenbook, 2007)

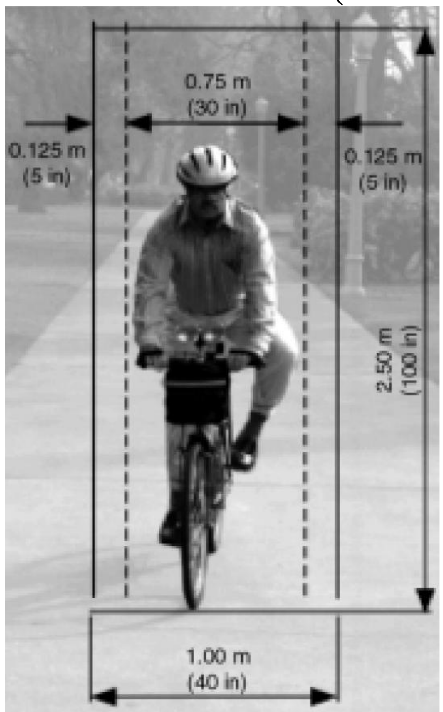
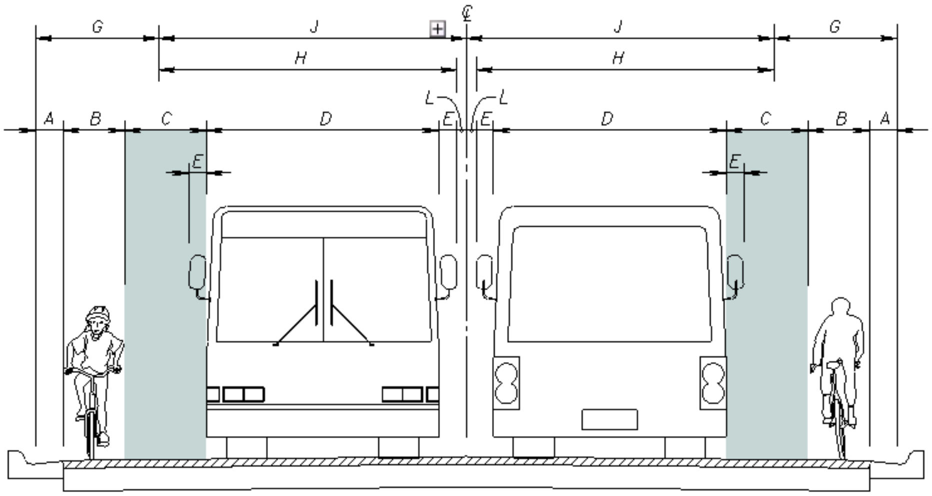


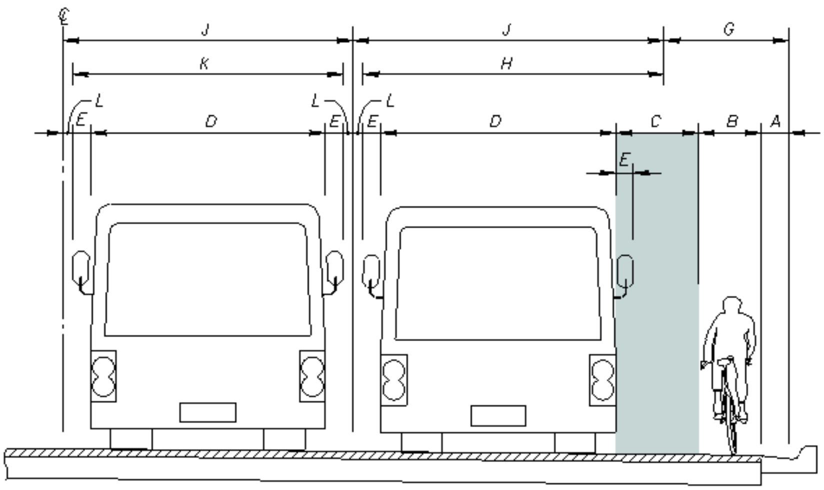
Figure 8.2. Bicycle operating space (AASHTO, 1999)

8.2.2 Curbed streets (four-lane, two-way undivided and four-lane, two-way divided)

The outside lane of four-lane, two-way curbed streets follows the same principles of the two-lane, two-way streets. For the inside lane, the only consideration is the bus dimensions and clearance from a vehicle in the adjacent lane. The worst case scenario is the bus passing another bus or heavy vehicle. Consider two buses on adjacent lanes and the following two assumptions; (1) the bus mirror-to-mirror width of 10.5 feet and (2) median roadside objects are placed with at least 1 foot horizontal clearance from the curb. The recommended inside lane width of 12 feet will allow two buses to pass each other with the lateral clearance of 1.5 foot from mirror- to-mirror. Figure 8.3(b) shows minimum lane width requirements for two buses to pass each other without encroaching into adjacent lanes and yet maintaining a 3 feet lateral clearance from bicycles.



(a) 2-Lane – 2-Way Curbed Roads



(b) 4-Lane – 2-Way Curbed Roads

All values in feet.

Type	A	B	C	D	E	F	G	H	J	K	L
2-Lane	1.25	2.5	3.0	8.5	1.0	16.25	5.0	11.25 2	12.0	0.0	0.75
4-Lane	1.25	2.5	3.0	8.5	1.0	16.25	5.0	11.25 2	12.0 1	10.5 1	0.75

1. For divided 4-Lane -2-Way roads with median, K = 9.5 ft, J = 11.0 ft.
2. Allowed only when right-of-way constraints prohibit recommended travel lane width.

A = Distance from face of curb to edge of bicyclist
B = Required bicyclist area
C = Clearance required between bicyclist and bus
D = Width of bus
E = Width of mirror
F = Distance from face of curb to outside left bus mirror

G = Width of bike lane
H = Minimum travel lane width
J = Recommended travel lane width
K = Minimum inside travel lane width
L = Minimum clearance

Figure 8.3. Recommended lane widths for curbed roads

8.2.3 Streets without curb and gutter

Consider Figure 8.1(c). The minimum bike space is 4 feet (from edge of vehicular lane to beginning of shoulder). The following steps were followed in deriving the minimum lane width requirements for the bus to safely travel on its lane without encroaching into an adjacent lane and violating Florida law requiring 3 feet of clearance to the bicycle.

- Assume that the bicyclists ride on the center of the bicycle space (2.0 feet from the beginning of shoulder and 2.0 feet from the edge of motorists' lane).
- This leaves only 0.75 feet lateral clearance between the bicyclist and the edge of vehicular lane.
- To maintain a 3 foot clearance from side of bus to bicyclist, an additional 2.25 feet is required.
- The width of a standard bus is 102 inches (8.5 feet), and a mirror-to-mirror width is approximately 10.5 feet.
- The distance from the beginning of the shoulder to the left (drivers side) mirror of the bus in feet is calculated as

$$A + B + C + D + E = F$$

- A minimum outside lane width for the bus (including the driver's side mirror) to barely stay in its lane is given as

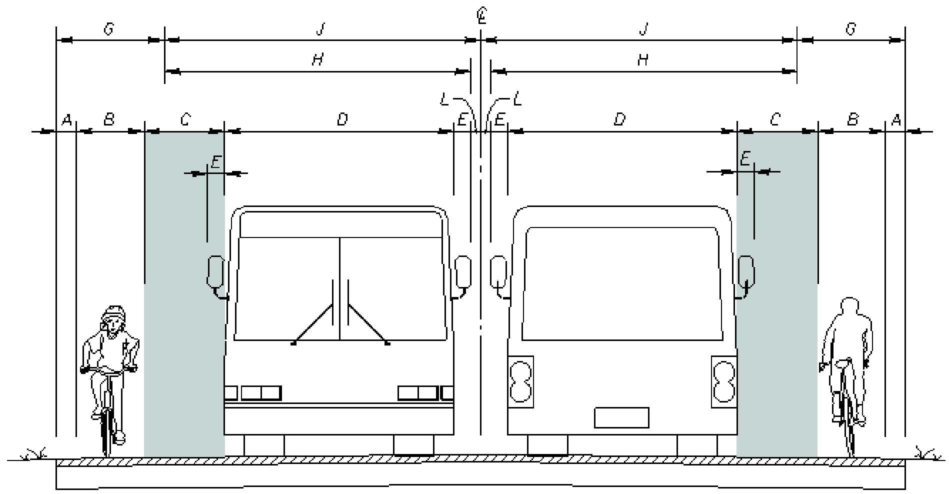
$$F - G = H$$

- Providing a minimum clearance (L), the minimum lane width becomes

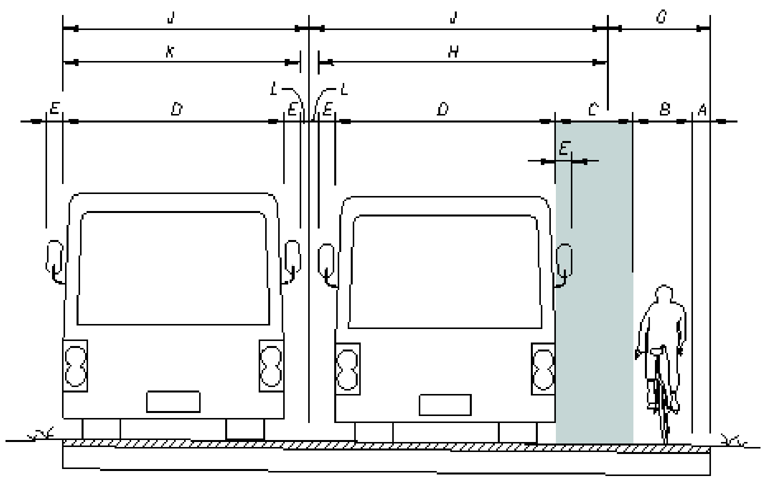
$$11.75 + 0.25 = 12.00 \text{ ft}$$

- A minimum of 12.00 ft is therefore recommended.

The minimum lane requirements for two-lane and four-lane two-way roadways are presented in Figure 8.4(a) and (b), respectively.



(a) 2-lane -2-way Suburban roads



(b) 4-lane -2-way Suburban roads

All values in feet.

Type	A	B	C	D	E	F	G	H	J	K	L
2-Lane	0.75	2.5	3.0	8.5	1.0	15.75	4.0	11.75	12.0	0.0	0.25
4-Lane	0.75	2.5	3.0	8.5	1.0	15.75	4.0	11.75	11.0 [1]	9.5 [1]	0.25

1. For undivided 4-Lane -2-Way roads with median, K = 10.5 ft, J = 12.0 ft.

A = Distance from face of curb to edge of bicyclist
B = Required bicyclist area
C = Clearance required between bicyclist and bus
D = Width of bus
E = Width of mirror
F = Distance from face of curb to outside left bus mirror

G = Width of bike lane
H = Minimum travel lane width
J = Recommended travel lane width
K = Minimum inside travel lane width
L = Minimum clearance

Figure 8.4. Recommended lane widths for suburban roads

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The main objective of this study was to evaluate the influence of lane width on the safety of transit vehicles. The research team conducted a comprehensive analysis of the influence of lane width on transit vehicle safety using a combination of methods. Each method was geared towards investigating whether there is a significant relationship between lane widths and bus safety. The five methods employed were: (1) Questionnaire Survey, (2) Statewide Bus Crash Analysis, (3) Transit Agencies Incident Reporting Analysis, (4) Field Observational Study, and (5) Physical Constraints Analysis. The results pertaining to each of the five methods are summarized below.

9.1.1 Questionnaire survey

The questionnaire survey revealed that most bus collisions occur on roadways with lane widths of 11 feet or less. The survey also revealed a relationship between tight turning geometry and lane width. Most of the intersections that were categorized as having tight turning geometry and most prone to bus crashes were found to have lane widths of less than or equal to 11 feet.

9.1.2 Statewide bus crash analysis

Nine out of ten segments in the list of the top ten segments with the highest frequency of sideswipe crashes had lane widths ranging from 9 feet to 11 feet. Seven out of ten were found to be 10 feet wide or narrower. The results of the Poisson Regression Analysis indicated a negative relationship between number of crashes on a segment and the lane width, suggesting that the decrease in lane width is likely to increase the frequency of crash occurrence. Apart from lane width, the results of the Poisson regression analysis indicated that the average annual traffic volume, posted speed limit, and median width have influence on occurrence of bus sideswipe crashes.

9.1.3 Transit agencies incident reporting analysis

The average width of the roadways that had sideswipe and mirror collisions was found to be 10.55 feet. A one-tail two-sample t-test revealed a significant difference exists with a p-value of less than 0.001. The results strongly suggest that sideswipe and mirror crashes occur predominantly on narrow roadways. A comparative analysis was performed to compare the percentage of each lane width on transit routes for three agencies – Tallahassee StarMetro, Jacksonville Transit Authority, and Miami-Dade Transit Authority. The analysis revealed that only 1.56% of the roadways used by transit routes are 9 feet while 67.49% of the roadways on transit routes were found to be 12 feet wide. The percentages of 10-foot and 11-foot wide roadways on transit routes were found to be 3.89% and 27.05%, respectively. This supports the fact that many transit agencies avoid traveling on roadways with narrow lane widths, often rerouting to parallel or adjacent facilities with wider lanes to safely accommodate buses.

Despite the fact that there are only 1.56% of the roadways on transit routes which were 9 feet wide, they represented about 23.22% of the sideswipe and mirror collisions. Overrepresentations in sideswipe and mirror crashes were also observed on 10-foot wide roadways. Ten-foot wide roadways accounted for 24.64% of all sideswipe and mirror collisions. On the other hand, the results indicate that 12-foot wide roadways accounted for only 26.07% of sideswipe and mirror crashes while they represent over 67% of the transit routes network. The ratio of the percentage of crashes to the percentage of roadways used for each lane width category suggests overrepresentation of 9 and 10-foot wide lanes on sideswipe crashes. Further analysis indicated that narrow lanes have higher rate of bus sideswipe crashes per miles traveled.

9.1.4 Field observational study

The results of the lane encroachment analysis led to the following conclusions.

- Narrower lanes make it difficult for bus drivers to position their vehicle completely within their lane.
- Buses fail to maintain their lanes when maneuvering tight horizontal curves on narrow lanes.
- The passing maneuver between two opposing buses on 10-foot, two-way, two-lane roadways was hard to perform. One bus had to stop to give room for another bus to pass.
- Buses were encroaching an adjacent lane whenever performing right turning maneuver onto a street with narrower lanes.
- Field observation also revealed a problem with location of bus stops. Most of the bus stops were located close to the intersections where in most cases the lanes were narrow. One of the reasons for the reduction of lane width at intersections was to allow for the addition of exclusive left-turn lanes by repainting the existing roadway surface. This forces buses to encroach on adjacent lanes, causing potential of mirror collisions.

9.1.5 Physical constraints analysis

Physical constraints analysis was conducted to determine the minimum space requirements for buses to operate safely without encroaching into an adjacent lane. It was assumed that streets will be designed using complete streets design principles. Two main requirements were considered: adhering to a 3-foot clearance for bicyclists (Florida Statute 316.083), and maintain the bus including its mirrors in the same lane without encroaching into the adjacent lane. The results of this analysis indicate that a minimum of 11.25 feet and 11.75 feet for the outside lane is required for curbed roadways and roadways without curb and gutter, respectively, to meet these requirements. However, a 12-foot wide outside lane is recommended for all bus routes. The physical constraints analysis suggests a minimum lane width of 11 feet for the inside lane for four-lane, two-way roadways (both curbed and uncurbed). Minimum requirements for roadways with on-street parking are the same as for the streets with curb and gutter.

In summary, this research project employed five different study methods to determine the influence of lane width on bus safety. The study considered sideswipe and mirror crashes as they are predominantly caused by narrow lane geometry. All five studies consistently suggest a strong relationship between lane width and bus safety. The results suggest that the narrower the lane width, the higher the likelihood of having bus sideswipe and mirror crashes. The results also indicate that locations with tight turning geometry were associated with narrow lane widths.

9.2 Recommendations for Safe and Convenient Transit Services in Traditional Neighborhood Design Communities

Based on the findings of this study, it is recommended that 12-foot wide lanes be provided as practical as possible for roadways located on transit routes. Narrower lanes cannot accommodate buses fully without causing encroachments into adjacent lanes. However, to achieve national sustainability and livability goals,many state and local governments will be encouraging the implementation of Complete Streets and TND communities which often include narrower lanes. To address these conflicting issues, this report also illustrates how TND and other livable communities can be designed to provide a bicycle and pedestrian friendly environment which also accommodates safe and convenient transit operations. Figures 9.1 to 9.4 depict prototypes of possible scenarios where bus routes can be established on the perimeter of the compact, walkable communities.

TND is characterized by more dense, compact development with shorter blocks, connected sidewalks and access to transit stops to support walkability and reduce dependence on the automobile. Narrow lanes are often recommended for the local residential streets to provide a pedestrian scale and reduce travel speeds within the residential neighborhoods. These communities are often bounded by major arterial or collector roadways which include wider lanes to support a higher volume of traffic and provide connectivity to activities outside the community. By locating transit routes and stops along the perimeter of the communities, within a ¼ to ½ mile from the center of the neighborhood, transit vehicles can operate more safely on the wider arterials and still provide residents with safe and convenient access to transit services.

Thus, the inclusion of both narrow lanes within compact urban areas to support walkability, and wider lanes on the perimeter of these communities to support safer transit operations, allows for a balanced approach to providing more walkable and livable communities to enhance sustainability and mobility within Florida.

Another important aspect of balancing the narrow lanes with safe transit operations is the need for continuous communication and coordination between local roadway designers and planners and the local transit agencies. If local transit agencies are included in the early conceptual design phases of the community and street network, issues affecting transit operations may be identified and resolved prior to construction. Coordination and communication can be achieved through local government development review meetings and processes, MPO technical committees and general coordination meetings between the two agencies.

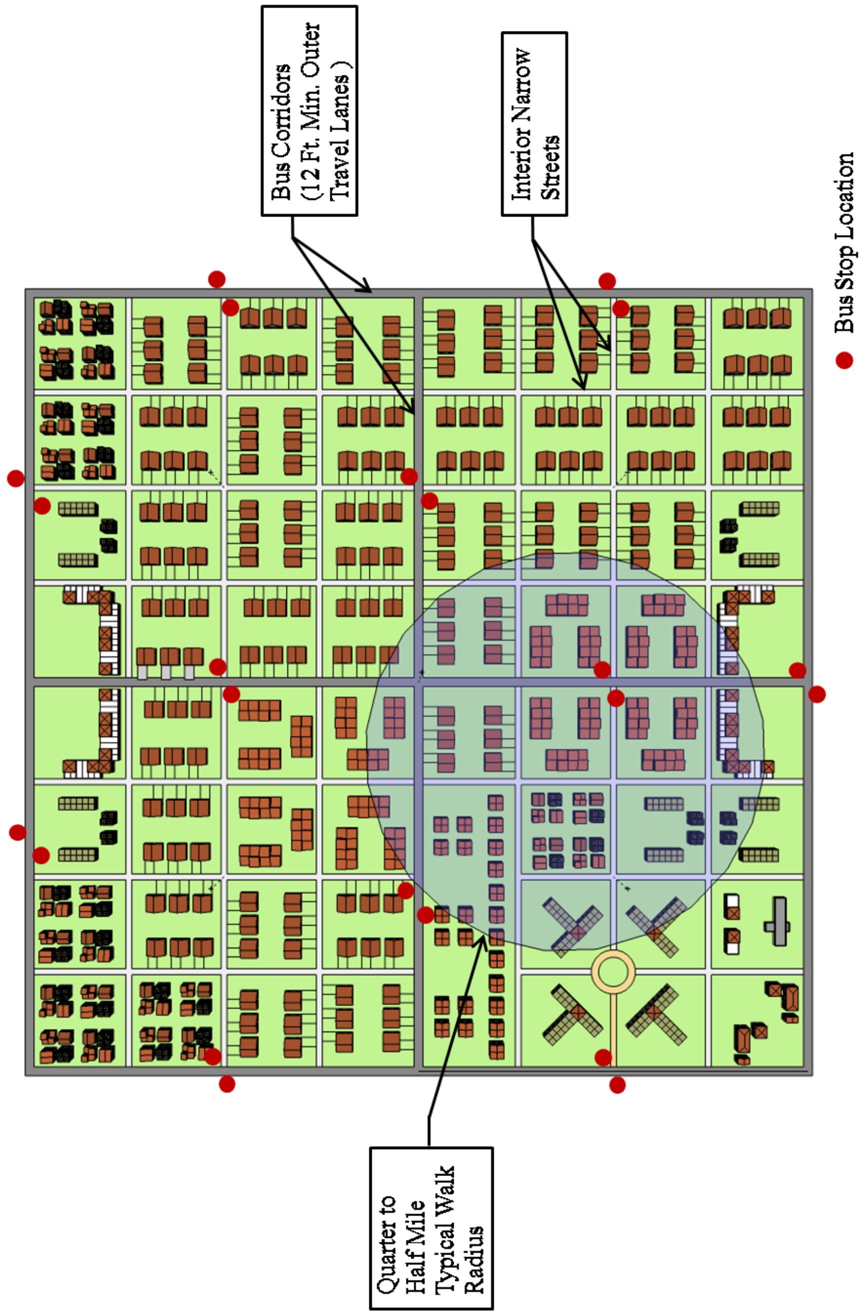


Figure 9.1. Mixed-Use Prototype

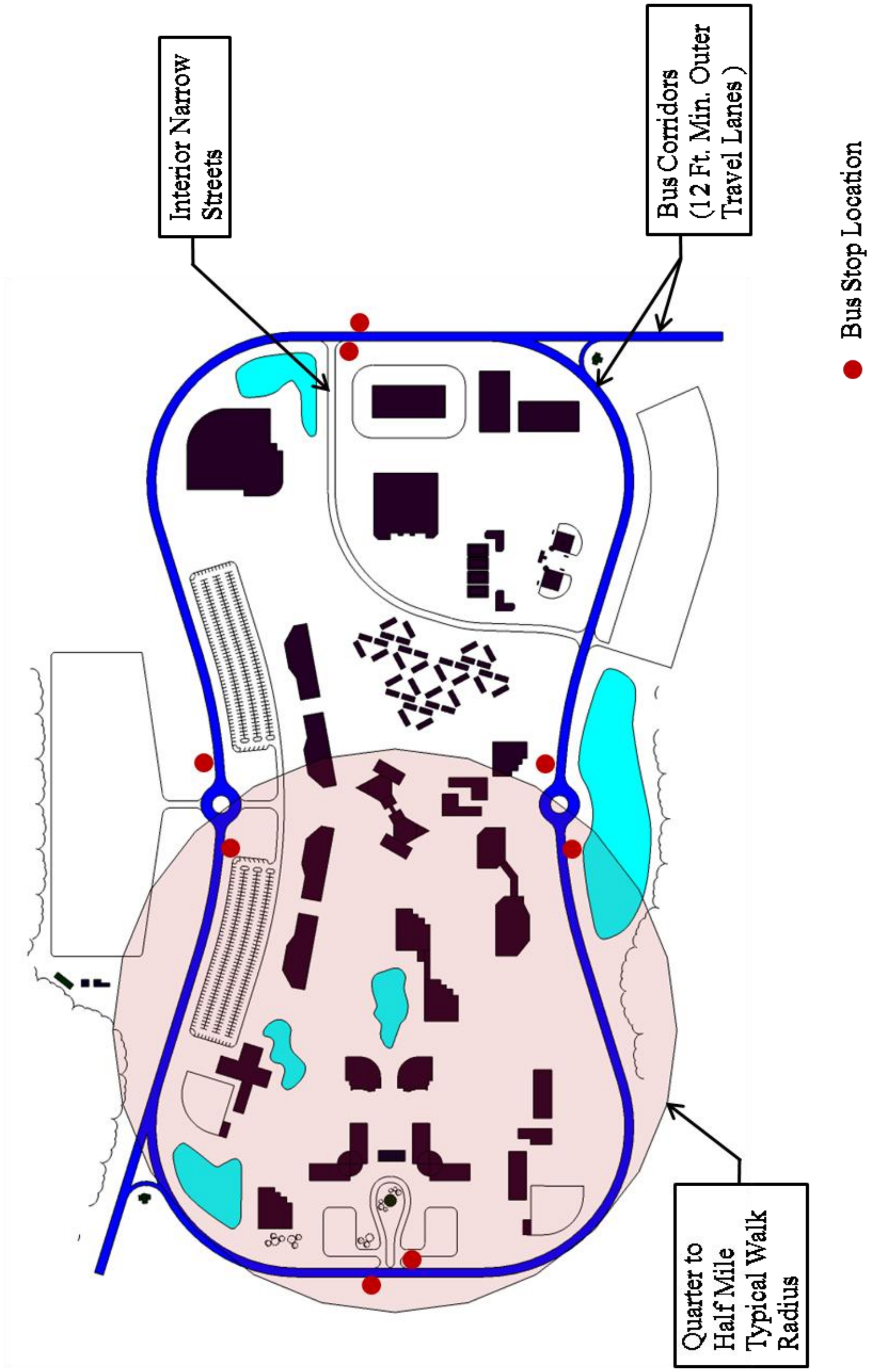


Figure 9.2. Campus/Institutional Prototype

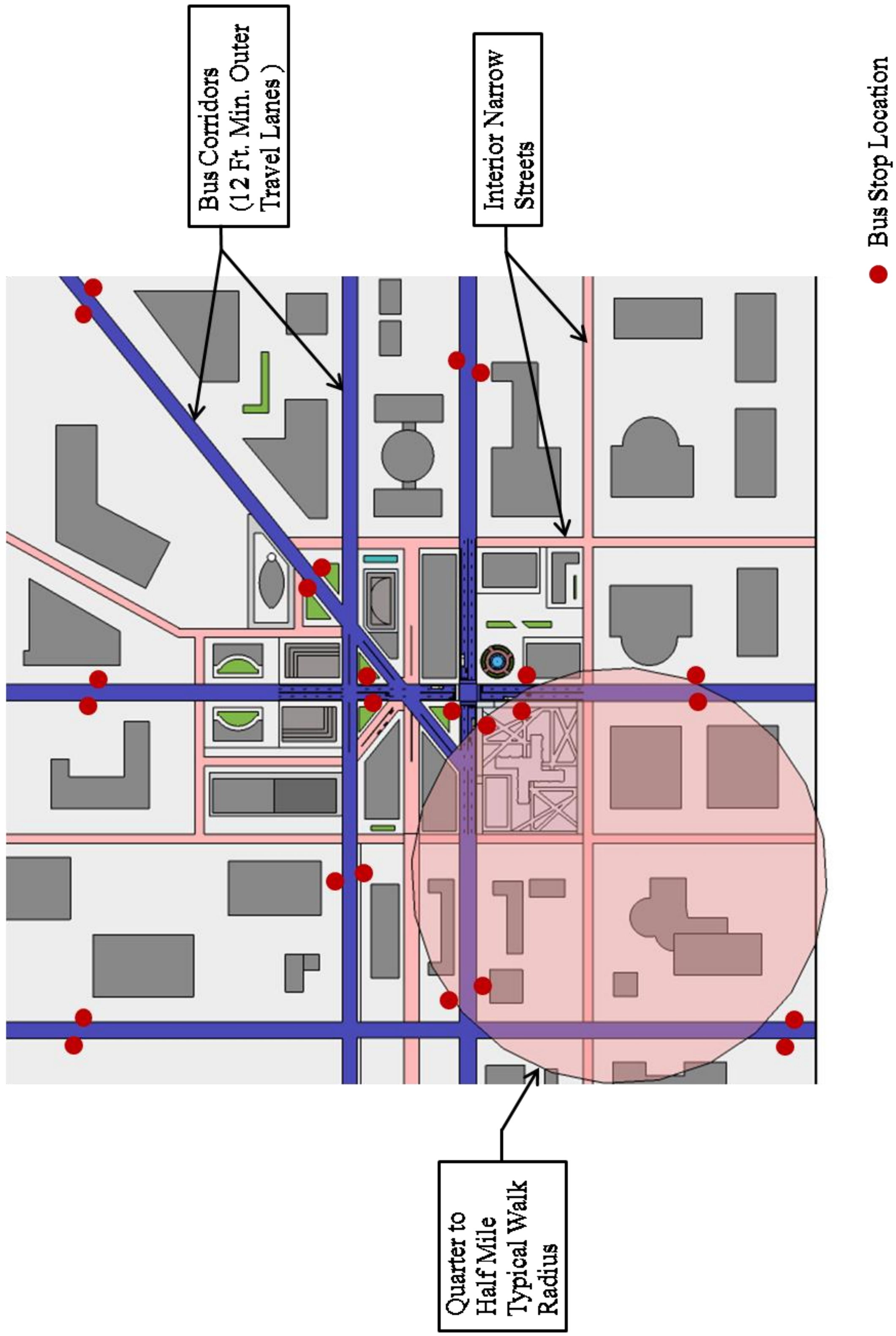


Figure 9.3. Central Business District Prototype

Figure 9.4. Suburban Residential Prototype

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Appendix A

Florida Traffic Crash Report

FLORIDA TRAFFIC CRASH REPORT

LONG FORM

MAIL TO: DEPT. OF HIGHWAY SAFETY & MOTOR VEHICLES, TRAFFIC CRASH RECORDS, NEIL KIRKMAN BUILDING, TALLAHASSEE, FL 32399-0537

DO NOT WRITE IN THIS SPACE

Time & Location

DATE OF CRASH | TIME OF CRASH AM PM | TIME OFFICER NOTIFIED AM PM | TIME OFFICER ARRIVED AM PM | INVEST. AGENCY REPORT NUMBER | HSMV CRASH REPORT NUMBER 76063003

COUNTY / CITY CODE | FEET or MILE(S) | N S E W of | CITY OR TOWN | (Check if in City or Town) | COUNTY

AT NODE NO. or FEET or MILE(S) | FROM NODE NO. | NEXT NODE NO. | NO. OF LANES | 1. DIVIDED 2. UNDIVIDED | ON STREET, ROAD OR HIGHWAY

AT THE INTERSECTION OF (street, road or highway) or FEET | MILE(S) | N S E W | FROM INTERSECTION OF (street, road or highway)

Section 1 — Vehicle / Pedestrian

DRIVER ACTION 1. Phantom 2. Hit & Run 3. N/A | YEAR | MAKE | TYPE | USE | VEH. LICENSE NUMBER | STATE | VEHICLE IDENTIFICATION NUMBER

TRAILER OR TOWED VEHICLE INFORMATION | TRAILER TYPE

2 3 4 5 6 7 — 1 15 16 17 8 — 14 13 12 11 10 9

18. Undercarriage 19. Overturn 20. Windshield 21. Trailer

SHOW FIRST POINT OF VEHICLE DAMAGE AND CIRCLE DAMAGED AREA(S)

VEHICLE TRAVELLING N S E W | ON | AT | Est. MPH | Posted Speed | EST. VEHICLE DAMAGE 1. Disabling 2. Functional 3. No Damage | EST. TRAILER DAMAGE

MOTOR VEHICLE INSURANCE COMPANY (LIABILITY OR PIP) | POLICY NUMBER | VEHICLE REMOVED BY: 1. Tow Rotation List 2. Tow Owner's Request 3. Driver 4. Other

NAME OF VEHICLE OWNER (Check Box If Same As Driver) | CURRENT ADDRESS (Number and Street) | CITY AND STATE | ZIP CODE

NAME OF OWNER (Trailer or Towed Vehicle) | CURRENT ADDRESS (Number and Street) | CITY AND STATE | ZIP CODE

NAME OF MOTOR CARRIER (Commercial Vehicle Only) | CURRENT ADDRESS (Number and Street) | CITY, STATE AND ZIP CODE | US DOT or ICC MC IDENTIFICATION NUMBERS

NAME OF DRIVER (Take From Driver License) / PEDESTRIAN | CURRENT ADDRESS (Number and Street) | CITY, STATE & ZIP CODE | DATE OF BIRTH

DRIVER LICENSE NUMBER | STATE | DL TYPE | REQ. END. | ALC/DRUG TEST TYPE 1 Blood 3 Urine 5 None 2 Breath 4 Refused | RESULTS | ALC/DRUG | PHYS.DEF. | RES. | RACE | SEX | INJ. | S. EQUIP. | EJECT.

HAZARDOUS MATERIALS BEING TRANSPORTED 1 Yes 2 No | PLACARDED 1 Yes 2 No | IF YES, INDICATE NAME OR 4 DIGIT NUMBER FROM DIAMOND OR BOX ON PLACARD, AND 1 DIGIT NUMBER FROM BOTTOM OF DIAMOND | WAS HAZARDOUS MATERIAL SPILLED? 1 Yes 2 No | RECOMMEND DRIVER RE-EXAM, IF YES EXPLAIN IN NARRATIVE 1 Yes 2 No | DRIVER'S PHONE NO. ( )

Section 2 — Vehicle / Pedestrian

DRIVER ACTION 1. Phantom 2. Hit & Run 3. N/A | YEAR | MAKE | TYPE | USE | VEH. LICENSE NUMBER | STATE | VEHICLE IDENTIFICATION NUMBER

TRAILER OR TOWED VEHICLE INFORMATION | TRAILER TYPE

2 3 4 5 6 7 — 1 15 16 17 8 — 14 13 12 11 10 9

18. Undercarriage 19. Overturn 20. Windshield 21. Trailer

SHOW FIRST POINT OF VEHICLE DAMAGE AND CIRCLE DAMAGED AREA(S)

VEHICLE TRAVELLING N S E W | ON | AT | Est. MPH | Posted Speed | EST. VEHICLE DAMAGE 1. Disabling 2. Functional 3. No Damage | EST. TRAILER DAMAGE

MOTOR VEHICLE INSURANCE COMPANY (LIABILITY OR PIP) | POLICY NUMBER | VEHICLE REMOVED BY: 1. Tow Rotation List 2. Tow Owner's Request 3. Driver 4. Other

NAME OF VEHICLE OWNER (Check Box If Same As Driver) | CURRENT ADDRESS (Number and Street) | CITY AND STATE | ZIP CODE

NAME OF OWNER (Trailer or Towed Vehicle) | CURRENT ADDRESS (Number and Street) | CITY AND STATE | ZIP CODE

NAME OF MOTOR CARRIER (Commercial Vehicle Only) | CURRENT ADDRESS (Number and Street) | CITY, STATE AND ZIP CODE | US DOT or ICC MC IDENTIFICATION NUMBERS

NAME OF DRIVER (Take From Driver License) / PEDESTRIAN | CURRENT ADDRESS (Number and Street) | CITY, STATE & ZIP CODE | DATE OF BIRTH

DRIVER LICENSE NUMBER | STATE | DL TYPE | REQ. END. | ALC/DRUG TEST TYPE 1 Blood 3 Urine 5 None 2 Breath 4 Refused | RESULTS | ALC/DRUG | PHYS.DEF. | RES. | RACE | SEX | INJ. | S. EQUIP. | EJECT.

WAS HAZARDOUS MATERIAL BEING TRANSPORTED 1 Yes 2 No | PLACARDED 1 Yes 2 No | IF YES, INDICATE NAME OR FOUR DIGIT NUMBER FROM DIAMOND OR BOX ON PLACARD, AND 1 DIGIT NUMBER FROM BOTTOM OF DIAMOND. | WAS HAZARDOUS MATERIAL SPILLED? 1Yes 2 No | RECOMMEND DRIVER RE-EXAM, IF YES EXPLAIN IN NARRATIVE 1 Yes 2 No | DRIVER'S PHONE NO. ( )

Code Information

VEHICLE TYPE
01 Automobile
02 Van
03 Light Truck / P.U. - 2 or 4 rear tires
04 Medium Truck - 4 rear tires
05 Heavy Truck - 2 or more rear axles
06 Truck Tractor (Cab-Bobtail)
07 Motor Home (RV)
08 Bus (driver + seats for 9-15)
09 Bus (driver + seats for over 15)
10 Bicycle
11 Motorcycle
12 Moped
13 All Terrain Vehicle
14 Train
15 Low Speed Vehicle
77 Other

VEHICLE USE
01 Private Transportation
02 Commercial Passengers
03 Commercial Cargo
04 Public Transportation
05 Public School Bus
06 Private School Bus
07 Ambulance
08 Law Enforcement
09 Fire / Rescue
10 Military
11 Other Government
12 Dump
13 Concrete Mixer
14 Garbage or Refuse
15 Cargo Van
77 Other

TRAILER TYPE
01 Single Semi Trailer
02 Tandem Semi Trailer
03 Tank Trailer
04 Saddle Mount / Flatbed
05 Boat Trailer
06 Utility Trailer
07 House Trailer
08 Pole Trailer
09 Towed Vehicle
10 Auto Transport
77 Other

RESIDENCE (Driver / Ped.)
1 County of Crash
2 Elsewhere in State
3 Non-Resident Out of State
4 Foreign 5 Unknown

DL TYPE
1 A 2 B 3 C
4 D/ Chauffeur
5 E/ Operator
6 E/ Oper.-Rest.
7 None

RACE
1 White
2 Black
3 Hispanic
4 Other

REQUIRED ENDORSEMENTS
1 Yes
2 No
3 No Endorsement Required

SEX
1 Male
2 Female

PHYSICAL DEFECTS
1 No Defects Known
2 Eyesight Defect
3 Fatigue / Asleep
4 Hearing Defect
5 Illness
6 Seizure, Epilepsy, Blackout
7 Other Physical Defect

INJURY SEVERITY
1 None
2 Possible
3 Non-Incapacitating
4 Incapacitating
5 Fatal (Within 30 Days)
6 Non-Traffic Fatality

ALCOHOL / DRUG USE
1 Not Drinking or Using Drugs
2 Alcohol - Under Influence
3 Drugs - Under Influence
4 Alcohol & Drugs - Under Influence
5 Had Been Drinking
6 Pending ALC/DRUG Test Results

SAFETY EQUIPMENT IN USE
1 Not in use
2 Seat Belt / Shoulder Harness
3 Child Restraint
4 Air Bag - Deployed
5 Air Bag - Not Deployed
6 Safety Helmet
7 Eye Protection

LOCATION IN VEHICLE
1 Front Left
2 Front Center
3 Front Right
4 Rear Left
5 Rear Center
6 Rear Right
7 In Body Of Truck
8 Bus Passenger
9 Other

EJECTED
1 No
2 Yes
3 Partial

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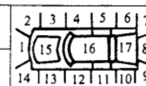
Section 3

Vehicle / Pedestrian

DRIVER ACTION 1. Phantom 2. Hit & Run 3. N/A	YEAR	MAKE	TYPE	USE	VEH. LICENSE NUMBER	STATE	VEHICLE IDENTIFICATION NUMBER
TRAILER OR TOWED VEHICLE INFORMATION			TRAILER TYPE				



18. Undercarriage
19. Overturn
20. Windshield
21. Trailer

SHOW FIRST POINT OF VEHICLE DAMAGE AND CIRCLE DAMAGED AREA(S)

VEHICLE TRAVELLING N S E W	ON	AT	Est. MPH	Posted Speed	EST. VEHICLE DAMAGE 1. Disabling 2. Functional 3. No Damage	EST. TRAILER DAMAGE

MOTOR VEHICLE INSURANCE COMPANY (LIABILITY OR PIP)	POLICY NUMBER	VEHICLE REMOVED BY:	1. Tow Rotation List 2. Tow Owner's Request 3. Driver 4.Other

NAME OF VEHICLE OWNER (Check Box If Same As Driver)	CURRENT ADDRESS (Number and Street))	CITY AND STATE	ZIP CODE
NAME OF OWNER (Trailer or Towed Vehicle)	CURRENT ADDRESS (Number and Street)	CITY AND STATE	ZIP CODE
NAME OF MOTOR CARRIER (Commercial Vehicle Only)	CURRENT ADDRESS (Number and Street)	CITY , STATE AND ZIP CODE	US DOT or ICC MC IDENTIFICATION NUMBERS
NAME OF DRIVER (Take From Driver License) / PEDESTRIAN	CURRENT ADDRESS (Number and Street))	CITY , STATE & ZIP CODE	DATE OF BIRTH

DRIVER LICENSE NUMBER	STATE	DL TYPE	REQ. END.	ALC/DRUG TEST TYPE 1 Blood 3 Urine 5 None 2 Breath 4 Refused	RESULTS	ALC/DRUG	PHYS.DEF.	RES.	RACE	SEX	INJ.	S. EQUIP.	EJECT.

HAZARDOUS MATERIALS BEING TRANSPORTED 1 Yes 2 No	PLACARDED 1 Yes 2 No	IF YES, INDICATE NAME OR 4 DIGIT NUMBER FROM DIAMOND OR BOX ON PLACARD, AND 1 DIGIT NUMBER FROM BOTTOM OF DIAMOND.	WAS HAZARDOUS MATERIAL SPILLED? 1 Yes 2 No	RECOMMEND DRIVER RE-EXAM, IF YES EXPLAIN IN NARRATIVE 1 Yes 2 No	DRIVER'S PHONE NO. ( )

	PROPERTY DAMAGED - OTHER THAN VEHICLES	EST. AMOUNT	OWNER'S NAME	ADDRESS	CITY	STATE	ZIP
# 1		$					
# 2	PROPERTY DAMAGED - OTHER THAN VEHICLES	EST. AMOUNT $	OWNER'S NAME	ADDRESS	CITY	STATE	ZIP

CONTRIBUTING CAUSES - DRIVER / PEDESTRIAN (1 2 3)
01 No Improper Driving / Action
02 Careless Driving (Explain In Narrative)
03 Failed To Yield Right - of - Way
04 Improper Backing
05 Improper Lane Change
06 Improper Turn
07 Alcohol - Under Influence
08 Drugs - Under Influence
09 Alcohol & Drugs - Under Influence
10 Followed Too Closely
11 Disregarded Traffic Signal
12 Exceeded Safe Speed Limit
13 Disregarded Stop Sign
14 Failed To Maintain Equip. / Vehicle
15 Improper Passing
16 Drove Left of Center
17 Exceeded Stated Speed Limit
18 Obstructing Traffic
19 Improper Load
20 Disregarded Other Traffic Control
21 Driving Wrong Side / Way
22 Fleeing Police
23 Vehicle Modified
24 Driver Distraction (Explain In Narrative)
77 All Other (Explain In Narrative)

VEHICLE DEFECT (1 2 3)
01 No Defects
02 Def. Brakes
03 Worn / Smooth Tires
04 Defective / Improper Lights
05 Puncture / Blowout
06 Steering Mech.
07 Windshield Wipers
08 Equipment / Vehicle Defect
77 All Other (Explain In Narrative)

POINT OF COLLISION (1 2 3)
01 On Road
02 Not On Road
03 Shoulder
04 Median
05 Turn Lane

WORK AREA (1 2 3)
01 None
02 Nearby
03 Entered

VEHICLE MOVEMENT (1 2 3)
01 Straight Ahead
02 Slowing / Stopped / Stalled
03 Making Left Turn
04 Backing
05 Making Right Turn
06 Changing Lanes
07 Entering / Leaving / Parking Space
08 Properly Parked
09 Improperly Parked
10 Making U-Turn
11 Passing
12 Driverless or Runaway Vehicle
77 All Other (Explain In Narrative)

VEHICLE SPECIAL FUNCTIONS (1 2 3)
1 None
2 Farm
3 Police Pursuit
4 Recreational
5 Emergency Operation
6 Construction / Maintenance

SOURCE OF CARRIER INFORMATION (1 2 3)
1 Not Applicable
2 Shipping Papers
3 Vehicle Side
4 Driver
5 Other

PEDESTRIAN ACTION (1 2 3)
01 Crossing Not at Intersection
02 Crossing at Mid-block Crosswalk
03 Crossing at Intersection
04 Walking Along Road With Traffic
05 Walking Along Road Against Traffic
06 Working on Vehicle In Road
07 Working In Road
08 Standing/Playing In Road
09 Standing In Pedestrian Island
77 All Other (Explain In Narrative)
88 Unknown

LOCATION TYPE
1 Primarily Business
2 Primarily Residential
3 Open Country

FIRST / SUBSEQUENT HARMFUL EVENT(S) (1 2 3)
01 Collision With MV in Transport(Rear End)
02 Collision With MV in Transport(Head On)
03 Collision With MV in Transport(Angle)
04 Collision With MV in Transport(Left Turn)
05 Collision With MV in Transport(Right Turn)
06 Collision With MV in Transport(Sideswipe)
07 Collision With MV in Transport(Backed Into)
08 Collision With Parked Car
09 Collision With MV on Roadway
10 Collision With Pedestrian
11 Collision With Bicycle
12 Collision With Bicycle (Bike Lane)
13 Collision With Moped
14 Collision With Train
15 Collision With Animal
16 MV Hit Sign / Sign Post
17 MV Hit Utility Pole / Light Pole
18 MV Hit Guardrail
19 MV Hit Fence
20 MV Hit Concrete Barrier Wall
21 MV Hit Bridge/Pier/Abutment/Rail
22 MV Hit Tree /Shrubbery
23 Collision With Construction Barricade Sign
24 Collision With Traffic Gate
25 Collision With Crash Attenuators
26 Collision With Fixed Object Above Road
27 MV Hit Other Fixed Object
28 Collision With Moveable Object On Road
29 MV Ran Into Ditch/Culvert
30 Ran Off Road Into Water
31 Overturned
32 Occupant Fell From Vehicle
33 Tractor/Trailer Jackknifed
34 Fire
35 Explosion
36 Downhill Runaway
37 Cargo Loss or Shift
38 Separation of Units
39 Median Crossover
77 All Other (Explain In Narrative)

ROAD SYSTEM IDENTIFIER
01 Interstate
02 U.S.
03 State
04 County
05 Local
06 Turnpike / Toll
07 Forest Road
08 Private Roadway
77 All Other (Explain In Narrative)

LIGHTING CONDITION
01 Daylight
02 Dusk
03 Dawn
04 Dark (Street Light)
05 Dark (No Street Light)
88 Unknown

ROAD SURFACE CONDITION
01 Dry
02 Wet
03 Slippery
04 Icy
77 All Other (Explain In Narrative)

WEATHER
01 Clear
02 Cloudy
03 Rain
04 Fog
77 All Other (Explain In Narrative)

ROAD SURFACE TYPE
01 Slag/Gravel/Stone
02 Blacktop
03 Brick/Block
04 Concrete
05 Dirt
77 All Other (Explain In Narrative)

ROAD CONDITIONS AT TIME OF CRASH
01 No Defects
02 Obstruction With Warning
03 Obstruction Without Warning
04 Road Under Repair / Construction
05 Loose Surface Materials
06 Shoulders - Soft / Low / High
07 Holes / Ruts / Unsafe Paved Edge
08 Standing Water
09 Worn / Polished Road Surface
77 All Other (Explain In Narrative)

VISION OBSTRUCTED
01 Vision Not Obscured
02 Inclement Weather
03 Parked / Stopped Vehicle
04 Trees / Crops / Bushes
05 Load On Vehicle
06 Building / Fixed Object
07 Signs / Billboards
08 Fog
09 Smoke
10 Glare
77 All Other (Explain In Narrative)

TRAFFIC CONTROL
01 No Control
02 Special Speed Zone
03 Speed Control Sign
04 School Zone
05 Traffic Signal
06 Stop Sign
07 Yield Sign
08 Flashing Light
09 Railroad Signal
10 Officer / Guard / Flagperson
11 Posted No U-Turn
12 No Passing Zone
77 All Other (Explain In Narrative)

SITE LOCATION
01 Not At Intersection / RR X-ing / Bridge
02 At Intersection
03 Influenced By Intersection
04 Driveway Access
05 Railroad
06 Bridge
07 Entrance Ramp
08 Exit Ramp
09 Parking Lot - Public
10 Parking Lot - Private
11 Private Property
12 Toll Booth
13 Public Bus Stop Zone
77 All Other (Explain In Narrative)

TRAFFICWAY CHARACTER
01. Straight - Level
02. Straight - Upgrade / Downgrade
03. Curve - Level
04. Curve - Upgrade / Downgrade

TYPE SHOULDER
01. Paved
02. Unpaved
03. Curb

Violator(s)

SECTION #	NAME OF VIOLATOR	FL STATUTE NUMBER	CHARGE	CITATION NUMBER
SECTION #	NAME OF VIOLATOR	FL STATUTE NUMBER	CHARGE	CITATION NUMBER
SECTION #	NAME OF VIOLATOR	FL STATUTE NUMBER	CHARGE	CITATION NUMBER
SECTION #	NAME OF VIOLATOR	FL STATUTE NUMBER	CHARGE	CITATION NUMBER

Page 2 Of ____

FLORIDA TRAFFIC CRASH REPORT
NARRATIVE/DIAGRAM

MAIL TO: DEPARTMENT OF HIGHWAY SAFETY & MOTOR VEHICLES, TRAFFIC CRASH RECORDS SECTION, NEIL KIRKMAN BUILDING, TALLAHASSEE, FL 32399-0500

DO NOT WRITE IN THIS SPACE

TIME EMS NOTIFIED (FATALITIES ONLY)	TIME EMS ARRIVED (FATALITIES ONLY)	DATE OF CRASH	COUNTY / CITY CODE	INVEST. AGENCY REPORT NUMBER	HSMV CRASH REPORT NUMBER
AM / PM	AM / PM				

(NARRATIVE)

SEC#	PASS#	PASSENGER 'S NAME	CURRENT ADDRESS	CITY & STATE	ZIP CODE	DATE OF BIRTH	RACE	SEX	LOC	INJ	S. EQUIP.	EJECT.
SEC#	PASS#	PASSENGER 'S NAME	CURRENT ADDRESS	CITY & STATE	ZIP CODE	DATE OF BIRTH	RACE	SEX	LOC	INJ	S. EQUIP.	EJECT.
SEC#	PASS#	PASSENGER 'S NAME	CURRENT ADDRESS	CITY & STATE	ZIP CODE	DATE OF BIRTH	RACE	SEX	LOC	INJ	S. EQUIP.	EJECT.
SEC#	PASS#	PASSENGER 'S NAME	CURRENT ADDRESS	CITY & STATE	ZIP CODE	DATE OF BIRTH	RACE	SEX	LOC	INJ	S. EQUIP.	EJECT.
SEC#	PASS#	PASSENGER 'S NAME	CURRENT ADDRESS	CITY & STATE	ZIP CODE	DATE OF BIRTH	RACE	SEX	LOC	INJ	S. EQUIP.	EJECT.
SEC#	PASS#	PASSENGER 'S NAME	CURRENT ADDRESS	CITY & STATE	ZIP CODE	DATE OF BIRTH	RACE	SEX	LOC	INJ	S. EQUIP.	EJECT.

Violator(s)	SECTION #	NAME OF VIOLATOR	FL STATUTE NUMBER	CHARGE	CITATION NUMBER
	SECTION #	NAME OF VIOLATOR	FL STATUTE NUMBER	CHARGE	CITATION NUMBER

WITNESS NAME (1)	CURRENT ADDRESS	CITY & STATE	ZIP CODE	WITNESS NAME (2)	CURRENT ADDRESS	CITY & STATE	ZIP CODE

FIRST AID GIVEN BY - NAME — 1. Physician or Nurse 2. Paramedic or EMT 3. Police Officer 4. Certified 1st Aider 5. Other — INJURED TAKEN TO: — BY - NAME

WAS INVESTIGATION MADE AT SCENE? 1. YES 2. NO — IF NO, THEN WHERE? — IS INVESTIGATION COMPLETE? 1. YES 2. NO — IF NO, THEN WHY? — DATE OF REPORT — PHOTOS TAKEN 1. YES 2. NO — IF YES, BY WHOM? 1. INVESTIGATING AGENCY 2. OTHER

INVESTIGATOR - RANK & SIGNATURE — ID/BADGE NUMBER — DEPARTMENT — FHP SO PD OTHER

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DIAGRAM

INDICATE NORTH
WITH ARROW

Page ________ Of ________

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Appendix B

Florida Highway Patrol Long Form Crash Reporting Criteria

Florida Highway Patrol Policy on Crash Reports

Long Form Crash Investigation

The Florida Highway Patrol shall respond to, investigate and document on the "Long Form" Report all traffic crashes brought to their attention which involve:

- Bodily injury or the death of any person.
- Leaving the scene of a traffic crash or involve driving under the influence.
- Hazardous material incidents, involving the actual/suspected release of toxic substances into the environment, or other unusual conditions that pose a significant threat to public safety.
- Vehicle crashes involving DHSMV vehicles.
- Damage to vehicles/property owned by components of government. Such investigations will only be undertaken at the direction of command or supervisory personnel.
- Crashes that result from the commission of a criminal offense (robbery, auto theft, etc.) or from any pursuit.
- Any crash which requires the completion of the Commercial Vehicle Supplement Report (HSMV 90007).

Short Form Crash Investigation

The Florida Highway Patrol shall respond to, investigate and document on the "Short Form" Report traffic crashes which do not include any of the criteria specified under the "Long Form" section but which do involve:

- Damage to any vehicle or other property in an apparent amount of at least $500.
- Removal of a vehicle from traffic by towing.
- Serious, potentially violent arguments, disturbances or confrontations involving principals or other persons present at the scene. (If such altercations involve the commission of a criminal offense, enforcement action/preparation of "Offense/Incident/Arrest" reports may also be required.)
- Major traffic congestion brought about by the crash, if one or more of the conditions specified in the Long Form Section or the Short Form Section applies.

Driver's Report of Traffic Crash

If you are involved in a minor traffic crash in where:

- there are no deaths or injuries,
- all parties remained at the scene of the crash
- alcohol/drugs are not involved
- damage is less than $500 per vehicle and
- involved vehicles can be driven from the scene,

then:

- drivers should exchange license, registration and insurance information
- then obtain a copy of a "Driver's Report of Traffic Crash" form from any law enforcement agency.

Appendix C

A Blank Questionnaire

Questionnaire to Solicit Information on the Influence of Roadway Geometrics on Transit Vehicle Safety

Survey Guide for Transit Agencies

Contact Person:__________________________________
Title:____
Transit Agency Name:______________________________
Address:____
Telephone: __________________Fax:_________________
Email address:___________________________________

The Florida Department of Transportation through its Transit Office is sponsoring a research project on evaluating the influence of lane width on the safety of transit vehicle, conducted by the University of North Florida. The standard bus mirror-to-mirror width is approximately 10.5 feet. Narrow lanes may lead to transit vehicles encroaching adjacent lanes which in turn may result in sideswipe collisions. Mirror damages can also be an indication of inadequate lane width. The objective of this research is to quantify the effect of tight roadway geometry on the safety of transit vehicles. More information about the project is available from the project manager and the principal investigator who can be reached using the following email addresses and phone numbers.

FDOT Project Manager: Amy Datz; Contact Info: Amy.Datz@dot.state.fl.us; (850) 414-4239
Principal Investigator: Thobias Sando; Contact Info: t.sando@unf.edu; (904) 620-1142

This questionnaire is designed to guide a transit official such as the operations manager to provide the agency's bus safety experience as it relates to roadway geometrics.

1. What are the roadway geometrics that you think are more critical to transit vehicle safety (e.g., lane width, turning radii, roadway curvature, etc.)?____
2. What is the narrowest lane width that you have your buses travel? __________________________________
3. Do you experience more sideswipe crashes and/or mirror accidents on narrow lanes compared to wider lanes? ____
4. Are there any streets that you avoid having bus routes because of tight geometry (lane width or/and turning radius)? Yes No
5. If the answer to question 4 is yes then mention street names. _______________________________________ ____
6. If there are crashes associated with lane width, are they mostly involving buses with other heavy vehicles or a combination of heavy vehicles and passenger cars? ____
7. Do you experience bus crashes to fixed objects (e.g., roadway sign, utility pole, etc.) that are caused by either narrow lane width or tight turning radius? ____
8. The cost of replacing mirrors is a good indication of crashes (reported and unreported) related to lane width. Who would be the person to contact to get the cost that your agency incurs per year for replacing mirror?
   Name:____________________ Email address: _______________ Phone Number: __________________
   Position:___________________
9. List 3 streets that are most prone to or potential of having bus accidents related to lane width.
   Street 1 Name_____________________ From____________________ to ______________________
   Street 2 Name_____________________ From____________________ to ______________________
   Street 3 Name_____________________ From____________________ to ______________________
10. List 3 intersections that have tight turning geometry and most prone to or potential to causing bus accidents.
    Intersection 1 ____
    Intersection 2 ____
    Intersection 3 ____
11. Approximately, how many standard buses does your agency operate? _________

12. Any Comments/Remarks.

____
____
____
____

Thank you for your participation in this important research aimed at enhancing bus safety and improving transit operations in the state of Florida. Please send the filled questionnaire by email, fax, or snail mail using the following contact information.

Thobias Sando, Ph.D., P.E., PTOE.
Assistant Professor
School of Engineering
University of North Florida
1 UNF Drive
Jacksonville, FL 32224
Phone: 904-620-1142
Fax: 904-620-1391
Email: t.sando@unf.edu

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Appendix D

Summary of Transit Agencies Responses

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Joseph Lewis Risk Manager Jacksonville Transportation Authority (JTA) 100 N Myrtle Ave, Jacksonville FL 32203 (904) 630-3182 (904) 632-5505 jelewis@jtafla.com	Jeffrey Thompson Safety and Security Manager Pinellas Suncoast Transit Authority (PSTA) 3201 Scherer Dr, St. Petersburg FL 33716 (727) 540-1878 (727) 540-1917 jthompson@psta.net	Peggy Ewald Transportation Operations Manager Pasco County Pubic Transportation 8620 Galen Wilson Blvd, Port Richey FL 34668 (727) 834-3200 (727) 859-0589 pweald@ridepcpt.com
1) What are the roadway geometrics that you think are more critical to transit vehicle safety (e.g., lane width, turning radii, roadway curvature, etc.)?	Turning radii & lane width	Lane width	Turning radii
2) What is the narrowest lane width that you have your buses travel?	unknown	10 feet	Moog Rd (Madison to US Hwy 19) - 20 ft
3) Do you experience more sideswipe crashes and/or mirror accidents on narrow lanes compared to wider lanes?	Yes - both types	No	Mirror accidents
4) Are there any streets that you avoid having bus routes because of tight geometry (lane width or/and turning radius)?	Yes	Yes	Yes
5) If the answer to question 4 is yes then mention street names.	College St	NE Coachman Road and some streets in the Old NE St. Petersburg	From Delmar St to MLK drivers have to go extremely slow because of road condition (dip in road)
6) If there are crashes associated with lane width, are they mostly involving buses with other heavy vehicles or a combination of heavy vehicles and passenger cars?	School buses & semi trucks	All the above	Heavy vehicles

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Joseph Lewis Risk Manager Jacksonville Transportation Authority (JTA) 100 N Myrtle Ave, Jacksonville FL 32203 (904) 630-3182 (904) 632-5505 jelewis@jtafla.com	Jeffrey Thompson Safety and Security Manager Pinellas Suncoast Transit Authority (PSTA) 3201 Scherer Dr, St. Petersburg FL 33716 (727) 540-1878 (727) 540-1917 jthompson@psta.net	Peggy Ewald Transportation Operations Manager Pasco County Pubic Transportation 8620 Galen Wilson Blvd, Port Richey FL 34668 (727) 834-3200 (727) 859-0589 pweald@ridepcpt.com
7) Do you experience bus crashes to fixed objects (e.g., roadway sign, utility pole, etc.) that are caused by either narrow lane width or tight turning radius?	Yes	Yes	Yes
8) The cost of replacing mirrors is a good indication of crashes (reported and unreported) related to lane width. Who would be the person to contact to get the cost that your agency incurs per year for replacing mirror? (Name, email address, phone number, position)		Jeff Easterling; jeasterling@psta.net; (727) 540-1820; Director Of Maintenance	Steve McNaughton; smcnaughton@pascocountyfl.net; (727) 861-3089; Fleet Maintenance Manager
9) List 3 streets that are most prone to or potential of having bus accidents related to lane width.	Beaver St from Edgewood to Liberty, Forsyth from Stuart to Liberty, Matthews Bridge [*Used sideswipe*]	22nd Ave S from 30th St S to 16th St S; 9th St S from 62nd Ave S to 45th Ave S; 4th St S from 45th Ave S to Pinellas Point Dr S	Moog Rd from Grand Blvd to Us Hwy 19; Main Street from US Hwy 19 to Madison; MLK from Roosevelt to 5th St
10) List 3 intersections that have tight turning geometry and most prone to or potential to causing bus accidents.	Jefferson & Water; Ocean & State; Beaver & Market [*Used right & left-turns*]	Pierce and N. Fort Harrison in Clearwater; Druid St and Martin Luther King in Clearwater; Drew St and Hampton St in Clearwater	Main St and Madison; Grand Blvd and Gulf; Pretty Pond to driveway into WalMart Super Center (Zephyrhills)

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Joseph Lewis Risk Manager Jacksonville Transportation Authority (JTA) 100 N Myrtle Ave, Jacksonville FL 32203 (904) 630-3182 (904) 632-5505 jelewis@jtafla.com	Jeffrey Thompson Safety and Security Manager Pinellas Suncoast Transit Authority (PSTA) 3201 Scherer Dr, St. Petersburg FL 33716 (727) 540-1878 (727) 540-1917 jthompson@psta.net	Peggy Ewald Transportation Operations Manager Pasco County Pubic Transportation 8620 Galen Wilson Blvd, Port Richey FL 34668 (727) 834-3200 (727) 859-0589 pweald@ridepcpt.com
11) Approximately, how many standard buses does your agency operate?	129	205	16 per shift, 32 daily
12) Any comments/remarks	NIL	NIL	NIL

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Mary Wardell-King Lost Prevention Coordinator Miami-Dade Transit 701 NW 1 Court, Suite 1600 (786) 469-5334 (786) 469-5576 mward@miamidade.gov	Joe Diaz Manager of Transit Services HART 4305 E 21st Ave (813) 449-4620 (813) 623-5836 diazj@gohart.org	Paul Goyette Operations Manager Lee Tran 6035 Landing View Rd, Ft. Myers FL (239) 533-0343 (239) 277-5011 pgoyette@leegov.com
1) What are the roadway geometrics that you think are more critical to transit vehicle safety (e.g., lane width, turning radii, roadway curvature, etc.)?	Lane width, turning radii & roadway curvature	Lane width, turning radii	Lane width, curbs, shelters and accessibility
2) What is the narrowest lane width that you have your buses travel?	10 ft	unknown	9 ft
3) Do you experience more sideswipe crashes and/or mirror accidents on narrow lanes compared to wider lanes?	Currently, no lane width analysis conducted for these type accidents	Mirror	Yes
4) Are there any streets that you avoid having bus routes because of tight geometry (lane width or/and turning radius)?	Yes	No	Yes
5) If the answer to question 4 is yes then mention street names.	A) 2nd St, Miami Bch (street width); B) NE 10 Ave (traffic circles); C) Coral Way (planned traffic circles), etc	But the operators are warned about several streets as Florida, Nebraska, & Columbus Blvd	Bay St, Second St, Matanza Bridge (old San Carlos), Estero Blvd

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Mary Wardell-King Lost Prevention Coordinator Miami-Dade Transit 701 NW 1 Court, Suite 1600 (786) 469-5334 (786) 469-5576 mward@miamidade.gov	Joe Diaz Manager of Transit Services HART 4305 E 21st Ave (813) 449-4620 (813) 623-5836 diazj@gohart.org	Paul Goyette Operations Manager Lee Tran 6035 Landing View Rd, Ft. Myers FL (239) 533-0343 (239) 277-5011 pgoyette@leegov.com
6) If there are crashes associated with lane width, are they mostly involving buses with other heavy vehicles or a combination of heavy vehicles and passenger cars?	Currently, no lane width analysis conducted	Combination	Mostly heavy vehicles & pick-up trucks
7) Do you experience bus crashes to fixed objects (e.g., roadway sign, utility pole, etc.) that are caused by either narrow lane width or tight turning radius?	Yes	Yes	Yes downtown Ft. Myers streets
8) The cost of replacing mirrors is a good indication of crashes (reported and unreported) related to lane width. Who would be the person to contact to get the cost that your agency incurs per year for replacing mirror? (Name, email address, phone number, position)	Mr. Kenneth Jones; kjo@miamidade.gov; (305) 638-7434; (786) 251-7450; Section Chief	Todd Parsons; parsonst@gohart.org; Joe Diaz; diazj@gohart.org; (813) 449-4620	Larry Relston; lrelston@leegove.com; (239) 533-0336; Maintenance Manager

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Mary Wardell-King Lost Prevention Coordinator Miami-Dade Transit 701 NW 1 Court, Suite 1600 (786) 469-5334 (786) 469-5576 mward@miamidade.gov	Joe Diaz Manager of Transit Services HART 4305 E 21st Ave (813) 449-4620 (813) 623-5836 diazj@gohart.org	Paul Goyette Operations Manager Lee Tran 6035 Landing View Rd, Ft. Myers FL (239) 533-0343 (239) 277-5011 pgoyette@leegov.com
9) List 3 streets that are most prone to or potential of having bus accidents related to lane width.	Washington Ave from 5 St to Lincoln Rd; 95 Express Lanes from NB 112 Entrance Ramp to Golden Glades; Flagler Street (downtown) from NW 1st Ave to Biscayne Blvd	Nebraska Ave from Downtown to Bearss Ave; Florida Ave from Downtown to Bearss Ave; Columbus Dr from Dale Mabry Hwy to 40th Street	Country Club Blvd from Veterans to Palm Tree; Bay St from First St to Monroe St; Second St from Monroe to Lee St
10) List 3 intersections that have tight turning geometry and most prone to or potential to causing bus accidents.	41st Street & Collins Ave Westbound; 193rd St & Collins Avenue (U-Turn); NW 2 St & 1st Court (Downtown Miami)	Too many to list	MLK & Hendry St; Jackson & MLK Blvd; Mohawk & Chiguita Blvd (Cape Coral)
11) Approximately, how many standard buses does your agency operate?	772 (excludes mini buses)	200	51
12) Any comments/remarks	NIL	NIL	Much of agencies problems are attributed to bus stops in turn lanes, bus stops not accessible or to no curbs + steep slopes; No bus berths on state owned roads

Contact Person Title Transit Agency Name Address Telephone Fax Email address	David Smith Operations Supervisor RTS (Gainesville) 100 SE 10th St, Gainesville FL 32602 (352) 334-3684 smithdw@cityofgainesville.org	Steven Neal General Manager SunTran 2100 NE 30th Ave, Building I (325) 401-6999 (325) 401-6995 sneal@ocalafl.org	Bill Mayer Operations Manager VOTRAN 950 Big Tree Rd S, Daytona FL 32119 (386) 763-3746 (386) 756-7487 bmayer@co.volusia.fl.us
1) What are the roadway geometrics that you think are more critical to transit vehicle safety (e.g., lane width, turning radii, roadway curvature, etc.)?	Lane width & turning radii	Lane width & turning radii	These three as well as tree encroachment
2) What is the narrowest lane width that you have your buses travel?	10ft	Old Blichton Rd between NW 16th to Hwy 27 (NW 10th St)	10 ft
3) Do you experience more sideswipe crashes and/or mirror accidents on narrow lanes compared to wider lanes?	Yes	Yes	
4) Are there any streets that you avoid having bus routes because of tight geometry (lane width or/and turning radius)?	Yes	Yes	Yes
5) If the answer to question 4 is yes then mention street names.	Woodlawn Between Museum and Stadium Road	N.E. 2nd and 25th S.E. 16th ST and S.E. 1 Ave._Note route had to be change because of Radii. Narrow roads N.E..3rd St had to move as well. I wish I could get off Old Blitchton Rd. but we can not due to passenger demand	Madeline Av, N John Anderson Dr and Derbyshire Av

Contact Person Title Transit Agency Name Address Telephone Fax Email address	David Smith Operations Supervisor RTS (Gainesville) 100 SE 10th St, Gainesville FL 32602 (352) 334-3684 smithdw@cityofgainesville.org	Steven Neal General Manager SunTran 2100 NE 30th Ave, Building I (325) 401-6999 (325) 401-6995 sneal@ocalafl.org	Bill Mayer Operations Manager VOTRAN 950 Big Tree Rd S, Daytona FL 32119 (386) 763-3746 (386) 756-7487 bmayer@co.volusia.fl.us
6) If there are crashes associated with lane width, are they mostly involving buses with other heavy vehicles or a combination of heavy vehicles and passenger cars?	Large vehicles, mirror-to-mirror strikes	They are mirror hits with other vehicles and the width is about 10.5 ft	Mostly trucks with wide mirrors
7) Do you experience bus crashes to fixed objects (e.g., roadway sign, utility pole, etc.) that are caused by either narrow lane width or tight turning radius?	Yes	Narrow Street. S.W. 5th and S.W. 23 Ave. and Old Blichton Rd	Yes
8) The cost of replacing mirrors is a good indication of crashes (reported and unreported) related to lane width. Who would be the person to contact to get the cost that your agency incurs per year for replacing mirror? (Name, email address, phone number, position)	Paul Starling; starlingpk@cityofgainesville.org; (352) 334-2603; Maintenance Manager	Steven Neal; sneal@ocalafl.org; (325) 401-6999; General Manager	
9) List 3 streets that are most prone to or potential of having bus accidents related to lane width.	N Main St from NE 8 Ave to NE 16 Ave; 11th Street from 6th St to 9th Rd	Old Blichton Rd. between N.W. 16th to Hwy 27(N.W.10 th ST Old Blichton Rd); N.E. 2nd and 25th	Eighth St from Nova to Derbyshire; Sixth St from Nova to Derbyshire; Second Av from Beach St to US1

Contact Person Title Transit Agency Name Address Telephone Fax Email address	David Smith Operations Supervisor RTS (Gainesville) 100 SE 10th St, Gainesville FL 32602 (352) 334-3684 smithdw@cityofgainesville.org	Steven Neal General Manager SunTran 2100 NE 30th Ave, Building I (325) 401-6999 (325) 401-6995 sneal@ocalafl.org	Bill Mayer Operations Manager VOTRAN 950 Big Tree Rd S, Daytona FL 32119 (386) 763-3746 (386) 756-7487 bmayer@co.volusia.fl.us
10) List 3 intersections that have tight turning geometry and most prone to or potential to causing bus accidents.	Depot Rd and Scull St	Narrow Street. S.W. 5th and S.W. 23 Ave. and Old Blichton Rd; Old Blichton Rd. between N.W. 16th to Hwy 27(N.W.10th ST)	LPGA & US1; Big Tree & US1; US1 & Ridge Blvd
11) Approximately, how many standard buses does your agency operate?	80	9	43
12) Any comments/remarks		Lane width are small enough now if we go smaller we will continue to lose monies in repairs of mirrors and side panels	

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Victor B. Wiley Operations Training & Safety Specialist (Former) StarMetro-COT 555 Appleyard Dr, Tallahassee FL 32304 (850) 891-5200	David Burnett Deputy Chief of Operations for Transportation LYNX, d.b.a., Central Florida Regional Transportation Authority 2500 Lynx Lane (407) 254-6193 (407) 254-6259 dburnett@golynx.com	Mark C. Betti Operations Superintendent Manatee County Area Transit 1108 26 Ave. E., Bradenton FL 34208 (941) 747-8621 Mark.Betti@mymanatee.org
1) What are the roadway geometrics that you think are more critical to transit vehicle safety (e.g., lane width, turning radii, roadway curvature, etc.)?	Approx 140 inches	Lane width	Lane width
2) What is the narrowest lane width that you have your buses travel?	Approx 102 inches	13'	14'
3) Do you experience more sideswipe crashes and/or mirror accidents on narrow lanes compared to wider lanes?	Mirror accidents	Narrow lanes	Yes
4) Are there any streets that you avoid having bus routes because of tight geometry (lane width or/and turning radius)?	Yes	No	No
5) If the answer to question 4 is yes then mention street names.	Gaines Street	Robinson Street in downtown Orlando; Fullers Cross Road in Ocoee/Winter Garden	We avoid roads that are too narrow

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Victor B. Wiley Operations Training & Safety Specialist (Former) StarMetro-COT 555 Appleyard Dr, Tallahassee FL 32304 (850) 891-5200	David Burnett Deputy Chief of Operations for Transportation LYNX, d.b.a., Central Florida Regional Transportation Authority 2500 Lynx Lane (407) 254-6193 (407) 254-6259 dburnett@golynx.com	Mark C. Betti Operations Superintendent Manatee County Area Transit 1108 26 Ave. E., Bradenton FL 34208 (941) 747-8621 Mark.Betti@mymanatee.org
6) If there are crashes associated with lane width, are they mostly involving buses with other heavy vehicles or a combination of heavy vehicles and passenger cars?	Both, but a majority of vehicle on vehicle collisions result from impacts with other, larger (wider) vehicles	Mostly trucks big and small	Larger vehicles
7) Do you experience bus crashes to fixed objects (e.g., roadway sign, utility pole, etc.) that are caused by either narrow lane width or tight turning radius?	Yes	Yes	No
8) The cost of replacing mirrors is a good indication of crashes (reported and unreported) related to lane width. Who would be the person to contact to get the cost that your agency incurs per year for replacing mirror? (Name, email address, phone number, position)	Mr. Ralph Wilder, (850) 891-5200, Superintendant of Maintenance	Linda Connell; lconnell@golynx.com; (407) 841-2279; Manager of Risk	Tony Tucker; Tony.Tucker@mymanatee.org; Fleet Supervisor
9) List 3 streets that are most prone to or potential of having bus accidents related to lane width.	Pullen Rd from Old Bainbridge to Monroe; Tennessee St from Adams to Dewey; Gaines St from Monroe to Woodward	Robinson Street from McGuire to Orange Avenue; Fullers Cross Road from Ocoee/Apopka Road to Lakewood Avenue	14 St; US 41; 9 St

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Victor B. Wiley Operations Training & Safety Specialist (Former) StarMetro-COT 555 Appleyard Dr, Tallahassee FL 32304 (850) 891-5200	David Burnett Deputy Chief of Operations for Transportation LYNX, d.b.a., Central Florida Regional Transportation Authority 2500 Lynx Lane (407) 254-6193 (407) 254-6259 dburnett@golynx.com	Mark C. Betti Operations Superintendent Manatee County Area Transit 1108 26 Ave. E., Bradenton FL 34208 (941) 747-8621 Mark.Betti@mymanatee.org
10) List 3 intersections that have tight turning geometry and most prone to or potential to causing bus accidents.	St. Augustine & Copeland; Palmer & Martin Luther King; Martin Luther King & Osceola	17-92 & Minnesota Avenue	Manatee Ave & 14 St; US 41 & 53 Ave; Manatee Ave & 9 St
11) Approximately, how many standard buses does your agency operate?	Number can be obtained from StarMetro maintenance	274	52

Contact Person Title Transit Agency Name Address Telephone Fax Email address	Victor B. Wiley Operations Training & Safety Specialist (Former) StarMetro-COT 555 Appleyard Dr, Tallahassee FL 32304 (850) 891-5200	David Burnett Deputy Chief of Operations for Transportation LYNX, d.b.a., Central Florida Regional Transportation Authority 2500 Lynx Lane (407) 254-6193 (407) 254-6259 dburnett@golynx.com	Mark C. Betti Operations Superintendent Manatee County Area Transit 1108 26 Ave. E., Bradenton FL 34208 (941) 747-8621 Mark.Betti@mymanatee.org
12) Any comments/remarks	The streets and intersections listed above are not inclusive; there are other areas within the city that poses at least the same risk as those areas mentioned above. Credit is given to a great group of operators. Please note that the answers I provided to #1 and #2 are based on the width of a standard bus and its position within a lane on a roadway. A more measure of the lane width of some of the roadways I've mentioned would provide a more accurate measurement. The comments I've provide in this questionnaire are based on my experiences as a coach operator, transit supervisor, and the StarMetro department training and safety specialist from September 1996 through October 2008. I am now an employee of the Florida Department of Transportation, so the information I've provided cannot speak for the management of StarMetro. For up to date information, please solicit comments from the operators, transit supervisors, and maintenance personnel of StarMetro.		