

Signage and Lighting Configuration Design for Bus Safety

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ABSTRACT

With the increase in number of bus pull-out bays in Florida, more and more bus operators find that it is very difficult to merge back into traffic from a bus pull-out bay. Some transit agencies do not support building new bus pull-out bays because of concerns that it will cause additional delays and safety problem. Bus operators sometimes refuse to use the existing bus pull-out bays because they know the difficulty of moving bus back into traffic. Without the proper traffic control devices, motorists do not know when and how they should yield to bus, which is part of the Florida Statutes requiring motorists to yield at specifically designated bus pull-out bays. This makes existing Yield-to-Bus (YTB) laws very difficult to be enforced. Field observations and conflict studies showed that additional delays and many traffic conflicts were caused when buses attempted to move back into traffic from a pull-out bay.

This paper uses bus operator surveys, crash data analysis, and field studies to develop recommendations for lighting and signage on the back of the bus, roadway signs and Florida yield-to-bus statues. The study found that the decal currently implemented on the back of bus has no significant safety and operational effects. There are no roadside signs or pavement markings for YTB laws. Proper signage and lighting were recommended to help the bus move back into traffic safely, decrease bus delay and improve bus operations however it must be accompanied by adequate laws and law enforcement.

Key words: rear-lighting, bus pull-out bay, yield-to-bus, bus safety

INTRODUCTION

Around the world, different lighting and signage technologies have been employed to improve the safety and operations of public transit buses. 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.

According to a study done by Luke Transportation Engineering (1), 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 state roads, more effective lighting configurations on the rear of buses, and state-wide bus stop design standards (1). The Luke Transportation Engineering study (1) put high crash locations into four categories, one being crash records that included a public transport bus within eighty feet of a bus stop or bus station (category 4). Bus accidents in category 4 accounted for 47% of these severe crashes that occurred within the visual influence or the rear of the 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 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. In order to achieve the overall objective of this project, three primary objectives have been identified. The first objective is to make recommendations on lighting configuration and signage practices for the back of transit buses; 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 enforce the YTB law and help increase its viability.

LITERATURE REVIEW

A comprehensive literature review was conducted which covered three areas. The first part was a review of lighting configurations and signage currently practiced with an emphasis on Florida practices. Included in this 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 part was a review of roadside signs and pavements markings as well as the location and design of bus stops. The third part was a review of current yield-to-bus and bus priority regulations.

Signage and Lighting Configuration

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 (4). The most common signage 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”. 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. These decals work best in situations where strong light sources are beamed directly at it (5). 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. LED lights with the word, “MERGING” have also been designed but not implemented. The new “Merging” signals will have to be approved by the National Highway Traffic Safety Administration (NHTSA) before it can be used on any vehicle. Since the Florida Yield-to-Bus law does not give any 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.

Roadway Signs and Pavement Markings

The Manual on Uniform Traffic Control Devices (MUTCD) has recommendations for “Yield” signs and also “Yield to Pedestrians” and “Yield to Bikes” signs but none for yielding to buses (6).

Past studies indicated that the effectiveness of pavement markings were not consistent (7). 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 (7). 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 (7). 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. Another study (8) was conducted to investigate the effect of the pavement marking with word message “Signal Ahead.” The study showed significantly positive effects on traffic safety at signalized intersections.

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. They are Florida, Washington, Oregon, New Jersey, California, and Minnesota. The laws vary in requirements for transit agencies and under what circumstances motorists are required to yield.

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.

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 survey done on bus operators in Florida showed that over 60 percent of them felt that very few motorists were aware of YTB laws. In Washington State where

the law was around before the Florida law, 40 percent of operators felt that very few motorists were aware of YTB laws (9).

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 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. 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.

METHODOLOGY

In order to determine the best practices in signage and lighting configuration for Florida's public transit buses, a statewide bus operators' survey was conducted to evaluate bus operators' perceptions on the effectiveness of different signs and lights. To supplement bus operator surveys, field data were collected at eight locations in three counties. Crash data analysis was conducted to evaluate the safety effect before and after a YTB decal was installed.

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 survey 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. The second section pertained to different technology 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.

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 re-entry delay, yield behavior and conflicts.

Re-entry Delay

Re-entry delay is the time for a bus to wait for a suitable gap to re-entry the traffic stream. It is a variable portion of the clearance time. The clearance time is defined 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 (10). 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. 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 (10).

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 (11). 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 data (12). A conflict is often determined by an abrupt braking maneuver, therefore vehicle tail-lights are watched and the drivers' speed and rapid deceleration are noted.

Yield behavior is determined by reviewing videos recorded 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 than at far-side and near-side bus stops.

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 aurally 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 addition, a visit was made to the bus operator lounge at the Jacksonville Transit Authority (JTA) during the bus operator practice day of 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. 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. Lee County Transit (Leetran) used both YTB decals and “Yield” LED signs but not on their entire bus fleet. Volusia County Transit (Votran) 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.

Mailed questionnaires were received from Leetran, Votran, PSTA, 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.

Field Observation

Field data were collected 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. Study locations should have enough passenger volumes to observe the bus moving in and out of traffic to load and unload passengers. The locations should have high traffic volumes otherwise there would be no difficulty for buses merging back into traffic. 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 on December 12-14, 2006. Field studies in Orange County were conducted during morning and afternoon peak hours on April 24, 2007. At least three hours of video was recorded at each location. Details of these study sites are shown in Table 1. In addition, two site locations were chosen to conduct a before-and-after study for a new YTB decal based on suggestions from the Starmetro bus operators in Leon County. Bus pull-out bays are not common in Leon County therefore one of the locations chosen was a bus stop located in a right-turn lane where the bus needed to move back into traffic from a right turn lane.

TABLE 1 Hillsborough, Orange and Leon 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 |
| Leon | Macomb St and Georgia St | 16-May-07 | 7:26 AM | 8800 |
| Leon | Monroe St and John Knox Rd | 16-May-07 | 9:18 AM | 21500 |

Conflict, Yield Behavior, and Re-entry Delay

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 braking maneuvers and weaving into oncoming traffic were considered as the severe conflicts. Changing lanes behind the bus into a clear lane was considered as minor 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 travel speed and awareness of the YTB law also influence 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.

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 survey 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. Table 2 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. It also shows the bus operators' perception of the safety effects for different YTB technologies and their response to question 8 on the questionnaire which asked how helpful the YTB signs were.

TABLE 2 Comparisons of Different YTB Signage and Lighting Configuration

| Response | Percent | | |
|---|---------|----------------|--------------------------|
| | Decal | Flashing Yield | Flashing Yield and Decal |
| Question 7: Do you feel that the Yield-to-bus signage (decal or LED yield sign) has made merging from a stop safer? | | | |
| Much safer | 7 | 27 | 29 |
| Some safer | 27 | 27 | 36 |
| No change | 56 | 27 | 29 |
| Less Safe | 3 | 0 | 0 |
| No response | 6 | 20 | 7 |
| Question 8: How helpful has the Yield-to-bus signage been in bus operations? | | | |
| Very helpful | 9 | 33 | 43 |
| Somewhat helpful | 36 | 20 | 36 |
| No opinion | 27 | 27 | 7 |
| Somewhat unhelpful | 15 | 7 | 7 |
| Very unhelpful | 13 | 7 | 0 |
| No Response | 0 | 7 | 7 |
| 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? | | | |
| Yes | 27 | 33 | 50 |
| No | 59 | 40 | 36 |
| No response | 14 | 27 | 14 |

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.

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. Table 3 summarizes the aggregated responses from all counties involved in the survey.

TABLE 3 Bus Operator Survey Results

| 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 |
| | | |
| 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 |

TABLE 3 Continued

| Response | Frequency | Percent |
|---|-----------|---------|
| 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 |
| 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 |
| 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 |

TABLE 3 Continued

| Response | Frequency | Percent |
|--|-----------|---------|
| 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 |
| 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 |

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.

Table 4 shows the average re-entry delay, conflicts per hour, average headway, and the average number of cars that passed the bus after the bus operator signaled to merge back into the travel lane.

TABLE 4 Average Re-entry Delay, Conflicts, and Yield Behavior by Location and AADT

| County | Location | Location type | 2006 AADT | Average Re-entry Delay (s) | Average Headway (minutes) | Conflicts per hour | Average number of cars that pass after left signal |
|--------------|-------------------------------------|---------------|-----------|----------------------------|---------------------------|--------------------|--|
| Hillsborough | Fletcher Ave and Bruce B Downs Blvd | Near-side | 23500 | 13 | 22 | 0.5 | 9 |
| Hillsborough | Hillsborough Ave and Florida Ave | Far-side | 29500 | 32 | 30 | 0 | 6 |
| Hillsborough | Fletcher Ave and Dale Mabry Blvd | Mid-block | 21000 | 15 | 34 | 0.9 | 3 |
| Orange | Kirkman Road and Conroy Road 1 | Near-side | 30000 | 13 | 24 | 0.2 | 10 |
| Orange | Kirkman Road and Conroy Road 2 | Far-side | 30000 | 13 | 25 | 0.8 | 0 |
| Orange | Orange Blossom Trail and Holden Ave | Mid-block | 33500 | 36 | 9 | 2.25 | 9 |

The delay of buses is dependent on several variables, including the number of lanes, location of bus stop, hourly traffic volumes, speed, and the attitude towards buses in that specific location. The average re-entry delays for the hours recorded ranged from 13 to 36 seconds. It should be noted that when traffic volumes increase to a certain amount, the re-entry delay will significantly increase.

Dangerous weaving and conflicts were observed as cars attempted to move out of the lane that the bus was merging into. There is no difference in motorist yield behavior with the presence of a decal. The weaving caused conflicts with other vehicles on the road, not just the buses. The number of conflicts observed during a specific time period was dependent on the traffic conditions and headway of the bus. The filed study indicated that higher traffic volumes and smaller headways will increase the number of conflicts.

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 that has signaled 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.

Before and After Case Study of A New Test Decal

Based on the results of the literature review, preliminary bus operator surveys and the MUTCD yield sign, 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. 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. Figure 1 shows the pictures of new decal on the back of bus. 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 1 New Decal Placements on Starmetro Buses

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.

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 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. There was an increase in bus accidents between 2001 and 2005. The HART decals were installed

between 2001 and 2002 therefore they do not seem to have any effect on bus crashes. The number of crashes fluctuated yearly with an increase from 8 to 12 crashes between 2001 and 2002 and a decrease from 12 to 8 between 2002 and 2003. The number of crashes rose again to 16 in 2004. The increase in number of crash may be due to the increase in number of bus pull-out bays in Hillsborough County.

CONCLUSION AND RECOMMENDATIONS

This research was conducted to help move the bus back into traffic safely from three aspects: signage and lighting configuration, roadside sign, and YTB regulations. A statewide bus operators' survey was conducted to find out their opinions in regards to the effectiveness of different signage and current Florida YTB statues. Field studies and preliminary crash data analysis were used to supplement the survey results. The study found that the decal currently implemented on the back of bus has no significant safety and operational effects and there are no roadside signs or pavement markings for YTB laws. Recommendations were made from three different angles as follows:

Signage and Lighting Configurations

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 majority of bus operators prefer the flashing sign with the word "MERGING" 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.

Roadside Signs

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.

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.

Yield to Bus Laws

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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REFERENCES

1. Luke Transportation Engineering Consultants, Inc. *Florida State Highway System Transit Safety Study*. Florida Department of Transportation, 2004.
2. National Institute for Aviation Research. *Mass Transit Crashworthiness Statistical Data Analysis*. Report No. FTA-002. Federal Transit Administration, 2005.
3. Lee, S., Wierwille, W., and Klauer, S.. *Enhanced Rear Lighting And Signaling Systems: Literature Review and Analyses of Alternative System Concepts*. USDOT Technical Report DOT HS 809 425, U.S. Department of Transportation, 2001.
4. Lehman Center for Transportation Research. *Development of Operational Performance Models for Bus Lane Preferential Treatments*. Florida Department of Transportation, 2002.
5. KRW, Inc. *TCRP Report 12: Guidelines for Transit Facility Signing and Graphics*. TRB, National Research Council, Washington D.C., 1996.
6. *Manual on Uniform Traffic Control Devices (MUTCD)*, Federal Highway Administration, Washington, D.C., 2003
7. Al-Masaeid, H., and Sinha, K. Analysis of Accident Reduction Potentials of Pavement Markings. *Journal of Transportation Engineering*, Vol. 120 No. 5, 1994, pp. 723-736.

8. Yan, X., Radwan, E., Birriel, E., Dahai, G: Effect of the Pavement-Marking Countermeasure to Improve Signalized-Intersection Safety Presented at 85th Annual Meeting of the Transportation Research Board, Washington D.C., 2006.
9. King, R.D. *TCRP Synthesis 49: Yield-to-Bus – State of the Practice*. TRB, Transportation Research Council, Washington D.C., 2003.
10. Kittelson & Associates, Inc., *Transit Capacity Quality of Service Manual*, 2nd Ed., TCRP Report 100, Transit Cooperative Research Program, Transportation Research Board, Washington, D.C., 2003.
11. De Langen M., Tembele R. *Guidelines for Pedestrian and Bicycle Traffic in African Cities*. SSATP Urban NMT studies. E & S. Africa. Report 2. Sub-Saharan Africa Transport Policy Program, 1994.
12. Muhlrad, N. *Traffic Conflict Techniques and Other Forms Of Behavioural Analysis: Application to Safety Diagnoses*. 6th ICTCT workshop Salzburg Proceedings. <http://www.ictct.org/workshops/93-Salzburg/Muhlrad.pdf>. Accessed July 10, 2007.