REMOTE SENSING AND SPATIAL INFORMATION FOR TRANSPORTATION DEMAND MANAGEMENT (TDM) ASSESSMENT

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ABSTRACT

This paper reports on four applications of remote sensing technology and spatial information and analysis for the assessment of TDM projects involving transit operations. The projects all aerial imagery and imagery interpretation to improve transit operations. The applications use remotely sensed imagery from manned and unmanned aircraft integrated with collateral spatial information using geographic information systems (GIS) to analyze transit operations to promote efficiency and effective service.

INTRODUCTION

Since 1942, aerial reconnaissance has been a main element in planning and carrying out military tactical operations. Few operational decisions are made in a major military campaign without conducting imagery analysis and collateral intelligence analysis. Yet, this mainstay of military operations decision support has not been used to assist public managers and policy-makers in transit operations and transportation systems management. Recently, the U.S. Department of Transportation (DOT), in cooperation with the National Aeronautics and Space Administration (NASA) inaugurated a program to promote technology application projects (TAP) for the commercialization of remote sensing and spatial information in transportation. This paper will outline three applications that have evolved from this U.S. DOT program, and a predecessor project that was reported at the U.S. DOT – NASA Conference on Remote Sensing and Transportation Applications in May of 1999. The paper will support a poster session at the November 2002 Transportation Research Board (TRB) Conference on Remote Sensing and Transportation, Track 4 – Traffic Flows. [*N.B.* Graphic displays will supplement this paper at the conference and will be available for download at www.e-transit.org following the conference.]

MBTA BUS ROUTE 1, 1972

In the early 1970's, the Massachusetts Bay Transportation Authority (MBTA) in Boston was working with the new Institute for Governmental Services in the President's Office of the University of Massachusetts (UMASS) to address the issues of timely bus operations along the MBTA's busiest bus route from Dudley Square in Roxbury along Massachusetts Avenue to Harvard Square in Cambridge. Working with the MBTA's Operations Directorate, the UMASS researchers identified a number of problems that could be assessed from aerial reconnaissance, documented, and presented to public administrators at the state and local government level. With the cooperation of the Massachusetts National Guard, a high-performance jet reconnaissance aircraft (RF-101 Voodoo) operated by the Kentucky Air National Guard (KY ANG) was scheduled to conduct a training mission along the MBTA bus route. The RF-101 was equipped with two military aerial survey cameras, each with a 6" focal length. One camera was in a forward oblique position. The other camera was in a vertical position set to produce 2/3rds overlap on the imagery for stereoscopic analysis. The mission was flown, at the convenience of the pilot's training schedule, at approximately 5 pm on July 6, 1972, during the pm rush hour and again at 7 am on July 7th. The imagery was initially processed by the KY ANG and two 9" x 9" paper prints were sent to UMASS for analysis.

The KY ANG pilot coordinated his flight plans with the FAA who were controlling air traffic at Logan Airport in East Boston. The aerial survey plans called for the pilot to fly the route at 2000' to accommodate the appropriate scale for ground coverage of the dog-leg Massachusetts Avenue route with the 6" focal length vertical camera. Unfortunately, the pilot flew the reconnaissance pass at 1000' altitude and the Cambridge portion of the route was not covered.

Despite the fact that this was the Fourth of July vacation week, the imagery analysis yielded significant documentation of the problems that the MBTA operations directorate had identified prior to the mission. The Thursday rush hour coverage revealed northbound traffic virtually stopped for twelve blocks on Massachusetts Avenue in Boston. The third northbound lane of Massachusetts Avenue was blocked by fifty (50) illegally parked vehicles, twenty-six (26) of which were in a tow-away zone. As result, eight (8)MBTA buses were caught in the traffic tie-up.

Recently, the imagery from the 1972 flight has been scanned as digital images. The forward oblique images have been displayed as a digital movie to document the changes in the Boston downtown area in relationship to the Central Artery/ Tunnel project and associated changes in transit capital infrastructure. The vertical imagery has also been scanned from the original (military grade film) negatives, cropped to form a digital mosaic of the flight path and georeferenced for incorporation into a geographic information system (GIS). These very large-scale images have excellent resolution qualities (up to .25 inches) for historical analysis of surface transportation systems and related land usage. With current compression software and bandwidth, there is potential for web mapping applications to analyze changes in transportation infrastructure over time at the same geographic position.

CAPE COD TRANSIT SHUTTLES – 2000

The Moakley Center for Technological Applications at Bridgewater State College (MA) teamed with the Transportation Center at the University of Massachusetts - Amherst to apply remote sensing and spatial information technologies in two areas: the assessment of transportation demand management (TDM) projects and the assessment of regional transit capital infrastructure projects. Since this Remote Sensing and Transportation Technology Application Project was funded by the Research and Special Programs Administration (RSPA), the Federal Transit Administration (FTA) and RSPA have moved aggressively to support commercialization of both applications through the Small Business Innovative Research (SBIR) Program.

The TDM assessment tool was developed and tested using several transit TDM projects on Cape Cod -- downtown trolleys, park and ride shuttles, and an intermodal shuttle to the National Seashore and other venues. The Cape Cod Regional Transit Authority's (CCRTA) transit and paratransit vehicles were all equipped with state of the art global positioning system (GPS) based automatic vehicle location (AVL) systems. Every sixty seconds the AVL geo-spatial data was transmitted to the GeoGraphics Laboratory at Bridgewater State, where it was mapped on the web for consumer travel planning and archived for TDM evaluation at www.e-transit.org/cape_cod/ . The TDM assessment tool recreated the travel patterns of the TDM project vehicles by tracking the AVL data on high-resolution digital orthophotos using a custom-built GIS application using Maptitude™ from Caliper Corporation of Newton, MA. The individual vehicle's GPS-based location data was associated with geo-spatial data collected by the mobile data computers as passengers boarded, alighted and made an electronic fare payment.

The resulting analysis provided the CCRTA management with unprecedented geospatial assessment on the management effectiveness and efficiencies of contract operators and individual drivers. It also provided unprecedented quality assurance and quality control (QA/QC) for transit and paratransit information systems. GeoGraphics Laboratory analysts were able to use the GPS/AVL tracker to display high-resolution temporal and spatial data from individual vehicles to evaluate driver's adherence to routes and schedules as well as to verify contractor billing for vehicle hours of service. As a result of the geospatial analysis, the transit authority terminated one contractor and disciplinary action was taken against both supervisory and operational staff of another contractor.

The same techniques of tracking vehicle locations against a back drop of high resolution digital orthophotos were used in adjudicating a traffic accident involving a CCRTA bus to determine if the accident was preventable and therefore chargeable against the driver for internal disciplinary action. In this instance, the union steward requested the use of the remote sensing and spatial information assessment tool to successfully make the case that the driver should be terminated. Mangement concurred with the union position, supported by the historical driving record of the driver.

MBTA COMMUTER RAIL TDM ASSESSMENT WITH SMALL UAVS FOR RS – 2001

In the process of evaluating parking lots associated with park and ride shuttles, the afore-mentioned project highlighted the need for inexpensive remotely sensed imagery with high spatial and temporal resolution. Previous research (Jensen 2000) had indicated that to evaluate the effectiveness of parking and traffic management schemes, imagery had to be available within a ten-minute period and with a spatial resolution of 6 inches. A prototype micro aerial vehicle (MAV) was developed and tested as a part of the project. The MAV carried two video cameras with a real-time 2.4 GHz downlink: a wide angle forward facing lens for piloting the aircraft and a vertical telescopic lens for sighting a film camera attached to the wing. The film camera was an off-the-shelf 35-mm auto-focus automatic rewind camera that was triggered by a servo (mechanical arm) hitting the shutter button at a radio signal from the 75 MHz hobbyist's radio controller. The MAV incorporated state of the art devices to assist the pilot/photographer, including wing leveling and altitude hold. The MAV also included safety devices such as an emergency parachute deployment and engine shut-off when the radio signal is lost with the controller. The MAV was hand launched and reaches operating altitude in about 90 seconds. It produces real-time high-resolution digital video stored on an off the shelf 8 mm portable video player. The 35-mm color photography was processed at a local 1-hour photo shop with close to 1-inch spatial resolution. In addition, miniaturized thermal infrared (IR) cameras are now available that can provide video based on thermal emissions of objects, albeit at considerable expense. The MAV operated under the FAA airspace limits over public property. Issues of liability were addressed through risk management; formation of a limited liability company (LLC) for those not covered by public liability caps and purchase of specific general liability insurance for UAV operation.

Following the September 11th terrorist attacks on Washington and New York, the usefulness of the MAV in providing transit infrastructure security beyond TDM assessment became readily apparent. With the support of RSPA and the FTA, the project staff met with transit security professionals to develop draft specifications for commercial off the shelf radio controlled aircraft with short take off and landing (STOL) and vertical take off and landing (VTOL) as a remote sensing platform for transit security and anti-terrorism. The specifications were published in the Final Report for the project.

MBTA UAV FOR BUS RAPID TRANSIT (BRT)
TRAFFIC MONITORING – AUGUST 2002

As a result of a U.S. Department of Transportation's Remote Sensing and Transportation Program, the GeoGraphics Laboratory at Bridgewater State's Moakley Center for Technological Applications has been developing innovative uses of unmanned aerial vehicles (UAVs) to improve transit operations. As a part of the U.S. DOT project, the MLB Company has developed state-of-the-art UAVs, derived from tactical military research and development, for civilian transportation application. This proposal would provide an opportunity to demonstrate MLB Co.'s small UAV in autonomous flight over the Massachusetts Bay Transportation Authority's (MBTA) new Bus Rapid Transit (BRT) Initiative, the Silver Line, along Washington St. in Boston.

During the week of August 19th, MLB Co.'s President, Dr. Stephen Morris, has offered to demonstrate the BAT UAV along the Silver Line route from Dudley Square to the New England Medical Center. The BAT flies autonomusly along a pre-determined course and provides real-time video to the mobile operations computer. The small (10 lbs. wt. and 4' wingspan) aircraft features the latest safety features including a *go home* feature and emergency parachute deployment.

The scope of the operations includes:
- Pre-programming a flight path for the autonomous flight (along Washington St.).
- Identifying problems that can be highlighted or resolved from aerial reconnaissance.
- Flying the aircraft to provide high-resolution vertical imagery that can be geo-referenced into geographic information systems.
- Integrating spatial data from global positioning systems (GPS) based automatic vehicle location systems (AVL) on the Silver Line buses with the geo-referenced video imagery products to provide a meaningful context for post operation analysis of AVL spatial data.
- Flying the aircraft to provide high-resolution real-time oblique imagery of the BRT operation to identify and resolve the conflicts between vehicle traffic and BRT Silver Line buses in real-time.

- Eliciting feedback from transit operations, transit police, and local government transportation professionals on the potential for using automated UAVs to improve transit operations on surface streets in urban areas.

The demonstration will be conducted as a cooperative project by the Massachusetts Bay Transportation Authority, the GeoGraphics Laboratory at the Moakley Center for Technological Applications at Bridgewater State College, the MLB Company, and Harman Consulting LLC. The demonstration will be conducted in cooperation with a Remote Sensing and Transportation Technology Application Project (TAP) by the U.S. Department of Transportation and the National Aeronautics and Space Administration under an agreement with the GeoGraphics Laboratory at Bridgewater State and the Transportation Center at the University of Massachusetts.

PROBLEMS AND OPPORTUNITIES

The four applications above have each helped to delineate the problems and opportunities posed by applying remote sensing and geospatial analysis to assessing transportation demand management projects.

- Using the RF-101 aircraft in 1972 as a remote sensing platform yielded a treasure trove of imagery that directly supported the beleaguered transit operations staff in addressing the inherent interagency problems of operating surface transit on city streets. The problem was that the personal relationships that brought a high-performance military tactical jet aircraft to fly through the approach zones of a major national airport (Logan) to provide high-resolution intelligence quality imagery were not institutionally or financially sustainable on a local or national scale. Thirty years later, with the availability of low-cost UAVs as remote sensing platforms, there is an opportunity to replicate this research on a meaningful scale, at reasonable cost and with minimal institutional issues.

- Integrating GPS-based AVL spatial information with digital orthophotos has a high payoff in monitoring contract transit operations by public adminis trators. It requires an investment in GPS-based AVL and a commitment to use the resulting spatial data integrated with GIS and digital orthophotos. The skill level to accomplish this may not be immediately available at the operational level of the typical transit agency. It also requires considerable courage for public mangers to deal with the resulting analysis. The payoff to the transit consumer and the operations manager in ensuring that service is performed on-time and according to published schedules appears to be worth the investment in developing the requisite geospatial skills among managerial staff. There is anecdotal evidence that a significant number of drivers may try to misuse on-board geospatial data collection equipment. A *no-excuses* managerial approach is required to deploy these data collection instruments (e.g. GPS/AVL, mobile data computers, automated passenger counters, electonic payment systems). Without a firm managerial commitment to data integrity, these costly technology investments are largely worthless.

- There is a real opportunity to use small UAVs as remote sensing platforms to meet Dr. John Jensen's temporal and spatial resolution requirements of 10 minutes (temporal) and 6 inches (spatial) for optimum traffic analysis with aerial imagery. The cost of these systems range from a few thousand dollars for model airplane based platforms to $35,000 for a custom built autonomous aircraft with professional quality sensors. These systems can provide high-resolution imagery in a timely manner that can be integrated with related geo-spatial data through low-cost fully featured geographic information systems. It does require transit managers and policy makers to understand what can be done and what cannot be done for reasonable expenditures. It also requires transit operations supervisors and operations analysts to use the data products as the intelligence community does, with intellectual openness and analytical integrity, for optimal results.

- The transit operator needs all the help it can get in getting an appropriate voice in traffic management. Using UAVs as remote sensing platforms to provide documentary analysis as well as real-time video of buses and street cars operating in city traffic should provide interagency decision-makers with the means to significantly improve transit efficiency and effectiveness. It is conceivable that MBTA operations supervisors can use small UAVs/RS platforms integrated with GPS-based AVL technology to perform real-time incident detection and problem solving in rush hour traffic. This can greatly improve the attractiveness of buses and streetcars and improve overall traffic flows as well.

AREAS FOR FURTHER RESEARCH AND DEVELOPMENT

The four projects have raised some research opportunities for the Federal and state transportation agencies.

- Evaluate how and why the U.S. military successfully integrates remote sensing and spatial information and analysis into decision support systems for both tactical and strategic decision-making.
- Evaluate the state-of-the-art of low-cost easy-to-use MAV robotic technology for remote sensing and propose technology transfer from national defense to homeland defense and transit operations analysis.
- Conduct demonstrations and technology transfer seminars for transit and traffic management personnel at the state and local government level, focusing on transit industry problems and issues that can benefit from applying RS and geospatial analysis.

Document the best applications of UAVs as RS platforms and integration of related geospatial data to improve transit and traffic flows. Measure the effectiveness and efficiencies that these technologies can bring to transit operations. Compare these costs against benefits of better transit service.

REFERENCES

Jensen, J (2000). "The Changing Face of Remote Sensing" *Remote Sensing for Transportation – Report of a Conference on December 4 – 5, 2000.* (Washington. D.C.: Transportation Research Board, The National Academies), 2001. Appendix A. (Table 1 and Figure 3 present the spatial and temporal requirements for selected transportation on other urban/suburban attributes that supported the GeoGraphics Lab's decision to build a UAV for TDMA.)