Intellimotion

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Improvements in Advanced Public Transportation Systems

PATH — Partners for Advanced Transit and Highways — is a collaboration between the California Department of Transportation (Caltrans), the University of California, other public and private academic institutions, and private industry. PATH's mission: applying advanced technology to increase highway capacity and safety, and to reduce traffic congestion, air pollution, and energy consumption.

CarLink: A Smart Carsharing System

Susan Shaheen, Institute of Transportation Studies, UC Davis

Carsharing organizations, which are becoming common throughout Europe, Asia, Canada, and the US, can reduce traffic congestion, air pollution, and government spending. Sharing vehicles means less traffic and fewer cars overall: by cutting down on the number of vehicles needed by households and society as a whole, and by facilitating and encouraging bicycling, walking, and increased transit usage, carsharing can reduce congestion. For commuters especially, shared-use vehicles offer a low-cost, low-hassle alternative for getting to and from their destinations. Carsharing fleets can also be made up of ultra-low-emission, energy-efficient cars. Because a carsharing organization would handle maintenance and repairs, these would be completed properly and on schedule, further reducing pollution and energy waste. Carsharing could reduce government spending on arterial street systems and mass transit by increasing transit ridership (e. g., attracting more riders and revenues to BART) through added reverse commuters and midday, evening, and weekend riders. Sharing vehicles would even free up parking spaces, because vehicles that serve multiple users each day would spend less time parked. Moreover, sharing could reduce the need for additional household vehicles to support a family's travel needs. Travelers would benefit by gaining the mobility of a car without having to carry the full costs of ownership; transit operators would benefit by being able to tap a much larger potential market; and society would benefit by diverting travelers from single-occupant vehicles to transit for part of their trips.

The Institute of Transportation Studies at UC Davis, and its partners Caltrans, the Bay Area Rapid Transit (BART) District; American Honda Motor Company, UC's Lawrence Livermore National Laboratory (LLNL), Teletrac, and INVERS are studying the use of intelligent communication and reservation technologies to reduce the inconvenience of carsharing, and to identify market segments where smart carsharing would be attractive. CarLink is the use of short-term rental vehicles and intelligent communication and reservation technologies to facilitate shared-vehicle access at transit stations or other activity centers for making local trips. CarLink vehicles, owned and operated by a transit district or third-party service provider, can be used by different drivers at different locations throughout a day.

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Photos: CarLink demonstration project launch at Dublin/ Pleasanton BART station. Clockwise from right: CarLink project manager Susan Shaheen with smartcard, CarLink lot with CNG Honda Civics, Susan Shaheen with PATH ATMIS acting Deputy Director Joy Dahlgren and Caltrans Advanced Public Transportation Systems Unit manager Cliff Loveland, accessing CarLink keybox.

Using advanced communication and reservation system technologies, they can be reserved in advance or rented automatically upon arrival at a CarLink lot. The union of "smart" or intelligent communication and reservation technologies with shared-use vehicles can provide convenient and flexible accessibility, offering both short-term, automatic services and a diverse fleet of low-emission vehicles to meet the mobility needs of system users.

Existing carsharing organizations typically provide a choice of vehicle type, rate, and convenience suited to the needs of participants. Many programs have found that participants are apt to more carefully consider the necessity of their trips, duration and distance of travel, and modal alternatives. Carsharing efforts have proven viable where environmental consciousness is high; where there are disincentives to driving, such as parking costs and congestion; where alternative modes of transportation are easily accessible; and where service attributes favor the substitution of a shared-use vehicle for trips that otherwise might have been driven alone.

The following scenario exemplifies CarLink usage. A commuter picks up a shared-use vehicle upon arriving at a transit station close to home on returning from work. They drive the CarLink vehicle home, and perhaps to other places during the evening, then drop it off at the station in the morning. After riding the train for the morning commute, they pick up another CarLink vehicle at their destination station, drive the short distance to work, and leave the car there.

CarLink System Components

A fully implemented CarLink system could radically change the way households use transportation. A basic system, modifiable to support the specific transportation needs of each community, would be composed of private-sector firms providing shared-use, low-emission vehicles and services, integrated with the mass transit systems of an urban/suburban area by Intelligent Communication and Reservation Systems. Users would have access to affordable, convenient, and user-friendly services, including both station cars and neighborhood and work-based CarLink services.

A CarLink system could be supported by a bundle of intelligent transportation system technologies, including: cellular and satellite-based global positioning systems (GPS) for use in automatic vehicle location and as navigational aids; advanced communication technologies linking vehicles to a central system controller; automated reservation systems via kiosks, telephone, or other user interface (such as an Internet-based travel planner linked to a range of intermodal travel modes); and smartcards for billing and to control vehicle access.

The CarLink Behavioral Study

The CarLink study has three components: First, a review of relevant technical and institutional literature, available at ITS-Davis (please contact our publications department at 530-752-4909 or by email at itspublications@ucdavis.edu for more information). Second, a longitudinal market survey of 330 individuals in the Bay Area, including focus groups with survey participants (approximately 40 individuals). Third, a six- to nine-month field test of the CarLink system that includes interviews and focus groups with field test participants. Many field test participants have been drawn from the longitudinal market survey. The survey and focus groups will evaluate participants' willingness to participate and pay for these innovations, and study data will be used to create a user-centered model for smart carsharing in the San Francisco Bay Area.

Participating households, for both the longitudinal survey and field test, include four groups: current BART commuters, individuals who might use BART when carsharing becomes available, people who do not usually take transit but could take it to work, and people who live in neighborhoods with substantial BART ridership. These groups represent potential CarLink participants. Participants access CarLink vehicles at the Dublin-Pleasanton BART station, about thirty miles southeast of the UC Berkeley campus, and at UC's Lawrence Livermore National Laboratory (LLNL), about fifteen miles east of the BART station. They may drive the cars to and from the lab, the BART station, and their homes in the suburbs nearby.

The field test employs a fleet of twelve 1998 Honda compressed natural gas (CNG) vehicles, a smart key manager and fleet management system developed by INVERS (a key dispenser and reservation system called Car-sharing Organization and Communication System (COCOS) and a fleet management system called COCOS Universal Communication Manager), and contactless smartcards. Reservations are made via COCOS and a Web site maintained at LLNL, and vehicles are monitored using Teletrac vehicle tracking technology. COCOS provides a two-way flow of information between a central control computer and the key manager. Teletrac is used to record the travel-use characteristics of the CarLink vehicles, as well as the household vehicles owned or leased by participants.

Longitudinal Survey

In evaluating a new technology, it is critical to document the processes of preference formation, social construction, and lifestyle. Since research into consumer responsiveness to innovations (especially those embodying new values and performance attributes) must be attentive to the evolution of these processes, the research team is using a longitudinal approach to evaluation throughout the study. Focus groups were held after the completion of the longitudinal survey, and additional focus groups and household interviews will be conducted after the field test.

From June to October 1998, researchers collected user evaluations of the CarLink system from 335 individuals (210 households) in the Bay Area to measure user acceptance of this new form of transportation and to learn how CarLink could affect the overall travel of households. Several ways to explain CarLink were used: an informational brochure; a video; and an interactive drive clinic with the Honda Civics, smartcards, and the smart key manager kiosk.

At the drive clinic, held in September 1998, participants used a smartcard to access a CarLink vehicle, release the immobilizer that blocks unauthorized users from starting the car, and took a test drive, accompanied by a researcher who documented their observations, questions, and concerns. Each participant completed a twenty-minute exit interview with a researcher on their response to the CarLink system and their willingness to participate in such a service. At the end of the clinic, participants received a final questionnaire and travel diary to take home and complete over the next several days, giving them time to reflect on their observations from the clinic and to answer questions about CarLink within the context of their own travel.

Field Test

Launched on January 20, 1999, the CarLink demonstration project involves over sixty participants sharing twelve CNG Hondas based at the Dublin Pleasanton BART station and at LLNL. Three types of participants use the cars at different times, paying different prices.

Home-side users drive a CarLink vehicle between home and the BART station daily, keeping the car overnight and on weekends for personal use. A $200 monthly fee includes a tank of compressed natural gas fuel, vehicle insurance, and maintenance costs. Participants can also pay for additional fuel with a refueling card at approximately $.80 per gallon.

Work-side commuters take BART to the Dublin-Pleasanton station and drive a CarLink vehicle to and from LLNL. A $60 monthly fee, which can be shared with a co-worker by carpooling, again includes fuel, insurance, and maintenance costs.

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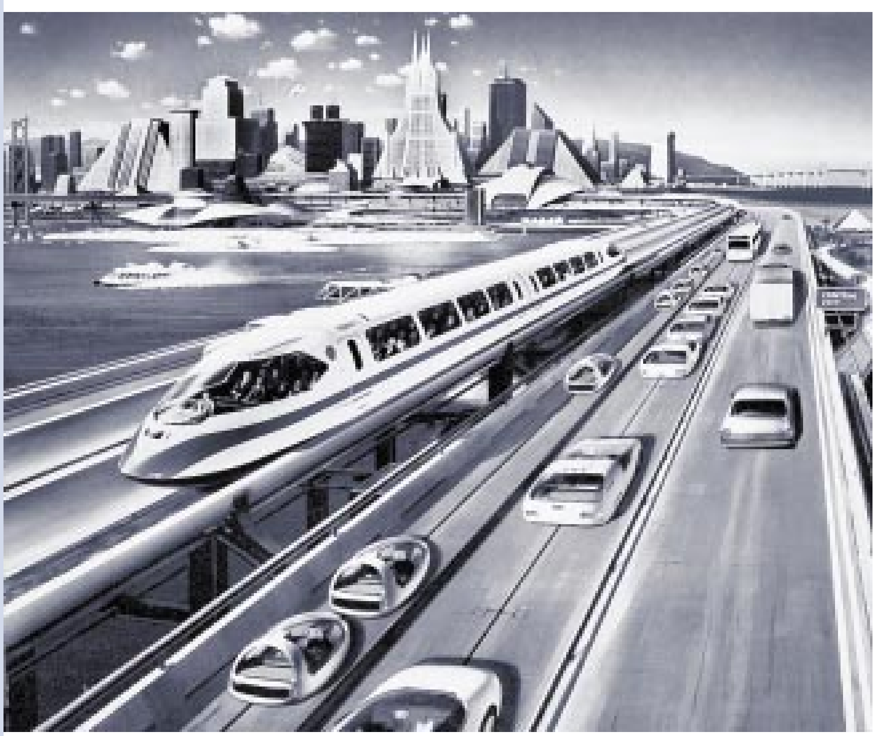
Why ITS Projects Should Be Small

Stein Weissenberger, PATH / Lawrence Livermore National Laboratory

Areas of ITS success seem to follow the "laws" of technological innovation.

Ten years ago, widespread implementation of Intelligent Transportation Systems (ITS) in the near future was commonly forecast. Traveler information systems, dynamic route guidance, and advanced transit applications, to name a few, were just around the corner. The past decade did see billions of dollars spent on ITS development in the US. The federal government alone distributed more than a billion dollars for research, development, and testing. Private companies, universities, professional and promotional organizations, and public agencies at all levels of government busied themselves at putting ITS to work. So why hasn't all this effort led to successful ITS implementations?

An obvious answer is that early promoters were overly optimistic. Like most enthusiasts for a hot new idea, they underestimated challenges and costs, and overestimated prompt benefits. They almost always grossly underrated the resources (financial, managerial, and technical) and the time required to successfully implement a new ITS-based system. Virtually the only such systems widely and successfully implemented in the US have been ones that are extensions or enhancements of technologies or functions already deployed in the 1980s (transportation management systems and electronic toll collection systems). There are virtually no widespread systems with the radically new functionality and impacts that had been forecast earlier (traveler information systems, dynamic route guidance, advanced transit applications, to name a few). And it seems doubtful to me that we are much closer to their realization than we were ten years ago.



Below: future perfect, as envisioned circa 1990. Opposite: future present,1999.

Why is this the case? To answer this question (beyond the unsurprising fact that early promoters promised more than they could deliver), and to try to understand how to better guide the deployment of ITS, several years ago I undertook a study of ITS implementation. This work entailed a broad review of the substantial literature on technological innovation processes, drawing especially on recent experiences in the explosive growth of the electronics, computers, and communications industries (Weissenberger). What I discovered was that a great deal is known about how this process works, and that much of this is applicable to the kind of technology that characteristic of ITS, with its complex and interconnected mixes of technologies and institutions. I found that many of the signal characteristics of successful historic technology implementations were markedly absent in the ITS world; conversely, I found that those singular areas of ITS success, like traffic management, seemed to be following the "laws" of technology innovation. Earlier studies of successful ITS implementations by myself and colleagues at PATH (Dahlgren) had previously discovered evidence of some of these principles; and they have been echoed repeatedly subsequently in further discussions with colleagues and interviews with practitioners.

"Necessity is the mother of invention" is a cliché, but nonetheless an important factor that underlies all technology deployment. The ATSAC traffic management system in Los Angeles was a pioneering ITS deployment in the 1980s (whose success in fact contributed to the enthusiasm for ITS in the 1990s): Los Angeles clearly had a tremendous *need* for such a system.

If needs are important, it is a corollary truth that associated innovation processes will start from the "bottom up," as opposed to "top down." Real needs are perceived where they exist, at a *local* level, not at the end of a distant hierarchy. We found in our case studies of ITS deployments that successes were inevitably built around strongly perceived, real local needs–often with quite different local flavors–ranging from Los Angeles' ATSAC to Transportation Management Centers (TMCs) in San Jose and Anaheim. In contrast, during the 1990s, the US ITS Program has been shaped to a large degree by federal dollars and priorities. There has been an emphasis on national standards and much less on local differences and the involvement of local experts.

While it is necessary that a strong *need* be present, researchers who have studied technology innovation have found that a successful development and deployment process generally follows certain general "laws." These laws describe how new technical knowledge is acquired and revised, and how corresponding supporting institutions evolve in parallel with the technology.

1. Technological knowledge is acquired through "learning by doing" and "learning by using."

As Nathan Rosenberg has pointed out, "doing" involves experience with the production process, while "using" involves the customer's experience with the product; both types of experience are crucial for innovation (Rosenberg). The majority of technological improvements are incremental ones, and depend on an intimate knowledge of the technology and how it is used, as well as complementary technologies, systems, and institutions in which the technology is imbedded. Rosenberg distinguishes between *embodied* and *disembodied* knowledge: embodied knowledge is associated with the details of the technology, and is required in order to make improvements in those details, while disembodied knowledge can be summarized in terms of operating characteristics and performance. Both kinds of knowledge are acquired through learning by doing and using, but only disembodied knowledge is readily communicated through formal, explicit means (e.g. books, journals, websites). Of particular relevance to ITS and the surface transportation setting, Rosenberg observes that "For a range of products involving complex, interdependent components or materials that will be subject to varied or prolonged stress in extreme environments, the outcome of the interaction of these parts cannot be precisely pre-

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Until Jove let it be, no colonist
Mastered the wild earth; no land was marked,
None parceled out or shared; but everyone
Looked for his living in the common wold.

And Jove gave poison to the blacksnakes, and
Made the wolves ravage, made the ocean roll,
Knocked honey from the leaves, took fire
away—
So man might beat out various inventions
By reasoning and art.

First he chipped fire
Out of the veins of flint where it was hidden;
Then rivers felt his skiffs of the light alder;
Then sailors counted up the stars and named
them;
Pleiades, Hyades, and the Pole Star;
Then were discovered ways to take wild things
In snares, or hunt them with the circling pack;
And how to whip a stream with casting nets,
Or draw the deep-sea fisherman's cordage up;
And then the use of steel and the shrieking saw;
Then various crafts. All things were overcome
By labor and the force of bitter need.

Virgil, Georgics: I, Work and the Earth
trans. Robert Fitzgerald

You can't always get what you want,
You can't always get what you want,
You can't always get what you want,
But if you try sometimes
You just might find
You get what you need.

Mick Jagger

...most changes are small and most innovations are incremental. Rarely do we entirely overhaul our basic ways of doing things....One reason for this consistent pattern is that proposals for change must pass many political tests. While victory at one level may only ensure that the idea will live long enough to be tested at another level of government, failure at any one level can whisk the idea out of systematic consideration for good. Usually it's only the safer, marginal changes that are supported by so many interests that they pass muster in every test. Entirely new ways of doing business are rarely adopted because their opponents need defeat them only a few times. New ideas must have tireless and sophisticated proponents who "work the system" in favor of their concepts. Usually, those who do work the system to promote some innovation have a lot to gain from its adoption.

Martin Wachs

We ought not to be surprised that organizations resist innovation. They are supposed to resist it. The reason an organization is created is in large part to replace the uncertain expectations and haphazard activities of voluntary endeavors with the stability and routine of organized relationships. The standard operating procedure (SOP) is not the enemy of organization; it is the essence of organization.

James Q. Wilson

In civil matters even a change for the better is suspected on account of the commotion it occasions, for civil government is supported by authority, unanimity, fame, and public opinion, and not by demonstration.

Francis Bacon, Novum Organum

dicted. In this sense, we are dealing with performance characteristics that scientific knowledge or techniques cannot predict very accurately."

The bottom line: early on, it is most important to *do* something, even if limited in scope; it will be much less useful (both to satisfy local needs and to further the development of ITS) to attempt grandiose projects, even if funding is successfully obtained from distant agencies. Many projects have been founded on the perceived need to integrate multiple services, technologies, and regions. Typically, these goals are inspired by the national program, which has a strong self-interest in promoting national standards and interconnections. While these objectives are abstractly desirable, they often entail very high costs without producing comparable benefits. Seeking early integration, when it entails large, slow, problematic implementations, is inconsistent with prompt learning through doing.

2. Technologies are most often developed *incrementally,* and inevitably through processes of making *errors*, and improving designs in an evolutionary fashion.

When I observed ITS projects that were failing, I frequently found managers who *failed to acknowledge their failures,* and therefore to learn from them. As Francis Bacon understood long ago, it is very difficult for public agencies to admit to failure, to write it off, and go on in a different direction, in the way that is routine for a private company (Gifford, Hall). The fundamental mechanism of learning by doing is thus precluded. I have also been struck by the fact that the agencies that appear most reluctant to admit their own failure are also those that seem least interested in *others'* mistakes: their habits of ignoring their own failures may inspire a blindness to the notion of learning from what doesn't work, wherever it occurs. In contrast, in their successful early public deployment of innovative ITS technology, ATSAC avoided this problem through energetic and wise management that hired appropriate skills and protected teams from the political process that undermines real technological learning.

The idea of building incrementally from a given starting point through the correction of errors is fundamental to the way most technology advances. (The occasional large discontinuous jumps in technology are important but rare compared to the workhorse mechanism of evolutionary change.) It is also connected with the primary way innovation occurs in a public agency. James Q. Wilson has vividly illustrated how public agencies resist changing their basic tasks, but he also shows that they can be very effective at adapting new technology to enhance the performance of their established tasks. Thus ATSAC has been highly motivated to improve traffic control, their fundamental reason for existence. In contrast, when Metropolitan Planning Organizations manage large innovative technology projects, they often fail, in part because the basic functions (operational traffic management, say) are entirely new to them. Traveler information systems have generally been unsuccessful and also fit this pattern: no public transportation agency has been in the business of providing traffic information to the public. In an instructive contrast, one of the few successful organizations in the world in this area has been a *private* company in England, TrafficMaster.

A successful local solution also provides a model for the diffusion of the technology to other regions. Orange County ITS deployments are an incremental adaptation of the Los Angeles ATSAC system, with a further local seed planted in Anaheim, and effecting installations in Santa Ana, Irvine, and the expanded Caltrans District 12 TMC.

3. Learning networks are crucial to the development of a complex new technology.

"Learning networks" are the formal and informal networks that support the development of any technological innovation, especially ones with the complex systems character of ITS. These networks range from the movement of people between organizations, the informal interchange of information through personal contacts, information exchange through professional associations, informal agreements among firms, and formal cooperative arrangements. Such networks have become increasingly important for "complex" technologies (Kash and Rycroft). These complex technologies are those that cannot be "understood entirely by an individual expert and accurately communicated among experts across time and distance." Complex technologies depend more on group-based, tacit knowledge than do simple technologies. Examples of the former are computers and communications, of the latter, industrial chemicals. The complexity of ITS arises largely from its interacting technologies and from its frequently extremely intricate mixture of diverse agents for planning, building, operating, maintaining, regulating, and using.

In observing field operational test projects, I was often surprised at how little knowledge seemed to be shared among implementers of related projects. Part of this problem is the lack of interest in learning from errors, either one's own or others'; part of it seems to be due to a lack of supporting networks of people with real experience in trusting, communicating, cooperating relationships with each other. The world of ITS seems unfortunately to be very different from that of Silicon Valley, with its web of intimate formal and informal supporting learning relationships.

Conclusions

ITS, like other new system technologies, requires the acquisition of knowledge by many diverse, interacting agents through active processes of learning by doing and by using. Small, local projects are valuable parts of this technology evolution process. They provide opportunities for learning about operations, maintenance, system integration, and customers, and help the growth of formal and informal supporting networks of experts and institutions. An important function of public policy should be the development and maintenance of these support and learning networks, in an environment of locally diverse and active operating experiences.

Small, local projects provide opportunities for learning and help the growth of supporting networks.

Interconnection and compatibility are inevitably important for ITS deployment, *at some scale, in some time frame, and for some technologies and services.* Integration should not be an end in itself, and should not be promoted to the degree that the many early virtues of small, local projects are lost. Public decision makers should think as much about how to value, honor, and exploit local differences, as how to submerge them within large interconnected sys-

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Caltrans' District 12 Transportation Management Center in Santa Ana.

Intelligent Technology Benefits Paratransit

Ted Chira-Chavala, PATH / Institute of Transportation Studies, UC Berkeley

Silicon Valley, hotbed of California's technological innovation, is also a geographical entity. Nestled at the base of San Francisco Bay, between the Santa Cruz and Diablo range of mountains, it comprises thirteen municipalities from Stanford to San José, all served by the Santa Clara Valley Transportation Authority, the VTA. Commuting young professionals among Santa Clara County's 1.6 million people account for the Valley's notorious traffic congestion, but the county also has its share of seniors and disabled people, many of whom are served by the VTA's paratransit services. In 1995 the VTA began operating an advanced paratransit system, primarily to meet the requirements of the Americans with Disabilities Act (ADA) in an efficient manner. This advanced public transportation system (APTS) was one of the first APTS implementations in the US to demonstrably increase transit operations' efficiency and productivity.

Above, from left: OUTREACH telephone scheduler inputs changes in real time (screens show schedule and vehicle locations); paratransit van equipped with wheelchair ramp, radio communication, and automatic vehicle location; OUTREACH dispatch center; AVL screen shows map of service area with position of vehicles; Automatic Trip Scheduling System hardware.

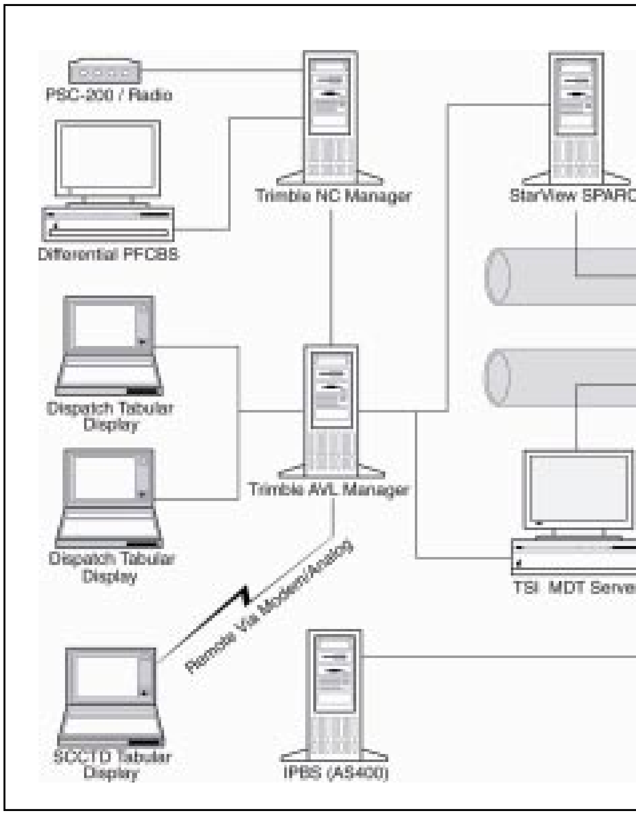
Center: OUTREACH system configuration.

The VTA paratransit system is based on an operational model with two main characteristics: (a) the transit agency books client rides and assigns ride requests to vehicles, but contracts a vendor or vendors who provide vehicles to transport clients door to door; and (b) booking of a client ride request and informing the client of a pick-up time are done in real time while the client is on the phone, and the transit agency does not yet know about future ride requests.

OUTREACH, a private, non-profit corporation, provides both scheduling and vehicles under contract to the VTA. OUTREACH uses two principal component technologies in its advanced paratransit system, an automated trip scheduling system (ATSS) and an automated vehicle location (AVL) system. In OUTREACH's application, the ATSS was deployed first, while the AVL was deployed in a second phase.

Automated Trip Scheduling System

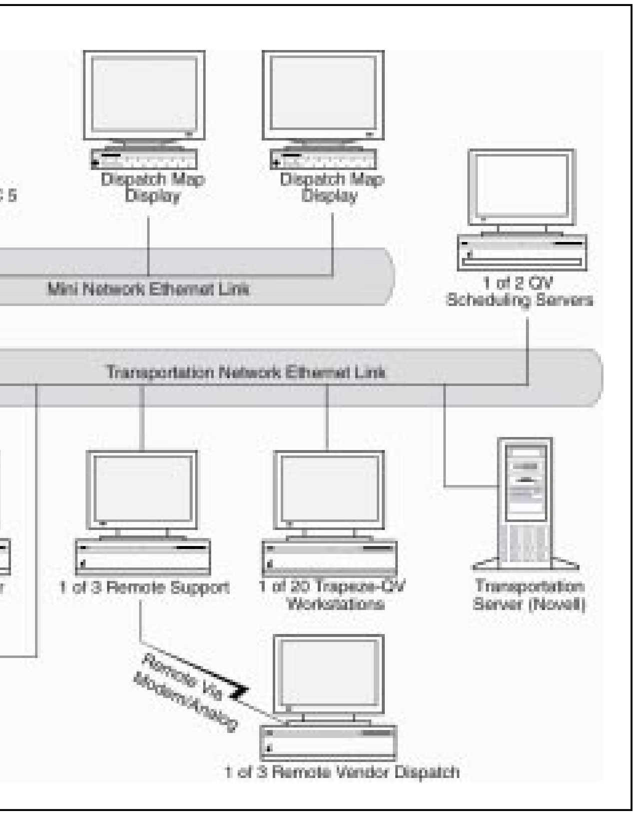
Primary functions of the ATSS include booking client rides, assigning client rides to vehicles, and informing clients of pick-up times. The ATSS, which is composed of trip scheduling software and a digital geographic database (DGD), accomplishes all these in real time while the client is on the phone. The DGD contains city and street names, the address range of each block, some traffic characteristics (e.g., road capacity, speed limits, traffic signals, and turn restrictions), and major destinations within the county. Geocoding of addresses is done via coordinates from the address range and coordi-



nates of each block. The trip scheduling software assigns client ride requests to vehicles, with a view to using available vehicles efficiently and maximizing ride sharing.

Booking Rides

Upon answering a client's telephone call, the telephone scheduler asks the client about the intended trip, and enters the pick-up time requested by the client. This initiates the ATSS, which seeks the "best" vehicle to accommodate the ride, and computes the expected travel time. It then suggests a pick-up time. If this pick-up time is not close enough to the time desired by the client, the client can negotiate a different time. The scheduler would then ask the ATSS to assign the new pick-up time to a different vehicle.



Assigning Ride Requests to Vehicles

During the day, as client ride requests are being booked, a trip plan evolves for each vehicle. This vehicle trip plan comprises a sequence of single and shared rides, as well as a sequence of pick-ups and drop-offs. The ATSS's assignment process has two modes of operation:

- Preassignment of "subscription" rides, i.e, regular trips that are always made at the same time on the same day of the week.
- Assignment of non-subscription or "casual" rides as they are booked.

Every month, the ATSS automatically assigns subscription rides to vehicles fourteen days before the travel day. Casual ride requests are assigned by the ATSS as they come in: each is inserted into a vehicle's trip plan. The assignment process attempts to minimize the following objective function:

$$F = \sum_k (w_1 \sum_j D_{jk} + w_2 \sum_j T_{jk} + w_3 \sum_j T_{jk} \cdot P_{jk})$$

where

D_{jk} = travel distance for trip segment j by vehicle k
T_{jk} = travel time for trip segment j by vehicle k
P_{jk} = number of passengers on board vehicle k for the duration of trip segment j.
w_1, w_2, w_3, = parameter weights for vehicle travel distance, vehicle travel time, and passenger travel time, respectively.

The three parameter weights are typically aimed at balancing client travel times with the costs of providing service.

Depending on the transit agency's operational policy and standards, the minimization of this objective function may be subject to further constraints. In OUTREACH's application, two service-quality constraints apply:

- Each client may not spend more than 60 minutes in the vehicle.
- Actual pick-up and drop-off times should be within 15 minutes of the requested times.

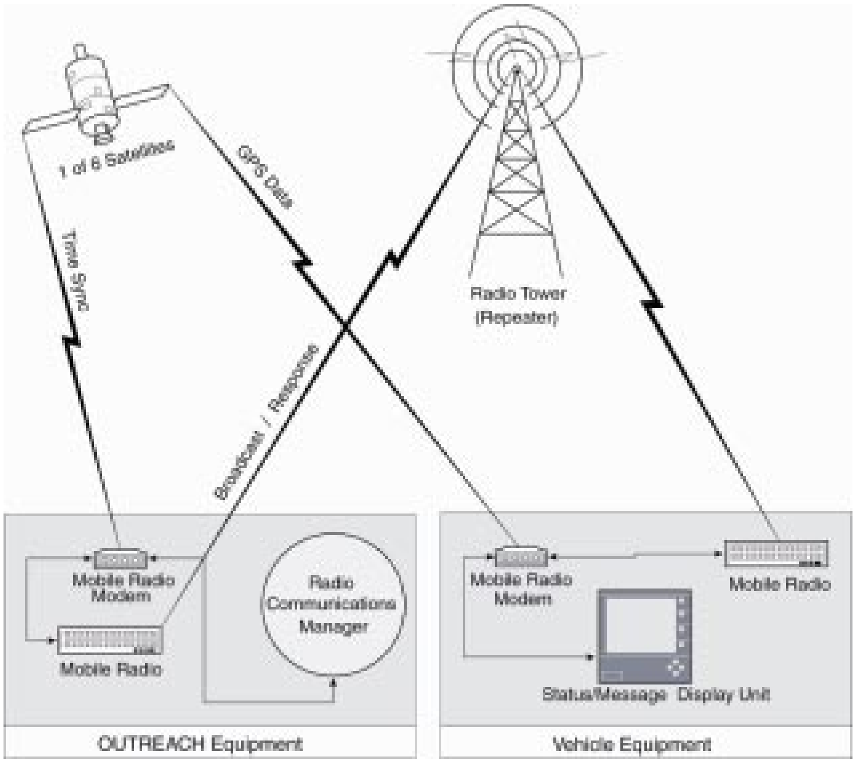


Figure 2.
AVL communication setup

Two situations may not be easily handled by the above assignment procedure. First, clients may not know their return time when requesting a ride, e. g. in the case of medical appointments, so their pick-up cannot be assigned to a specific vehicle at the time of booking. In the case of these "open returns," clients call the transit agency as soon as they know when they need to be picked up, and their ride is scheduled when they call. Second, on rare occasions there are not enough vehicles available to accept some trip requests at the time of booking. These trips are allocated to some "virtual vehicle," and additional vehicles are put into service to provide these rides.

As part of its scheduling function, the ATSS prepares three reports: a list of pick-ups and drop-offs in time sequence for each vehicle, a list of pick-ups and drop-offs for all vehicles in time sequence, and a list of open-return trips that have not been assigned to any vehicle. These reports are automatically transmitted from the transit agency to each vendor on-line.

Same-Day Changes

When the client wishes to change a scheduled trip on the day of travel, the telephone scheduler inputs the change into the computer, which is then transmitted to the vendor on-line.

The use of the ATSS requires that personnel be able to operate the software, and be familiar with all facets of the entire automation process. This requires extensive personnel training. A systems analyst with considerable experience in computer hardware and software is also needed to be in charge of operating and trouble-shooting the system.

Automated Vehicle Location (AVL) System

AVL opens up new opportunities for transit agencies to further improve the efficiency of paratransit operations. In OUTREACH's application, the AVL system consists of: mobile data terminals on vehicles, radio equipment, workstations, remote dispatching computers, and tower and differential base station equipment to transmit messages to and from vehicles. The software includes: Network Communications Management, AVLManager, and StarView(TM) real-time map display.

The AVL system essentially monitors the real-time status of vehicle and passenger trips. This information is accessed by the ATSS, and displayed on screens and screen maps. The value of AVL data depends on the extent to which the transit agency is able to develop control strategies to utilize it. Some use scenarios and benefits are described below:

Short-Term Scenarios

One important short-term use of AVL data is to improve a transit agency's management information capability. For example, AVL data makes it easy for a transit agency to accurately monitor vehicle on-time performance and to identify problems that exist. In this way, problems can be remedied in a timely manner, and effective strategies to improve vehicle on-time performance systemwide can be developed. For example, AVL data allows OUTREACH to learn how long it takes clients to board and alight from vehicles. This information can be used in scheduling future rides for individual clients, particularly those who are likely to need extra time. Another short-term use of AVL data is to improve the communication capabilities between the transit agency, dispatcher, and driver. For example, the AVL has the ability to delete canceled trips from the list broadcasted to the mobile data terminal onboard the vehicle. Therefore, vehicle schedules can be updated in a timely manner. AVL data allows the dispatcher to help drivers who are lost (or uncertain about directions) to pick up or drop off passengers in a timely manner. Also, when there are on-the-road problems with the vehicle, the transit agency and the dispatcher immediately know about them without the driver having to initiate the communication.

Long-Term Scenarios

Clockwise from left: Interior of OUTREACH van; dashboard display; display can inform driver of riders' pertinent medical conditions; GPS hardware mounted under seat

Automatic vehicle location offers tremendous potential long-term benefits for transit and paratransit operations. AVL data provides continuous feedback about the vehicle location, status, and speed. Because travel time is a parameter in the ATSS trip scheduling, AVL data can be used to improve the accuracy of the ATSS scheduling algorithm. This adjustment may be done in real time or periodically. AVL data also makes it possible for the transit agency to implement a strategy to schedule vehicles to serve open-return trips in real time. This can help to increase the vehicle productivity and reduce client waiting time significantly. AVL equipment has been widely installed on transit fleets all over the US in recent years. OUTREACH currently has installed GPS units synchronized with radio communications equipment on half the 160 vehicles in its fleet, and plans to equip twenty percent more of its vehicles with AVL next year. Installing AVL equipment on both paratransit and fixed-route vehicles would permit a transit agency to develop real-time strategies for a multimodal timed-transfer system that would enable paratransit clients (who currently depend on door-to-door service by paratransit vehicles to make trips) to use a combination of door-to-door and fixed-route services. Such a "hybrid" service would significantly reduce the cost of providing paratransit service. At this time, usable research to utilize AVL data in these long-term scenarios is lacking, and is urgently needed.

PATH and OUTREACH are currently investigating several opportunities for future joint projects, among them: using OUTREACH'S AVL-equipped vehicles as probes to provide information on travel times and incidents, using the vehicles to transport former welfare recipients from their new jobs, and enhancing the ATSS to provide vehicle operators with alternate routings when there are delays.

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PATH Presentations

Recent and Upcoming Presentations of PATH Sponsored Research

ITS America '99 , Ninth Annual Meeting and Exposition, Washington D.C., April 19-22, 1999
• CY Chan, HS Tan, "Automated Steering Control in Vehicle Following Collisions" presented by James Misener.
• Youngbin Yim, "Consumer Response to Advanced Traveler Information Systems:A Focus Group Results," publication only.
• A .Deshpande, D. Godbole, N. Kourjanskaia, B. Michael, J. Misener, R. Sengupta, "Targeted Survey of Intelligent Vehicle-Highway Simulation Tools".
• Wei-Bin Zhang (moderator), "ITS in China".
• James Misener (moderator), "Enabling Tools to Analyze and Evaluate AVCSS services".
• Datta Godbole, "Emerging Analyses and Evaluations for AVCSS/IVI Services".
• James Misener, "Increasing the intelligence of Intelligent Vehicles: A Case for Cooperative Marking".
• Steven Shladover (Moderator), "International Activities in Advanced Vehicle Control and Safety Systems".

American Collegiate Schools of Planning 40th Annual Conference; Transport in the City: Los Angeles Stream Panel Tomorrow's Cities Today: Building for the Future, Pasadena, California, November 8, 1998
• James E. Moore II, Genevieve Giuliano, Elif Karsi, and Susan Rossbach, "New Technology In Transit: The Smart Card Story".

Annual Aerospace Lighting Institute Advanced Seminar, Los Angeles, California, February 3, 1999
• Theodore E. Cohn "Roadwise Signalling in the New Millenium". At the same meeting Professor Cohn was named the recipient of the ALI's annual Appreciation Award (details at www.aligodfrey.com)

1999 ASME International Mechanical Engineering Congress and Exposition (IMECE), Anaheim, California, November 1999
• M. Tai and M. Tomizuka, "Dynamic Modeling of Multi-Unit Heavy Vehicles," DSC-Vol. 64, Proceeding of the ASME Dynamic Systems and Control Division, ASME 1998, pp. 673-680.
• J-Y. Wang and M. Tomizuka, "Analysis and Controller Design Based on Linear Model for Heavy-Duty Vehicles," DSC-Vol. 64, Proceeding of the ASME Dynamic Systems and Control Division, ASME 1998, pp. 729-735.

University of Southern California, February 10, 1999
• M. Tomizuka, "Lateral Control of Automated Heavy-Duty Vehicles".

Daimler Chrysler Research and Technology Center, Esslingen, Germany, November 1998 (invited seminar)
• Ioannis Kanellakopoulos, "Longitudinal Control of Automated Commercial Heavy Vehicles".

Department of Electrical and Computer Engineering, University of Newcastle, Australia, February 1999 (invited seminar)
• Ioannis Kanellakopoulos, "Sensors and Control for Autonomous Vehicles".

18th Benelux Meeting on Systems and Control, Houthalen-Helchteren, Belgium, March 1999 (plenary talk)
• Ioannis Kanellakopoulos, "Nonlinear Control for Advanced Vehicle Systems".

Department of Automatic Control, Lund Institute of Technology, Lund, Sweden, March 1999 (invited seminar)
• Ioannis Kanellakopoulos, "Nonlinear Control for Advanced Vehicle Systems".

Department of Signals and Systems, Chalmers Institute of Technology, Goteborg, Sweden, March 1999 (invited seminar)
• Ioannis Kanellakopoulos, "Sensors and Control for Autonomous Vehicles".

AAG Annual Meeting, Hawaii, 1998
• Reginald Golledge, "Learning Spatial Configurations Using Auditory Cues".

SAE '99, Cobo Center, Detroit, Michigan, March 1-4, 1999
• Bogdan Marcu and Fred Browand, "Aerodynamic Forces Experienced by a 3-Vehicle Platoon in a Crosswind", SAE Paper No. 19999-01-1324, reprinted from Vehicle Aerodynamics and Wind Noise, SP-1441.

TRB Annual Meeting, Washington, D.C., Wednesday January 13, 1999
• Susan Shaheen, "CarSharing and Partnership Management: An International Perspective."

Media Day Launch of the CarLink Field Test (Dublin-Pleasanton BART Station), Tuesday, February 2, 1999
• Susan Shaheen, "Introduction to the CarLink Demonstration".

Metropolitan Transportation Commission, Oakland, California. Monday, February 8, 1999
• Susan Shaheen, "CarLink: A Smart CarSharing System".

SPIE's 13th Annual International Symposium on Aerosense, Unmanned Ground Vehicle Technology, Orlando, Florida, April 5-9 1999
• Anouck Girard, James Misener, Joao Sousa, Karl Hedrick, "Control and Evaluation of Mobile Offshore Base Operations".

CarLink: A Smart Carsharing System

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Day Users pick up a CarLink vehicle at either BART or LLNL and use it for business trips or personal errands during the day at a fee of $1.50 per hour and $.10 per mile. Users are not charged for business trips because LLNL has donated the fuel to this demonstration. Approximately30 day-use members are signed up to participate at LLNL.

Focus Groups and Household Interviews

In this study, the focus groups are designed to provide a setting in which several individuals who participated in the study come together at a later date to explore a larger vision of shared-use vehicle services in the San Francisco Bay Area. By discussing members' experiences in the study and subsequent reflection on the CarLink concept, each group will construct an imaginative image of a carsharing service operating throughout the San Francisco region. Through the process of building such images, participants reveal what they consider to be the essential features of these systems. These include important system design elements, such as what types of vehicles are available, where they are available, how they are accessed, and how use is billed. In constructing their image, people reveal how much they value the new transportation service, how that value is constructed, and whether this new transportation mode in fact complements conventional transit services (e.g., adds riders to transit). Thus, the final images produced are less important than what is revealed in the process of building those images. A consensus image of widespread smart carsharing services need not emerge from such groups.

Focus groups with longitudinal survey participants were conducted in October 1998, and groups with field test participants will be conducted in the fall of 1999. In the fall, researchers will also conduct ten two-hour household interviews using Interactive Stated Response (ISR) techniques to deepen the consideration of CarLink and willingness-to-pay for this system. ISR interviews, which are fundamentally grounded in the actual behavior of participants, will ensure that households explore the impacts of new travel options on their lifestyle, activity, and travel choices.

The fundamental goal of the interviews is to ensure that researchers perceive smart carsharing through the eyes of users and possible users, and how participants construct and value these services. Households will complete travel diaries prior to the field test and after several months of experience using CarLink. The interviews will employ data from before and after the CarLink field test to explore differences in travel and activity choices, as expressed in the diaries and the travel data collected by the Teletrac system.

CarLink field test vehicle displays logos of project partners.

Conclusion

A wide variety of users, including public agencies and private-sector companies, should find this study of smart technologies valuable. It will provide user response data, vehicle trip data for energy and emissions analysis, and experience applicable for a larger-scale demonstration and deployment of other personalized public-transportation services.

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For further information about this and other ITS-Davis projects, please go to the Web URL http://www.engr.ucdavis.edu/~its/research.htm

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Intelligent Cruise Control System Design Based on a Traffic Flow Specification, D. Swaroop, R. Huandra, February 1999, $5.00
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Final Report: Mobile Surveillance and Wireless Communication Systems Field Operational Test; Volume 1: Executive Summary, Lawrence A. Klein, March 1999, $10.00
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The Design of a Controller for a Following Vehicle in an Emergency Lane Change Maneuver, D. Swaroop, Seok Min Yoon, February 1999,
UCB-ITS-PWP-99-3*$5.00

Studies of Vehicle Collisions - A Documentation of the Simulation Codes: SMAC (Simulation Model of Automobile Collisions) Update 1, Ching-Yao Chan, March 1999, 5.00
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Predictability of Time-dependent Traffic Backups and Other Reproducible Traits in Experimental Highway Data, Karen R. Smilowitz, Carlos F. Daganzo, March 1999, $10.00
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Why ITS Projects Should Be Small

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tems. Best of all, diversity of practice and experience can be respected within an evolving framework that supports cost-effective coordination. As services and products mature they become more useful, standardized, less expensive, and easier to operate, maintain, and interconnect. Local projects and services can then be replicated, adapted, and joined together into larger systems.

Planning should be done in close contact with developers, testers, and operators. Funding agencies should require that planning agencies establish technical review panels composed of objective, technically knowledgeable people to review and comment on regional transportation plans that involve new technology. Similarly, at state and federal levels, local operators and experienced developers and consultants should be involved in significant review and advisory capacities. Funds should be provided to facilitate the participation of such experts. Test beds should be incorporated into regional operations and should include a broad range of partners, each executing tasks that match their core competencies, and contributing to the execution of projects that are locally important. Wherever relevant, private industry skills should be tapped. Operations experts should have a substantial role in setting the research and development agenda. Regional and local forums should be established for sharing planning questions (from cities, regions, and states), operational experience and needs (from public operating agencies), and research and test results (from University and industry developers). The objective of such forums should not be promotion of ITS, nor should it be similarly motivated "education" of operators; rather it should be on exchange of core factual experience on operating conditions and needs, and performance experience with new technologies. Even beyond sharing this kind of information, such forums, if they include people with real knowledge and experience, can help establish trusting relationships for future interactions and information exchange, based on need rather than promotional visions.

...most innovation involves the interaction of a technological community and a technological trajectory...the members of the community share a common, experience-based, body of heuristics (i.e., how to do things, where to search) and have broad agreement on the key technological and organizational opportunities and obstacles likely to be encountered in the further evolution of the trajectory. The community will have some consensus on how to advance the state of the art.

Success requires that networks self-organize themselves in ways that enable them to co-evolve with technologies. Only self-organization and coevolution offer the structural capacity to flexibly and intimately connect diverse technical expertise (e.g., engineering design, prototype development) with diverse capacities (e.g., political, legal, or financial skills).

Donald Kash and Robert Rycroft

...the production of knowledge is contextual, burdened with the specific circumstances in which it occurs. The communication of knowledge from one context to another, from one individual, firm, industry or country to another , is not unproblematic...

...individuals accrue advantages over all others in that they have access to unique information that can be put to beneficial use, but only if the decisions depending on it are left to specific individuals or are made with their active co-operation.

Anders Lundgren

To build improved information bases, more comprehensive and credible system performance measurements should be made routinely, based on a solid foundation of effective traffic surveillance. At best, Intelligent Transportation Systems without such information forego what is arguably their special strength; at worst, they are doomed to drift without consciousness of their value or direction. The availability of such information will make planning more meaningful and honest, and make real benchmarking possible. With benchmarks founded on useful measures (including user valuations), progress toward stated planning goals could be tracked, thereby reducing the role of after-the-fact spin doctoring of project results, and supporting real learning.

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