THE USE OF GPS-BASED AUTOMATIC VEHICLE LOCATION TECHNOLOGIES FOR BUS TRANSIT: STATE OF THE PRACTICE IN THE USA AND LESSONS FOR ELSEWHERE

Robert S Bain
Institute for Transport Studies, University of Leeds

SUMMARY

This paper reports the results from a recent survey of bus transit operations in North America – specifically looking at their experience with GPS-based Automatic Vehicle Location (AVL) technologies and related systems. Additionally, the paper brings forward the results from a similar survey conducted in 1995 and explores the lessons that have been learned over the past six years.

AVL technologies nest within the broader field of Intelligent Transportation Systems (ITS). Although mature in some areas, a number of these initiatives could be classified as 'emerging technologies'. As such, the experience of early adopters is likely to shape the way in which these technologies are embraced by a broader market. However, as the author notes, many of the problems that were being encountered in 1995 still challenge the bus transit industry today.

1. AVL: AN 'ENABLING TECHNOLOGY'

Strictly speaking, the heart of modern AVL systems – the GPS receiver – by itself does nothing to benefit transit passengers, bus operators (drivers), supervisory staff or management. Only when it becomes integrated with a data transmission medium (usually radio) and a digital mapping capability can it start to provide useful information – the real time or *near* real time location of a vehicle or vehicles. Taken one step further, it can be integrated with other vehicle systems (as described in Table 1), through an on-board computer or event recorder, significantly enhancing their functionality.

For this reason, AVL has been described in earlier literature as "*an enabling technology*".

Table 1: AVL Systems Integration

AVL	+ Scheduling Software	For real time schedule adherence monitoring (allowing corrective actions to be taken immediately by the operator or supervisory staff).
		For subsequent (ie. 'off line') schedule adherence analysis and fine-tuning.
	+ Silent Alarm, On-Vehicle Microphone and/or Video Cameras	For incident detection, comprehension and rapid (and appropriate) operational response.
	+ Automatic Passenger Counters	Monitoring boardings and alightings, and thus actual vehicle loadings.
	+ Traffic Signal Communications Device	Triggering signal priority (or conditional signal priority) as required.
	+ On-Vehicle Communications Systems	Automated audio and/or visual announcements (eg. stop announcement systems).
	+ Public Information Channels	Real time passenger information via bus stop displays, kiosks, the internet, wireless PDAs etc.

Through its integration with other systems, therefore, AVL technology can provide the following *potential* benefits:

<u>For Passengers</u>:

- Improved service timekeeping and reliability;
- Reduced journey time by triggering signal priority systems;
- Enhanced on-vehicle safety and appropriate/timely incident response;
- Readily accessible, real-time (even customised) service information;
- Better connection/transfer protection;
- Better on-vehicle communications (particularly for disabled passengers);
- Reduced overcrowding on the bus (see 'enhanced fleet management' – below).

<u>For Operators</u>:

- Reduced voice traffic by radio;
- Immediate indication of early/late running;
- Enhanced on-vehicle safety and incident response;
- More realistic schedules.

<u>For Supervisory Staff/Management</u>:

- Real-time despatching (particularly for paratransit/dial a ride operations);
- Real-time schedule, headway and running time performance monitoring;
- Enhanced fleet management: **on-line**: such as despatch of a spare vehicle behind a bus becoming heavily loaded; **off-line**: such as reduction of the peak fleet requirement, evaluation of service modifications and traffic management initiatives, service planning etc.
- Improved incident management;

cont./

- Automated data collection and analysis;
- Better use of on-street supervisory staff, inspectors and surveyors;
- Opportunities for schedule adjustment to reflect actual operating conditions;
- Resolution of customer complaints (eg. regarding early/late running);
- Improved service delivery.

These benefits have been emphasised as *potential* benefits because, although there is no technical barrier(s) to their realisation, no systems in North America – to the author's certain knowledge – provide them all. In fact, the majority of AVL technology procurements have realised only a fraction of their full potential.

2. THE AVL SURVEYS

2.1 Background

In 2000, Steer Davies Gleave (1) prepared a technical specification for the procurement of GPS-based AVL technology for the Metropolitan Bus Authority (MBA) in San Juan, Puerto Rico. The AVL functionality was but one component of a broader systems upgrade of the existing radio communications infrastructure employed by MBA. Indeed, the need to improve and/or modernise a bus company's communications platform is often the incentive for the procuring agency to investigate current state-of-the-practice – and that investigation will lead them quickly to computer-aided despatch capabilities allied to dynamic, digital mapping, and data transmission possibilities (including the broadcast and receipt of vehicle location information).

The author contends that this series of events has an important bearing on much of what follows in this paper. Note that the primary motivator (in the example given above) was the need to improve radio communications between the bus operator and some central despatch or control room. The procuring agency is asking:

- "*How can I contact my drivers more easily*?" or

- "*How can my drivers contact supervisory staff more reliably*?" or

- "*How can I reduce traffic on my radio system*?"

These are different questions from:

- "*If I knew exactly where my buses were in* (near) *real-time, I could react more quickly to incidents, improve fleet management and provide a better service. How can I do that*?"

As always, simply because a technology is available does not mean that its application is appropriate in every circumstance. Similarly, simply because a technology is acquired does not mean that it will be (or can be) exploited in full.

2.2 The 1995 Survey

In 1996, as part of the Transit Cooperative Research Program sponsored by the US Federal Transit Administration, Synthesis Number 24 was published entitled "AVL Systems for Bus Transit: A Synthesis of Transit Practice". Amongst other things, this synthesis reported the results from a survey of bus transit agencies conducted in late 1995. The key findings from that survey can be summarised as follows:

A. AVL systems have been used by bus transit agencies in the United States since 1969. Various technologies have been applied over the years however the reducing costs and increased precision afforded by GPS receivers now make it the technology of choice.

B. Data problems were frequently encountered because of an interface mismatch between the (new) AVL system and the agency's (existing) scheduling software.

C. Successful implementation and on-going support of an AVL system required skills that were not traditionally present within the transit agency – such as those required for digital map manipulation and updating, and database management and analysis. Training required a significant amount of time (investment) and commitment.

D. Many of the early system problems were attributed to the procurement process itself which required a clarity of vision about the procurement objectives, considerable technical insight and a flexibility to be able to adopt the newest technology in this rapidly evolving field.

E. Successful implementation of an AVL system required broad staff and inter-departmental support (across the agency) for the initiative.

Perhaps most concerning, the Synthesis noted that few transit agencies had conducted any formal assessment of the benefits they derived from their AVL system, and relied almost entirely on anecdotal evidence to justify the not-inconsiderable investment costs that were incurred.

2.3 The 2001 Survey

In April 2001, questionnaires were sent to the 31 bus transit agencies which had responded to the earlier (1995) survey. A further five questionnaires were sent to other agencies which, according to vendor sources, had expressed an interest in AVL or had recently acquired the technology. A sample of 36 does not allow conclusions to be drawn about the industry's views regarding AVL (or anything else for that matter) however that was not the purpose of the survey. As stated at the outset, the focus of this research was upon early adopters and the lessons that might be learned from their specific experiences.

To date (early-July 2001), 22 questionnaires have been returned. What follows is a report from a work-in-progress as questionnaires continue to be received by the author.

2.3.1 Overview

Of the 22 returned questionnaires:

- Three were returned by agencies still at various stages in the procurement process, so only partial information was available.
- One was returned by an agency that, after conducting feasibility studies in 1996 and 2000, and having hosted several vendor demonstrations, had yet to implement any AVL system.
- One was returned blank, accompanied by a copy of the (completed) 1995 survey.

The remaining 17 questionnaires came from transit agencies representing a surprisingly broad industry sample:

- A mix of service-area types (urban, suburban, rural and combinations thereof);
- A mix of fleet sizes (from 23 vehicles to over 2,000), and a corresponding mix of agency performance statistics (eg. from an annual ridership of 900,000 to one of over 100,000,000 passengers – the Maryland Mass Transit Administration).

2.3.2 AVL System Characteristics

<u>Radio Platform</u>

The radio platforms being used by these agencies were divided – almost equally – between a conventional radio system and a trunking one (allowing frequency sharing by dynamic re-use).

<u>Location Technology</u>

The location technology of choice was GPS, most commonly with some form of differential correction. Only two respondents reported the use of odometer-based vehicle location systems; one by itself and the other to augment a GPS system.

<u>Systems Integration</u>

Earlier, in Table 1, the possibilities for the integration of AVL technology with other systems were introduced. The extent of actual systems integration was explored in the questionnaire and the results are presented in Table 2.

Table 2: Extent of Systems Integration

AVL Integrated with…	No. of Respondents
Computer-Aided Despatch	16
Schedule Adherence Monitoring	14
Alarms, Cameras, Microphones	1
Automatic Passenger Counters	7
Signal Communications/Priority	1
On-Vehicle Displays/Annunciators	0
Public Information	1

The results in Table 2 demonstrate that:

- Nearly all respondents employ some form of computer-aided despatch system;
- Nearly all respondents integrate their AVL with their scheduling software (although, answers to subsequent questions revealed that this was mainly for on-line monitoring rather than off-line interrogation, analysis and reporting);
- The extent of integration with other systems is, however, very limited;
- Integration with Automatic Passenger Counters (usually light curtains) was not uncommon however, largely due to cost constraints, transit agencies typically install counters only on a sample (generally around 10%) of their fleet;
- Only one agency used AVL for signal priority purposes (the Napa County Transportation Planning Agency – the smallest fleet operator from the survey);
- Only one agency used AVL for real-time information purposes (the Regional Transportation District in Denver). Their website is at: http://www.rtd-denver.com where details can be found of a program to receive bus information in a wireless PDA. They also provide real-time information to kiosks located throughout the city.

2.3.3 System Objectives and Expectations

Respondents were asked about their original objectives for their AVL system and whether, or not, their expectations had been realised.

Table 3: System Objectives

Stated Objectives	No. of Respondents
Improve Radio System/System Management	7
Computer-Aided Despatch	5
Improve On-Time Service Performance	4
Improve Security and Incident Response	4
Better Fleet Management	3
Reduce Operational Costs	2
Automate Record Keeping/Eliminate Paper	2
Collect Data for Schedule Analysis	1

The results in Table 3 support the suggestion made at the start of this paper that many agencies become involved in vehicle location technologies through a need for an improved radio system. Additionally, several agencies mentioned that their AVL system had been purchased following attacks on operators and/or other serious incidents on the vehicle. Interestingly, only one respondent (King County Metro Transit in Seattle, Washington) specifically mentioned the collection of data for off-line analysis and schedule refinement.

14 respondents answered questions about whether (or not) the delivered system met their expectations. Seven replied ‘yes’ and seven replied ‘no’. Those replying in the negative were asked for their comments. Typical replies included “*System is not reliable*”, “*We’re still reaching for our goals*”, “*Many glitches. Data entry difficult*” and three respondents complained that they were receiving too much information!

2.3.4 Purchase Price and Related Annual Costs

A direct cost comparison has proved to be difficult to derive from the survey responses. Different respondents included different elements within their cost calculations. Furthermore, different functionality requirements led to different system specifications. The more broadly comparable costs (full costs, including new radio systems, AVL/CAD and some other systems integration) are summarised in Table 4.

Table 4: Cost Summary

Agency	No. of Buses	Purchase Cost	Annual Cost
Maryland Mass Transit Administration	832	$20.0m	n/a
Regional Transportation District, Denver	1,069	$12.0m	$236k
King County Metro Transit	1,077	$11.6m	$1,350k
Milwaukee County Transit	525	$10.0m	$300k
Niagara Frontier Transportation Authority	330	$9.5m	n/a
Regional Transportation Commission of S. Nevada	424	$9.2m	n/a

The purpose of including Table 4 is not for comparison purposes, but instead to show the order-of-magnitude costs that a fleet-wide radio infrastructure replacement programme (enabling and allowing for data transmission and analysis) can incur. These are not small capital investments, and can have significant on-going costs.

2.3.5 Major Hurdles and Challenges: During and Since Installation

The questionnaire prompted agencies to identify particular problems that had arisen during installation of their AVL system or subsequent to installation.

<u>During AVL Installation</u>

Installation challenges reported fell under the following headings:

- Vehicle and fleet-related issues: “*Logistics*”, “*Co-ordinating fleet availability for installation*” and “*Difficulty in locating the on-board computer*”;
- Employee suspicion and lack of support: “*Employee resistance to new technology*” and “*Computer fear, negativity, fear of ‘Big Brother’, fear of job loss/change, sabotage*”;
- Software/integration-related problems: “*Getting an accurate base map, integrating with internal systems (eg. scheduling), resolving polling issues, agreement on testing/acceptance*” and “*Installation of software that was not fully developed*”.

Since AVL Installation

Day-to-day challenges included:

- Problems with vendors: "*No vendor support*" and "*Getting contractor to respond*";
- Personnel/training issues: "*Lack of personnel for systems administration, operation and maintenance*", "*Manpower and equipment needs*", "*Getting all personnel to use the system*" and "*Driver training*";
- Software/data problems: "*Data entry difficult*", "*Occasional software glitches*" and "*What to do with all the data*".

Many of these challenges are identical to those reported from the 1995 survey, and some agencies appear to have evolved from a situation where they had no data to one in which they now feel that they have too much.

2.3.6 Evaluating the Performance Benefits of AVL

There was little evidence from the survey results that any of the AVL systems had been the subject of rigorous (ie. quantified) evaluation. Even in circumstances where the primary motivation for procuring this technology was for its on-line functionality, it is not difficult to imagine measures against which system performance could be gauged (average incident response time or average deviation from schedule, for example).

Most of the comments received regarding evaluation were 'soft' and largely anecdotal. Evaluation concentrated on inputs (such as the percentage of the fleet that could be monitored in real time) rather than outputs (such as service reliability improvements). Passenger opinion surveys were mentioned by none of the respondents.

This is not to say that transit agencies did not benefit from the technology, sometimes significantly. "*Enhanced operator safety", "Much reduced radio traffic"* and *"Improved complaints procedures*" are undoubtedly benefits however the fact remains that few agencies have wanted to, needed to or even could explore the full functionality of their systems in areas such as detailed analysis of actual versus scheduled running times. As such, rigorous evaluation of AVL systems has not been a priority for North American transit agencies.

2.3.7 Lessons Learned and Advice for Others

In closing, the survey asked open questions about the agencies' experiences with AVL. Summary responses are contained in the following text boxes.

What are the main lessons that you have learned from your AVL system experience?

- "*Be very clear in your specification on what you want.*"
- "*Specification reality and compliance. Vendor honesty!*"
- "*Begin with tight specifications and make them tighter*."
- "*AVL changes the way that you do business. A business re-engineering effort is an important step in the implementation process. Mindsets must be changed before the implementation is completed to get best results*."
- "*Do not use technology to handle people problems*."
- "*Systems are very complex and integration is critical. Need to make sure that you have good source data (GIS, scheduling, patterns, stops etc.). Best to choose a vendor with previous experience who understands transit. AVL should be regarded as a … resource, not just an operations tool. Historical data should be made as widely available throughout the organization as possible*."
- "*Be patient. Installation and acceptance of new technology takes longer than expected*."
- "*If system was fully implemented, it would have required a large manpower pool of highly trained personnel*."

What advice would you give to a bus transit agency considering adopting AVL technologies for the first time?

- *"Don't go half way and expect to change the way you do business."*
- *"Document everything."*
- *"It's worth the effort."*
- *"Plan ahead. Technology has a short life before it changes."*
- *"Visit other agencies to understand what is available. Do not tie the performance specification to existing technology. Make sure that the operations and maintenance are user-friendly."*
- *"Review all new technology (GPS), manpower needs and what you want from the system. Get views from a cross-section of you agency."*
- *"Radio system integration (with AVL) has been a big challenge for many agencies. AVL requires a lot of supporting infrastructure eg. scheduling system, GIS, bus stop and pattern maintenance. Make sure you can provide these before jumping into AVL. AVL also requires a significant amount of staff expertise eg. radio technicians, database administrators, report writing and system analysis skills. Make sure you have staff that are up to these tasks – this is critical to your success."*
- *"Develop a master plan and conduct peer reviews. Involve end users in the process. Develop very clear specifications. Document all changes. Insist on factory acceptance tests. Check vendor references."*

3. CONCLUSIONS

A comparison of results from the two AVL surveys, conducted six years apart, suggests both good and bad news for the transit industry. On the one hand there appear to be fewer procurement problems as agencies learn what can and can not be achieved given certain budgets. Vendors, those that remain, are also more experienced and their products have undoubtedly benefited from the rigours of day-to-day use and feedback from early adopters. Systems integration, although still a complex undertaking, is less plagued by the challenges of getting different sub-systems to communicate effectively with each other. GPS accuracy has improved and related costs continue to fall. Furthermore, software development appears to have overcome many of its early problems.

On the other hand, many of the issues identified in the 1996 Synthesis still seem to confront the transit industry today:

- Employee indifference and/or resistance;
- Underestimation of the ongoing commitment and resources required by AVL and related systems;
- Poor skills matching between what an agency has and what will be required;
- Limited evaluation to demonstrate the true costs and benefits of AVL;
- Limited capabilities of handling large (in some cases, very large) data sets in order to extract and fully use information from the data.

Most systems – with a few exceptions - operate towards the lower end of the functionality spectrum. Radio infrastructure is expensive to replace, however estimates from the 2001 survey suggest that AVL-related costs can increase communication system replacement costs by around 25%. At the level of functionality currently being employed, one wonders whether the passenger is benefiting fully from that additional investment?

The 1996 Synthesis concluded with the following observation:

> "*Although some AVL systems have been in operation for more than 10 years, transit agencies are still challenged by collecting and using AVL data…*"

The evidence from the 2001 survey suggests that the collection and use of the AVL data itself continues to be the major constraint in terms of extracting the full potential from an AVL system.

Notes

1. The author is currently a PhD research student at the Institute for Transport Studies at the University of Leeds. Previously he was an Associate with transport consultants Steer Davies Gleave. The research reported in this paper was started while at Steer Davies Gleave and was completed by him subsequent to his departure. The author can be contacted at: rbain@its.leeds.ac.uk.

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