RESEARCH NOTES
TRAFFIC OPERATIONS RESEARCH
Task Order 4229
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Development of Demonstrations Systems For Demo 2003

Why This Research Undertaken

This research was undertaken to show that a variety of cooperative vehicle-highway automation technologies that were previously developed and tested on passenger cars could be successfully integrated into heavy-duty vehicles (transit buses and Class-8 trucks). This is important because the technical challenges are considerably more difficult to make these systems work well on heavy vehicles, which have much lower performance capabilities than passenger cars, but they are also more likely to be early adopters of the technologies for use on BRT busways or dedicated truck lanes. The public is likely to gain earlier benefits from use of these technologies when they are deployed on buses and trucks.

What Was Done

Three transit buses and three Class-8 tractors and trailers were acquired and were then equipped and tested with automation systems. These control systems were designed to make use of commercially available sensor, communications, actuation and computer technologies to the maximum extent possible, but in a few cases it was necessary to have components built to the project specifications. The PATH research staff modified the buses and trucks, installing both electrical and mechanical equipment to implement the systems to enable automatic steering, speed and spacing control, and developed all the control and communications software. The vehicles were initially tested at low speeds at the PATH Richmond Field Station test track, then at higher speeds at the Crows Landing airfield. The trucks received limited testing on the I-15 HOV lanes, but the buses were extensively tested there during the summer of 2003, and a select group of visitors was invited to observe the final weekend of testing on I-15 as a low-profile substitute for the originally planned public demonstration, in deference to the state budget difficulties.

What Was Concluded From the Research

The research showed conclusively that both trucks and buses could be controlled accurately and smoothly while driving up to highway speeds. Specific findings included:

- A standard transit bus can be steered to dock itself at a bus stop to within a lateral accuracy of better than one inch and a longitudinal accuracy of better than four inches, which is more than adequate to meet performance needs of transit agencies.
- The automatic docking could be done reliably enough that the bus was docked even with the driver having left the driver's seat.
- Both 40-foot and 60-foot articulated transit buses could be steered very accurately under automatic control while driving at highway speed on the HOV lanes, with most errors with 4 inches for the shorter bus and most within 6 inches for the articulated bus. This means that busways that use automatic steering buses would only need to be about one foot wider than the buses (except on sharp curves), potentially saving significant construction and right of way costs.
- Buses can automatically change lanes virtually anywhere on the highway, even when the reference markers that they follow are only installed along the centers of the lanes, providing great flexibility for automated busway system implementations.
- Drivers can easily transition between automatic and manual driving using a simple and well-designed user interface.
- Buses of significantly different design and performance capabilities (40-foot CNG powered and 60-foot diesel powered) can be electronically coupled into a platoon and follow each other accurately on the highway, even with significant grades.
- Three buses can be coupled together electronically to form a platoon, maintaining effective speed and spacing control using wireless communications combined with forward ranging sensors.

- Full-size Class-8 tractor-trailer trucks can be automatically steered to enable the tractor follow a lane within 4 inches of lane center at highway speed, making it possible for dedicated truck lanes that require automatic steering to be designed to be narrower than conventional lanes (but we do not have measurements of the maximum trailer tracking errors to determine the precise lane width that would be needed).

- Full-size Class-8 tractor-trailer trucks can be electronically coupled together to form a platoon at short enough spacing to produce measurable savings in aerodynamic drag, fuel consumption and pollutant emissions. Provided that their maneuver profiles do not exceed the power limitations of the trucks, these platoons can mix trucks that are both empty and fully loaded.

- The Class-8 tractor-trailer trucks can be driven as close as ten feet from each other at highway speed, automatically maintaining their separation to within an accuracy of about a foot under normal conditions.

- When the tractor-trailer trucks are driven at close separations, they can produce fuel consumption savings in the range of 5% to 10% for the lead truck and 10% to 12% for the following truck, compared to operations at normal large spacing.

- When the tractor-trailer trucks are driven at close separations, they can reduce CO2 emissions in the range of 8% to 15% for both trucks, but there are negligible savings in NOx emissions.

The Researchers Recommend

The most mature capability that was tested is the bus precision docking, which is now ready to proceed into field operational testing in a normal transit operation (based on development of an implementation that is designed for intensive daily use, rather than the experimental prototypes that were tested in this project). The automatic steering capability is similar in its technological state of development, but its public FOT and implementation depends on availability of a lane that can be designated for its operation. Test sites should be sought for both of these technologies, and federal funding support should be sought to help defray the costs of the initial pilot fleet of equipped buses, since a small production run would otherwise have very high unit costs. Further testing and refinements are needed on the longitudinal control systems, to determine the most suitable combination of ranging sensors to use and to verify system performance under a wider range of difficult operating conditions. Further research is also needed on providing fault detection and fault management capabilities for these systems under diverse fault scenarios.

Implementation Strategies

The implementation strategies need to vary with the maturity of the technology under consideration. For the most mature of the technologies, precision docking and automatic steering, the first steps are educating potential host transit operators about the benefits of these technologies for their applications and showing them the feasibility of the technologies. Site-specific case studies should be developed for the most promising applications and transit operators. Then, with their support and interest, funding and commercialization partners need to be sought for the field operational test system "productization" and testing, since the unit costs of the first few equipped vehicles would otherwise be prohibitive.

For the less mature technologies, involving the longitudinal control, refinements of the technology should be developed in parallel with application case studies that can quantify the economic benefits of use of the technology, for both public and private sectors. This is particularly important for the trucking applications, which will be motivated by private sector profit and loss considerations. When the performance of the technologies can be demonstrated convincingly to the relevant stakeholders (truck operators and manufacturers) and the public sector benefits can be shown through case studies of dedicated truck lanes in specific settings, the stage will be set for bringing together all the interests that need to be involved in decisions about deployment.

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