



Real-Time School Bus Tracking: Building the Business Case

A White Paper by **Trapeze Group**

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Abstract

GPS-based automatic vehicle location (AVL) technology has been in use for years in commercial truck fleets and public transit organizations, but is only recently being adopted by the student transportation sector. Interest in this technology has been driven in the past by safety concerns and the many other intangible benefits AVL provides. In the current funding climate, however, it is critical that organizations understand and communicate the significant operational savings that can justify an AVL investment on economic terms alone.

This paper looks at the business advantages an AVL system can offer school districts and contractors in the form of greater efficiency and lower operating costs. This paper is designed for student transportation professionals who seek a more detailed understanding of the role AVL can play in their organizations and offers some models for estimating ROI and investment recovery times.

What an AVL System Delivers

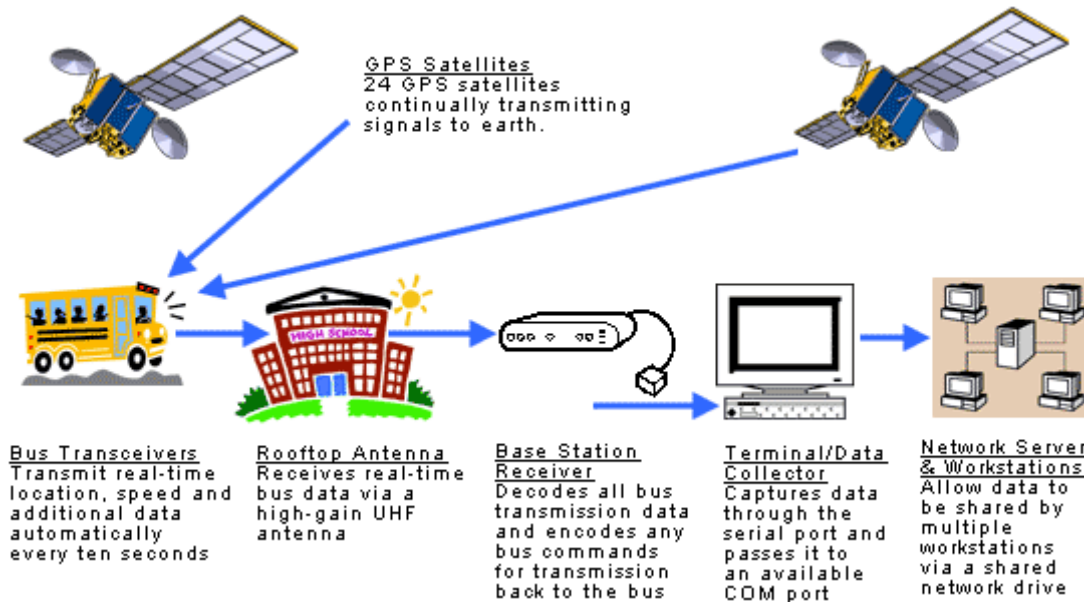
Before looking at the demonstrable benefits of an AVL system, it's important to understand, at least at a high level, how such systems work and the types of information they can deliver.

There are two sides to the AVL installation: in-vehicle equipment and the infrastructure to manage and measure its output. The specifics of each installation will vary depending on the type of system deployed, but will generally include a transceiver installed in each bus which transmits information about the vehicle. At a minimum this will include:

- Location to within a few yards or feet
- Speed
- Direction

More comprehensive systems may also include the following information and features:

- Stops (planned and unplanned)
- Idle time
- Door openings/closings
- Passengers embarking/disembarking
- Swipe card information such as driver sign in or electronic bus passes
- Emergency/panic button
- Engine temperature
- Brake pressure
- Tire pressure
- Other mechanical data



Using the 24 GPS satellites orbiting the Earth, the transceiver notes the vehicle location and sends it, along with any other vehicle data, to a base station. Data is transmitted at pre-set intervals, ranging from every ten seconds to every few minutes, via either two-way radio or cellular network. Once data is received at the base station, it is decoded, collected and passed along to the software used to manage the routes and schedules. Messages from the base station to the bus can also be sent.

Trapeze AVL - Managing the Data to Maximize Efficiency

Real-time information is accurate and up-to-date; however there is a large quantity of it to manage. Some AVL systems include stand-alone software that can show vehicle locations on a map, create alerts in case of emergency or safety violation, and generate reports for further analysis. While useful, these systems tend to be limited in terms of delivering maximum value from the data because they leave planned and actual data separate, thereby restricting the level of analysis that can be done.

Since most districts use some form of routing software, the ideal implementation feeds the AVL data directly into this application so that data about where the bus should be can be easily compared with information about where the bus actually is. This ability to produce comparative analyses very quickly is a key value of the Trapeze AVL system.

Districts contemplating an AVL system should ensure their routing software can easily integrate tracking data in order to maximize system efficiency and minimize learning curves for staff. Fully integrated systems work better, both in terms of managing real-time situations, and in pulling all the data together for management reports such as route mileage, variances and deviations, incident summaries, ridership analysis, contractor performance, policy compliance and so forth.

Better Data = Better Routes = Lower Costs

Each summer, school districts spend weeks, and sometimes months, planning and testing their routes for the start of the next school year. An experienced route planner working with route-optimizing software will generally produce realistic and drivable routes, based on assumptions about average speeds, road conditions, board times and so forth. The problem with this method is that the quality of the output is proportional to the quality of the input. So, inaccurate or generalized road speed data, coupled with factors that planners cannot foresee, such as road closures, poor weather or new students, can produce real-world experiences that vary significantly from the plan. Further, routing software by itself has no way to adapt to these real-world conditions without significant user research and input modifications.

With AVL data input, planners now have a powerful new tool in the form of historical location, student load and drivability data which can be used to manage both the time capacity and the ridership capacity of routes at both the collective and individual levels.

Where planners once assumed a speed limit on a given road to be 25 miles per hour, they can now state with certainty, that the average speed is 16.5 miles per hour. Where once they assumed a load time for six children to be 30 seconds at a particular stop, they can now accurately count on 43 seconds. By replacing assumptions with observations the routing software's capabilities can be fully tapped to create optimized routes.

Route Optimization

Properly optimized routes have the immediate effect of reducing time spent making adjustments, particularly at the beginning of the school year. Optimized routes also provide the long-term benefit of compounding real-world data day-on-day, month-on-month to create a storehouse of information that supports routing and management decisions from one year to the next.

Looking at measurable impacts, optimized routing works to improve time capacity, the most complex variable with which route planners must work. Time capacity is measured by the available time to run a given route versus the time it actually takes, including stops, idling, boarding/alighting, dead-heads and traffic delays. If all buses in the system are cumulatively using less time than is available to run the routes, then there is extra time capacity available; conversely, if actual route times are greater than the amount of time available to run those routes, there is a time capacity deficit.

Route optimization, using real-world data collected by AVL systems, empowers transportation departments to maximize time capacity. By looking at virtually every aspect of every vehicle, run, driver, stop, and transfer, planners can identify patterns where actual performance deviates from what was planned. Routes that are chronically late can be evaluated to find inaccurate assumptions or deviations from policy, such as excessive idling or unplanned stops. Corrective measures in the form of redefined routes, additional driver training or more appropriate vehicles can restore unproductive routes.

Time Capacity

School districts are acutely sensitive to service delays, so over-capacity situations (i.e. late buses) are usually dealt with immediately. Under-utilized time capacity, however, is much harder to identify without good tracking data. Once a bus leaves a depot, there is little information as to whether it sits for five minutes or 30 minutes between routes; or whether drivers are idling along the route when they are ahead of schedule. When too much time has been planned for a route, time capacity is wasted. Drivers paid by the hour have little incentive to bring such situations to the attention of planners, and so field inspections or AVL data are the only tools that will present the real-world data needed to reallocate this excess capacity where it is needed.

Through ongoing route restructuring efforts, school districts can build an iterative process that creates repeated opportunities to reduce driver hours or the number of buses needed to cover the routes.

The following calculation puts these savings in financial terms. In a small fleet of 200 buses, assuming an average annual operating cost of \$27,500¹ per year per bus, a reduction of five percent (or ten buses) creates an immediate operating expense reduction of \$275,000. This does not include future capital expenditure reductions due to the reduced operating needs.

Time capacity is a complex variable, but balancing that capacity is only half the battle. Ridership too can be optimized for clear, bottom-line results. Rider capacity is the capacity of the district's transportation system to transport children. This is a function of the capacity of each bus, and the number of children assigned to that bus along a specified route.

Rider Capacity

Tracking and non-tracking environments are quite different in their ability to understand rider capacity. Without tracking, planners know which students are assigned to a given bus, but have no real idea which ones actually ride the bus and how often. In fact, there may be only a handful of days each year when all assigned students will actually ride their bus morning and afternoon. The rest will be driven by parents, stay home sick, walk to school or ride their bicycles. Planners have known for years that some buses run with empty seats, but in the absence of any concrete data, have been unable to make policy decisions to manage this excess rider capacity.

AVL systems can be extended with student tracking technology that captures the number of students boarding and alighting during a route. Some tracking systems simply count the number of passengers, while others will be able to identify which students are on which vehicle, by using electronic bus passes. In either case, real-time passenger loads can be used to make service adjustments "on-the-fly". For example, a route running unusually light on a given morning may be redirected to pick up the final few stops on a route where there has been a delay.

¹ National Center for Education Statistics, 'Table 51: Public school pupils transported at public expense and current expenditures for transportation: 1929-30 to 1998-99', adjusted for 2000-03 Consumer Price Index.

Again, however, it is the longer-term trend analysis where the greater cost savings will be found. By comparing planned and actual rider counts in the routing software, reports can be generated to express the deviation of the average actual rider ship by bus from the planned rider count. This can then be sorted by magnitude of deviation, and again by bus number. The data can then be reviewed for buses in the same service area with high deviations between planned and actual rider counts. Restructuring these routes can very quickly reduce excess rider capacity.

Before planners can reallocate rider capacity among routes, they need to ensure buses are not over-filled on a regular basis. This can be accomplished by reviewing the student counting data. For example, if a bus has a planned ridership of 52 students (the capacity), averages only 35, has never carried more than 45 and has only twice in the past two months exceeded 40, an acceptable amount of excess capacity might be 10 students (52 minus 42). There is now an opportunity to reassign 10 students to this bus, assuming it will not adversely affect the time capacity of the run. As in the example for time capacity optimization, the reassignment of students can reduce the number of buses required or allow the district to put smaller vehicles on less-traveled routes. A reduction of even a single bus can produce an immediate savings of \$27,500 per year².

For districts facing budget cuts, growing student populations and driver shortages, running buses at optimum capacity is not any longer a luxury but a necessary business strategy.

Expense Reduction Opportunities

While better routes with their optimized time and rider capacities will produce substantial quantifiable savings, almost immediately, there are several other areas in which the use of real-time AVL data can have an impact.

Contingency Costs

Many districts have significant numbers of buses on stand-by each day in case of break-down, major delay or an unforeseen needs to supplement capacity. In some districts, contingency vehicles comprise 10 percent of the fleet, and in larger districts this is a relatively hidden cost since the focus tends to be on the many daily route vehicles. Regrettably, most of these buses sit in unknown locations, with unknown travel times to wherever they are needed and, at the end of the day, planners have no idea how effective their contingency vehicles might have been had they been deployed.

With school bus tracking, the transportation department can know exactly where the vehicles are, without manually contacting the driver. Contingency vehicles can be identified on the map in relation to regular buses, and their travel times can be accurately calculated for the most efficient deployment. This is particularly critical in the event of a bus breakdown where students must be transferred to another vehicle. AVL systems can pinpoint the location of the disabled bus, quickly find the closest

² National Center for Education Statistics, 'Table 51: Public school pupils transported at public expense and current expenditures for transportation: 1929-30 to 1998-99', adjusted for 2000-03 Consumer Price Index.

contingency vehicle and provide an accurate ETA for its arrival on-scene. This can result in fewer buses needed for contingency purposes.

As with route optimization, the real value of the AVL system becomes apparent when historical data is analyzed and compared with actual need. By examining where contingency buses typically sit, and comparing that with their historical use, planners can identify areas that are over- or under-served by the contingency fleet. Assuming a given district keeps a 10 percent contingency, at least half of which proves unnecessary on closer examination, the cost savings in labor, fuel, insurance and mileage can be easily quantified if the fleet is reduced to five percent. Savings of this magnitude can be a very large number, as will be discussed later in this document.

Labor Costs

Almost half of the annual school bus operating cost of \$27,500 is labor³. Assuming a typical bus driver's day is five hours long, a very minor two percent improvement in productivity will result in a paid time reduction of about six minutes per day. Though not impressive on a daily level, this adds up to \$275 per year per vehicle. In a mid-sized fleet of, say, 500 vehicles, the two percent cost reduction delivers \$137,500 in bottom line savings.

There are additional efficiencies to be found in labor cost management using AVL systems. First, time cards can be audited against run start and stop times, and tracking data can be exported into a payroll system as back up.

Drivers who routinely deviate from planned routes, run late or idle unnecessarily can be identified for additional training.

A less tangible benefit derives from the simple fact that drivers know the tracking equipment is on their bus and will be more likely to perform as expected, and charge their time appropriately. And while drivers may resist the added scrutiny, they also benefit from the security of being easily located in the event of a breakdown, sick passenger or security incident. Lost drivers can be talked step-by-step back to their routes because the depot can see their location in real-time.

Efficiency Improvement Opportunities

In addition to the substantial savings that can be realized in the form of better routes and lower labor and contingency costs, there are four key areas in which an AVL system can deliver measurable efficiency benefits.

Transportation Reimbursements

For districts reimbursed by state or local governments, vehicle tracking technology can be an invaluable tool in calculating loaded and unloaded miles. By collecting

³ From *School Bus Fleet* magazine, 2002 School District Survey, median wage of \$13.50 per hour, increased to \$15 per hour for overhead and employer taxes; assuming 5 hours per day, 180 days per year. This totals \$13,500 per driver.

actual route mileage and passenger counts, transportation departments can more accurately determine, and ultimately prove, their reimbursement levels. This data can also be analyzed in detail to look for opportunities for maximizing loaded miles. For example, AVL and passenger data can be quickly analyzed by a routing application to identify routes where buses dead-head or travel empty over great distances before their first pick-up. Rearranging these routes can maximize reimbursements while reducing operating costs.

Contractor Management

Many districts use one or more commercial contractors for some or all of their routes, and most depend on the contractor to report their mileage and performance accurately. At best, casual audits by field staff are used to verify billing reports.

A bus tracking system with route mileage as a data point can be used to review the accuracy of contractor billings, as well as to ensure that routes are being run as planned. On the safety side, AVL is an essential tool for monitoring contractor compliance with safety rules, minimizing unplanned stops and providing back-up data in the event of an incident.

For contractors, an AVL system can be a good value-added service for clients who require accurate billing back-up and who may want to make use of the data collected for routing and other tasks. AVL also provides a differentiating service in a highly competitive market.

Automated Reporting

All transportation departments are responsible for generating dozens of daily, weekly, monthly and annual reports on just about every aspect of their operations. As in any organization, data gathering is the most time-consuming and, often, the most frustrating part of the reporting process.

Tracking data from an AVL system can provide detailed information for reimbursement reports, management reports, safety audits, vehicle performance reviews and much more. Combined with route and ridership data, tracking information can be used to satisfy a range of reporting requirements including passenger information, driver performance, route mileage, idle and stop times and much more, without the need for manual field checks or the re-keying of data.

Administrative Efficiency

In most districts, transportation staff spend a good portion of their day dealing with routine inquiries from caregivers, schools and drivers. Much of this time is consumed with tracking down the most accurate information they can find from drivers, dispatchers or schools. With bus tracking, many of these routine inquiries can be dealt with quickly, if not immediately. Parents who want to know if their child boarded the correct bus, or schools which need to find out if a given bus is late, can be responded to more quickly and with more accuracy than ever before. In addition, real-time information can be delivered via the Internet or through an automated telephone system to further reduce staff time spent on the phone.

Knowing where the vehicles are and what is happening in the field can also reduce response times when there is an incident. Breakdowns, accidents, delays and absent drivers can be dealt with faster when staff have an accurate picture of what is happening and are able to make adjustments in real time. This results in fewer delays, better deployment of contingency resources and, ultimately, better services to students, caregivers and schools.

With less time devoted to day-to-day queries, transportation staff can focus instead on proactive tasks such as route planning and cost control. As the body of data grows, planners have more historical information to build and test scenario models for everything from emergency response to school closings to redistricting to contractor performance metrics. Better planning allows resources to be allocated cost-effectively

Building the Business Case

The preceding sections identify specific areas in which demonstrable economic benefits can be achieved, often very quickly, with real-time bus tracking systems. School districts seriously considering the installation of such a system will need to tie this together into a cohesive and persuasive business case that clearly illustrates not just the benefits but the time required to recover the initial investment.

A viable business case must include the initial system cost, the operating expenditures and the savings expected throughout the operation.

Initial System Investment

This includes the purchase and installation of the tracking hardware, software, and related infrastructure items, such as servers or database integration. In today's marketplace, the purchase costs of tracking systems vary widely depending on features, communication protocol, infrastructure and software capabilities. These investments can range from hundreds to many thousands of dollars per bus.

There is also a wide variation in what each vendor offers as part of its solution, which in turn determines where the savings are likely to occur and to what extent. For example, some systems provide only location data, while others communicate speed, direction, mileage, stops, emergencies, rider information and other relevant status data. The more data a district is able to extract from the system, the more quickly the system is likely to produce a positive ROI.

Many tracking solutions use standalone tracking software that presents the 'as is' vehicle location situation, while integrated tracking and routing applications are able to compare actual performance with planned performance. In general, districts should attempt to purchase the most comprehensive routing software they can afford, as this will accelerate the payback time and ultimately deliver more value in the form of better routing, accurate planning and streamlined administration.

Ongoing Costs

Assuming all components are operating as planned, there are just two ongoing expense areas for most tracking systems: software maintenance fees and communications expenses. Software maintenance fees are generally a percentage of the license fee and cover such things as technical support for users, patches, and routine upgrades.

The most significant ongoing expense for cellular-based bus-tracking systems is the airtime fee charged by the carrier. A recent study of a pilot AVL system in Florida found:

“Almost all AVL systems rely on proprietary cell phone technologies (mostly using CDPD) to exchange information. And while this architecture provides large bandwidth for data transfer and national wireless coverage, its costs for a large fleet can be prohibitive. This is primarily due to typical monthly subscription costs for the service. Orange County Public Schools owns about 1,100 buses... Equipping these buses with cell phones would cost the district a staggering \$400,000 per year just in cell phone costs (\$30/month for each bus). This expenditure is well beyond the means of most school districts.”⁴

Fortunately, these enormous costs can be avoided through the use of radio-based communication. As discussed earlier in this paper, radio communication incurs no monthly fees. The payback analysis below, assumes a radio-based communication system.

Sample Payback Analysis

The following payback example uses approximate costs of an AVL system using comprehensive vehicle data tracking with an integrated routing and planning application. These amounts are on a per-bus basis, with standard hardware and software costs included, but no customization to either system. This model assumes that communication will be via radio frequency as opposed to cellular networks. To calculate payback with cellular fees, add \$30 per bus per month.

Assumptions:

Total five-year investment per bus: ⁵ \$1,200
 Monthly communication expense: \$0
 School bus operating cost per year: ⁶ \$27,500

⁴ *Web-based Tracking of School Buses Utilizing GPS & Voice Radios* by Dr. Amr Oloufa, P.E., Transportation Research Board paper 2003

⁵ Includes bus transmitters and antennae, base station receives and antennae, cabling, software and all associated training. This also presumes the present value of software maintenance costs and replacement units in years 2 through 5. Installation is assumed to be performed by the school district. The amount shown is for the purpose of providing a reasonable payback example. Actual costs for a specific school district may be higher or lower than this figure.

⁶ National Center for Education Statistics, 'Table 51: Public school pupils transported at public expense and current expenditures for transportation: 1929-30 to 1998-99', adjusted for 2000-03 Consumer Price Index.

Payback will depend, of course, on the degree to which efficiencies are achieved. The model below illustrates the five-year savings for minimal to moderate efficiency gains, and the number of years per bus required to recover the initial investment.

Per-Bus Savings & Payback by Efficiency Gain

Efficiency Gain	Year 1	Year 2	Year 3	Year 4	Year 5	5-Year Total Cost	5-Year Net Savings ⁷	Years to Payback
1%	\$275	\$275	\$275	\$275	\$275	(\$1,200)	\$175	4.4
2%	\$550	\$550	\$550	\$550	\$550	(\$1,200)	\$1,550	2.2
3%	\$825	\$825	\$825	\$825	\$825	(\$1,200)	\$2,925	1.5
5%	\$1,375	\$1,375	\$1,375	\$1,375	\$1,375	(\$1,200)	\$5,675	0.9
10%	\$2,750	\$2,750	\$2,750	\$2,750	\$2,750	(\$1,200)	\$12,550	0.4

The table below illustrates total net five-year savings for small to very large school districts, and demonstrates how incremental efficiency increases significantly change the amount of net savings accrued to the school district.

Five-Year Savings Fleet Savings by Efficiency Gain

Efficiency Gain	50 Buses	100 Buses	200 Buses	500 Buses	1,000 Buses
1%	\$8,750	\$17,500	\$35,000	\$87,500	\$175,000
2%	\$77,500	\$155,000	\$310,000	\$775,000	\$1,550,000
3%	\$146,250	\$292,500	\$585,000	\$1,462,500	\$2,925,000
5%	\$283,750	\$567,500	\$1,135,000	\$2,837,500	\$5,675,000
10%	\$627,500	\$1,255,000	\$2,510,000	\$6,275,000	\$12,550,000

It is important to note that these illustrations do not include any consideration of intangible benefits such as increased safety, improved service or other perceived value.

Summary

Real-time bus tracking has evolved into more than a technological gadget, and is a demonstrable asset to almost any school transportation organization. For transportation managers who want to leverage this technology for better, safer, more efficient services, significant cost savings can be quantified in a number of key areas.

Even a nominal improvement of one percent each in time capacity, rider capacity, transportation reimbursements, contingency cost reductions and lower driver or contractor costs will return an overall savings of five percent. This results in a payback period of about one year. Looking beyond payback, however, AVL continues to deliver advantages in the form of substantial year-over-year cost reductions that can be applied

to new vehicles, transportation technologies or other critically under-funded areas. Subsequent savings can also be applied in numerous other areas within the school district.

Best Practices

- Chose a radio-based system over one transmitting via cellular network
- Ensure your routing software integrates easily with the AVL system
- Buy the most feature-rich tracking system you can afford
- Invest in fully integrated route planning software
- Focus on presenting the payback period on the initial investment, along with the long- term expense reduction and opportunities to improve efficiency and redeploy savings in other areas.