

<u>New York State Thruway Authority</u> Automatic Vehicle Classification (AVC)

RESEARCH REPORT

For the Federal Highway Administration (FHWA)

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I. Executive Summary

In December 2007, the N.Y.S. Thruway Authority ("Thruway") concluded a Federal funded research effort to study technology and develop a design for retrofitting devices required in implementing a fully automated vehicle classification system in Thruway toll plazas and barriers.

A project team consisting of representatives of all functional business areas affected by this project was formed and research occurred under the guidance and direction of a Steering Committee consisting of Executives from each major business area (Finance, Operations/Maintenance, Engineering, Information Technology, Legal and the Chief of Staff).

The research performed focused on technology available within the current market and study of infrastructure to identify how the technology could be retrofit into the Thruway's toll plazas. The research successfully yielded selection of technology that will provide a fully automated system that classifies vehicles according to the Thruway's toll structure. Additionally, the research team developed a highly efficient design for incorporating the technology within the Thruway's 50+ year old toll infrastructure. The Key Findings section of this document details the positive results of this research effort.

A. Background

In Q4 of 2006, the Thruway embarked on an effort to research the technology and impact on infrastructure of building an Automated Vehicle Classification (AVC) System. The purpose of the AVC system is to improve E-ZPass usage in the Thruway's 61 toll plazas and barriers where E-ZPass is installed in exit lanes while securing the Thruway's revenue.

The Thruway's E-ZPass transponders have specific vehicle information programmed on the transponder. This information is used to determine the classification and therefore the toll amount. Customers that use the E-ZPass transponder in a vehicle of a different class are instructed to go through a staffed lane. This procedure slows down traffic that could utilize an E-ZPass lane and allow for revenue loss for customers that do not. Once implemented the system would eliminate the need for E-ZPass customers to use staffed lanes when they are in a vehicle of a different class than that programmed on their E-ZPass tag. The goals of the research effort were to:

- Identify appropriate equipment such as laser sensors for vehicle height, profile and separation information and fiber optic axle sensor devices for vehicle axle count information;
- Identify a plan on how to retrofit AVC equipment into Authority's existing toll plaza infrastructure;

- Develop an rudimentary AVC system prototype to facilitate system performance analysis of equipment in various conditions (I.E. high and low speed lanes, weather conditions, etc) and
- Identify potential operational issues / costs (i.e. maintenance).

In December, 2007 the AVC Project Team concluded the research effort. The effort consisted of testing various electronic and laser sensor devices, studying Thruway infrastructure with intent to understand how best to retrofit equipment and the development of rudimentary software to support testing various equipment.

Details of the research findings are below.

II. Research Effort

A. Personnel/Management

Though there are several experienced solution providers in the open market that provide AVC solutions, the Thruway opted to conduct this research under the constraint that the system will be designed using in-house forces. The Thruway maintains a highly skilled staff that consists of electrical and electronics engineering under the direction of Dr. Julius Madey and software engineering under David Martin (both directed the development and installation of E-ZPass system throughout the Thruway in the 1990s and installation of the Thruway's first Open Road Tolling site in Spring Valley, New York in 2006). Furthermore, the Thruway's toll structure differs from many other transportation agencies within the E-ZPass Interagency Group. Therefore, the Thruway opted to use its ability to perform in-house research to develop a tailored solution meeting the Thruway's toll requirements.

This Research project was managed by the Thruway's Project Management Office (PMO). The PMO follows the Project Management Guidelines as developed by the N.Y.S. Office for Technology (NYSOFT). Under the guidance of the Thruway's Project Management Office, the project manager coordinated the various activities between stakeholders and the project's Steering Committee. More information regarding project management practices are available on NYSOFT'S website under "Program and Project Management" or using the following link: <u>http://www.oft.state.ny.us/Policy/projectmanagementindex.htm</u>

B. Infrastructure/Toll Systems

The Thruway's current toll structure classifies vehicles by height and axle. In staffed lanes, a toll collector will use the height and axle combination as well as recognize the type of vehicle by distinguishing height over second axle to classify the vehicle. The height over second axle is applied for vehicles that are hauling a trailer. In these cases, the height of the vehicle is used when applying the height

attribute as opposed to an aggregate height measurement of both vehicle and trailer (See Images II-A). The toll structure also has exceptions and discounted vehicle classifications that the collector must account for while classifying a vehicle. The Thruway's Executive Management and project stakeholders recognized the need to have the Automatic Vehicle Classification system follow the same procedures as manual toll collection to insure classification and tolling consistency between staffed and E-ZPass lanes. Details of toll structure are beyond the intent of this report, but a high level understanding is applicable in recognizing the nature of the research that was funded through this project to insure a highly functional AVC system was possible and cost effective. Further information regarding the Thruway's toll classification structure can be found on the following link:

http://www.nysthruway.gov/tolls/classes.html

Images II-A – Sample Toll Classifications



Classification 4-Axle "L" – Low

Classification 4-Axle "H" - High

C. Thruway Infrastructure

In addition to recognition and analysis of the Thruway's toll classification structure, the project team surveyed the toll plaza infrastructure for which devices would be retrofit. The Thruway has various toll plaza structures with different width/speed lanes and different spatial relationships of existing E-ZPass components for which AVC devices would interact. This increased the challenge of identifying devices that would interoperate within the existing infrastructure and E-ZPass equipment.

Images II-B – Various Plaza Canopies Over Toll Lanes



"Original" Style Canopy



"Gull-Wing" Style Canopy



"Standing Seam" Style Canopy



No Canopy Over Lane

III. Detailed Research Conducted

Technology projects at the Thruway typically follow a pre-established set of phases that take the project though inception to implementation, these phases are:

- Phase 1: Proof of Concept,
- Phase 2: Prototyping,
- Phase 3: Finalized Design, and
- Phase 4: Project Rollout

For purposes of the Federal Research effort, the funding was to cover Phases 1, 2 and most of Phase 3.

A. Phase 1: AVC - Proof of Concept (POC)

1. Proof of Concept – General Description

The purpose in establishing a proof-of-concept is to insure that technology is available to address a specific need. Furthermore, the effort seeks to limit the investment in resources in determining if a strategic need can be addressed. Through limiting resources, the team can focus on the technology aspects of a issue without risking time and resources of other business areas should the technology prove to be insufficient or unable to provide sufficient return on investment if implemented. Technology staff and engineers work together to conceive ideas of how to address a certain problem/need. Limited interaction occurs with Thruway Operational and Maintenance staff while the engineers determine various means to approach the problem. The resulting information gained from the Proof-Of-Concept effort is a high level technology design that will be reviewed by all stakeholders in the project to insure project feasibility, document project scope and identify issues of quality and project maintainability.

2. Proof of Concept – AVC Effort

The Proof-of-Concept phase for the AVC project entailed the usage of several preexisting test sites including; a test bed located at the Thruway's Headquarters; Building 11 in Albany, a toll lane at the Albany Interchange 23 Plaza, a test bed located under the Coxsackie overpass at approximately milepost 124 southbound and the Spring Valley Open Road Tolling (ORT) Facility located at approximately milepost 23 northbound. The Spring Valley ORT Facility and Coxsackie test bed provide a mechanism for testing equipment in open highway situations. Plaza 23 afforded the Thruway the ability to test AVC equipment in a setting that is similar to the intended environment for which AVC is to be implemented. Specifically, the Plaza 24 test lane provides:

- high traffic volumes;
- infrastructure (canopy type, lane width, toll features) that is similar to approximately 60% of the toll lanes for which AVC will be implemented and
- proximity to Albany Headquarters (thereby facilitating construction, and support and testing of AVC equipment).



Spring Valley Open Road Tolling and Test Facility



Coxsackie – Interchange 21B Overpass Test Bed



Toll Plaza 23 AVC – Proof of Concept / Test Site



Thruway Headquarters Building 11 Test Bed

3. AVC Transportation Agency Survey

The team surveyed other agencies within the E-ZPass Interagency Group (IAG) to determine various systems and technologies that are currently employed by other toll agencies. Although, the team acknowledged that the Thruway's toll structure is different than other agencies surveyed in the IAG, the team wished to determine if there were common implementation and operational best practices that could be employed by the Thruway in installing and operating an AVC system. The results of this survey were documented and presented to the project's Steering Committee.

4. Technology Review / Data Collection and Analysis

The project team predominately focused on researching devices that could obtain a vehicle height and profile of vehicle. The Thruway has axle counting devices already installed within each toll lane. As primary requirements, the devices to be selected for research must be able to function in the climate that is typical for Northeastern United States (I.E. operating temperature ranges, high humidity, accumulating snow, fog, rain, etc.). The Thruway has gained experience in laser sensor technology from other major projects implemented within its New York Division. Laser sensors are deployed for both Open Road Tolling and Higher Speed E-ZPass lanes. However, as compared to AVC these systems have different:

- functional and operational requirements;
- system components and
- environments for which they operate (I.E. higher / highway speed traffic, with no forced lane delineation such as "Jersey" barriers).

Acknowledging these differences, the Thruway understood the necessity and importance of this research effort to review technology and confirm that selected technology will facilitate the development of a highly functional AVC system.

The AVC system will be maintained using Thruway staff. Therefore, it was also critical that in-house maintenance staff be involved in the design effort to insure that the resulting AVC system can be efficiently maintained. Another benefit for maintenance involvement earlier on in the development process was to document the maintenance requirements so that service level expectations can be established as well as staffing requirements necessary to support the system.

a) **Devices Researched**

The following devices were the primary focus for this research effort. See Images III-B.

OSI Laser Sensor:

Two-beam laser sensor device developed and sold by manufacturer as a vehicle classification device that is capable of obtaining vehicle height, length, vehicle separation and classification into preset classifications as identified by manufacturer.

Sick Laser Sensor:

Single-beam laser sensor device capable of obtaining distance between object passing through field of beam and separation of objects through beam.

Ultrasonic Side-Fired Array:

Thruway in-House design using light-based technology commonly used in manufacturing/assembly plants capable of obtaining distance of object within field of "view". Field of "view" breadth and distance is configurable.

Ultrasonic Canopy Installation:

Overhead installation of single Ultrasonic device.

Note: Other past research has been conducted by the NYS Thruway staff approximately 10 years prior to this effort. This research included light curtains and other laser sensor technology.

Images III-B



OSI Laser Sensor – 600 Series For further information:

http://www.osi-laserscan.com

http://www.osils.com/pdfs/Autosense%20600%20Seri es%20Users%20Guide%20R3_7.pdf





OSI Laser Sensor at Plaza 23



Sick Laser Sensor – LMS Series For further information:

http://www.sickusa.com/gus/en.html

http://www.sick.com/gus/about/news/ar chive/listing/lmssensors/en.toolboxpar. 0004.file.tmp/LMS%20211%20Tech% 20Info.pdf 20Info.pdf



Sick Laser Sensor and Overhead Ultrasonic Sensor at Plaza 23



Ultrasonic Side-Fired Array



SICK Ultrasonic Sensor – UM 30 Series For further information:

http://www.sick.com/home/factory/catalog ues/industrial/ultrasonic/en.html

http://www.enm.com/eandm/products/sick/ 23ISULTRAS.pdf



MassaSonic Sensor – M5000 Series For further information:

http://www.massa.com

http://www.vydas.co.uk/PDF/MP/M5 00095DataSheet.pdf



Ultrasonic Sensor – UM30

Power and Signal Junction Box

As a result of research conducted from June, 2007 through August 2007 the team agreed to abandon any further research associated with the Ultrasonic technology. The team discovered inconsistent performance associated with the technologies inability to measure distances due to vehicle reflectivity especially associated with transparent objects (such as vehicle windows). Furthermore, in the sensor array implementation, the sensors are required to have a spatial relationship distance between each unit that limited the configuration that would be necessary to obtain vehicle profile (sensors ability to obtain trailer separation and simultaneous height of vehicle).

b) **Business Rule Concept**

During research of the various technologies, the team identified the need to address anomalies between vehicle's electronic profile as obtained from sensors vs. actual classification of vehicle. For example, a passenger vehicle carrying a tall load must not be misclassified as a larger vehicle such as a delivery van. The team used the test site at Plaza 23 to collect vehicle profile data and potential misclassifications in an effort to identify the types of issues that may occur and gain an estimate of the volume of occurrences. Data collected from both the Spring Valley ORT Facility and Coxsackie test sites were also used.

c) <u>Infrastructure Inventory</u>

Upon narrowing down the technology to overhead laser sensors a survey of 142 toll plaza lanes was conducted to review toll plaza infrastructure and determine retrofit issues. The preliminary design using laser sensors also included spatial relationship requirements to other E-ZPass and toll equipment along with other infrastructure within the toll lanes. Therefore, the survey included measurements between the different E-ZPass and toll devices and measurements of canopy height, width and other infrastructure that may impede the installation of AVC.

B. Phase 2 – Prototyping

1. Prototyping – General Description

The Prototyping Phase is an extension of the Proof of Concept. Upon establishing that there is sufficient technology to address a certain business need and that the technology can be retrofit into the Thruway's infrastructure, a larger team is formed to develop a system design. Typically, the team that is formed is a cross section of:

- technology and software staff;
- ITS and infrastructure (bridges, highways and facilities) maintenance staff and
- design engineering.

The goal of the Prototype Phase is to develop a robust system design that incorporates the technology researched in the Proof of Concept Phase. The inclusion of Thruway Maintenance staff in the design/prototype phase has proved to be a crucial element in insuring successful system implementation and operation long after a system has been implemented. The maintenance staff provide years of experience in best practices and lessons learned from past projects. The Prototype Phase includes development of system prototypes constructed by Thruway maintenance staff so that the design team can obtain first-hand input on improvements and potential issues in both construction and maintenance of the system.

2. Prototyping – AVC Effort

The Proof-of-Concept phase for the AVC project entailed development of three prototype sites located in 3 of the 4 Thruway divisions. Maintenance staff were mobilized to construct the prototypes in plazas that reflect the most difficult installation scenario when compared with the approximate 140 lanes. Other design scenarios were roughly a subset of the work that would be required for these plazas. See images below for each prototype.

As part of the prototype construction process, the project team completed a draft detailed design that included a list of materials and scenarios for installation practices. Ultimately, division staff were responsible for choosing how best to perform the work under the requirements that the design and schedule were met. Division staff were required to report status and issues to the headquarters team. The team (including Division staff) hashed out solutions for installation problems and notified other divisions to insure consistency in construction. Upon construction, analysis of each prototype plaza took place using rudimentary AVC software that was developed to support the prototype effort. During this analysis, division staff were required to make adjustments to the prototype installations regarding mostly laser sensor positioning and communications devices. Upon final completion of the

prototype sites all construction issues were identified as well as best practices and lessons learned.

Images III-C



Prototypes at Plaza 41 Waterloo and Plaza 48A Pembroke



OSI Laser Sensor (From under the Canopy)



Sensor Housing

C. Phase 3 – Document Final Design

This phase completes the detailed design effort by documenting the design plans which include engineering diagrams, specifications and other documentation that provides instruction on building the system. The design incorporates the best practices and lessons learned from the prototype effort. Upon completion of design documentation, the Thruway continues through a series of internal reviews and approvals. If the job is to be built using internal Thruway forces, the plans are sent to each division contact previously established earlier during project initiation. Otherwise, the team follows the Thruway's procurement practices associated with construction contract lettings (I.E. contract print, advertisement, letting, bid reviews, internal approvals, Office of State Comptroller and Attorney General's office approvals). This federally funded research effort concluded with the development of the AVC design plans. The plans incorporate engineering drawings, specifications and installation instructions for implementing AVC in 134 toll plaza lanes in all four of the Thruway's divisions. As part of the final system design, the team continues to refine the business rules as described above and design the software system that is necessary to operate AVC.

IV. Key Findings / Best Practices

Below is a list of positive results that this research effort yielded.

A. Overall Implementation Findings

1. AVC Rollout

The Thruway determined that the AVC system could be rolled out predominately by Thruway forces. Prior to the prototype effort, the project was envisioned to be constructed entirely through contracted forces. The AVC budget was predicated off of the usage of construction contracted forces for the rollout. However, after the prototype sites were built and division staff provided input, the Thruway executive level requested that the team plan to implement AVC using internal forces with the exception of 2 plazas in New York Division and axle sensor replacement in Buffalo Division. The estimated savings resulting from using internal forces is approximately \$400K - \$500K.

2. Efficient AVC Retrofit Design

The Thruway's 50 year old toll plaza infrastructure became a key constraint in designing the AVC system. The team reviewed 59 toll plazas containing a total of 142 lanes to identify and understand potential retrofit issues. The team used the information to arrive at a design that met the AVC requirements yet worked within each plaza's unique attributes. This design negated earlier ideas that incorporated separate free standing structures such as gantries and additional toll equipment (axle sensors) which would have cost the Thruway significantly more to construct and maintain.

3. Technology Selection

Through the research effort, the team was able to select the best technology available to support the concept of a fully automated classification system. The technology selected is highly functional and poses reduced maintenance effort / costs as compared with side-fired technology (I.E. technology that obtains vehicle information from ground level through various heights up to 8'). The overhead laser sensor design is well suited to the Thruway's existing

toll plaza and E-ZPass/toll infrastructure. Through this research, the team obtained crucial information regarding:

- sensor position / correlation to performance (the team will closely follow the manufacturer's recommendations for installation height of the laser sensor);
- sensor position in correlation to other E-ZPass/toll infrastructure (I.E. formed spatial toll device relationship requirements) and
- video / image enforcement.

The team has identified that video enforcement may not provide return on investment in achieving the final minor percentage of vehicles that may not be able to be automatically classified as compared the Thruway's toll structure. The Team will perform further research upon construction and preliminary operation of sites through the end of the year (2008).

4. Miscellaneous Detailed Design Findings

- Laser sensor structural rail support to aid in laser sensor positioning of height and lateral adjustments
- Laser sensor covering required to seal "window" cut in to toll plazas (seals out running rain water or snow build-up around the laser sensor
- No catwalks or attached stairways in or on the toll plazas canopies are required, the in many cases, the laser sensor is accessible from a lift truck
- Additional communications box within toll booths to shelter wiring and connections which are typically can have a high failure rate
- Increase size/gauge of cables from manufacturer's product thereby allowing for an easier and stronger wiring connections

V. Next Steps

The AVC project is scheduled to be competed by the end of 2008. The team is currently working with division staff in constructing AVC in 121 lanes and managing a construction contract to build out AVC in another 13 lanes in the Thruway's New York Division. The team is also continuing analysis of Business Rules and building the AVC software system. Other facets of the AVC effort include:

- Development of an AVC Maintenance Plan
- Management of procurement effort for all required parts necessary to construct AVC
- Development of fully functional AVC Software
- Development of an AVC Test and Implementation Plan
- Development/Documentation of Project Lessons Learned and Best Practices

VI. Conclusion

This federally funded project facilitated the successful research of technology, infrastructure, retrofit plans and procedures and yielded an efficient and effective AVC design. The completion of this research effort positions the Thruway to fully implement an automated vehicle classification system that will enable the Thruway to:

- improve traffic throughput in an around toll plazas / thereby decreasing fuel consumption and pollution associated with idle traffic;
- protect revenue associated with E-ZPass tag usage and capitalize on increased E-ZPass usage in-turn providing internal efficiency via automated toll collection efforts; and
- reduce budgetary commitment associated with AVC rollout through implementation of the AVC plan/design obtained from this research effort.

VII. Roles / Contacts

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