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Operational and safety effects of signage and lighting configurations for public transit buses in Florida

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Operational and Safety Effects of Signage and Lighting Configurations for Public Transit
Buses in Florida

by

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A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Civil Engineering
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OPERATIONAL AND SAFETY EFFECTS OF SIGNAGE AND LIGHTING CONFIGURATIONS FOR PUBLIC TRANSIT BUSES IN FLORIDA

Stephanie Antoinette Bromfield

ABSTRACT

Although public transit bus accounts for only a small percentage of the mode share for transportation in Florida, the annual passenger miles were over 1 billion with over 200 million passenger trips in 2005. These numbers warrant close attention to be paid to the safety of public transit vehicles. Despite the relatively low occurrence of fatalities and bus crashes, each crash of a high occupancy vehicle such as a public transit bus could expose more people to injury than a private automobile crash. Bus crashes also have a significant impact on the automobiles that are involved. Since a high percentage of bus crashes in Florida are caused by rear-end collisions with private automobiles, improving the signage and lighting that will allow buses to move back into traffic safely is very important for bus safety and operations. This paper uses bus operator surveys, crash data, and field studies to develop recommendations for lighting and signage on the back of the bus, roadway signs and revised Florida legislations. Improved signage and lighting will help the bus move back into traffic safely, decrease bus delay and improve bus operations however it must be accompanied by laws and law enforcement.

CHAPTER 1

INTRODUCTION

According to previous research, the most common cause of bus crashes was inattentive or careless driving on the part of private automobile operators. The transit agencies surveyed recommended the installation of more bus pull-out bays on the state roads, more effective lighting configurations on the rear of buses, and state-wide bus stop design standards (Luke Engineering 2004). In 2006, the Center for Urban Transportation Research (CUTR) began a study on behalf of the Florida Department of Transportation (FDOT) to develop recommendations for bus lighting and signage to improve bus safety and operations moving into traffic. This paper is based on the findings of that research as well as information obtained from a literature review.

The Buses Involved in Fatal Accidents (BIFA) census from 1999-2001 indicates that approximately 50% of fatal transit bus involvements occur during rush hour, from 6:00 to 9:59 a.m. and from 3:00 to 6:59 p.m. In the total of 246 fatalities with transit bus involvements from 1999-2000, 43% of the fatalities were drivers of other vehicles, 37% were pedestrians, 13% percent were passengers of other vehicles. BIFA census also shows that 68% of the fatal transit bus collisions occurred from the vehicle striking the bus (National Institute for Aviation Research 2005). In 2005, 82 transit buses were involved in fatal crashes nationwide. Only 0.1% of fatalities in Florida were on buses (National Center for Statistics and Analysis 2005), making travel by bus one of the safest

modes of transportation. The United States Department of Transportation (USDOT) Traffic Safety Facts from 1999-2003 indicate that 40% of bus occupant injuries resulted from school bus crashes, 24% from intercity bus crashes and 23% from transit bus crashes. It also showed that an average of 12,000 bus occupants per year are injured in two vehicle crashes while 6,000 were in passenger cars and 2,800 were in light trucks (National Institute for Aviation Research 2005). This is indicative of the severity of a single bus crash since each crash may expose many passengers to injury. According to 2005 data, there are 28 fixed-route transit systems operating in Florida. The annual passenger miles were over 1 billion with over 200 million passenger trips (Center for Urban Transportation Research 2006) therefore particular attention needs to be paid to the public transit bus. Since a high percentage of bus crashes in Florida are caused by rear-end collisions with private automobiles, improving the signage and lighting that will allow buses to move back into traffic safely is very important for bus safety and operations.

The Luke Engineering study put high crash locations into four categories, one being crash records that included a public transport bus within eighty feet of a bus stop of bus station (category 4). It was not specified whether these accidents occurred close to a bus pull-out bay specifically. Over the study period of 1998 to 2002, there was no apparent reduction or decrease in frequency of crashes. The study also found that between 53% and 84% of the crashes were at an intersection, as opposed to mid-block locations. Bus accidents in category 4 accounted for 47% of these severe crashes that occurred within the visual influence or the rear of the bus.

When it comes to property damage among mass transit modes, motor bus has the highest costs among mass transit systems. This is expected since transit buses often share the right-of-way with other vehicles.

Table 1 Property Damage by Year and Mode

	2001	2002	2003	2004	Total
Automated Gateway	\$0	\$0	\$44,500	\$0	\$44,500
Commuter Rail	\$5,770,575	\$177,292	\$20,953,278	\$15,373,025	\$42,274,170
Demand Response	\$2,876,041	\$1,449,932	\$1,313,490	\$964,499	\$6,603,962
Heavy Rail (Rapid Transit)	\$20,175,819	\$2,475,703	\$5,652,164	\$3,677,529	\$31,981,215
Light Rail (Street Car)	\$2,684,714	\$2,107,570	\$2,432,328	\$2,756,920	\$9,981,532
Motor Bus	\$41,045,818	\$25,662,251	\$28,706,533	\$20,461,125	\$115,875,727
Vanpool	\$527,641	\$312,334	\$112,808	\$139,773	\$1,092,556

(Source: Federal Transit Administration, <http://transit-safety.volpe.dot.gov>)

Table 1 shows the high cost of bus crashes in the United States. Apart from safety and operational difficulties with bus crashes, there are also financial concerns. Improved signage and lighting that aids in moving the bus in traffic safely should therefore yield many benefits to Florida transit agencies.

Around the world, different lighting and signage technologies have been employed to improve the safety and operations of public transit buses. In the United States, the extent to which lighting on the rear of the bus is modified is bound by the National Highway for Transit Safety standards. The effectiveness of different lighting configurations on the back of the bus can be hard to evaluate since some transit agencies

may have buses in their fleet with different lighting layouts, and the effectiveness of the lighting configuration may depend on external factors such as the driver populations understanding of bus signals and laws such as the yield-to-bus (YTB) and bus priority laws employed around the world. Different signs have also been used to improve bus safety and operations. Yield-to-bus and bus priority signs are used in conjunction with laws that give the bus priority when entering traffic.

Objectives

The overall objective of this project is to help improve transit service by improving on-time schedules and the quality of service by assisting transit vehicles in safely reentering the traffic stream. The final recommendations include roadside signage and pavement markings in compliance with the Manual on Uniform Traffic Control Devices (MUTCD) that would help to reduce rear-end collisions when buses are merging back into traffic as well as lighting configurations on the back of buses to improve auto driver awareness of the presence and operation of the buses.

In order to achieve the overall objective of this project, three primary objectives have been identified. The first objective is to make recommendations to the National Highway Traffic Safety Administration (NHTSA) on lighting configuration and signage practices for the back of transit buses that will be expected to reduce rear-end collisions. The second objective would be to develop MUTCD-compliant signage and pavement markings to address Yield-to-Bus (YTB) safety issues. The third objective would be recommendations for draft statutory language or modifications to existing statutes that would be needed to help increase viability of the YTB law.

CHAPTER 2

LITERATURE REVIEW

The literature review consists of three sections. The first section outlines lighting configurations and signage currently practiced with an emphasis on Florida practices. Included in this section is a review of Yield-to-bus programs and the signs and lights associated with them, as well as the signage and lighting associated with school buses and specific research into signage and rear-lighting technologies. The second section is a review of roadside signs and pavements markings as well as the location and design of bus stops. The third section is a review of current yield-to-bus and bus priority regulations.

Signage and Lighting Configuration

Florida Statute 316.301 requires vehicular hazard-warning signal lamps for all buses 30 feet or more in length or 80 inches or more in width. All buses, whatever their size, must have on the rear two reflectors, one at each side, and one stop light but on every bus 80 inches or more in overall width must additionally on the rear two clearance lamps, two reflectors, one at each side. These larger buses must also have on each side:

- a. two side marker lamps, one at or near the front and one at or near the rear,
- b. two reflectors, one at or near the front and one at or near the rear and,
- c. one side marker lamp and one clearance lamp which may be in combination, to show to the front, side and rear.

The Florida Administrative Code (FAC) 14-90.007(1) states that all transit systems must meet the minimum requirements of the Federal Motor Vehicle Safety Standards and Regulations (FMVSS). The National Highway Traffic Safety Administration (NHTSA) has a legislative mandate to issue Federal Motor Vehicle Safety Standards (FMVSS) and Regulations. Manufacturers of motor vehicle and equipment items must conform and certify compliance with NHTSA.

Two stop lamps must be on the rear of the bus that display red or amber light when the brakes, service (foot) brakes or air activated parking brakes are applied, or if the passenger exit door control to open position is activated, according to 14-90.007(9), FAC. The lamps must be securely mounted and visible from a distance of no less than 300 feet. In addition, the FAC requires buses to have clearance lamps and tail lights on the rear of the bus.

Both Florida Statute 316.235(5) and FAC 14-90.007(13) say that buses may have deceleration lights that caution following vehicles that the bus is slowing, preparing to stop, or stopped but these lights are not required. Florida Statutes describe the deceleration lighting system as amber lights mounted in horizontal alignment on the rear of the vehicle at or near the vertical centerline of the vehicle, not higher than the lower edge of the rear window or, if the vehicle has no rear window, not higher than 72 inches from the ground. Deceleration lights must be visible from a distance of not less than 300 feet to the rear in normal sunlight. These lights are permitted to light and flash during deceleration, braking, or standing and idling of the bus. Vehicular hazard warning flashers may be used in conjunction with or in lieu of a rear-mounted deceleration lighting system. Several letters were written to NHTSA about the use of flashing

deceleration lights and they responded by saying that the simultaneous use of flashing and steady-burning lamps have the potential for creating confusion in vehicles to the rear and impairing the effectiveness of the required stop lamps (Recht 1995). This has caused several agencies in Florida to stop installing deceleration lights on the buses.

FMVSS Standard No. 108 includes lamps, reflective devices, and associated equipment for the reduction of traffic crashes and deaths and injuries resulting from traffic crashes. These devices enhance the conspicuity of motor vehicles on the public roads so that their presence is perceived and their signals understood. The standard requires that multipurpose passenger vehicles, trucks and buses, 80 inches or more in overall width, have two red tail lamps, two red stop lamps, one white backup lamp, two red or amber and two amber turn-signal lamps, a vehicular-hard warning-signal operating unit and flasher, turn-signal operating unit and flasher, three amber and three red identification lamps, two amber and two red clearance lamps, two amber intermediate side marker lamps, and two amber intermediate side reflex reflectors. No additional lamp, reflective device or other motor vehicle equipment shall be installed that impairs the effectiveness of lighting equipment required by these standards.

Federal Motor Carrier Safety Administration – Federal Regulation 393.22 states:

“(a) Permitted combinations. Except as provided in paragraph (b) of this section, two or more lighting devices and reflectors (whether or not required by the rules in this part) may be combined optically if —

(a)(1) Each required lighting device and reflector conforms to the applicable rules in this Part; and

(a)(2) Neither the mounting nor the use of a nonrequired lighting device or reflector impairs the effectiveness of a required lighting device or reflector or causes that device or reflector to be inconsistent with the applicable rules in this Part.

(b) Prohibited combinations. (1) A turn signal lamp must not be combined optically with either a head lamp or other lighting device or combination of lighting devices that produces a greater intensity of light than the turn signal lamp;

(b)(2) A turn signal lamp must not be combined optically with a stop lamp unless the stop lamp function is always deactivated when the turn signal function is activated;

(b)(3) A clearance lamp must not be combined optically with a tail lamp or identification lamp.”

Federal standards do not implicitly state that additional signs cannot be used on the back of the bus; instead they give guidelines as to the number and type of each light required on the bus and mention that additional lamps should not reduce the effectiveness of required lamps. Regulations from the Federal Motor Carrier Safety Administration permits lighting devices and reflectors to be combined optically if the use of a non-required lighting device does not impair the effectiveness of a required lighting device or reflector or causes that device or reflector to be inconsistent with the applicable rules.

The exact placement of these lights and markers vary by bus make and model. The lights are sometimes placed low on the bus close to the bumper, other times they are placed higher up. Lights may be aligned vertically or horizontally as shown in Figure 1, as long as they are located at the corner of the bus.



Figure 1 Vertical and Horizontal Light Configurations

Additional light emitting diode (LED) lights and deceleration lights are sometimes added to improve bus safety. Options available in LED lights include lights that spell the word STOP and YIELD (Figure 2). Transit agencies may also change the positions of amber and red lights and increase the size of the lights. Reflective tape is also used to increase the conspicuity of buses. Other lighting used to improve the conspicuity of the bus includes daytime running lights, additional lights around the bus, and strobe lights. LED lights have additional benefits as they are said to have a useful life approximately 100 times greater than incandescent bulbs. Incandescent lights have been traditionally used for the external lighting on buses.



Figure 2 YIELD and STOP LED Lights

The University of California Transportation Center initiated a study to create a device that would warn motorists approaching a bus that is stopped. Radar would be attached to the back of the bus, which will survey traffic behind the bus and report its location and the rate at which the gap between the bus and any approaching vehicle is decreasing (Cohn 2002). Other collision avoidance systems are being researched by different entities (Moffa et al. 1996).

NHTSA has received many new ideas for stop lamp improvements over the last 30 years but they are reluctant to alter the current stop lamp configuration because it may create ambiguous signals. NHTSA acknowledges that it is possible to improve the current configuration but only if there is scientific evidence to demonstrate that the change would yield net safety benefits (Lee et al. 2002).

Different bus manufacturers use different rear lighting configurations for their buses, within the limits of NHTSA standards, and may change the configurations for different models of buses. Transit agencies also do some modifications on the buses or order a special configuration from the manufacturer. Table 2 shows various modifications employed by transit agencies to improve safety or help with bus operations.

Table 2 Various Lighting Technologies Employed in North America

Transit Agency	Technology
Anchorage Transit, Alaska	Implemented strobe lights and flashers on the back of the bus since 1986
British Columbia Transit, Victoria	Converted from incandescent to LED lights
Ames Transit, Iowa	Installed LED lights in 1990 and included three turn lights at each side of the rear of the bus
Laketrans, Ohio	Double stop lights on each side of bus plus 2 on each side of the rear number sign. They also have double amber turn signals, one of which is high-mounted.
Duluth Transit Authority, Minnesota	Installed amber flashing lights connected to the rear door interlock since passengers exit at the rear
Houston Metro, Texas	Experimenting with two additional red flashing brake lights mounted high in the center on the rear of the bus.
Metro Transit, Seattle, Washington	Uses LED brake lights for its new Gillig buses.
Link, Wenatchee, Washington	Has used strobe lights at the front and rear of the bus since 1996.

Table 2 (Continued)

Transit Agency	Technology
Metropolitan Atlanta Rapid Transit Authority (MARTA), Atlanta, Georgia	MARTA acquired buses with 8 inch center brake lights that flash when bus is braking. MARTA also has one bus with amber lights in the upper corners and believes this will be effective. MARTA incorporates a new rear brake light configuration. They removed the original eight inch center brake light and modified the existing amber and red lights so that they flash when bus is braking and stopped. MARTA uses reflective tape on the sides and at the rear of the bus to increase bus visibility.
Pierce Transit, Tacoma, Washington	High-mounted center red light and two amber lights on each side of the red light. The red light is steady while the amber lights flash alternately when the brake is pressed.
Pinellas Suncoast Transit Authority, Florida	Installed deceleration lights on their entire fleet

School Buses

One thing of particular concern to school bus safety is the unloading and loading of children on the bus. Children are at greater risk when in school bus loading or unloading zones since many accidents occur as children attempt to cross the road around a school bus. School bus passing laws and different technologies have therefore been employed to prevent other motorists from passing a stopped school bus. Devices intended to enhance the visibility of a school bus and to inform drivers of their responsibility to stop during loading and unloading operations are implemented.

Along with the stop arm, school buses are equipped with flashing amber lights to indicate that the bus is preparing to stop, flashing red lights that extend from the left side

of the bus, flashing red lights indicating that the bus has stopped and students are preparing to board or leave the bus, and other warning lights to increase the visibility of the bus. Decals are placed on the bus to inform the motorists of the meaning of the flashing lights. The “School Bus Stop Ahead” sign can be used to provide additional advance warning. A static sign, which is only applicable on occasion when a school bus stops, may become ineffective due to rapid motorist desensitization to the risk and a subsequent degradation in safety at school bus loading/unloading zones (Carson et al. 2005). One remedy for this situation is to add flashing beacons that are activated when a school bus is in the loading/unloading zone.

Video enforcement for stop-arm violations has been attempted. In North Carolina, school bus drivers are trained to activate the vehicle’s amber warning lights 300 feet before the stop, stop the bus 15 feet short of the closest waiting passenger, come to a complete stop, check the traffic, and then open the door. Opening the door activates the red warning lights and the stop arm. The North Carolina Department of Public Instruction and the Institute for Transportation Research and Education at North Carolina State University set out to find ways to reduce the illegal passing of stopped school buses. The study focused on three coastal school districts: Onslow, Pender, and New Hanover counties. In Onslow County, bus-mounted video cameras were used. The Onslow County project team mounted weatherproof video cameras outside the bus near the stop arm of selected school buses operated by drivers who had reported frequent illegal passing. The video cameras recorded the date, time, speed of the bus, activation of the amber warning lights, and the deployment of the stop arm. The initial use of the video cameras was to perform a time and motion study of how bus drivers were operating the traffic control

devices—the amber warning lights, the red warning lights, and the stop arm. The videos showed that bus drivers sometimes failed to come to a complete stop before activating the red warning lights and stop arm (Tai and Graham 2005).

The time and motion study revealed that drivers did not keep to the 300-foot warning stage and sometimes deployed the stop arm before the bus came to a complete stop. Some violation reports filed by bus drivers had been dismissed and were not pursued through the judicial system because bus drivers sometimes deployed the stop arm before coming to a complete stop. The study also showed at least one or two vehicles illegally passing while the stopped bus was loading and unloading school children. A training videotape was developed for school bus drivers that emphasizes that the only way to communicate with motorists are through the vehicle's amber warning lights and red flashing lights.

After reinforcement training for school bus drivers in Onslow County, the average daily number of reported violations of the no-passing law filed by the 203 bus drivers dropped. More cameras were installed on the school buses to capture violations to assist in issuing citations. Video footage from stop arm violations was then highlighted on the news in Onslow County. All these measures further decreased stop arm violations (Tai and Graham 2005).

The Center for Urban Transportation Research conducted a study to determine drivers' understanding of Florida's school bus stop law and school bus signalization devices. A survey was developed and issued at 30 driver license examining offices throughout Florida. The finding suggested that, while many motorists do not understand the school bus stop law contained in one scenario, many more motorists are, in fact,

intentionally violating the school bus stop law. According to the study, in general, the knowledge of drivers in Florida regarding their responsibilities as defined in the school bus stop law is significantly lacking (Center for Urban Transportation Research 1997).

Yield to Bus Programs

Bus stops located outside of the traffic lane help to improve the flow of traffic behind the bus. However, during congested periods it may be difficult for the bus to re-enter back into the flow of traffic. Yield to Bus (YTB) programs and bus priority programs in Europe were created to improve bus service and safety. Some states in the US have passed laws requiring motorists to yield to buses re-entering a roadway. The re-entry delay of buses varies according to the degree of compliance to the laws (Lehman Center for Transportation Research 2002).

In the 1970s, several European countries initiated laws that allowed priority for buses leaving a bus stop. These European programs go under the name of bus priority systems and are comparable to the Yield-to-Bus programs in the United States, but generally more extensive. Along with bus priority laws, in Germany, Austria, and Scandinavia, the distance between bus stops is widened to reduce the number of times a bus must decelerate, accelerate and re-enter traffic flows. Various bus priority signs in Europe and Australia obtained from TCRP Synthesis 49 are shown in Figure 3.

In Great Britain, the sidewalk is extended to prevent obstructions of parked cars, create more space for queuing riders, and reduce the need for buses to maneuver in and out of the traffic stream (National Academics Press 2001). In Western Europe, transit vehicles are given priority in traffic to a greater extent than the USA. In 1994 there was an initiative in London, England to improve bus service by setting up the London Bus Priority Network (LBPN). Bus bays have been used in London to allow cars to overtake stopped buses, however they did have the same problems as the US when attempting to re-enter the flow of traffic. To remedy this situation, one approach of the LBPN is to pave or infill the bus bay in order to re-create a flush curb at which the bus stops in the nearside traffic lane. This is intended to enable the bus to resume its route without delay, although it may cause the delay of other vehicles. Another approach is to have bus bays in exclusive bus lanes. Since regular traffic is not permitted in these lanes, there is no longer a problem when merging back into traffic (UK Department of Transportation 2003). The United Kingdom Highway Code 198 for buses, coaches and trams says, “Give priority to these vehicles when you can do so safely, especially when they signal to pull away from stops. Look out for people getting off a bus or tram and crossing the road”. One of the aims of the priority system in Germany is to decrease the delay time for transit vehicles. Exclusive lanes are used alongside arterials with high bus volumes and frequent traffic jams. Another method in Germany to improve transit service includes changing existing bus bays into street based stop areas called “buscape”. Buses travel in a straight line along the street and car traffic is stored behind the bus when it makes a stop. This is similar to the treatment used in England; it increases the delay of cars but decreases the delay of buses (Brilon and Laubert 1994).

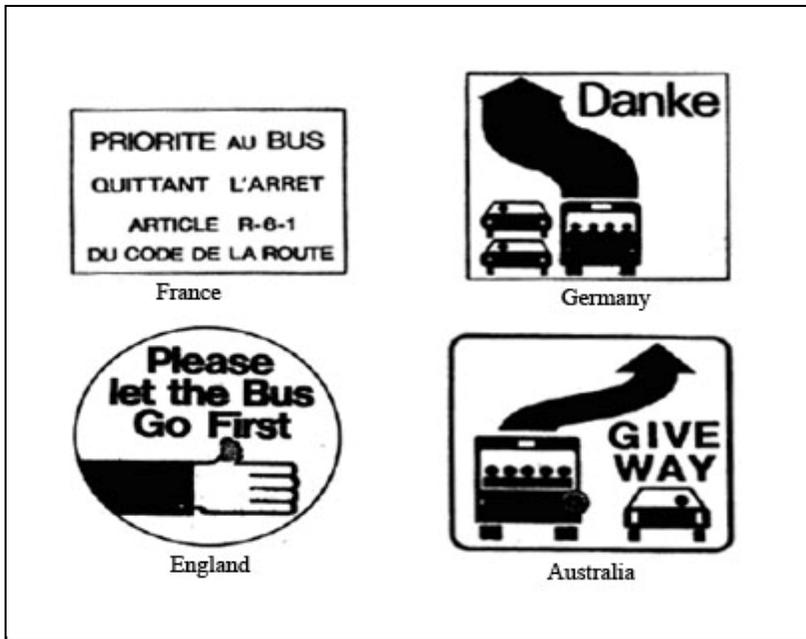


Figure 3 Bus Priority Signs in Australia and Europe

In 2004, Ontario, Canada passed a Yield to Bus law similar to the ones in the US. The new law applies to all buses that bear the YIELD / CÉDEZ decal shown in Figure 4 (City of Ottawa Homepage 2006) near the left turn signal on the rear of the bus. When a bus displaying the sign is signaling its intention to leave a bus bay by activating the left turn signal, drivers approaching from the rear, in the adjacent lane, are required to slow down or stop to allow the bus to re-enter the lane, unless it is unsafe to do so.



Figure 4 Yield/Cédez Decal in Canada

Yield-to-Bus legislation has been in effect in Quebec since 1982. The law was drafted similar to the European laws. A decal is placed on the lower-left corner of the rear window of the bus. The decal consists of an inverted equilateral triangle with sides 38 cm and a red message on a white back ground (Figure 5).



Figure 5 Société de Transport à Montréal Bus in Montreal, Canada

In the United States, the Yield-to-Bus legislation began in Washington State in 1993. The law is simple and does not specify the type of signs needed. Metro Transit in King County, Washington, created a YTB decal. A more detailed law was passed in Oregon in 1998. The Yield to Bus law in Florida was added a year later, in 1999, to the Florida State Uniform Traffic Control laws. The law is similar to the law in Washington and does not specify any specific decal or lights to be used.

The most common sign associated with the YTB legislation in both Europe and North America is the YTB and bus priority decal. In England the decal is a simple graphic with the words "Please let the bus go first". In North America, the yield decal consists of a downward pointing triangle. This decal is placed on the rear of the bus to the left in North America and to the right in European countries where vehicles drive on the left side of the road. The two main locations for this decal are above the bumper and in the middle of the rear corner. The decals are made of reflective film. Maximum visibility of the sign is obtained from contrasting values of colors. These decals work best in situations where strong light sources are beamed directly at it (KRW 1996).

Other signage directly related to YTB programs includes light emitting diode (LED) signs. These LED signs generally consist of a flashing "YIELD" sign activated by the bus operator when he or she attempts to re-enter the traffic lane. In 2006, Transpec Worldwide introduced a new LED flashing sign for the YTB programs. The new Transpec Merge Alert motorist warning device has been developed to assist with motorist education of YTB laws. The merge Alert delivers a highly-visible, high-brightness LED message that the bus is merging back into traffic. The device flashes a "Yield" sign, along with the word "MERGING," and then alternates to a flashing, left pointing "ARROW" along with a second "MERGING" text (Figure 6). In transit operations tests, the Merge Alert significantly reduces difficulty in the bus reentering traffic and reducing rear-end collisions.

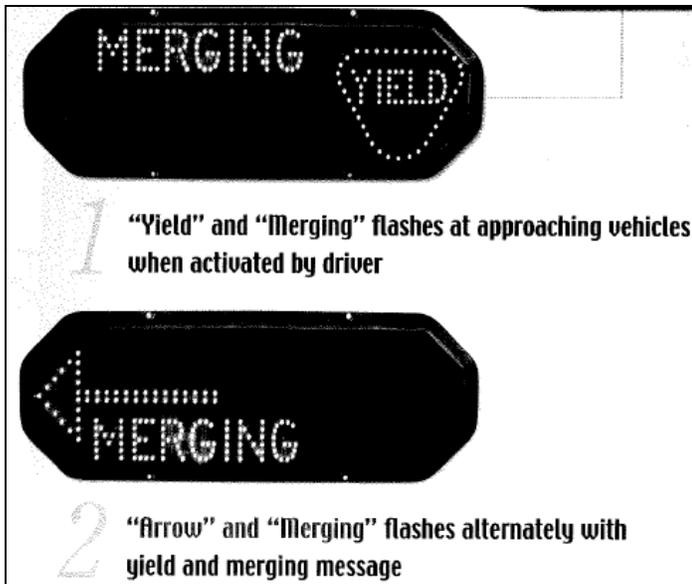


Figure 6 Transpec Merge Alert LED Sign

Another company developed a merge alert and wide-turn alert system. The Advance Safety Wheel and Hubs, LLC company has been developed a system to prevent accidents from wide right turns and assisting the operator to re-enter traffic a stop. For this concept, two safety control boards are placed on the back of transit buses, parallel to each other (Figure 7). On the left side, rear end of the bus, the control board is activated by the left turn signal. The message "Merging Left" flashes, then strolling arrows pointing left, and then the message "Thank You" when the turn signal is turned off. On the right side rear end of the bus, the control board is activated by the right turn signal activating the message "Wide-Right Turn", then strolling arrows pointing right. A "Thank You" message appears when turn signal is turned off.



Figure 7 Advanced Safety Wheel and Hubs Alert System

Since the Florida Yield-to-Bus law does not give guidance as to how to implement the law, there is no set signage and lighting uniformly used in Florida. A Yield-to-Bus decal mounted on the back of the bus is widely used; however, there are two agencies in Florida that use a flashing yield sign and others that use no special decals or signs.

The common signs associated with the YTB laws in the North America are LED signs and decals. Transit Agencies in California and Oregon use a flashing red triangle with the word “yield” in the center of the triangle. Votran in Florida has recently implemented a similar flashing yield signs on 8 new buses in their fleet. Leetran in Florida has also put flashing yield signs on a few of their buses. In British Columbia, a flashing sign with the word “yield” is used along with a decal. The decals range in size, location and colors.

Broward County Transit

Broward County Transit (BCT) in Florida uses a reflective Yield-to-Bus (YTB) decal on the lower-left rear corner above the bumper of the bus. The decal is an equilateral triangle with sides approximately 18 inches in length as shown in Figure 8 (King 2003). The triangle is red on a yellow background with white words on a black background. BCT also considered using an electronic flashing yield sign but they were concerned with electrical power load (King 2003).



Figure 8 BCT Decal

King (2003) summarized the survey of 150 transit operators from Broward County Transit in Transit Cooperative Research Program (TCRP) Synthesis 49. When asked whether they believed that the yield sign has made merging from a stop safer, 67 percent of the operators responded that there was no change.

Coast Mountain Bus Company

Coast Mountain Bus Company (CMBC) in Canada uses a reflective square decal with sides approximately 10 inches in length. Inside the square is a red equilateral triangle on a yellow background as shown in Figure 9 (King 2003). Inside the triangle is white with “Yield” written in black letters and the silhouette of a bus below it. The decal is located to the left of the rear window on the back of the bus. A decal was chosen over the electronic yield sign because the decal was significantly less expensive; however, some CMBC buses that operate in West Vancouver use LED yield sign in combination with the decal. On the rear bumper, CMBC also includes YTB-related decal signs that say “Thanks for the Brake” and “Please Yield it’s the Law”, as shown in Figure 10 (King 2003).



Figure 9 CMBC Decal



Figure 10 CMBC Bumper Decals

TCRP Synthesis 49 summarized the survey of 167 transit operators from Coast Mountain Bus Company. When asked whether they believed that the yield sign has made merging from a stop safer, 59 percent of the operators responded that it was some safer. When asked what percentage of motorists stops when bus operators signal their intent to merge into the traffic lane, most of the bus operators believed that a low percentage of drivers will yield to bus. The detailed survey results are shown in Figure 11.

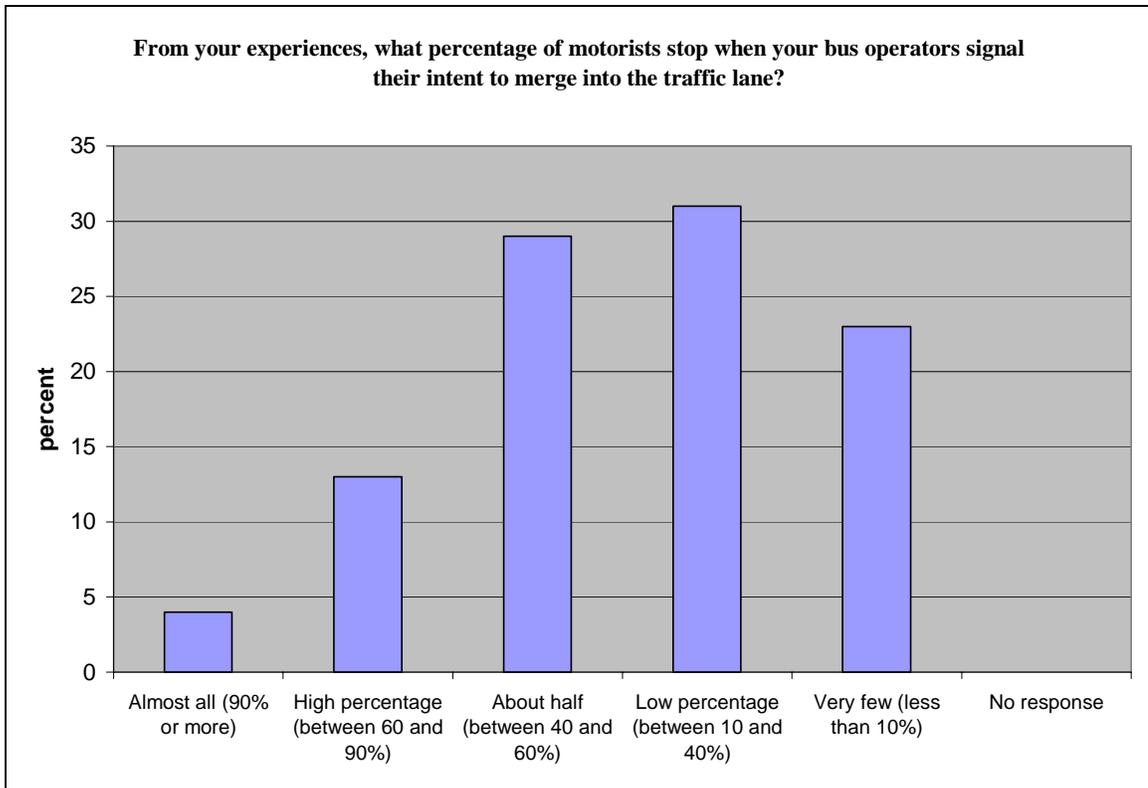


Figure 11 Perception of Drivers' Yield Behavior of CMBC Decal

Washington Metro Transit

Metro Transit uses a reflective decal located to the left of the rear window on the back of the bus. They chose this location because a lower location was believed to be too difficult for the second and third following vehicle to see. The decal consists of a red triangle on a yellow back ground. Inside the triangle is white with the word "Yield" inside and "For Buses" directly below the triangle as shown in Figure 12 (King 2003).



Figure 12 Washington Metro Transit Decal

A survey response from Washington stated that the electronic version of the yield sign is promising but the decal might as well not be there.

British Columbia Transit

British Columbia (BC) Transit uses a six inch square reflective yield decal and a LED yield sign. Inside the square is a red equilateral triangle on a yellow background. Inside the triangle is white with “Yield” written in black letters and the figure of a bus below it. This decal is used throughout British Columbia and is similar to the CMBC decal. The LED yield sign is located in the lower-left corner of the rear window as shown in Figure 13 (King 2003).



Figure 13 British Columbia Transit YTB Decal and Yield LED Sign

Tri-County Metropolitan Transportation District

In Oregon, specifications have been developed by the Oregon Transportation Commission for a yield sign that includes a 6.75 tall triangle with the word “Yield” inside. Both the triangle and yield message must be red when flashing. Tri-County Metropolitan Transportation District (Tri-Met) uses a red LED flashing yield sign with a triangle that is approximately eight inches on each side as shown in Figure 13 (King 2003). The flashing yield sign is located on the lower-left corner above the bumper. A control switch is used by the bus operator to activate the yield sign. The operator first activates the amber turn signal then the yield sign. The yield sign is deactivated when the left turn signal switch is released.



Figure 14 Tri-Met LED Yield Sign

In the TCRP Synthesis survey of Tri-Met bus operators, there was a positive response for the operators' perception of safety when using the yield signal as shown in Figure 15 (King 2003). The majority of bus operators also felt that other road users allowed them to merge back into traffic at least some of the time as shown in Figure 16 (King 2003).

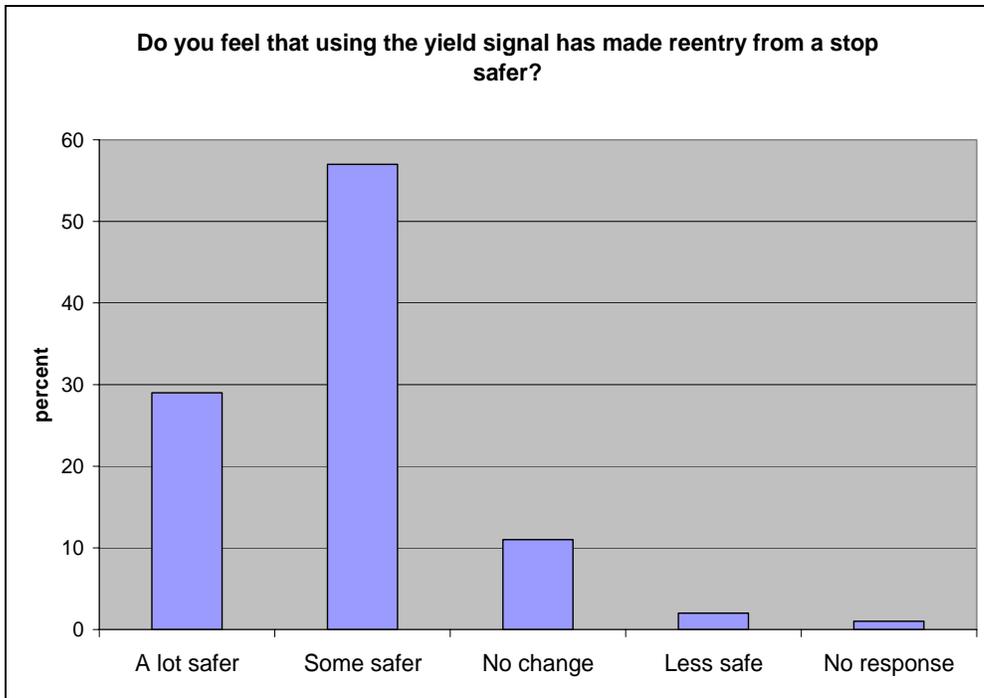


Figure 15 Tri-Met Bus Operators' Perception of Safety

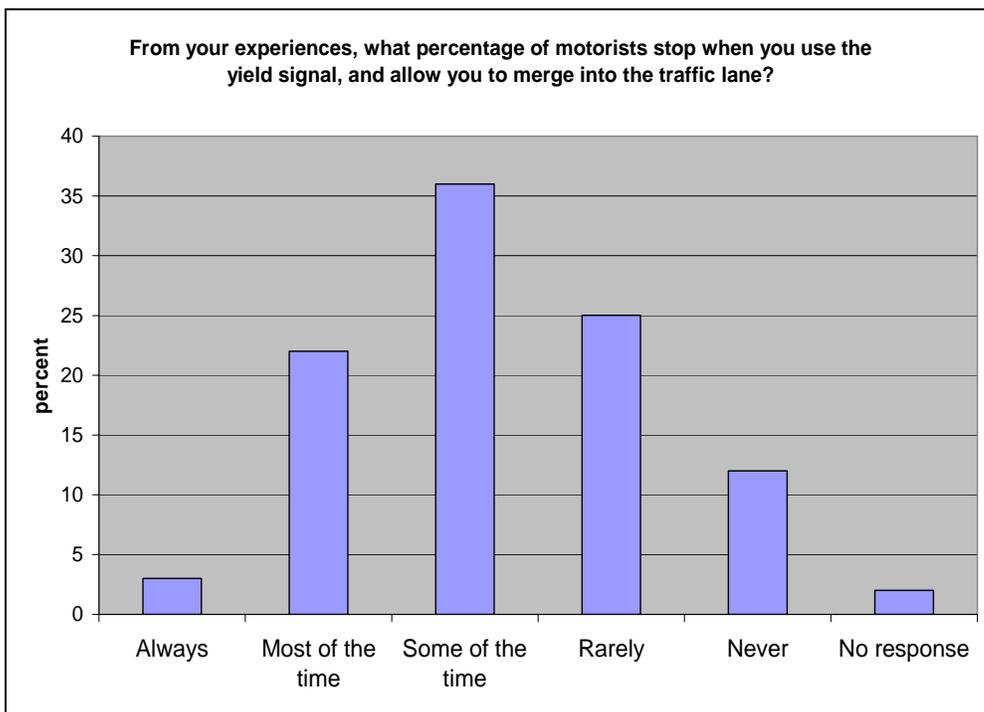


Figure 16 Tri-Met Bus Operators' Perception of Yield Behavior

Santa Clara Valley Transportation Authority/ Santa Cruz Metropolitan Transit District

California law requires that buses be equipped with a yield right-of-way sign on the left rear of the bus. The sign must be illuminated by a flashing light when the bus is signaling to enter a traffic lane. The Santa Clara Valley Transportation Authority (VTA) and the Santa Cruz Metropolitan Transit District use the same flashing yield sign as Oregon, mounted on the rear left of the bus above the engine access door as shown in Figures 17 and 18 (King 2003). The yield sign is activated first, followed by the left turn signal and both signals will stop when the left turn signal is turned off. Arming the yield signal first allows the bus operator to have both hands on the steering wheel when pulling out from a stop. After 10 to 15 seconds, the yield sign deactivates therefore if the operator cannot move before then, the left turn signal must be released and the yield control button pushed again.



Figure 17 Santa Clara Valley Transportation Authority Bus with LED Yield Sign



Figure 18 Santa Cruz Metropolitan Transit Bus with Yield LED Sign

One of the survey questions for bus operators in TCRP Synthesis 49 was for the operators' perception of drivers' yield behavior. The question was asked for their perception with and without the use of the flashing yield signal. Bus operators at VTA had a positive perception of drivers' yield behavior when using the flashing decal as shown in Figure 19 (King 2003). The majority of bus operators also had a positive perception on the helpfulness of the yield signal in their bus operation as shown in Figure 20 (King 2003).

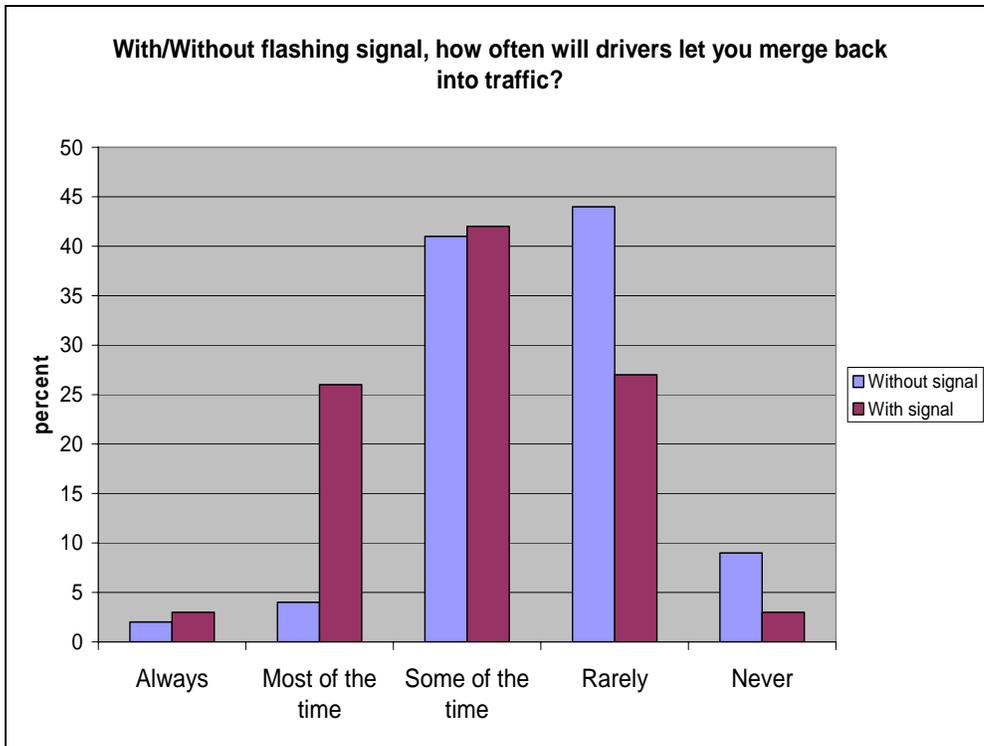


Figure 19 VTA Bus Operators' Perception of Yield Behavior

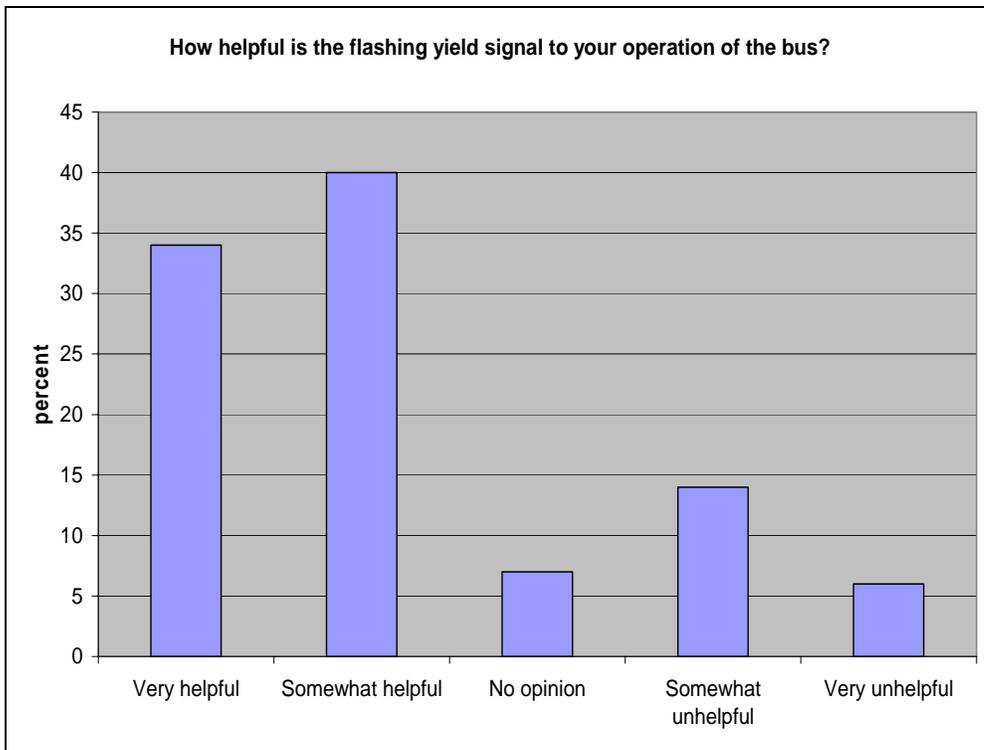


Figure 20 VTA Bus Operators' Perception of Flashing Yield Signal

Minnesota Metro Transit

The Metro Transit decals feature a red yield sign along with a reference to the Minnesota statute that gives buses priority. The decals are being positioned on the left side and above the brake lights for maximum visibility as shown in Figure 21 (Metropolitan Council Homepage 2006). These decals have only recently been developed even though the law requiring motorists to yield to the bus have been around for many years.



Figure 21 Minnesota Metro Transit Decal

Practice Comparisons

Of the five transit agencies that were highlighted in TRCP Synthesis 49, two of these used a similar YTB decal. Coast Mountain Bus Company (CMBC) and Broward County (BC) Transit both use a similar decal, but the CMBC decal is placed higher than the BC Transit decal. CMBC also has additional decals above the bumper. In the perception of safety, the CMBC operators have a more positive response compared to BC Transit. CMBC operators also perceive higher motorist yield rates than the BC Transit operators. Tri-Met uses a red LED flashing yield sign, and the operator's perception of safety for this sign is higher than that of the CMBC decal. Tri-Met bus operators were

asked what percentage of motorists stops when they use the yield signal and allow them to merge into the traffic lane. Similarly, Santa Clara Valley Transportation Authority (VTA) bus operators were asked how often drivers let them merge back into traffic. The LED Yield Sign from VTA had a slightly more positive response than LED Yield sign from Tri-Met when the operators were asked about their perception of driver yield behavior.

Costs of YTB Signage and Lighting

According to the study done for TCRP Synthesis 49, the cost of electronic yield signal ranged from \$250 to \$600 per bus for the U.S. agencies and from \$600 to \$800 CAN (\$390 to \$520 US) per bus for the transit agencies in British Columbia, Canada. The costs for the yield decals ranged from \$5 to \$20 per decal. These figures are currently outdated. When the project team enquired about the cost to make reflective yield decals, the prices ranged between \$40 and \$80 per decal since the reflective vinyl was an expensive material.

Roadway Signs and Pavement Markings

Only one transit agency reviewed in this study was seen to use roadside signs for their YTB program. Lee County Transit (Leetran) placed the sign shown in Figure 22 at designated bus stops. Pavement word markings reading “Bus Only” were sometimes used in bus pull-out bays. The Manual on Uniform Traffic Control Devices (MUTCD) has recommendations for “Yield” signs and also “Yield to Pedestrians” and “Yield to Bikes” but none for yielding to buses.



Figure 22 YTB Roadside Sign in Lee County

Manual on Uniform Traffic Control Devices

According to section 2B.08 of the MUTCD, the yield sign should be a downward-pointing equilateral triangle with a wide red border and the legend “Yield” in red on a white background (Figure 23). Yield lines must be white and if used, yield lines shall consist of a row of solid white isosceles triangles pointing toward approaching vehicles extending across approach lanes to indicate the point at which the yield is intended or required to be made (US Department of Transportation Federal Highway Administration 2003).



Figure 23 MUTCD Yield Sign

Vehicles controlled by a yield sign need to slow down or stop when necessary to avoid interfering with conflicting traffic but the MUTCD states that the yield sign assigns right-of-way to traffic on certain approaches to an intersection. It makes no mention of using yield-to-bus signs but they do have special yield signs for yielding to pedestrians (Figure 24). If yield lines are used in advance of an unsignalized marked midblock crosswalk, “Yield Here to Pedestrians” signs should be placed 6.1 to 15 m (20 to 50 ft) in advance of the nearest crosswalk line. The “In-Street Pedestrian Crossing” sign may be used to remind road users of laws regarding right of way at an unsignalized pedestrian crossing. The legend “State Law” may be shown at the top of the sign if applicable. The legends “Stop for” or “Yield to” may be used in conjunction with the appropriate symbol. Yield lines may be used to indicate the point behind which vehicles are required to yield in compliance with a “Yield” sign or a “Yield Here to Pedestrians” sign.



Figure 24 MUTCD Yield to Pedestrians Signs

The yield line consists of individual triangles with a base of 300 to 600 mm (12 to 24 in) wide and a height equal to 1.5 times the base. The space between the triangles should be 75 to 300 mm (3 to 12 in). Yield lines may be used to indicate the point behind which vehicles are required to yield in compliance with a yield sign (Figure 23) or a “Yield Here to Pedestrians” (Figure 24) sign. Yield lines are placed a minimum of 1.2 m (4 ft) in advance of the nearest crosswalk line at controlled intersections, except for yield lines at roundabout intersections and at midblock crosswalks. In the absence of a marked crosswalk, the stop line or yield line is placed at the desired stopping or yielding point, but should be placed no more than 9 m (30 ft) nor less than 1.2 m (4 ft) from the nearest edge of the intersecting traveled way. If used at an unsignalized midblock crosswalk, yield lines are placed adjacent to the “Yield Here to Pedestrians” sign located 6.1 to 15 m (20 to 50 ft) in advance of the nearest crosswalk line, and parking should be prohibited in

the area between the yield line and the crosswalk (Figure 25). Drivers who yield too close to crosswalks on multi-lane approaches place pedestrians at risk by blocking other drivers' views of pedestrians. Yield lines are shown in Figure 26.

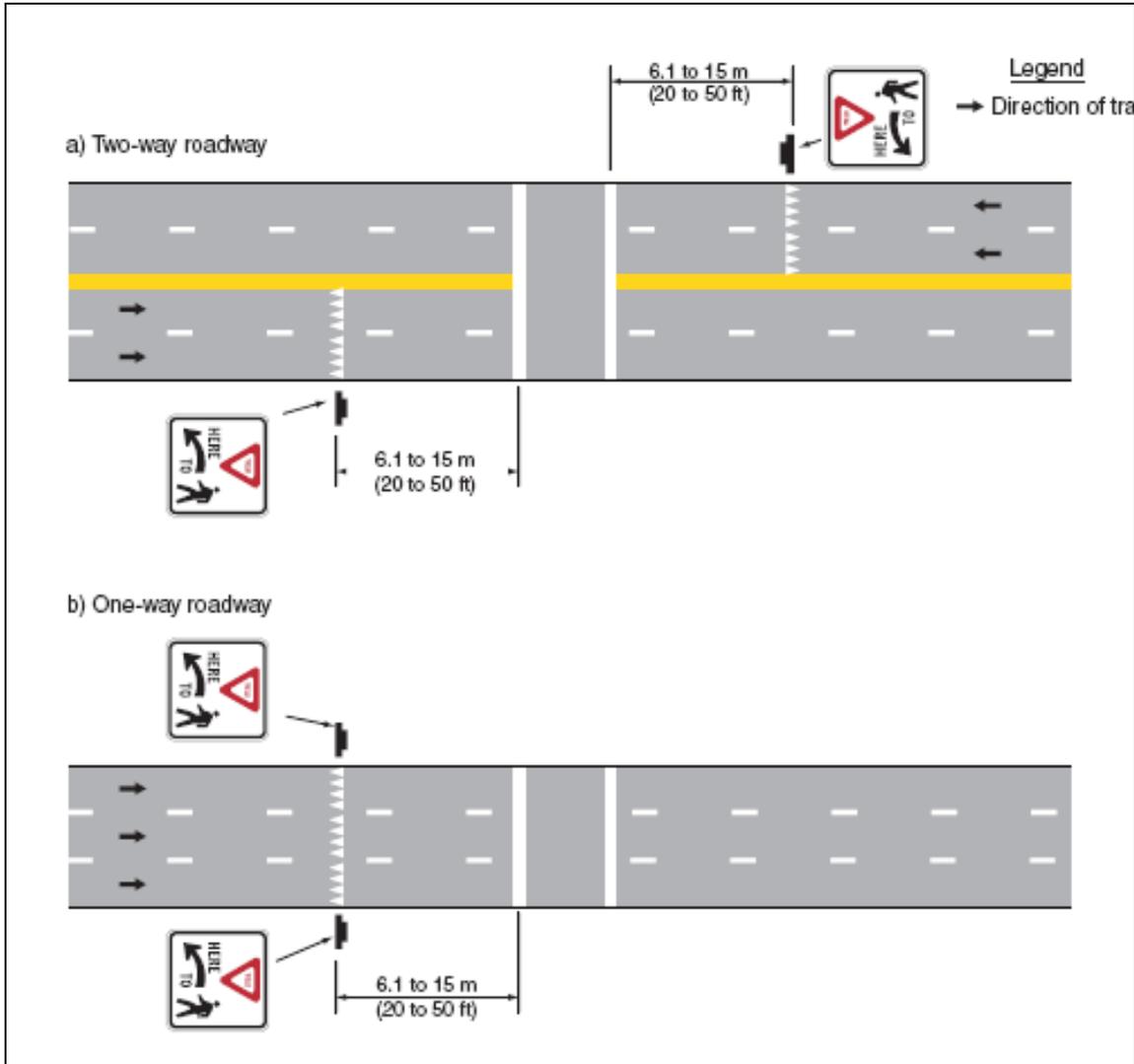


Figure 25: MUTCD Placement of Yield Markings

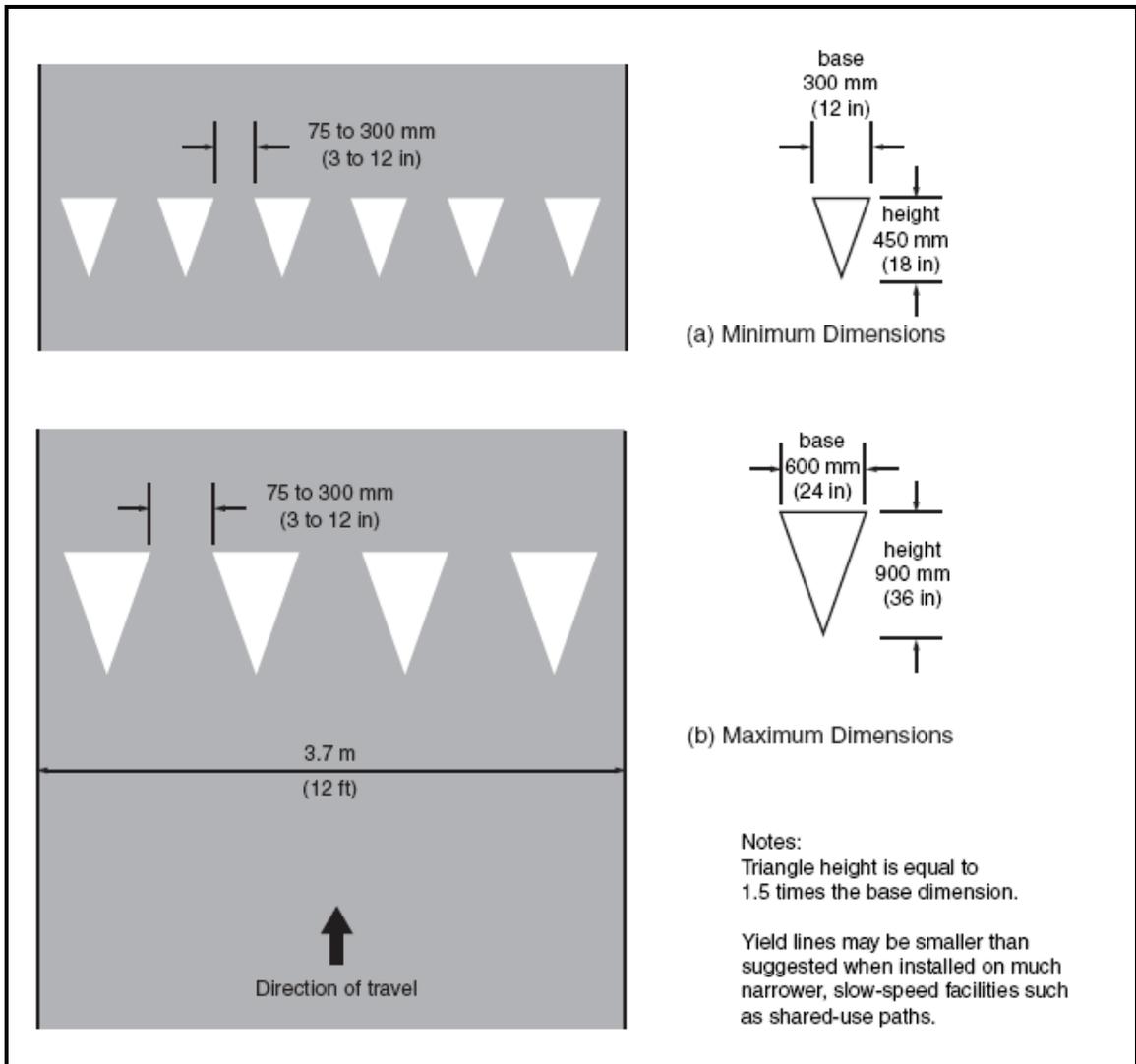


Figure 26 MUTCD Yield Pavement Markings

At roundabout intersections, a yield line (Figure 27) may be used to indicate the point behind which vehicles are required to yield at the entrance to a roundabout intersection (US Department of Transportation Federal Highway Administration 2002).

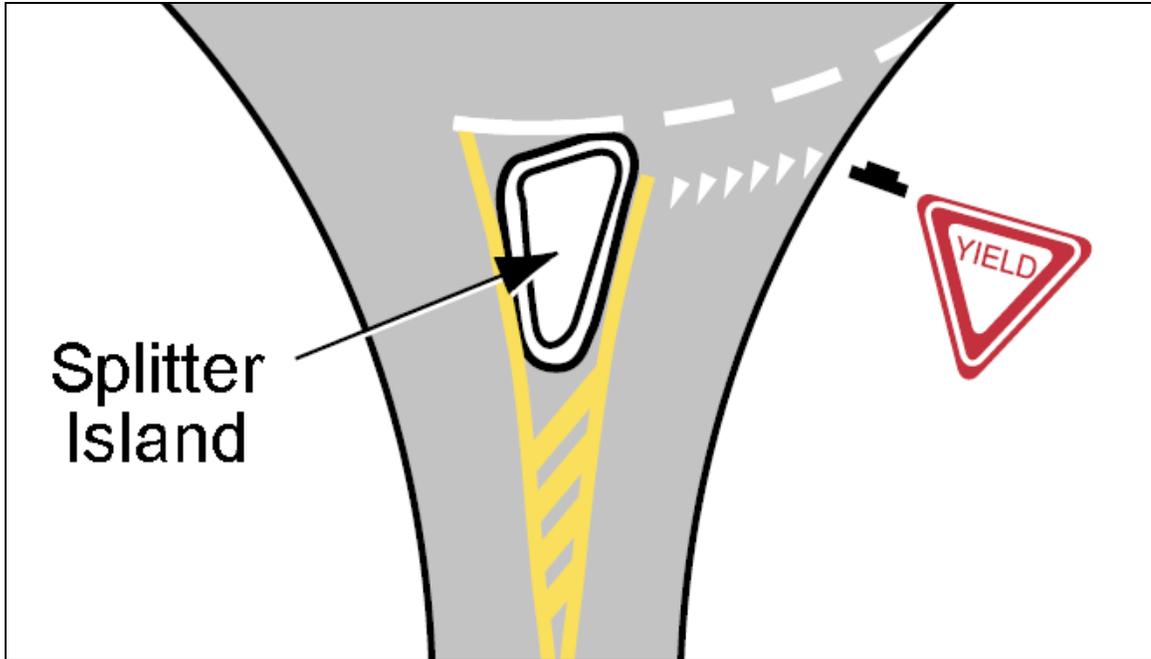


Figure 27 MUTCD Yield Marking for Roundabout

A yield-ahead triangle symbol (Figure 28) or “Yield Ahead” word pavement marking may be used on approaches to intersections where the approaching traffic will encounter a yield sign at the intersection. The yield-ahead triangle symbol or “Yield Ahead” word pavement marking cannot be used unless a yield sign is in place at the intersection.

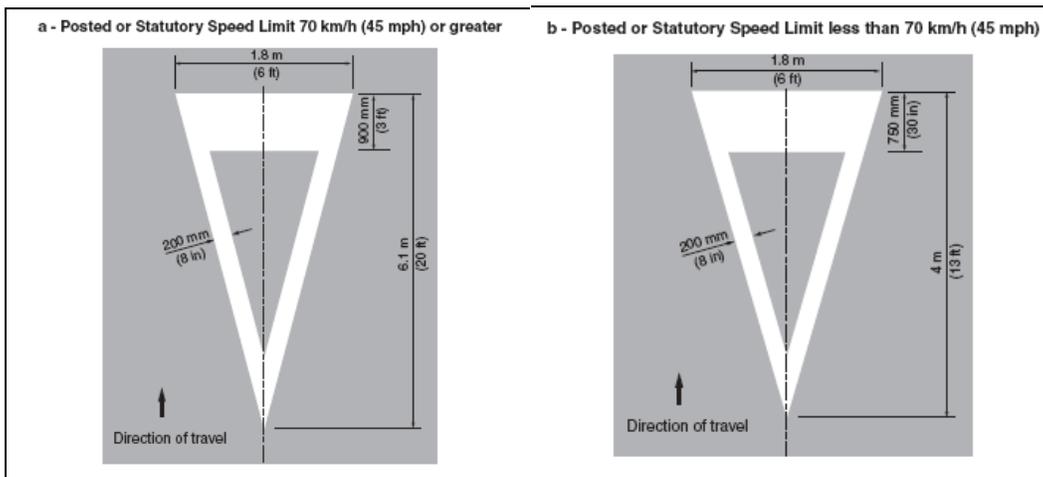


Figure 28 MUTCD Yield Ahead Triangle

Al-Masaeid and Sinha (1994) suggest that studies on the effectiveness of pavement markings are not consistent. Derived accident reduction factors due to pavement markings for all average daily traffic volumes on rural roads and for all lane widths varied from -13 percent to +35 percent. For a specific countermeasure, there is no exact estimate of accident reduction factor. Regardless of the method of estimation, nature of the environment, or accident experiences, the estimation of accident reduction factor is uncertain (Al-Masaeid and Sinha 1994). Safety studies on pavement marking however tend to be mostly focused on visibility; therefore, it is hard to say that this may apply to a safety study of whether pavement marking changes yield behavior of motorists.

Yan et al. (2006) conducted a study on the pavement marking with word message “Signal Ahead.” The study investigated the effect of this pavement marking on signalized intersections and safety. The “Signal Ahead” pavement marking is intended to encourage drivers to located upstream of the marking to stop at the intersection at the onset of the yellow phase. In their experimental design, the pavement marking position is related to the speed limit and vehicle’s deceleration rate. The study showed a significantly positive effect on signalized-intersection safety (Yan et al. 2006).

Other yield signs available are for yielding to bicyclists. The sign is 900 mm by 750 mm. The sign is used where motor vehicles entering an exclusive right-turn lane must weave across bicycle lanes; the “Begin Right Turn Lane Yield to Bikes” (R4-4) sign (Figure 29) may be used to inform both the motorist and the bicyclist of this weaving maneuver.



Figure 29 MUTCD Begin Right Turn Lane Yield to Bikes Sign

The MUTCD also does not have any standard signs to warn road users of the possibility of vehicles unexpectedly stopped in the travel lane but they do have general guidelines for signs governing the parking, stopping, and standing of vehicles. Discussions of parking signs and parking regulations in Section 2B.40 of the MUTCD apply to parking and stopping. Prohibitive signs should have a red legend and border on a white background while permissive signs should have a green legend and border on a white background. Alternate designs may include, on a single panel, a transit logo, an approved bus symbol, the words “Bus Stop”, and an arrow. The preferred bus symbol color is black, but other dark colors may be used. Additionally, the transit logo may be shown on the bus face in the appropriate colors instead of placing the logo separately. The reverse side of the sign may contain bus routing information. Parking prohibition signs around bus stops are illustrated in this section of the MUTCD (Figure 30).



Figure 30 MUTCD No Parking Signs Related to Transit Stops

Bus Stop Location and Design

Since Florida Statutes indicated that vehicles must yield the right-of-way to a publicly owned transit bus from a specifically designated pullout bay, it would be helpful to understand the detailed information regarding the bus pull-out design. The location and design of bus pull-out bays may also influence the placement and types of roadway signs and pavement markings.

There are various types of bus stops which are dependent on location, ridership, and adjacent land uses. The Pasco County Public Transportation (PCPT) identifies three types of bus stops used: standard local stops, major local stops and superstops. These designs range from a single signpost to a full bus bay with other special facilities. Bus

bays are typically constructed on high-volume or high-speed roadways (TCRP 1996). Other types of bus stops are curb-side, open bus bay, queue jumper bus bay, bus bulbs and nub stops.

TCRP Report 19 contains the factors which would lead to the construction of bus bays. Bus bays should be considered on roads where curb lane traffic exceeds 250 vehicles during the peak hour but bus drivers will not use bus bays when traffic volumes exceed 1000 vehicles per hour per lane. Heavy volumes make it very hard for buses to merge back into the flow of traffic. Acceleration lanes, signal priority, or far-side placements are potential solutions for this. Bus bays are ideal where traffic speeds exceed 40 miles per hour, where vehicles are prone to collide with the rear end of a stopped bus and locations with high passenger volumes or where the dwell time exceeds 30-seconds during peak hours. Areas where there are extended layover times and high volumes of buses at peak hours are also ideal for bus bays. Bus bays should be designed to reduce automobile-bus conflict, provide greater separation between traffic and pedestrians waiting for the bus, and allow the bus to quickly regain its travel speed upon re-entry into the traffic (Florida Planning and Development Lab 2004). The total length of a bus bay consists of an entrance taper, deceleration length, stopping area and acceleration length. Figure 31 shows the bus bay dimensions based on through speed and entering speed (Florida Planning and Development Lab 2004).

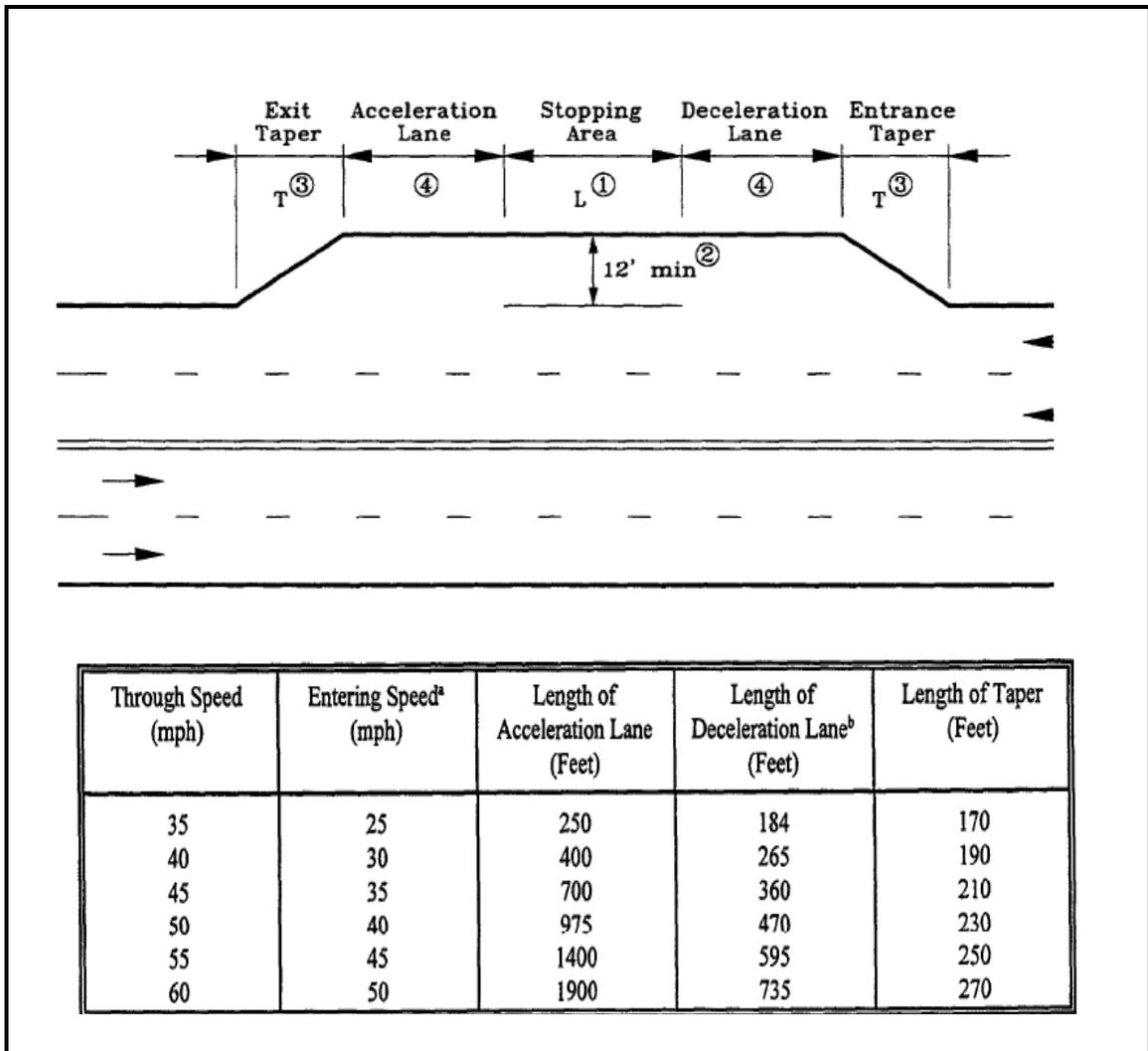


Figure 31 Bus Bay Configuration

Yield-to-Bus Legislation

In the United States, six states have passed laws requiring motorists to yield to buses attempting to merge back into traffic. The laws vary in requirements for transit agencies and under what circumstances motorists are required to yield. The following are excerpts from different states pertaining to YTB laws. Details of these laws are presented in Appendix A.

Florida

Florida Statute 316.0815 states that “vehicles must yield the right-of-way to a publicly owned transit bus traveling in the same direction which has signaled and is reentering the traffic flow from a specifically designated pullout bay. The operator of the bus must also drive with due regard for the safety of all persons using the roadway.” This law is concise and makes no mention of specific signs, lights, fines or implementation.

The Florida Driver’s Handbook 2007 was checked to see if there was any mention of requirements to yield to the bus. Under the heading of “Right-of-Way”, the handbook says, “Who has the right-of-way in Florida? The answer is no one! The law only says who must yield (give up) the right-of-way.” Under this is the subheading “Public Transit” where it does mention the yield-to-bus law. It says, “All drivers should yield the right-of-way to public transit buses traveling in the same direction which have signaled and are reentering the traffic flow from a specifically designated pullout bay.”

There are special sections for sharing the road with trucks, bicyclists and motorcyclists. In the part for trucks they say, “Whether you are sharing the road with a car, truck, bus, or other large vehicle, it’s important for safety’s sake to obey traffic laws, abide by the rules of the road, and drive defensively.” This section continues to point out different issues when sharing a road with trucks and mentions that buses have the same issues. It includes blind spots, methods for passing a truck or bus, wide right turns, following a truck and unsafe passing. There is also a section on defensive driving which addresses how to avoid rear-end collisions. This section recommends that drivers check their brake lights often, know what is going on around them, use rearview mirrors, signal in advance for turns, stops and lane changes, slow down gradually and avoid any sudden

actions, drive with the flow of traffic (within the speed limit), and keep at least two seconds following distance.

Washington

The Revised Code of Washington (RCW) 46.61.220 is very similar to the Florida statute 316.0815. RCW 46.61.220 states that “the driver of a vehicle shall yield the right of way to a transit vehicle traveling in the same direction that has signaled and is reentering the traffic flow.” It differs from the Florida statute in that it does not specify the type of bus stop; it does, however, go on to state that the driver of a transit vehicle shall drive with due regard for the safety of all persons using the roadway. Washington Administrative Code (WAC) 204-10-020 specifies the required lighting for motor vehicles and buses. Municipal transit vehicles may be equipped with a single additional hazard strobe lamp. This strobe lamp is activated by a switch independent of other switches and used when in situation where sight is obscured, or to improve the visibility of the bus when stopping, standing, or starting onto a highway.

Oregon

Oregon Revised Statute 811.167 states that a person commits the offense of failure to yield the right-of-way to a transit bus entering traffic if they do not yield the right-of-way to a bus bearing a yield sign as described in that subsection displayed on the back of the transit bus. They also commit an offense if the person is operating a vehicle that is overtaking the transit bus from the rear of the transit bus; and the transit bus, after stopping to receive or discharge passengers, is signaling an intention to enter the traffic lane occupied by the person. The section describes the type of YTB decal to be used as well as a fine.

California

California Vehicle Code 21810 states that the driver of a vehicle overtaking a transit bus shall yield the right-of-way to the bus if all of the following conditions are present:

1. “The transit bus has entirely exited an active traffic lane to board or deboard passengers at a designated bus stop, and is attempting to reenter the lane from which it exited.
2. Directional signals on the transit bus are flashing to indicate that the bus is preparing to merge with traffic.
3. The transit bus is equipped with a yield right-of-way sign on the left rear of the bus.”

The code goes on to specify the YTB sign to be used and how the law is to be implemented. It also requires transit agencies to conduct a public awareness campaign.

New Jersey

The New Jersey statutes say that the driver of a non-emergency vehicle shall yield the right of way to any bus provided that:

1. “The driver is operating a vehicle that is in a position to overtake the bus from its rear; and
2. The bus, after exiting an active traffic lane for the purpose of stopping to receive or discharge passengers is attempting to reenter the lane from which it exited and to enter the traffic lane occupied by the driver by signaling its intention to do so. No other lane changes shall be applicable.”

The original bill included specifications for a right-of-way yield sign to be placed on the left rear of the bus, illuminated by a flashing light when the bus driver signals intention to enter an active traffic lane. It also stated that the Director of the Division of Motor Vehicles shall adopt rules and regulations governing the message or messages on the yield sign, specifications for the size, color, shape, lettering and illumination of the sign and specifications for the placement of the sign on the bus. These details, however, were not enacted and were omitted from the law when it was passed in 2004.

Minnesota

Minnesota Statute 169.20 Subdivision 7 for Transit bus states that:

“The driver of a vehicle traveling in the right-hand lane of traffic shall yield the right-of-way to any transit bus attempting to enter that lane from a bus stop or shoulder, as indicated by a flashing left turn signal.”

Oregon, Washington, Minnesota, and Florida share the basic elements of the law by stating that motor vehicles should yield to publicly owned transit buses. Oregon, Washington and Florida also state that the driver should operate with due regard for the safety of all persons using the roadway. Oregon and California, however, are more specific by defining the yield signal. They also mention overtaking a bus as failure to yield the right-of-way under certain conditions. Originally, the New Jersey bill for the new Yield-to-Bus law specified a yield sign but this was omitted from the law in 2004.

A clearer, more defined law seems to be best for compliance. In the bus operators survey in TCRP Synthesis 49, bus operators in Florida and Washington felt that most people were unaware of the Yield-to-Bus law (Figure 32).

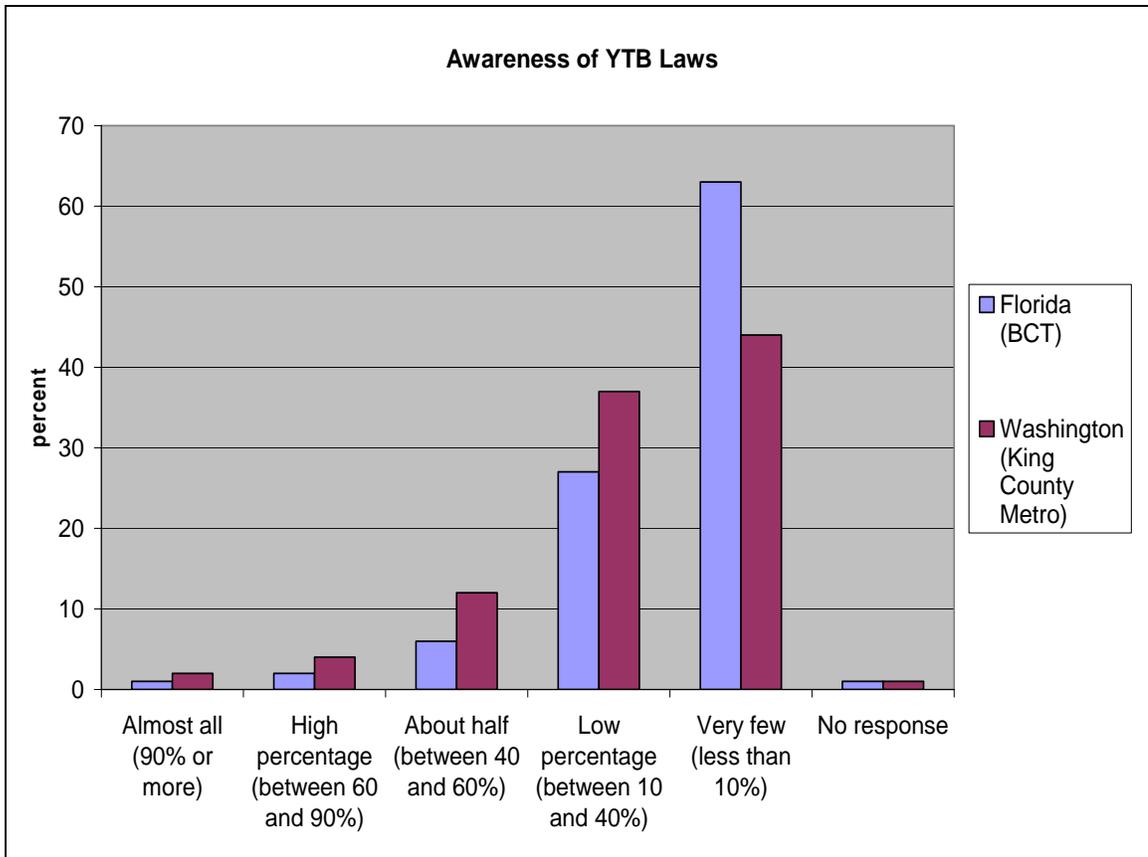


Figure 32 Operators Perception of Motorists' Awareness of YTB Laws

Europe

There is not much information on the YTB legislation in Europe because of a strong push for the exclusive bus lanes and other priority measures. In England and Germany, bus bays have been filled, and these stops have been turned into regular curbside stops so that buses do not have the problem of re-entering the traffic. There seems to be more concerned about the delay of buses than the delay of cars, so they allow cars to queue behind the bus. Implementation of the exclusive bus lanes also prevents bus merging problems.

Summary

Based on the literature review, the most effective technology used to supplement the YTB laws in North America is the flashing yield sign. Different states, however, may have different laws regarding the implementation of additional flashing lights on the back of the bus. The Florida YTB law is one of the least comprehensive laws and does not specify how the law is to be implemented. The awareness of the law also seems to be lacking considering even though it is mentioned in the Florida Driver's Handbook.

The Manual on Uniform Traffic Control Devices (MUTCD) does not address traffic control devices for the YTB law; however, it does specify pavement markings and signs for general yielding intersections, and yielding for pedestrians and bicyclists. The bus activated flashing beacon seems to be a promising technology for school buses; however, the flashing beacon, due to restrictions on use in the MUTCD, may have limited use in YTB applications. Warning beacons are used as supplemental emphasis to regulatory signs, except STOP, YIELD, DO NOT ENTER, and SPEED LIMIT signs. Other types of flashing beacons mentioned in the MUTCD include intersection control beacons, speed limit sign beacons, and stop beacons. Installing video cameras on school buses to capture people illegally passing the school bus seems to have a significant effect on compliance with school bus laws.

Roadside signage could provide additional information to motorist to warn them of the potential of buses merging into traffic. In the event that a sign on the back of the bus is not seen, the roadside sign may serve to inform the motorist that they must yield to the bus at bus bay locations. A roadside sign may not be necessary for all bus bay

locations, but at specific locations where rear-end collision are observed to be high due to non-compliance with the YTB laws. Also, in high crash locations, additional pavement markings can be used to remind motorists to yield.

CHAPTER 3

METHODOLOGY

This thesis seeks to make recommendations for improving bus safety and operations in Florida. In order to determine the best practices in signs and lighting for Florida's public transit buses a literature review was conducted to find any previous research on the effectiveness of different signs and lights. The literature review also covered research on bus stop design and location, lighting and signs for school buses, and pavement markings. Under contract with the Florida Department of Transportation, the Center for Urban Transportation Research (CUTR) sought to develop the best practices in moving the bus back into traffic safely in Florida. Bus operator surveys from this CUTR study was employed to evaluate bus operators' perceptions. Case studies of transit agencies were developed using bus operator surveys, field studies and crash data.

Bus Operator Survey

Bus operators have first hand experience with the difficulty of moving in traffic safely and therefore it was important document their experiences. A bus operator questionnaire was developed to aid in recommendations for the project objectives. The questionnaire was formatted in three sections. The first section asked questions about bus operations and perceived motorist yield behavior. There were questions on their use of bus pull-out bays, right-turn lanes and wide shoulders for loading and unloading passengers. The second section pertained to different technologies available on the back

of the bus for moving the bus back into traffic safely. The third section pertained to the current Florida laws and any additional safety concerns. At the end of the questionnaire was a narrative portion where bus operators were able to make recommendations for their own bus safety program as well as any additional comments and concerns. A copy of the questionnaire developed is shown in Appendix B.

Field Observations

To supplement bus operator surveys, observations in the field can provide valuable information on current conditions and driver behavior. Three variables that can be recorded in the field are clearance times, yield behavior and conflicts.

Clearance Time and Re-entry Delay

The clearance time is defined in the Transit Capacity and Quality of Service Manual as the minimum time required for one bus to accelerate out of and clear the loading area and the next bus to pull into the loading area, including any time spent waiting for a gap in traffic (Kittelson and Associates 2003). Part of the clearance time is fixed and consists of the time it takes the bus to start up and travel its own length. The variable part of clearance time is only apparent for off-line stops when a bus must wait for a suitable gap in traffic. This variable portion of the clearance time is known as the re-entry delay. The Transit Capacity and Quality of Service Manual suggests that in states with yield-to-bus laws, the re-entry delay can be minimized or eliminated depending on how well motorists comply with the laws. Table 3 shows the average re-entry delay for adjacent lane of different mixed traffic volumes. These values were computed using the HCM 2000 unsignalized intersection methodology therefore these results can only be

applied to off-line stops where buses must yield to other traffic when re-entering, and the stop cannot be influenced by a signalized intersection.

Table 3 Average Bus Re-entry Delay

Adjacent Lane Mixed Traffic Volume (veh/h)	Average Re-entry Delay (s)
100	1
200	2
300	3
400	4
500	5
600	6
700	8
800	10
900	12
1,000	15

(Source: Transit Capacity and Quality of Service Manual)

Off-line bus stops are subject to re-entry delay which is dependent on traffic volumes and the platooning effect from upstream traffic signals (Gan et al 2002). According to TCRP Report 26, one element that affects bus capacity is the clearance time. In order to remedy the negative effects of clearance time, the report suggest using on-line stops and enacting and enforcing laws that require cars to yield to buses re-entering traffic (Jacques and Levinson 1997).

Conflict Study and Yield Behavior

A conflict study can be used to determine hazardous locations and situations. A traffic conflict is a situation in which a collision would have occurred if road users had continued with unchanged speeds and directions. Counting the number of serious conflicts that occur at a location can be used to determine the level of traffic hazard (De Langen and Tembele 1994). Traffic Conflict Techniques (TCTs) have been developed in a number of European and North American countries to add relevant information to

existing accident data, or replacing missing accident (Muhlrad 1993). A conflict is often determined by an abrupt braking maneuver, therefore vehicle tail-lights are watched and the drivers' speed and rapid deceleration is noted.

Yield behavior is determined by inspection of videos taken in the field. Like a conflict study, yield behavior is determined by the observer and is a subjective measure of traffic safety. Yield behavior varies by location since an intersection affects driver behavior. Yield behavior at mid-block locations are therefore expected to be different that at far-side and near-side bus stops.

CHAPTER 4

DATA COLLECTION

Bus Operator Survey

Preliminary bus operator questionnaires were conducted at the State Bus Roadeo in Jacksonville, Florida in March 2007. Twelve bus operators from several different transit agencies across Florida participated in the Roadeo, which is an event where bus operators and maintenance staff compete in various competitions. Questionnaires were handed to each bus operator on the first day of the Roadeo and were collected on the following day. Additional surveys were administered orally for the operators that did not complete the survey prior to the second day of the Roadeo. A total of ten questionnaires were received from operators representing ten different transit agencies. In Jacksonville a visit was made to the bus operator lounge for Jacksonville Transit Authority (JTA) during the bus operator practice day for the Roadeo. Most of the questionnaires were administered by reading the questions to bus operators and filling in their responses, a few operators took questionnaires and filled them out and returned them by the end of the visit.

Additional surveys were done at the bus operator facilities for Lynx in Orange County and Hillsborough Area Regional Transit (HART) in Hillsborough County. In these areas, bus operators waited on their shifts and therefore it was an opportune time for questionnaires to be completed. At these locations questionnaires were also completed in

two different ways; questions were read directly to the bus operator while the responses were filled out by the person administering the survey while other surveys were handed directly to the bus operator for them to be filled out. Surveys were conducted at Lynx on Wednesday, March 28, 2007 between 12 noon and 2 PM. HART surveys were conducted on Thursday, April 26, 2007 between 2 PM and 4 PM. Data collection dates and times were suggested by supervisory staff. The method of survey administration was also dependent on the preference of transit agency staff. Additional questionnaires were left at the Lynx and HART facilities for operators who were not present at the time of the survey but wished to participate. The additional Lynx questionnaires were mailed back, while the HART questionnaires were collected at a later date.

The transit agencies chosen for the survey represented a range of practices in Florida. JTA in Duval County did not have any YTB decals or LED lights therefore their responses represented operators who were not using any YTB technologies. Pinellas Suncoast Transit Authority (PSTA) in Pinellas County and HART both had YTB decals on their entire fleet; therefore their responses represented agencies with a widely used YTB technology. Lynx in Orange County had three different YTB decals, but they were not installed on all buses. Operators from Lynx were able to compare the different YTB decals and comment on their effectiveness. Leetran in Lee County used both YTB decals and “Yield” LED signs but not on their entire bus fleet. Votran in Volusia County never had any YTB decals, but they did have “Yield” LED lights on a few of their buses. Leetran and Votran represented the only agencies in Florida that employed a technology other than the decal for YTB laws.

Reading out questions directly ensured that surveys were filled out completely and questions were understood properly. Questionnaires that were handed out had more sources of error since questions could be misunderstood and questionnaires could be filled out incorrectly.

Additional questionnaires were mailed and e-mailed to transit agencies for responses to be mailed back when completed by the bus operators. Mailed questionnaires were received from LeeTran in Lee County, Votran in Volusia County, Pinellas Suncoast Transit Authority (PSTA) in Pinellas County and Starmetro in Leon County. Surveys from Lee County and Volusia County were completed between March and April 2007. Surveys from Pinellas County were completed in May 2007 and surveys from Leon County were completed between May and June 2007.

A total of 277 bus operator questionnaires representing 12 counties were obtained. Only one questionnaire was received from Polk, Manatee, Broward, Brevard and Alachua counties during the preliminary survey in March 2007, therefore information from these counties were not greatly represented. The aggregated responses from the bus operators are available in Appendix B.

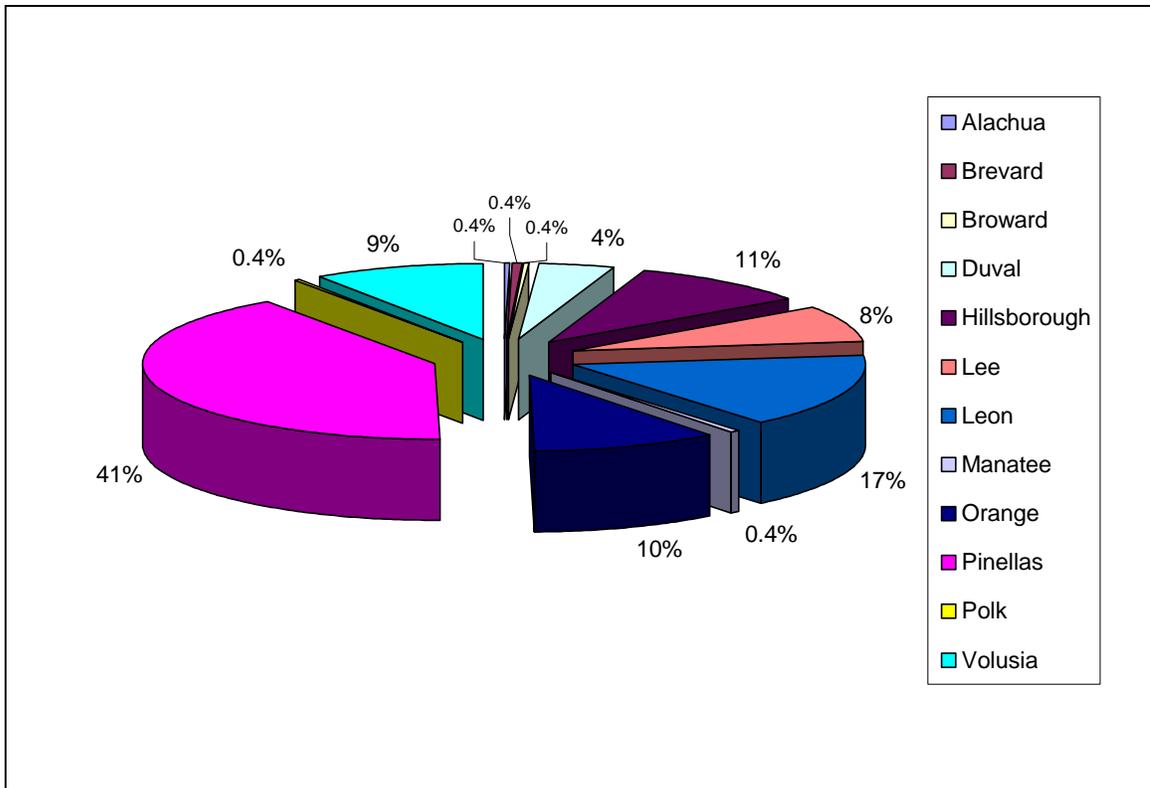


Figure 33 Counties Involved in Survey

There are a few shortcomings with the operator surveys. Bus operators sometimes answered the questions incorrectly, filling in sections that did not apply to their agency practices. In the section where they stated the current practices in signage and lighting of their transit agency, some bus operators either selected technologies that were not currently being used or responded that a technology currently being used was being used. These responses could be due to the fact that Lee County Transit (LeeTran) and Volusia County Transit (Votran) employed flashing yield signs on a limited number of buses and therefore it is possible that some bus operators had no experience with the signs and therefore indicated that their agency did not have them. Some transit operators may have also worked with different technologies in the past and therefore commented on them even though their current agency did not employ these technologies.

Another problem with the questionnaire responses was the possibility for other operators and transit agency employees to influence the bus operators' perception of a new technology. Constant negative or positive feedback can influence the bus operators' view of a certain practice.

The number of survey results received from each transit agency can also impact the survey results. As shown in Figure 33, survey results from Pinellas County accounted for 41 percent of the bus operator survey. Weights could possibly be added to the transit agency responses, however, the results were very similar across counties with YTB decals and weights would not significantly impact the final results. LeeTRAN and VOTRAN responses only accounted for 8 and 9 percent of responses respectively, and this was another challenge since they are the only agencies that employed flashing yield signs in Florida, compounding the already existing issue of only a few buses in the fleet having this technology. JTA was the only agency in the study that employed no signs or lighting for the YTB law.

Field Observation

Field studies were conducted using a video camera mounted on a tripod. The camera was positioned at enough distance to capture buses moving in and out of bus pull-out bays. Locations therefore had to be selected where a camera could be mounted and positioned with a clear view of the buses and cars. Far-side bus stop locations posed a particular challenge since the camera had to be located across the intersection. At certain times, the cross street traffic would block the view of the buses at far-side.

Site Selection

Three locations were chosen in Hillsborough County for field studies of HART buses, and three locations were also chosen in Orange County for field studies of LYNX buses. From each county were one far-side, one mid-block and one near-side bus stop. The locations were chosen based on the traffic conditions and the existence of a bus pull-out bay. For there to be any significant data, these locations had to have enough passenger volumes to observe the bus moving in and out of traffic to load and unload passengers. The locations also had to have high traffic volumes otherwise there would be no difficulty in merging back into traffic. At least three hours were spent at each location. The locations chosen in Orange County were based on recommendations by Lynx staff. Field studies in Hillsborough County were conducted during the afternoon peak hours in December 2006. Field studies in Orange County were conducted during morning and afternoon peak hours. Details of these field observations are shown in Table 4.

Table 4 Hillsborough and Orange County Field Data Locations

County	Location	Date	Start Time	2006 AADT
Hillsborough	Fletcher Ave and Bruce B Downs Blvd	12-Dec-06	1:00 PM	23500
Hillsborough	Hillsborough Ave and Florida Ave	13-Dec-06	2:20 PM	29500
Hillsborough	Fletcher Ave and Dale Mabry Blvd	14-Dec-06	12:37 PM	21000
Orange	Kirkman Road and Conroy Road 1	24-Apr-07	6:44 AM	30000
Orange	Kirkman Road and Conroy Road 2	24-Apr-07	7:56 AM	30000
Orange	Orange Blossom Trail and Holden Ave	24-Apr-07	1:09 PM	33500

Basic geometrical information at Orange County locations was taken, which includes the distance from the bus stop to the nearest intersection and the geometry of the bus pull-out bay. The Average Annual Daily Traffic (AADT) for these locations was obtained from the Florida Department of Transportation to compare relative traffic conditions. Details of these field locations are presented in Appendix D.

Site visits were also made to Volusia County and Lee County in January 2007. Pictures were taken of potential data collection locations and YTB signage practices. Some of the pictures collected from Volusia and Lee County are presented in Appendix E along with pictures from Hillsborough County and Orange County.

During field visits to Volusia County, drivers were not observed to be using the flashing yield signs and the flashing yield signs in Lee County were not yet implemented therefore further video data was not collected in these counties.

New Test Decal

Based on the results of the literature review and preliminary bus operator surveys, a new YTB decal was designed by the Center for Urban Transportation Research and produced by Next Day Signs to be tested on Starmetro buses in Tallahassee. The new decal was made larger than the average decal in Florida to see if the larger sign has any effect on a transit system that previously never employed any YTB signage or lighting. Ten decals were made using reflective vinyl. The decal was made as an 18 inch square with the Florida Statute listed (Figure 34). The design of the new decal was based on results from the literature review, bus operator survey and the MUTCD yield sign. In the narrative portion of the questionnaire, some bus operators recommended a larger YTB decal; therefore the new test decal was made larger than the typical decals seen in

Florida. The red triangle, which is the sign used in the MUTCD was also made brighter and more like the MUTCD yield sign. The basic elements of the YTB decal were made similar to other YTB decals used in Florida. Initially, a large 69 inch decal, similar to the one used by Lynx in Orlando was considered but Starmetro did not want this larger decal to conflict with advertising on the back of the bus.



FIGURE 34 New YTB Decal for Starmetro

The Starmetro bus fleet consisted of 68 buses and the maintenance personnel were instructed to put the decals in the upper-left corner of the rear door panel of 10 buses.

The site locations chosen for the new test decal were based on suggestions from the Starmetro bus operators. Bus pull-out bays are not common in Tallahassee therefore one of the locations chosen was a bus stop located in a right-turn lane where the bus needed to exit and go straight after loading and unloading passengers. The bus operators therefore have to merge into traffic from the right-turn lane. The locations chosen are presented in Table 5.

Table 5 Leon County Field Data Locations

Location	Date	Start Time	2006 AADT
Macomb St and Georgia St	16-May-07	7:26 AM	8800
Monroe St and John Knox Rd	16-May-07	9:18 AM	21500

Yield Behavior, Re-entry Delay and Conflict Study

From videos taken in the field, the re-entry delay, conflicts, and yield behavior of motorists were recorded. Different types of conflicts were observed in the field. Hard breaking maneuvers, weaving into oncoming traffic were, changing lanes abruptly behind the bus into a clear lane were considered conflicts. Secondary conflicts were created when motorists weaved into another lane causing drivers in that lane to abruptly apply the brakes. Yield behavior was determined by cars slowing down to allow the bus back into traffic. The purpose of the YTB law is to make motorists yield to the bus when it attempts to re-enter traffic from a specifically designated bus pull-out bay. The number of cars that would pass a bus attempting to merge back into traffic was also used as a measure of yield behavior. The number of motorists that would pass a bus attempting to merge is dependent on several variables including the traffic volume, road geometry and general visibility of the bus. The speed of the road and awareness of the YTB law also influences the motorists' yield behavior.

The motorists' yield behavior has a significant impact on the re-entry delay of buses. The re-entry delay for this study was used to evaluate the difficulty of bus operations in traffic. The re-entry delay of buses with different YTB technologies was compared to ascertain whether there was any noticeable difference in motorists' reaction to merging buses with and without YTB decals.

Crash Data

FDOT District 7 crash data which includes Pinellas and Hillsborough counties was used to look at bus crash trends between 2001 and 2005 for the Hillsborough Regional Area Transit (HART) and Pinellas Suncoast Transit Authority (PSTA) buses. The crash data is based on police crash reports. Bus crashes were separated in the database by vehicle type and vehicle use. Crashes where the bus was not at fault and the cause was rear-end or side-swipe was then separated. As buses move in and out of bus pull-out bays, they are prone to rear-end and side-swipe collisions. A total of 65 crashes in this category were obtained for Hillsborough County and 120 for Pinellas County.

CHAPTER 5

DATA ANALYSIS

Survey Results

Based on the literature review, electronic signs on the back of the bus are favored more than the decals. The bus operator questionnaires conducted produced these same results. When asked which technology they preferred, the majority (73 percent) chose the LED merging sign. The bus operators perceive the electronic sign to be more helpful in bus operations and they also perceive it to help with safety more than the decal. The only positive responses for the decals were in mentions of the large 69 inch decal present on some of the LYNX buses in Orlando. When asked if there was a noticeable difference in motorist yield behavior compared to before the implementation of the YTB technology, the bus operators with experience using the decal were more inclined to answer negatively. Figure 35 shows the results from question 9 of the survey which asked whether there was a noticeable difference in yield behavior before the implementation of the YTB technology. Figure 36 shows the bus operators' perception of the safety effects for different YTB technologies. Figure 37 shows the bus operators' response to question 8 on the questionnaire which asked how helpful the YTB signs were.

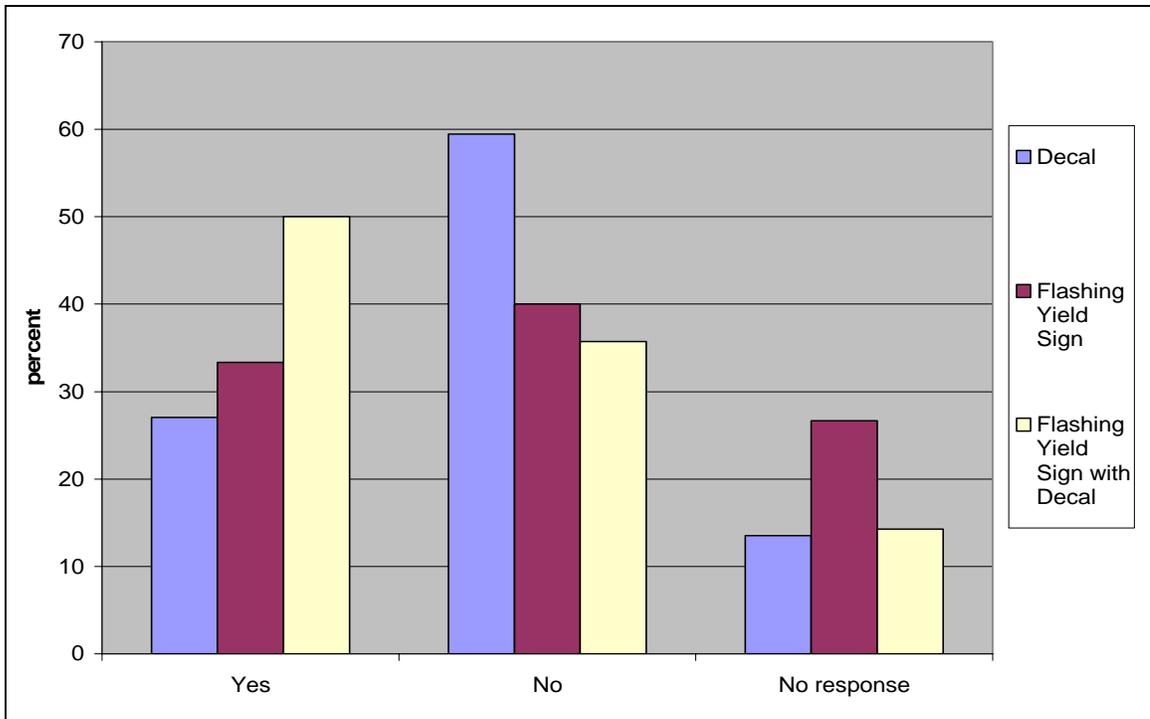


Figure 35 Differences in Yield Behavior Reported by Bus Operators

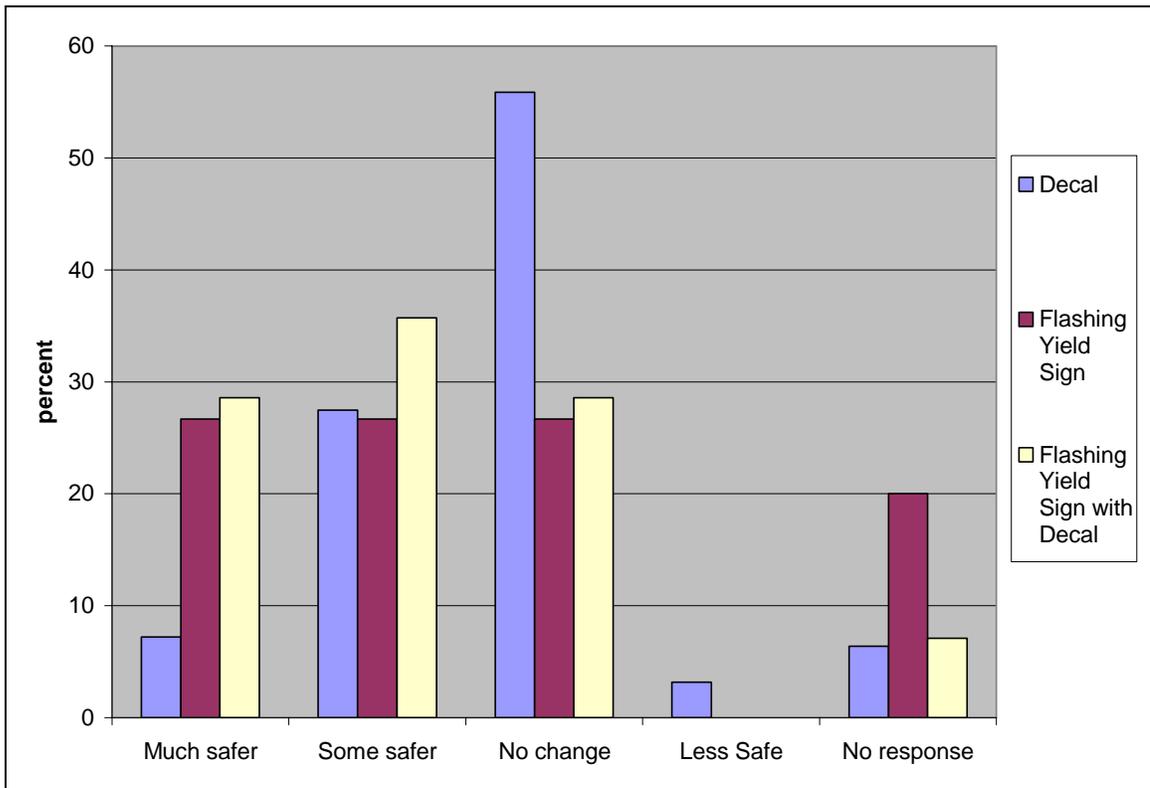


Figure 36 Bus Operators' Perception of Safety Effects

In the narrative portion of the questionnaire, the most common recommendation for a bus safety program was better police enforcement of the laws and more public service announcements about the presence of the YTB laws. Other recommendations made by the bus operators were to install stop arms like school buses and improve the existing lighting and signs. When asked about the current Florida laws, 50 percent of bus operators felt that the current laws are insufficient and 5 percent had no response. When asked about the conditions where motorists should yield to the bus, 76 percent of operators felt that there are other conditions in which motorists should yield.

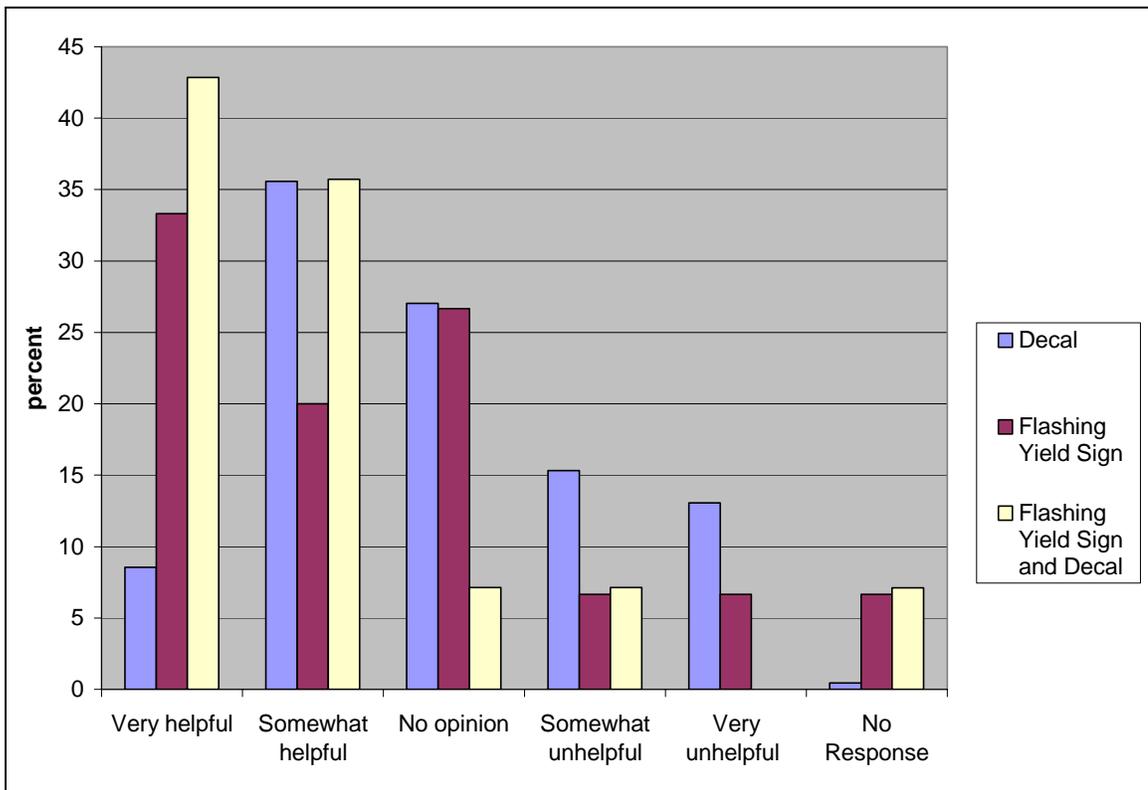


Figure 37 Bus Operators' Perception of the Helpfulness of YTB Signs

In order to evaluate whether there should be consideration for expanding the current Florida statute to include yielding to a bus merging back from any offline stop, the operators were asked if they have any bus pull-out bays on their route. Although 74

percent of operators responded that there were bus pull-out bays on their routes, many of them also responded that they use right-turn lanes or wide shoulder lanes to load and unload passengers as seen in Figure 38 which shows how often bus operators use these other offline stops. Some operators also commented that they do not use designated bus pull-out bays because it makes pulling into traffic more difficult.

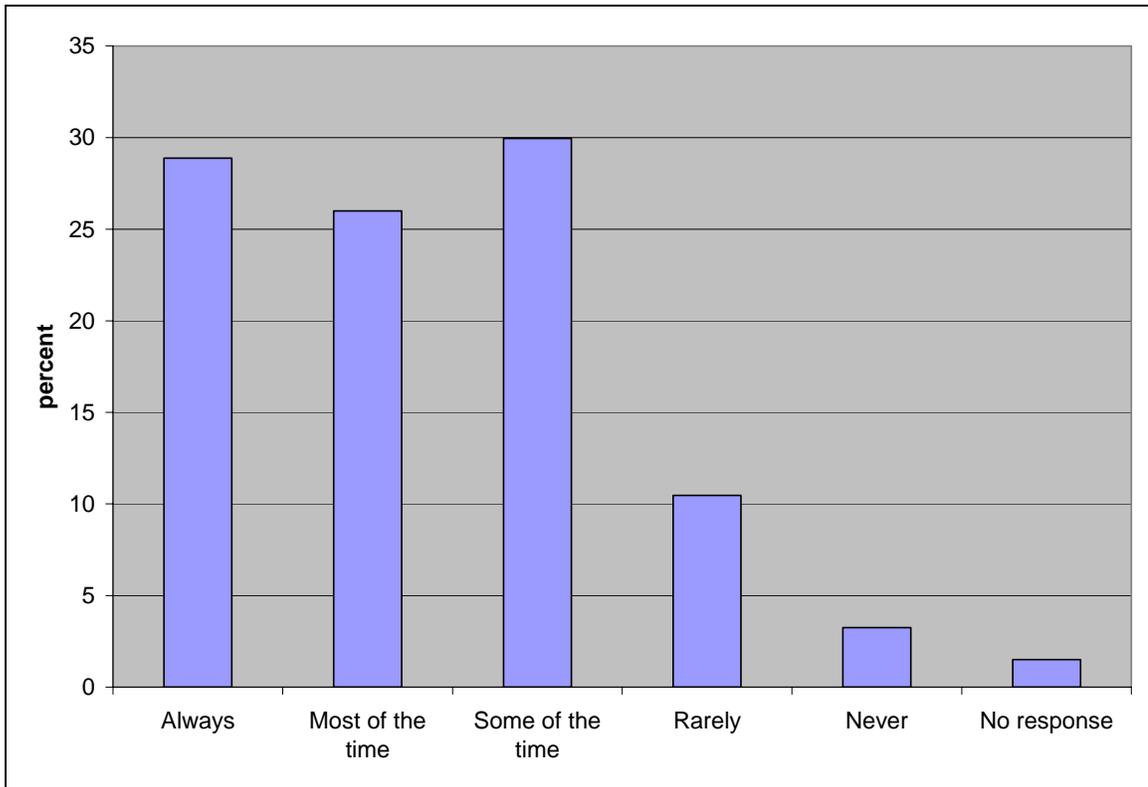


Figure 38 Bus Operators' Use of Right-turn Lane or Shoulder

Field Observations

From the field data collected it was obvious that the location of the bus pull-out bay and the traffic volume affected the yield behavior of other motorists. Far-side bus stop locations had the unique problem of being located where drivers would have to yield in the physical area of the intersection to allow buses to enter. Motorists therefore never yielded to the bus at a far-side stop unless the bus did not use the pull-out bay, forcing traffic to accumulate behind the bus. This location may be a dangerous place to attempt to yield since following motorists do not expect another motorist to slow down in the middle of the intersection. The average re-entry delays for the hours recorded ranged from 13 to 36 seconds as shown in Table 6.

Table 6 Average Re-entry Delay by Location and AADT

County	Location	Location type	2006 AADT	Average Re-entry Delay (s)
Hillsborough	Fletcher Ave and Bruce B Downs Blvd	Near-side	23500	13
Hillsborough	Hillsborough Ave and Florida Ave	Far-side	29500	32
Hillsborough	Fletcher Ave and Dale Mabry Blvd	Mid-block	21000	15
Orange	Kirkman Road and Conroy Road 1	Near-side	30000	13
Orange	Kirkman Road and Conroy Road 2	Far-side	30000	13
Orange	Orange Blossom Trail and Holden Ave	Mid-block	33500	36

The delay of buses is dependent on several variables, including the number of lanes, location of bus stop, hourly traffic volumes and the attitude towards buses in that specific location.

Dangerous weaving and conflicts were observed as cars attempted to move out of the lane that the bus was merging into. There seems to be no difference in motorist yield behavior with the presence of a decal. The weaving observed caused conflicts with other vehicles on the road, not just the buses, therefore the crash data consisting of bus accidents only may not accurately predict the accidents caused as buses merge into traffic. Some accidents may occur between the weaving automobile and the automobile in the lane in which the weaving motorist is trying to merge. The number of conflicts observed during a specific time period was dependent on the traffic conditions and headway of the bus. Higher traffic volumes and smaller headways will increase the number of conflicts.

In these studies there were no occurrences observed of drivers yielding to the bus, therefore the number of vehicles that would pass the bus as it attempted to merge into traffic was the only variable recorded for yield behavior. The only time drivers were seen slowing down while approaching a bus operator that has signaled his or her intent to merge into traffic was when traffic was backed up to the bus pull-out bay, allowing the bus operator to merge in-between two stopped cars. In this scenario there were no conflicts recorded, which was the situation often at the Florida Avenue and Hillsborough Avenue location in Hillsborough County.

Table 7 shows the conflict rate expressed in conflicts per 100 buses obtained at each site location as well as the average headway of the buses that stopped and the average number of cars that passed the bus after the bus operator signaled his or her intent to merge back into the travel lane.

Table 7 Average Headway, Conflict rate and Yield Behavior from Field Data

County	Location	Average Headway (minutes)	Conflicts per 100 buses	Average number of cars that pass after left signal
Hillsborough	Fletcher Ave and Bruce B Downs Blvd	22	18	9
Hillsborough	Hillsborough Ave and Florida Ave	30	0	6
Hillsborough	Fletcher Ave and Dale Mabry Blvd	34	51	3
Orange	Kirkman Road and Conroy Road 1	24	8	10
Orange	Kirkman Road and Conroy Road 2	25	33	0
Orange	Orange Blossom Trail and Holden Ave	9	34	9

New Test Decal

No significant findings were obtained from video data of the new decal used at Starmetro possibly because the video was take the same day the new decals were implemented. During the hours of data collection there was no significant difference in motorists' behavior around buses with and without the new decal. Video data was collected the morning after the new decals were implemented therefore the motorists possibly did not have a chance to react to the new signs. Operator questionnaires were then distributed 2 weeks after the new decals were implemented to see if they noticed any difference in motorists' behavior after 2 weeks. Forty-one percent of operators said there was a noticeable difference in yield behavior but a few operators commented in the narrative section that they are still not used to the new decals.

The decals were restricted to buses that did not have advertising on the back and also to the newer Gillig buses since the older RTS models did not have adequate space to accommodate an 18 inch decal. The lighting configuration on the back of the buses constrained the exact location of the decal. On the older Gillig buses, the decal could be placed in the corner of the rear door panel but on the newer Gillig models, the decal had to be placed closer to the center to avoid the rear lights. Figure 39 shows the locations where the new test decals were placed on the Starmetro Gillig buses.



Figure 39 Starmetro Decal Placements

Crash Analysis

The Pinellas county crash data suggests that bus crashes between 2001 and 2005 remained constant. The YTB decals were installed on all PSTA buses in 2005 but no noticeable trend was seen in the bus crashes from January 2005 to December 2005. The exact date of the installation of YTB decals was not ascertained therefore these results are inconclusive.

The bus crash trends from 2003 to 2005 in Pinellas County, using crash data, shows that for crashes involving at least one vehicle defined as a public transit bus, the

bus was only at fault in 31 percent of cases. In the cases where the bus was not at fault, 48 per cent of accidents occurred at an intersection, 25 percent were not at an intersection, 10 per cent were influenced by an intersection and 9 percent were in a public bus stop zone. In these cases the 51 percent of the cases involved a bus slowing/stopped or stalled and in 38 percent the bus was traveling straight ahead. These findings are consistent with previous research and the field observations.

The 2003 to 2005 Hillsborough crash data shows that 34 percent of bus crashes were rear-end collisions, 23 percent were angle collisions and 24 per cent were side-swipe collisions. The bus was at fault in only 25 percent of bus crashes. There was an increase in bus accidents between 2001 and 2005 as shown in Figure 40. The HART decals were installed between 2001 and 2002 therefore they do not seem to have any effect on bus crashes.

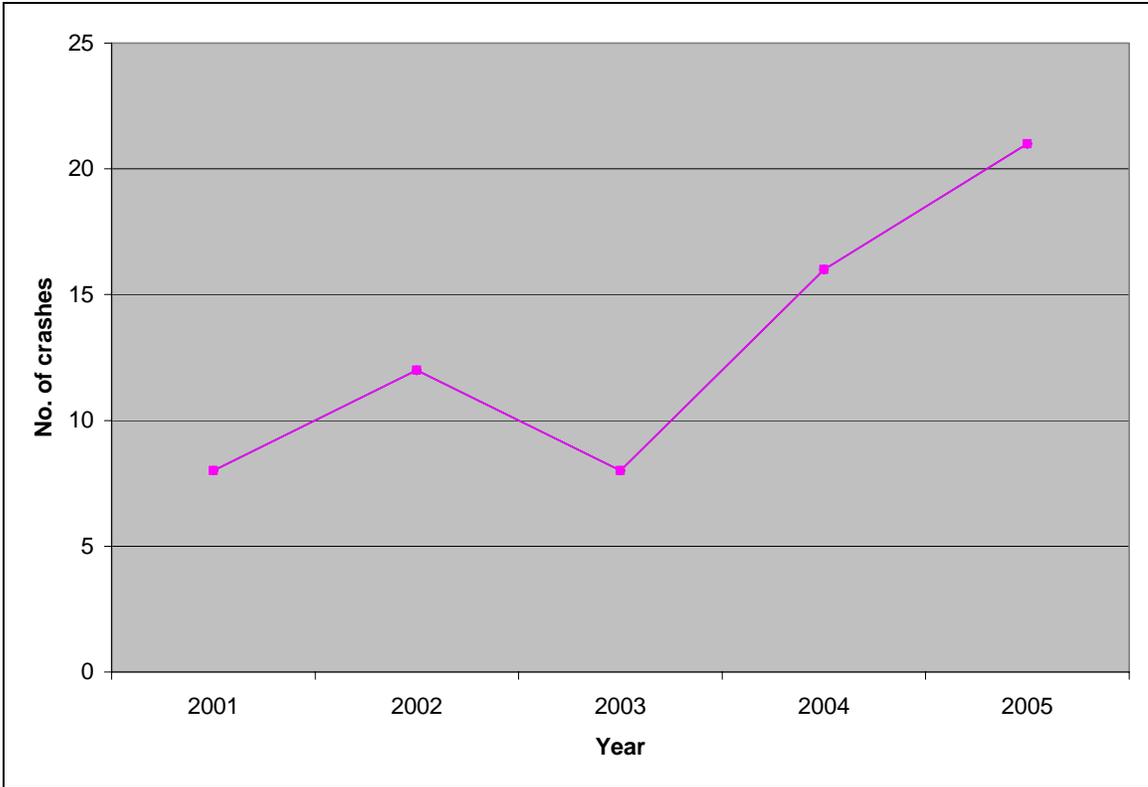


Figure 40 Hillsborough Bus Side-swipe and Rear-end Collisions

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

Signs and bus exterior lighting can be used to improve bus safety and operations but the proper law enforcement must be in place for the technology to be effective. Exterior bus lights can warn motorist that the bus is merging into traffic but they must be able to understand the meaning of these signals. There needs to be a standard procedure for buses merging into traffic because many different lights of different colors can be confusing to the motorist. There is also a stigma attached to driving behind slow moving buses, therefore motorists will find a way around them regardless of the laws and warning lights. Law enforcement is therefore needed to change the drivers' yield behavior. There is some question as to the extent to which the public is being educated about the law. Currently in the 2007 Florida Driver's Handbook, there is mention of the law requiring motorists to yield to the bus, but this is just a small section of the handbook and therefore it could easily be overlooked unless it is being tested in driver exams. Further research can be done to evaluate both the public's understanding of bus rear lighting and their knowledge of the laws. This awareness can be compared to other states in which the laws are present to see if a different environment and attitude towards transit will also affect yield behavior. Additionally, a look into citations issued would be a good measure of law compliance and enforcement.

Decals, although they do not get favorable responses from bus operators, can be used as public announcements. These decal, although they do not change driver yield behavior, can act as a small advertisement on the back of the bus provided motorist get the time to read it. The dilemma with bus decals is that the lighting configuration does not always allow for larger decals and small decals cannot easily be read by other motorists. Standardizing a yield decal for Florida buses may be a difficult feat since the lighting layout on the back of the bus constrains the size and location of the decals. Larger decals have a more favorable response from bus operators; however, these decals cannot be accommodated on all buses due to conflicts with advertising and lighting configurations. The flashing yield sign or one of the more recent technologies that are not yet on the market may be more beneficial for bus operations and safety, however there needs to be a standardized way to use the flashing warning signs so that motorists can understand what the sign means. NHTSA recognizes that adding more lights will not necessarily improve bus safety and therefore there must be further research into these new LED lights with dynamic messages. Public awareness of the dangers of hastily weaving behind a bus and awareness of the existence of yield-to-bus laws is vital for supporting any new technology employed to improve bus safety and operations.

Bus pull-out bays are sometimes needed in certain locations. In places where dwell times are long, the buses should be out of the travel lane in order to increase the capacity of the road. This has delay savings for other road users but unfortunately, the bus loses some time when trying to merge back into traffic. Yield-to-bus laws were created to alleviate this problem; however, it is not safe to apply it to all off-line bus stops. At far-side bus stops, it is not safe for motorists to yield to a bus in an intersection.

More in-depth research can be conducted to justify the use of pull-out bays and delay savings to the transit agency when there is compliance with the law. The figures presented in this research for re-entry delay could be explored to see the impact these small delays will have on the entire route. Future research can be done to explore re-entry delay, delay propagation and schedule adherence. A model can be developed to predict the delay a bus will have based on variables such as the number of lanes, location of bus stop, distance to the nearest intersection, hourly volumes, speed limit, and bus headway.

Additionally, research needs to be done on the dynamic LED signs mentioned in this research. If implemented, they do not appear to cause any conflicts with other rear lighting and since they display a clear message, they do not appear to have any ambiguous meanings. This, however, would have to be tested in the field to make sure drivers do understand the meaning of the word messages.

Recommendations

NHTSA Recommendations

Based on field observations of the rear-lighting on Florida buses, there is no set lighting configuration used. Although a basic configuration is observed based on NHTSA standards, the colors and types of lights vary greatly within the limits of NHTSA. The amber strobes lights can be confused with turning signals if only half of the bus rear is visible, which is the situation at some bus bay locations. In this situation it is therefore difficult to tell if a bus is stopped and picking up passengers or trying to merge into traffic. The typical motorist does not have the time to decipher the bus actions therefore there needs to be some guidelines for the placement of optional lights on the back of the

bus. The Federal Motor Vehicle Safety Standards and Regulations (FMVSS) allow for stop lamps that are activated by the braking system to be red or amber and the turn signals can also be red or amber. To standardize the lighting on the back of the bus, a set color should be chosen.

The majority of bus operators prefer the flashing Merge Alert sign but it is currently not being used. Further tests can be done on this LED sign to see if it is worth applying. If it is implemented, there needs to be clear guidelines as to what other optional lighting is added to the bus. If a dynamic LED sign is placed on the back of the bus, it probably should not be used simultaneously with flashing hazard lights or deceleration lights.

MUTCD Recommendations

Since the MUTCD currently has no signage or pavement markings for the YTB law, new signage and pavement markings can be developed based on the existing practices for yielding to pedestrians and bicyclists. A concern would be that adding more to the MUTCD may only add to driver confusion. Many roads are already congested with roadway signs and pavement markings that give drivers more information than they are able to digest. Additional signs and pavement marking for the YTB law would therefore have to be used under strict engineering judgment in areas where many conflicts are observed. Figure 39 shows possible YTB roadway signs that can be added to the MUTCD.

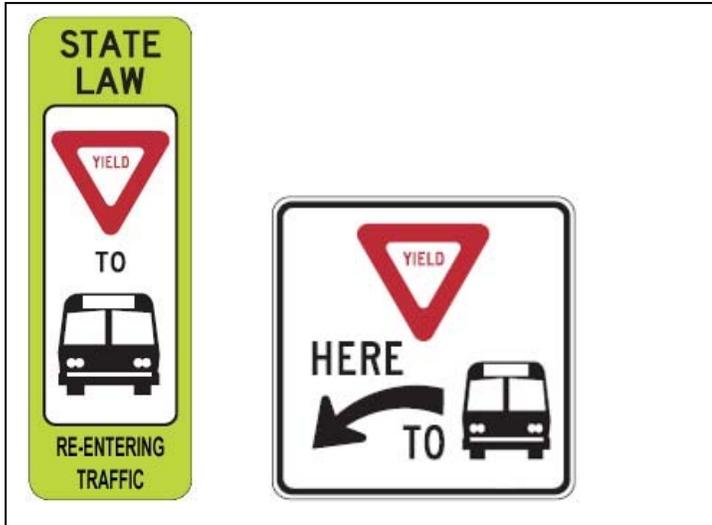


Figure 41 Yield-to-Bus Roadway Signs

Additionally, flashing beacons that are activated by a bus in a bus pull-out bay can be explored. The location of these beacons would be very strict since it may conflict with intersection lights at near-side and far-side bus stop locations.

Florida Statute Recommendations

The current Florida statutes make no mention of how the YTB law is to be implemented and this possibly contributes to the lack of law enforcement. Taking the example of other states, the Florida Statute can be expanded to include a penalty for not yielding to the bus or a classification for the type of offence committed. The viability of the law is partially dependent on how well it can be enforced and therefore adding more information on the implementation and penalties should be beneficial.

Other States require a public awareness campaign to let motorists know about the yield-to bus laws and this is something that needs to be done in Florida. Like in other states, a system should be set up to evaluate the necessity of the law based on the total number of traffic collisions, traffic congestion issues, public opinion and the efficiency of transit operations.

According to the bus operator survey, the majority of operators believe that there are other conditions in which motorists should yield to a public transit bus. The bus operators also reported that they use shoulders and right-turn lanes to pull out of traffic, not just a specifically designated bus pull-out bay. A detailed look into Florida bus crashes and delay problems can be used to determine whether it is necessary for motorists to yield under other conditions. Other states have not specified that motorists should yield at specifically designated bus pull-out bays, therefore buses that pull over in any off-line stop would be covered under the laws. Removing the requirement of a designated bus bay can be considered especially since some counties do not have many bus bays, but still have difficulty merging into traffic after loading and unloading passengers.

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APPENDICES

Appendix A: Yield to Bus Laws

California Vehicle Code (CVC) Section 21810

21810 Right-of-Way: Yielding to Buses

- a) The driver of a vehicle overtaking a transit bus shall yield the right-of-way to the bus if all of the following conditions are present:
 - 1) The transit bus has entirely exited an active traffic lane to board or deboard passengers at a designated bus stop, and is attempting to reenter the lane from which it exited.
 - 2) Directional signals on the transit bus are flashing to indicate that the bus is preparing to merge with traffic.
 - 3) The transit bus is equipped with a yield right-of-way sign on the left rear of the bus. The sign shall be both of the following:
 - A. Designed to warn a person operating a motor vehicle approaching the rear of the bus that the person is required to yield the right-of-way to the bus when the bus is entering traffic.
 - B. Illuminated by a flashing light when the bus is signaling in preparation for entering a traffic lane after having stopped to receive or discharge passengers.
- b) Nothing in this section requires a transit agency to install the yield right-of-way sign described in paragraph (3) of subdivision (a).
- c) This section does not relieve the driver of a transit bus from the duty to drive the bus with due regard for the safety of all persons and property. Nothing in this

Appendix A: (Continued)

section relieves the transit agency from complying with the standard of care for its passengers established by Section 2100 of the Civil Code.

- d) The provisions of this section are applicable to the Santa Cruz Metropolitan Transit District, the Orange County Transportation Authority, the Alameda-Contra Costa Transit District, and the Santa Clara County Transit District, if the governing board of the district approves a resolution, after a public hearing on the issue, requesting that this section be made applicable to it, and transmits a copy of the resolution to the commissioner.
- e) (1) Notwithstanding Section 7055.5 of the Government Code, on or before December 31, 2002, the commissioner, after consultation with the participating transit agencies, participating law enforcement, and the advisory committee established pursuant to paragraph (3) of subdivision (a) of Section 34501 of the Vehicle Code, shall report to the Legislature on the effectiveness of the right-of-way for transit vehicles established by this section, including, but not limited to, any impact on the highway and local road safety and the efficiency of transit operations. The report shall recommend whether or not the right-of-way established by this section should be made permanent on a local basis, and whether it would be effective if implemented on a statewide basis. (2) The commissioner, in consultation with the participating transit agencies, the California Transit Association, the advisory committee, and the participating local law enforcement agencies, shall identify the information required for preparation of the report required under paragraph (1).

Appendix A: (Continued)

This information may include, but need not be limited to, all of the following:

- (A) The total number of traffic collisions causing fatalities or injuries, and the number causing only property damage.
- (B) Traffic congestion issues.
- (C) Public opinion issues.
- (D) Efficiency of transit operations.
- (E) The public education program required under subdivision (i).

(3) The commissioner may develop a format and schedule for reporting the information identified under paragraph (2), and the local law enforcement agencies, transit agencies, and the California Transit Association shall provide the commissioner with the information by using that format and in compliance with that schedule.

- f) Each transit agency participating in the program shall undertake a public education program to inform motorists of the requirements imposed by this section.
- g) The base fine for a violation of subdivision (a) is thirty-five dollars (\$35).
- h) This section shall remain in effect only until January 1, 2004, and as of that date is repealed, unless a later enacted statute, that is enacted before January 1, 2004, deletes or extends that date.”

Appendix A: (Continued)

Florida Statutes, Title XXIII, MOTOR VEHICLES Chapter 316

316.815 Duty to yield to public transit vehicles

(1) The driver of a vehicle shall yield the right-of-way to a publicly owned transit bus traveling in the same direction that has signaled and is reentering the traffic flow from a specifically designated pullout bay.

(2) This section does not relieve the driver of the public transit bus from the duty to drive with due regard for the safety of all persons using the roadway.

Minnesota Statutes 2006, Chapter 169, Traffic Regulations

169.20 RIGHT-OF-WAY

Subdivision 7 Transit bus. The driver of a vehicle traveling in the right-hand lane of traffic shall yield the right-of-way to any transit bus attempting to enter that lane from a bus stop or shoulder, as indicated by a flashing left turn signal

Appendix A: (Continued)

New Jersey Public Law 2003, Title 39 Motor Vehicles and Traffic Regulations

39:4-87.1 Right of way of certain buses reentering traffic c.226

1. a. The driver of a non-emergency vehicle upon a highway shall yield the right of way to any bus, provided that:

- 1) The driver is operating a vehicle that is in a position to overtake the bus from its rear; and
- 2) The bus, after exiting an active traffic lane for the purpose of stopping to receive or discharge passengers is attempting to reenter the lane from which it exited and to enter the traffic lane occupied by the driver by signaling its intention to do so. No other lane changes shall be applicable.

As used in this act, "bus" means a bus as defined in section 3 of P.L. 1995, c.225 (C. 48:4-2.1e), in regular scheduled service, and a motorbus operated in regular route service pursuant to P.L. 1979, c.150 (C. 27:25 -1 et seq.).

b. The New Jersey Transit Corporation shall conduct a public education program to inform motorists of the requirements imposed by this section relating to bus rights-of-way.

c. The Commissioner of Transportation shall study the need for further action to effectuate the purposes of this 2002 amendatory act and shall, no later than 18 months after the effective date of this 2002 amendatory act, report to the Governor and the Legislature.

d. This section shall not relieve the driver of any bus from the duty to drive with due regard for the safety of all persons, nor shall it protect the driver

Appendix A: (Continued)

from the consequences of his reckless disregard for the safety of others.

Nothing in this section shall be construed to limit any immunity or defense otherwise provided by law.

Oregon Revised Statutes (ORS) Chapter 811, Rules of the Road for Drivers

811.167 Failure to yield right-of-way to transit buses, rules, penalty

- 1) A person commits the offense of failure to yield the right of way to a transit bus entering traffic if the person does not yield the right of way to a transit bus when:
 - a. A yield sign as described in subsection (2) of this section is displayed on the back of the transit bus;
 - b. The person is operating a vehicle that is overtaking the transit bus from the rear of the transit bus; and
 - c. The transit bus, after stopping to receive or discharge passengers, is signaling an intention to enter the traffic lane occupied by the person.

The yield sign referred to in subsection (1)(a) of this section shall warn a person operating a motor vehicle approaching the rear of a transit bus that the person must yield when the transit bus is entering traffic. The yield sign shall be illuminated by a flashing light when the bus is signaling an intention to enter a traffic lane after stopping to receive or discharge passengers. The Oregon Transportation Commission shall adopt by rule the message on the yield sign, specifications for the size, shape, color, lettering and illumination of the sign and specifications for the placement of the sign on a transit bus.

Appendix A: (Continued)

- 2) This section does not relieve a driver of a transit bus from the duty to drive with due regard for the safety of all persons using the roadway.
- 3) As used in this section, “transit bus” means a commercial bus operated by a city, a mass transit district established under ORS 267.010 to 267.390 or a transportation district established under ORS 267.510 to 267.650.
- 4) The offense described in this section, failure to yield the right of way to a transit bus entering traffic, is a Class D traffic violation.

Revised Code of Washington (RCW) Chapter 46.61, Rules of the Road

RCW 46.61.220 Transit Vehicles

- (1) The driver of a vehicle shall yield the right-of-way to a transit vehicle traveling in the same direction that has signaled and is reentering the traffic flow.
- (2) Nothing in this section shall operate to relieve the driver of a transit vehicle from the duty to drive with due regard for the safety of all persons using the roadway.

Appendix B: Bus Operator Questionnaire

Center for Urban Transportation Research
National Center for Transit Research

FDOT Project: BD 549-34

Moving Bus Back into Traffic Safely – Signage and Lighting

Bus Operator Questionnaire

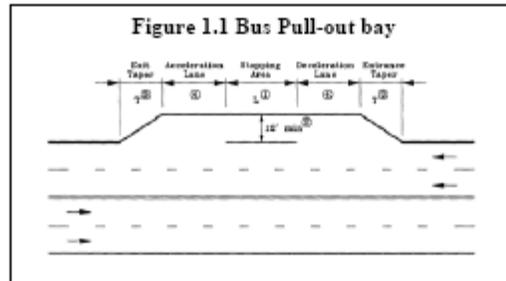
The purpose of this survey is to evaluate bus operators' perception of driver behavior and Florida yield-to-bus programs. The project team will use this information to evaluate existing signs and lights on the back of the bus as well as current problems drivers may face with off-line bus stops. Your participation in this survey is greatly appreciated.

County: _____ Years of experience as a bus operator: _____

Section I: Bus Operations

1 Are there any bus pull-out bays (figure 1.1) on any of the bus routes you have been assigned?

- Yes
 No



2 Do you use the shoulder or right turn lane to pull out of traffic at bus stops?

- Always
 Most of the time
 Some of the time
 Rarely
 Never

3 Do you ever have difficulty while attempting to merge back into traffic when the bus is out of the traffic lane?

- Always
 Most of the time
 Some of the time
 Rarely
 Never

Appendix B: (Continued)

**Center for Urban Transportation Research
National Center for Transit Research**

FDOT Project: BD 549-34

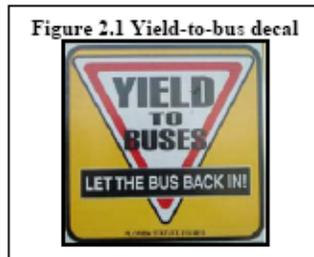
Moving Bus Back into Traffic Safely – Signage and Lighting

Bus Operator Questionnaire

- 4 From your experiences, what percentage of motorists yields when you signal your intent to merge into the traffic lane?
- Almost all (90% or more)
 - A high percentage (between 60 and 90%)
 - About half (between 40 and 60%)
 - A low percentage (between 10 and 40%)
 - Very few (Less than 10%)

Section 2: Yield-to-bus technology

- 5 Does your agency have a yield-to-bus decal (figure 2.1) or flashing yield sign (figure 2.2) on the back of the bus?
- Yes
 - No (*If no, skip to question 12*)



- 6 What type of yield-to-bus signage or lighting configuration does your agency have on the back of the bus?
- Decal
 - Flashing yield sign
 - Other
- 7 Do you feel that the Yield-to-bus signage (decal or LED yield sign) has made merging from a stop safer?
- Much safer
 - Some safer
 - No change
 - Less safe
 - No response

Appendix B: (Continued)

**Center for Urban Transportation Research
National Center for Transit Research**

FDOT Project: BD 549-34

Moving Bus Back into Traffic Safely – Signage and Lighting

Bus Operator Questionnaire

- 8 How helpful has the decal been in bus operations?
- Very helpful
 - Somewhat helpful
 - No opinion
 - Somewhat unhelpful
 - Very unhelpful
- 9 Is there a noticeable difference in the percentage of motorist who would yield to the bus as it attempts to merge before the implementation of the decal?
- Yes
 - No

If your transit agency has electronic signs, please answer question 10 and 11

10 When you are NOT using the flashing yield signal, how often will other drivers let you merge into traffic?

- Always
- Most of the time
- Some of the time
- Rarely
- Never

11 When you DO use the flashing yield signal, how often will other drivers let you merge into traffic?

- Always
- Most of the time
- Some of the time
- Rarely
- Never

12 Does your agency employ any other technologies (signs, alternative lighting, etc.) to improve bus safety?

- Yes
- No

If yes, specify _____

Appendix B: (Continued)

**Center for Urban Transportation Research
National Center for Transit Research**

FDOT Project: BD 549-34

Moving Bus Back into Traffic Safely – Signage and Lighting

Bus Operator Questionnaire

13 Which of these yield-to-bus signs do you think would be most effective for bus operations and improved safety?

a. Bus decal



Currently being used by most agencies in Florida
Size range from 6" triangle to 21"x69" rectangle

b. Flashing yield sign



Used by LEETRAN and VOTRAN
Flashing sign activated by driver

c. Merge Alert flashing sign



Awaiting approval by NHTSA
Approximately 2.5"x1"

Section 3: Florida Statute

The current Florida Statute 316.0815 states:
"The driver of a vehicle must yield the right-of-way to a publicly owned transit bus traveling in the same direction which has signaled and is reentering the traffic flow from a specifically designated pullout bay. The operator of the bus must also drive with due regard for the safety of all persons using the roadway."

14 Do you think that the current Florida Statutes are sufficient for increasing the safety of bus operations?

- Yes
- No

15 Do you think there may be other conditions in which motorists should yield to a public transit bus apart from when the bus is re-entering from a specially designed pull-out bay?

- Yes
- No

16 If you could design a safety program for the operation of buses in traffic what would you like to see implemented?

Appendix C: Bus Operator Questionnaire Responses

Table 8 Responses from All Counties Involved in Survey

Response	Frequency	Percent
County		
Alachua	1	0.4
Brevard	1	0.4
Broward	1	0.4
Duval	12	4.3
Hillsborough	27	9.7
Lee	22	7.9
Leon	44	15.9
Manatee	1	0.4
Orange	29	10.5
Pinellas	112	40.4
Polk	1	0.4
Volusia	26	9.4
Total	277	100.0

Question 1: Are there any bus pull-out bays on any of the bus routes you have been assigned?

Yes	206	74.4
No	58	20.9
No response	13	4.7
Total	277	100.0

Question 2: Do you use the shoulder or right turn lane to pull out of traffic at bus stops?

Always	80	28.9
Most of the time	72	26.0
Some of the time	83	30.0
Rarely	29	10.5
Never	9	3.2
No response	4	1.5
Total	277	100.0

Appendix C: (Continued)

Table 8 (Continued)

Response	Frequency	Percent
Question 3: Do you ever have difficulty while attempting to merge back into traffic when the bus is out of the traffic lane?		
Always	109	39.4
Most of the time	85	30.7
Some of the time	67	24.2
Rarely	9	3.2
Never	2	0.7
No response	5	1.8
Total	277	100.0
Question 4: From your experiences, what percentage of motorists yields when you signal your intent to merge into the traffic lane?		
Almost all (90% or more)	6	2.2
A high percentage (between 60 and 90%)	15	5.4
About half (between 40 and 60%)	49	17.7
A low percentage (between 10 and 40%)	73	26.4
Very few (Less than 10%)	129	46.6
No response	5	1.8
Total	277	100.0
Question 5: Does your agency have a yield-to-bus decal or flashing yield sign on the back of the bus?		
Yes	252	91.0
No	24	8.7
No response	1	0.4
Total	277	100.0

Appendix C: (Continued)

Table 8 (Continued)

Response	Frequency	Percent
Question 6: What type of yield-to-bus signage or lighting configuration does your agency have on the back of the bus?		
No signage or Decal	22	7.9
Decal	222	80.1
Flashing yield	15	5.4
Other	3	1.1
Decal and flashing yield	14	5.1
No response	1	0.4
Total	277	100.0
Question 7: Do you feel that the Yield-to-bus signage (decal or LED yield sign) has made merging from a stop safer?		
No signage or Decal	21	7.6
Much safer	25	9.0
Some safer	70	25.3
No change	133	48.0
Less safe	7	2.5
No response	21	7.6
Total	277	100.0
Question 8: How helpful has the decal been in bus operations?		
No decal	22	7.9
Very helpful	30	10.8
Somewhat helpful	88	31.8
No opinion	67	24.2
Somewhat unhelpful	36	13.0
Very unhelpful	31	11.2
No Response	3	1.1
Total	277	100.0

Appendix C: (Continued)

Table 8 (Continued)

Response	Frequency	Percent
Question 9: Is there a noticeable difference in the percentage of motorist who would yield to the bus as it attempts to merge before the implementation of the decal?		
No decal	22	7.9
Yes	74	26.7
No	145	52.3
No response	36	13.0
Total	277	100.0
Question 10: When you are NOT using the flashing yield signal, how often will other drivers let you merge into traffic?		
No flashing yield	235	84.8
Most of the time	5	1.8
Some of the time	17	6.1
Rarely	14	5.1
Never	1	0.4
No response	5	1.8
Total	277	100.0
Question 11: When you DO use the flashing yield signal, how often will other drivers let you merge into traffic?		
No flashing yield	235	84.8
Always	6	2.2
Most of the time	12	4.3
Some of the time	13	4.7
Rarely	6	2.2
No response	5	1.8
Total	277	100.0
Question 12: Does your agency employ any other technologies (signs, alternative lighting, etc.) to improve bus safety?		
Yes	81	29.2
No	120	43.4
No response	76	27.4
Total	277	100.0

Appendix C: (Continued)

Table 8 (Continued)

Response	Frequency	Percent
Question 13: Which of these yield-to-bus signs do you think would be most effective for bus operations and improved safety?		
Decal	25	9.0
Flashing yield sign	20	7.2
Merge alert	203	73.3
Two technologies	13	4.7
No response	16	5.8
Total	277	100.0
Question 14: Do you think that the current Florida Statutes are sufficient for increasing the safety of bus operations?		
Yes	126	45.5
No	137	49.5
No response	14	5.1
Total	277	100.0
Question 15: Do you think there may be other conditions in which motorists should yield to a public transit bus apart from when the bus is re-entering from a specially designed pull-out bay?		
Yes	209	75.5
No	51	18.5
No response	17	6.1
Total	277	100.0

Appendix D: Field Data Collection Locations

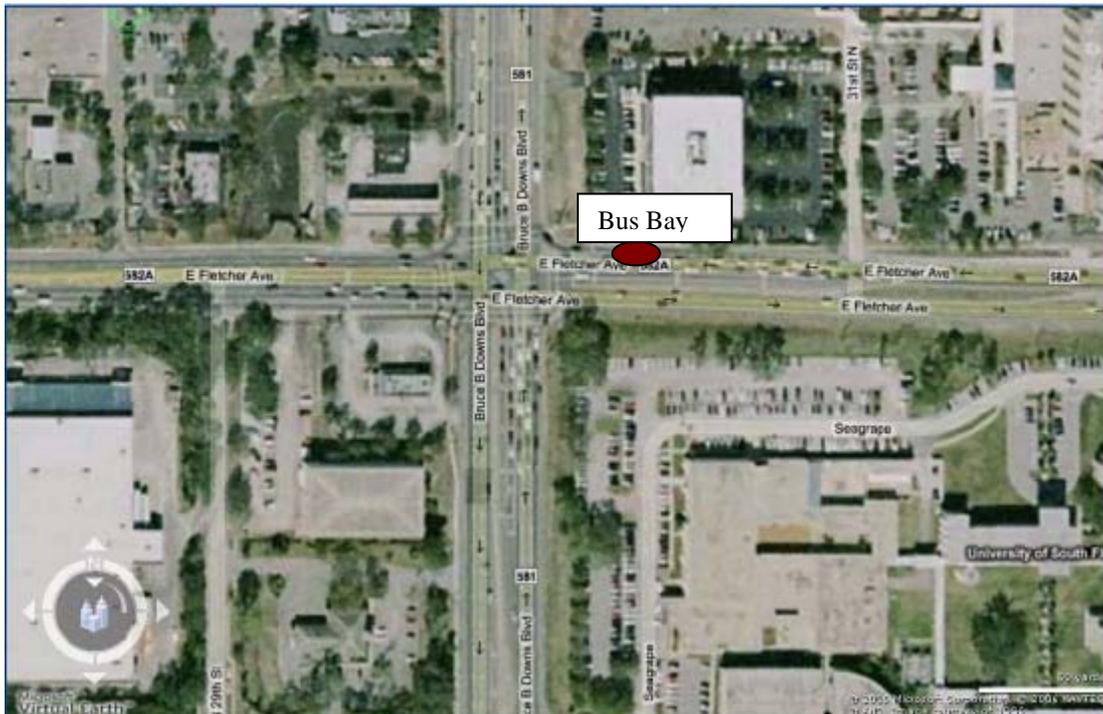


Figure 42 Aerial View of Fletcher Ave and Bruce B Downs Blvd



Figure 43 Aerial View of Fletcher Ave and Dale Mabry Blvd

Appendix D: (Continued)

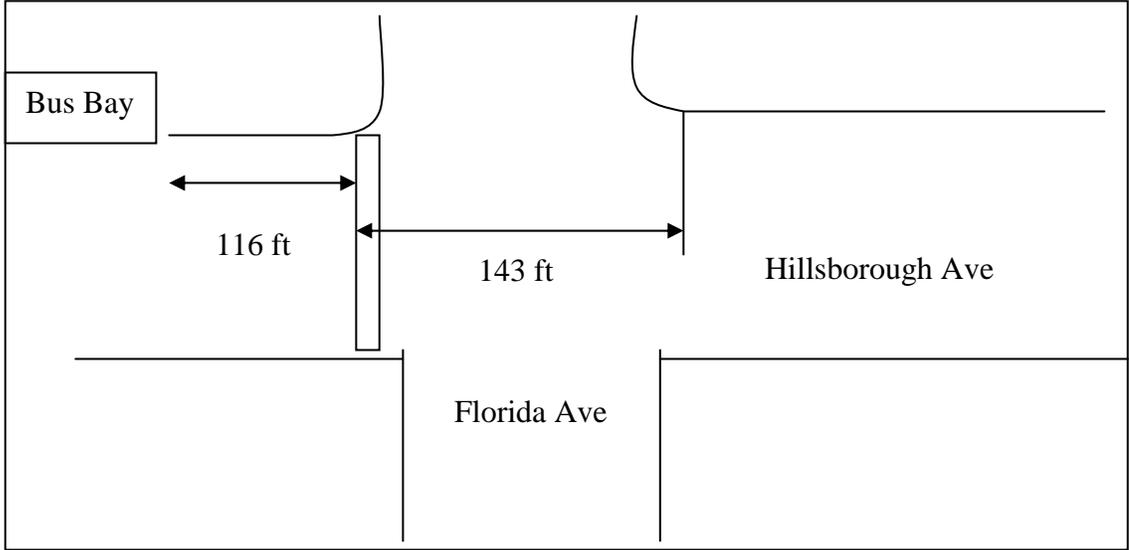


Figure 44 Sketch of Hillsborough Ave and Florida Ave

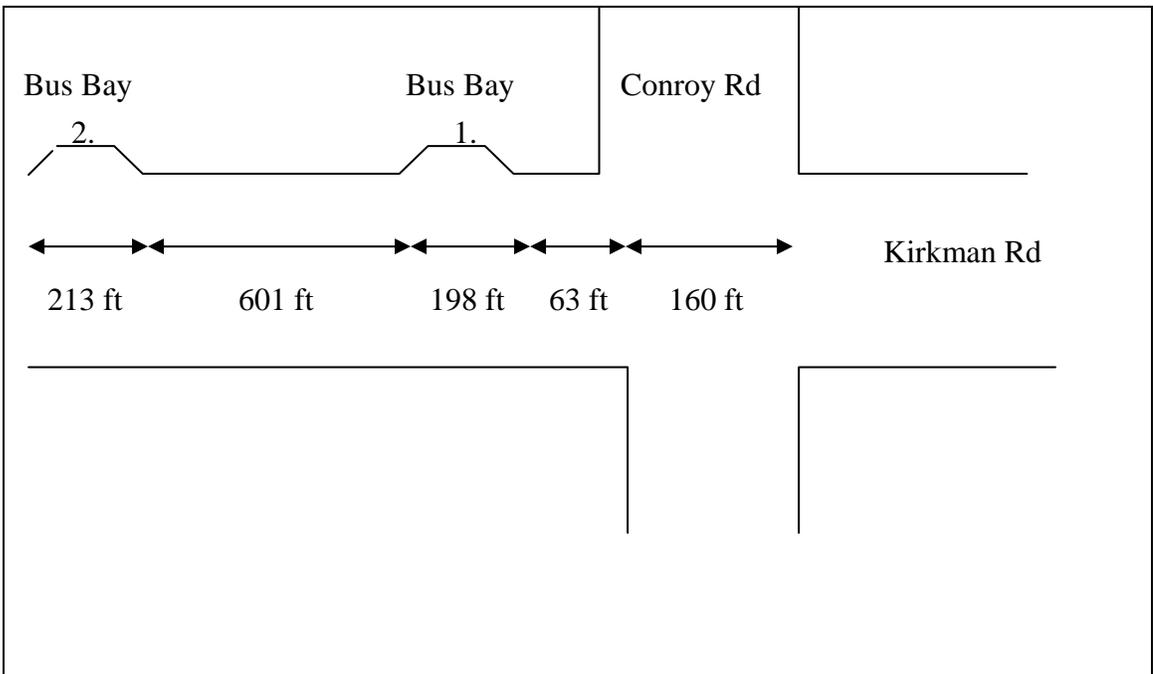


Figure 45 Sketch of Kirkman Rd and Conroy Rd

Appendix D: (Continued)

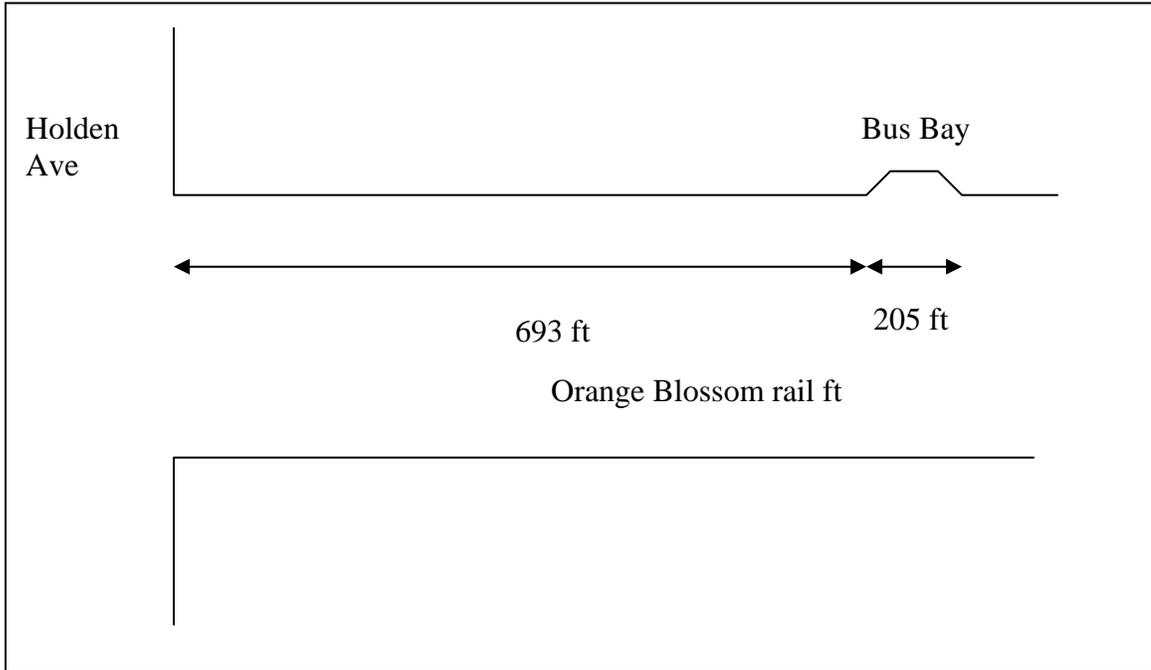


Figure 46 Sketch of Orange Blossom Trail and Holden Ave

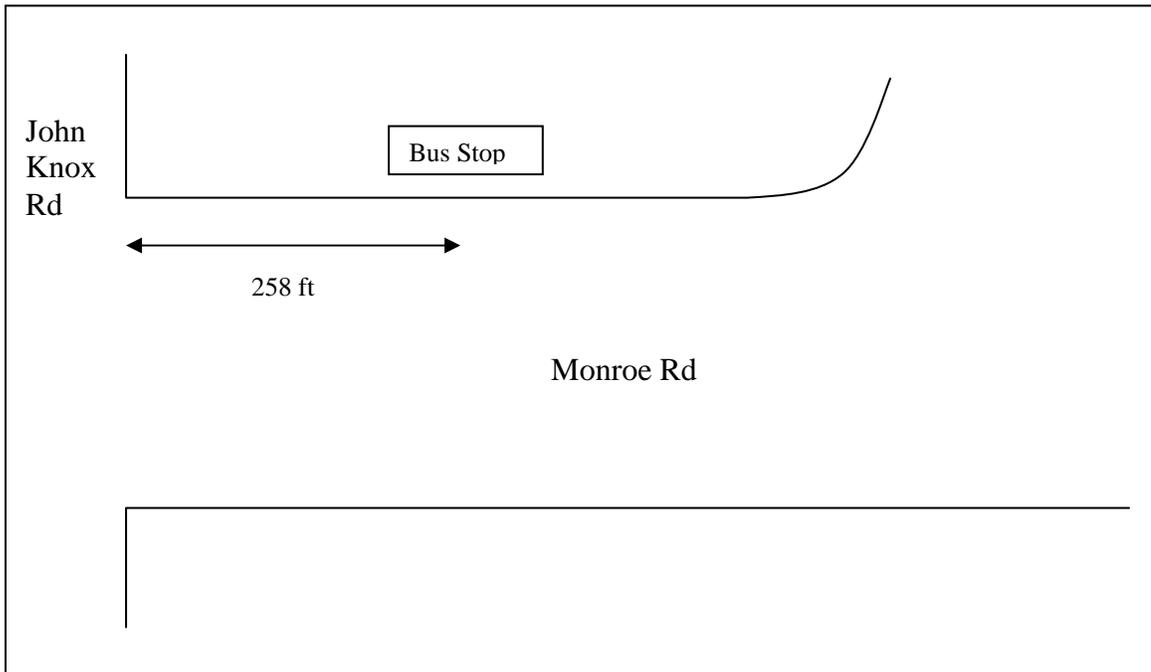


Figure 47 Sketch of John Knox Rd and Monroe St

Appendix D: (Continued)

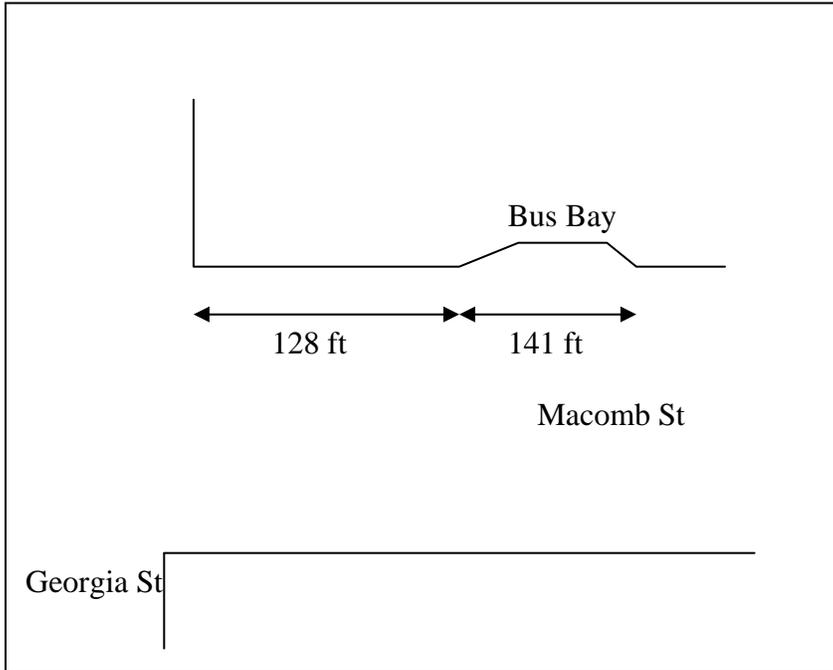


Figure 48 Sketch of Georgia St and Macomb St

Appendix E: Field Data Pictures



Figure 49 Votran Bus with New LED Sign

Appendix E: (Continued)



Figure 50 Leetran Bus with YTB Decal

Appendix E: (Continued)



Figure 51 Lynx Bus with Large YTB Decal and Small YTB Decal

Appendix E: (Continued)



Figure 52 HART Bus with YTB Decal and Dimensions