ADVANCED DRIVER ASSISTANCE SYSTEMS (ADAS) FOR TRANSIT BUSES DEMONSTRATION PROJECT

THE UNIVERSITY OF ALABAMA®

ADVANCED DRIVER ASSISTANCE SYSTEMS PILOT PROJECT FOR LARGE TRANSIT BUSES

UNIVERSITY OF ALABAMA (UA)

IN PARTNERSHIP WITH PERRONE ROBOTICS INC. AND CRIMSON RIDE

U.S. Department of Transportation

Federal Transit Administration

PROJECT SUMMARY

Automation Level(s):

Automation levels are defined in the SAE J3016_202104 standard (https://www.sae.org/standards/content/j3016_202104/), which is universally used in the automotive world. According to this standard, six levels of automation are described:

Level 0: No Driving Automation
Level 1: Driver Assistance (ACC Adaptive Cruise Control)
Level 2: Partial Driving Automation (ACC plus Lane Keeping)
Level 3: Conditional Driving Automation
Level 4: High Driving Automation
Level 5: Full Driving Automation

A number of ADAS hardware/software solutions have reached market readiness, and yet the application of the system is barely observed in transit operations. Currently, the market is small for transit ADAS and there is a lack of interest and investment in the industry. In this project, the University of Alabama (UA) will team with Perrone Robotics Inc. to deploy ADAS technologies in both diesel and electric buses and assess technology readiness and effectiveness to identify feasible technology transfer routes for general transit agencies.

The specific ADAS technologies the team proposes to demonstrate include (1) assisted smooth acceleration and deceleration for improved energy efficiency and safety, (2) automated detection and emergency braking for mitigating pedestrian collisions, (3) curb and position detection to enable automated precision docking, and (4) assisted driving in narrow roads with automated steering correction.

To support the deployment and assessment of ADAS technologies, the team will set up an in-lab simulation environment and real-world testbeds. An in-lab XIL (mixed software- and hardware-in-the-loop) simulation environment of bus routes, vehicle dynamics, and ADAS sensing, and actuation will be developed and serve as the foundation for technology validation. An experimental close-circuit testing site will be prepared for collision avoidance-related tests. Selected route segments will be used to validate the technology for curb detection, docking assistance, and driving on narrow roads. Based on the above testing setting, a staged evaluation process will provide a comprehensive understanding of the benefits, costs, and impacts of revenue-based transit services. The team will summarize lessons learned, practice-ready implementations, and workforce training and transition guidance for transit agencies.

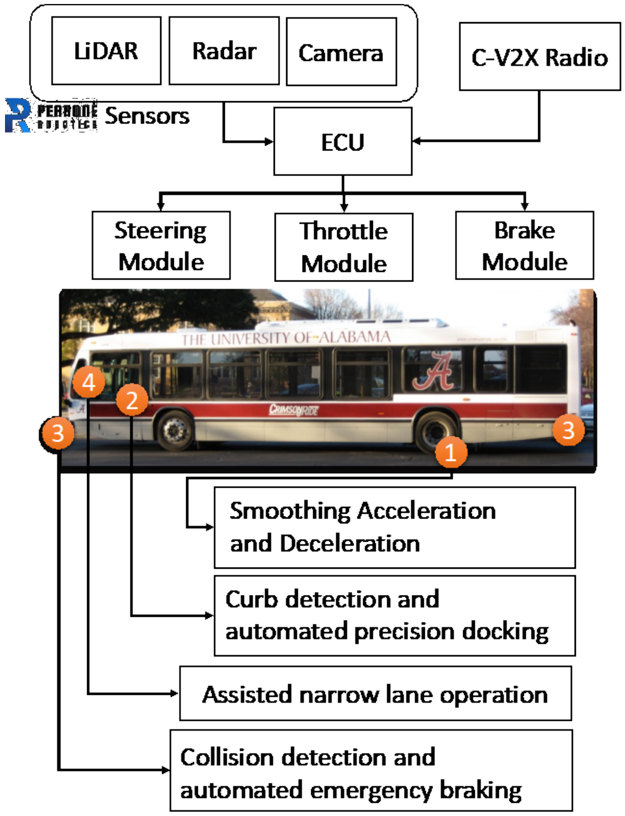
PROJECT GOALS

There are four major technical challenges for integrating ADAS into large transit buses. (1) Conventional diesel buses do not have any automated brake actuation through electronic stability control, which is universally available in passenger cars and light-duty trucks since 2013. (2) Large transit buses also have servo-hydraulic power steering systems, which need to be augmented through some new electro-mechanical actuator system. (3) The vehicle longitudinal and lateral dynamic response of large transit vehicles (35-40 ft length & over 40,000 lbs.) is much slower than in small vehicles. (4) Packaging space must be designed for large actuators suitable for transit buses.

The project team represents a collaboration among the higher-education research institute (UA), the UA transit agency (Crimson Ride), and the industry partner (Perrone Robotics Inc.) on hardware and software products for ADAS. The team has multidisciplinary competencies and significant experience in the automotive and automation areas. The team has full capability to address all the above technical challenges during the project and pilot testing, to ensure smooth real-world implementation and knowledge transfer to the broad transit agency community.

Specifically, a staged implementation plan is proposed to fully address potential challenges of this project. The team will start with the full integration of a commercial ADAS product into the large transit buses. Following the hardware integration, the project team will focus on the preparation of hardware and experiment environment, including redesigning and retrofitting the diesel bus with onboard loggers and perception sensors for real-world operation data collection. An XIL simulator including vehicle dynamics and perception models will be customized to allow for in-lab testing of ADAS control algorithms for efficiency and safety. Next, the project team will start piloting pedestrian collision avoidance features in a close-course testing facility with gantry and pedestrian dummies. Meanwhile, other functionalities will be piloted during the non-revenue service period with loaded buses (e.g., sandbags or water drums) for further calibration and validation. Finally, in the third stage, the team will start operating ADAS technologies in diesel and electric buses for a year of revenue service on the UA campus.

FRAMEWORK FOR INTEGRATING ADAS TECHNOLOGY



ANTICIPATED OUTCOMES, BENEFITS, IMPACTS

By developing, validating, and piloting ADAS technology for large transit buses, the outcomes of our project will include the development and real-world piloting of the following tasks. All validation will be done with driver oversight and intervention at all automation levels

Outcome #1: Automated smooth acceleration and deceleration (Level 1 Automation). The team will deliver a fully validated and tested ADAS integration framework and software control logic to enable safe and smooth driving in both diesel and electric buses. This will not only utilize vehicle intrinsic sensors but also connectivity through C-V2X OBUs to inform vehicles about signal phasing and timing (SPaT message) transmitted by existing roadside C-V2X units installed at signalized intersections.

Impacts: Energy consumption reduction in diesel and electric buses, comfort and safe riding environment for passengers, improved travel time when passing intersections.

Outcome #2: Automated pedestrian collision detection and avoidance (Level 1 Automation). The team will deliver a sensor suite and detection algorithms for pedestrian collision avoidance fully calibrated in a closed-course testing facility and pilot the effectiveness in real-world revenue services.

Impacts: Resolving blind-spot safety concerns for large transit buses, enhancing perception ability of the surrounding environment for bus drivers, and improving pedestrian safety even at highly populated locations.

Outcome #3: Curb detection and automated precision docking (Level 4 Automation). The team will calibrate sensors for detecting road curbs and develop control logic to enable automated precision docking. This will also be piloted in real-world revenue services. Level 4 Automation will only be used in the last 50 to 100 feet before a bus stop with full driver oversight.

Impacts: Reducing docking gap and alignment at bus stops to benefit mobility-impaired populations for ease of access to the bus.

Outcome #4: Assisted narrow lane operation (Level 2 Automation). The team will enable control of steering for automated lane keeping while traversing through narrow lanes and acoustic warning of potential collisions. This will also be piloted in real-world revenue services.

Impacts: Safer driving in narrow lanes and reducing cognitive burdens for drivers in lane keeping.

With the above outcomes and impacts, the project will benefit a series of public and private stakeholders, including but not limited to (1) System software and hardware companies related to ADAS technologies will benefit from the test and validation outcomes from a comprehensive pilot. (2) National public transit agencies will learn about the cost savings and operational benefits of implementing ADAS for transit buses. (3) The general public transit users will benefit from smoother and safer transit rides. (4) People with disabilities and senior citizens will benefit from precision docking technology for improved public transportation access.

VEHICLE INFORMATION

This project anticipates using diesel and electric buses equipped with an ADS provided by Perrone Robotics.

DATA COLLECTION, MANAGEMENT, & SHARING

Data to be Collected: The project will collect data from multiple sources, which can be categorized into three groups.

- **Public data:** road segment and test site geometry and built-environment data, vehicle trajectory data (latitude, longitude, and time stamp) for both non-revenue and revenue service pilots, aggregated performing metrics for all four testing tasks.
- **Operation data for internal uses and sharing:** traffic signal specification and traffic volume data, powertrain dynamics data, data capturing drivers' responses to the developed technology, and aggregated performance metrics (e.g., fuel consumption).
- **Proprietary data:** Data acquisition and evaluation of sensor and actuator signals during drive-by-wire operations for the four use cases (e.g., throttle position, steering wheel position, lateral acceleration, brake pressure etc.), operation data that could be reverse-engineered to reveal the core logic of PRI's product, personal information of drivers participating in the pilot.

Both public and operation data for internal uses will be shared with FTA following suggested procedures that can be used to advance USDOT's ADAS research.

Project Performance Measure: Table 1 summarizes quantitative metrics that will be evaluated for major ADAS testing tasks. Towards the end of the project, a testing report summarizing testing configurations and final outcomes will be prepared to help information dissemination among transit agencies in the U.S.

Table 1: Quantitative metrics for ADAS tasks

Task	Quantitative metrics
Smooth acceleration and deceleration	Aggressiveness of acceleration and deceleration (m/s^2), The time derivative of acceleration (m/s^3, for measuring smoothness), Average intersection delay with and without ADAS (s), Fuel consumption (diesel bus)
Collision detection and avoidance	Detection accuracy (%), False alarm rate (%), Distance to collision (ft), Response time (ms), and the aggressiveness of braking (m/s^2)
Curb detection and automated precision docking	Detection accuracy (%), Lateral and longitudinal error in docking position (ft), Docking time (s)
Assisted narrow lane operation	Deviation from center line (ft), Travel time through narrow segment (s), Number of steering corrections

The effective management and sharing of collected data are crucial to the success of our project. Data management will involve rigorous processes to ensure accuracy, privacy, and security. For public and operational data, the team will utilize a centralized database system that supports real-time data integration and retrieval. This system will allow for efficient categorization and storage of data types such as road segment details, vehicle trajectory, traffic specifications, and performance metrics. Data sharing protocols will adhere to FTA guidelines to promote transparency and collaboration with the USDOT for the advancement of ADAS research. Public data and non-sensitive operational data will be made available to research partners and stakeholders through a secured data-sharing platform. This platform will facilitate the dissemination of processed data and aggregated performance metrics to transit agencies nationwide, fostering an environment of shared knowledge and best practices. Proprietary data, such as detailed sensor and actuator signal evaluations and any data that could potentially reveal proprietary technology or personal information, will be strictly safeguarded. Access to these datasets will be restricted to authorized personnel only, with stringent data usage policies in place to prevent unauthorized access or reverse engineering.

Overall, our data management and sharing strategy aims to support the project's objectives while ensuring compliance with legal and ethical standards. This approach will not only enhance the project's efficiency and integrity but also contribute to the broader field of ADAS research and development.

PROJECT STATUS & SCHEDULE

Milestone	Timeline	Description
1	Y1-Q1	Testing routes and locations identified, and real-world environmental and operational data collected on identified routes and locations
2	Y1-Q2	Finishing the integration of ADAS kit, and a diesel bus configured ready for preliminary testing and data collection
3	Y1-Q4	XIL platform developed and functions validated using real-world data
4	Y2-Q1	Facility for pedestrian safety testing ready
5	Y2-Q2	User interface for assisted bus driving developed and validated
6	Y2-Q3	Smoothing acceleration and deceleration algorithm developed and tested in the XIL platform and real-world pilot of diesel bus begin
7	Y2-Q4	Object detection and collision avoidance algorithms validated in XIL platform, and real-world testing of ADAS safety features began in closed-course facility.
8	Y2-Q4	Automated precision docking and assisted narrow lane operation development finished and real-world pilot begin
9	Y3-Q2	ADAS kit integrated into an electric bus and real-world pilot begin
10	Y3-Q3	In-person ADAS demonstration event for transit buses completed
11	Y3-Q3	All real-world pilot completed after one year of revenue services and final report on testing scenarios, performances and public acceptance evaluation completed
12	Y3-Q4	Workforce development and training materials prepared

BUDGET

Federal Amount ($)	Non-Federal Cost Share	Total Amount
$2,000,000	$1,050,000	$3,050,000