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Bus Rapid Transit and the use of AVL Technology: A Survey of Integrating Change

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Bus Rapid Transit and the Use of AVL Technology: A Survey of Integrating Change**

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** Portions of this report include work undertaken in the EDAPTS program which was examining the benefits of AVL deployment in San Luis Obispo.

1 ITS AND ORGANIZATIONAL CHANGE

1.1 INTRODUCTION:

AVL represents a radical change to many working in the public transit industry. When a new technology is introduced factor proportions change, responsibilities are altered and procedures change. There are threats to lines of authority, job security and responsibility. In all cases there are threats and the successful implementation of a new technology into any firm requires that it be managed, it will not happen automatically and ultimate success of the firm will be contingent on the implementation.[1]

The adoption of new technologies has always presented challenges for managers, employees, and organizations in general. As the advent of mass production in the assembly line and more recent models of flexible specialization required planners and workers alike to adapt to and exploit new ways of interacting and organizing the productive process, so too have advances in Information Technology (IT). The three key obstacles: employee resistance, insufficient management support, and inadequate resources explain the major part of difficulties in implementing of new technology.

These new technologies offer great benefits for public and private firms, but when a new technology is implemented the organization faces a new and sometimes unexpected problem: employees resist the new technology. The consequences can be severe - experienced specialists may quit or retire because they don't want to adjust to new technologies and, the remaining staff may work more slowly and less efficiently.
In this paper we will examine employee and organizational reactions to technical change in both manufacturing and information management sectors, discuss the findings of previous studies, and identify ways for organizations to deal with the employee-oriented challenges of change.

Employee resistance to change is a critical topic of study because of the impact it has not only on the psychology and everyday workings of organizations, but also because it fundamentally affects how completely and effectively new technologies can be implemented. In the modern service-oriented market an organization and its employees must react to and make effective use of changes in market and technical conditions if they hope to be competitive – or in the case of public sector groups, recipients of future funding. However, employees often have concerns about changes in the workplace, and these concerns have real-world effects on firms. Thus, recognizing the nature of change, of its implementation, and its eventual consequences is key to understanding employee resistance and overcoming it.

1.2 PSYCHOLOGICAL ASPECTS OF TECHNICAL CHANGE

So what is it then that makes technological change so threatening to employees as well as managers? Naturally, the ultimate concern of any employee is that he or she will lose his job, but the reality that can lead to resistance is often far more nuance. New technology has the effect not only of eliminating some jobs, but more importantly, of changing existing jobs. The responsibilities,

[1] In a number of cases where a new technology has not provided the firm with a competitive solution, it has been found that it was not the choice of technology but rather the way it was integrated into the firm that was the root cause.

demands, skills, and workplace relationships central to a job are altered in many technological changes, leaving the worker uncertain of more than just his binary employed/not employed status. Fournier (1986) cites deskilling, polarization, time pressures, uncertainties, isolation, loss of social interaction, job transfer, boredom, new accountability, safety, and a shift to new, more complex perceptual and communications skills as sources of anxiety, and thus, of resistance in employees.

Many of these are the consequence of the fact that much technological innovation enhances the processes of division of labor and job specialization. In this process, human skills are broken down into basic components and jobs are designed such that workers can pass some responsibilities over to machines. As Braverman (1974) argues, this often results in increasingly specific, simplified, and boring jobs.

After a time, workers have imbedded a certain set of assumptions in their minds about the way their job is done and evaluated, and changes in technology threaten that familiar framework. Hertzberg (1966) identifies a feeling of competence in one's job as the primary engine of motivation, and Odiorne (1981) argues that this feeling of competence is built through successfully managing problems in a familiar operational framework. The more times a worker finds that he deals with a situation well, the better he feels about his performance in his job, and the more he likes doing it. However, when the operational environment changes and the worker no longer feels comfortable with procedures, methods, or the nature of problems themselves, he is likely to feel less competent and happy in his work. If given the option, he would prefer that there be no change at all. This effect is supported by Verdin (1988), in which employees that exhibit the least resistance to, and the greatest increases in productivity through new technology were found to be those with the least tenure in the firm. These employees had the least entrenched expectations about their jobs, and had more incentive to adapt to new technologies than workers with more time in the firm and more invested in the status quo.

Aside from fears about the future of their jobs, resistance among employees can also spring from frustration with changes. New responsibilities, expectations, and systems can leave employees confused and uncertain of their work, which can lead to job stress, frustration, and resistance. Karasek (1979) studied the relationship of increased job responsibilities and decision latitude to employee stress factors. In his findings, and in those of researchers who have completed similar studies, increased work demands do not in and of themselves lead to psychological stress, but when coupled with real or perceived reduced decision latitude, often result in high stress and lower reported job satisfaction.

New factory-floor technologies do often result in more narrowly defined jobs for first-line workers and their immediate supervisors, resulting in "the decrease in freedom to schedule work," a "general decrease in decision-making influence given up to engineering, production control, accounting, and long-range planning," and "increased technical skill demands of the job." (Dill, 1965) Perceived reduced decision latitude is commonplace in situations where people are unsure of their new organizational or productive system, and it follows that these employees will feel more restrained, confused, and stressed in their newly-defined jobs.

Norman (1988) discussed the phenomenon called "learned helplessness." It refers to the situation in which people experience failure at a task, often numerous times. As a result, they decide that they cannot complete it: they are helpless. They stop trying. If this feeling covers a group of people

the result can be the end of productive work of the whole organization. This kind of passive non-compliance or lack of effort can undermine and even kill an organization's effort at change.

1.3 MANAGEMENT RESPONSE

Clearly there is a place for management response to these issues. If the overall effectiveness of technical change can be so adversely affected by employee impressions, then managers must anticipate and shape them in ways that effectively promote firm goals. Four factors important to employee resistance to change emerge from readings of relevant literature. Employee perceptions of the change, employee perceptions of those leading the change, commitment to the organization, and commitment of resources within the organization all determine how well a change proposed by management will be accepted and implemented.
Many authors have tried to explain the forces at work behind employee resistance and ways to cope with it. Kurt Lewin's force-field-theory explains the forces in favor and in opposition to a behavior, in this case, acceptance of technological change. Lewin's central idea is to separate out and identify these forces, and then work at reducing the negative.

Another factor important to resistance to change is employee perception of those leading or pushing for change. The way employees feel about their supervisors, managers, and leaders will influence how they perceive their plans and motives. Clearly, the more leaders are trusted and respected, the more likely employees are to accept proposals for change their leaders make. As a result, explaining the change and its benefits thoroughly, demonstrating confidence in, and commitment to the change, and encouraging feedback from employees are ways for managers to secure employee support for change. Change agents must demonstrate a clear desire and support for the change, and explain the change and its benefits to their jobs and the organization.

Commitment to the organization also plays a key role in how employees will react to technological change. Employee commitment can be defined as an employee's identification with and involvement in, an organization (Mowday, 1982). That is, the extent to which an employee sees the goals of the organization as his goals, and to which he sees the success of the organization as tied to his success. While other factors are more directly related to the change itself, commitment to the organization can make an employee likely to accept any policy implemented within it. When employees are included in the decision-making process, they become more ego involved in the outcome, identify more with the issues, and become more committed to the organization and its fate. As a result, soliciting the opinions of employees before the change, as well as asking for feedback once the change is being made is critical to employee commitment and acceptance of change.

The fourth factor in reducing resistance to change is organizational commitment of resources, especially time and money in terms of training employees to adapt to change and benefit from it. Gillam (1986) explains that uninformed employees often resist changes that are accepted and supported by those trained to understand them and operate in the new environment. Education, training, and active listening by mangers are all ways he suggests of overcoming this problem. Employees react well to training not only because it makes them work effectively in the organization, but also because it makes them feel valued by the organization and more informed and marketable in general.

Noori (1990) touches on the distinct challenges faced by small and large manufacturers in implementing new technology. Larger firms are more likely to initiate technical change for many reasons (research budgets, risk tolerance, etc.), but suffer from more serious coordination and communications problems that can feed employee discontent and resistance. Large firms tend to be more vertically aligned, and strategic decision-makers are farther removed from the front-line employees most affected by change.[2]
On the other hand, small firms may experience implementation issues not suffered by larger ones. For instance, budgets are often not large enough to fund the extensive training and support programs sometimes needed to help technical change along.

Researchers and management experts have recognized two fundamental truths, namely, that change is inevitable and change is hard. As a result, a new field of study called change management evolved. Change management addresses aspects of initiating, implementing, managing, and rewarding change. Richard-Carpenter (1995) discussed the benefits of Information Technology implementation - increased speed and productivity, but noticed that "to achieve step changes in productivity of their people, organizations will need to develop more sophisticated management techniques", but did not suggest any.

Gupta (1999) gives some strategies for overcoming some of the obstacles in implementing the new technology:

- Identify the purpose for change. Most employees are willing to change if they understand why they should change. The organization must explain what the purpose of the change is and what is at stake if it doesn't change.
- Stay focused on the change goals. Many organizations' change programs fail because the goals of change efforts change frequently.
- Top management should lead the charge. One reason why many change efforts fail is because top management fails to support it. Successful change management efforts almost always begin with top management.
- Communicate clearly and consistently. A U.S. research company investigated 531 organizations undergoing major change and asked the CEOs, "If you could go back and change one thing what would it be?" The most frequent answer was "The way I communicated with my employees." Experts recommend that management communicate openly with all employees and tell them the truth about the reason and possible effects of the changes.
- Acknowledge that change is continuous. To maintain a competitive advantage, an organization must continuously devise new and better ways to operate. When an organization reaches one goal, management should anticipate, plan, and initiate the next change management program to ensure leadership.

Lewis (1999) supported the idea that thorough explanations at all-hands meetings can help organizations become a supporter of change. Mariotti (1999) described the effects of the processes of learning new technology and behavior through different types of training. He also discussed the importance of unlearning the way of work with previous technology and "old" behavior. Mariotti also found that because of the pressure of continued change, organizational

[2] Furthermore, labor unions are more influential in firms with many employees, such as General Motors, than in a small shoe company like Vans. These unions almost categorically resist changes that could threaten wages, employment, or the relevance of their skill sets and make large-scale changes in technology or processes difficult.

stress can be so strong that resistance may appear even with careful learning and unlearning. Norman (1988) suggested the technical staff and technology designers should make the design as simple as possible and avoid elements that could potentially confuse workers.[3]

Strong support by organization's leaders, effective training and technological adjustments are frequently suggested in the literature as the solution to the problem of employee's resistance to new technology implementation in an organization. Training is the most flexible option in this list. But even the basic level of training has to be based on the knowledge of what exactly needs to be explained to the staff.

The main thrust of Tompkins, et al. (1992) is that many of the problems of implementing new technological systems derive not from resistance, but from a lack of competence in the use of new systems. However, insofar as a perceived lack of competence leads to frustration, alienation, and resistance, as argued in Hertzberg (1966), Odiorne (1981), and Karasek (1979), then we can expect that training which increases competence and familiarity with new technology and methods will consequently serve to minimize employee resistance as well.

Tompkins, et al. propose an increased focus on what they call "competency-based training" and "pay-for-skill" payment structures to make for more productive and better motivated employees. Competency-based training is a process by which employees are evaluated based on specific tasks critical to their jobs. Their performance is weighed against desired competence or productivity at those tasks, and specific training is directed at tasks problematic for individuals or groups of employees. Following this targeted training, employees are again evaluated, and retained if necessary.

Pay-for-skill payment programs play a cooperative role with competency-based training in that they are based on competence evaluations and that they round out a program of training new methods or procedures by providing incentives for employees to adapt and adapt productively to change. After employees are evaluated for critical skills, they are then paid according to their skill level and competencies, rather than by their inflexible job title. This sort of structure encourages employees to take on new skills more thoroughly than they might otherwise; their compensation depends on it.

Another method of easing employee transition in times of technological change, and one analyzed by Mueller and Cordery (1992), is increased internal labor flexibility. By making job categories less strictly defined and by broadening employee skill bases through training, the firm can benefit not only from the functional flexibility of more liquid human assets, but also from the productivity and morale gains of a more satisfied workforce.

1.3.1 CASES

Mueller and Cordery (1992) examine a large multinational corporation operating a small minerals processing site of about 300 employees. In contrast to the rigid job demarcation at other sites the firm operated, this greenfield site included the promotion of flexibility in the internal deployment of

[3] Microsoft products can be a good example of following to this advice: all their software follows the same design. Users find if easy to interact with similar interfaces where the terminology and icons are the same. This makes it easier for people to get used to any new type of Microsoft software.

labor and skills, and the provision of more interesting, less-static jobs. A "team concept" approach to work organization and skills resource management was introduced, under which production workers were organized into two large, functionally-distinct teams, each responsible for a half of the production process and afforded a high degree of self-regulation of daily operating decisions.

In addition to the team concept, employees were trained such that each could perform all of the production tasks within each operating area, as well as important maintenance tasks. This training was assessed and planned according to the competency-based training model, and multi-skilling was rewarded by the adoption of a pay-for-skills pay system. Instead of a number of distinct job titles linked to specific functions, a generic title of "shift process worker" was created, with three levels defined by the number of task competencies possessed. Movement between classification levels indicated an increase in the range of tasks able to perform in the production system, and was rewarded with an automatic pay increment.

Within each team's area of responsibility, groups of tasks were associated with particular factory locations. To promote labor flexibility, employees were required to rotate periodically through the different locations, and this rotation ensured that employees were given hands on training and that they maintained their skills so they could be reallocated to other tasks if needed.

Mueller and Cordery performed a longitudinal study based on questionnaires from all employees at the site, interviews with a random sample of operators and supervisors, inspection of company records, and informal interactions with company employees. They make no quantitative analysis of productivity gains or losses, but instead measure employee support or resistance to the change and identify elements of the plan that contributed to them.

As would be predicted by Verdin (1979), many employees who had worked for the firm for a period of time longer than five years were found to resist the change in organization and techniques. They cited such factors as job ambiguity and discomfort with unfamiliar processes as major problems and reasons for their resistance. On the other hand, most newer workers showed enthusiasm for the multi-skilling program and the opportunities it offered for advancement. They took to their new rotations with more excitement and showed higher rates of skill-classification advancement than their longer-tenured coworkers.

In sum, Mueller and Cordery find that the entire program at the greenfield site fell short of expectations. They attribute the shortcomings of the multi-skilling and job-rotation program largely to vestiges of traditional middle management and supervisory authority relationships in the new system. Essentially, the original system design was undermined by the abandonment of values and mechanisms to support employees during the transition. Ending pre-shift meetings, partial reintroduction of supervisory hierarchy, and limitation of resources to the multi-skilling program had the effect of confusing and demoralizing employees because management objectives – and the future of their jobs – were no longer clear and consistent.

In another paper dealing with the introduction of Computer Aided Manufacturing (CAM), and focusing specifically on the relationship between job design and acceptance of new technology, Wall et al. (1990) examined a group of nineteen employees in a company that assembled circuit boards for computers. All of these employees operated computer-controlled machines which automatically assembled the boards from their constituent parts and left to the workers only

loading, monitoring, and unloading the machines. As a result, these "operators" had little control over their work, and when there was an error they were to notify a shop-floor-specialist who would make the needed corrections. Due to the mundane nature of this work, few operators expressed much satisfaction with their job.

To address this problem, the company redefined the operators' job responsibilities as to include many of the tasks of the specialists. In this move towards "operator control," these operators were trained and made responsible not only for identifying errors, but classifying and solving them as well. In the fifty days following this change, company records showed a forty percent drop in machine downtime from the previous fifty days. In addition, employee questionnaires showed that operators were far happier with their jobs when they had more autonomy and variety on a day-to-day basis. The authors offer several explanations for this effect. First, as Hertzberg (1966) argued, more variety, control, and discretion in work leads to more job satisfaction and motivation. This higher level of motivation and diligence may have been directly responsible for the drop in machine downtime. A second argument offers that by placing control and problem solving discretion closer to the source, errors can be identified and corrections made in less time. Finally, the authors offer the possibility that "tacit skills" learned by operators through close contact with the machines enable the operators to understand and operate the productive technology in ways not possible by specialists or supervisors. This better, hard to teach familiarity results in more efficient and error-free processes and outcomes.

1.4 SUMMARY

Technological change is vital to gains in productivity and competitiveness in the modern economy. However, imposing change on a labor force with calcified conceptions and entrenched expectations about the nature of their jobs can quickly lead to resistance to the change and undermine short and long-term goals. Traditionally, much of this resistance springs from concerns about loss of work to machines, but employees may resist technological change in the workplace for other reasons as well. Feelings of confusion, alienation, abandonment, helplessness, and betrayal may arise from unsettling changes. Moreover, increased specialization and a perceived loss of autonomy as a result of new technologies can hurt job satisfaction, employee moral, and overall productivity.

To address these issues and smooth the transition period, managers and planners must take these psychological factors into account and be sensitive to their real-world consequences. Among responses offered in the literature are open two-way communication, clear explanation of change to employees, and a demonstrated firm commitment to change and long-term goals of the firm. Managers who pursue these reduce the ambiguity and confusion which can come with change. On the structural side, better tailored training, more responsive incentive systems, and job redesign can help employees adapt effectively and productively to the new operational environment.

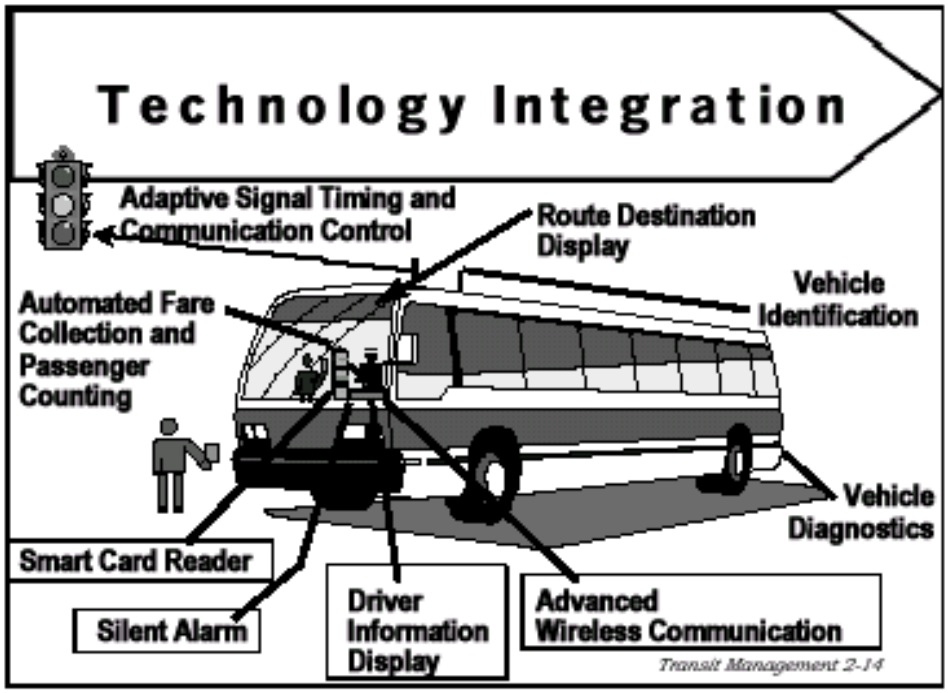
2 ITS APPLICATIONS IN PUBLIC TRANSPORTATION

The importance of technology to the future of public transportation cannot be overstated. As transit agencies are pushed to produce greater ridership and hours of services while keeping costs down, technological advancements will help agencies be as efficient as possible with their resources.

The immense size of many agencies, with many responsible for hundreds of buses, presses the need for greater automation to more closely monitor services and ridership. And the number of vehicles is not the only issue relating to agency size. Many agencies have enormous networks that may cover hundreds of miles throughout a region. In such a large system, precise information may have a large impact on agency operations. Smaller agencies also present special challenges, with large headways and often widely dispersed routes. The need for information in such a system is equally important.

Many of the technologies implemented by transit agencies can be considered part of a larger system called Automated Vehicle Monitoring (AVM). These technologies improve emergency location of vehicles, vehicle performance monitoring and service control, data collection, passenger information communication including compliance with the Americans with Disabilities Act, fare collection and traffic signal priority. Figure One shows these technologies together on a single, “smart” motor bus. Implementation of AVM systems, either piecemeal or as a complete system, is a complicated process that can take years to operate smoothly. There are a number of different ways in which AVL and other technologies can improve transit

Figure 1 Technology for Motor Bus Services



performance. In the "Advanced Public Transportation Systems: The State of the Art Update 1996", a number of ways in which technology can affect transit are cited. They are:

Fleet Management: Effective vehicle and fleet planning, scheduling, and operations. Fleet Management focuses on the vehicle, improving the efficiency and effectiveness of the service provided (the "supply side"), and on passenger safety.

Traveler Information: Facilitate decision making before a passenger's trip and during the trip (en-route). Information can be provided to trip makers at home, work, transportation centers, wayside stops, and on-board vehicles.

Electronic Fare Payment: A variety of benefits are anticipated from EFP. They are: more sophisticated fare pricing systems; elimination of cash and coin handling; automation of the accounting and financial settlement process; the creation of multimodal and multi-provider transportation networks that are seamless for the rider but operationally and organizationally sound for the multiple modes and providers.

Transportation Demand Management Technologies: The goal of these technologies is to maximize the ability of the current transportation network - roads and transit - to serve the recent rapid increase in demand for transportation. This is accomplished through a combination of, among other things, coordination of transportation service providers, and enhanced incident response and monitoring.

2.1 AVL TECHNOLOGY: A DESCRIPTION AND EXPERIENCE

Advanced Vehicle Location (AVL) systems, in their most basic form, help track the whereabouts of vehicles on a network. AVL is considered part of the fleet management technologies, which concentrate on improving vehicle operations, future planning efforts and safety. By knowing the exact (though this varies across different AVL technologies) location of vehicles on a transit network, the agency has clear, objective information regarding those vehicles. Historically, dispatchers would need to verbally confirm the position of buses spread across a city. As AVL systems are implemented, vehicle information is automated and available for both current operations and planning purposes.

AVL systems have been in use for 30 years. Starting in 1969, transit agencies in the U.S. of all sizes and regions, experimented with various AVL systems. There are four basic technologies employed for AVL systems.

- Signpost and odometer
- Radio navigation/location
- Dead-reckoning
- Global Positioning System (GPS Satellite Location)

2.1.1 SIGNPOST AND ODOMETER

The signpost/odometer system has been the most common until recently. In this system, a receiver is mounted on the bus, while transmitters are placed along the bus' route. Utility poles and signposts are most commonly used as mounting locations for these transmitters. The bus picks up a low-powered signal from these transmitters as it passes by, and the mileage noted. When the bus reports its location, the distance from the last pole is used to locate the vehicle's position on a route. The system can be run in reverse, with the transmitter on the bus and multiple receivers mounted along the route. However, should the bus need to leave the route, there will be

no information about the bus, so most agencies prefer to have a receiver on the bus. This older technology has some drawbacks. Creation of new routes requires the placement of new transmitters, and the system is maintenance intensive due to the relatively high number of transmitters and receivers involved.

2.1.2 Radio-Location Systems

Radio-location systems use a low-frequency signal to cover the system, and the buses are located as they receive the signal. Loran-C (Long Range Aid to Navigation) is the most common type of land based radio-location. Despite the simplicity of the system, it is subject to some major drawbacks. Overhead power lines or power substations can cause signal interference, and signal reception is typically very poor in canyons.

2.1.3 Dead Reckoning Systems

Dead reckoning is among the oldest navigation technologies. Dead reckoning sensors can measure distance and direction from a fixed point (under the most basic setup, an odometer and compass could be used to calculate position from a specific stop on a route). Typically, these systems act as a backup to another AVL system. This relatively inexpensive system is self-contained on the bus. This system has a number of drawbacks. Uneven surfaces and hills can compromise the positioning information. Should the vehicle leave a fixed route, its location will no longer be known since there will be no waypoints off the fixed route. Also, accuracy degrades with distance traveled, and regular recalibration is required (tire circumference changes with wear).

2.1.4 Global Positioning Satellite Systems

Due to the shortcomings of the other AVL technologies, GPS became the most popular system for new installations over the last few years. GPS utilizes the signals emitted from a network of 24 satellites, which are picked up by a receiver placed onboard the bus. The satellite system covers almost all of North America, eliminating the need to place transmitters/receivers along any route. The existence of the satellite system means that the main cost for the agencies result from purchase of the GPS receivers and equipment to transmit to dispatch. While the U.S. military, which oversees the satellite system, has limited the accuracy of the system in the past, it is now allowing more accurate readings. Since the GPS service was improved in August of 2000 (the service prior to that was “degraded”, meaning the signals were slightly scrambled), accuracies are now between 10-20 meters, or 35-70 ft. Plans to improve the system’s operations are in place for the next decade, including greater positional accuracy and better time accuracy.

The accuracy and widespread availability of GPS makes it the most appealing, though it too has some problems. Foliage, tall buildings, and tunnels can temporarily block the satellite signal, and at times satellite signals do not reach specific locations. Typically dead reckoning is used in conjunction with GPS to fill in such gaps in the positioning process.

2.2 POLLING TECHNOLOGIES: FINDING THE BUSES

The final issue regarding the technology concerns the relay of the buses’ positions to a central dispatcher. A central computer communicates with each bus and exchanges the information automatically over radio waves. There are two different methods for collecting this information, *polling* and *exception reporting*. Under polling, the central computer contacts each bus on the network in turn. When it has reached the ‘last’ bus, it will start over from the beginning. This process can take a few seconds or many minutes, depending on the number of buses and the

capabilities of the computers. With exception reporting, the buses send in their signal only at a few specific locations, or if they have fallen far off of their schedule. Under exception reporting, dispatch not only knows the position of the bus, but also the scheduled position of the bus. This extra amount of information makes exception reporting more useful, though somewhat more expensive. The speed of polling becomes increasingly important depending on the needs of the system. Future upgrades for the GPS system are intended to further improve both accuracy and the speed of the positioning process.

This information is then typically sent to a pair of personal computers (PCs) at the dispatch office. One computer serves as the communication machine, making contact with the buses. The second PC will usually map the vehicles' location on the network. These PCs help anticipate and address bus failures, monitor schedule adherence and emergency response, and they can trigger location specific audio and visual announcements to comply with the Americans with disabilities act (ADA).

2.3 SOFTWARE CONSIDERATIONS FOR AVL SYSTEMS

It is important to realize that proper use of mapping software like a geographic information system (G.I.S.) is required in order to display this information effectively. Another important software consideration is the link between the AVL system and the computer aided-dispatch (CAD) software employed by the agency, along with any applicable scheduling software. Should these programs be incompatible with the AVL system structure or data format, major integration issues will likely result, as will added costs for customized programming by the system installers. Software issues are a concern for many agencies with limited technology resources at their disposal. Many agencies have neither the money for additional equipment, nor for the trained personnel required. Training of employees is a key to maximizing the use of an AVL system.

3 THE EXPERIENCE OF AVL IN CALIFORNIA

On the basis of the evolving literature review we have been interviewing a number of transit agencies in the Bay area and California who have introduced AVL into their systems and have been trying to understand the pitfalls. This is something we want to share with Laidlaw. This work is a prelude to some in depth case studies that we will undertake at two or three transit agencies after Christmas.

Transit agencies are under pressure to try and improve ridership and services. One technology that may be instrumental in bringing bus services into the 21st century is Advanced Vehicle Location, or AVL. The question for consideration is twofold. One, what type of system should be chosen for a given agency and why. Secondly, how is this decision being made, and how well are these systems implemented upon procurement.

As a part of Santa Clara Valley Transit's (VTA) bus rapid transit project (BRT), this report will offer insights on the implementation and integration of an AVL system into the BRT project. While VTA has selected the vendor for their project, there are still many considerations for the agency in terms of expectations, capabilities and operation. The experiences of other agencies may prove helpful for any agency considering an AVL system investment.

This section will examine the reasons for pursuing AVL technology. By examining literature on Intelligent Transportation Systems (ITS) for transit, this paper will produce a list of expected

benefits and realized benefits. Also, by contacting agencies directly, their experiences with AVL can be organized to help with future implementation.

The importance of technology to the future of public transportation cannot be overstated. As transit agencies are pushed to produce greater ridership and hours of services while keeping costs down, technological advancements will help agencies be as efficient as possible with their resources. The immense size of many agencies, with many responsible for hundreds of buses, presses the need for greater automation to more closely monitor services and ridership. And the number of vehicles is not the only issue relating to agency size. Many agencies have enormous networks that may cover hundreds of miles throughout a region. In such a large system, precise information may have a large impact on agency operations. Smaller agencies also present special challenges, with large headways and often widely dispersed routes. The need for information in such a system is equally important.

Many of the technologies implemented by transit agencies can be considered part of a larger system called Automated Vehicle Monitoring (AVM). These technologies improve emergency location of vehicles, vehicle performance monitoring and service control, data collection, passenger information communication including compliance with the Americans with Disabilities Act, fare collection and traffic signal priority. Figure One shows these technologies together on a single, "smart" motor bus. Implementation of AVM systems, either piecemeal or as a complete system, is a complicated process that can take years to operate smoothly.

Based on the APTS Deployment in the U.S. update from January 1999, 61 agencies are currently using an AVL system (this does not necessarily mean that the system is 100% functional). 154 agencies are in the operating, installing or planning stages of an AVL system at the time of publication. Of those, two-thirds of the systems are operating on a GPS platform. The recent acceptance of GPS has made it the dominant choice for future AVL systems. Of the agencies considering an AVL system, more than **80%** will be using GPS, and many of the undecided agencies will likely choose GPS as well (this is largely a function of the fact that most systems currently available are GPS).

3.1 AVL USE IN CALIFORNIA

California's transit agencies have been eager to employ AVL systems. The following graph, based on the APTS paper, summarizes California transit agencies use of AVL. The preference for GPS is very clear here in California, and the number of agencies moving towards AVL operations also show the anticipation for technological help at the agency level.

Table 1

California Transit Agencies and AVL

California Transit Agencies and AVL			
AGENCY	**CITY**	**# Buses**	**System**
Alameda Contra Costa Transit District	Oakland	705	[gps]
Antelope Valley Transit Authority	Lancaster	42	[gps]
Camarillo Area Transit	Camarillo	1	gps
Central Contra Costa Transit Auth.	Concord	112	gps
City of Glendale	Glendale	25	[gps]
Eastern Contra Costa Transit Auth	Antioch	33	[gps]
Emery-Go-Round	Oakland/Emeryville	5	(gps)
Fairfield/Suisun Transit	Fairfield	26	[gps]
Fresno Area Express	Fresno	100	gps
Gardena Municipal bus Line	Gardena	45	gps
Golden Empire Transit District	Bakersfield	72	[unknown]
Golden Gate Bridge District	San Francisco	280	[gps]
Livermore/Amador Valley Transit Auth	Livermore	60	[gps]
Los Angeles County Metropolitan Transportation Authority	Los Angeles	2278	so, [dgps]
North San Diego County Transit Auth	Oceanside	154	[gps]
Norwalk Transit System	Norwalk	25	[gps]
Omnitrans	San Bernardino	153	[dgps]
Orange County Transportation Auth	Orange	460	[gps]
Riverside Transit Agency	Riverside	97	otr
San Diego Transit Corporation	San Diego	307	[gps]
San Francisco Municipal Railway*	San Francisco	945	so
San Joaquin Regional Transit District	Stockton	98	gps
San Mateo County District (Samtrans)	San Carlos	314	[gps]
Santa Clara Valley Transit Authority	San Jose	471	[dgps]
Santa Monica Municipal Bus Lines	Santa Monica	141	otr
Simi Valley Transit	Simi Valley	9	[unknown]
Sonoma County Transit	Santa Rosa	57	[gps]
Stanislaus Regional Transit	Modesto	4	gps
Sunline Transit Agency	Thousand Palms	40	[gps]
The Vine/Napa Valley Transit	Napa	19	gps
Thousand Oaks Transit	Thousand Oaks	5	(gps)

* San Francisco Muni limited use of motor bus GPS to emergency response only, though it has recently implemented an AVL/GPS system for its light-rail services
[ ] : Planning phase
( ) : Implementation phase
GPS: Global Positioning System (includes dgps, differential GPS
SO: Signpost/Odometer
DK: Dead reckoning
OTR: Other

3.2 BENEFITS FROM AVL

There are numerous anticipated benefits resulting from the use of AVL. These benefits include:

- Increased dispatching and operating efficiency
- More reliable service (on-time performance, leading to increased ridership)
- Improved transfer coordination
- Quicker response to service disruptions
- Information to be used in passenger information systems
- Increased driver and passenger safety and security (silent alarms with precise location information)
- More effective response to mechanical failures, reducing maintenance costs
- Limits need for road supervisors
- Inputs to traffic signals for signal preemption use
- Improved data (quantity and quality) automatically collected for agencies at a lower cost

Only a few agencies have recently begun to quantify the benefits of AVL to their services. However, a recent report from the ITS Joint Program Office and the Federal Transit Administration did suggest that at least a handful of agencies have calculated benefits associated with AVL. In Milwaukee, on-time performance improved 4.4%. In the words of Milwaukee's planning director Kujawa, quoted in Mass Transit Magazine, "GPS has improved our on-time performance dramatically. It has allowed us to be more efficient in scheduling buses. And scheduling is where you make or lose money." Kansas City's transit agency had and 8.5% improvement to their schedule adherence, while MTA Maryland saw on-time service improve by 23%.

Fresno reported a 3% increase in schedule adherence, but they were also able to achieve this on a new and tighter schedule. IDAS, a software program developed by Cambridge Systematics for use by metropolitan planning organizations, assumes a 10% reduction in travel time resulting from the implementation of an AVL system on 100% of the buses. An operations employee at Golden Gate transit pointed out the reasons they are investigation an AVL system are their struggle with on-time performance, the ability to improve current info on schedule efficiencies, and get information to customers. Customer driven for on-time performance is very important, as is the ability to obtain more automated reports. A number of more anecdotal benefits have been cited, but are harder to quantify. However, it is assumed passenger safety has improved, as has response time to unanticipated events en-route.

3.2.1 SIGNAL PRIORITY, THE MISSING BENEFIT

Of the above benefits, most have already come to fruition to at least some degree. However, we can likely remove signal preemption from the list of anticipated benefits from AVL. The long polling cycles means that for a bus at operating speed, current systems are not responsive enough. Unless polling times were reduced to a matter of seconds, it will likely mean that signal preemption will be done as it is in Seattle, by use of a transponder system which holds the green by communicating directly with the signal controller to allow passage of the bus. The only other possibility for AVL would be the use of customized polling on a specific route where signal preemption is desirable. It is unclear if the existing hardware and software are capable of that type of service yet. Also, the additional relay back to the traffic signal from dispatch would add time to the process, further necessitating the fastest possible polling.

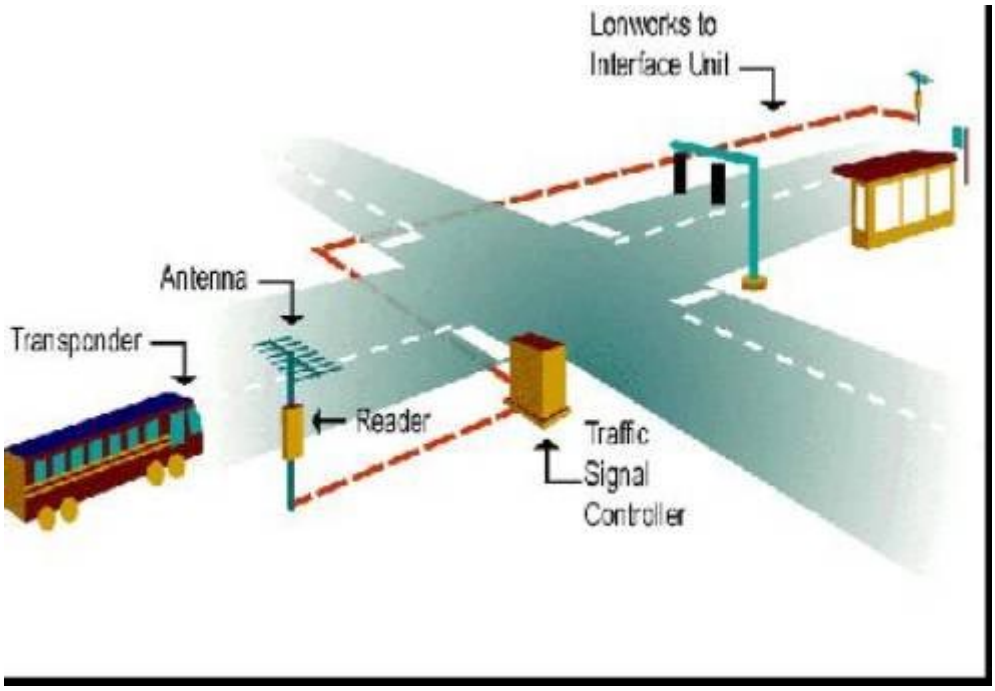


Figure 2 Transit Signal Priority

The Seattle project has been very successful thus far. Though it is in its earliest implementation on one corridor only, roughly 50% of red lights are avoided, and travel times are down 10-15%. The system is a carefully coordinated effort between King County Transit and the city's traffic operation department with public and political support. The fact this corridor serves over 2 million passengers likely explains the resounding support. Preemptions are negotiated between city operations personnel and the transit agency, with an average of 12 preemptions allowed an hour. Most of these will occur during peak travel times into and out of downtown Seattle. An important consideration is which buses will receive priority. Load factors and on-time status will be important considerations, and the AVL system may be able to help with the movement and processing of such data. It will also be important to examine the compatibility of the AVL data with that of the signal priority system's needs. While signal priority is not directly tied to AVL use in the present, it is clear that the AVL system may help with the data needs of the system. It will be interesting to see if these two systems will be able to complement one another when they are both installed.

3.3 IMPLEMENTATION: THE REAL CHALLENGE

All of the above information makes a compelling case for the use of AVL. Even at a cost of $6000-$30,000 per bus (agencies contacted reported costs of $12,000-17,000 per bus for systems from Rockwell and Nextbus), there seems to be some evidence that the system can help generate the anticipated benefits. However, it is very important to consider the procurement, funding,

installation and operation of the system. From the technology acceptance work of Karahanna, Straub, and Chervany, we learn that pre-adoption attitude towards a given technology is based on:

- Perceptions of usefulness
- Ease of use
- Result demonstrability
- Visibility
- Trial ability

In order to gain acceptance of an AVL system, suppliers and agencies need to work together to foster an environment, which support these attitudes.

As we know, technology is only useful if it is accepted by employees and fully functioning. The ITS/FTA paper discusses some of the prominent challenges to AVL use. In a recent article in Mass Transit, where Milwaukee Transit was named best transit operator of 2000, an interview with Planning Director Kujawa points to the importance of a highly effective system. MCTS was the second major transit system in the U.S. to get a GPS based AVL system, second only to Denver. In the words of Kujawa:

> "The GPS company came to us and wanted to install the system. We said, 'yes', but first you settle all the problems (with the new technology) in Denver before you come here. Take care of those growing pains in Denver."

These 'growing pains' should be a major concern for agencies. The institutionalization of transit agencies has made them less dynamic and generally slow to change. As a result, it may be difficult to generate widespread support within an agency for AVL. Driver acceptance is especially important, as the ability of an AVL system to monitor driver performance may be considered a threat to employee autonomy.

There is also likely a need for additional employees with relatively advanced technical skills to operate the system. Since AVL requires additional computer power, GIS skills, and CAD (computer aided-dispatch) skills to name a few, agencies will be under pressure to hire quality employees with appropriate skills. Or, instead, they will need to find operating funds to pay the necessary contractors.

The lengthy funding and procurement process will also limit the number of agencies able to fund AVL systems and hold up the installation of many, many more. However, funds are often located with relative ease for AVL, and as a result, large capital projects can be funded. Funding sources include, but are not limited to, regional congestion management sources, government air quality agencies, state transportation funds, and FTA funds as well. However, finding the money to **maintain** and **operate** the system will pose a continuing challenge for many agencies who decide to invest in this technology.

4 THE AGENCY PERSPECTIVE: PLANNING AND IMPLEMENTING AVL IN THE REAL WORLD

As indicated, the planning and implementation of an AVL system appear to be a critical issues relating to the eventual use of AVL. To that end, discussions with transit agency professionals in California were completed to discuss the decisions that go into obtaining a system, the goals for the system, and the results of use, when applicable. It is important to see how different agencies hope to use AVL to their benefit, to better understand how effective systems are brought online, and how well they are serving the agency members. To that end, conversations were completed with employees from eight transit agencies, all but one in California. Agencies contacted included:

1) Eastern Contra Costa Transit Authority (TriDelta Transit)
2) Contra Costa County Transit (CCCTA)
3) Riverside Transit
4) Golden Gate Transit Authority (GGTA)
5) Sonoma County Transit
6) Fresno Area Express
7) Fairfield/Suisun Transit
8) King County Transit, Seattle Metro

Of the agencies contacted, CCCTA, Riverside, Fresno and Settle had operating AVL systems. TriDelta is likely one year or less from having an AVL system, at least for its paratransit services, while GGTA recently began their planning process for an AVL system, though procurement sounds very likely. Both Suisun/Fairfield and Sonoma County transit are unlikely to be pursuing AVL systems any time soon. The main reasons given were increased workload, relatively simple networks where they did not have great needs for such a comprehensive system, and the relative difficulty of finding an effective, "off the shelf" product that would fit with existing services smoothly. With limited resources, smaller agencies simply do not have the extra resources required of an AVL system, especially the needed person-hours to install and debug such a system (financial resources, as mentioned before, seem to be fairly available for ITS/Transit projects).

The subjects discussed varied depending on agency's status with regards to AVL. However, the following questions and topics guided the talks.

- Why are you planning to get an AVL system (or to not get one)?
- What type/technology/vendor will your system be?
- What are your requirements, expectations for the AVL system?
- What is the approximated cost for the system (and how many buses are being equipped)?
- What does your system do well? Do poorly?
- How did the installation process go?
- What are the workload implications?
- Other information will be gathered as possible.

As a result of this research effort, a number of important lessons have been discovered. While technology may hold the *promise* of getting the most out of transit, be that passenger trips or reduced dollars-per-service-mile, it can only do so when it is fully utilized by an agency's employees. The remainder of this report will further examine the human dimension to AVL at these agencies.

4.1 GENERAL OBSERVATIONS FROM CONVERSATIONS WITH AGENCIES

- Counting on private industry is risky, change is constant
- Uncertain profits may not encourage full commitment; limit competition
- Company change can undermine long-term projects
- Internal employee turnover harmful
- Importance of standards for data when many suppliers, agencies involved

It is well known that the transit agency is not prone to fast change. However, technology, and the companies building and selling new technologies, changes constantly. The long time horizon for transit suppliers means that they need contractors that can make long-term commitments to their product. However, this is not always the case. Agencies reported that companies changed or sold their products to other companies. The use of small subcontractors put the CCCTA project in the hands of too many parties, and as a result, their system was never well developed. Rockwell, which sold the AVL system to Fresno and solicited Sonoma County Transit as well, sold its AVL system to Seimens. Fortunately, Seimens has made a strong commitment to the project, but the project's future was unclear until recently. This type of uncertainty does not promote a lot of faith from transit agencies.

Another aspect to implementation and contract negotiation is the ability of a supplier to promise in excess of their capacity to deliver. As the planner from CCCTA stated, "If you ask for the world, some one will promise you the world." Agencies will need to be very active to keep contractors accountable and keep project costs in line. A contract with Tri-Delta Transit for 40 motor buses and 16 paratransit vehicles went from $300,000 initially to nearly $1 million before the agency decided it could not afford the system. At least they were able to conclude this before entering into the contract. Nevertheless, project creep is hard to track and halt. Incremental funding may help limit this effect, as will carefully written contracts with suppliers.

Within the agency, turnover can be especially difficult since so few employees may be aware of the system's development. It is typical for technology projects to be guided by a very small number of employees prior to installation, at which time more employees are taught to use the system. If any key personnel involved in system procurement depart, the agency may find it difficult to continue the process. While it may be good to have a "champion" of technology at transit agencies, they must work to incorporate as many co-workers as possible. Employees contacted should include: drivers, maintenance workers, dispatchers, planning/operations employees, and managers. Without complete involvement, employee acceptance will be much weaker upon system completion.

While these general lessons are useful, it is also important to examine specific issues that each agency must consider on their own. These evaluation criteria may help an agency decide on an AVL system and better prepare for its future use.

4.2 CHALLENGES TO BE ADDRESSED

The following tables list some of the most important considerations for any agency considering an AVL system.

Important Evaluation Considerations for AVL

PRO s	CON s
• Tremendous information • Live inputs, outputs • Timely buses • Safety improvements • Responsiveness, flexibility	▪ Assessing Agency Needs ▪ Staffing Availability ▪ Data Overload ▪ Fear of the Unknown ▪ Ability to effectively integrate with existing system

While most of the points made in the PRO's column have already been examined, some of the points in the CON's column require further examination. These each represent possible stumbling blocks on the way to system operation. Each agency must consider on their own whether or not a system will be beneficial and whether or not they will indeed be able to put it to good use. With prices of $12,000 per bus and up, agencies must examine their real needs for the technology. Tri-Delta transit and Sonoma County transit each cited a shortage of available employee work hours as a consideration. Each agency has two total planning/operations employees. Neither felt they could spare time to figuring out a new system, especially one that has a reputation of difficult operation. As well, suppliers must continue to demonstrate a commitment to their AVL systems so that agencies can count on them for support throughout the life of the product.

Another challenge for AVL implementation is its ability to integrate with existing services. For example, most GPS software functions on the Windows platform, while many agencies continue to run MSDOS programs. This was took additional effort in Fresno to circumvent, though they were indeed able to do so. It is also necessary to consider scheduling software that may not be fully compatible with the AVL system. At CCCTA, their Trapeze scheduling software did not work with the data generated by their AVL system. Since their scheduling software only can handle certain nodes on a given route, while the AVL generates a near-continuous stream of data, the AVL data does the agency little good. As well, the CAD software is still not linked to the AVL system at CCCTA, despite its existence for more than five years.

These technical issues can be addressed, it is assumed, with an open-architecture design. By designing systems with an eye towards future needs and expansion, many of the above issues could be avoided. This is, again, the reason some agencies are just now considering AVL systems which are more complete and should be fully integrated since they come from a single manufacturer (Seimens, Orbital, Ericksson, and Motorola are all expected to offer complete systems in the coming years). The example of Seattle's TSP program should remind us that a flexible design will not only improve the use of data, it will make the process of sharing data easier.

4.3 PLANNING AND IMPLEMENTATION RECOMMENDATIONS

If an agency has the need and resources for an AVL system, they offer an excellent opportunity for planners and dispatcher to gain better overall control of their network and performance. As a result of the discussions with transit agencies and the reading accomplished on technology acceptance, I would offer the following recommendations to help transit agencies realize the many benefits available from an AVL system.

- Full involvement in planning and procurement
- Inter-agency coordination
- Shared IT resources for urban regions
- Dedicate resources, personnel for ITS implementation/integration
- Incremental implementation, funding

4.3.1 *Involvement in Planning Process*

Full involvement means all employees (or representation from all departments at least) should be involved with the planning and procurement of the system. This will insure not only a system that addresses an agency's needs, it is also more likely to gain acceptance of the agency's employees when it comes time to learn how to operate the system.

4.3.2 *Inter-Agency Cooperation*

Next, an effort should be made to promote cooperation between agencies. Too often battles over funding dollars and services can lead to division between transit providers when they have so much to learn from one another. Instead, agencies should be reaching out to one another to cooperate and share information and experiences. Both Sonoma County and GGTA plan to use other agencies as resources. For agencies which do not have adequate staffing for more advanced technology growth, it may be useful to consider shared IT resources, be they employees, hardware, or dollars to appropriate as needed. While agencies do differ from one another, they similar experiences can form a vitally important 'how-to' procedure of their own instead of counting on the supplier to offer theirs.

4.3.3 *Dedication of Resources*

If an agency plans to use an AVL system, they must be prepared to dedicate the necessary resources to the project. This will include not just money and time, but also office space and widespread employee support. The transition into an AVL system is very difficult, as reported by both CCCTA and Fresno Express. The change to an AVL system may coincide with changes to communications systems, scheduling software, dispatching patterns and software, and the computing hardware used. It may be the case these changes are never really 'done'. However, they will never get done without a clear focus on the new system and what it can offer.

4.3.4 *Incremental Approaches to AVL*

One way to ease this shift to AVL is through the use of an incremental installation approach. Tri-Delta transit plans to 'practice' with AVL on its paratransit services. Fresno left its paratransit and supervisory vehicles until after the motor buses had been switched and the system functioning. Given the slower pace of change at many agencies, this method should ease transition to a fully integrated AVL system.

4.4 SUMMARY

The need for a more demand-responsive transit network guides increasing numbers of transit agencies towards the use of ITS which creates a better information base for their own use and the

use of the rider. When a transit agency considers the procurement of any new technology, it is important that the process is well thought out. Given that transit has historically not been a very dynamic or high-tech industry, it may be more difficult for agencies to fully realize all the benefits of an ITS investment. To that end, a transit agency should be mindful of a number of points throughout the planning, procurement, installation and integration process.

First, it is necessary to consider how a new technology will work with existing in-place technologies. As noted, technology may not change rapidly at transit agencies. Therefore, any relatively new technology may be incompatible with existing tools. This should not immediately preclude its use, rather it should guide the planning process.

Another important item for the planning process is to pursue technologies that are highly "modular". The system design of the new technology should be flexible enough to work with both existing hardware and software in addition to future technological change (to whatever extent possible). An open architecture will allow a number of different technologies to complement one another and could possibly create unforeseen benefits.

Finally, to ensure that an ITS project will realize long-term benefits, it is important that the agency is fully dedicated to the continued operation and maintenance of the system. That is, the agency should routinely evaluate the performance of the projcct and be flexible enough to make necessary modifications to the system. Also, reinforcing this notion of commitment, it is critical that the agency's budget takes into account the need for full-time knowledgeable staff and appropriate marketing initiatives.

Hopefully, the result of these ITS investments will benefit both transit agencies and transit riders. "Smarter" agencies will hopefully be able to increase service efficiency, quality, and reliability. And consequently riders will hopefully be able to make well-informed travel decisions and take transit with greater confidence.

5 REFERENCES

Casey, Robert, Lawrence Labell, Ross Holmstrom, Joseph LoVecchio, Carol Schweigaer and Terrence Sheehan from Volpe Transportation Systems Center and EG&G Dynatrend Inc., "Advanced Public Transportation Systems: The State of the Art Update 1996", January 1996

FTA website, http://www.fta.dot.gov/research/index.htm

IDAS Software Program, Users Guide, Appendix A-21, 2000

Johnson, Christine, Thomas, Edward, Automatic Vehicle Location: Successful Transit Applications, ITS Joint Program Office and Federal Transit Administration, August 2000

Karahanna, Elena, Straub, Detmar, Chervany, Noman, "Information Technology Adoption Across Time: A Cross-Sectional comparison of pre-adoption and post-adoption beliefs", MIS Quarterly, 6/1999, pg. 183-213

Mass Transit Magazine, America's Best Transit Agency: GPS and Community Service, July/August 2000

Mobile Data Solutions Inc. Website, http://www.mds-inc.com/AVLMain.htm

Okunieff, Paula E., *Synthesis of Transit Practice 24: AVL Systems for Bus Transit*, Transportation research Board, National Academy Press, Washington, 1997

Orbital Company Website, http://www.orbital.com/tms/publictransit/index/html
United States Department of Transportation, Benefits Assessment of Advanced Public Transportations Systems, 1996

United States Department of Transportation, Advanced Public Transportation Systems Deployment in the United States Update, January, 1999

Weston, Rusty, "The Techno-Adoption Curve," *Information Week*, August 23, 1999, p.109-111