Operational Test of AHS Applied to a High-Capacity Transit Corridor, The Lincoln Tunnel XBL.

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Executive Summary

Background
It is proposed that AHS technology be applied to further increase the safety, service reliability and capacity of the exclusive bus lane (XBL) leading from the New Jersey Turnpike to the 42nd Street Bus Terminal in Manhattan. The XBL has enjoyed an almost unblemished safety history while being the highest passenger volume bus route threading through arguably the most dense and physically constrained corridor in the United States. Only one major head-on accident has occurred during the 25 years of operation of this transit lane that serves 30,000 riders per hour every morning. The three parallel in-bound auto lanes, consume three times as much infrastructure while serving less than one-sixth the riders, less than 5,000 riders per hour combined. A more detailed description of the current operation of the XBL can be found in Appendix A.

Current demand has over-saturated the corridor resulting in a poor levels-of-service involving numerous minor accidents, extensive delays and large variations in travel times. This is true the especially in the auto lanes, but also the bus lane. It is believed that substantial latent demand exists for the corridor. This demand could be attracted to additional bus services if delays and uncertainty can be eliminated. In fact, recent decisions by NJ Transit to favor expanded bus services rather than redevelopment of abandoned rail service will require the provision of additional bus capacity into Manhattan via the Lincoln Tunnel.

Safety
While one might suggest the conversion of one of the auto lanes to another exclusive bus lane, this option is politically intractable. A potentially better option is to apply AHS technology to buses operating on the XBL. AHS could ensure the continuation and even increase of the excellent safety achievements of the XBL. For example, only rubber cones separate west-bound auto traffic from east-bound XBL bus traffic causing the XBL's greatest safety risk. One doesn't know when a west-bound auto will swerve into the XBL causing a major catastrophe. The demonstrated high-level of fault-tolerant and drift-free lateral control currently available on AHS prototypes suggest that a moveable Jersey-type concrete barrier could be deployed every morning between the two opposing lanes of traffic. Automated steering would allow the buses to travel the narrower road safely and reliably. Even more-so than conventional buses using the current road width. The presence of the physical barrier would essentially eliminate the current danger of head-on collisions.

Reliability
Automation can also dramatically increasing the capacity of the bus lane by allowing buses to operate reliably at closer headways. The first benefit of increased capacity is the reduction in the instability of the flow of buses. This allows the buses to operate through the corridor at a constant reliable speed. Uncertainty in travel time is reduced and the customer level of service is enhanced.

Capacity
Reliable closer headway operation also yields substantial opportunities to serve more riders. Modest increases in bus through-put has an enormous leverage in people throughput. A 50% increase in the capacity of the one bus lane translates into an increased passenger throughput of 15,000 people per hour. A comparable increase in all three of the auto lane would serve additionally only one-sixth, or 2,500, as many new users.

Only Modest Technology Needed
The technology needed to automate busses in this corridor, while challenging, is well within reach. The current maximum flow rate of buses is constrained to approximately 750 busses per hour by the downgrade on the helix portion of the corridor, the constrained environment of the toll plaza and the Lincoln Tunnel, and the complex operations of the 42nd. St. Bus Terminal. This flow rate corresponds to an average time headway of 4.8 seconds. To achieve a 50% capacity improvement would mean that the automated buses would need to operate at an average headway of 3.2 seconds. An AHS headway control system geared at a minimum headway of 2.5 seconds would reliably deliver the additional capacity. At an operating speed of 50 ft/sec (34 mph) there would exist a minimum separation 70 feet between buses. Such performance requirements are well within current conventional headway control technology.

Institutionally Tractable
Institutionally, this operational test is very doable. There are only a few institutions involved in operating and managing the system. Also, the universe of vehicles that would use the system is small.

The facilities are managed by either New Jersey Department of Transportation (NJDOT), (manages the I-495 corridor), or the Port Authority of New York and New Jersey (PANYNJ), (manages the Lincoln Tunnel and the 42nd St. Bus Terminal). New Jersey Transit (NJT) operates most of the buses. The rest are operated by a handful of private bus companies. More importantly, essentially all of the buses are purchased by the PANYNJ and leased to NJT and the other private operators for $1 per year. Thus, a natural process exists by which essentially all busses using the AHS facility could be acquired AHS-equipped by the PANYNJ.

A permanent implementation of this operational test is sufficiently confined to be realistically achievable. A full-blown implementation does not encompass a very large fleet of vehicles. At present, all the busses that use the XBL comprise a fleet of only 1500 busses. Planning for a 50% capacity improvement suggests that only 2250 busses need to be AHS-equipped for the corridor to fully deliver the capacity enhancement. In comparison with any other substantial AHS implementation, these are extremely limited institutional and market challenges that need to be overcome to evolve this test to a full daily operation. The limited fleet size places a ceiling on the vehicle-based hardware costs. The physical length of the corridor is only 2.6 miles so infrastructure cost are also bounded. These factors substantially constrain the eventual costs of an on-going operation.

While this operational test has many positive attributes it also has some significant challenges. Since public transit riders are involved, safety is an even greater concern. Moreover, the physical constraint surrounding the project are substantial. One must face the issue of applying automation to a lane that is used for such purposes for only a portion of the day. This undoubtedly means that one cannot provide a physical barrier on one (left) side of the lane. (A New Jersey barrier already exists on the right side of the XBL.) Concerns about this are ameliorated by the presence of an alert and professional bus driver who will continuously monitor the operation of each bus. If necessary, the introduction of a movable NJ barrier as exists at the Tappan Zee bridge may be needed to provide a sturdy physical separation for the counter-flow lane. Another challenge is the operation of the 42nd St. Bus Terminal. It is well recognized that each AHS application has entrance and exit challenges. In this operational test a significant challenge will be the operational management of busses as they flow through the bus terminal to and from their loading platforms.

Benefits

Benefits of such an implementation are enormous:

- The increased safety derived from the virtual elimination of the head-on collision threat, is in itself has enormous benefits.
- The improved reliability of transit times would benefit each passenger,
- The simplicity by which substantial addition capacity can be provided At present the PANYNJ is investigating the possibility of building a new vehicular tunnel between New Jersey and Manhattan. The cost of such an undertaking are in the Billions of dollars. This is one area where the application of AHS technology can provide the needed capacity at a much lower cost. Additionally, because AHS is applied to transit it is available to everyone, not just the minuscule segment of the population that has been able to equip their personal automobile with AHS hardware.

Given the limited technological requirements of this AHS operational test, its conducive institutional environment, its manageable physical expanse and its ability to deliver benefits to a broad spectrum of users, the XBL is a most interesting operational test of AHS technology.

Purpose of Operational Test

The purpose of the XBL operational test is to perform a proof-of-concept for the application of the AHS technology to bus corridor and terminal operations in preparation for a full-blown implementation of the technology in daily operation between the New Jersey Turnpike and The 42nd St. Bus Terminal in Manhattan. In particular, the operational test will:

- investigate and select a test track site. Possibilities include use of the Meadow land parking lot and MacGuire or Lakewood air force bases and facilities at Ft. Dix and Ft. Monmouth.
- thoroughly analyze and evaluate the safety implications of the application of AHS technology to the XBL,
- survey the available moveable-barrier technology
- select and test the operation of longitudinal and lateral control systems that will deliver the with performance enhancements needed for the XBL,

- investigate alternative approaches to ensuring physical lane separation on the counter flow portion of the XBL,
- investigate the terminal management problem that exists at the 42nd St. Bus Terminal and develop solutions that deliver the needed increased capacity.
- investigate the institutional arrangement that need to be created to make the final implementation possible,
- develop an implementation plan for the conversion of the operational test into a full-blown daily operation.

Schedule
The operational test will be conducted over a 3-year period.

The first year will be devoted to
survey and assess the appropriateness of the various AHS hardware configurations for this operational test. The product of this test will be an acquisition plan for the AHS hardware that will be acquire and installed during the second year
investigate and select a test site and make recommendations,
investigate the terminal problem and make recommendations,
investigate the physical barrier problem and make recommendations,
develop a cost proposal for years two and three that encompass the cost of acquisition and installation of the AHS hardware as well as the cost to use the transit buses and the test track,

The second year will focus on acquiring the AHS vehicle-based hardware and installing it in a limited number (probably 3) transit buses. Additionally a test track will be instrument with the infrastructure-based hardware.

The third year will be devoted to performing field tests of the AHS transit buses at the test facility and to finalize the full-blown implementation plan.
Budget
A personnel budget of $300,000 is sought for the first year. This will include a 20% cost sharing.

Appendix A: Description of Current XBL Operation

The Port Authority of New York and New Jersey, in conjunction with the New Jersey Department of Transportation, operate an east-bound counter-flow exclusive bus lane, (XBL), along a 2.5 mile stretch of I-495 leading from the New Jersey Turnpike through the Lincoln Tunnel to the Port Authority bus terminal located on 8th Avenue in Manhattan. Used is the left most west-bound lane. It is separated from on-coming west-bound traffic by temporary cones that are deployed every morning. The permanent concrete New Jersey-type barrier separates the XBL from the three east-bound lanes. The lane leads to an exclusive, bus-only lane in the Lincoln Tunnel. Tolls are collected electronically, requiring no stopping at the toll plaza. .
The XBL is in operation from 6:30 am to 10:00 am on weekday mornings. It serves an average of 1600 buses per morning at a peak rate of approximately 700 buses per hour. This one lane serves about 65,000 riders every morning, about 30,000 during the peak hour. It saves riders an average of about 20-25 minutes of delay in accessing and traveling through the Lincoln Tunnel. This facility is the most productive bus-only lane in the US. This one lane delivers the people-moving capacity of 10 lanes of automobiles.

At present the facility is at capacity for two reasons. Wide variations in the spacing of buses caused in part by varying driver responses to speed variations along the XBL limit its capacity to 700-800 buses per hour. Speed variations exist at the downward helix, passing through the toll plaza, at the entrance to the tunnel and on the upgrade leading to the exit on the Manhattan side of the tunnel. The most severe capacity constraint exists in the bus terminal on the Manhattan side of the tunnel. Here the bottleneck is caused by buses maneuvering for docking space. This causes backups. It is a classic entry/exit problem. Neither bottleneck has had a simple solution. Drivers need to be more consistent and responsive and better real time communications, management and control are needed to route buses through the bus terminal.

Task Plan

Task 1. Coalition Building and Definition of the Problem. The first year, NJIT and Princeton University will build the coalition for this operational test which may include the following agencies: New Jersey Transit, New Jersey Department of Transportation, New Jersey Turnpike, the Port Authority of New York and New Jersey, New York State DOT, New York City DOT, TRANSCOM, FHWA as well as the NAHSC. The final members who will participate in this operational test will finalize the problem to be addressed in this study. The NAHSC is expected to provide leadership in finalizing the scope as well as propose additional members who may want to participate in this study. A test facility will be identified which will be available and secure for conducting preliminary tests.

Task 2. Literature Review on Automated Highway System Technologies. A literature review will be conducted during the first year which will provide the state of the art of existing and emerging technologies which are applicable for a bus AHS system. The existing concepts of the NAHSC as well as other international AHS concepts will be thoroughly examined to identify the advantages and disadvantages of the existing and emerging technologies for a bus automated highway system.

Task 3. Preliminary Screening of Technologies. During the first year a preliminary screening of technologies will be identified as the most promising ones for a bus automated highway system. Focus will be placed on investigating the safety implication of the technology. Applicability of moveable barriers to the corridor will be studied. A preliminary testing of existing technologies will be undertaken using a few buses which will be acquired by New Jersey Transit. The testing will be undertaken on a facility which will be identified by the coalition. This preliminary test will examine longitudinal and lateral control and the communication technologies.

Task 4. Finalize the Concept and Develop a Work Plan for the Next Two Years
The principal investigators will submit at the end of the first year a work plan that will cover the activities of the next two years. The coalition will need to approve this work plan.

Task 5. Testing of the Concept on the Test Facility
The test facility will be instrumented as well as a number of buses where the concept will be tested on a small scale. Different alternatives are expected to be tested as well as a number of different technologies. This task is expected to be completed within the second year of the operational test.

Task 6. Test on the Actual Facility
A number of test runs will be undertaken on the test facility to demonstrate the bus automated highway system concept as finalized in year two. Route 3, Lincoln tunnel and the bus terminal will be instrumented according to the finalized concept. It is expected that a larger number of buses will be instrumented in order to perform this task. The test will be undertaken at times which will be found acceptable by New Jersey DOT, New Jersey Police, New York City Police, the PANYNJ, as well as other agencies that may be involved. The reliability of the system and its components will be tested under various conditions. This task will be undertaken during year three. Task 7. Final Report

Potential Benefits
This operational test will demonstrate the potential capabilities of a bus automated highway system in carrying an enormous amount of commuters to a central business district area under a fail safe system.

Estimated Cost

Year 1: $ 300,000
Year 2: $ 300,000
Year 3: $ 300,000

NJIT AND PRINCETON COST SHARING (20%) = $ 180,000
TOTAL COST = $ 900,000

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