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NATIONAL POLICY CONFERENCE ON INTELLIGENT TRANSPORTATION SYSTEMS AND THE ENVIRONMENT

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New Strategies and Technologies

Intelligent Transportation Systems for Sustainable Communities

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EXECUTIVE SUMMARY

"Intelligent Vehicle and Highway Systems" (IVHS) and "Advanced Transport Telematics" are the names which have been used in America and Europe, respectively, to describe the application of information, communications, data acquisition, and control system technologies in surface transportation. These range from mundane traffic advisory message signs on freeways and transit passenger information systems to visionary automated highways where computer-controlled cars might tailgate a few feet apart at 100 mph or more.

IVHS technologies could reshape our communities and societies in far-reaching ways over the next several decades, affecting our lifestyles, environment, economic structure, and social equity nearly as much as the automobile has over past decades. The fundamental architecture and vision of IVHS established in the mid-1990s may serve as a foundation for a technology-driven transformation with considerable consequences. We must ensure that these technologies are harnessed to serve our long-term social, economic, and environmental goals. This will require much broader public participation in IVHS policy making, the establishment of clearer performance objectives and measures for transportation management systems to guide IVHS deployment, and broad-based assessment of the social and environmental impacts of IVHS.

This paper discusses efforts to define the vision and future of these technologies. IVHS will help support more sustainable transportation system development only if it is redefined as part of a broader vision. Recasting IVHS in the multi-modal framework of "Intelligent Transportation Systems" (ITS) -- as has been recently proposed by the Coordinating Council of IVHS America, a US Department of Transportation (DOT) advisory group -- is symbolic of the beginning of this redefinition process. Alternative visions of IVHS/ITS should be explored with vigor as part of the IVHS architecture development process, which is working to establish national system standards over the next two years. A premature forced consensus on the vision of IVHS/ITS will lay the foundation for long-term conflict rather than cooperation. It is in the interests of industry, transportation interests, the environmental community, and society at large to seek out a win-win vision for IVHS/ITS that meets shared objectives and goals.

If IVHS/ITS is to serve the goals of sustainable communities and transportation, what should be the requirements for its system architecture and its functions? The answer lies not in the selection of one or several isolated "user services", but in the development and deployment of appropriate bundles of technology to ensure that IVHS/ITS can help to manage the growth and patterns of travel demand while improving the efficiency and performance of transportation systems. The most promising elements of IVHS/ITS for meeting these objective are --

- smart public transportation, which would allow bus drivers to override traffic signals to speed up bus travel and permit people waiting at a bus stop or at home to know instantly when the next bus is coming, and to feel and be safe when using transit.

- smart paratransit systems to arrange for inexpensive share-ride taxis and to assemble carpools and Vanpools on a day-to-day or instant basis.

- smart goods movement systems to help firms arrange for lower cost and less resource-intensive transportation of goods using intermodal systems, improved manufacturing logistics to reduce the need for long-distance shipping, and improved information, communications, and delivery services to help individuals purchase goods from home or local stores.

- the automated collection of parking and road user fees to reduce taxpayer subsidies to driving and allow market-based pricing of scarce highway capacity during rush hours, with rebates of surplus revenues to all residents to boost equity. These pricing systems could complement or support smog fees that charge more for dirtier vehicles and reduce the cost of using clean modes of travel.

- limiting vehicle speed and acceleration rates on individual roads and in sensitive areas electronically to slow down and "calm" traffic on low-volume residential streets and in commercial areas where pedestrians, bicycles, and transit have priority, to smooth traffic flow on arterial roads with computer-synchronized traffic signals, to reduce emissions and safety problems on high speed expressways caused by speeders, and to reduce top vehicle speeds automatically when icing and fog or accident tie-ups occur.

Such ITS strategies could expand the market potential for small, light weight, neighborhood vehicles suitable for short non-freeway travel. Whether propelled by batteries, small engines, supercapacitors, flywheels, human power, or a combination, these vehicles would allow individuals and firms the opportunity to better tailor the vehicle chosen for a particular trip to their end use requirements. Such ITS could help complement a needed realignment of transportation subsidies and investments, the reallocation of street space to restore opportunities for walking, bicycling, and rapid transit, and smart land use policies that encourage reinvestment in cities and inner ring suburban centers where managed growth will help solve rather than exacerbate pressing traffic and social problems.

BACKGROUND

IVHS/ITS promises to help in the switch from military to civilian production and could be a major source of long-term economic growth and increased productivity. Projected IVHS/ITS deployment costs over the next 20 years in America alone are expected to be about $40 billion in public infrastructure and $170 billion in private spending. The promise of an even larger future global market for IVHS/ITS has US automobile and electronics firms in heated competition with the Europeans and Japanese to gain a lead in developing these technologies. This accounts for the strong bipartisan support in Congress and from the Bush and Clinton Administrations for increased US Department of Transportation IVHS research, which will reach almost $300 million annually in FY 1995. A recent US DOT plan guiding IVHS research notes that, "Over the next 20 years, a national IVHS program could have a greater societal impact than even the Interstate Highway System."

Appropriately directed, these technologies could undo much of the damage caused by short-sighted transportation policies of the past several decades, improving air quality and community livability and improving our ability to finance needed transportation and community infrastructure and services while sharply reducing traffic congestion, energy use, and the toll of traffic accidents. But as it has been developed to date, IVHS threatens to repeat the mistakes of the past, increasing suburban sprawl, air pollution, and dependence on automobiles and imported oil, while further reducing our freedom to walk and bicycle in our communities.

There is a danger that IVHS/ITS will be used only to buy another couple decades for unsustainable transportation and land use policies. Instead we could use this opportunity to begin the long-term transition away from unsustainable policies. Smart technologies, like cleaner motor vehicle technologies, can help us, but must be harnessed to serve environmental and energy requirements and a vision of more sustainable and livable communities. Sustainable transportation requires adoption of a new paradigm emphasizing multimodal accessibility and the re-integration of communities, not the blind pursuit of expanded mobility.

IVHS PROGRAM PLANNING IN AMERICA

The direction for IVHS developed in the late 1980s and early 1990s has been shaped by visionary traffic engineers, hardware manufacturing firms, and traditional highway user interests. These groups played a central role in organizing the federal advisory committee, IVHS America, which has guided IVHS policy and program development. While making worthy contributions in advancing both IVHS technologies and Congressional support for them, IVHS America and the US DOT IVHS program now face a considerable challenge in expanding public understanding and support for the program.

IVHS Strategic Plan

The *Strategic* Plan for IVHS in the *United* States, issued in May, 1992, acknowledged new policy orientations related to the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) but fell far short of embracing these or the participative processgoals of these-acts. As a vision-of thefuture, the Strategic Plan reflected the perspectives of those involved in its creation, who were largely bright, affluent, white, male, suburban-dwelling professionals. Their vision for IVHS has reflected overwhelming optimism in technology to solve problems while often downplaying the potential for major secondary social, environmental, and economic impacts. This vision of IVHS has emphasized strategies for squezing more cars and trucks onto existing highways and making motor vehicle use more attractive, rather than favoring strategies to manage growing motor vehicle travel demand. It has focused less attention on strategies that could reduce the current forced dependence on automobiles so common in American suburbs and edge cities. It has focused little on the needs of children, the poor, or the elderly. Indeed, IVHS has been set on a possible collision course with the Clean Air Act in America's more polluted cities. Major concerns are being raised about IVHS by environmentalists, traffic safety advocates, representatives of inner city interests, bicycle and pedestrian interest groups, and others.

National IVHS Program Plan

Since mid-1993, US DOT has been developing a new National Program Plan for IVHS. This effort is being undertaken with an intent to broaden outreach to new constituiencies and to address emerging issues regarding transportation system sustainability. A May 1994 draft of this Plan shows significant improvement over an earlier version circulated for comment in the fall of 1993, and will be subject to a broader public review process. US DOT has begun to address vital issues of program support, assessment, and public involvement, but much further effort will be necessary to evoke and evaluate a range of alternative visions and scenarios for IVHS/ITS development which reflect the perspectives and values of those not well represented in IVHS America.

A broad-based technology assessment will be vital critical to evaluating the systemic impacts of interlinked bundles of IVHS/ITS technologies. The relationship of transportation demand management (TDM) to even the latest draft IVHS Program Plan remains similar to that of icing on the cake, with TDM is identified as a "user service bundle," rather than a metastrategy which infuses the design of the overall system architecture. This almost guarantees that the resulting IVHS/ITS program will, with few exceptions, ineffectively integrate demand management into what many continue to see as its primary task of increasing transportation capacity and vehicle throughput.

While the latest draft IVHS Program Plan takes a less reductionist engineering approach to the problem of assessing costs, benefits, and impacts than the earlier draft, there is still too little consideration of the potential interaction of "user service bundles." Interaction of IVHS/ITS technologies with broader social and economic forces and trends is given little thought. The latest Plan does begin to discuss how these technologies could be used in a goal-directed fashion to help implement the Clean Air Act and develop effective ISTEA-mandated management systems, but this needs to be expanded. Much greater attention-needs to be-given to the many potential effects of IVHS/ITS technologies on-travel behavior, land use patterns, vehicle acquisition decisions of households and businesses, and corporate planning related to logistics and facility location. These are not minor secondary impacts which can be ignored. Indeed, they must be carefully evaluated in a holistic analytic framework which considers alternative deployment scenarios for alternative bundles of IVHS/ITS technologies. The latest Plan draft recognizes the need for scenario evaluation, but needs to emphasize a greater involvement of social scientists and the broad public in this work. These activities are not suitable for conventional engineering analysis, but require the perspectives of anthropology, sociology, systems analysis, and economics.

Expanding Participation for a New Vision

Recent positive steps to broaden participation in the IVHS program have yet to fully overcome the effects of past neglect for the concerns of environmentalists, transportation and land use reform activists, inner city interests, and other groups in IVHS planning. The continuing legacy of distrust and opposition to IVHS program deployment and funding from these communities of interest will be overcome only by further expanding participation of non-traditional transportation and community interest groups and by making environmental, social equity, and community livability goals central elements in IVHS/ITS program planning, assessment, and management.

The vision and architecture of IVHS in America is undergoing an important process of redefinition and reappraisal in the mid-1990s. This is a natural outgrowth of significant transportation policy reforms set in motion by the forces which helped craft and win passage of the Clean Air Act Amendments of 1990, the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991, the Energy Policy Act of 1992, and the U.S. government's committment to reduce CO2 emissions to 1990 levels by 2000 as part of the National Climate Action Plan and Rio Accord implementation.

Recognizing the need for reform, US DOT has begun to change the focus of its IVHS/ITS program. A management reorganization has put a spotlight on the need for a stronger intermodal and multi-modal program focus. The federal advisory committee used by US DOT is contemplating a change in its name from IVHS to ITS -- Intelligent Transportation Systems. Greater public input is being sought to help define the vision and system architecture for IVHS/ITS Environmentalists, transportation policy makers, and leaders of the IVHS community are beginning to explore common ground. In many cases they are finding broad opportunities for successful cooperation focused on a refined win-win vision for ITS.

US DOTS progress in moving the IVHS program towards a broader ITS framework and in placing greater emphasis on the environmental and societal impacts of these and other transportation technologies and policies is encouraging. However, this needs to affect agency policy-making, regulatory actions, program coordination, and funding in a more systematic fashion. US DOT Funding now dedicated solely to support involvement of traditional transportation interest groups must be similarly targeted to support involvement by non-traditional constituiencies and non-governmental organizations (NGOs) in transportation planning and policy making, especially at the metropolitan and national levels.

For example, resources have recently been increased by US DOT and EPA for long-term improvement of transportation models and data collection, essential to measuring the effects of IVHS/ITS deployment on air quality and congestion. Still, short-term reforms of these models and data systems at the local, metropolitan, and state level too often languish because of inadequate regulatory requirements, guidance, incentives, technical support, and public oversight. NGOs representing broad public interests are frequently denied ready access to these taxpayer-funded data and analysis systems, which are being manipulated and abused to resist ISTEA and CAA reform initiatives. Changes in the right direction are beginning to occur, but too slow]y to provide the information which may be needed to ensure that IVHS/ITS will not violate Clean Air Act requirements in the areas with serious air quality problems which could benefit most from a reoriented IVHS/ITS program. Bad models, inadequate data, and resistance to public oversight and public participation make litigation, rather than cooperation, the most likely future course for metropolitan transportation planning in many regions, putting IVHS/ITS at risk.

A WIN-WIN VISION FOR IVHS/ITS

If IVHS/ITS is to ultimately give us not just smart cars and smart highways, but smart communities, US DOTS research program needs a new vision to ensure that it will boost environmental sustainability and community livability while promoting economic growth, defense conversion, and US competitiveness. What might some key elements of this new vision for IVHS/ITS include? What strategies might merit greater or less emphasis for taxpayer-supported investment in R&D?

Electronic Road and Parking Pricing

IVHS/ITS could worsen congestion and pollution problems in the long-run if it expands highway capacity without first applying its potential for automated road pricing. However, IVHS/ITS could provide the enabling technology for automated high-speed electronic toll collection systems which could help reduce traffic congestion and manage the increased demand for travel demand stimulated by other IVHS/ITS technologies. This could be the most important breakthrough in surface transportation in recent decades, but has been put on a slow track for IVHS/ITS development. Electronic highway toll systems have been successfully pioneered in Norway, Sweden, Singapore, and several American communities. Major American firms, such as AT&T are poised to provide new "smart cards" which could be the foundation of new approaches to transportation user fees.

The costs and delays associated with toll collection have throughout this century encouraged us to give away free use of-our-highways rather than charging users-directly and charging more in times of peak demand, as is done for telephones, airlines, and electricity. By not paying the full costs for transportation, we have been encouraged to over-consume

CAN SMART EXPRESS LANES MAKE ROAD PRICING ACCEPTABLE?:

Road pricing has for years been rejected as technically impractical and politically unacceptable, although virtually every transport economist has advocated the concept as the single most important innovation in surface transportation which could increase system efficiency and performance. IVHS/ITS removes the technical barriers to road pricing. Now the task is to devise a politically sound implementation strategy.

Acceptance of road pricing will require public education, marketing, and a gradualist approach. The most promising strategy may be to use non-contact electronic smart debit cards for payment of user fees for transit, parking, and high speed automated toll lanes. "Smart Express Lanes" could represent a pragmatic strategy for the gradual conversion of our existing, inefficiently managed road system to a more efficient, market-oriented management system. This approach would guarantee congestion-free travel for those willing to pay to use Smart Express Lanes, offer others the option of using free but more congested lanes, and distribute to all residents the surplus revenues from the system, avoiding the creation of new taxes. Everyone is set up to get what appears to be something for almost nothing.

At first, only existing toll roads and a single lane of congested multi-lane Interstate highways in a metropolitan area might be converted to Smart Express Lanes. Smart card readers would be offered for free installation in all vehicles at the owners' option at the time of annual vehicle safety and emissions inspection and would be mandatory in all new vehicles sold in the region. Smart cards usable in the readers would be anonymous and could be exchanged, purchased, or have value added to them at banks, gas stations, and selected convenience stores. Low energy sensors planted at frequent intervals in the Smart Express Lanes would interact electronically with the smart debit cards at full highway speeds -- eliminating toll booths -- deducting value from the card for each mile driven. Video cameras would record the license plates of those using the lanes without proper payment, leading to a ticket by mail. Smart cards could be used also for automated parking charge payment, with low cost entry-way sensors used to convert ubiquitous uncontrolled suburban parking lots to a price-mediated system.

The periodic rebate of the large revenues from the Smart Express Lanes to all residents in the metropolitan area, after deducting system costs, would avoid new taxs, promote more equitable income distribution, and create a constituency favorable to increasing the lane-miles of smart roadways and the price of using them. A bond issue that pays for installation of the system could finance issuance of rebate checks in advance to residents when the pricing system begins operation to build public support.

travel, especially by automobile, leading to growing congestion, delay, oil imports, and pollution. However, this will not be achieved unless new approaches to selling road pricing are developed, which will require as much emphasis to human and marketing factors as to engineering, such as "Smart Express Lanes" (see Box later in this paper) and rebates of road pricing revenues to a region's residents through direct payments or tax reductions. Such approaches need to be more fully developed and evaluated as part of IVHS/ITS planning.

Another IVHS/ITS technology, Automatic Vehicle Identification (AVI), can be used to track the location of trucks and cars and for automatic payment of tolls without stopping at toll booths. While this eliminates the congestion and delay associated with charging tolls, it raises questions about privacy which must be addressed, since they may make it acceptable only for commercial vehicles. The early committment to AVI technologies for road pricing related IVHS operational tests may 'lead to missed strategic opportunities to use IVHS/ITS as the enabling technology for more equitable highway user charges, which are necessary for the long-term efficient management of our surface transportation system and attainment of healthy air quality in major cities. What are public attitudes towards AVI and road pricing? How aware is the public of current large hidden subsidies which encourage overuse of the automobile and the costs of these subsidies to individuals and businesses? How could AVI or electronic smart card pricing systems best be implemented to minimize public opposition? These key questions should be evaluated in the IVHS/ITS program to help move forward with positive environmental benefits rather than simply promoting further dependence on subsidized private motor vehicle travel.

IVHS/ITS and Transit

The current IVHS/ITS research program is pursuing some technologies which will help to reduce automobile dependence, although funding priorities need to be re-examined. Advanced public transportation systems have received a relatively small share of the IVHS/ITS research budget to demonstrate technologies in which the US lags far behind the Europeans and Japanese. For example, real-time transit passenger information systems allow travelers to know from their home or from a bus stop exactly when the next bus will come, reducing wasted waiting time and boosting the attractiveness of transit. Many elements of such systems have been in use in France, Japan, and elsewhere for over a decade. Another example is systems for real-time transit communications and operations management. These track transit vehicles and enable quick responses to delays or problems and enable bus drivers to override computerized traffic signals to reduce delays experienced by transit, boosting both speed and schedule reliability. Such systems have been widely developed abroad and were beginning to come into more widespread use in the US in the late 197Os, but fell victim to transit funding cutbacks of the 1980s. The IVHS Program Plan should recognize and draw on this experience and propose these elements for early deployment as "low hanging fruit."

Other current IVHS/ITS program elements-which offer promise include development of new premium dial-a-ride services and new travel information services from homes, workplaces, and public kiosks. The next wave of wireless communications devices could complement these by enabling instant carp001 matching systems. The IVHS Program Plan begins to address these concepts, but will need to do far more to consider how these might interact with new multi-media communication and information system developments now being led by private sector initiative.

Automatic Speed Limitation

The IVHS research program has focused mostly on engineering solutions to increase both highway capacity and the attractiveness of the automobile. One major area of research is on devising automated collusion avoidance systems and automated highways to squeeze more cars into the same road space at higher speeds, potentially doubling or tripling the amount of traffic without widening highways. Congress has put a high priority on automated roadway technologies, seeking a demonstration of the concept by 1997 and earmarking funds for this purpose. However, major questions remain about the consequences of inevitable computer failures, where all this traffic will go when it leaves automated highways and is dumped onto non-automated urban and suburban streets, and the environmental effects of a sharp increase in long-distance driving.

The IVHS/ITS national program plan needs to undertake a critical appraisal of the near and mid-term goals for the Automated Highway System program, asking the right questions about its potentially devistating effects on cities, on air quality, and on energy and land use. A more practical early deployment of AHS technologies might be to mandate that motor vehicle manufacturers install the capability for local-option speed limitation controls on vehicles.

IVHS/ITS could develop technology that automatically limits cars and trucks to the posted speed limit on streets and highways and prevents red light running, resulting in fewer accidents and traffic deaths, less aggressive driving, smoother traffic flow, reduced air pollution, and more livable communities. In short, a part of a "green vision of law and order." This technology could be used to help ensure that arterial traffic moves at a speed synchronized with computerized traffic signal progressions, rather than in the "hurry up and wait" pattern, with its associated high air pollution emissions related to rapid vehicle acceleration and deceleration, common in US cities and suburbs. It could reduce the emissions associated with over 55 mph freeway driving. It could accomplish "electronic traffic calming," slowing traffic on residential and commercial streets to restore options for safe walking and bicycling, reducing vehicle miles of travel, the number of motor vehicle trip starts, and emissions of VOC, CO, PM-10 and NOx.

This could produce tradable emission credits for local communities that decide to implement these strategies, supporting local economic development opportunities in polluted regions. Such technologies could-expand the potential market for safe and attractive-use of small, lightweight, non-polluting, efficient electric neighborhood vehicles for use on all but the largest high speed highways, dramatically cutting US dependence on imported oil and reducing greenhouse gas emissions. However, the concept of vehicle speed limitation is not now a part of the IVHS Program Plan, which has limited itself to ideas such as "reminding motorists that they are exceeding the speed limit."

Smart Drivers or Smart Communities?

A major thrust of the current IVHS/ITS program is to give information on traffic congestion as it occurs to drivers who invest in special in-vehicle communications and computer display equipment, enabling them to take alternative routes. So long as only a few drivers have these expensive systems, they will likely save time and reduce traffic problems. If most drivers have such systems, however, the benefits will tend to diminish as alternative routes themselves become congested. In some circumstances, research has suggested that these systems could lead to increased rather than reduced congestion. The IVHS/ITS national program should work to improve understanding of these potential complex system questions.

In-vehicle travel information may be useful and may find a ready market among drivers who can afford it. However, public investment might be better directed at development of new Smart Community information systems to enable everyone to meet their daily activity needs with less need to travel and less automobile dependence. For example, most of us now use a "hunt and gather" approach to errand running -- driving around to different shopping centers and stores, often without knowing which shop has the goods or services desired. A Smart Community information system would provide an "expert system" to exploit the new information superhighways and identify where and how you can get desired goods and services with the least amount of time, cost, and hassle. This would expand opportunities to order goods for home delivery, eliminating the need to travel or the need to carry loads if shopping in-person. In other cases, these systems would enable you to find out which stores have the goods you want in stock, at what price, with expert system help in suggesting the most efficient iteneary for running errands, given your expressed intentions, constraints, and usual preferences. However, there needs to be a careful consideration of the potential effects of such systems on the retail sector and community structure. System designs that can support, rather than undermine neighborhood shopping opportunities should be explored.

CONCLUSION

Unless demand management strategies are tightly bundled in with highway capacity enhancing IVHS/ITS systems, these systems will face opposition in many communities in America as they will lead to a degradation of air quality and community livability. Without vision and foresight, IVHS/ITS will be just another drain on the public's tax dollars, a barrier to healthy air quality, a contributor to more rapid global warming and rising fuel import bills, a source of ongoing legal and political conflict, and yet another costly mistake for our country. With proper redirection, however, IVHS/ITS could be the most important enabling technology driver in decades for reform and progress in American transportation, winning for our citizens sustainable high wage jobs, reduced traffic delay, more livable communities, and a healthy environment. Hopefully, the environmental community and the IVHS community will find the win-win strategies and till together common ground to build sustainable communities and an efficient, sustainable economy.

APPENDIX A: REVIEW OF SPECIFIC IVHS/ITS USER SERVICES

The November 1993 draft IVHS ***Program Plan*** discusses a number of "user services" which together make up the IVHS/ITS program. The following section identifies these in three clusters based on EDF's judgement regarding their relative importance in the IVHS/ITS program. ***The Program Plan*** attempts to discuss the potential costs and benefits of these user services one-by-one. However, a proper consideration of the program's costs and benefits will depend on a broad based technology assessment of bundled user services and technologies at different stages in a deployment scenario. There has not been sufficient time for a review of the extent to which the May 1994 draft Plan addresses these issues.

High Priority Services

#10: Electronic Payment Services. This should be the highest priority IVHS/ITS service concept. Efficient user fee systems that increase the cost of driving motor. vehicles and fully capture the costs of driving to society are essential if travelers are to make efficient and socially rational choices of when, how, and why to travel. Supply-side oriented IVHS/ITS services which increase highway capacity and the attractiveness of driving will not be feasible for implementation in areas of the U.S. with air quality problems except when they are implemented together with road and parking pricing systems. Innovative approaches to the introduction of road pricing should be identified, such as the incremental development of "Smart Express Lanes" (see accompanying Box for description). To make these services more acceptable to the public, citizens should be educated about the costs of current subsidies which are now given to automobile drivers which result in higher taxes, higher insurance costs, and reduced freedom to meet daily needs without forced dependence on the automobile. Rather than distributing the dividends from past taxpayer investments in highway capital facilities based on how much one drives, these dividends should be "cashed out" as payments to every citizen regardless of how much they drive by charging users at least their full share of costs. Electronic road pricing, combined with the rebate of surplus revenues to all members of the community, could meet this objective.

NEW: Automated Speed Limit Enforcement. IVHS/ITS should include the service of automated speed limit enforcement. Speeding accounts for a significant share of traffic accidents. High speed differentials between law-abiding drivers and speeders contributes to a large number of traffic related injuries and fatalities. Automated Speed Limit Enforcement would use a speed governor on vehicle engines linked to low-power transmitters which would communicate to the vehicle the speed limit. This would improve the safety of urban and suburban freeways, allowing police to reduce speed limit enforcement activities in favor of other types of law enforcement and incident response. In residential and commercial areas with substantial pedestrian and bicycle travel, it would allow automated traffic calming and management of cut-through traffic, by slowing all traffic entering-neighborhood streets to 10 or 15 mph. This would substantially reduce pedestrian and bicycle traffic fatalities and injuries, improve the quality of life in these neighborhoods, reduce competition between drivers gunning to make the next traffic light, calm down driving behavior (with benefits for air pollution emissions and energy consumption), encourage traffic to stay on streets appropriate for through traffic, rather than cutting through neighborhood streets, and would help manage travel demand. By automatically enforcing speed limits, traffic flow on arterial streets could be better matched to flow in "green waves" with automated traffic signal control systems. High emissions high speed travel on freeways would be reduced. The system should be established so that emergency acceleration beyond the speed limit would be possible for short periods of time, but this would activate an incident report under appropriate circumstances and be discouraged. Deployment should initially be in large metropolitan areas, such as the Northeast Corridor, major metropolitan areas in California, and similar regions. Western rural states and other regions with long distances between communities should not be subject to this technology.

#l: Pre-Trip Travel Information. This user service should definitely be part of broader information services which help people to decide on the most efficient way to meet their activity needs, rather than providing only a narrow range of travel information. Travel is a derived demand, while activities generate travel demand. There is a great need for information services which provide expert system support to those wishing to explore how they can meet activity needs with less need for travel. This system must include information on where services are available, how they can be procured, and pedestrian and bicycle access must be included within the travel options. Travel information should be embedded into hypertext information services. Price information should also be included. These systems should be integrated with ISTEA mandated congestion management systems. Data collection and systems monitoring requirements should be described in the IVHS *Program Plan* as they relate to this user service.

#4: Traveler Service Information. This should be expanded to encompass broader information services intended to help people figure out more efficient ways of meeting their daily activity needs. This means extending IVHS/ITS beyond the narrow bounds of "smart cars" and "smart highways" to encompass "smart communities." This user service should be combined with #l (Prc-Trip Travel Information). It may be that a combination of CD-ROM storage for base information, combined with real-time on-line data services functions (rather like the French MiniTel system) and distributed expert systems software would be an efficient way of distributing, managing, and processing information.

#3: En Route Transit Advisory. These services have already been proven in many cities in Europe and Japan and should be aggressively pursued in U.S. metropolitan areas. These should be re-titled as "Real-Time Transit Passenger Information Services" and should be available not only en route, but from homes and businesses. These should be a particular priority for deployment in lower density suburban areas where transit frequency is low and where real-timeinformation on when-the next bus is-coming can reduce wait times and the feeling of loss of control which accompanies waiting for a bus that "seems to take forever" to come. Such information systems should be integrated with real time transit operations management and vehicle dispatching.

#16: Public Transportation Management. This is a very high priority for improving public transportation operations reliability and system performance. Such systems are already well advanced in some European and Japanese communities. It is high time the U.S. caught up.

#17: Personalized Public Transit. This is a promising set of services, but will tend to work best with small vehicles, due to cumulative delays imposed on passengers by each route deviation from a direct route. This strategy should be modified to provide for premium subscription transit services, especially in lower density suburban areas where corridor travel demand is not concentrated enough to justify frequent transit services. Using vans or small buses with a base of subscriber passengers (who get a price break for subscribing on a regular basis), supplemented by a smaller group of on-route or near-on-route dispatch pickups (who pay a higher fare), it may be possible to produce higher speed and more convenient transit services in markets now not very economically supportable for conventional transit.

#12: Automated Road Side Safety Inspection. This should be a high priority as poor truck safety is one of the larger causes of serious traffic incidents, particularly as price pressures have increased on many independent truckers.

#13: Commercial Vehicle Administrative Processes. This is a useful concept which can increase efficiency for the private and public sector while providing useful and needed data and information for user fees and goods movement planning and operations.

Medium Priority Services

#2: En Route Driver Advisory. In-vehicle information services should be developed after providing home-based information services, not before. These systems should be designed with great care not to distract drivers from attention to the driving environment. Rather than reminding motorists that they are exceeding the speed limit, IVHS/ITS systems should include automated speed limit enforcement mechanisms on vehicles, at least within metropolitan areas. In-vehicle signing should be dropped from further development unless the private sector chooses to pursue it on its own. Those who cannot see adequately to read signs cannot see adequately to avoid hitting pedestrians and bicyclists and should not be driving. It is a heroic assumption to assert that increased in-vehicle information will result in less VMT and environmental and energy conservation benefits. Investments in roadside infrastructure should be dedicated first to electronic road pricing, not to in-vehicle advisory systems. Development of a nation-wide map database with standardized information, format, content, and accuracy is an excellent idea which should be accelerated, as it can support a variety of services and planning needs.

#5: Route Guidance. This should be integrated with #2 (En Route Driver Advisory). These systems should include information on the price of travel on various routes (assuming that road pricing is in place on a significant portion of the street network), as well as travel time and optimal route. In-vehicle information services should be developed after providing home-based information services, not before. The discussion of "no-pedestrian zones," sounds ominously like a more intense version of America's recently developed suburban arterial and freeway street systems (no sidewalks, no safe place to cross the street, such intense separation of land uses that there is little one would want to walk to).

#6: Ride Matching and Reservation. This system will face barriers of trust in American communities which are increasingly tom apart by too many guns, too much violence, increasing socio-economic stratification, and racism. However, it is worth a try. This might be linked to Personal Communication Services (PCS) with their highly localized communications cells which could be used for real-time localized ride-matching.

#7: Incident Management. While such systems can be quite useful in reducing incident-related delays and congestion, they can be very expensive and will tend to stimulate more driving over time by reducing average travel time on congested facilities. These systems should not be developed at general taxpayer expense. All system costs should be borne out of road user fees on monitored highways, using automated toll collection. Thus, these systems should be implemented together with automated road pricing, not on their own.

#9: Traffic Control. In the absence of transportation demand management and pricing strategies, major investments in areawide computerized traffic signal systems of this sort will tend to encourage more driving, rather than less. While in the short run this may reduce air pollution emissions and energy use, these reductions will tend to be ephemeral, as traffic growth will soon recongest the system at higher volumes of traffic, leading to more, not less pollution and energy use, and even greater automobile dependence. Thus, these expensive systems should be implemented together with "smart card" based road and parking pricing systems to ensure that environmental gains from the technology are not lost in uncontrolled traffic growth. This Traffic Control system description is too oriented too "areawide optimization of traffic movement." These systems should not optimize traffic movement, but overall transportation system goal attainment, including goals for mode shift towards walking, bicycling, and transit. This means sometimes compromising vehicle throughput in order to ensure that pedestrians have enough time to cross the street but are not overly inconvenienced by excessively long traffic signal cycles. This means providing transit vehicles with capabilities for traffic signal pre-emption, even if this disrupts traffic green waves. This means providing bicycle-sensitive loop detectors and quick-response special pedestrian and bicycle traffic signal request buttons with priority for such non-motorized travelers needing to cross streets, as is done in the Netherlands and other parts of Europe. Special sound systems should be installed as part of pedestrian crossing traffic signals in neighborhoods where visually disabled individualslive, as in Japanese cities.

#14: On-Board Safety Monitoring. This promises to improve truck and overall traffic safety. However, it appears to be somewhat vague in describing what types of technological systems might be devised to address the issues raised. It appears to merit further research but not at a high level of support relative to other areas. The motor vehicle manufacturers should play a major role in this area, with encouragement from the trucking and insurance industry and others.

Low Priority Services

#25: Safety Readiness. This appears to be an extension of in-vehicle warning systems which many automobile manufacturers already provide. These would logically be the subject of NHTSA regulations on vehicle manufacturers rather than apt subjects for extensive federally-sponsored research. Impaired Driver Warning and Control Override could be a useful technology for reducing drinking and driving, improving public safety and welfare. Vehicle condition warnings should be encouraged through NHTSA regulations. Warnings to other vehicles and infrastructure condition warnings could create a false sense of security among drivers unless they were quite comprehensive. Presumably, the pedestrian or bicycle crossing the road would not put out a warning to drivers, then becoming more vulnerable to being overlooked. Rather than warning drivers of hazardous conditions, it would be better to assert positive control over maximum vehicle operating speeds on individual roadway segments through automated speed controls. These controls could be dynamically adjusted to lower vehicle speeds during hazardous rain, snow, ice, or fog conditions, reducing the likelihood that the cautious slow driver will be rammed from behind by the overconfident fast driver, for example in low visibility conditions.

#20: Emergency Vehicle Management. This proposed service could reduce response times to life-threatening emergencies and thus may be a useful development. However, the costs of developing this system for automated traffic accident monitoring should be borne by motor vehicle users through user fees, not general taxpayer support. It appears likely that these systems would be available only to users paying a considerable cost for special in-vehicle monitors and communications equipment. It may be useful to mandate that vehicles equipped with such devices also be fully equipped for use of automated toll and parking fee collection. The provision of such emergency call equipment as part of Personal Communications Systems (PCS) appears to be a likely market-driven service, not needing public investment. The same may be true for on-vehicle systems.

#26: Pre-Crash Restraint Deployment. This seems like a very expensive proposition in terms of required sensors and on-board computing power, along with the provision of additional air bags for side collisions. It would thus appear to be a very long-range research concept, not a priority for the near future. A more sound proposition would be to mandate front air bags on both driver and passenger side on all cars and trucks sold in the U.S. and to better enforce speed limit and seat belt laws. --

#27: Fully Automated Vehicle Operation (AHS). This proposed set of technologies could substantially expand the operating speed and capacity of selected existing highway right-of-way and lead to explosive growth in motor vehicle travel demand, with negative consequences for air quality, energy conservation, alternative modes to the automobile, and ironically, traffic congestion. These types of automated roadways could turn streets into impenetrable barriers to pedestrian and bicycle travel. Automated roadways could bring vast amounts of traffic into an area's non-automated local streets, swamping local road capacity and leading to a situation of high speed travel by car followed by gridlock at destinations. Research into this area should proceed only accompanied by much broader technological assessment and impact analysis, considering secondary effects and means to manage them. There should be no implementation of automated roadway systems except in the context of fully developed road and parking pricing systems with electronic payment systems, since pricing systems will be the only effective way to manage the potential travel demand impacts of these highway capacity increasing technologies.

#21: Longitudinal Collision Avoidance. This proposed set of technologies could substantially expand the operating speed and capacity of selected existing highway right-of-way and lead to explosive growth in motor vehicle travel demand, with negative consequences for air quality, energy conservation, alternative modes to the automobile, and ironically, traffic congestion. These technologies could turn streets into impenetrable barriers to pedestrian and bicycle travel unless specially developed to scan for such travelers and to give them priority in a fair manner. Research into this area should proceed only accompanied by much broader technological impact analysis, considering secondary effects and means to manage them. There should be no implementation of longitudinal collision avoidance or automated roadway systems except in the context of fully developed road and parking pricing systems with electronic payment systems, since pricing systems will be the only effective way to manage the potential travel demand impacts of these highway capacity increasing technologies.

#22: Lateral Collision Avoidance. This proposed set of technologies could substantially expand the operating speed and capacity of selected existing highway right-of-way and lead to explosive growth in motor vehicle travel demand, with negative consequences for air quality, energy conservation, alternative modes to the automobile, and ironically, traffic congestion. These types of systems could encourage lane narrowing, which could be used to free up street space for pedestrian and bicycle travel. However, research into this area should proceed only accompanied by much broader technological impact analysis, considering secondary effects and means to manage them. There should be no implementation of lateral collision avoidance or automated roadway systems except in the context of fully developed road and parking pricing systems with electronic payment systems, since pricing systems will be the only effective way to manage the potential travel demand impacts of these highway capacity increasing technologies.

#23: Intersection Crash Warning and Control. This technology is similar to #21 (Longitudinal Collision Avoidance) and #22 (Lateral Collision Avoidance), although it would probably have somewhat lesser effect on transportation system capacity. Implementation of this technology in the absence of fully automated controls could lead drivers to accept smaller "gaps" in traffic at intersections and could make it harder for pedestrians and bicyclists to cross streets. Much further fundamental investigation of the secondary effects would be needed if this is to receive anything other than low research priority.

#24: Vision Enhancement for Crash Avoidance. This technology appears to be very long-range in nature. It might be better to accept slower traffic speeds in low visibility situations than to sink large resources into speeding traffic during these conditions.

#ll,15: Commercial Vehicle Preclearance and Commercial Fleet Management. These appear to be promising technologies which can increase the efficiency of trucking industry. It should be financially supported by those who will directly benefit from it -- the trucking industry -- with little need for public investment, except to coordinate system elements with larger IVHS/ITS components for appropriate standard setting.

Services Which Should be Dropped From Further Action

#8: Travel Demand Management. TDM is not a user service, but an operating philosophy that needs **to** permeate the entire IVHS ***Program Plan. TDM*** must be integrated into overall system management and operations in order to be accomplished. As an add-on, it is destined to failure. The description of TDM in this section of the Program Plan reveals a shallow understanding of the range of factors which must be considered in comprehensive demand management. These include not just transit service and HOV elements, but pedestrian and bicycle conditions, land use and urban design elements, and telecommunication and delivery service elements. Pricing strategies include the unbundling of automobile costs into smaller fixed elements and larger elements tied closely to consumer decisions about use of the automobile for each trip, rewarding those who drive less and fairly charging users for what they consume, with systems such as pay-as-you-go or pay-by-the-mile automobile insurance. This section of the ***Program Plan*** should thus be dropped and its elements merged and strengthened throughout the entire ***Plan.***

#18: Emergency Notification and Personal Safety. This proposed service can be well satisfied by cellular telephones and the emerging technology of Personal Communications Systems (PCS).

#19: Public Travel Security. This proposed service is also redundant with the emerging Personal Communications Systems (PCS) market, which can be well developed by the private sector without government interference. Some of the IVHS/ITS Public Travel Security monitoring systems which are proposed smack too much of "Big Brother is watching."

Consideration should instead be given to improved public travel security by other means, which will take innovative and new types of strategies. This may mean consideration of gun control laws, decriminalization of drugs combined with expanded drug treatment programs and public education on drug abuse, improved public schools through expanded choice of schools and stricter certification standards, providing jobs and job training to the hard core unemployed, and encouraging reinvestment in America's declining older urban centers, rather than fostering more suburban sprawl as so much proposed IVHS/ITS technology would tend to promote. We need to fix our broken social compact, not impose new technologies or repressive policing systems for control, if we are to create safe communities.

INTELLIGENT AND ENVIRONMENTAL-SENSIBLE TRANSPORTATION SYSTEM: AN ALTERNATIVE VISION

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Introduction

A recent US DOT plan guiding IVHS research correctly notes that, "Over the next 20 years,a national IVHS program could have a greater societal impact than even the Interstate Highway System. " But what will those impacts be? what could they be?

The primary thrust of current **IVHS** initiatives is to accommodate more vehicles more safely using existing roadapace. The principal focus is an two sets of technologies: 1) real-time information to manage traffic! flows better; and 2) automated controls to pack vehicles closer together, A variety of other applications are also being pursued, including transit and goods movement, but are receiving much less attention and government resources. The benefits of current IVHS initiatives are coming under increasing scrutiny, It appears unlikely that deployment of IVHS technologies, other than automated vehicle controls, will lead to major congestion reductions or road capacity expansions (e.g. , Hall, 1993; Al-Deck et al, 1989). Highway automation could provide large capacity improvements, but perhaps at a huge economic, environmental, and social cost (Burwell, 1993; Gordon, 1992; Johnston and Ceerla, 1994).

The current thrust of IVHS activities, as indicated above, has its historical origins in the highway engineering community; it is described in detail in the 1993 Draft National Program Plan for IVHS prepared by IVHS America. One might extrapolate these unfolding IVHS initiatives into the future and treat them as one potential IVHS scenario. It is a scenario that could be described as a pragmatic attempt to guide the development and deployment of information and control technologies or, 1433 charitably, as a reductionist engineering approach to the problem of congestion and safety.

An alternative IVHS vision is proposed here. The overarching goal inspiring this vision is increased accessibility

-- not mobility; that is, improved access to goads and services, but with little or no increase in vehicle travel. Three complementary goals, suppressed or ignored in current IVHS activities,are also fundamental to this alternative vision: greater consideration of the less privileged, enhanced environmental quality,and community livability.

Pursuit of these goals would lead to a very different transportation future than in the first scenario, Many of the same IVHS products would be commercialized end promoted in both scenarios, with the difference being that in this second scenario government more activelysupports products and activities that benefit lower income classes and the environment. Government marshals its R&D resources, infrastructure investments, and rulemaking authority in such a way that goals of accessibility, equity, and environmental quality dominate the design of the overall system architecture. The many effects of IVHS technologies on travel behavior, land US8 patterns, Vehicle acquisition decisions of households and businesses, and corporate logistical and facility location decisions are treated as primary impacts. The power of IVHS technologies to transform the urban and social landscape, similar to that of the Interstate Highway System, is acknowledged and harnessed.

Toward a wider Range of Technologies

This alternative vision implies a very different future, One major difference is that a wider range of technologies are envisioned, as suggested below. They include technologies that have been mostly ignored by IVHS propsnenta, such as smart tele-shopping, neighborhood electric vehicles, electronic speed controls, and emissions monitoring devices, as well as others, such as smart paratransit,that are under the current IVHS umbrella, but not receiving high priority.

Shopping through interactive television and other smart information systems might halt the trend toward longer shopping trips to regional warehouse stores. (Facilitating the use Of more and better information far goods movement and inventory management by smaller businesses would also offset the trend toward large warehouse stores and long shopping trips.)

Neighborhood electric vehicles, combined with other initiatives discussed below, can be an attractive option for maintaininq (or even increasing) accessibility and mobility. Older and less physically-capable people would especially benefit, thanks to the greater ease of driving and the ease of incorporating semi-automated driver-assists into low-speed vehicles. These driver aids would include enhanced collision avoidance, smart cruise control, and assisted steering. Recent market research on vehicle purchase desires in California suggests that a sizable number of households would purchase a small neighborhood car (Kurani et al, 1994; Sperling, 1994).

Electronic speed controls can be used on a variety of roads to provide a variety of benefits They can be used on residential and low volume roads to increase overall safety and enhance the attractiveness of non-motorized travel and small neighborhood vehicles; on arterials to smooth flows and thereby reduce emissions from gasoline-pawcred vehicles (and in a manner that enhances neighborhood car safety); and on freeways to reduce speed differentials to improve safety and reduce emissions. Provisions could be made for manual overrides in emergencies and for emergency vehicles such as ambulances, fire engines, and police cars.

Smart paratransit, whereby real-time information is used to connect commercial providers and subscribed rideshare vehicles with travelers, may be the single best opportunity for substantial reductions in vehicle use. Accordingly, it would be given very high priority in this scenario.

Technology as a Catalyst for Change

A second major feature of this alternative vision is the identification and promotion of technologies that could be catalysts for more far reaching and positive changes. The neighborhood electric vehicle is one example. By presenting a viable alternative to the full-size car, these small and low-speed vehicles could be the catalyst for renewed local emphasis on strengthened neighborhood centers and non-motorized travel, Their development and initial deployment might set in motion a series of events that transform communities and road infrastructure.

Another example is the use of IVHS as the enabling technology for more equitable and efficient highway user charges. Better pricing is necessary for the long-term efficient management of our surface transportation system and attainment of healthy air quality in major cities.

Linking Technology and Demand Management

A third feature of this environmental scenario is a tight linkage of technology deployment with demand-side initiatives in a deliberate attempt to create synergies. The benefits for both technology initiatives and demand-side initiatives will be much greater when paired together than when pursued in isolation. For instance, efforts to price roadspace are unauaccsaful because of strong political opposition and inelastic responses by motorists -- for the fundamental reason that drivers see few alternatives to driving. The new fees are seen as punishment, not as incentives to change.. If road pricing were introduced as a package with new service and vehicle options, such as smart paratransit and electric vehicles, and used to subsidize those services and products, as well as offset existing taxes then drivers would more willingly accept road pricing and more quickly embrace the new services and products. Similarly, pairing technology mandates (such as a requirement for zero emission vehicles) with fees o n dirtier cars and rebates for cleaner-burning cars would be far more effective than adopting ZEV mandates or "fee-bates" in isolation.

Social Equity

The emphasis on social equity is also all important feature of this scenario. Rather than exacerbating the chasm between social and economic classes, it aims to close them by providing high levels of accessibility, not only to the well-to-do, but also poorer people. Instead of IVHS benefits accruing to affluent drivers in the form of expensive safety, navigation, and control devices, the emphasis would be on improved accessibility for all.

Pricing Social

Attention to distributional effects does not, however, imply naivete about the capitalist nature of the economy. The highest priority needs to be given to full social cost pricing. This is a fifth feature of this scenario. The purchase and use of vehicles must be priced to account for the large unpaid social costs associated with motor vehicle use. Doing s o we note, does not necessarily place a larger burden on the poor (Cameron, 1994). In any case, the unpaid costs do not accrue evenly across vehicles, fuels and drivers, The unpaid costs may be near zero in some situations, such as uncongested, unpolluted areas, and huge in others, such as peak times in polluted downtowns. IVHS technologies can and should be used to create clever pricing strategies to target those trips and vehicles that are most. costly-- clever in the sense of being politically acceptable and not overly compromising equity goals. Examples include fees on polluting cars with rebates for zero emission and neighbor-hood electric vehicles; road pricing on congested roadways; pricing revenues used to cross-subsidize various smart paratransit operations; and pay-offs to local residents that have their streets priced or restricted in other ways.

Conclusion

Most of the current IVHS services and products will probably lead to large new markets far a wide variety of companies in communications, automotive manufacture, electronics and other hiqh-technology industries. We ask two questions, though; 1) Will those IVHS technologies provide large enough social benefits to justify large government. subsidies and support? 2) Is government being assertive enough in guiding technology development and deployment toward the public interest? We think not in both cases. We suggest a new vision of IVHS policy and investments that embrace social goals of environment quality, transportation access for all, and urban livability. If public funds and public agencies are to continue playing a prominent role, as they should given the large public presence in the transportation system, then a stronger social vision needs to be articulated and pursued. Expanding highway capacity and creating a market for private business is insufficient justification, A more appropriate and desirable IVHS vision is one premised on increased accessibility to goods and services without increased vehicle travel, greater consideration of the less privileged, enhanced environmental quality, and more livable communities.

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ATHENA

An Advanced Public Transportation / Public Information System

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ATHENA

An Advanced Public Transportation 1 Public Information System

Robert W. Behnke - Beaverton, Oregon

EXECUTIVE SUMMARY

ATHENA is an IVHS/NII-based "smart community" system . It is designed to be a user-friendly, taxpayer-friendly and environment-friendly way to:

reduce traffic congestion, gasoline consumption, air pollution and mobility problems, and

increase business, employment, education, recreation and other opportunities

for residents of urban, suburban and rural communities. Since it employs advanced communications and computer technologies to improve the transportation of people and goods, ATHENA is an Intelligent Vehicle-Highway Systems (IVHS) or "smart cars, smart highways' project. Since it employs advanced communications and computer technologies to improve access to information and information-based services, ATHENA is a National Information Infrastructure (NII) or "information superhighway" project.

ATHENA uses telephone-based information systems to create new types of on-call transportation services (e.g. smart jitneys, taxi-like Carpools) that can provide

guaranteed seating and door-to-door delivery at a low cost, even in low-density areas. ATHENA uses telephone-based information systems and other computer and communications technologies to integrate these new personalized transportation services with conventional transit, paratransit and ridesharing modes to develop more cost-effective public transportation systems. Market research studies indicate that this IVHS-based approach can reduce “cold starts” and vehicle miles traveled (VMT) per capita in U.S. metropolitan areas significantly, particularly during peak commuting hours.

The interactive computer system used by ATHENA to provide drivers and riders with the capability to quickly and easily find the best ways to get between any two points in the region - in light of the latest information about the weather, traffic congestion, transit accidents, construction projects and other conditions - will also be used to provide a wide variety of other personalized public information services. These include home-shopping, telebanking, electronic mail, auto-instructional training courses, video games, stock and bond prices, sports scores and reservations for trains, buses, restaurants and parking spaces. These and other new NII-based information services will not only reduce the need for some vehicle trips and VMTs per capita, they will also generate revenues from users and advertisers to help operate and maintain ATHENA.

The City of Ontario and its public and private partners are planning to conduct a comprehensive test of ATHENA in Southern California during the next five years. The purpose of this operational test is to measure how cost-effective ATHENA is in reducing transportation, energy and environmental problems and in improving the quality of life of residents and workers in suburban communities. The multi-county test area provides homes and jobs to people with a wide range of income levels and ethnic backgrounds. The test area also has some of the worst traffic congestion, air pollution and unemployment problems in Southern California and, therefore, in the United States.

JAUNT, one of the outstanding specialized and rural public transportation providers in the United States, and its public and private partners are planning to conduct an operational test of the demand-responsive transportation elements of ATHENA in and around Charlottesville in Central Virginia during the next three years. JAUNT is also the regional ridesharing agency for the five-county Thomas Jefferson Planning District. The primary objective of JAUNT's ODYSSEY project is to find out if a small fleet of "smart jitneys" can be used to create and maintain a large fleet of "taxi-like carpools" and significantly improve the cost-effectiveness of public transportation services in small cities and in rural areas.

If the IVHS operational tests of ATHENA are as successful as projected, similar systems can be set up quickly throughout the United States. Just as a small tax on basic telephone bills now finance many 9-1-1 emergency vehicle information systems, a small tax on gasoline sales could finance ATHENA-like "smart community" systems in the future. Just as the Electronic Telephone Directory System was the foundation of the French "Minitel" System, ATHENA-like "smart community" systems could be the foundation for the U.S. "Information Superhighway" Program.

BACKGROUND

The wasted time and wasted fuel from traffic congestion now cost U.S. residents more than $100 BILLION per year. The medical problems from gasoline pollution now cost U.S. residents an additional $50 BILLION per year. However, efforts to get more Americans to use transit and ridesharing since the late 1970s have been costly and ineffective.

For example, dividing the increase in annual transit subsidies by the increase in annual transit ridership in the U.S. since 1980 shows that each additional one-way passenger trip on transit has cost taxpayers more than $10 (in 1994 dollars) in capital and operating subsidies. Each additional commuter automobile that transit has been able to take off the road in the U.S. since 1980, therefore, has cost taxpayers more than $5,000 (in 1994 dollars) per year in increased subsidies. In some metropolitan areas, the cost to taxpayers has been much higher than this.

Although federal, state and local taxpayers in the U.S. have spent billions of dollars a year since 1980 to encourage greater use of multi-occupant vehicles (MOVs), both transit and ridesharing have continued to lose market share to single-occupant vehicles (SOVs). According to the latest Census Bureau data, the percentage of motor vehicle commuters who used MOVs declined from 29 percent in 1980 to 20 percent in 1990. Data collected in several metropolitan areas show that the use of MOVs is still declining throughout the United States.

There are many reasons for the decline of transit and ridesharing in U.S. metropolitan areas. Three of the most important are:

1. Automobile users, particularly SOV drivers during peak commuting hours, are heavily subsidized. Gasoline taxes and automobile registration fees cover only a portion of the costs of building, operating and maintaining the highway-road-street network and cover none of the costs of the traffic congestion delays, air pollution and other problems caused by SOV users.

2. Transit has become more costly for users as well as for taxpayers. Fares and subsidies per passenger trip have increased 60 percent and 130 percent faster than inflation since 1965, respectively, while the cost of operating automobiles has declined in real terms.

3. Most of the population and employment growth in U.S. metropolitan areas is occurring in the suburbs. In fact, more than half of all US. metropolitan area workers now have jobs in the suburbs and almost 90 percent of these workers also live in the suburbs.

The June 1992 National Housing Survey by pollster Peter Hart found that “80 percent of all Americans identify the traditional single-family detached home with a yard is the ideal place to live” (IA). It appears, therefore, that there will be pressures to continue the suburbanization trends of the past few decades into the future. Data collected by the American Public Transit Association (APTA) show that buses operated in low-density areas have operating costs per passenger trip that are 50 percent higher than buses operated in urban areas. (1B). A study by Barton-Aschman Associates (1C) found that sixty percent (60%) of Americans will not walk more than one-eighth mile (i.e. the length of two football fields) to a bus stop. It is very difficult, therefore, for U.S. transit agencies to obtain the funds to provide frequent and convenient bus, rail or paratransit services in low-density suburban areas.

Tables 1,2 and 3 were prepared to help those who are concerned with either government spending or with quality-of-life issues to understand what suburbanization has done to the use of conventional public transportation and conventional ridesharing. This background information is important in evaluating the cost-effectiveness of new approaches to reduce traffic congestion, gasoline consumption, air pollution and mobility problems in the United States.

Tables 1, 2 and 3 divide the journey-to-work trips of U.S. metropolitan areas (aka SMSAs) into four mutually exclusive commuting groups - those who live and work (1) within the central city and (2) within the suburbs, and those who commute (3) between the suburbs and the central city and (4) between the central city and the suburbs. This market segmentation strategy was originally developed by Dr. Phillip Fulton of the Census Bureau and refined by transportation consultant and author Alan Pisarski to analyze journey-to-work flows in U.S. metropolitan areas.

Table 1 provides important information about the variations in the use of public transportation and ridesharing in each market segment. For example, it shows that those who live and work in the central city use public transportation much more (18.2%) than those who live and work in the suburbs (1.8%). This is not surprising since quality public transportation services are difficult to find within lower-density suburban areas and it is more costly for users to park automobiles near work sites in higher-density central cities. The large difference in public transportation use between suburb-to-suburb commuters and central city-to-central city commuters is a direct result of rational consumers examining the pros and cons of the transportation alternatives available to them today and selecting the alternatives they find most attractive.

Table 1 also shows that those who live in the suburbs and work in the central city tend to use public transportation slightly more (8.1%) than those who live in the central city and work in the suburbs (5.8%), but significantly less than those who live and work in the central city (18.2%). Again, this is not surprising because it is more difficult to find quality public transportation for those who commute to and from the suburbs than for those who commute within the central city. Public transportation services for commuters to and from the suburbs usually require higher subsidies because the trips are longer and the passenger loads are highly peaked and highly directional. As Table 3 shows, three times as many suburban residents commute into the city as city residents commute into the suburbs. It is difficult to manage transportation resources efficiently under these conditions.

One of the facts presented in Table 1 that surprises many transit advocates is that commuters in U.S. metropolitan areas prefer Carpools and Vanpools (20.1%) to buses and trains (8.8%). As might be expected, suburb-to-suburb commuters use ridesharing modes much more (20.0%) than they use public transportation (1.8%). However, the fact that central city-to-central city commuters use lightly-subsidized ridesharing modes as much as they use heavily-subsidized public transportation modes is usually not expected. There is a lesson here for public transportation advocates about the importance of door-to-door service and guaranteed seating to attract suburban residents out of their automobiles, station wagons and vans.

Table 1

The Means of Transportation for Each Type of Motorized Journey-to-Work Trip By Workers Who Lived and Worked in SMSAs in 1980

Type of Commuter Work Trip		Percent of Workers For Each Type			
Place of Residence	Place of Employment	Drive Alone	Ride Share	Public Trans	Total
Central City	Central City	63.4%	18.4%	18.2%	100.0%
Central City	Suburbs	71.4%	22.8%	5.8%	100.0%
Suburbs	Central City	69.3%	22.6%	8.1%	100.0%
Suburbs	Suburbs	78.2%	20.0%	1.8%	100.0%
1980 SMSA Average		71.1%	20.1%	8.8%	100.0%
Projected 1990 SMSA Average		79.6%	13.2%	7.2%	100.0%

A cursory examination of Table 1 would lead one to conclude that suburb-to-suburb commuters use Carpools and Vanpools more than central city-to-central city commuters. Although this is true if one measures the rates of ridesharing of all motor vehicle commuters, it is not true if one measures the rates of ridesharing of all non-transit motor vehicle commuters. Table 2, which was derived from the data in Table 1, shows that among workers who commute by private vehicle, ridesharing is more popular among those who live and work in the central city (22.5%) than it is among those who live and work in the suburbs (20.4%), where employee parking is usually free and where it is difficult for carpoolers and vanpoolers to find attractive backup public transportation services.

Table 2

Rates of Ridesharing Use for Each Type of Motorized Journey-to-Work Trip By Workers Who Lived and Worked in SMSAs in 1980

Type of Commuter Work Trip		Percent of Non-Transit Motor Vehicle Commuters Who Rideshare	Percent of Non-Ridesharing Motor Vehicle Commuters Who Use Public Transit
Place of Residence	Place of Employment		
Central City	Central City	22.5%	22.3%
Central City	Suburbs	24.2%	7.5%
Suburb	Central City	24.6%	10.5%
Suburb	Suburb	20.4%	2.3%
1980 SMSA Average		22.0%	11.0%
Projected 1990 SMSA Average		14.2%	8.3%

Table 2 also shows that public transportation continues to be much more popular for commuters who live and work in the central city and don't rideshare (22.3%) than for commuters who live and work in the suburbs (2.3%) and don't rideshare. It is unfortunate that it was not possible to obtain segmented journey-to-work data from the 1990 census for Table 1,2 and 3. The unsegmented 1990 data shows significant declines in public transportation's share of commuting trips and even more significant declines in ridesharing's share of commuting trips in U.S. metropolitan areas since 1980. Although no surprises are anticipated, it would be interesting to examine the changes in market share for each of the four commuting groups since 1980.

Table 3

Change in Journey-To-Work Trips by Workers Who Live and Work Within SMSAs With a Population of 250,000 or More

1960-1990

Type of Journey-To-Work		Percent of Workers			
Place of Residence	Place of Employment	1960	1970	1980	1990 Projected
Central City	Central City	47.2%	37.6%	31.7%	27.0%
Central City	Suburbs	5.2%	7.5%	6.6%	6.0%
Suburbs	Central City	17.1%	18.6%	19.8%	20.0%
Suburbs	Suburbs	30.5%	36.3%	41.9%	47.0%
	TOTAL SMSA	100.0%	100.0%	100.0%	100.0%

Table 3 traces the changes in the relative size of each of the four U.S. metropolitan area commuting groups between 1960 and 1990. It shows that more than half (53%) of all jobs in U.S. metropolitan areas are now located in the suburbs, up from 35.7 percent in 1960, and that almost 90 percent of all these suburban jobs are filled by suburban residents. Table 2 also shows that more than two-thirds (67%) of all U.S. metropolitan area workers now live in the suburbs, up from 47.6 percent in 1960, and that less than 30 percent now commute into the central city. After examining the suburbanization trends of recent decades, it should not be surprising that the use of public transportation and ridesharing has declined and that traffic congestion has increased in U.S. metropolitan areas. It should also not be surprising that the productivity of the U.S. transit industry has declined, in terms of passenger trips per vehicle mile, and that transit fares and transit subsidies per passenger trip have risen much faster than inflation in U.S. metropolitan areas. References 2-4 discuss these cost and subsidy issues in more detail.

STATEMENT OF THE PROBLEM

By any yardstick, U.S. metropolitan areas are still losing their battles against traffic congestion, and the efforts to reduce our dependence on imported oil and to reduce motor vehicle-generated air pollution are going much slower than hoped. Table 4, which uses data obtained from the U.S. Census Bureau, shows that 3.8 million fewer workers used multi-occupant vehicles (MOVs) for commuting in 1990 than in 1980, even though the work force increased by 18.5 million during this same period. The evidence is mounting that these trends are continuing into the 1990s.

Table 4
Means of Transportation to Work
in the U.S.: 1990 and 1980

	1990 Census		1980 Census	
	Number	Percent	Number	Percent
Drive Alone	84,215,298	73.2%	62,193,449	64.4%
Ride Share	15,377,634	13.4%	19,065,047	19.7%
Public Transportation	6,069,589	5.3%	6,175,061	6.4%
Other	9,407,753	8.1%	9,183,739	9.5%
Totals	115,070,274	100.0%	96,617,296	100.0%

The evidence is also mounting that driving a single-occupant vehicle to a park-and-ride lot to take a bus, train, Carpool or vanpool does little to reduce air pollution.“ For a typical trip of 5 to 20 miles, approximately 50 percent of the emissions come from the cold-start stage, occurring in the first minute after the engine is started. For a seven mile trip, 90 percent of the emissions occur in the first mile.” (1D)

“Because cold-starts generate such a significant share of the pollution for

> most trips, auto use reduction strategies should eventually give greater emphasis to reducing the number of vehicle trips taken, rather than simply reducing total miles traveled. For example, a 20-mile trip by a Vanpool of six passengers where each rider drives to and from a park-and-ride lot would reduce miles traveled and increase average vehicle occupancy. But it would do relatively little for air pollution reduction, since each rider started and drove his or her own car to the park-and-ride lot. On the other hand, if that same Vanpool picks up riders at home, it would make a significant contribution to emissions reductions". (1D)

Public transportation and ridesharing must become less dependent on "park-and-ride" lots and "kiss-and-ride" feeder services in suburban areas in order to reduce "cold starts" and air pollution levels.

Improved transit/paratransit/ridesharing services are a key to reducing traffic congestion and air pollution problems in suburban areas, where most metropolitan area residents now live and work. However, it does not appear that any mix of conventional transit, paratransit and ridesharing services will be able to provide a level of service that is attractive to residents in these low-density areas, at subsidy levels that are attractive to taxpayers. Something more is needed to solve the transportation, energy and environmental problems of suburban areas in a cost-effective manner.

Improved transit/paratransit/ridesharing services are also a key to improving the quality of life in rural areas. However, it does not appear that any mix of conventional transit, paratransit and ridesharing services will be able to provide a level of service that is attractive to residents in these low-density areas, at subsidy levels that are attractive to taxpayers. Something more is needed to solve the transportation, energy and environmental problems of suburban areas in a cost-effective manner.

> “Although the drama of inner city poverty walks away with the headlines, poverty in the countryside, particularly among the working poor, is becoming more acute,” according to a study by Center on Budget and Policy Priorities, a non-partisan, non-profit research group. “Nearly one in three of all hourly-paid rural workers earn at or near the minimum wage.” (2A)

> “Though the Census Bureau reports the population of Farm Belt states is up, only 4.9 million (7.6%) of the 64 million people (approximately 25 percent of the population) live in the USA’s 2,400 rural counties, but nearly 500,000 of them are leaving annually” . . . “The million who abandoned small towns have moved into urban areas, increasing traffic congestion, air pollution and other problems there. Rural towns have to provide a reason to stay. We don’t just want to preserve rural areas for people to drive to on weekends”. (2B)

The United Sates must develop new ways to give rural area residents - particularly those who do not drive because they are too young, too old, too poor or too disabled - better access to people, goods, services and information available to urban area residents.

GENERAL METHOD OF APPROACH

Over the years, many transportation experts have pointed out that the traffic congestion, gasoline consumption, air pollution and parking problems of the U.S. are not caused by a shortage of transportation resources. Most areas in the U.S. have enough transit vehicles and automobiles to handle their existing travel demands, using only the front seats of the automobiles. Most areas also have enough roadways and parking to handle all these multi-occupant vehicles without traffic congestion.

Most areas of the U.S. also have enough automobiles and other transportation resources to provide good public transportation services for all their existing residents, including he poor, the aged and the disabled. The transportation-related problems of the U.S. are largely the result of not having information systems that will permit decision-makers to manage their existing transportation resources effectively, particularly in low-density suburban and rural areas.

The following section discusses the French “Minitel” System, German “Smart Bus” Systems, and the California “Smart Traveler” System. These three innovative information systems provide insights into possible ways to use new technologies to reduce traffic congestion, gasoline consumption, air pollution and mobility problems in the United States. The following section also discusses The ATHENA System.

DISCUSSION

The French “Minitel” System

During the 198Os, the government-owned telephone company in France distributed small, low-cost, black-and-white computer terminals (called Minitels) to millions of homes and offices instead of printed telephone books. Using a Minitel terminal, connected to the telephone line, anyone could find the current listed phone number of any person or business in France. Unlike the printed phone book, the “Minitel Electronic Directory” is always up to date. As a result of this system, the telephone company received fewer requests for information and directory service personnel could be transferred to other activities.

Since most Minitel terminals are only used a few minutes a month for directory information, the telephone company invited other government agencies and the private sector to provide other telephone-based, videotex information services (e.g. home banking, teleshopping, electronic mail, video games) to Minitel owners for a fee. Today, there are more than 10,000 information services available to Minitel users and they generate millions of dollars in revenue to the telephone company from advertisers, users and fees for centralized billing and collection services. They also provide jobs.

Although the graphics and the technologies are primitive by today's PC standards, the Minitel videotex system is a successful National Information infrastructure (NII) project. The Minitel system can also be virwed as a successful, public-private IVHS/Advanced Traveler Information System (ATIS) project, because users can use it to find transit schedules, check traffic conditions on the freeways, book train reservation, order taxis, etc. at any time, without operator assistance. By imbedding the ATIS functions in a multi-purpose information system, France was able to save hundreds of millions of dollars in design, development, implementation, training, marketing and administrative costs. For more information on the French Minitel System consult Reference 7.

German Smart Bus Systems

In order to increase transit ridership and reduce operating costs in suburban and rural areas, some counties in Germany have installed new transit-telecommunications systems (e.g. FOCUS) that permit residents to request "bus" rides between any two checkpoints (e.g., bus-stops) at any time. These "smart bus" systems are user-friendly. A prospective rider does not need to know the route number, the schedule of the "bus", or the are structure. To use a "smart bus" (i.e. a "bus" equipped with an on-board computer terminal and a wireless data a wireless data communications link with the control dispatching computer), a prospective rider calls an easy-to-remember telephone number. A telephone operator enters the following trip request information into a computer terminal: (1) Origin checkpoint number, (2) Destination checkpoint number, (3) Requested departure time (including ASAP), (4) Number of people traveling together, and (5) Special needs (e.g. wheelchair, seeing-eye dog, baby stoller).

The central computer matches the trip request against the available resources, and quickly dispatches the most cost-effective bus, mini-bus, or microbus (i.e. taxi) to pick-up the rider and his or her traveling companions. The telephone operator tells the passenger when to be at the checkpoint, the fare, and the number of the bus, van or automobile (i.e. taxi) that will provide the ride. The average waiting time for a passenger is less than eight (8) minutes. Alternatively, riders can use kiosks at some major bus stops to enter trip requests directly into the FOCCS computer and bypass the telephone operator. However, the waiting time for the "smart bus" then starts at the bus stop rather than in the home, office, shop, etc. of the caller. This can be a disadvantage to users in bad weather. Furthermore, the kiosk tend to be costly to install, operate and maintain.

The FOCCS system can use any bus, mini-bus or micro-bus in fixed-route mode, route-deviation mode or demand-responsive mode, at any time of the day or night. This multi-modal transportation capability had helped to improve service and to reduce operating costs in low-density areas and during low-travel periods. Despite the sophistication and elegance of the FOCCS transit-telecommunications system, however, the Germany and Australia are barely enough to cover the costs of the additional computer and telecommunications equipment that is required. Although the FOCCS "smart bus" system is more user-friendly than traditional transit- paratransit systems, it is not more taxpayer-friendly. For more information on German "Smart Bus" Systems consult Reference 3.

California Smart Traveler (CST) System

Both the California Department of Transportation (Caltrans) and USDOT have established major IVHS programs to investigate ways that computers, telecommunications and other electronic technologies could be used to improve the cost-effectiveness of local and regional transportation systems. In the early 1990s, these organizations jointly sponsored two "California Smart Traveler" studies to investigate how telephone-based information systems could be used to:

- Develop new types of low-cost, door-to-door public transportation services.

- Integrate these new services with conventional transit, paratransit and ridesharing modes to create more user-friendly and more taxpayer-friendly public transportation systems.

- Provide drivers and riders with the capability to quickly and easily find the best ways to get between any two points in the region, in light of the latest information about the weather, traffic congestion, construction activities, transit accidents, etc.

The "California Smart Traveler" studies also examined a number of potential test sites and prepared cost projection for IVHS operational tests in three suburban communities in the State.

Caltrans, USDOT, Tri-Met (Oregon's largest transit agency) and others have been studying FOCCS and other German "smart bus" systems to find ways to make these systems more user-friendly and more taxpayer-friendly, particularly for use in low-density area of the United States. For example, substituting door-to-door services for checkpoint-to-checkpoint services would make the FOCCS system more user-friendly. Adding features that would reduce subsidies per passenger trip would make the FOCCS system more taxpayer-friendly.

One way to make the German FOCCS system both more user-friendly and more taxpayer-friendly is to add an interactive, multimedia, front-end computer to the central dispatching computer system. With this capability, would-be riders would be able to simulate the use of a FOCCS kiosk with a touch-tone telephone (i.e., audiotex), personal computer (i.e. videotex) or some other input/output (I/O) device. The front-end computer would let a would-be rider bypass telephone operators and quickly enter his or her ride request directly into the FOCCS dispatching computer by pressing one or two buttons on a touch-tone telephone, PC or other I/O device. This would make the FOCCS system more user-friendly when the telephone operators are busy. The front-end computer would also reduce the number of telephone operators required to handle a given number of ride requests each day. This would make the FOCCS system more taxpayer-friendly. The proposed California Smart Traveler System has an interactive, multimedia, front-end computer in its design.

A second way to make FOCCS more user-friendly and more taxpayer-friendly is to add new ridesharing services. The front-end computer makes it possible to develop single-trip carpool matching capabilities. A would-be rider would be able to request a ride (e.g. between home and school) by merely pressing one or two keys on a touch-tone telephone, PC or some other I/O device. The detailed specifications (e.g. origin address, destination address) for the trip will be pre-stored in a computer file. A would-be driver would be able to offer a ride (e.g. between work and home or points in-between) by merely pressing one or two keys on a touch-tone telephone, PC or some other I/O device. The central dispatching computer would try to match them with other ride offers and ride requests. This is a way to provide low-cost, door-to-door transportation services to residents of low-density suburban and rural areas and to provide part-time work for single-trip carpool drivers. The proposed California "Smart Traveler" System also has single-trip carpool matching capabilities in its design.

The following two subsections outline the process for requesting and offering single-trip or taxi-like carpool (TLC) rides in the California Smart Traveler (CST) System:

Requesting a Single-Trip Carpool Ride

An individual desiring to obtain a single-trip carpool ride would make a telephone call to the local ride-request number. The would-be rider would provide his of her travel itinerary, including date-time, origin, destination and number of seats required . The information would also include any specific restrictions or preferences (e.g. no smoking, no radio). The CST computer system would then search through the database of active information about the make and color of the vehicle, license number, driver's name or ID number, telephone number, scheduled pick-up time, etc. although this is not a requirement, the would-be rider could call the would-be driver to confirm the match and to "iron-out" any other details.

If no match is found, the would-be rider would be told about the availability of other public transportation services for his or her trip or would be asked to call back at a scheduled time to see if a match could be found. In the latter case, the would-be rider's request would be added to a database of active single-trip carpool ride requests. The CST computer system would continue to analyze new ride offers to look for a match until the scheduled call-back time.
Alternatively, the CST computer could notify the would-be rider via a paging service as soon as a match was found. In the future, would-be riders who own

micro-cellular Personal Communications Network (PCN) phones or Personal Digital Assistants (PDAs) could be "called" as soon as a match was found and provided with the match details.

Offering a Single-Trip Carpool Ride

individual desiring to offer a single-trip carpool ride would make a telephone call to the local ride-offer number. The would-be driver would provide his or her travel itinerary, including date-time, origin, destination and number of seats available. The information would also include any specific restrictions or preferences. The CST computer system would then search through the database of active single-trip requests for a match. If a match is found, the would-be driver would receive information about the location of the pick-up point, riders name or ID number, scheduled pick-up time, etc. although this is not a requirement, the would-be driver could call the would-be rider to confirm the match and to "iron-out" any other details.

If no match is found, the would-be driver would be asked to call back at a scheduled time to see if a match could be found. In this case, the would-be driver's offer would be added to a database of active single-trip carpool ride offers. The CST computer system would continue to look for a match until the scheduled call-back time. Alternatively, the CST computer could contact the would-be driver via a paging service as soon as a match was found. In the future, would-be drivers who own PCN phone or PDA devices or whose vehicles are equipped with cellular phone could be "called" in their vehicles. The ability to contact a would-be driver enroute to his her destination would increase the likelihood of finding a would-be rider.

Another way to make the German FOCCS system more user-friendly is to add driver information services. Connecting the multimedia front-end computer to a regional Traffic Operations Center's (TOC's) computer system would permit drivers to get more timely and more accurate information about the status of the regional roadway network in the future. By pressing one or two keys on a PC or a telephone, a driver of a taxi, truck, shuttle or private automobile would be able to quickly find out if his or her planned route is experiencing unusual traffic delays and, if so, to find the best alternative route. This personalized traveler information service would be particularly useful during commuting hours and during storms. The proposed California "Smart Traveler" System is being designed to provide personalized traveler information services in the future. The ATHENA System is an enhanced California "Smart Traveler" System. For more information on the California "Smart Traveler" System, consult References 4 and 5.

The ATHENA System

USDOT and IVHS AMERICA released a draft National IVHS Program Plan which provides a blueprint for the work needed to achieve the goals and objectives stated in the IVHS Strategic Plan. The draft Program Plan focuses on IVHS services from the perspective of potential users. It identifies 27 IVHS user services and sets out a program for the development and deployment of each service over the next five years. One of these IVHS user services is the Ride Matching and Reservation user service.

The National IVHS Program Plan describes the Ride Matching and Reservation user service as a mechanism for expanding the market for shared-ride transportation by providing real-time ridematching information, along with reservations and vehicle assignment, and by serving as a clearing house for financial transactions. According to the program plan, these capabilities will not only expand the market for ridesharing as an alternative to single-occupant vehicles (SOVs), they will also provide enhanced alternatives for special population groups. For example, “Human services agencies (could) benefit from this user service by having access to broader transportation service options with reduced administrative overhead”. (6)

Although the National IVHS Program Plan notes the success of low-technology single-trip ridematching systems (i.e. “slug lines” or “instant/casual carpools”) for the Shirley Highway Corridor in Washington D.C. and the Bay Bridge Corridor in the San Francisco Bay Area, it does not mention that these are very special situations. Both of these corridors have attractive incentives for using MOVs rather than SOVs, dependable public transportation services for backup, and there are “enough” drivers and riders traveling in the same direction at the same time. Nor does the Program Plan mention that there are few, if any, successful single-trip Carpool operations in other high-volume travel corridors in the United States and there are no successful single-trip Carpool operations in any low-volume travel corridors in the United States.

It will be difficult to establish successful single-trip Carpool systems in low-density suburban and rural areas. One reason is the costs of providing attractive backup with either conventional or “smart” transit-paratransit modes will be very high. A second reason is it will be difficult to attract drivers before there are riders and riders before there are drivers. This is the “chicken-and-egg” problem of single-trip ridesharing. A third reason is the problem of sustaining rider and driver interest if the match rate is low for single-trip Carpools. This low match rate for conventional ridesharing services is major metropolitan areas (e.g. Washington D.C., Los Angeles) suggests that it will be difficult to maintain a “critical mass” of drivers and riders in low-density areas.

The ATHENA System contains enhancements to the proposed California Smart

Traveler System that address both the "chicken-and-egg" and the "critical mass" problems for single-trip ridesharing in low-density areas. One enhancement is the use of "smart jitneys" to provide dependable and low-cost backup services for single-trip Carpools. "Smart jitneys" (e.g. usually 8-12 passenger vans) will be equipped with personal digital assistants (PDAs). These devices will enable a small fleet of "smart jitneys" to provide flexible-route, personalized MOV transportation services in corridors where conventional public transportation services would not be cost effective.

Most "smart jitneys" will be owned or leased by driverswho regularly make long trips on the same routes (e.g. home to work, school to home) in the region. Workers, students and others who drive "smart jitneys" will be told by their on-board PDA when and where to deviate from their regular routes to pick up and deliver passengers enroute. These "smart jitney" drivers will be paid a minimum each month (e.g. $400) for spending on the order of one hour per day, five days a week, providing personalized MOV transportation services on their way to and from work, school, etc.

When a "smart jitney' gets to a pick-up point, the driver will use the on-board communications equipment to advise the ATHENA dispatching computer if the passenger was on-board or a "no show". The on-board PDA will then tell the driver the location of the next stop to pick up or deliver passengers. In the future, GPS receivers may be added to the 'smart jitneys" to provide automatic vehicle location (AVL) capabilities that can be used to check if the "smart jitney" driver was at the right place at the right time. This AVL capability should improve the quality of transportation services for " smart jitney" riders and provide an extra measure of security for both " smart jitney" drivers and riders.

If a typical "smart jitney" driver spends 15 minutes picking up riders in his or her origin neighborhood and another 15 minutes delivering riders in his or her destination neighborhood, the average delay time and the maximum delay time for a smart jitney rider will be 15 minutes and 30 minutes, respectively. Although these delays in door-to-door travel time may be acceptable to some riders, many riders would rather save this time by driving alone. These time-sensitive riders will be able to eliminate or greatly reduce travel-time delays by using single-trip Carpools most of the time. Single-trip Carpools, which need not be equipped with "smart" equipment (i.e. PDAs), will only pick up one passenger group per trip and will deliver the group to its destination without intermediate stops. The single-trip Carpool driver will get the name and address of the passenger over a telephone, usually before starting out. However, single-trip Carpool vehicles that are equipped with cellular phones or PDA terminals can obtain this information enroute.

Although ATHENA's "smart jitneys" are expected to be more "taxpayer friendly" than fixed-route buses or dial-a-ride minibuses in low-density rural and suburban areas, they will still need to be subsidized. Consequently, the fleet of "smart jitneys" in the area will be small and their primary mission will be to complement and supplement a much larger fleet of very low subsidy vehicles (e.g. single-trip carpools, taxi-like Carpools (TLCs), voice-dispatched jitneys, parataxis). Since these very low-subsidy vehicles will not require on-board PDA terminals or other computer/telecommunications equipment, they can be added to regional fleet of ATHENA public transportation vehicles quickly, and at a low-cost to taxpayers.

The interactive computer network that is used by ATHENA to process ride offers and ride requests, to dispatch and monitor vehicles, and to collect and disburse "fares", will also be used to provide a wide variety of personalized information services to travelers in the future. By merely pressing one or two keys on a touch-tone telephone, cellular phone, personal computer, multi-media kiosk, personal digital assistant (PDA), etc., drivers and riders will be able to find the best ways to get between any two points in the region in light of the latest information on weather conditions, traffic conditions, transit accidents, construction activities and others.

Advertisers who sponsor these pre-trip or en-route traveler information services and new types of traveler services information (e.g. electronic Yellow Pages) will keep the cost of ATHENA low to both users and taxpayers. Like the Minitel system in France, the ATHENA system will also encourage government agencies and private organizations to utilize its telephone-based computer network to provide a wide range of new information services (e.g. home shopping, telebanking, electronic mail, video games, auto-instructional training courses) to community residents.

France has spent 15 years and over $2 billion (in 1994 dollars) to develop a multi-purpose, telephone-based information system. The French Minitel system has created many new business, employment, education and other opportunities for residents of urban, suburban and rural areas. Users and advertisers now pay all of the costs of operating and maintaining the nationwide French system. ATHENA will take full advantage of the lessons learned by operators of the Minitel system and other videotex information systems (e.g. Prodigy, CompuServe).

Moreover, ATHENA plans to use touch-tone telephones, as well as personal computers (PCs) and videotex terminals, to provide access to ATHENA’s wide range of information services. This will not only cost much less than the French approach to get it started, it will also save time in establishing a critical mass of users who are ready to use ATHENA’s driver, rider and other information services.

CONCLUSION

Intelligent Vehicle-Highway Systems (IVHS) technologies can be used to develop new types of public transportation services (e.g. “smart jitneys”, taxi-like Carpools) and to integrate these new services with conventional transit, paratransit and ridesharing modes to form multimodal Advanced Public Transportation Systems (APTS). Preliminary market research studies indicate that APTS can significantly reduce traffic congestion, gasoline consumption, air pollution and mobility problems at a low cost to taxpayers.

A user-friendly Advanced Traveler Information System (ATIS) is a critical component of a well-designed APTS. By pressing one or two buttons on a touch-tone telephone, personal computer (PC), videotex terminal or other input/output device, a “smart traveler” will be able to quickly find the best ways to get between two points by public transportation. These public transportation vehicles can be either privately-owned or publicly-owned ferries, trains, buses, minibuses, vans or automobiles. Their drivers, like the drivers of some rural fire departments, can be full-time, part-time, piece-work, or volunteers.

A user-friendly ATIS system is also an important partner for a well-designed Advanced Traffic Management System (ATMS). By pressing one or two buttons on an input/output device, a “smart traveler” will be able to quickly find the best routes to take to drive between two points, based on the latest information about accidents, construction projects, weather, etc. Integrating ATIS with other audiotex or videotex information services (e.g. home-shopping, telebanking, electronic mail, video games, interactive training programs) could reduce the need for some trips and VMTs per capita, as well as the cost of the ATIS services.

ATHENA has been designed to help urban, suburban and rural communities use their existing telephone systems to:

- make more efficient and effective use of their existing public and private transportation resources,

- increase the mobility of all residents, including the poor, the aged and those with disabilities,

- reduce traffic congestion, air pollution and parking problems,

- control spending at all levels of government,

- reduce oil imports and improve the U.S. balance of trade, and

- create new transportation service jobs, information service jobs, and other jobs for local residents.

If the IVHS operational tests of ATHENA are as successful as projected, similar systems can be set up quickly throughout the United States. Just as a small tax on basic telephone bills now finance many 9-1-1 emergency vehicle information systems, a small tax on gasoline sales could finance ATHENA-like “smart community” systems in the future. Just as the Electronic Telephone Directory System was the foundation of the French “Minitel” System, ATHENA-like “smart community” systems could be the foundation for the U.S. “Information Superhighway” Program.

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A LEAST COST APPROACH TO COMPARE IVHS LAND USE, MANAGEMENT AND MULTI-MODAL INFRASTRUCTURE ALTERNATIVES

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WHY A LEAST COST APPROACH?

The new environment for transportation planning in the 1990s presents a challenge to planners and decision makers in evaluating multimodal alternatives. The Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991 provides new intermodal funding flexibility. Also, ISTEA requires consideration of efficiency, socioeconomic and environmental factors in the evaluation process. The Act's emphasis on "management" as against infrastructure investment calls for development of procedures that allow comparisons across management-type solutions (e.g. land use and demand management) as well as investment-type solutions. Additionally, the Clean Air Act Amendments (CAAA) of 1990 also emphasize vehicular demand management as an important strategy to reduce air pollutant emissions. Future evaluation procedures will thus need to: (a) give adequate consideration to economic efficiency and social and environmental impacts; and (b) be capable of allowing comparisons across modes as well as across infrastructure investment and management strategies.

In the past, Metropolitan Planning Organizations (MPOs) have usually compared transportation projects using measures of effectiveness which are uniquely applicable to a specific mode. For example, measures of highway project effectiveness commonly used are improvement in highway level of service (LOS) or highway speed, reduction of highway accidents or savings in highway user costs. Transit project effectiveness, on the other hand, is usually measured by transit ridership or public capital and operating costs per new rider. It is likely that IVHS projects will also use different measures of effectiveness, depending on their modal orientation. If IVHS projects or programs benefitting different modes (e.g. highway solo-driver, highway shared ride or transit) are to be compared amongst one another or with other types of investment or management strategies, common measures of effectiveness will have to be used i.e. measures applicable across modes, and across supply-enhancing and demand-reducing strategies.

The least cost approach uses a common measure (i.e. cost) which is applicable across all types of alternatives. It attempts to account for the full costs of each alternative. The main advantages of this approach are: (1) It allows comparisons of transportation investments across modes; (2) It allows comparisons of major investment alternatives (e.g. new highway or transit capacity) with management alternatives (e.g. IVHS pricing strategies, land use strategies and other strategies which moderate travel demand).

The least cost approach facilitates accounting for costs of competing highway-oriented and transit-oriented IVHS projects in a comparable manner. For example, in current practice, when computing costs for for transit alternatives, analysts include vehicle capital and operating costs and costs for garaging the vehicle. On the other hand, analysts computing the costs for highway travel may include the variable portion of vehicle operating costs (i.e. costs for gas and oil, maintenance and tires), but exclude the fixed costs (i.e. vehicle ownership costs and parking or garaging costs at each end of the trip). For valid comparisons across modes, the full costs of each alternative will have to be taken into account, not just costs incurred by transportation agencies for capital investment and operation. Public costs incurred by non-transportation public agencies (e.g. police, fire, court systems, etc.), fixed private costs (e.g. auto ownership costs), and external social and environmental costs cannot be ignored. From a societal point of view, it is irrelevant whether costs are borne privately, publicly or socially.

The base to which alternatives are compared in current practice also poses a problem. In current practice, the base used for comparison is usually a future year “do-nothing”,or “no-build plus Transportation System Management (TSM)” alternative. Benefits of the alternatives are calculated based on savings with respect to the base. However, the savings estimates will not be real if the base itself could never exist in reality, which is often the case. For example, before the large delays forecasted under base conditions could ever occur, it is probable that travelers would change their travel patterns (either traveling at different times of the day, by different modes, to different destinations, or by different routes); or they may even decide not to make the trip. It is therefore probable that benefits claimed for alternatives by comparing them to the base are inflated.

The least cost approach embodies the following major differences from current practice:

1. A comprehensive accounting is made of the full costs of the current transportation system as well as the future alternatives, to the maximum extent feasible.

2. The effectiveness of alternatives is measured using a common measure which describes the chief “deliverable” of an urban transportation system i.e. access. The measure is person trips served, or the ability of alternatives to accommodate the future increment in demand for trips. Where policies to shift person travel demand to telecommutmg, walk or bicycle modes are to be evaluated, it is

assumed that walk and bicycle trips as well as "eliminated" trips from telecommuting are included in the total of trips accommodated. Each alternative is assumed to be capable of providing for the increment in demand for access, but at differing incremental cost, reducing the problem to one of finding the least cost alternative.

3. Incremental costs of alternatives may be calculated relative to a real base, i.e. the existing system and its travel demand, performance and cost.

4. Major investment alternatives oriented to any mode can be compared. Also, they can be compared with alternatives which involve no differences in public investment, but only policy differences (e.g. land use plan and zoning changes, trip reduction ordinances, and parking surcharges).

5. Incremental cost per added trip may be computed by dividing the incremental costs above the current year costs by the increment of tips served above the current year trips. This measure clarifies the true costs of growth.

APPLYING THE LEAST COST APPROACH

The approach is demonstrated in this paper through application to a case study using a simplified microcomputer-based spreadsheet (LOTUS 123). The focus of the case study is on comparison of land use and IVHS strategies. A previous paper presented a case study application of the approach focusing on evaluation of major transportation investments (8). Unit costs of travel differ depending primarily on two variables: (1) time of day e.g. peak or off-peak; and (2) type of trip e.g. personal travel for work, personal travel for non-work purposes, or freight travel. These two variables can be used to categorize travel demand into six travel markets. The case study application focuses on the peak period work (person) travel market.

All costs for providing access are included in the evaluation of costs for accommodating future trips, whether or not the tripmaker bears them directly. Costs may be categorized based on whether or not they have market prices. Market-priced costs include dollar costs borne privately by system users and publicly by transportation or other agencies. Market-priced costs may be categorized as private vehicle costs, public transportation system costs, highway facility costs and safety and security costs. Costs which have no market prices include travel time costs, environmental costs, pain and suffering components of accident costs, and other social costs such as community disruption. They may be borne by system users (e.g. travel time costs) or externally (e.g. environmental costs).

Dollar value estimates of many of these costs may be found in the literature, as indicated in Table 1. However, there are other social costs for which it is unlikely that dollar values can be developed -- they will simply have to be listed for consideration in the decision-making process. Examples of these impacts are: national defense implications for protection of oil sources, community cohesion or disruption, community pride, aesthetics, accessibility of disadvantaged segments of the population, loss of cultural, historic, recreational and natural resources, loss of open space and depletion of non-renewable energy resources.

Cost parameters used in the application example presented in this paper are based on values shown in Table 1, with adjustments for IVHS alternatives (see Table 3) to account for cost increases due to IVHS gadgetry (both public and private) and cost savings from reduced accidents and reduced needs for new highway lanes. More detailed methods for calculation of costs could certainly provide more accurate estimates of costs. The purpose of the example is simply to demonstrate how the approach may be used in real world situations, and not to provide definitive answers about the cost-effectiveness of the alternatives evaluated.

The basic process for computation of costs is indicated in Figure 1. The process relies heavily on output from the four-step travel demand modeling process (9), both for the base year condition as well as for future year alternatives. As Figure 1 indicates, the outputs from the travel models needed for input into the costing procedures are the following, for each person travel market: (1) Person trips by mode (from mode choice); (2)Travel miles (from trip assignment) by mode -- person miles of travel (PMT) on transit line-haul and transit access modes, as well as vehicle miles of travel (VMT) on the highway system; (3) Travel minutes (also from trip assignment) by mode. As Figure 1 indicates, the travel measures output from the travel models are input into cost models which provide unit cost parameters for the various cost components. Unit costs may be costs per trip, per PMT, per VMT or per minute of travel time, as indicated in Table 1.

The case study urban area was Washington, DC. A previous study (10) provided model output data. In cases where needed travel parameters were not available from the study report, national averages from the Nationwide Personal Transportation Study (NPTS) were used (11). The Washington, DC study involved analysis of the systemwide travel and transportation system impacts of two alternative urban development patterns for the year 2010. The first alternative (BAL) promoted a closer balance between housing and employment growth, both regionwide and within individual "employment growth" subareas within the region. The second alternative (CONC) maintained regionwide balance between housing and employment as in the first alternative, but concentrated employment in areas with good transit service and significant levels of transit use at the job end of the work trip. The study also provided a base model run for 1995. To demonstrate the application of the least cost approach to IVHS alternatives, two new alternatives were developed by the author. Both built upon the concentrated (CONC) alternative. The first alternative, IVHS(S), assumed use of only supply-enhancing IVHS technologies such as technologies to smooth the flow of highway traffic, to provide priority to transit vehicles, to provide real-time information to highway and transit users, and to enhance highway and transit safety. The second alternative, IVHS(D), added to IVHS(S) by managing demand through pricing mechanisms for peak use of highways and for parking.

The travel data and results of the cost analysis are presented in Table 2. A comparison of total costs which were calculated by the spreadsheet suggests that the concentrated (CONC) alternative has lower total costs than the balanced alternative (BAL). Based on the liberal use of cost and travel demand assumptions for IVHS by the author, the IVHS(s) scenario could save about $400,000daily in aggregate mobility costs relative to the concentrated (CONC) scenario. For the IVHS(D) scenario, the savings would be about $6.6 million daily. Public agency costs (for highways and for public transportation deficits assuming a 40% farebox recovery rate) would be about $244,000 lower daily under IVHS(S) and $3.4million lower daily under IVHS(D). As indicated earlier, the cost totals exclude certain environmental and social costs which are primarily related to auto travel. Since the IVHS(D) scenario involves much less auto travel than the other scenarios, additional savings in environmental and other social costs may be expected.

Table 2 also indicates that, while providing mobility currently costs about S5.9Oper work trip (including travel time), the cost per new trip added by 2010 will be significantly higher under all future alternatives except for IVHS(D). Average cost per added trip (including travel time) amounts to $11.34 under the balanced scenario, $10.97 under the concentrated scenario and $10.48 under the M-IS(S) scenario, but only $3.00 under the IVHS(D) scenario. Table 2 also provides a breakdown of market-priced costs by mode. The relative economic efficiency of accomodating additional trips by alternative modes is reflected in the estimates of market-priced costs per added auto trip and per added transit trip. The average cost to accomodate an additional auto trip is negative for IVHS(D) due to a reduction in single occupant vehicle (SOV) trips relative to the base year. It is estimated to be about $9.00 under the first three future scenarios, with slightly lower costs for M-IS(S) due to savings in new highway capacity and accident costs. These auto costs are almost twice the costs to accomodate an additional transit trip, which are estimated to be about $4.70.

CONCLUSIONS

This paper has explained the theory in support of a least cost approach to compare transportation investment alternatives across modes, and to compare significant changes in management and land use policies. The approach is based on assessing the relative economic efficiency of alternatives by determining which alternative involves the least total cost for providing access for various travel markets. The approach has been demonstrated through application of a simplified analysis technique using a LOTUS 123 spreadsheet. Results from the analysis have been presented for demonstration *purposes* only. The application of the approach to the case study suggests that the approach can be a useful tool for comparison of multimodal investment, IVHS, management and land use policy alternatives.

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TABLE 1

EXAMPLE UNIT COSTS

Cost Component	Unit Cost	Source
Market-Priced Costs:		
Vehicle		
Operation	7.4 cents/VMT	Ref. 1 (less 1 cent fuel tax)
Ownership	$3.12/trip	Ref.1 (less acc. insurance)
Parking – Downtown	$3.00/tlip	Ref.1 (plus land cost)/2 trips
-- Other	$ 1.00/trip	Ref.1 (plus land cost)/2 trips
Highway		
Oper. & Maint. – auto	1.8 cents/VMT	Ref.2
-- bus	2.9 cents/VMT	Ref.2, bus/car eqivalency = 1.6
Added capacity -- auto	62 cents/added VMT	Ref.2, Los Angeles Plan data
-- bus	99 cents/added VMT	Ref.2, bus/car eqivalency = 1.6
Public Trasnportation		
Bus system -- line-haul	$3.00/tlip	Ref.3, in current dollars
– feeder	$ 1.50/trip	Ref.3, divided by 2
Subway system	$4.25/trip	Ref.3, in current dollars
Safety & Security		
Public services – auto	1.1 cent/VMT	Ref.4, in current dollars
-bus	1.1 cent/VMT	Ref.4, in current dollars
– rail	0.22 cent/VMT	Ref.4, adj. for acc.rate in Ref.1
Accident (market) – auto	4.2 cents/VMT	Ref.7
– bus	8.4 cents/VMT	Ref.7
-- rail	1.68 cents/VMT	Ref.7 adj. for acc. rate Ref.1
Costs With No Market Rices		
Travel time	$4.50/hour	Estimated
Environmental		
Air pollution	2.4 cents/VMT	Ref.4, in current dollars
Water pollution	0.2 cent/VMT	Ref. 12
Noise	0.16 cent/VMT	Ref.4, in current dollars
Solid/chemical waste	0.2 cent/VMT	Ref.5
Oil extraction	1.5 cent/VMT	Ref.5
(Subtotal)	4.46 cents/VMT	
Accidents (non-market) -- auto	7.8 cents/VMT	Ref.7
– bus	15.6 cents/VMT	Ref.7
-- rail	3.12 centsNMT	Ref.7

TABLE 2

COSTS FOR WEEKDAY PEAK PERIOD WORK TRAVEL

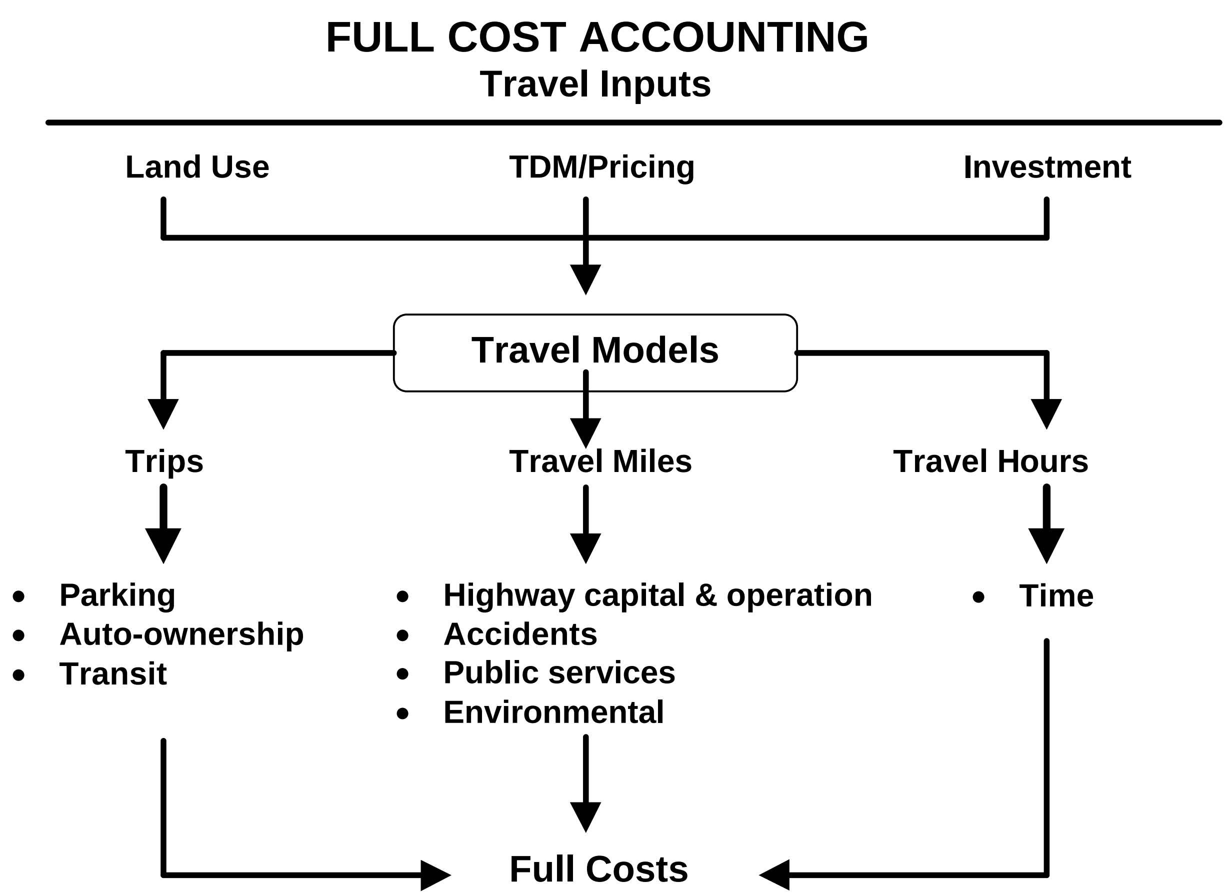
		1995 BASE	2010 BAL	2010 CONC	2010 IVHS(S)	2010 IVHS(D)
Peak Period travel data (millions per day)						
Trips:	SOV trips	1.3748	1.9308	1.8749	1.8749	0.8583
	Carpool person trips	0.9904	1.1483	1.1751	1.1751	2.0916
	Transit person trips	0.4599	0.5563	0.5855	0.5855	0.6855
	Total person trips	2.8251	3.6354	3.6355	3.6355	3.6354
	Total vehicle trips	1.825	2.453	2.409	2.409	1.809
VMT:	Total (incl.bus and transit access)	19.329	25.931	25.498	25.498	19.333
Time:	Total (incl. walk and wait time)	69.7967	88.4880	89.1946	86.2673	91.6269
Peak Period travel costs (dollars per day)						
Market costs:	Auto ($M)	6.883	13.408	12.964	12.956	6.738
	Transit ($M)	2.106	2.560	2.697	2.696	3.166
	Total ($M)	8.989	15.968	15.662	15.651	9.904
	Avg. cost per auto trip	2.910	4.354	4.251	4.248	2.284
	Avg. cost per transit trip	4.579	4.602	4.607	4.605	4.618
	Incr. cost per added auto trip		9.139	8.881	8.869	-0.247
	Incr. cost/ added transit trip		4.711	4.711	4.698	4.698
Non-mkt costs:	Time ($M)	5.235	6.637	6.690	6.470	6.872
	Environmental ($M)	0.862	1.157	1.137	1.137	0.862
	Accident (pain) ($M)	1.514	2.031	1.997	1.831	1.392
Total costs:	Total ($M)	16.600	25.791	25.486	25.090	19.030
	Avg. cost per trip	5.876	7.095	7.010	6.901	5.235
	hr. cost per added trip		11.344	10.966	10.477	2.999
Tramp. agency:	Total costs ($M)	1.817	6.350	6.171	5.927	2.761
	Incr. cost per added trip		5.594	5.373	5.071	1.164

TABLE 3

UNIT COST CHANGES FOR IVHS

Cost Components	Unit Cost	Rationale
Market-Priced Costs:		
Vehicle		
Operation	8.4 cents/VMT	1 cent added for veh. gaddetry
Ownership	$ 3.22/trip	10 cents added to veh. cost
Highway		
Oper.& Main. -- auto	2.3 cents/VMT	0.5 cent added for oper
-- bus	3.4 cents/VMT	0.5 cent added for oper
Added capacity -- auto	56 cents/added VMT	6 cents reduced for efficiency
-- bus	90 cents/added VMT	9 cents reduced for efficiency
Safety & Security		
Accident (market) -- auto	3.2 cents/VMT	1 cent reduced for acc. savings
-- bus	6.4 cents/VMT	1 cent reduced for acc. savings
-- rail	1.68 cents/VMT	No change

Figure 1



NEAR-TERM RFID APPLICATIONS IN TRANSPORTATION SYSTEMS

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INTRODUCTION

Current or near-term applications of radio frequency identification (RFID) technology demonstrate positive environmental contributions in the M-IS arena. Today, the use of RFID technology in intelligent transportation systems are most obvious in Electronic Toll and Traffic Management (ETTM), Commercial Vehicle Operations (CVO), and Automatic Equipment Identification (AEI) applications. The primary environmental benefits of RFID-based ETTM and CVO applications are gained from relieving congestion and improving the efficient and safe movement of vehicles. RFID-based AEI applications also favorably impact the environment, chiefly through operating efficiencies gained from improved asset utilization. Following are explicit examples of some of the ways in which RFID technology in transportation systems promote environmental benefits.

ELECTRONIC TOLL AND TRAFFIC MANAGEMENT (ETTM)

ETTM applications provide integrated revenue collection and traffic management information systems. These applications address key environmental considerations through:

- Optimizing the use of existing transportation infrastructures to minimize environmental encroachment.
- Improving traffic and operating efficiency, minimizing wasted energy and toxic emissions.
- Implementing congestion pricing to discourage excessive usage and encourage use of mass transit options.
- Improving the safety of passenger travel, circumventing any environmental hazards resulting from accidents and congestion.

Establishing ETC in a toll lane requires minimal additional hardware -- a reader system, RF module (which generates the RF signal) and antenna. Vehicles are equipped with tags, or transponders, that are "read" as they pass through the RF field in the lane. These systems contribute minimal electromagnetic emissions to the environment and always comply with governmental safety regulations regarding human radiation exposure. Systems that use "reflective" tags do not even generate a signal of their own, but simply bounce radio signals back to the broadcasting antenna. Thus, RF emissions are confined to a small area around the antenna.

Infrastructure Optimization

Environmental encroachment can be minimized through the optimization of existing transportation infrastructures. Toll authorities have found that lanes equipped with RFID-based electronic toll collection (ETC) systems can process vehicles far more efficiently than cash collection lanes. It takes only a fraction of a second to process an electronic transaction; throwing coins in a basket takes several full seconds and manual collection can take substantially longer. The ability of ETC lanes to substantially increase the capacity of existing lanes defers the necessity to invest in the more expensive and intrusive means of expanding capacity -- expanding the right of way with concrete and steel.

RFID allows tag equipped vehicles to automatically conduct toll transactions while moving past a reader. This allows drivers to pay tolls without stopping, therefore increasing throughput capability in the lane. which allows for increased capacity. This fully supports IVHS goals to enhance the capacity and efficiency of highways.

Traffic and Operating Efficiency

Several examples exist in which RFID technology is used to relieve congestion and facilitate the flow of traffic. Congestion is one of the key problems at toll barriers, and improvement in throughput benefits the environment through reduced emissions and reduced vehicle wear and tear. An analysis completed by Berger, Lehman Associates, P.C. at the Tappan Zee Bridge in New York, indicated that the increased capacity resulting from improved throughput with ETC would improve air quality in the vicinity of the toll plaza, decrease noise levels during morning peak periods, and result in a net decrease in electrical energy use at the toll plaza.

Automatic vehicle identification (AVI) tags installed on vehicles can also serve as intelligent "probes" which relay information regarding highway traffic flow and travel times to a traffic management facility. The Texas Transportation Institute recently implemented such a program under contract to the Department of Transportation in the Houston area. Using data primary from existing ETC tags, information regarding travel times and alternate routing advisories is provided to motorists via variable message signs on the roadway or through local radio broadcasts. Traffic advisories encourage the use of alternate routes on high occupancy vehicle (HOV) lanes and toll facilities.[2] Probe data can also be analyzed in real time for incident detection. The use of common AVI technology for all ETTM functions reduces the overall hardware required to implement cost effective solutions in high congestion regions.

Excessive Usage and Mass Transit Options

The implementation of road access pricing with ETTM systems can likewise help to manage congestion. Although this method of traffic management has not yet taken hold on a large scale in the United States, it has been shown to be a cost-effective method to reduce congestion. The Los Angeles International Airport (LAX) is a recent example of the success of road access pricing. To meet the increasing demands for curbside space, airports tried a variety of solutions and found access fees to be most effective. The LAX access fee collection system, originally based on an honor system, was enhanced through use of RFID-based automatic monitoring. This solution not only further reduced traffic congestion by 20 % , but increased revenues collected by more than 250%, allowing for a reduction in the fee schedule.[3]

With ETTM systems in place, travelers can be encouraged to consider more energy-efficient modes of mass transit or car pooling, leading to a decrease in the number of single occupancy vehicles on the road. For example, ETC lanes at the Lincoln Tunnel in New York and the Cross Harbour Tunnel in Hong Kong are dedicated to bus-only traffic, thus speeding HOVs through the toll plaza. Other identified uses for the technology include priority traffic-signal timing for HOV lanes, managing shuttles for special events, and provision of bus or people-mover terminal information. Virtually all vehicle based transit systems can be better managed using AVI technology, thus making mass transit options even more attractive.

Improving Safety

ETTM systems not only help drivers avoid delays and reduce congestion, but also improve safety. Accidents are more likely to occur at or near toll collection plazas and barriers as drivers slow their vehicles, fumble for change, and change lanes to position themselves to pay tolls. ETC lanes that do not restrict the normal flow of traffic are safer for motorists. In its first year of operation, the Oklahoma Turnpike Authority reported no accidents in any of its ETC lanes, while multiple accidents occurred on conventional lanes.

Electronic traffic management systems can also improve safety by warning motorists of approaching road hazards so drivers can avoid the area, just as they make informed choices based on congestion traffic advisories. On-board devices that provide this type of information are destined to be part of future vehicle-roadside communication systems.

COMMERCIAL VEHICLE OPERATIONS (CVO)

CVO applications provide fleet managers economic incentive to maximize environmental benefits through:

- Environmental benefits directly resulting from improved economies of operation.
- Improved safety of freight movement, preventing vehicle failure and operator errors resulting in accidents, spills, fumes, etc.
- Non-stop implementation of state line and port-of-entry monitoring to eliminate unnecessary stops and starts for interstate trucking.
- Real-time vehicle status and information exchange to monitor environmental controls, alarms and hazards.

Real Time Status and Information Exchange

RFID tags used in commercial vehicle operations provide valuable vehicle status and information exchange. "Dynamic" tags that interface with on-board sensors and other monitoring devices can store valuable sensor data which can then be read remotely by roadside readers. Dynamic tags are particularly useful in tracking and monitoring vehicle and cargo status while en route. Specific examples include reporting fuel levels, temperature deviations, shock impacts, tank pressures, leaks, and system failures. Other examples of RFID applications used by fleet managers today include automatic fuel dispensing and shut-off, and automated scale systems to ensure safe loading.

Non-Stop Interstate Trucking

Motor carriers using AVI for non-stop state line and port-of-entry monitoring improves the movement of shipments by allowing trucks to bypass inspection stations. Not only can truckers make better time without stopping at toll booths and weigh stations, but they also reduce engine wear from repeated stopping and starting, save wasted energy, and decrease toxic emissions. Such a system has been in operation on the New Mexico border for over four years, benefitting over 8,000 drivers who regularly travel along the I-40 corridor.

AUTOMATIC EQUIPMENT IDENTIFICATION (AEI)

RFID-based AEI applications allow rail, motor freight, maritime, ports/terminals, and intermodal transport companies to effectively move and track shipments, improving asset utilization and processing time, minimizing fuel consumption, infrastructure, and equipment needs.

The use of a common RFID tag across all transportation modes is slowly becoming a reality. National and worldwide standards adopted by multimodal transportation bodies assures compatibility among systems and across jurisdictional lines. Collectively, these standards allow companies to globally track cargo through various transportation modes and regulatory environments through use of “frequency agile” tags capable of reliable operation no matter which frequency band is used in various locations.

Users benefit from the adoption of these standards – extensive independent testing during evaluations of alternate technologies provide substantiated evidence of equipment performance. Reliability and accuracy, for example, is of utmost importance in monitoring the transport of certain shipments, particularly perishable goods and hazardous materials. RFID products that conform to the ISO 10374 standard for containers require a reliability level of 99.99% (not more than one non-read event every thousand readings) and an accuracy level of 99.9999% (not more than one undetected wrong reading in one million readings).4 These stringent performance requirements ensure that RFID systems will adequately perform even while exposed to the harsh environmental conditions of marine, rail and road transportation (sand, dust, salt, grime, heat, cold, etc.).

Near-term AEI applications will monitor tanks and equipment, track hazardous waste shipments, and effectively provide environmental safeguard measures. AEI tags can contain precise information regarding the content of shipping containers, as well as monitor the status of their contents. Trucks or train cars carrying hazardous materials can be monitored and checked automatically for compliance with local and other governmental regulations. These same systems can help ensure that shipments remain intact and undamaged during transport.

SUMMARY

Although its use is gaining in momentum, RFID technology is just beginning to affect the nation's transportation system in several key areas. Current or near-term applications of RFID technology in Electronic Toll and Traffic Management, Commercial Vehicle Operations, and Automatic Equipment Identification are favorably impacting the environmental aspects of providing more efficient, productive and safe transportation systems. Use of compatible systems across multimodal transportation systems facilitates increased utilization of these systems, further leveraging their positive effect on the global environment.

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Geographic Policy Analysis

Intelligent Transit Information Systems

Presented by

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To date, Intelligent Vehicle Programs have largely benefited single occupancy vehicles (SOVs) with the primary focus being technological solutions to improve the efficiency of road networks. From an environmental perspective, however, the most intelligent vehicle is one that you do not drive. For IVHS to be truly successful, attention should be shifted toward alternatives to SOVs. In an era where the top 10 automobile brands spend $1.99 billion a year to promote their vehicles', IVHS programs need to place emphasis on projects which market transit systems and improve access to information about transit systems and options. Broadcast quality multi-media production, dedicated cable television channels and geographic information systems are powerful tools to make transit information more accessible. It is our contention that access to high quality information about transportation options would result in significant increases in transit ridership and shared rides.

This paper will introduce three concepts which bundle intelligent technologies for the purpose of improving transit by improving transit information systems.

- "GO-TV" is a regional Cable TV, multi-modal transportation channel created to bring accurate, on-line information on traffic systems and conditions into the home.

- "MYRIDE"- is a GIS based system to produce personalized routes and schedules for commuters, ideal for batch processing by large employers.

- INFOSHELTER" - presents accurate route and scheduling transit information at bus shelters.

These three concepts market directly to preference riders. Many people take transit because they must. Providing for the transportation needs of those who cannot afford, or are incapable of operating, a car represents an important social justice function of mass transit. Yet, if significant gains are to be made in environmental quality and "community livability", mass transit must also reach out to those who do not need to use transit. Transit operators, to fulfill this goal, must cultivate a strong positive image. They must improve communication OF multi-modal scheduling information in an attractive and interesting format. Finally, transit must create for itself a positive physical presence in neighborhoods. Intelligent transit programs should, therefore, focus on the marketing end OF operations, for it is here where significant ridership gains are to be made,

' Competitive Media Reporting, **1993**

GO-TV

Traffic reports have become a mainstay of daytime radio and are creeping into the information mix available on morning and afternoon TV news programs. We have come to rely on these reports, like weather reports, to help us prepare For our day. Trouble is, traffic information alone allows only for route choices and does not promote shifts in mode choices. Studies have demonstrated that commuters will consider changing their transportation mode based on pre-trip information*. Commuters and travellers contemplating alternatives to the SOV must have easy access to reliable information in their homes, before they get into their cars. **"GO-TV"** is a concept to create a regional Cable TV, multi-modal transportation channel to fill that need. The effectiveness of broadcast video communication surpasses audio or graphic presentation and till make quantitative transportation information both appealing and meaningful. By presenting this information with broadcast quality production techniques, a multimodal transportation channel till attract a viewership large enough to significantly impact ridership.

A proposal to demonstrate **"GO-TV"** in the Metropolitan Boston Area is pending before the Transportation Research Board. A pilot program till be produced and tested in focus groups composed of commuters and travellers to determine program format appeal and demand for specific information. We believe that **"GO-TV"** will bea success as commuters realize the extent OF traffic problems caused by the construction of Boston's Central Artery Project. Placed in context along side images of massive traffic tie ups, alternatives to SOVs will be looked at in a new light) as realistic, often preferable, options to the personal automobile.

"GO-TV" will disseminate information on both system conditions and transportation options. Commuters till see live video signals of road conditions and hear on-line traffic reports to allow them to make appropriate route choices. Commuter travel segments till present route, schedule and pricing information for all available transportation modes including: bus, van pool, commuter train and subway to afford commuters the opportunity to make mode choices. Regional travel segments produced will present schedules for: AMTRAK, airlines and intercity bus lines. Moreover, the channel till keep travelers aware of how changing weather conditions impact Metropolitan Boston's transportation network.

Intelligent use of a regional cable network will allow this channel to become an unparalleled source of regional and local transportation information. Because each cable franchise is community based, a regional cable network allows for programming information to be community "addressable", customizing a portion of the programming cycle for transit schedules and transportation options for that particular community. Community specific, broadcast quality on-line transit information in the home is critical if people are to broaden their awareness of their transportation options and &come less dependent on automobiles.

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[2] Washington State Department OF Transportation, Improving Motorist Information Systems Toward o User-Based Motorist Information System for the Puget Sound Area, April 1990

MYRIDE

The current difficulty in obtaining specific route and schedule information presents another significant impediment to transit usage. **MYRIDE** is a concept to print personalized schedule and route information on demand from a home or office. **MYRIDE** would provide potential transit users with the transit information they need to use the system.

A Geographic Information Systems (GIS) will serve as the primary intelligent technology for MYRIDE. Street and address information can be linked using a GIS to transit routes and schedules. This information, in turn, can be used to create customized information schedules for potential transit users. A system can generate a route map with recommended stop, time elapsed and walking distance to stops and any appropriate route or mode transfer information. This transit "ad-matching" tool is most easily applied through batch processing of personnel lists from large employers. A municipality could use it to match new residents' home and work commutes. Processing can also facilitate the arrangement of car and van pools. The matching can also be made available to inquiry via: moderns, touch tone phones, and fax machines to allow for individual inquiries, non-work trips and small businesses.

MYRIDE will perform two useful functions. As an employer based system, it till allow transit to market directly to persons who may have never considered transit or shared rides as an option. As an on demand system, it is vastly superior to collecting hard copy schedules from limited distribution points or accessing phone systems which cannot supply maps or personalized schedules.

INFOSHELTER

Transit stops represent critical marketing and information distribution nodes. Here, as potential preference riders wait, their opinions of the service are formed and reinforced. Transit stops must be intelligently designed to retain these riders. There must be sufficient information within the shelter to let the rider know that this stop is on the desired route. Three levels of information display can be considered.

- **Sign INFOSHELTER.** Route, stop and transit operator identification are elemental to all locations. Permanent maps would convey route and, separately, complete system information. Printed schedules for routes should be posted. A shelter name, which would correspond to the printed schedules, would help riders and reinforce neighborhood identity.

- **BUS Tracking INFOSHELTER.** Intelligent technology applied to this basic bus stop could tell the rider where the bus is. By placing transmitters on buses and receivers on the shelters, a bus can be tracked as it moves along its route. information can be displayed using lights on a durable map or on a video monitor. This dynamic map will relieve the stress, very real to those accustomed to using cars, of wondering whether the bus will ever arrive. From an operational perspective bus tracking can also be used in a central dispatch area to monitor and improve system performance.

- **Interactive INFOSHELTER**. In its most advanced form bus shelters can be equipped with MYRIDE capabilities. A rider could query the system map and GIS through a computer touch screen or voice recognition system. Route information could be delivered via printed map, as described above, or on a video monitor.

While the decision as to the level of sophistication for information within the shelter till ultimately depend on budget and ridership, in all cases stops should be designed to prevent riders from feeling lost.

Conclusion

If a bus runs on a scheduled route and potential riders are unaware, is it service? Yet, much transit service, particularly bus, van and Carpool service operates in this manner - quietly underutilized. Two significant impediments to increased transit usage are a general lack of marketing information about the full range of transit options available and poor access to scheduling and route information. IVHS programs such as we have outlined specifically address these programs.

LandNet believes in cost effectively improving the efficiency of our transportation system. Improved intelligence is not merely a matter of the application OF advanced technology. We must be just as concerned about whether a proposal is good policy as whether it is smart engineering. We also must ensure that our purported intelligence does not come at the expense of common sense. I believe the specific transit projects put forth here meet this definition of intelligence.

HIGH TECHNOLOGY TRANSPORTATION AND THE INFORMATION HIGHWAY

A Global Market Strategy for the United States

by Ellen Williams

Transportation investments and the global market

The United States has a significant opportunity in the global market place to establish dominance in high technology transportation. A major confluence of economic, societal, and technological trends and an infusion of public funds for transportation has created this opportunity.

Gaining maximum advantage from transportation investments will require innovative and creative thinking as to how those fund should be spent. With precious few capital dollars available to invest in the United States, we must spend available dollars in a way which yields maximum return on the investment. We cannot afford to spend those dollars without some kind of vision of how those dollars fit into an international economy. According to Dr. Michael Porter, in his book *Competitive Advantage of Nations,* "choosing a domestic focus in a global industry is perilous, no matter what the firm's home nation."[1]

The high technology transportation strategy

If we choose to spend transportation dollars in ways which create a competitive advantage, then how do we spend those dollars? That is just the question asked by a group of California leaders participating in what is known as Project California, sponsored by the California Council on Science and Technology. The group's focus is on six major transportation industries: high speed rail, alternative fuels, Intelligent Vehicle Highway Systems, electric vehicles, mass transit, and advanced telecommunications. From these industries, they want to know what is the best way to build a sustained economy which creates jobs especially for the defense industry worker. "The state is serving", observed Malcom Currie, retired chairman of Hughes Aircraft Co., "as the prime research laboratory for the rest of the United States, Japan and Europe. . . .We need to turn our research into products and jobs. . . ."[2]

In terms of creating a sustained economy and jobs, Project California's assessment of high technology transportation is now available. The assessment places Intelligent Vehicle Highway Systems and Advanced Communications and electric vehicles at the top of the list. Those three areas have the best chances of producing jobs and a highly sustained economy. Although I could build a strong case for all forms of high technology transportation to create a globally competitive industry, for the purposes of this essay, I intend to focus on the investment in a ubiquitous high capacity Advanced Communications System or "Information Highway" for the purpose of moving images and information. After defining the "Information Highway," I will discuss how it competes with Japan and major countries in the European Common Market and how it provides ancillary benefits to the United States.

Information highway defined

An Information Highway, from a technology perspective, is everything it takes to deliver images and information from point A to point B. This includes communications networks, personal computers, information appliances, televisions, cable networks, systems applications, information storage devices, facsimile, multimedia. it means using this highway to deliver health care services to the patient; education to the student from the worlds teachers; information to the researcher from the world's libraries; governmental services to citizens and energy management information to residences.

The Clinton/Gore administration also thinks part of the investment in infrastructure needs to go beyond traditional transportation to include a high speed communications infrastructure. The goal is ". . . a nation that uses information more effectively than industrial rivals — is no less ambitious than the construction of the transcontinental railroad system or the race to put a man on the moon."[3]

Current efforts to build the Information Highway are extremely fragmented, resulting in many failed attempts to deliver an Information Highway Platform available to everyone. For example, education leaders try to build separate networks to support education. Financial institutions try to build their own consumer networks. Library leaders want to build separate networks for electronic libraries. Consumers have to buy their own personal computers and facsimile machines to receive information services. And even information policy leaders try **to** lead from the point of view of the advantages associated with high tech. We need a new approach. Perhaps we can learn from those who built the Interstate Highway System where combinations of public and private dollars produced, for its time, the most enviable surface transportation system in the world. That principle can be applied to the construction of a high speed public access Information Highway designed for the purpose of moving images and information wherever possible.

To make the Information Highway happen, what is needed is a coordinated, systems approach to maximizing the benefit of technologies and network platforms in the global market place. It is an issue of leadership and public policy. We have to make decisions to place value on transporting, wherever possible, information and images, as the most cost effective, energy efficient, non-polluting, fastest way to travel.

According to Albert Core, "Our current information policy resembles the worst aspects of our oldagricultural policy, which left grain rotting in thousands of silos while people were starving. We have warehouses of unused information 'rotting,' . . "[4] It is information which is the capital of the Information Age just as iron ore was to the Industrial Age. We can not afford to leave information rotting in silos. Information delivered in an easily accessible, rapid format can make the difference in our industrial competitiveness. "The critical difference between now and twenty years ago is that the manufacturer can no longer just use more energy to increase productivity. It's too expensive. Instead, the manufacturer has to become smarter at what he(she) does."[5] Therefore, if we want to manufacture a new product or service, having access to the "information silos" is critical to being able to produce that product in the most cost effective manner.

Different infrastructures for different times

Different infrastructures are needed for different times. In an *agricultural* economy, emphasis was placed on cheap methods of moving bulk *grains* i.e., *an* orientation toward *canals* and *rural* roads. *In an industrial economy* more emphasis was placed on rail, ports and trucks for goods movement. However, *in an information economy, as we* are in today, the greatest emphasis has to be placed on the movement of information. In fact, Alvin Toffler, noted *futurist was* heard *to say, "If we are in the midst* of *an information economy,* then why to we spend billions to fix pot holes?"6

Global context of the information highway

No other country in the world has placed focus on the value of using communications and information technologies to move images and information for transportation purposes. If the United States were to lead an effort to build Information Highways, three things would happen. One, investments in information highways creates exportable products in software, hardware and systems platforms. Two, investments in building ubiquitous high capacity information highways provides a cost effective solution to other infrastructure problems associated with education, health care, library services, and public services. Three, the information highway would provide a transportation alternative which is not highly dependent upon energy, thereby reducing the United States from the vulnerability of fluctuating oil prices.

Creation of the Information Highway means the creation of a whole new epoch of products and services that can be delivered over a public access high capacity network. Seventy percent of the high capacity networks are privately owned. Just think of how travel behavior might change if this capability was publicly available to everyone in their homes. The same network used for meetings can be used for a full compliment of services including the delivery of health care, education. governmental services, financial services and more.

Public policy leaders have often expressed concern regarding the creation of an information-rich and information poor society based on a person's ability to use a computer. Most of this concern is because, with our current infrastructure, to gain the benefits of an information society means being computer literate. However, this becomes a non-issue in an environment of broad band technologies to homes. Instead of using a computer to gain information, information is delivered in the most commonly used delivery format — television, and television in a two-way, interactive format.

Ancillary benefits

Once the platform is in place for the delivery of information in video format, new users and information providers would begin to evolve. Healtb care, for example, changes when it becomes possible for disease prevention information to be universally delivered to everyone in the privacy of their homes. ln the case of public health, advocates for high capacity Information Highways into homes state, " . . .the first task in developing a responsible General Public/Health Information Interface is to get health information and decision-making tools to people before they enter the health system all too often presenting an urgent, high-cost problem which sometimes can no longer be resolved. "7 This leads to the next point, investments in the Information Highway bring other infrastructure improvements. In the global economy, in order to be competitive, we must address other major infrastructure issues including education and health care. With the Information Highway in place, new paradigms for the delivery of these services can take place. Be it the classroom or the home, the world's leading educators would become available to every-one. Vocational education programs could be delivered from anywhere to everywhere. Health care changes into preventive health care with patient/consumers making informed choices of how they want to live.

Becoming less consumptive

Energy savings and independence is another ancillary benefit of the Information Highway. Spending money on more costly forms of energy to provide goods and services robs us of the capital dollars needed for investments in our economy. We spend more money on energy largely due to the way we organize. We are paying the price for the choice we make to have the house on a plot of land, unlike the rest of the world that is much more concentrated around transportation facilities and uses high density housing principles. Energy savings resulting from the delivery of services in an information format, instead of more expensive forms of transportation, quickly becomes energy redeployed toward making goods and services less expensive and more competitive in the global market. We become less consumptive with the Information Highway. Notable economist, Dr. Robert Meyers, Principle Economist, World Bank points out, "We have to become a less consumptive society in order to be globally competitive."*

Information highways in Japan and the ECM

Our global competitors Japan and the European Common Market are not without a plan for making an investment in advanced communications systems. We are at the point where we must make the investment in the Information Highway or fall further behind. "But there is a risk of doing nothing, too. The Japanese government has committed to investing about $120 billion by 1995 to develop a new communications infrastructure. Although a similar U.S. effort could exceed $200 billion, computer makers believe investing in new digital communications technologies will pay off by creating thousands of jobs."9

In France, a low technology Information Highway already exists. It is known as the Minitel. Although the French do not view the Minitel as a part of their transportation system, it is, in fact, part of their system. Seven years ago the French made the decision to provide its citizens with an information appliance which would be used for access to what would be the equivalent of White Page and Yellow Page information. By doing this, they no longer would use a paper-based information service. Because the French created a ubiquitous information platform, they now have 18,000 information providers using the system which after six years of operation makes Minitel a totally self-funded information platform. Upon closer examination of the Minitel, information services actually expand France's transportation system delivering, for example, financial, library, education, and health care services.

Even with Japan's investment in advanced communications and France's Minitel, the United States is in the best position to set the de&to standard for a high capacity, public access Information Highway/Advanced Communications Platform. Public access will make the difference in the economic value of investments in advanced communications.

The reason why Japan and Europe may not have the same scale of benefit as the United States has a lot to do with cnltural orientation. Both Japan and the European Common Market countries are still very oriented toward industrial organizing principles. To gain the real benefit from Advanced Communications means a willingness to use decentralized organizing principles. Despite concerted efforts on the part of the Japanese government to encourage decentralization, the Japanese continue to be highly concentrated in a few urban centers. The Japanese business culture is based on face-to-face interaction and they are willing to incur great costs to perpetuate the culture. The cost has come in terms of long commutes, expensive housing and poor quality of life. Until their culture changes, the real benefit of a public access Information Highway cannot be available to them. Their investment in advanced communications will likely be oriented toward closed organization systems. In Europe, there is a much broader issue of cultural and language diversity. Also, they use the industrial, centralized organizing principle. The presence of a European Common Market does not necessarily assure full participation in a common ECM Information Highway platform. Nationalism is alive and well.

For the United States, we are already beginning to use the decentralized organizing principle, particularly for work-related activities. According to Link Resources, over 40 million people are already working full and part-time from their homes. Corporations are decentralizing through satellite facilities located in rural areas.

> "Pressured by rising global competition, U.S. companies operating in big cities were faced with some hard questions: Can we afford to pay $50.00 a square foot for office rent and $11 an hour to people who clean our floors? Can we continue to attract top-notch employees if up to 40 percent of their adjusted gross incomes will be devoted to housing? Can we compete in the world

economy with workers who have graduated from substandard high schools where drop out rates often exceed 35 percent? For more and more businesses the answer is. 'No."10

Even though corporations have begun to decentralize through communications and information technologies, the full benefit of being able to decentralize is not available because there is no provision for ubiquitous access to a high speed Information Highway which would make the same services that are available to a corporation available to home consumers.

In education and health care, we have early examples of using technology to distribute services. Education has long been the front runner of using video technology for distributed education. The next leap is to have a video repository of lectures where a student could call up a given lecture on demand. Increasing the bandwidth into homes will make this possible. Health care already has example of patient care through remote patient diagnostic systems which monitor patient health care over the current communications network. Many more examples exist, but the point is the willingness of Americans to be innovators and to try doing things a different way. In doing this, the United States stands to have the best chance of realizing the full potential of a common, public access Information Highway.

Conclusion / recommendation

To become the international leader in the provision and use of Information Highway technologies products and services is a leadership issue — not a technology or even a cost issue. It is where will we place our public policy emphasis as we go into the 21st Century. "Telecommunications infrastructure should be the heart of public policy at the state and federal level. Building a telecommunications-based infrastructure is a national economic need, not just a social need." l2

We need all forms of transportation to produce the world's highest levels of mobility, whether it is moving people, goods, services, or information. The infusion of information and communications technologies in all forms of transportation will serve to differentiate the United States transportation system while producing a global industry.

Success in leveraging high technology transportation in the global market place must include a public/private economic development effort. The United States must be viewed as the place to come to see the "Information Transportation System" and the world model for this system. We cannot afford to lose this emerging industry. When people come to view the United States transportation system, they will see Intelligent Vehicle Systems making it possible to increase the utilization of our current surface transportation system; our electric vehicle industry; smart rail cars in the rail system; high speed rail; cars using alternate fuels; a fully integrated public transit system which tells the traveler, before they depart, when and what is the best route to travel; and the most technologically advanced Information Transportation system in the world.

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INTELLIGENT VEHICLE-HIGHWAY SYSTEMS

&

BICYCLING

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Abstract

Intelligent Vehicle Highway Systems (IVHS) have important implications for bicycling. Such systems may be designed to specifically encourage and facilitate bicycle transportation, although technology of this nature offers little to directly address the well documented impediments to bicycle transportation. More importantly, IVHS will likely effect the bicycling environment as a side effect of its main design function.

This paper examines direct IVHS applications for bicycling other applications that will effect bicycling, and assesses the impacts of major proposed IVHS projects on the bicycling environment.

Background

Many proponents and opponents of IVHS technologies acknowledge that IVHS is only a tool that can be used to increase vehicular occupancies or to "fit" more vehicles on a given roadway. Many proponents see growth in vehicle miles travelled (VMT) as inevitable, and IVHS as the most efficient and effective means to accommodate this. Proponents argue that there are many positive IVHS applications, including efficient road pricing, measures to accommodate ride sharing, and prioritization schemes to speed transit service, which improve air quality, increase vehicular occupancies, and provide mobility to the transportation disadvantaged. Many opponents acknowledge this potential but are concerned that putting this technology into the hands of state highway departments will inevitably lead to system capacity improvements which will have the opposite effects. Opponents believe that investing so heavily in IVHS demonstrates a high perceived value in its uses, before such uses have even been decided.

Many in the bicycling community share this belief. At the federal level, USDOT has demonstrated only marginal interest in bicycling. As an example, USDOT took well over a year to fill the vacancy of the only bicycling and walking position (out of about 1,000 jobs) in the Office of the Secretary (OST), and filled it only after a Congressional mandate, relentless pressure from the bicycling community, and the potential embarrassment of having the release of the Congressionally mandated National Bicycling and Walking Study being marred by this vacancy. While budget constraints precluded spending about $50,000 to put a full time program manager in OST, they did not get in the way of increasing the USDOT research budget from $647 million in 1993 to $688 million in 1994, 80 percent of which will be spent on IVHS. This is a huge budget for a program with an ill-defined mission. Bicycle activists and others who have traditionally been left out of the transportation decision-making process are understandingly reluctant to trust powerful highway departments to ensure that their interests will be incorporated into the application of these technologies. When the U.S. Secretary of Transportation addressed the Transportation Research Board and Congress at the beginning of 1994, he touted the virtues of IVHS technologies in solving our transportation problems but said nothing about land use, traffic calming, or bicycling accommodations. Bicycle activists are reluctant to support the technology solution, when its main proponents do not define the national transportation problems as they do.

Bicycle and neighborhood activists share a perspective on the use of street space that differs from that of the highway engineer. The former are concerned with maintaining the quality of destinations, not merely enhancing travel efficiency. They are concerned with how streets function in terms of allowing or obstructing social interaction and their effects on the human environment. Bicyclists, more than motorists, are concerned with the travel experience. An important aspect of bicycle transportation is that it can be combined with exercise and recreation, essentially allowing multiple functions to be served with a single trip. Excessive automobile traffic combined with an automobile-oriented design (large signs, billboards, parking lots, etc.) makes the roadway environment unpleasant. While many motorists may tolerate this because they believe they have no choice, many bicyclists will opt to become motorists for utility trips where route choice is limitted, thereby bicycling only for recreation. IVHS seems to concentrate on quantity and efficiency--getting the maximum movement of people and goods using a minimum of road space--but it seems to ignore the importance of neighborhoods and the environment in discouraging trip-making and encouraging the use of alternative transportation.

Bicycle-Specific IVHS Technologies

A number of bicycle-specific IVHS applications have been proposed. The most developed application to date is an intelligent bicycle routing program which allows bicyclists to enter origin, destination, topography preference, cycling ability, importance of route directness, and comfort on busy roads. The computer prints out a detailed route map with accompanying written directions accounting for these preferences. (See "Intelligent Bicycle Routing in the United States, Transportation Research Board Paper 930472, 1993.) While this IVHS application could certainly be useful to bicyclists, its utility is greatest where cyclists are unfamiliar with an area, and it is no more useful than a map in areas where cyclists are familiar with their general layout.

The European Cycling Federation (ECF) in "What Do Bicycles Have to do With Advanced Transport Telematics?" (August 1992) suggested applications such as providing weather forecast information, map information (including topography), and public transportation information (including bicycle transport information). One particularly innovative suggestion was a bicycle theft prevention system where computer chips which could respond to certain signals would be built into bicycles to identify the location of stolen bicycles. ECF also suggested systems that count bicycles on roadways to measure usage. Finally, ECF endorsed car warning systems which would warn turning motorists of bicyclists' presence.

Other IVHS Technologies that will Effect Bicycling

At the most basic level, if the effect of IVHS applications is to reduce the number of vehicles on the road, then IVHS will benefit bicycling. The inverse is also true. Additionally, increases in motor vehicle speeds require more roadway space to allow "sharing the road," and thus are often detrimental to bicycling. The USDOT recognizes as a matter of policy that increased motor vehicle traffic and higher motor vehicle speeds make bicycling less safe and desirable. (See "Selecting Roadway Design Treatments to Accommodate Bicycles,' FHWA-RD-92-073, 1994.) This is particularly important on main arterials and secondary roads that are popular for bicycle commuting and other utilitarian bicycling.

Capacity enhancements are explicitly recognized as one goal of IVHS in the Intelligent Vehicle-Highway Systems Act of 1991 (see Part B of the Intermodal Surface Transportation Efficiency Act, Title VI, Section 6052 (b)(l)). Capacity enhancing IVHS applications such as signalization improvements and other 'smart" technologies may apply directly only to freeways where bicycles are either prohibited or their usage is very low. While adding motor vehicle traffic to these roadways may not concern bicyclists directly, the fact that these vehicles are used for trips that start and end on major arterials and secondary roadways is a major concern. Even measures to reduce travel demand, such as congestion pricing, may adversely impact bicycling if such pricing is applied only to freeways and motorists attempt to avoid them by using secondary roadways.

Specific Applications

A large number of proposed IVHS applications would have little or no effect on bicycling. Given the tremendous financial resources that are being provided for these applications, many bicycle activists believe that the money could be better spent on bicycle lanes, traffic calming measures, bicycle parking, and bicycle/transit accommodations. Nonetheless, these "neutral" IVHS applications are not what most concerns bicycle activists.

USDOT and IVHS America issued their April 1994 Interim Status Report, *IVHS Architecture Development Program, which* identified 28 different user services. Many of these services, such as pre-trip travel information, traveler services information, incident management, commercial fleet administrative processes, and emergency vehicle management, would have little or no effect on the bicycling environment. Some user services could worsen bicycling conditions by encouraging solo driving. Examples include some route guidance and traffic control applications. Some user services would benefit bicyclists by getting motorized vehicles off the road. Examples include many of the public transportation applications such as ride matching and reservation and personalized public transportation.

The Interim Status Report mentions only positive implications of IVHS and does not even acknowledge the possibility that some IVHS applications could have negative implications. In a few instances, the report states that bicyclists and pedestrians will benefit from specific IVHS applications. It says, for example, that hand held devices can be used to give bicyclists and pedestrians route information. But bicyclists and pedestrians would need to have these devices with them, and these devices would probably be quite costly and, except in limited cases, provide only minor benefits to their users.

The report also says that traffic control measures which would be used by vehicle drivers and public transportation operators would benefit bicyclists and pedestrians from improved traffic flow. This is a stretch and could actually have the opposite effect if motor vehicle speeds were increased as a result.

The effects of many other IVHS applications on bicyclists are not acknowledged by the report. One application is an electronic payment system using smart cards. Related to this idea, one author has suggested applying the cash-out concept to congestion pricing; that is, offering commuters free smart cards with cash values based on commute distances, which could be cashed out for a transit pass or money. (See "Applying the ‘Cashing Out* Approach to Congestion Pricing" by Patrick DeCorla-Souza, Transportation Research Board Paper 940375, 1994.) While the cash-out concept would be good to create the political will to implement congestion and other road pricing schemes to discourage driving alone, offering higher valued cards to those commuting in from the outer suburbs would encourage locating in those suburbs. To encourage bicycling, people need incentives to live close to work, and cash out and other schemes need to be designed to provide such incentives.

The last broad category of IVHS applications is safety equipment. In general, such applications would benefit bicyclists. One such beneficial application is a warning system to alert motorists to the presence of bicyclists and pedestrians. Other applications, such as automated roadside safety inspections and on-board safety monitoring for commercial vehicles, would enhance overall roadway safety, as would many collision avoidance applications. But safety equipment such as automatic crash protection mechanisms may encourage drivers to be less careful, to the peril of other road users. There have also been a number of of recent newspaper articles about cars with anti-lock brakes getting into as many collisions as those without them, to the dismay of insurance companies that provide discounts for this equipment. There is probably a limit on the effectiveness of in-vehicle safety equipment, and related IVHS applications should not be seen as panaceas.

Despite the report alluding to beneficial bicycling and pedestrian applications, the opinions of the bicycling community have not been solicited. League of American Bicyclists staff attended one IVHS America subcommittee meeting at the Transportation Research Board meeting in January 1994 and was informed that in order to attend subsequent meetings, a $1000 membership fee would be required. Page 13 of the Interim Status Report explicitly refers to bicyclists as "non-vehicular travelers," which is not only untrue but is considered an insult by many bicyclists. Lack of understanding and inadequate communication have thus far precluded appropriate consideration of the interests of bicyclists in the IVHS program.

Conclusions

IVHS is coming whether or not the bicycling community likes it. Some of its applications are already here. Bicycling and other organizations will be keeping a close eye on how IVHS monies are being spent and will attempt to hold governmental entities accountable to the environmental, community, and bicycling and pedestrian transportation effects of IVHS expenditures.

The problem with the U.S. transportation system is not the lack of technology. Instead, it the lack of coordination with land use, and inadequate integration of land use, housing and transportation policy. IVHS may help to address these issues, but it could also make things worse. With a tight budget climate, IVHS should be required to compete with other measures to prove its effectiveness and investment worth.

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II.

Energy and Environmental Impacts

How Responsive Multimodal Transportation Management Linked To IVHS Can Improve Environmental Quality

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BMI

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CONTENTS

EXHIBITS

1. INTRODUCTION

1.1 Purpose

This paper has the following four objectives:

- To review Multimodal Transportation Management Strategies Linked to IVHS
- To review the potential of various strategies and technologies to improve environmental quality
- To discuss a process by which IVHS can be involved in environmental evaluations
- To outline concerns that should be addressed to improve the Multimodal IVHS Environmental Quality Process

1.2 Background

Responsive Multimodal Transportation Management Strategies include those actions which involve more than one mode of transportation, provide real or semi-real time information to users of IVHS technology, and achieve the following goals and objectives established by the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA):

1) Improve the market share and operations of high occupancy vehicles (HOV), ridesharing and mass transit:
2) Provide for more efficient use of existing transportation facilities and resources:
3) Provide for more efficient use of energy sources:
4) Enhance the efficiency of urban goods movement:
5) Improve the usefulness of existing TSM strategies:
6) improve air quality:

7) Improve transportation safety:

8) Improve the economic efficiency of transit and paratransit operations:

9) Improve the mobility of the elderly, handicapped, and the transportation disadvantaged; and

10) Improve mobility in rural areas.

This paper presents findings related to conceptual evaluations of scenarios from a two year FHWAFTA project conducted by a team led by Bellomo-McGee, Inc. (BMI). The objectives of the research study were to:

1) Identify candidate real or semi-real time multimodal transportation management scenarios which use new and emerging IVHS technologies;

2) Determine their usefulness and feasibility;

3) Develop additional innovative concepts:

4) Evaluate the potential utility and cost of each scenario; and

5) Provide recommendations for additional research, development, and operational tests.

A framework for evaluating the potential benefits and costs of multimodal functional scenarios was successfully applied to a conceptual evaluation of some 27 scenarios involving mass transit, paratransit/ridesharing, general highway multimodal, airports, and commercial ports/intermodal facilities. This conceptual evaluation addressed environmental effects and can also be transferrable to the IVHS America mode-specific 27 user groups identified as part of the United States Department of Transportation (USDOT)/IVHS Strategic Program Plan Draft (I).

The conceptual evaluation of environmental effects focused on the physical and socio-economic environment and was based on studies and research to date. Physical environmental effects covered potential impacts on traffic (improved HOV, rideshare, and mass transit, better use of existing facilities) traffic safety, air quality (reduced emissions) and energy (efficiency improvements). Socio-economic areas effects included improved mobility for the elderly, handicapped and transportation disadvantaged, improved rural area mobility, and potential human factors effects. It should be noted, however, that the precise environmental effects of many of these technological advances will not be known until proper evaluations are made during operational tests, data is gathered, and improvements in models are completed.

Before proceeding with the paper, it is important to overview the assumptions and scenarios used in the research.

Assumptions

The scenarios presented in this paper were developed for a mature IVHS environment that is assumed will exist at some time in the future. The following assumptions have been made about the expected level of IVHS maturity in the urbanized areas and in major rural highway corridors under implementation consideration for this study:

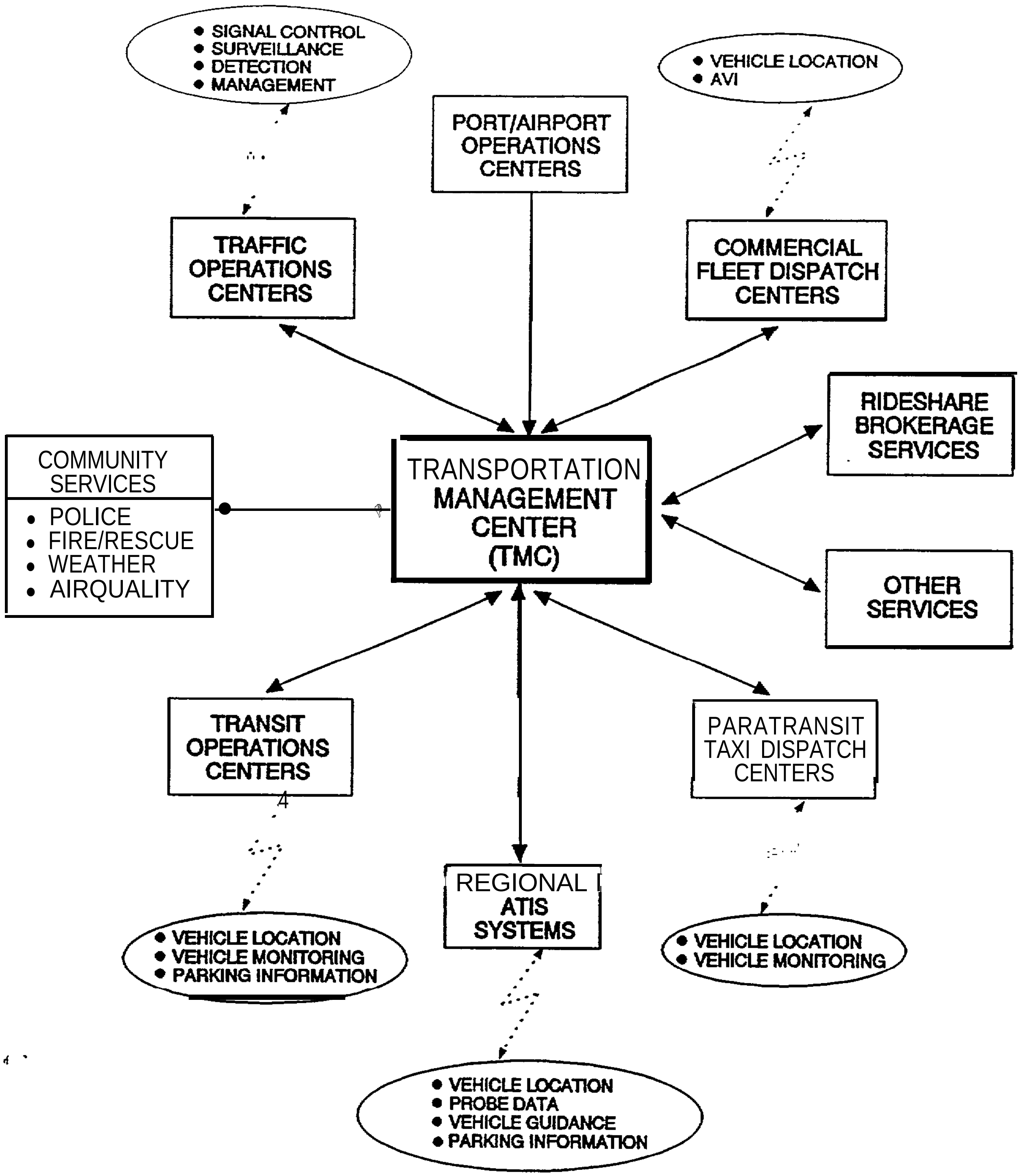
- Traffic signal control, freeway management, and transit fleet management systems have been deployed throughout most of the area.

- The systems are physically/electronically linked.

- Each location has a Transportation Management Center (TMC), similar to Exhibit 1, where information is received, fused, and disseminated to travelers.

- Commercial vehicles are linked to fleet management centers which provide them with traffic and route information.

- There is a large market penetration of in-vehicle navigation devices whereby the above information is provided to passenger car, transit vehicle, and commercial vehicle drivers and recommended routing is



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Transportation Management Center Concept

Exhibit 1

provided based on real-time information.

- Reduced scale in-vehicle systems which provide continuous traffic information on selected corridors are also available. They are less sophisticated and less costly than the fully functional ATIS devices described above.

- Traffic information centers and systems, similar to those described above, exist in major rural highway corridors and areas. However, these systems are not deployed throughout the entirety of the rural networks.

These functional requirements were taken as given during the development and evaluation of the candidate scenarios. Exhibit 2 presents selected criteria used for the evaluation of the multimodal transportation management strategies linked to IVHS. This study was not concerned with the practicality of these requirements or whether or not they are attainable, rather the focus was on how the candidate scenarios would perform given this assumed operating environment.

Scenarios

The 27 candidate multimodal scenarios are discussed here. Although all scenarios have multimodal applications, they are presented according to their major modal applications:

- Mass Transit (10)
- Paratransit/Ridesharing (5)
- General Highway/Multimodal (7)
- Airports (1)
- Commercial Ports/Intermodal Facilities (4)

1. Applicability to Multi-Modal Transportation Management - Criteria include:

- HOV/Ridesharing utilization
- Coordination with mass transit
- Applications to goods movement
- Compliance with Clean Air Act Amendments '90
- Compliance with the Americans with Disabilities Act

2. Technical Feasibility - Screening criteria include:

- Feasibility (need for new technology)
- Flexibility (alternate technologies)
- Reliability
- Expandability & upgradability

3. Potential Benefits - Criteria include:

- Reduced Single Occupant Vehicles
- Congestion reduction & avoidance
- Improve commercial vehicle productivity
- Pollution reduction
- Improved tansit/rideshare operations
- Improved safety
- Energy savings

4. Potential Costs - Criteria include:

- Implementation costs
- Operation & Maintenance costs
- Out of pocket user costs
- Non-monetary costs

5. Institutional and Legal Issues - Criteria include:

- Passenger security/safety
- Operator/manufacturer liability
- Need for inter-jurisdictional/inter-agency cooperation
- Opportunity for public/private cooperation
- Legal and regulatory restrictions

6. Financial Feasibility - Criteria include:

- Need for government subsidies
- Potential for commercialization
- User willingness to pay
- Applicability to existing funding programs

7. Attractiveness to Users, Operatiors, and Society - Criteria include:

- Acceptability to management
- Ease of learning system (users & providers)
- User and provider convenience
- Provision of incentives
- Impacts on non-users

8. Human Factors - Criteria include:

- Target audience
- Ability to gain larger user population
- Ease of use for all user populations
- Effectiveness in addressing human concerns

9. Potential for Success - Criteria include:

- Potential market penetration
- Long-term viability
- Integratability with other scenarios

10. Implementation Potential -Criteria include:

- Barriers to deployment
- Compatibility with existing systems/modes
- Implementation sequence
- Areas of greatest potential impact (e.g. urban CBD, urban non-CBD, suburban, high activity centers, etc.)

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Selected Evaluation Criteria

Exhibit 2

Mass Transit Scenarios have been designed to increase transit usage, enhance the efficiency of transit operations, ease transit use, and improve the overall quality of mass transit services. The scenarios include applications to route deviation service, transit management information, smartcards, and automatic vehicle location systems.

Paratransit and Ridesharing Scenarios were designed to increase the use of HOV and ridesharing, enhance the operations of paratransit services, and generally improve personal mobility in both urban and rural environments. The scenarios include real-time ridesharing, improved paratransit dispatching, rural ATIS systems, and using courier vehicles to move people on HOV facilities.

General Highway/Multimodal Scenarios were designed to improve travel on the transportation system and encourage the awareness and use of alternate modes of travel. The scenarios included providing travel information in homes and workplaces, using IVHS to reduce travel demand during air quality alerts, using ATIS to monitor parking availability, and developing a hand-held portable ATIS unit.

The Airport Scenario was designed to improve travel and traffic flow at airports.

Ports/Intermodal Facilities Scenarios were designed to improve the operation and efficiency of intermodal port and rail facilities. The scenarios provide for improved truck access to ports and rail facilities, improved vehicle processing at ports, and coordination of river and drawbridge traffic.

13 Organization

The paper is organized into five sections. Section 2 presents the multimodal transportation management scenarios and environmental concerns identified during the conduct of workshops. Section 3 highlights at a conceptual level broad, potential environmental effects. Section 4 discusses how multimodal transportation management can be related to the environmental processes. Section 5 presents concerns that need to be addressed and Section 6 presents conclusions.

2. MULTIMODAL TRANSPORTATION MANAGEMENT SCENARIOS

The study developed 27 conceptual IVHS scenarios covering a wide range of modes, user services, and areas of applicability. Exhibit 3 presents a sample scenario, "Air Quality Alert." Its purpose is to assist transportation managers in air quality non-attainment areas to manage travel during air quality alerts. Exhibit 4 presents a summary evaluation of this scenario based on each of the evaluation criteria identified in Exhibit 2 (more detailed evaluations were also performed and included as an appendix to the Final Report).

2.1 Modal and Area Applicability

Exhibit 5 presents a correlation of the 27 scenarios to their various modes. While all of the scenarios are multimodal in scope, they are grouped according to their primary mode of application. In developing these scenarios, an attempt was made to consider all modes, and not just the traditional highway modes.

2.2 Linkage to IVHS

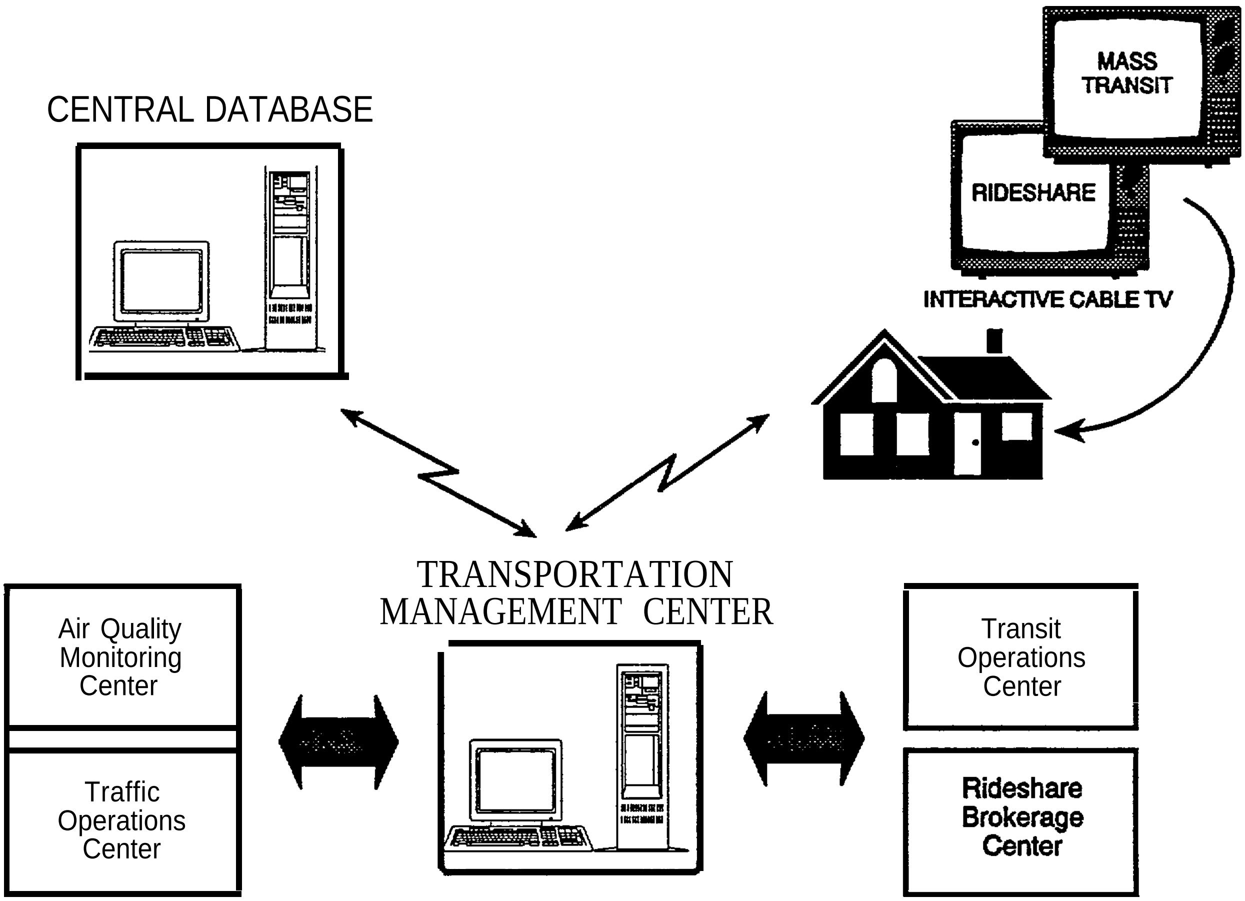
Exhibit 6 correlates each of the scenarios with the relevant IVHS technology areas (ATMS, ATIS, CVO, APTS, and AVCS) and areas of applicability. It can be seen that many of the scenarios have correlations to several IVHS technology areas.

It should be noted that although each scenario is listed individually, the scenarios can be combined in "packages" which might yield greater benefits than what could be obtained from the scenarios individually. For instance, scenario 18 "Air Pollution Alert," scenario 11 "Real Time Ridesharing," and scenario 4 "Transit Park & Ride Information" could be combined for use during air quality alerts or special events to encourage travelers to use Carpools or transit. Together, they would likely encourage greater use of alternate modes than any one scenario would on its own.

Not all scenarios, however, could be combined with positive results. While some combinations would enhance the overall benefits, others may prove counterproductive. Exhibit 7 presents the interrelationship between multimodal

SCENARIO NO. 18
AIR POLLUTION ALERT

GOAL: Reduce mobile source emissions and encourage use of alternate modes during non-attainment periods.



SCENARIO

1. Air Quality monitoring center identifies non-attainment areas or forecasts potential air quality problems.

2. Persons within these areas are notified and presented with alternate travel modes.

3. Road pricing policies could be implemented using AVI equipment on cars.

4. Real-time travel data allows cities to adjust management strategies once they have been implemented.

SCENARIO: 18. AIR QUALITY ALERT

Summary Evaluation

Criteria Category	Summary Rating/Comment	Comments
1. Applicable to MM Transportation management?	YES	Would permit implementation of Multi-modal transportation controls to meet air quality attainment goals.
2. Technically Feasible?	YES	Would largely use other IVHS systems to gain and disseminate information.
3. Potential Benefits	HIGH	Could help reduce mobile emissions and facilitate use of other modes.
4. Potential Costs	MODERATE	If system uses existing IVHS infrastructure, additional costs should be moderate.
5. Institutional/Legal Barriers	MODERATE	Will require regional (multi-jurisdictional) pollution control authority to coordinate mitigation measures.
6. Financially Feasible?	YES	Services could be provided through other IVHS systems. Would not need to dedicate an entire system solely to this purpose.
7. Attractiveness to Users, Operators, and Society	MODERATE	While mitigation measures themselves may be seen as unattractive, this system should be useful for users and operators during alerts.
8. Human Factors Effectiveness	HIGH	Will increase information available to travelers during alerts. Information will need to be accurate, timely, and accessible.
9. Potential for Success	HIGH	Should be a useful element of regional air quality plans. Could help to significantly reduce mobile source emissions.
10. Implementation Potential	HIGH	The CAAA '90 set out federal mandates to address air quality problems. This will be a major concern for non-attainment areas.

SCENARIO	MODE										
	PERSONS								GOODS		
	AUTO	HOV	TAXI	BUS	RAIL	AIR	BIKE	PED	TRUCK	PORT	RAIL
MASS TRANSIT											
1. Transit Route Deviation				X	X			X			
2. Ral-Time Bus Location information				X				X			
3. Timed Transfer Management				X	X						
4. Transit Park-Ride Information	X	X		X	X						
5. Samrtcard Fare Collection				X	X						
6. Transit Priority on signalized Networks	X	X	X	X	X	X	X				
7. In-Vehicle Information Displays				X	X			X			
8. Transit Schedule Reliability				X	X						
9. Improved Transit Management Info.				X	X						
10. Accident Data Recording	X	X	X	X	X				X		X
PARATRANSIT & RIDESHARING											
11. Real-time Ridesharing		X		X					X		
12. Paratransit Dispatching		X		X							
13. Taxi Management w/Smartcard		X		X							
14. Urban Goods/Passenger Movement		X							X		
15. Rural ATIS/Route Guidance	X	X	X	X					X		
GENERAL HIGHWAY											
16. Real-Time Transportation Information	X	X		X	X						
17. Needs Scheduling	X			X	X						
18. Air Quality Alert	X	X		X	X		X	X	X		
19. Weather/Roadway Condition Monitoring	X	X		X					X		
20. ATIS- Parking Availability	X	X							X		
21. Personal ATIS System			X	X	X		X	X			
22. Traffic Management at parks/Monument	X	X	X	X	X						
AIRPORTS AND PORTS											
23. Airport Access - Passenger Pick-Up	X	X				X					
24. Truck Access to Ports/Rail									X	X	X
25. Vehicle Processing at Ports/Rail									X	X	X
26. River and Drawbridge Coordination	X			X					X	X	
27. Moving Urban Goods on Ferries									X	X	

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Scenarios and Modal Applicability

Exhibit 5

SCENARIO	IVHS FUNCTIONAL AREA					URBAN AREA			RURAL
	ATMS	ATIS	APTS	CVO	AVCS	REGION	SUB AREA	FACILITY	
MASS TRANSIT									
1. Transit Route Deviation	X	X	X			X	X	X	X
2. Real-Time Bus Location Information	X	X	X			X	X	X	X
3. Timed Transfer Management	X	X	X					X	
4. Transit Park-Ride information	X	X	X			X	X		X
5. Smartcard Fare Collection	X		X				X	X	X
6. Transit Priority on Signalized Networks	X		X			X	X		
7. In-Vehicle Information Displays		X	X				X	X	X
8. Transit Schedule Reliability	X	X	X					X	X
9. improved Transit Management Info.		X	X		X	X	. X	X	X
10. Accident Data Recording		X	X	X	X				
PARATRANSIT & RIDESHARING									
11. Real-Time Ridesharing	X	X	X			X	X		X
12. Paratransit Dispatching	X	X	X			X	X		X
13. Taxi Management wl Smartcard		X	X	X			X		X
14. Urban Goods/Passenger Movement		X	X	X			X		X
15. Rural ATIS/Route Guidance	X	X	X	X					X
GENERAL HIGHWAY									
16. Real-Time Transportation Information	X	X	X	X		X	X		X
17. Needs Scheduling	X	X	X			X	X		X
18. Air Quality Alert	X	X	X	X		X	X	X	X
19. Weather/Roadway Condition Monitoring	X	X		X	X	X	X	X	X
20. ATIS - Parking Availability	X	X		X			X	X	
21. Personal ATIS System	X	X	X			X	X		X
22. Traffic Management at Parks/Monument	X	X	X					X	
AIRPORTS AND PORTS									
23. Airport Access - Passenger Pick-Up	X	X						X	
24. Truck Access to Ports/Rail	X	X		X				X	X
25. Vehicle Processing at Ports/Rail	X	X		X				X	X
26. River and Drawbridge Coordination	X	X		X			X	X	
27. Moving Urban Goods on Ferries	X	X		X		X	X	X	

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Scenarios and IVHS/Area Applicability

Exhibit 6

IVHS Action Group

	Increase Carpool	Increase Walk & Bike	Improve Paratransit & Goods Movement	Restricted Traffic	Pricing Measures	Parking Management
Increase Transit	C	A	A	A	A	A
Increase Carpool		I	I	C	A	A
Increase Walk & Bicycle			I	A	I	I
Improve Paratransit & Goods Movement				C	I	I
Restricted Traffic					C	C
Pricing Measures						A

A - Action Groups assist each other.
I - Action Groups are independent of each other.
C - Action Groups are counterproductive to each other.

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Interrelationships Between Multimodal Action Groups

Exhibit 7

transportation action groups. It can be seen that some action groups assist one another, some are independent of one another, and others are counterproductive. Before operational testing or implementation, careful consideration will need to be given to how an IVHS scenario will interact with other transportation management measures already in place in an area.

2.3 Environmental Concerns

As part of the study, a series of eight workshops were held at sites across the country. The one-day workshops were attended by transportation professionals from Federal, State, and local highway and transit agencies, representatives from airport and port authorities, and transportation planners from State planning agencies and MPOs. At the workshops, various participants discussed their concerns for IVHS and the environment. Some of the key points are summarized in Exhibit 8.

2.4 Relationship to Operational Tests

A final task of the study was to correlate the 27 scenarios with on-going or planned IVHS operational tests. This helped to identify potential test sites where each of the scenarios could be tied into ongoing tests. The correlation identified all ongoing and planned IVHS operational tests in the U.S. and determined whether they could provide a useful basis for testing any of the candidate scenarios. Exhibit 9 presents a sample correlation of a candidate scenario ("Transit Route Deviation") with ongoing operational tests. These correlations were useful not only for identifying sites where the candidate scenarios could be tested, but also for identifying areas where there is currently not enough IVHS research being done. The areas where there was a lack of current activity included air quality, environmental concerns, and intermodal ports and terminal facility operations. None of the IVHS operational tests currently being conducted in the U.S. has as one of its primary goals the reduction of air emissions or the improvement of environmental quality.

- For IVHS to be effective in reducing air quality there is a need to focus on parking availability and price. Volunteer efforts are ineffective during air quality episodes.

- Integrated Smart Cards covering mass transit, tolls, parking, congestion, pricing, etc. are needed to address reductions in emissions through SOV trip and VMT reduction. This will require a concerted partnership among the institutions.

- For mass transit to be effective in reducing SOV's, VMT, and emissions, there is a need to make it more customer oriented through improved mobility management (APTS) and driver training. AVL and AVI systems have been found to be effective in our management efforts.

- Nonrecurring congestion on freeways and arterials is a big part of the problem resulting in idling, emissions and wasted fuel. There is a need to develop ATMS, ATIS and other IVHS infrastructure to address the problem. However, it (IVHS) will not work unless there are alternative routes with capacity to choose from.

- Since many of the environmental benefits of IVHS are subjects of various demonstrations and are uncertain, how can these projects be considered in LRTP, TIP and SIP developments at the State and Local level?

- For IVHS to be effective in improving environmental quality, IVHS related projects need to be integrated into plans and programs with conventional highway, transit, airport/port, ground access and other projects. It took us 8 years to get a signal implemented, how do we get our board to act on items in the research/demonstration stage?

- When you look at the environment, think beyond the physical impacts (air quality, energy, congestion, traffic safety, etc.) to human factor effects (reduced anxiety and stress, improved driver/vehicle navigation, etc.). As IVHS makes better use of intrastructure, we have to account for new demands created, human factors, and socio-economic effects.

- We have trouble getting travel and environmental models (emissions, fuel consumption, etc.) to work with conventional plan and project evaluation. How do you get environmental models to work for real and semi-real time evaluations?

- Is there a clearinghouse to go to for reliable evaluation data and findings related to IVHS demonstrations and case studies? This is a particular concern for intermodal/multimodal projects.

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Workshop Environmental Concerns

Exhibit
8

APPLICABLE OPERATIONAL TEST SITES		COULD BE TESTED SOON (FULLY)	COULD BE TESTED SOON PARTIALLY	MAY NEED NEW INFRA-STRUCTURE	NOTES/ COMMENTS
Number	Description				
C-I-11	Fredericksburg ARTIS (VIRGINIA)		X	X	Needs to relate to VDOT
A-II-4	Advance (Illinois)	X			NHTSA is cooperating
A-II-5	Fast Trac (Michigan)			X	NHTSA is cooperating
C-I-5	TravLink (Minnesota)		X		Need outputs on initial project
C-II-15	Portland SmartBus (Oregon)		X	X	Future Smart Vehicle projects could benefit.
C-II-16	Denver SmartBus Stage I		X	X	Future Smart Vehicle projects could benefit.
C-II-17	Baltimore SmartBus (Maryland)		X	X	Future Smart Vehicle projects could benefit.
C-III-19	Ann Arbor Smart Intermodal (Michigan)		X	X	Future Smart Vehicle projects could benefit.
C-III-20	Chicago Smart Intermodal (Illinois)		X	X	Future Smart Vehicle projects could benefit.
C-I-12	Winston Salem Mobility Manager (N.C.)		X	X	
C-I-13	Delaware County Mobility Manager (Pennsylvania)		X	X	

COMMENTS

Presently only area where this is being done is C-I-11. There is not a lot going on in this area. Need to be more pro-active promoting this scenario.

Modal administrations interested include FTA, FHWA, and NHTSA. The agencies are participating in the operational tests noted above.

*only arterial and collectors can be displayed in FastTrac. Display and navigation for residential streets is required for this scenario.

A - PRESENT OPERATIONAL TESTS (FHWA)
B - PLANNED OPERATIONAL TESTS
C - APTS PROGRAM (FTA)
D - TRANSIT OPERATIONS OPERATING/PROCURING AVL SYSTEMS

CORRELATION OF SITES WITH SCENARIO I.

Environmental concerns are often being addressed only as secondary impacts of IVHS research, not as primary goals. Secondly, the lack of operational test activities means a corresponding lack of available operational test data on which future evaluations of IVHS environmental impacts could be based. There is currently very little data on the potential environmental effects of IVHS.

3. POTENTIAL ENVIRONMENTAL EFFECTS OF SCENARIOS

3.1 Range of Environmental Effects

Intelligent Vehicle Highway Systems have the potential to create positive environmental effects in a number of areas, including reductions in congestion and vehicle emissions, reduced VMT, improved safety, and improved economic efficiency. Exhibit 10 presents a list of environmental elements and potential IVHS effects. It should be noted that the magnitude of these potential impacts remains to be determined through modeling and operational testing.

3.2 Analytic Uncertainties

There are inherent uncertainties in trying to assess the potential impacts of IVHS scenarios. Current models are not necessarily accurate and may not consider the full range of IVHS impacts. This problem was discussed by Brand in a paper describing criteria and methods for evaluating IVHS plans and operational tests. In the past, techniques for evaluating IVHS scenarios and operational tests have tended to underestimate the mobility and personal benefits of new technology and have not taken into account the time frame for impacts or the differences between supply and demand impacts. With IVHS, evaluations must be based not just on the use of infrastructure, but on the use of information as well.‘“” Traditional evaluation methods may therefore not provide accurate estimates of potential benefits and costs.

There are similar uncertainties with the existing models used to project impacts of IVHS scenarios, particularly as they relate to air quality. Current emission models have high levels of uncertainty and may not yield accurate forecasts. Combined with

Traffic: • Safety • V M T • Speed Congestion	• Reduced Accident Potential • Reduced Trip Ends, VMT • Reduced Idling, Improved Speeds, Managed Congestion
Physical: • Cultural Resources	• Reduced Tourist Anxiety • Improved Pretrip Planning
• Air Quality	• Reduced Emissions, Concentrations Better Information During Episodes
• Noise & Vibration	• Reduced Truck Speeds
• Biota	• Less Construction. More Efficient Use of Facilities.
• Energy	• Improved Speeds, Reduced Fuel Consumption.
Social: • Community Cohesion	• Less Time in Traffic Jams. More time with community.
• Accessibility of Facilities and Services	• Better Real Time Responses for Police, Fire, Ambulance, and Other Services.
• Displacement	• Minimal Land Requirements.
Economic: • Employment, income	• New Techolology and New Jobs.
• Business Activity	• More Predictable Passenger and Freight Movements. Increased Productivity.
• Residential Effects	• Minimal
• Property Tax	• Unknown
• Resources	• More Efficient Use of Resources.

* Impression subject to verification and validation using demonstrative test results and acceptable environmental assessment models/procedures.

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Potential Environmental Effects of Scenarios

Exhibit 10

the uncertainties associated with the impacts of IVHS on VMT, travel patterns, and transit/HOV use, the magnitude of potential environmental impacts are unclear.

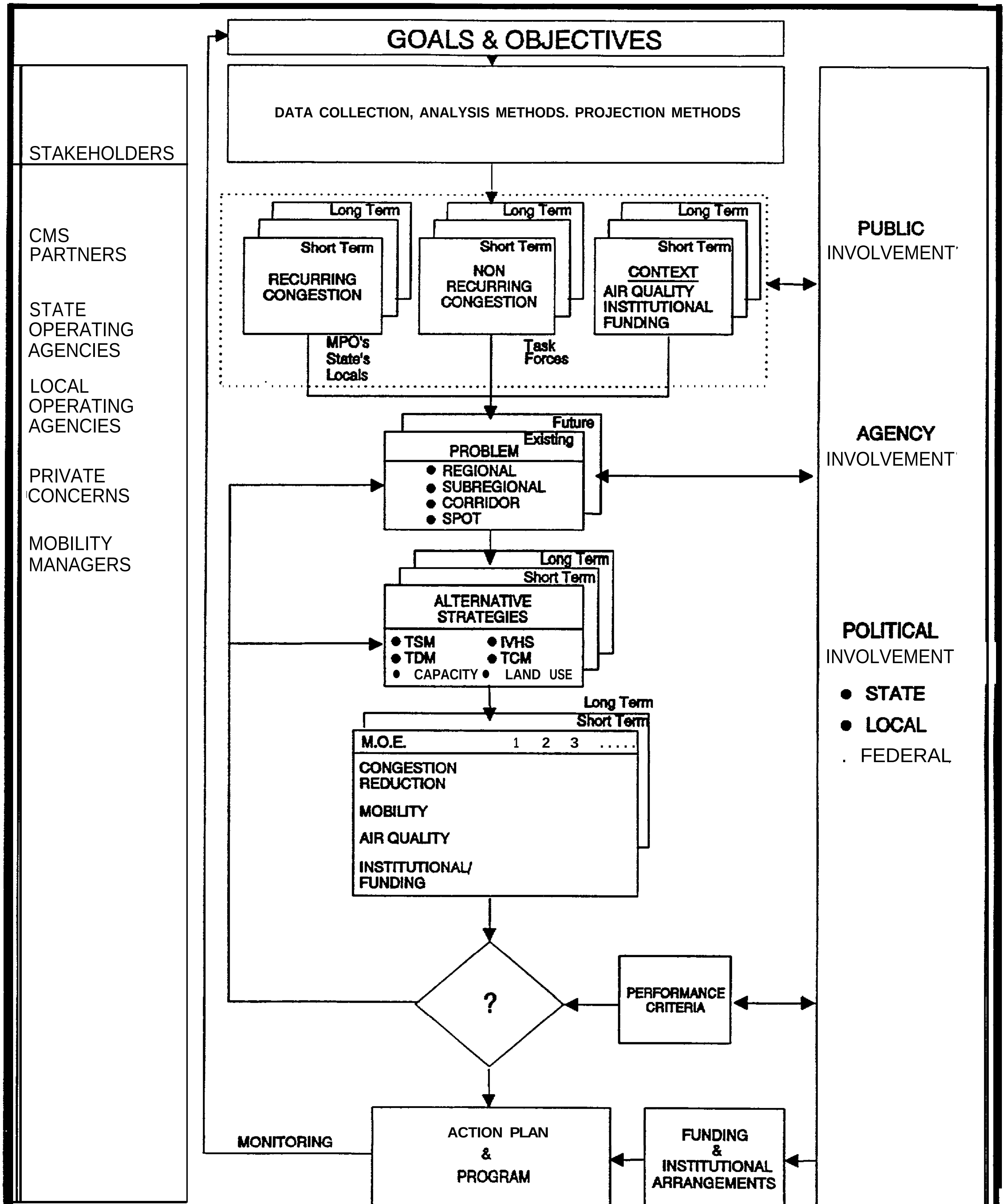
4. RELATING MULTIMODAL IVHS TO ENVIRONMENTAL PROCESSES

The previous sections have highlighted the multimodal IVHS scenarios and potential environmental effects as well as uncertainties. For IVHS to be fully integrated and implemented, it will need to be incorporated into ISTEA, CAAA, management systems, planning activities, and the NEPA process.

4.1 Congestion Management and Air Quality

Multimodal transportation management strategies linked to IVHS have potential impacts on ISTEA's management system requirements, particularly the Congestion Management System (CMS), which **is** one of the six major management systems. Other management systems that could benefit from IVHS advanced technologies could include: Intermodal, Public Transportation, Highway Safety, Highway Pavement and Bridge Management Systems.

Exhibit 11 illustrates a general CMS process for addressing recurring congestion, non-recurring congestion, and air quality. As indicated, multimodal and mode specific actions incorporating IVHS technologies should be considered and evaluated with respect to their effectiveness along with other actions. It will be important to know the effects for existing, short term, and long term conditions. The challenge of examining IVHS will be to evaluate the use of information (not just infrastructure) on a real time basis. Presently, our analytic procedures and data are not providing practitioners what is needed for definitive evaluation. If IVHS is to be implemented, it will need to address state of the art improvement and present the relevant costs and environmental effects to the decision makers. Principles related to this new evaluation process where highlighted by Brand at TRB (5).



BMI Congestion Management, Air Quality, and IVHS

Exhibit 11

4.2 State and Local IVHS Strategic Plans

Incorporation of environmental quality concerns should be an integral part of IVHS Strategic Plans under development and refinement by State and Local governments. Most plans today highlight current and planned demonstrations of transportation - IVHS applications with a focus on the technical feasibility of the technology. Often times, many of the demonstrations give a cursory view of the evaluation activities rather than making it a formal activity upfront. This environmental evaluation will need to be done using best available data and models. As noted at the National IVHS and Air Quality Workshop (3) there needs to be a stepped up effort in micro and macro scale models and data in order to achieve this improvement with respect to the IVHS Strategic Planning process.

43 State and Local LRTP's and SIP's

To increase the implementation of multimodal transportation management, IVHS will require incorporation of these actions into State and Local Long Range Transportation Plan (LRTP's) and State Implementation Plan (SIP's). A key problem here is evaluation methodology and clear communications on the costs and environmental benefits, particular details on how the transportation/IVHS action contributes to the reduction of emissions and achievement of air quality standards.

In conducting the multimodal IVHS workshop, a clear theme was the importance of showing the decision makers the environmental benefits in terms understandable for that region or area.

- Will arterial and freeway volumes and speed change? If so, by how much?
- Will HC, NO and CO emissions change?
- Will fuel consumption decrease?
- Will the quality of flow be improved?
- What are the socio-economic benefits?

Without definitive information, IVHS implementation can be stalled. The TSC is undertaking development of integrated models to assess IVHS impacts for Advanced Traffic Management Systems (ATMS), Advanced Traveller Information Systems (ATIS), and Advanced Public Transportation Systems (APTS) (3) There is a need to include other technology groups such as CVO, ARTS, and AVCS in the model development process.

4.4 EIS, EA's Under NEPA

How Multimodal-IVHS projects are examined under the NEPA environmental process is unclear. However, IVHS has been included for site access EIS's/EA's and at the corridor level associated with other transportation actions. At the site level, multimodal-IVHS actions can aide TDM, TSM, and TCM actions which can reduce SOV use, thereby improving air quality, reducing energy consumption, and providing benefits. At the corridor level, IVHS can assist multimodal HOV actions organized to increase auto occupancy in the corridor.

The decision of whether or how to include IVHS in the environmental process is largely an administrative decision based on the lead and cooperating agencies involved.

5. CONCERNS TO BE ADDRESSED

The study and workshops have identified a number of concerns that need to be addressed before more meaningful evaluations can be made of IVHS's potential to improve the environment.

5.1 Comprehensive Evaluation Framework

There needs to be a comprehensive framework for evaluating IVHS projects that includes environmental considerations. Too often, environmental impacts are given only secondary consideration when evaluating potential IVHS benefits. A comprehensive framework of the type shown in Exhibit 2 that includes benefits (and costs) to air quality, the environment, the economy, and to society should be developed.

5.2 Reliable Data Sources

There is a need for more reliable data sources than are currently available. IVHS will be hard to sell at the state and local levels if there is not data to justify large expenditures on IVHS infrastructure and communication systems. Data from programs across the nation need to be consolidated and made available through a clearinghouse so that IVHS planners may have accurate data on which to base projections of benefits and costs.

53 Improved Modeling

The current models used to project impacts on air quality and the environment need to be updated to provide more accurate estimates of IVHS impacts. New models which take into account the wide range of potential IVHS impacts should also be developed.

5.4 Improved Operational Test Evaluations

There is a need for operational test data which can be used to assess the environmental effects of IVHS scenarios. Future operational tests must have evaluation programs that will yield reliable data. Appropriate measures of effectiveness should be developed to ensure that the data generated is meaningful and useful to transportation planners and engineers.

6. CONCLUSIONS

- IVHS Actions have potential positive environmental quality effects.

- When assessing environmental effects of IVHS, there needs to be a broad outlook to include social and economic effects in addition to traffic, air quality, energy and physical environmental effects.

- IVHS actions need to be incorporated into CMS, LRTP/TIP, and other processes where environmental concerns are addressed. It is difficult to assess IVHS as a stand alone action.

- A number of concerns need to be addressed including a data/finding clearinghouse function, better data, and better models.

- Priority needs to be given to scenarios with obvious environmental benefits including air quality alert, port/airport intermodal facilities, etc.

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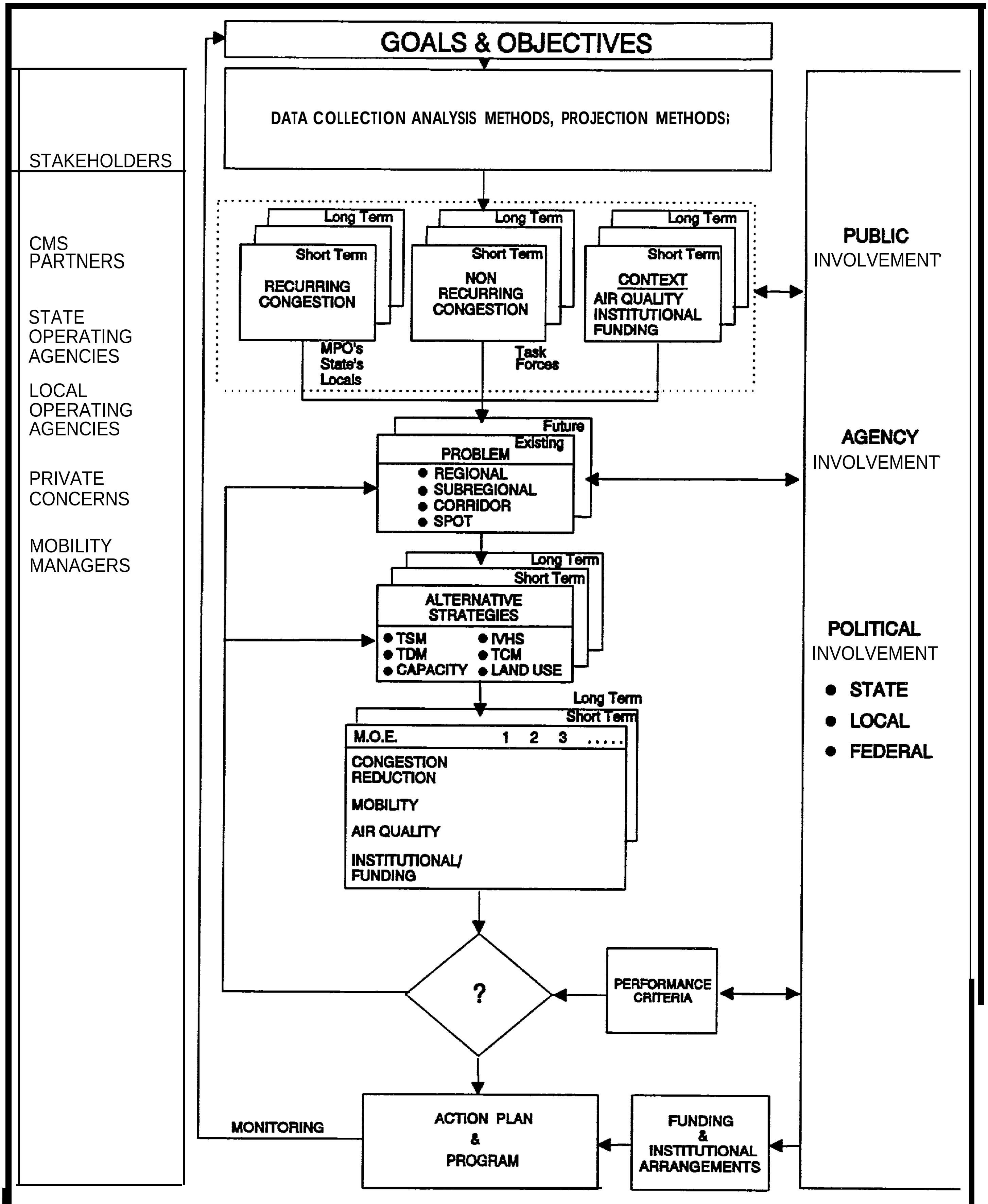
GOALS & OBJECTIVES
DATA COLLECTION ANALYSIS METHODS, PROJECTION METHODS;
STAKEHOLDERS
CMS PARTNERS
STATE OPERATING AGENCIES
LOCAL OPERATING AGENCIES
PRIVATE CONCERNS
MOBILITY MANAGERS
Long Term
Short Term
RECURRING CONGESTION
NON RECURRING CONGESTION
CONTEXT
AIR QUALITY
INSTITUTIONAL
FUNDING
MPO's
State's
Locals
Task Forces
PUBLIC INVOLVEMENT
AGENCY INVOLVEMENT
POLITICAL INVOLVEMENT
STATE
LOCAL
FEDERAL
Future
Existing
PROBLEM
REGIONAL
SUBREGIONAL
CORRIDOR
SPOT
ALTERNATIVE STRATEGIES
TSM
TDM
CAPACITY
IVHS
TCM
LAND USE
M.O.E. 1 2 3 .....
CONGESTION REDUCTION
MOBILITY
AIR QUALITY
INSTITUTIONAL/ FUNDING
?
PERFORMANCE CRITERIA
MONITORING
ACTION PLAN & PROGRAM
FUNDING & INSTITUTIONAL ARRANGEMENTS

The Greening of IVHS

Integrating the Goals of Air Quality, Energy Conservation, Mobility and Access in Intelligent Transportation Policy

BY

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IVHS is an amplifier. It amplifies both what is good and what is bad about our transportation system, and extends the consequences to other domains, such as energy, environment, and land use. In some configurations, IVHS technologies promise to boost mobility and safety dramatically, while at the same time inviting increases in vehicular pollution, demand for foreign oil, and inequality in transportation access. Travel safety and capacity enhancement are of course desirable, but what if their achievement comes at the expense of air quality, energy security, and perceived equity?

The answer to this question depends on fundamental assumptions about latent travel demand, modal choice, and the capabilities of vehicles and route guidance systems operating in the future, which in turn involve assumptions about technological innovation, commercialization, and government policy and enforcement with respect to emissions standards, fuel efficiency standards, transit use, and a variety of transportation control measures. Clearly, a doubling of capacity2 on existing roadways would induce some additional demand, but would the increased number of vehicles emitting pollution and consuming gasoline be more than offset by the emissions savings and fuel savings gained from reduced congestion? And for how long? Would transit applications of IVHS compensate for potentially negative energy and environmental consequences of enhanced mobility for automobiles? And assuming that the paramount goal of IVHS advocates is the efficient movement of people, rather than vehicles, how are tradeoffs between access, mobility, air quality, and energy conservation to be decided?

No one should feel confident that these questions can be satisfactorily answered for all regions and circumstances in which IVHS technologies are envisioned. To a large extent, the answers depend on a combination of future behavior changes, market conditions, political leadership and entrepreneurial abilities that can only be dimly discerned today. Moreover, the lack of adequate, tightly coupled, system-wide models of modal choice, trip generation and distribution, on-road driving behavior, vehicle emissions, and pollution dispersion, suggests that no definitive answers will be forthcoming in the near future.

Rather than bemoan the lack of integrated, systemwide models, this paper seeks to refocus attention on the vehicle technology assumptions used by modelers. Recent advances in clean car technology -- e.g., electrically heated catalysts, remote sensing of on-road emissions, reformulated fuels, and ultra efficient, zero- and ultra low-emission "supercars" -- suggest that conventional projections of vehicle fleet characteristics with incremental improvements will overstate future environmental and energy risks of mobility enhancement. In other words, incremental extrapolation of today's vehicle inputs and outputs for purposes of IVHS simulation represents more of a political judgment than one based on technological foresight. The technologies needed for nonincremental change are becoming available with astonishing speed; it is the political will and administrative capacity to employ these green technologies that is, as usual, lagging behind. Even in California, where political mandates for clean car technology are strongest, public acceptance and scattered support from the private sector is wavering. Foremost among the reasons for concern is the huge gap that remains between policy goals and market incentives to develop zero- and ultra low-emission vehicles with ultra high fuel efficiencies.

Viewing IVHS as a potential amplifier of on-road vehicle emissions and fuel consumption implies that the critical factors in determining future impacts are the emissions control capabilities and fuel efficiency ratings of vehicles that are forecast to be on the road during each phase of IVHS implementation. While IVHS also can and should be used to amplify transit use and trip avoidance strategies. the assumption made in this paper is that the impacts of such use, given transportation policies that satisfy near-term conditions of political and economic feasibility, will be small in comparison with the effects of cleaning up single occupancy vehicles (SOVs). For example, removing one vehicle from commuter traffic in 1992 using Southern California's rideshare program (Regulation XV) was estimated to cost nearly $3,000.[3] Investing the same amount of money in remote sensing and related programs for identifying and fixing, or retiring, gross polluting vehicles -- the roughly 10 percent of the vehicle fleet responsible for more than 50 percent of on-road emissions -- would result in emissions reductions that were, according to the author's calculation, at least 14 times greater, and probably much more than that.[4] Similarly, air quality gains from light rail transit compare very unfavorably on an abatement cost basis with clean car programs, and offer little justification by themselves for the enormous subsidies involved in transit ridership -- up to $8,000 per roundtrip passenger per year in Southern California.[5] While many proposed IVHS designs are biased to expand route choices for SOVs without first and foremost increasing modal choices (e.g., enhancing the ***ease*** of choosing existing transit systems), the strong likelihood remains that the negative energy and environmental consequences of this bias will shrink rapidly in the next decade as SOVs become much cleaner and, hopefully, more efficient.

Although transit enhancement, travel safety, and economic stimulation from technology development are all important objectives of IVHS, by far its greatest challenge over the next twenty years will be to double mobility for SOV trips, while enabling pricing strategies (e.g., congestion pricing) and "green" technology applications to achieve net reductions in vehicle emissions and fossil fuel consumption.IVHS by itself is unlikely to contribute greatly to the goals of environmental quality and energy security. It is primarily a bridge to other solutions in these areas, and its potential for ***indirect*** contributions is what matters most. Accordingly, IVHS should not be thought of as a bundle of end-state products linked to throughput efficiency so much as a set of ***enabling*** technologies for optimizing among the sometimes conflicting goals of efficiency, safety, equity, and sustainability. Given that there are tens- and perhaps hundreds-of-billions of dollars at stake, it is not surprising that the instrumental nature of IVHS has sometimes been lost in the scramble to transform IVHS deployment itself into a national goal. As the remainder of this paper attempts to demonstrate, however, the desirability of IVHS deployment depends heavily on how problems that are external to the transportation system are resolved.

CONSTRAINTS MAPPING

Because thinking about IVHS development and deployment continues to suffer from what Langdon Winner refers to as "reverse adaptation" of ends to means, there is a tendency within the IVHS community to regard issues of social equity and ecological sustainability as constraints rather than goals.[6] Some engineers, for example, may allow their fascination with IVHS as a technological means to shape their vision of social ends -- principally, mobility and safety, if not technological progress, itself The investigation of technical requisites of IVHS deployment (e.g., systems architecture) has tended to far outpace investigations of its social, environmental, and institutional implications. As a result, much of the activity surrounding IVHS appears to foster "technology push" rather than "market pull" behavior, and efforts to gauge public acceptance have predictably emphasized consumer issues over those of community and neighborhood livability.

Despite the relatively lavish attention and funding devoted to matters of IVHS technical performance, systems integration, and cost studies, so-called "nontechnical" issues may ultimately play a more influential role in IVHS adoption than straightforward matters of market demand and technological readiness. Grassroots public acceptance and IVHS goal conformity with cross-cutting policies originating outside the transportation sector have already surfaced as pivotal issues in development and implementation. One way to appreciate the nontechnical barriers that stand in the way of rapid deployment of IVHS is to trace systematically the constraints that arise at each stage of implementation -- from conceptual design to full-scale operationalization. An abbreviated constraints map of this sort is presented in Figure (1). Following the conventional view that deployment is the goal, it treats all other variables as either bridges or barriers to that goal. Unlike a critical path diagram or a technology-centered risk assessment, the constraints map attempts to show how limitations in knowledge, finance, hardware, political support, and ecological carrying capacity can influence the strategies of public and private actors and institutions interested in IVHS, and how these strategies are linked to key enabling policies (i.e., ISTEA), which must later be reconciled with other policies (e.g., Clean Air Act Amendments, Energy Policy Act, Americans with Disabilities Act), and made compatible with co-evolving organizational structures and market forces. 7

The fears and hopes that arise from technological innovation provide the basic driving forces for moving IVHS through the political constraints process that determines the fate of nearly all large-scale policies and projects, especially those that cannot claim national security status or the legitimacy conferred by crisis-driven decision making. These fears and hopes are themselves amplified and sometimes distorted through advocacy coalitions and media coverage. In the case of intelligent transportation systems, most of these fears and hopes are based less on assumptions about human travel behavior than on assumptions about the kind of vehicles and transportation alternatives that will be available in the near- to mid-term. Consider the effects of assumptions about modal choice and vehicle technology on some of the major arguments of IVHS critics and supporters listed below:

Fears of IVHS critics:

- Increases aggregate vehicle emissions and energy consumption due to increased trips and VMT

- Increases travel on arterials by diverted travelers, exposing many neighborhoods to greater smog, air toxics, and noise

- Perpetuates auto dependency -- a “reprieve” for SOVs
  (e.g., Increased auto dependence owing to induced land use patterns that increase average distances traveled by commuters as average travel times decline from congestion relief)

- Imposes large social opportunity costs (IVHS seen as a megaproject that uses up scarce resources needed for achieving other public goals)

- Exacerbates perceived inequalities among travelers (e.g., expense of onboard ATIS may widen gap between information-rich and information-poor travelers)

- Preoccupation with mobility will lead to furthr neglect of accessibility

- Fosters "dispersed" congestion (as opposed to congestion that is concentrated in CBD)

Hopes of IVES supporters:

- Improves travel patterns to achieve congestion relief, and thereby reduces emissions and fuel consumption associated with congestion

- (Related to #1) Smoothes traffic flows, thereby reducing emissions and fuel consumption from repeated acceleration and deceleration

- Serves as a bridge to pricing solutions for use in demand management (e.g., road pricing)

- Enhances attraction of transit and paratransit programs through dissemination of real-time information, etc.

- Encourages ridesharing and trip linking among SOV operators by providing accurate traffic-sensitive and weather-sensitive travel information

TEE CAR OF TOMORROW

The single most important factor for deciding whether the critics or supporters have the better case is the predisposition of the participants in the debate toward vehicle technology improvements. In the case of environmentalists, there are two major and competing predispositions: (1) that technology "fixes" have been greatly oversold and will cause more problems than they will solve, and (2) that technological solutions are promising, but unwanted because they undermine more basic environmental arguments for changing human lifestyles. To the first group, the concept of a "green" car is an oxymoron; to the second, it represents a paradoxical improvement and, hence, a bonafide threat to the continuing campaign against the automobile as a symbol of environmental destruction. Having spent more than two decades trying to convince people to break their auto-dependency, the very real prospect of strong, safe, ultra-light, ultra-clean Supercars within ten years8 can only be accepted by such groups with a certain amount of ambivalence.

Emissions Control

Since 1961, when California mandated the use of positive crankcase ventilation (PCV) on cars sold within the state beginning in 1963, emissions control for motor vehicles has developed into a major industry. The key advance came during the mid-to-late 1970s with the introduction of the catalytic converter, as well as engine gas recirculation and evaporative recovery systems. This was followed shortly by the improved three-way catalytic converter and by electronic fuel injection, which adjusts the air/fuel mixture to meet the exacting specifications of advanced emissions control systems. These advances made possible a 96 percent reduction in tailpipe emissions of CO and HC, and a 76% reduction in NOx, between 1960 and 1990.[9] During this same period, fuel consumption per mile for new cars dropped nearly 50 percent and accidental deaths per mile declined 65 percent.[10] In short, emissions abatement, fuel efficiency, and auto safety were all major technological success stories during this period, but their achievements were tempered by sheer growth in the number of vehicles, vehicle trips, and vehicle miles traveled. For example, total VMT increased by over 170 percent between 1960 and 1990. While most of this increase can be attributed to the addition of over 250 million new passenger cars registered during this period[11] per capita increases in travel and VMT also played a significant role. During the 1980-1989 period, for example, VMT per vehicle increased 16 percent, contributing to an aggregate increase of 40 percent.[12]

As progress has been achieved in emissions control and automotive engineering, more and more attention has been devoted to emissions caused by cold engines, vehicle acceleration and deceleration, and fuel evaporation. Emissions from what are called “cold starts” and “hot soaks” (emissions that occur at the beginning and at the end of a trip), account for roughly two-thirds of the total emissions from a ten-mile trip under normal driving conditions. If strong acceleration or deceleration occurs, large emission “puffs” will usually be produced as a consequence. Given that it is easier to improve emissions control technology than the driving behavior of tens-of-millions of Americans, potential solutions for cold start and hot soak problems look much more promising than public appeals to step lightly on the accelerator and brake pedals. While IVHS may make its most significant air quality contribution in this latter problem area by smoothing traffic, or providing automatic speed governors,[13] the biggest payoffs are likely to come in the cold start category from the installation of new electrically heated catalyst (EHCs).

Because today’s catalytic converters must reach temperatures of 250-300 ^{o}C for optimal performance, the first few minutes of any trip undertaken with a cold engine is a period in which much of the exhaust gas flows through the converter without the catalytic action needed to breakdown harmful emissions. A cold engine typically requires over 100 seconds to heat the catalyst to its start-up temperature.[14] While heated catalysts have been around for many years, the electricity they consumed from the battery made them impractical. Recent advances in EHCs, however, have brought the battery drain down from over 600 amps to about 175 amps (power and energy consumption level of 2 kW and 8 W-hrs. at 15 seconds duration). This is well within the limits of battery and alternator systems, and is sufficient to warm up some catalysts in as little as 5 seconds. Test results of the new EHC systems are summarized in Table 1 and suggest that a significant leap forward in emissions control technology is at hand. Total costs to vehicle manufacturers of producing EHCs (with light-off catalyst, but without precious metal) have been estimated to be $95 per unit, assuming a production volume of 300,000 units. Total cost for a complete alternator-powered EHC system (loaded with precious metal, plus light-off catalyst, plus air injection components, switches, valves, and cables) is estimated to be $165.[15] During the startup phase, costs of these units will of course be higher, perhaps exceeding $400 per vehicle.

Table 1
Emissions Levels of Different EHC Systems
(grams per mile)

Source[16]	*Vehicle Type*	*CO*	*HC*	*NOx*
Corning		0.62	0.02	0.16
SAE	'88 Volvo	0.46	0.06	0.07
ASME	'86 Camry	0.38	0.03	0.25
ASME	'90 Celica	0.40	0.03	0.05
ASME	'90 LeSabre	0.25	0.02	0.18
CARB	'90 LeSabre		0.03	0.27
Average (EHC-equipped vehicles)		0.42	0.03	0.16
1980-1993 Federal Standard		7.00	0.41	2.00
1994-2003 Federal Standard		3.40	0.25	0.40
1997 ULEV Standard (California)		1.70	0.04	0.20

Other advances in emissions control technology will add significantly to the air quality improvements promised by EHCs They include reformulated gasoline, introduction of electric and compressed natural gas vehicles, and advanced on-board diagnostics systems (OBDs) that provide real-time information about emissions performance, as well as fault tree data that can be downloaded for monitoring and repair purposes. A summary of these and other clean car innovations and policies, along with fuel economy measures, are provided in Table 2.

Fuel Economy

Given the enormous advances in vehicle design and emissions control technology, it seems reasonable to expect that similar advances have occurred in the fuel efficiency area. The fact is, however, that while major efficiency improvements have been achieved with experimental vehicles, the commercial and near-commercial applications of energy-efficiency for automobiles and, especially, trucks, have been disappointing by comparison. Average fuel efficiency of new American cars actually declined by 4 percent from 1988 to 1992. 17 Fuel prices, unlike the price of clean air, have not figured prominently in discussions about vehicle design since the early 1980s although conflicts like the 1992 Gulf War served to remind many Americans that a fateful link -- oil -- still ties our foreign policy and transportation policy together.

Table 2

Green Car Technologies

*Emissions Control**

- electrically heated catalysts
- remote sensing of emissions
- oxygenated fuels
- leak free exhaust/double wall pipes
- improved fuel atomization
- dual oxygen sensor compensation
- palladium catalysts with cerium washcoats
- on-board diagnostic systems
- reformulated gasoline
- alternative fuels
- sequential fuel injection
- vapor recovery systems
- adaptive transient fuel control

Fuel Economy

- use of composites in body molding
- hybrid electric drives
- advanced radial tires
- recapture of braking energy
- aerodynamic design

*Many of the emissions control technologies may also help to improve fuel economy, just as some of the fuel economy measures may also offer emissions benefits.

The role of IVHS in helping to achieve energy conservation goals is based largely on the premise that smoothing traffic flows, finding the most efficient routes, and eventually providing automated vehicle control systems, will reduce unnecessary VMT and improve actual on-road fuel economy for all classes of vehicles. Initial estimates of energy impacts of IVHS projected 6.5 billion gallons of furl being conserved by the year 2010, however these estimates have been reduced substantially as additional induced demand factors have been consifered. 18 While some advocates of supercars are touting ultra-light hybrids that they claim will travel coast to coast on 8 gallons of gasoline, 19 the apparent demand for such vehicles is low. Since fuel costs represent less than 13 percent of the direct costs of driving, there is little incentive for travelers to make fuel economy a major consideration in their modal choices and vehicle purchases. Absent higher gasoline taxes, efficiency rebates (e.g., California's DRIVE+ program), greater political instability in oil-rich regions, or the imposition of stronger corporate fuel economy standards (CAFE), there is little reason to expect that fuel savings of future fleets will approach their emissions savings.

While several innovative pricing measures, such as pay-at-the-pump auto insurance, might have a significant salutary effect on both fuel economy and vehicle emissions, the political obstacles to such measures have so far been daunting.20

TECHNOLOGY, POLITICS, AND MARKETS

It is customary in papers of this type to pause at this point in order to sharpen the contrast between the promise of new technologies, the dismal impedance of politics, and the redeeming pull of the marketplace. Only the power of the market, many believe, can rescue publicly regulated technoscientific triumphs from the mire of bureaucracy and interest group struggle. A free market, in their view, is the best antidote to the paretic poison of modem politics. It seems to follow that only strong market forces can assure successful navigation of IVHS through the complex corridors of power and channels of public acquiescence. Idealistic environmental, energy, and equity concerns in such a setting are assumed to yield to the logic of the market as marginal costs and benefits -- those that can be easily measured -- are added and compared. Such perspectives lead many to view the implicit demands and constraints placed on IVHS by the Clean Air Act and other policies as excessive, even counterproductive. Why expect IVHS to solve air pollution problems that ought to be tackled by auto manufacturers and by designers of vehicle inspection and maintenance programs?

The above characterization arguably represents the conventional wisdom of many in the IVHS community. It does not, however, do justice to the complexity and significance of public policy making. Politically speaking, IVHS acceptance may ultimately depend less on drawing attention to the problems that it solves than on managing the problems that it amplifies. Americans confronted with a technology or a policy that takes them three steps forward for each step backward may nevertheless choose to emphasize losses over gains. Such behavior may seem irrational to many, but it is understandable to many social psychologists and experts on risk perception.21 In cases where the implementation of the technology or policy being considered is virtually a foregone conclusion, as with IVHS, the tendency to focus on problems rather than opportunities may grow even stronger. Given the decentralized, staged deployment process that IVHS will almost surely follow, there will be multiple intervention points and policy venues for those who wish to stop or slow implementation. As any activist knows, it is usually easier to block initiatives in our political system than it is to get them adopted. Those who believe that market forces will sweep away these islands of resistance would do well to remember the lessons of the American SST program or the RU 486 “abortion pill.”

To some extent, IVHS represents a set of technologies in search of applications. But it could also be said that IVHS represents a set of disparate policy goals in search of integration. Environmental and other non-transportation objectives will have to play a major role in determining IVHS configurations and applications if substantial compliance with pre-existing goals and policies is to be achieved. In the policy arena, tails *do* wave dogs, especially when they are dogs (e.g., transportation) with multiple tails (e.g., air quality, access for the disabled, energy conservation, etc.). But this indicates a further problem with the conventional wisdom. It conceives of problems and solutions too narrowly. The remedy perhaps can be found in the emerging insights of sustainable transportation thinking, an alternative viewpoint that offers a much more integrated and collaborative approach to problem solving. The sustainability paradigm begins with a simple and, some say, simplistic goal: "[To meet] the needs of the present without compromising the ability of future generations to meet their own needs."[22] The test of a sustainable transportation technology is whether it is compatible in the long run with basic ecological precepts and collective human needs. Rather than drawing sharper distinctions between technology, politics, and markets, the approach of sustainable transportation is to recognize the interdependence of all three in forging long-term solutions to what are predominantly urban problems. As important as markets and trade are in shaping our future way of life, they are nevertheless derivatives of politics, and probably always will be. They cannot operate independently of politics anymore than Wall Street can separate itself from the actions of the Federal Reserve. Based on the premise that there is no such thing as a free market or free trade, only designed markets and designed trade, the central question becomes how to foster cooperation within and between business and government for the purpose of designing technologies, policies. institutions, and markets that will improve our quality of life. IVHS represents a test case for this kind of thinking, and the "greening" of IVHS, if indeed it occurs, will reflect a change in values every bit as important as the change in technology that it represents.

POLICY WEDGES

The analytical challenge of sustainable IVHS deployment is essentially one of optimizing across competing public policies for the purpose of minimizing the zone of incompatibility between stated or implied policy goals. Although the idea that official policies often work at cross purposes may sound like an indictment of the American policy making process, in reality, a certain amount of incongruity in policy objectives is unavoidable in political systems that depend on compromise and on the strategic use of ambiguity in coalition building. Our system being one that occasionally raises policy incompatibility to absurd heights (e.g., tobacco subsidies and anti-smoking programs), it should come as no surprise that intelligent transportation technology and intelligent transportation *policy* may sometimes follow different paths. Successful deployment of

IVHS will require more of a reconciliation process involving multiple goals and objectives than a linear implementation process pegged to efficiency. Furthermore, given the inter-jurisdictional challenges of federalism, it will require a reconciliation of the interests of multiple agencies and levels of government, not to mention a profound reconciliation of the different cultures and customs that divide public and private sector actors.

In thinking about how to relate advances in vehicle emissions control and fuel efficiency to prospects for IVHS deployment, it is helpful to recognize three cross-cutting policy issues that link the goals of clean air, energy security, mobility, and access to transportation. The first is the growing preference for demand-side management (DSM) rather than supply-side management of public problems.[23] The second, and related, issue is the growing reliance of governments on market-based tools for problem solving (and the concomitant erosion of command-and-control regulation).[24] The third involves the application of technology-based solutions to problems that were previously thought to require fundamental changes in human behavior for their successful management. While achievements made possible by DSM, market-based tools, and technical fixes are often oversold or uncritically accepted (especially in the case of technical fixes), the unmistakable trend over the past decade has been nevertheless toward greater reliance on these approaches. Applications of joint DSM-market incentive programs have revolutionized energy and water resource management, for example, and seem poised, with the help of automatic vehicle identification (AVI) and road pricing, to offer the same kind of benefits for the management of transportation. Technological innovations, such as IVHS, heated catalysts, gas-sipping vehicles, and the information highway, promise large additional benefits that should ease the transition to more sustainable lifestyles and forms of development, despite some unforeseen and unintended consequences that are likely to be viewed negatively by some groups in society.[25]

Tying these three policy trends together in a way that assures broad political support and mutual gains is a matter of some urgency for the IVHS community. Without greater attention to the empirical bases for environmental, energy, and social concerns about IVHS, some members may make the mistake of assuming that public relations and education campaigns will overcome any negative images. A long list of failed efforts in this vein -- from nuclear power to chlorofluorocarbons -- reveals that control of the public agenda is often fleeting. A far more promising strategy may be to develop a common core of tools and objectives that treat environmental, energy, mobility, and transportation access issues in an interactive fashion, using sustainability as a design standard.

One approach worth considering would be to note the consistent patterns in policy design that are developing in each of these four issue areas. All reveal the same basic substitution trends whereby centralized, technology-forcing regulations and supply enhancement programs are slowly replaced by decentralized, market- and performance-based standards, and demand reduction programs. For reasons that will soon become obvious, I have termed this the "Wedge Strategy." Figure 2 depicts a rudimentary form of the wedge strategy as it might be applied to each of the aforementioned issues. Each wedge represents a policy instrument that is either growing or declining in use over time. Those showing growing reliance involve demand-side management, market-based tools, and green technology innovations. Those portrayed with a proportional drop in reliance are measures based on supply-side management and command-and-control regulation. The wedge strategy is merely a heuristic device for the present; something intended to help in the construction of conceptual frameworks with which to understand IVHS goal conformity. The point of the strategy is to recognize that IVHS will contribute positively to goal integration and conformity on multiple fronts if and when it is employed in the service of DSM, market-based pricing, and development of green vehicles.

Of the policy goals presented, equitable access may be the most difficult to achieve politically and economically. As an overconfident Werner von Braun once observed, technology has the potential to address all public problems except for equity and corruption. In the case of IVHS, addressing the equity problem may become easier as telecommunications substitutes for both work and nonwork-related travel become available for low-income households, but this will depend on progress achieved in other areas, such as the degree to which universal access is achieved in deployment of the super-information highway.

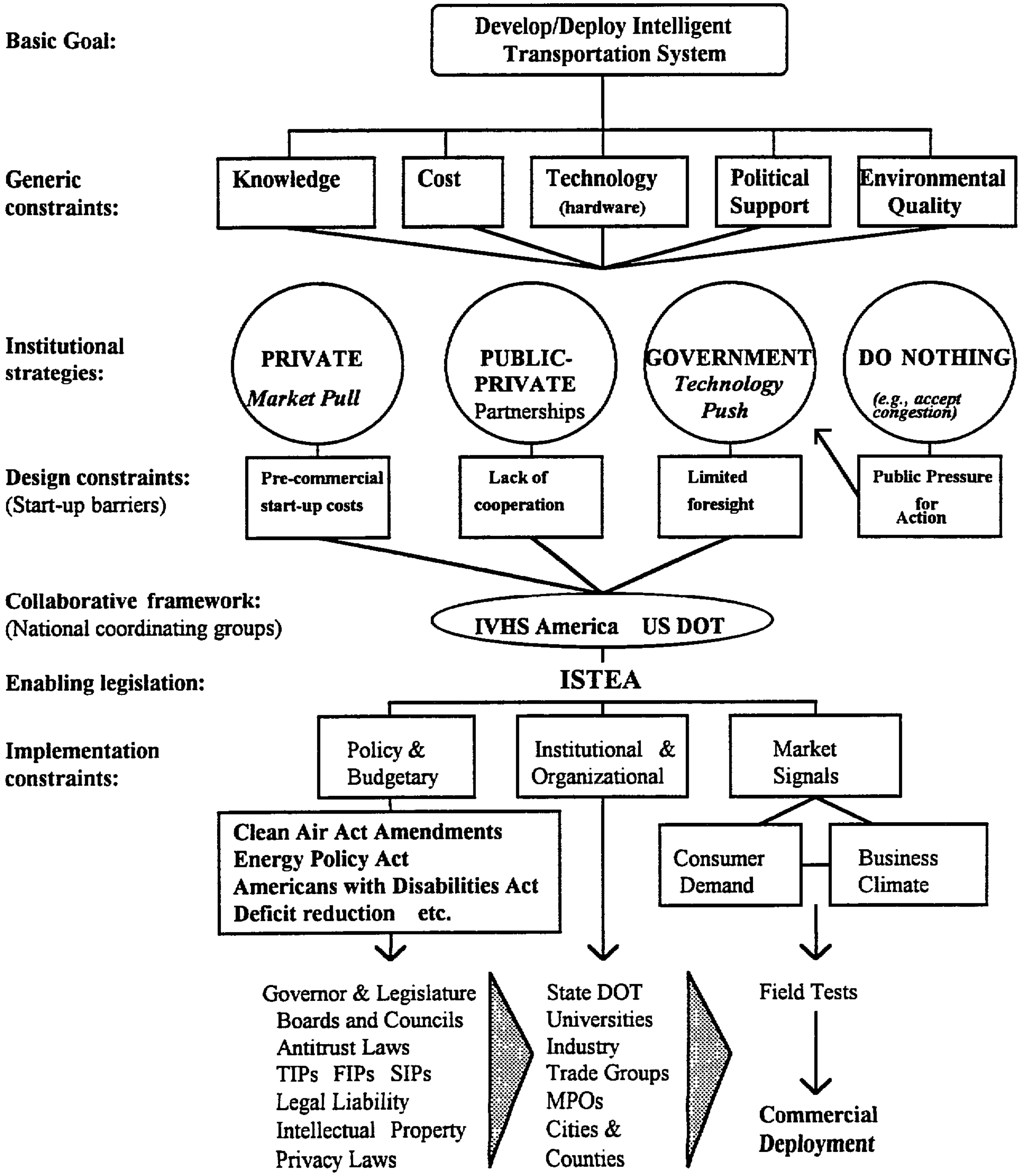
CONCLUSION

This paper has assessed the role of IVHS as an amplifier of emissions and fuel consumption characteristics of on-road vehicles. To a lesser extent, it has addressed equity issues that arise in the course of using IVHS to resolve conflicting policy goals in the transportation, environment, energy, and land use arenas. It is clear from the preceding discussion that reducing travel delay is desirable, with or without accompanying net reductions in vehicle emissions and fuel consumption (as long as there are no net increases). At the same time there is a growing suspicion on the part of many environmentalists that IVHS will be deployed primarily as a capacity enhancer, without accompanying growth management incentive programs. As such, it could justifiably be viewed as a "ratchet" policy that merely pushes back or defers many urban problems, while increasing their scale.

I have tried to demonstrate that advances in green vehicle technology provide strong reason for optimism about our future ability to increase the volume of vehicles, trips and miles traveled, while sharply reducing the levels of emissions and fuel consumption. The political will and market capability to introduce that technology appropriately and in a timely fashion is a matter for more sober consideration. If the current pace of political support and technological innovation continues, advances on the clean car front are likely to reduce concerns about emissions associated with IVIIS capacity enhancement. Fuel economy concerns, on the other hand, will prove to be a more difficult challenge for IVHS designers, given current policies on automotive fuel efficiency and gasoline pricing.

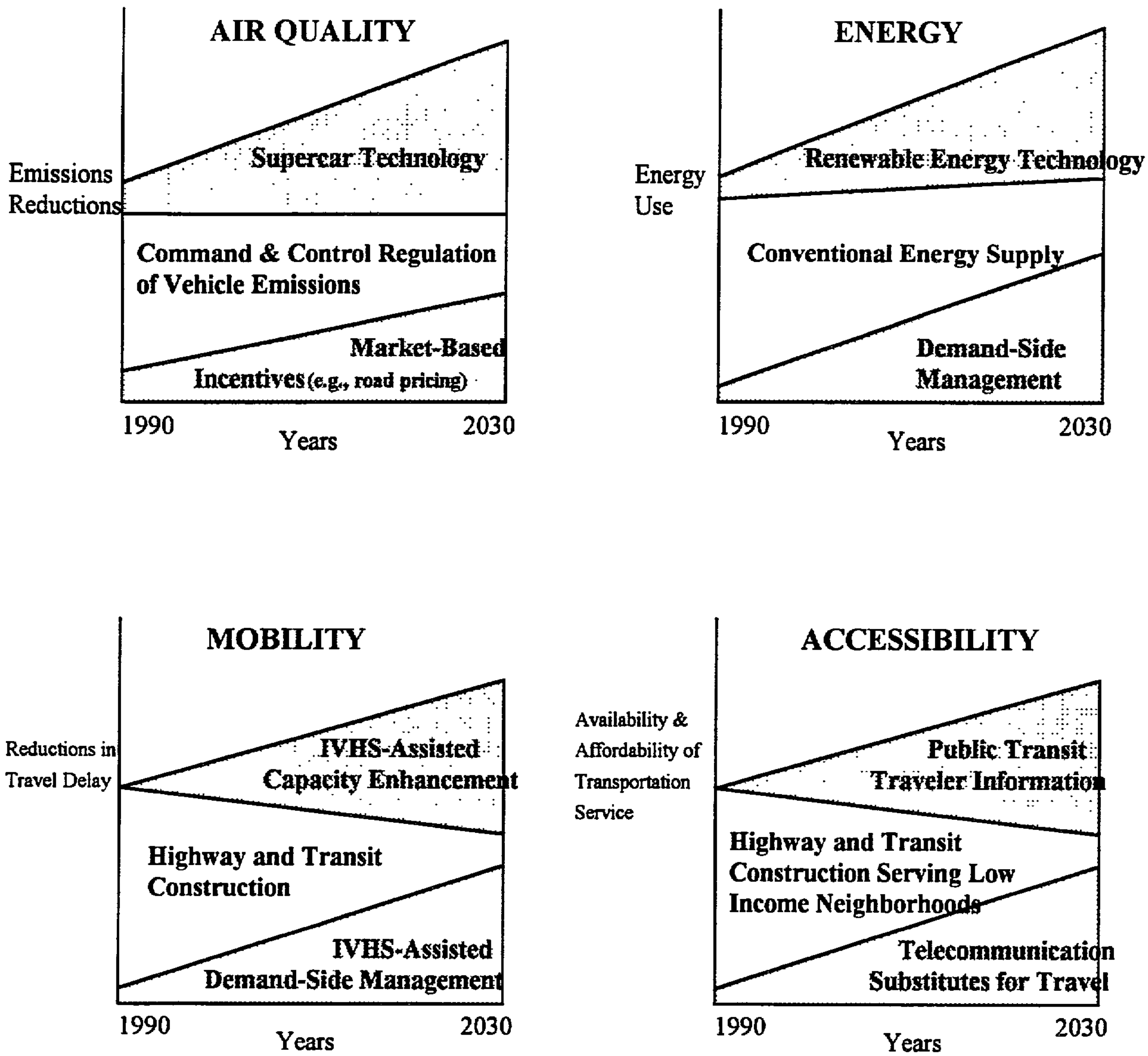
Figure 1

CONSTRAINTS MAP OF I.T.S. IMPLEMENTATION



Hempel, 1994

Figure 2
"Wedge Strategies" for Achieving Transportation-Related Policy Goals



ENDNOTES

‘Intelligent Vehicle Highway Systems (IVHS) is used here in recognition of the technical transportation community’s familiarity with and historical preference for the term. The author, however, prefers “Smart Access,” or the term “Intelligent Transportation Systems” (ITS). The reliance of IVHS on the words “vehicle” and “highway“ has unnecessarily widened the gulf separating the concerns of many transportation professionals from those of environmental, energy, and community equity/access groups.

2A doubling of capacity would probably require widespread use of AHS/AVCS technology. Depending on assumptions about transit use and the type and configuration of AHS/AVCS and other IVHS technologies, some analysts have suggested that even a tripling of capacity may be economically possible.

3Harry W. Richardson (with Chang-Hee Christine Bae), “Brown Sky Blues: Are Transportation Rx’s a Cure?” in ***Resource Papers for the 1994 ITE International Conference,*** Institute of Transportation Engineers, March 1994, p. 17.

4The compliance cost to employers of the South Coast Air Quality Management District’s ridesharing program (Regulation XV) in 1992 was estimated to be $160 million. It was credited with eliminating approximately 54,000 vehicles from the road, making the cost per vehicle $2,963. Generously assuming that each vehicle removed due to ridesharing was a super emitting vehicle, one could compare cost effectiveness by applying the $2,963 to anon-road remote sensing and repair program in which it is assumed that 80 percent of super-emitters (representing 10 percent of all vehicles in use) are correctly identified and 80 percent of that number are successfully repaired or retired at an average cost of $200 per vehicle. Assuming that the average test costs $ 1 .OO per vehicle, a minimum of 14 super-emitters (from a tested field of 215 vehicles) would be successfully repaired or retired for each one that is removed by ridesharing (in reality, of course, only about 10 percent of vehicles eliminated by rideshare programs are likely to be gross polluters, hence the cost advantages of abatement programs based on remote sensing are being understated in this example).

5J. E. Moore, "Ridership and Cost on the Long Beach-Los Angeles Blue Line,” ***Transportation Research Annual,*** 1993, p. 27.

6 Langdon Winner, ***Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought*** (Cambridge: The MIT Press. 1977). pp. 226-251.

‘The conformity requirements imposed by the Clean Air Act (CAA) amendments of 1990 are among the most important constraints affecting future IVHS deployment. But it is important to note that ISTEA, itself, is a powerful constraint on the way in which intelligent transportation technologies are utilized. It is, of course, also the principal enabling legislation for developing IVHS. The linkage of Air and Transportation policy is provided principally through the Congestion Mitigation and Air Quality Improvement Program (CMAQ) of ISTEA and the periodic review (joint EPA-DOT analysis) of transportation impacts on air quality required in Section 108(f)(3) of the CAA.

8For a discussion of the concepts and potentials of Supercars, see Amory B. Lovins et al., “Supercars: The Coming Light-Vehicle Revolution” (Rocky Mountain Institute, 1739 Snowmass Creek Road, Snowmass, Colorado:81654-9199, Publication T93-10 1993).

9Jack Keebler, ‘Makers Look at Setting Trap for Emissions,” ***Automotive News,*** July 27, 1992, p. 35.

10Elmer Johnson, ***Avoiding the Collision Of Cities and Cars: Urban Transportation Policy for the Twenty-first Century*** (Chicago: Academy of Arts and Sciences, 1993), p. 4.

11 Calculated on the basis of annual new passenger ***car*** registrations, 1960-l 990, in ***World Motor Vehicle Data*** (Detroit: Motor Vehicle Manufacturers Association, 1992 edition).

12Steve Nadis and James J. Mackenzie, ***Car Trouble*** (Boston: Beacon Press, 1993), p. 18.

13A proposal to introduce vehicle speed governors is developed by Michael Replogle in "M-IS At Risk: A Review of Draft National Program Plan for Intelligent Vehicle Highway Systems" (Washington, DC: Environmental Defense Fund November 25,1993).

14Robert J. Farrauto, Ronald Heck, and Barry Seronello, "Environmental Catalysts," ***Chemical and Engineering*** News, September 7, 1992, p. 34.

15Califomia Air Resources Board, "Draft Discussion Paper: Low-Emission Vehicle Program Costs" (Sacramento, CA: March 25, 1994 CARB Workshop), Table 4. Note: 8 cylinder engines qualifying for California's ULEV standards are assumed to require a dual EHC system costing approximately $285.

16Data in Table 1 is taken from S. Albu M.J. Heimrich, and M. Ahuja, "Electrically Heated Catalysts for Cold Start Emission Control," ***Transactions Of the American Society Of Mechanical Engineers,*** July 1992, pp. 496-501; California Air Resources Board March 25, 1994 Workshop; and S. Wallman, I. Gottberg, and H. Swars, "New Potential Exhaust Gas Aftertreatment Technologies for 'Clean Car' Legislation," SAE Technical Paper Series, No. 910840 (1991)

17Steve Nadis and James J. Mackenzie, ***Car Trouble*** (Boston: Beacon Press, 1993), p. 18.

18M, Cheslow, "Energy Estimates for the ***Years 2000*** and 2010," ***Surface Transportation and the Information Age: Proceedings from IVHS America 1992*** (Washington DC: IVHS America), Vol. I, pp. 404-412.

19 Amory Lovins, Presentation at the 1993 Conference on Transportation and Energy, Asilomar, CA (August 22-25). A summary is provided in the Winter 1994 issue of ITS ***Review*** (November 1993/February 1994), p. 6.

20Advocates of "pay at the pump" no-fault auto insurance have been conducting a statewide initiative campaign in California to offer voters an alternative to the current system of auto insurance. They plan to have their initiative on the March 1996 ballot. Organized as the Coalition for Common Sense Auto Insurance, supporters claim that a 25-tents-per-gallon surcharge on gasoline, plus an annual vehicle registration fee of $14 1 ($9 1 for low income and senior citizens), would provide basic coverage for all California motorists, while reducing insurance premiums for most drivers by 30% to 40%. The initiative campaign has encountered heavy resistance from the state's trial lawyers and insurance industry, and is not expected to make it to the 1996 ballot with the pay at the pump provision in tact.

21 See., for example, Amos Tversky and Daniel Kahneman "The Framing of Decisions and the Psychology of Choice," Science 211 (1981) pp. 453-458; and Mary Douglas and Aaron Wildavsky, ***Risk and Sulture: An Essay on the Selection Of Technological and Environmental Dangers*** (Berkeley: University of California, 1982).

22World Commission on Environment and Development, ***Our Common Future*** (London: Oxford University, 1987), p: 8.

23Demand-side management generally holds that when scarcity and the cost of technological fixes for providing public services are greater than the costs of limiting demand for those services, governments should seek to reduce public demand through education, market incentives and, if need be, rationing.

24For a general discussion of this trend, see David Osborne and Ted Gaebler, ***Reinventing Government: How the Entrepreneurial Spirit is Transforming the Public Sector*** (New York: Penguin/Plume, 1993), pp. 280-3 10. For a discussion focused on environmental and energy implications, see Robert Stavins and Bradley Whitehead, "The Greening of America's Taxes: Pollution Charges and Environmental Protection," ***Policy Report No. 13*** (Washington, DC: Progressive Policy Institute, February 1992).

25For example, market and technology innovations will be viewed by some as offering unwanted reprieves for a discredited car culture. It is difficult however, to imagine voluntary behavior changes (e.g., widespread use of transit and ridesharing programs) that promise the same degree of benefits without assuming sweeping and unprecedented changes in human values and economic rationality.

26See for example Frank R Baumgartner and Brian D. Jones, Agendas and Instability in American Politics (Chicago University of Chicago, 1993). A model for IVHS deployment that would obviously be more appropriate than that of nuclear power would be an environmentally sensitive and access-oriented version of U.S. commercial airline development. Being able to convince millions of people that they could move safely, affordably, and efficiently at 30,000 feet above the ground was no small feat. Convincing even more people that a diverse set of electronic, robotics, and information technologies will rescue their ground transportation systems from traffic "crawl" may require no less imagination and critical awareness.

CAPACITY-INDUCED INCREASES IN THE QUANTITY OF TRAVEL WITH SPECIAL REFERENCE TO IVHS

BY

Sergio J. Ostria, Michael F. Lawrence, and Don I-L Pickrell

ABSTRACT

Many IVHS products and user services have been designed to alleviate urban traffic congestion by improving level of service and increasing vehicle throughput.There is concern that such improvements in the efficiency of the transportation system could lead to increases in travel demand and motor vehicle emissions. The cornerstone of arguments against IVHS deployment on the basis of air quality is the notion that increased roadway capacity will result in a new system with equal congestion but more vehicles and emissions. Some IVHS detractors argue that the detrimental effects of induced demand, manifested in increases in the number and length of vehicle trips, may outweigh the potential emission benefits of improved traffic operations and system efficiencies that are brought about by IVHS. This argument, however, reflects a misunderstanding of the economic mechanisms leading to changes in the quantity of travel, as well as confusion between demand increases asocialted with induced traffic versus secular volume growth. The purpose of this paper is to present an analytical framework based on microeconomic principals for evaluating the potential impacts of IVHS on travel demand with emphasis on changes in consumers' surplus and external costs.

BACKGROUND AND MOTIVATION

Intelligent Vehicle-Highway Systems (IVHS) have generated considerable enthusiasm in the transportation community as potential strategies to reduce highway congestion, improve highway safety, enhance the mobility of people and goods, and promote economic productivity in the country's transportation system. However, there is concern that while IVHS technologies alleviate congestion, resulting mobility improvements could lead to further increases in travel demand with the concomitant potential for increases in emissions. This concern stems from widespread community opposition to highway investments on the basis of the potential for "induced travel" and its associated external effects such as increased congestion, noise, air pollution, and energy consumption. Since the 1970's, environmental advocates have viewed highway investments, specifically road buildingg, as causing a degradation to air quality because of the effect of induced traffic on trip generation and trip length.[l] The potential for IVHS to improve level of service and increase vehicle throughput has generated a similar undercurrent of opposition to IVHS investments. Arguments against IVHS on this basis are often articulated as follows:

> "A principal objective of IVHS — to minimize total vehicle-hours of delay — has little in common with the social imperative of reducing the environmental impacts of driving. The stated measurable goal for IVHS is to effectively double infrastructure capacity; these are the

> gains predicted for highly advanced technologies. Thus a successful IVHS program could effectively double (or significantly increase) vehicle-miles of travel assuming that total demand for travel is not fixed. And even if there is a theoretical saturation point for the number of automobiles and the number of trips taken, distances traveled have a tendency to increase as people and jobs move farther out to the suburbs and even back to more affordable rural areas."[2]

The underlying economic principals behind travel demand and transportation supply have been largely ignored in the debate concerning the induced travel impacts of IVHS. But in order to evaluate the potential for induced travel from IVHS, it is necessary to understand the behavior mechanisms that lead to induced travel, as well as the different components that define changes in the quantity of travel. This latter issue is of special importance since there seems to be confusion between travel growth that stems from induced travel versus travel growth that is generated by demand increases in rapidly growing areas or individual corridors where highway investments tend to be located. Therefore, it is critical to distinguish between increases in travel demand caused by decreases in perceived ***user costs*** and increases in the quantity of travel caused by demographic and economic factors.

The central purpose of this paper is to present an analytical framework based on microeconomic principals for evaluating the potential impacts of IVHS on the quantity of travel with emphasis on changes in consumers' surplus and external costs. A second objective is to identify the policy implications of these impacts. The paper is targeted to non-economists involved in the evaluation of the air quality and emission repercussions of IVHS or any other highway investment project.

AN ECONOMIC INTERPRETATION OF TRAFFIC VOLUMES

The first step in formulating the analytical framework is to review the interaction between transportation demand and facility performance (i.e., supply). The need for transportation originates from the interaction among social and economic activities dispersed in space. Unlike most goods and services, transportation services are derived demands, meaning that in isolation travel seldom generates any measurable utility to the consumer. Rather, travel is an intermediate input to the consumption and production process.

When separated by space, individuals satisfy their need for social and economic interaction by engaging in travel. In most urban areas, the production of trips is satisfied by three general modes of travel: motor vehicles, walking and bicycling, and mass transit. IVHS has the potential to influence all three of these modes but most predominantly motor vehicle and mass transit, which are the focus of this paper. While many of the concepts that are elaborated in this paper are applicable to commercial vehicle travel, this type of motor vehicle travel is not the focus of the analysis.

As with any other economic activity, tripmaking involves a cost. Faced with alternative modes of transportation and routes from an origin to a destination, the consumer selects a mode and route on the basis of money cost, time cost, comfort, carrying capacity, and convenience.[3] In the case of motor vehicle travel, money costs often include operating costs, such as gasoline, parking, vehicle repair, and toll costs, and ownership costs, such as vehicle depreciation and insurance. Costs associated with the time involved in undertaking a trip are referred to as the time costs of travel. These costs reflect an opportunity cost to the consumer since the time devoted to travel could be used to generate income, consume utility, or engage in leisure. The perceived comfort and convenience of a given route or mode must also be accounted for in the total cost of tripmaking. These qualitative cost measures differ from one individual to another, and modes and routes are often rank-ordered by consumers based on comfort and convenience given an estimate of the associated money and time costs.

An important element in the derivation of the factors that determine the demand for travel is the effect of carrying capacity (i.e., facility performance) on perceived user costs. Congestion can be defined as affecting activities in which:

- motorists (i.e., consumers) supply some of the variable inputs (i.e., time, vehicles, fuel, etc.) required to produce travel (i.e., the service); and
- the required quantity of these inputs per unit of output or the quality of the product itself (e.g., level of service) depend on the consumption rate.

As a given highway becomes congested, virtually every component of user cost increases. Money costs increase in proportion to fuel costs and vehicle depreciation (the wear and tear of stop and go driving). Comfort and convenience decrease. But more importantly, time costs increase dramatically. As congestion worsens on a given facility, consumers switch to alternative modes, routes, or times of travel. Travel demand on the highway is inversely related to perceived user costs — as costs increase, users demand less travel on the facility. Therefore, travel demand is a function of user costs, and given a cost level, demand varies based on income, population, and other variables described later in the analysis.

Likewise, facility performance is influenced by the quantity of consumers using the system. In general, the supply function (i.e., facility performance) gives the level of service attributes that affect the realization of traffic volumes, as they are affected by these volumes. Level of service attributes include those components of travel cost that are outlined above. The relationship between travel cost and the supply of transportation services is opposite to that of demand. The demand function shows how traffic volume **is** affected by the level of service attributes of the transportation system, while the supply function shows how these attributes are influenced by the traffic volume using the system.[4]

The observed level of traffk on a highway or system reflects the interaction between travel demand and the performance of capital facilities (i.e., supply). As mentioned above, demand varies with the perceived prices or opportunity costs of user-supplied inputs necessary to produce trips. The quantity of user-supplied inputs, and thus the price to users of making trips, varies in response to traffic volume given a fixed complement of highway facilities.

The discussion presented above focuses on the general interaction between travel demand and supply. However, even the casual observer of traffic notices the differences in volume during different hours of the day and along different highways. Spatial and temporal variations in traffic volumes along individual corridors or on specific highways reflect the dynamic nature of the equilibrium between demand and supply. Traffic volumes on individual corridors and the utilization of specific facilities reveal the interaction between corridor- or facility-specific demand and supply functions. For a particular highway during a given hour of the day, a unique supply and demand relationship will prevail that characterizes the traffk volume on that highway at that time.

Various IVHS strategies have the potential to directly alter the interaction between demand and supply by changing the perceived user costs of travel. For instance, route guidance systems could decrease time costs by allowing users of the system to select the most expedient route from an origin to a destination. By diverting travelers from congested routes to free flowing routes, or less congested routes, geographic and temporal travel patterns may change, altering the global and local equilibriums between travel demand and supply. The remainder of this section derives the demand curve and supply curve for motor vehicle travel. This derivation will facilitate the analysis of the impact of IVHS on facility performance and travel demand.

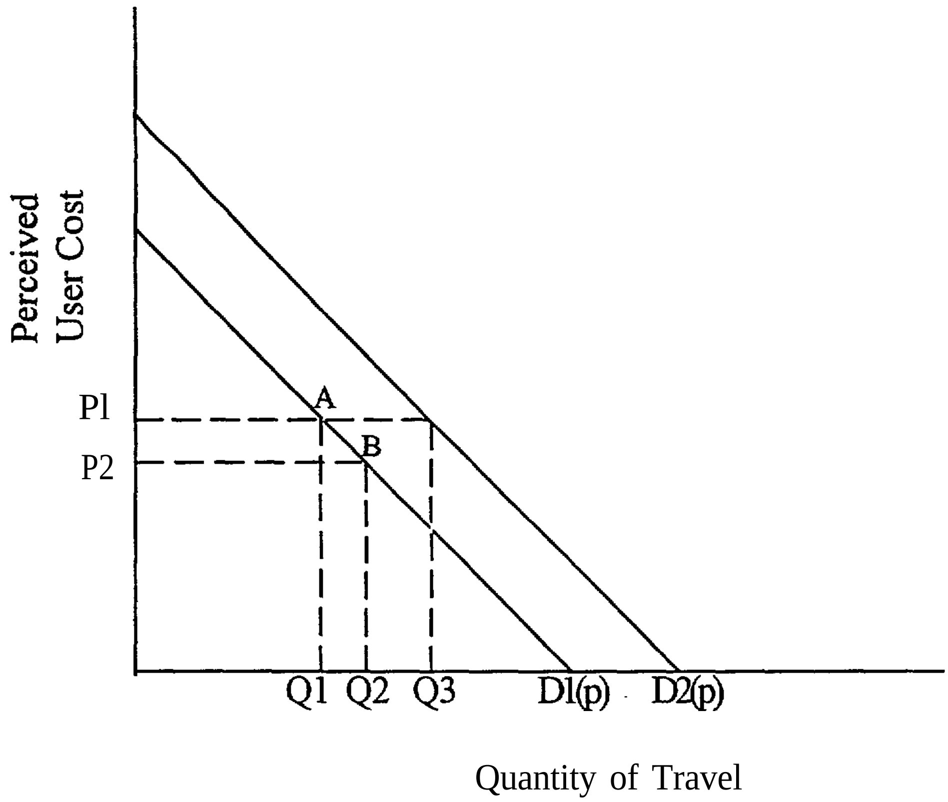
Characteristics of the Demand Curve for Motor Vehicle Travel

The quantity demanded of a good or service at different price levels — holding constant all other determinants of demand, such as income, population, prices of all other goods, etc. — is represented in economics by a demand curve. For most goods and services, the law of demand suggests that as price increases the quantity demanded of the good or service decreases. As a result, demand curves are usually downward sloping.

Exhibit 1 shows a hypothetical demand curve for motor vehicle travel — drawn as linear in order to simplify the analysis. Perceived user cost is represented on the vertical axis and the quantity of travel (e.g., traffic volume, vehicle trips, vehicle miles traveled) on the horizontal axis. Unlike most goods, transportation is a derived demand since by itself it does not produce any measurable utility but rather serves as an intermediate service in the supply of labor or consumption of goods, services, and leisure. If it is accepted that tripmaking permits individuals to partake of a socioeconomic activity that generates utility and that transportation is simply a means to overcome the spatial separation between an origin and a destination of a trip, then transportation will be governed by the same microeconomic demand principals as all other normal goods.[4] Specifically, and as depicted in Exhibit 1, as perceived user cost increases (as a result of either increases in money cost, time cost, or increased inconvenience), the demand for motor vehicle travel decreases.

Several basic features of the demand curve for motor vehicle travel should be noted. First, the demand curve depicts the functional relationship between travel and perceived user cost assuming that there is no change in the values of other pertinent variables such as the prices of complementary and substitute services (e.g., automobile travel versus public transportation), personal income, vehicle ownership, population, and other pertinent economic and demographic factors. Second, the demand curve depicts the situation at a single point in time and a specific geographic location (e.g., a segment of a roadway, a corridor, a network, etc.). Hence, all but one of the user costs (prices) and travel quantities must be hypothetical — the curve must generally answer the "iffy" question: "If price were to change, how much travel would be demanded by an individual or set of individuals)?"[5] Third, changes in perceived user costs cause movements along the demand curve (depicted in Exhibit 1 by the movement from point A to point B). Corresponding changes in the quantity of travel demanded (i.e., depicted in Exhibit 1 as the change from Q1 to Q2 represent what has been referred to as "induced demand". (It should be noted that "induced demand" is not a term used in economics since the entire area beneath the demand curve is potential demand. Price simply determines the level of demand throughout the demand function.0 Fourth, changes in the price of complementary and substitute goods, personal income, vehicle ownership, population, or other economic and demographic factors cause the entire demand curve to shift so that either more or less travel is demanded at a given price. For example, an increase in population (in a particular region) causes the demand curve (for that region) to shift outward to D2 as shown in Exhibit 1. This shift generates an increase in the quantity of travel from Q1 to Q3 that is generated by secular growth rather than by a reduction in price. It is important to distinguish between increases in travel caused by decreases in price and increases in travel stemming from demand increases in rapidly growing urban areas or individual corridors where highway investments tend to be located. Finally, the magnitude of changes in demand in response to changes in price depends on the elasticity of demand. Elastic demand (i.e., represented by a relatively flat demand curve) implies that a change in price leads to

Exhibit 1
Demand Curve for Road Travel: Induced vs. Secular Growth



It is important to distinguish between increases in travel associated with changes in perceived user cost and increases resulting from changes in economic and demographic factors.

A decrease in price from Pl to P2 causes an increase in the quantity of travel of Q2-Ql . This change in travel is what has been termed as "induced demand".

An increase in personal income, for example, causes the entire demand schedule to shift from Dl to D2 so that at Pl the quantity demanded is now Q3. The difference, Q3 - Q1, is secular growth, large changes in quantity. Inelastic demand (i.e., represented by a relatively steep demand curve) implies that a change in price leads to small changes in quantity. In the short run, the demand curve for travel is relatively inelastic since travelers cannot readily alter their fixed travel demand resulting from existing housing and employment locations. As a result, changes in price have a relatively smaller impact on travel demand. In the long run, however, households have the capability to select different housing locations and alter behavior. Therefore, the long-run demand curve for travel is more elastic than short-run demand. An important conclusion is that land use patterns are represented by the more elastic long-run demand curve, and changes in these patterns do not change the short-run demand curve. Exhibit 2 graphically depicts this relationship.

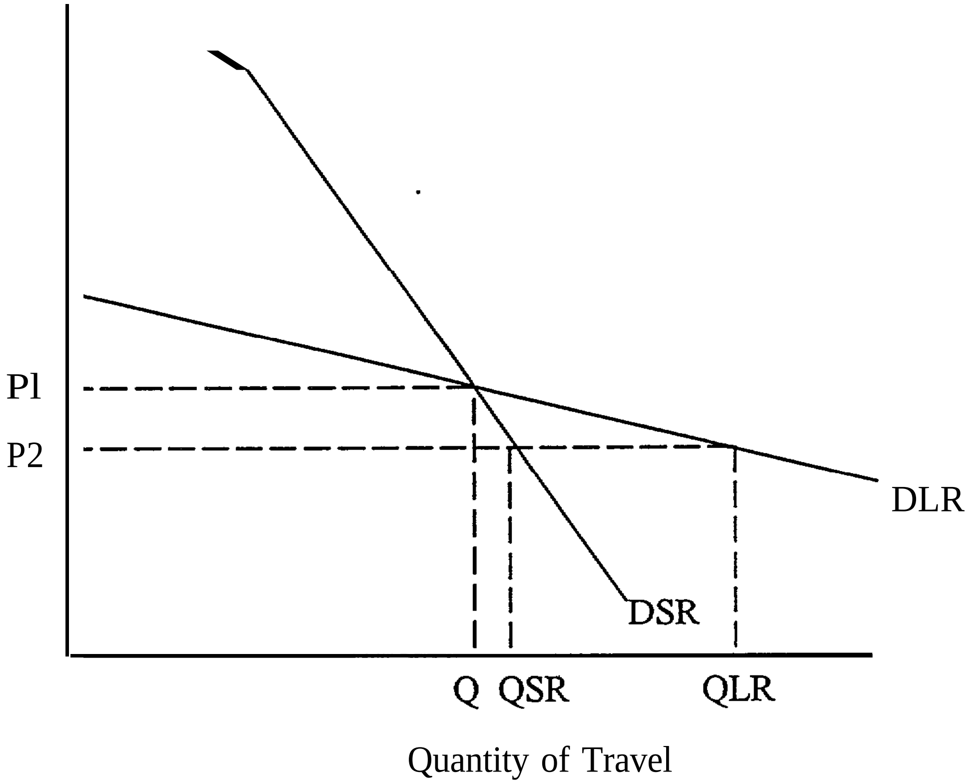
Consumers' Surplus

Individuals engage in travel so that they can engage in socio-economic activities and accrue some sort of economic or social benefits. In economics, the benefits of consuming a good or service are represented by consumers' surplus. Consumers' surplus is defined as the net benefit that consumers get from being able to purchase a good at the prevailing price — i.e., the difference between the maximum amounts that consumers would be willing to pay and what they actually do pay. As depicted in Exhibit 3, consumers' surplus is represented by the triangular area under the demand curve and above the prevailing market price (e.g., P1). Changes in the market price for travei (i.e., the perceived user cost) alter the magnitude of consumers' surplus. For example, decreases in travel time that result from highway investments, such as advanced traffic management systems or capacity expansion, lower total user cost, represented in Exhibit 3 by the fall in price from P1 to P2 The fall in price results with increased benefits to the system's users depicted by the increase in consumers' surplus. Therefore, insofar as analyzing IVHS projects in this manner indicates that they are likely to induce traffic growth, they will also produce benefits to users of the system or roadway. Determining the net effect of changes in externalities associated with increased travel and increases in consumers' surplus requires the incorporation of the supply curve for travel into the analytical framework, which is the subject of the following subsection.

Derivation of the (Short-Run) Supply Curve for Motor Vehicle Travel

Microeconomic theory defines the supply curve as a function that provides the quantity of a good that a seller is willing to offer in a market at a given price. The higher the price, the more of the good that the seller is willing to offer. While this definition is adequate for many goods and services, it is not well suited for analyzing travel supply. This inadequacy largely stems from the fact that much of what determines the attributes of travel supply is a result of user rather than supplier behavior. As discussed above, facility performance is directly determined by how travelers use the transportation system. Thus, many of the

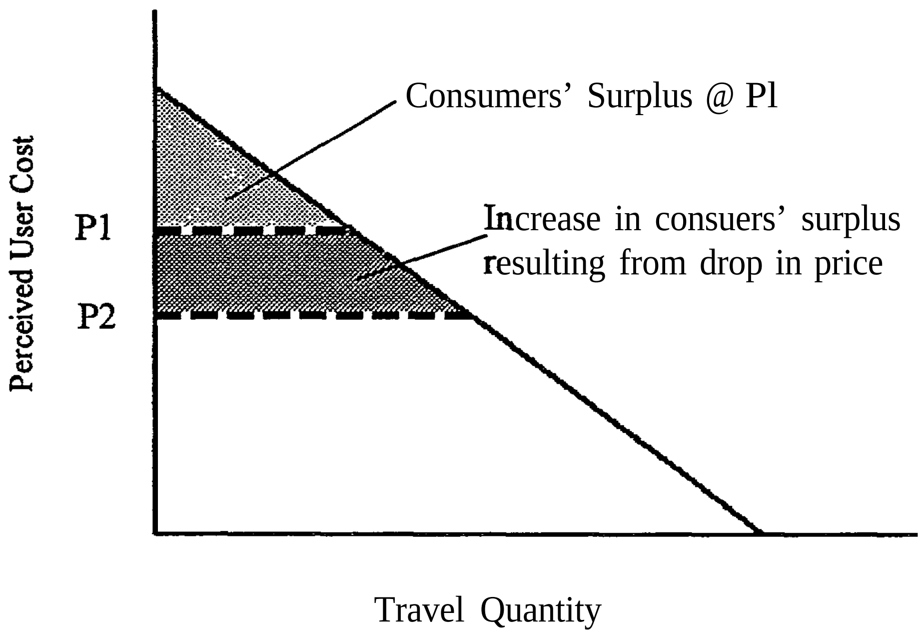
Exhibit 2
Short-Run vs. Long-Run Demand and the Role of Land Use



Short-run demand is relatively inelastic when compared to long-term demand. In the short run travelers cannot easily alter housing location nor travel behavior so that changes in user cost have a relatively smaller impact on travel demand. For example, as price falls from Pl to P2, the effect on long-run demand is much greater (i.e. QLR-Q>QSR-Q).

Land use patterns are represented by the long-run demand curve, when businesses and/ or households can alter location decisions.

Exhibit 3
Consumers' Surplus



Consumers' surplus represents benefit to users (i.e. consumers) of the transportation system. Investments that decrease user cost increase consumers' surplus as depicted above.

important aspects of transportation level of service that directly affect the evolution of traffic flows depend on user behavior and cannot be considered as supply attributes determined by a supplier.[4] In deriving the short-run supply curve for travel, the following measures which define the operational state of any given traffic stream must be considered:

- ***Speed,*** defined as the rate of motion expressed as distance per unit of time, usually expressed as miles per hour (mph);
- ***Traffic*** Density, defined as the number of vehicles occupying a given length of a lane or roadway, averaged over time, usually expressed as vehicles per mile (vpm); and
- ***Traffic*** Volume, which measures the quantity of traffic passing a point on a lane or roadway during a designated time interval, usually expressed as vehicles per hour (vph).

Travel time, or the reciprocal of speed, is an important measure of the quality of traffic service provided to the motorists. It is used as one of the more important measures of effectiveness defining level of services for many types of facilities.[6] As a result, speed is an important component of facility performance and perceived user cost which determines driver behavior.

Traffic density is a critical parameter describing traffk operations since it describes the proximity of vehicles to one another. Vehicle proximity is a function of spacing. Spacing is defined as the distance between successive 'vehicles in a traffk stream, as measured from front bumper to front bumper. As speed increases, spacing increases (usually at a decreasing rate) so that spacing is also a function of speed. The time between successive vehicles as they pass a point on a lane or roadway is defined as headway, which is also a function of speed. Empirical evidence suggests that vehicles do not travel at constant headways. Rather they tend to travel in groups, or platoons, with varying headways between successive vehicles.[6] As a result, these phenomena also depend on driver behavior, specifically the rules that motorists follow to determine a safe following distance.

Mathematically the relationships between speed, following distance, and traffic density are expressed below.

1. $H = G/S$

   where:

   H = headway, in seconds per vehicle;

   G = spacing (or the gap between vehicles), in feet per vehicle; and

   S = the speed of the second vehicle in a given pair of vehicles, in feet per second.

   Rearranging this equation, we see that spacing is given by G = $H * S$.

2. $D = 5{,}280/G$

where:

D = traffic density, in vehicles per mile;

5,280 represents the number of feet in a mile; and

G = spacing, in feet per vehicle.

Since spacing is itself a function of speed, traffic density also depends on speed. Specifically, as speed increases traffic density decreases at an increasing rate. As traffic density increases, speed decreases. The relationships between speed, following distance, and traffic density are depicted graphically in Exhibit 4.

Traffic volume is given by

$$V=S*D,$$

where:

V = rate of flow, in vehicles per hour (vph);

S = average travel speed, in miles per hour (mph); and

D = traffic density, in vehicles per mile (vpm).

Given the expression for traffic density and headway, we can show that traffic volume can be expressed as follows:

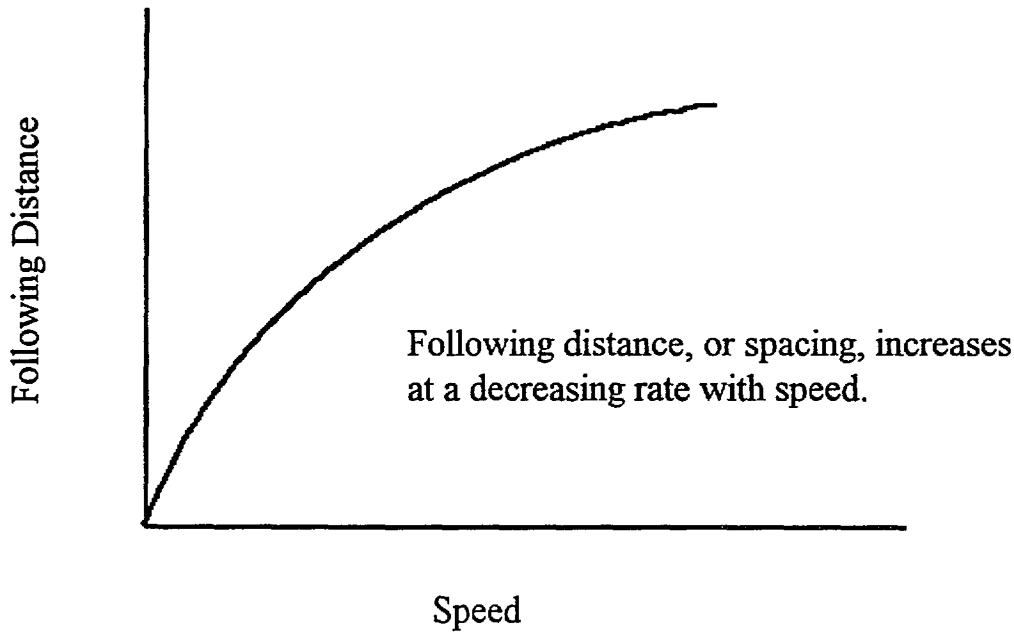
$$V = (5280 * S)/G.$$

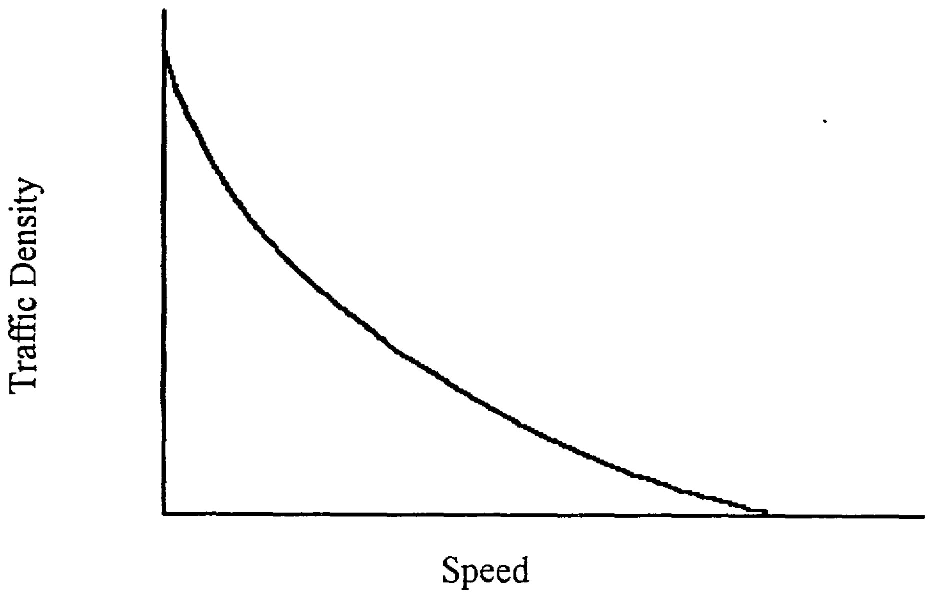
Note that G, or the distance between successive vehicles in a traffic stream, increases with speed. Given the correct functional relationship between spacing and speed, the interaction between traffic volume and speed takes the form of that shown in Exhibit 5. Note that a zero flow rate occurs under two very different conditions [6]:

1. When there are no vehicles on the facility, the rate of flow is zero since density is zero.
2. When density becomes so high that speed converges to zero (total gridlock), the rate of flow is also zero. The density at which all movement stops is referred to as jam density.

As density increases from zero, the rate of flow also increases as vehicles enter the roadway. Due to the interaction of vehicles, speed begins to decline as flow increases (i.e., we move backwards on the spacing-speed curve shown in Exhibit 4). As more and more vehicles enter the traffic stream, a point will soon be reached where with increase in density, speed is reduced so much that the flow of vehicles reaches a maximum. If the density of vehicles on the road is increased further, the reduction of speed will be so large that the flow will be reduced.[7] The maximum rate of flow, or capacity, is reached when the product of increasing density and decreasing speed results in reduced flow. Therefore, any rate of flow other than

Exhibit 4
Derivation of the Supply Curve for Road Travel: Spacing and Density as a Function of Speed

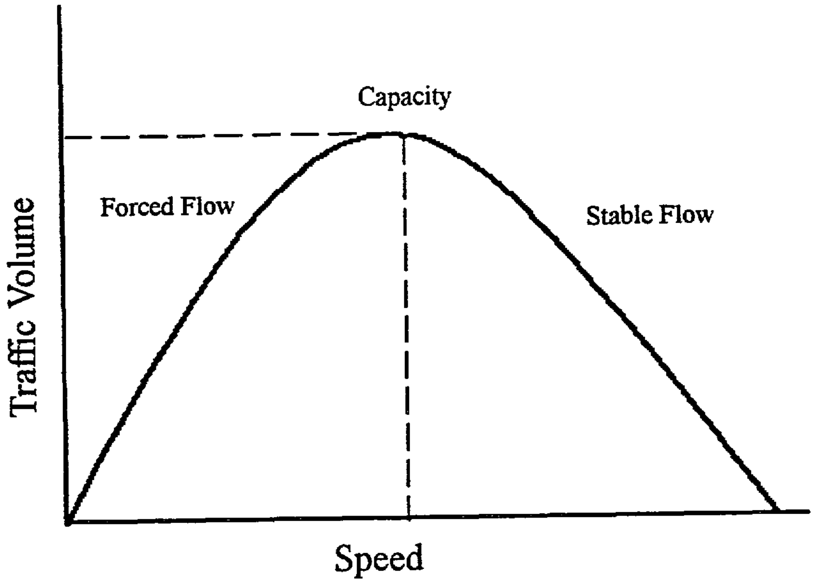




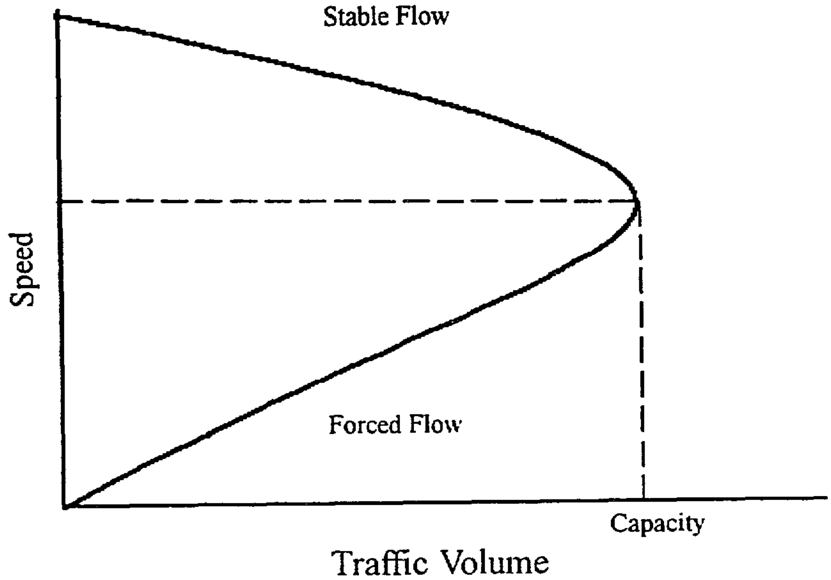
Traffic density decreases at an increasing rate with speed.

Exhibit 5

Derivation of the Supply Curve for Road Travel: Traffic Volume - Speed Relationship



The maximum rate of flow is reached when the product of increasing density and decreasing speed results in reduced flow.



Inverse of volume-speed relationship (above) gives conventional backward bending speed-volume curve.

capacity can occur under two different conditions — with high speed and low density, or with high density low speed.[6] Conditions characterized by high-density and low-speed reflect roadway congestion. So, points to the left (or to the south) of the maximum flow on Exhibit 5 reflect congested conditions.

The translation of the speed-volume relationship depicted in Exhibit 5 into the supply curve for travel involves the dependency of perceived user costs on travel time (i.e., the reciprocal of speed). Realizing that travel time per unit of distance (e.g., minutes per mile) is given by the amount of time spent traveling (such as 60 minutes) divided by speed (miles per hour), the cost of travel time per unit of distance traveled can be represented as:

$$c=t*v,$$

where,

c = travel time cost per unit distance, in cents per mile;

t = travel time per unit distance, in minutes per mile; and

v = value of time, in cents per minute.

Total perceived user cost (TC) per unit distance traveled is then given by the following expression:

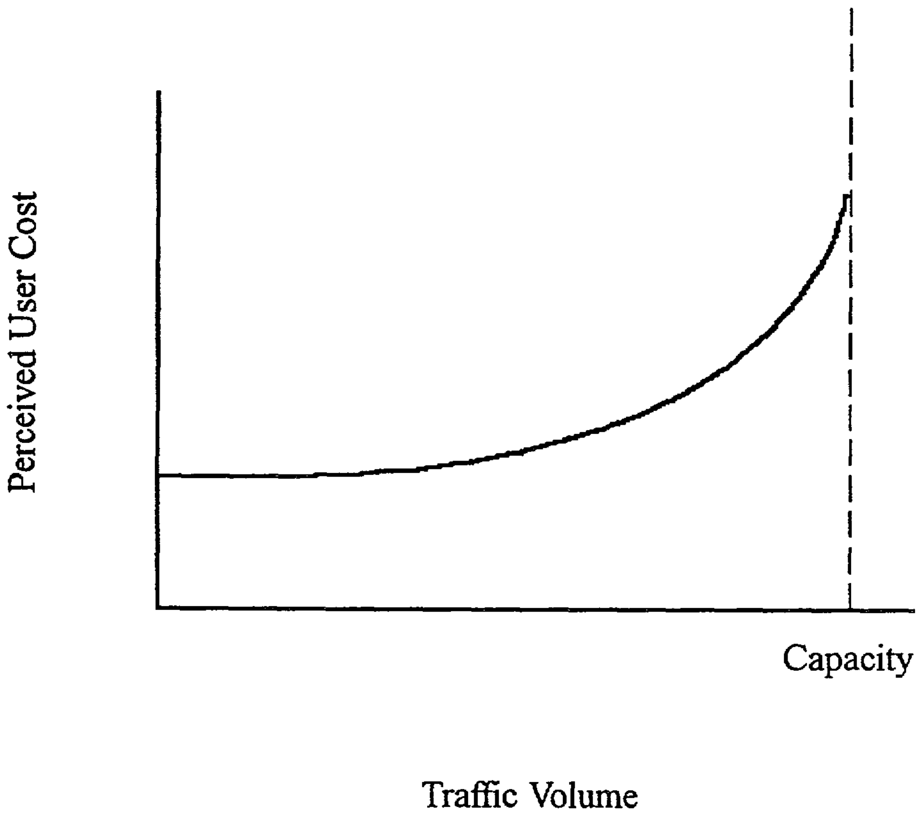
$$TC = OC + c$$

where OC represents vehicle operation cost. Since c is a function of speed — as speed decreases c increases — perceived user cost increases as speed decreases. The resulting relationship between the cost per unit of travel (marginal cost) and volume is depicted in Exhibit 6. As volume increases, marginal perceived user cost increases slowly, if at all, at first. As volume approaches its maximum rate of flow, marginal perceived cost begins to increase very rapidly. This relationship describes the short-run travel supply curve that shows the quantity of travel services that can be accommodated by a facility (or corridor, region, etc.) as a function of marginal perceived personal cost. Quantity of travel can be represented by a number of measures including traffic volume, number of vehicle trips, vehicle miles of travel, and others. Cost functions that represent a system with fixed capacity are referred to as short-run functions. When the capacity of the system is expanded as the output level increases, then the resulting cost function is referred to as a long-run cost function.[4]

In summary, perceived user costs are critical to driver behavior including mode and route choice. For a particular trip, the supply function for passenger travel is therefore commonly dependent on the following user cost parameters.

- ***Total money cost.*** In addition to vehicle operation costs, such as fuel, parking and vehicle depreciation costs, out-of-pocket costs include implicit costs such as indirect taxes. The potential

Exhibit 6
Supply Curve for Road Travel



As volume approaches its maximum flow rate (i.e., capacity), perceived user cost increases rapidly.

effect of IVHS implementation and operation on the out-of-pocket aspect of travel has largely been ignored in the debate concerning induced travel from IVHS deployment. Yet, highways in this country are operated under the user pays principle and there is no clear evidence that the implementation and operation of IVHS will not result in increased out-of-pocket costs through changes in excise taxes to support the Highway Trust Fund and state and local highway funding.

- ***Total travel time.*** This cost element involves opportunity costs associated with access time, waiting time, transfer time (applicable to transit), and line-haul time (time actually spent in motion). Many IVHS products and user services will reduce total travel time by decreasing recurrent and nonrecurrent congestion. For example, traffic signalization systems allow vehicle movements to be controlled through time and space segregation, speed control, and advisory messages. Advances in traffic signalization involve the incorporation of real time data on network capacity and demand, thereby facilitating the optimization of network efficiency and reducing delays associated with congestion.

Other parameters accounted for by the supply function include comfort and convenience. The discomfort and inconvenience of travel will be alleviated by many IVHS strategies, such as advanced vehicle control systems that will eventually remove, or minimize, the human element from the vehicle operation process.

These attributes of the supply function suggest that even a facility with fixed physical capacity has a supply curve associated with it, and congestion (resulting from changes in driver interaction behavior with travel speed) causes supply curves to be upward sloping.

The steepness (i.e., elasticity) of the supply curve as congestion sets in depends on driver behavior. The influence of a facility's physical design on traveler behavior determines the sensitivity of travel cost to changes in the quantity of travel services. The effect of IVHS on travel supply will depend on the cumulative impact of IVHS on travel cost, often as a result of decreases in travel time.

External Costs

Externalities in the form of congestion, air pollution, noise, and other disamenities are prevalent in motor vehicle travel, so that the private cost of a mile of urban travel is often significantly less than its full social cost. Congestion is a societal as well as a private problem. By entering a congested traffic stream, an individual motorist not only increases his/her own private cost, but also increases the private cost of other motorists on the roadway. Therefore, congestion costs are a form of externality — the action of one individual imposes costs on others in addition to those he/she bears.[3] The quantification of this component of social cost is a difficult task but can be measured as losses in productivity, wages, fuel, etc.

Noise and air pollution are also disamenities associated with motor vehicle travel that cause divergences between private costs and social costs. Both of these phenomena worsen with increases in road travel. The measurement of these external costs depends on the societal value placed on cleaner air, for example.

External costs can nevertheless be calculated in abstract. For illustration purposes, assume that the cost of motor vehicle travel is given by the following expression:[7]

$$TC_{n-1} = M*C*(n-1)/S$$

where,

TC = the total cost of motor vehicle travel,

M = the number of miles traveled,

C = the marginal cost of travel per minute,

S = the average travel speed, and

n-1 = the number of travelers on the facility.

Assuming that as soon as an additional driver enters the traffic stream, the average speed per vehicle will fail by X as a result of congestion, total cost will change as follows:

$TC_n = M*C*n/(S-X)$,, where X is positive but smaller that S.

Therefore, marginal social cost, or the additional cost imposed by the ***nth*** motorist, is simply the difference between ***TC,*** and ***TCn-1*** given by:

$$MSC_n = [M*C*n/(S-X)] - [M*C*(n-I)/S]$$

$$= [M*C/(S-X)] + [M*C*X(n-l)/S*(S-X)].$$

To any individual motorist, the marginal private cost of travel is given by:

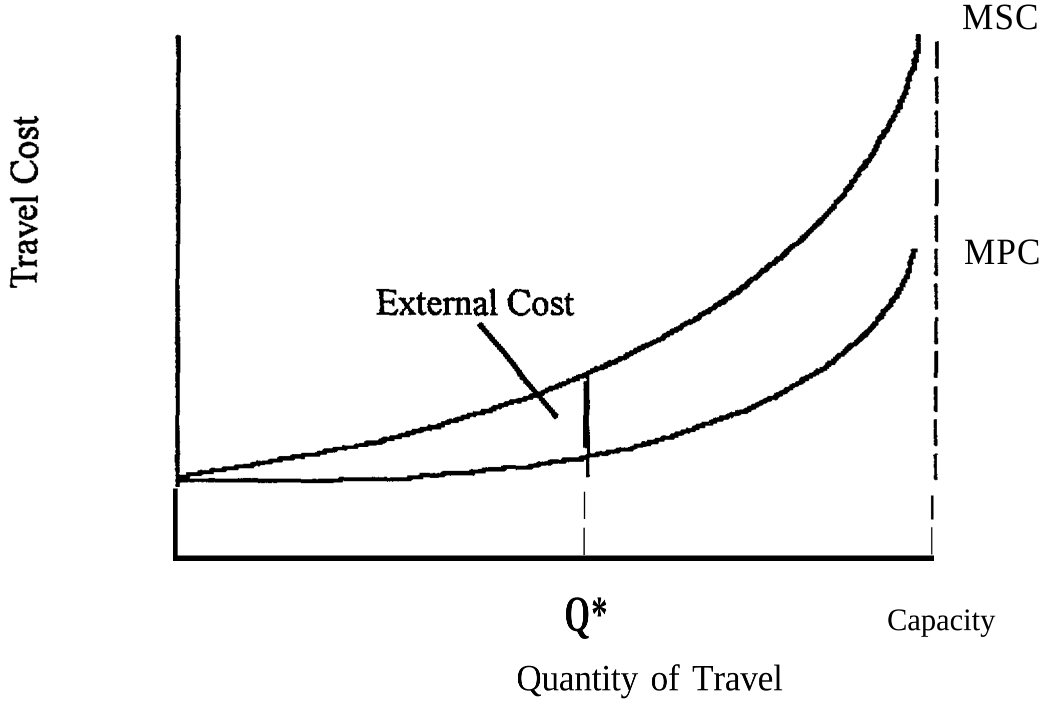
$$MPC_n = M*C/(S-X)$$

The difference between marginal social cost and marginal private cost defines the ***external cost.*** In our simplified example, external cost is given by:

$$MSC_n - MPC_n = M*C*X(n-I)/S*(S-X).$$

By construction X, ***M, C,*** n-l, S, and S-X are positive. So, the expression for external cost is positive and the ***nth*** individual imposes an additional cost to society by entering the traffic stream. Graphically, this difference is depicted by the vertical distance between the MSC curve and the MPC curve as shown in Exhibit 7. The effect on consumer surplus and external cost determines the societal value of deploying IVHS technologies,

Exhibit 7
External Cost



External cost at quantity of travel **Q*** is given by the difference between marginal social cost (MSC) and marginal private cost (MPC).

products and user services.

The Equilibrium Quantity of Travel

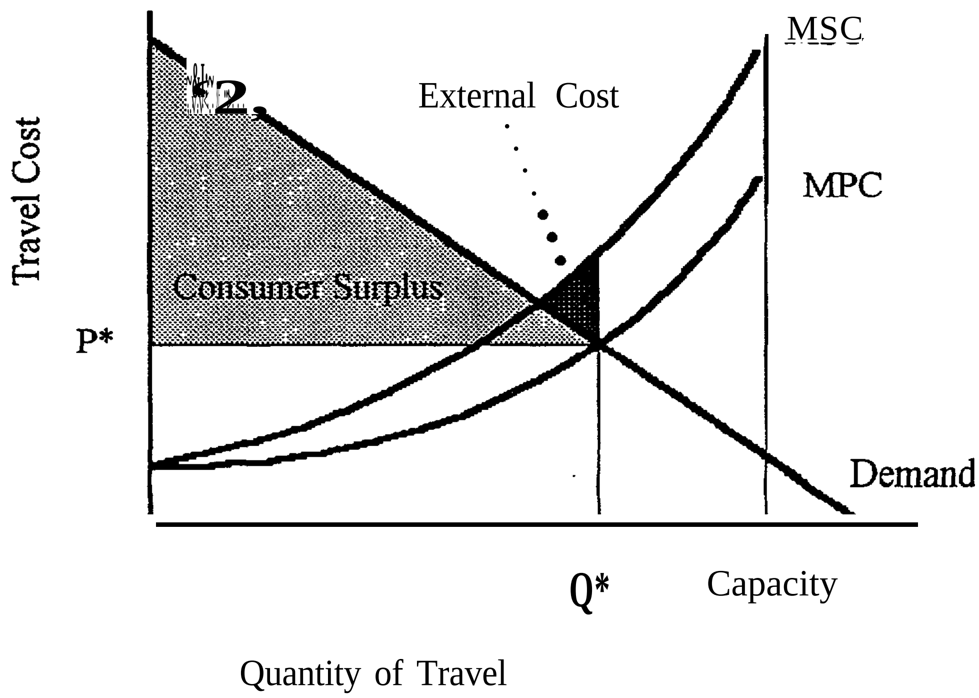
The interaction between travel demand and travel supply determines the observed level of traffic on a system at a given point in time. Exhibit 8 graphically demonstrates this interaction. Shifts in either the demand or the supply curve will establish new equilibrium levels of both the quantity of travel services (i.e., volume, vehicle trips, vehicle miles traveled, etc.) and the price per unit of those services (i.e., dollars per trip, cents per mile, etc.). The relative magnitudes of supply and demand price elasticities determine the response of the equilibrium level of travel and its associated cost to changes in demand or supply. Shifts in supply are commonly associated with capital investments that increase the quantity and/or quality of the road infrastructure, while shifts in the demand curve are brought about by changes in economic and demographic factors (as discussed earlier). The potential impact of some IVHS products on facility performance, travel demand, and the equilibrium quantity of travel is the subject of the following section.

POTENTIAL IVHS IMPACTS ON THE QUANTITY OF TRAVEL

Many IVHS technologies, products, and user services can be analyzed within the travel demand and supply framework that has been described above. For instance, advanced vehicle control systems will affect the response of driver interaction behavior, such as following distance, to variations in travel speed. Changes in the following distance-speed relationship will translate into changes in the other relationships that determine facility performance (i.e., travel supply). Other systems that improve the quality and reliability of travel information will affect travel demand by altering the departure profile of trips and route selection.

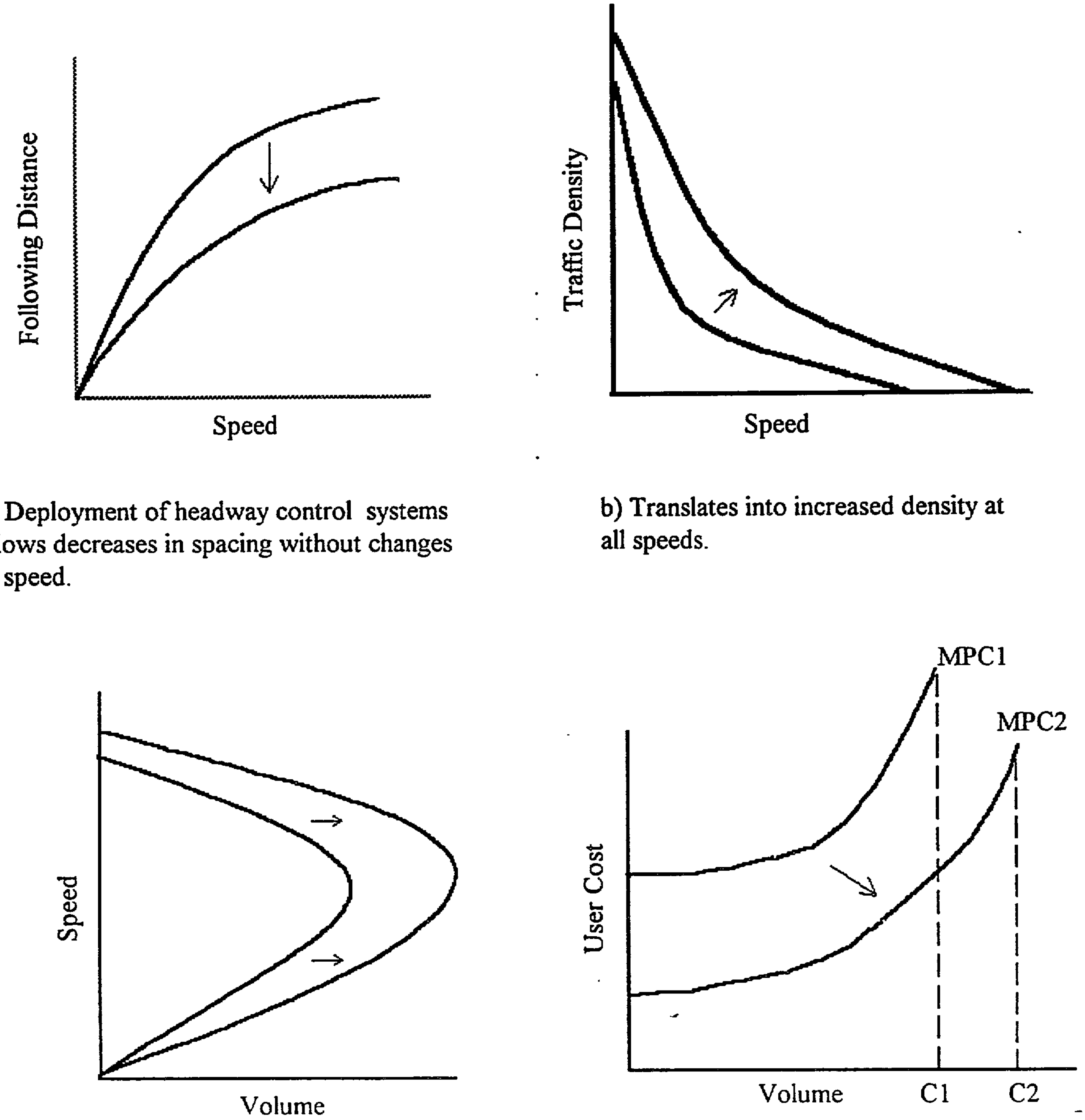
An example of the effect of an IVHS strategy on the quantity of travel is depicted in Exhibits 9 and 10. Automatic headway control systems, for instance, employ vehicle sensors to maintain constant distances between vehicles traveling in a particular lane or highway. Distance monitoring is combined with brake and speed control in order to decrease following distance and increase vehicle throughput. Therefore, the implementation of these systems will change the following distance-speed relationship depicted in Exhibit 4 by decreasing the spacing between vehicles for any given travel speed. This effect, as shown in Exhibit 9, can be represented by a downward shift in the following distance-speed curve so that at any particular speed (other than zero) shorter following distances will prevail. Decreases in spacing will also impact traffic density. Specifically, as spacing decreases for any given speed, density increases, thereby shifting the density-speed curve outward to the right. The end result will be a downward shift in the cost curves that are shown in Exhibit *7* so that facility performance (supply) increases at every user cost.

Exhibit 8
Equilibrium Quantity of Travel



The equilibrium quantity of travel (i.e., observed traffic volumes) at a given point in time along a specific route or entire system is given by the interaction between travel demand and supply.

Exhibit 9
Example Effect of IVHS on the Determination of Supply



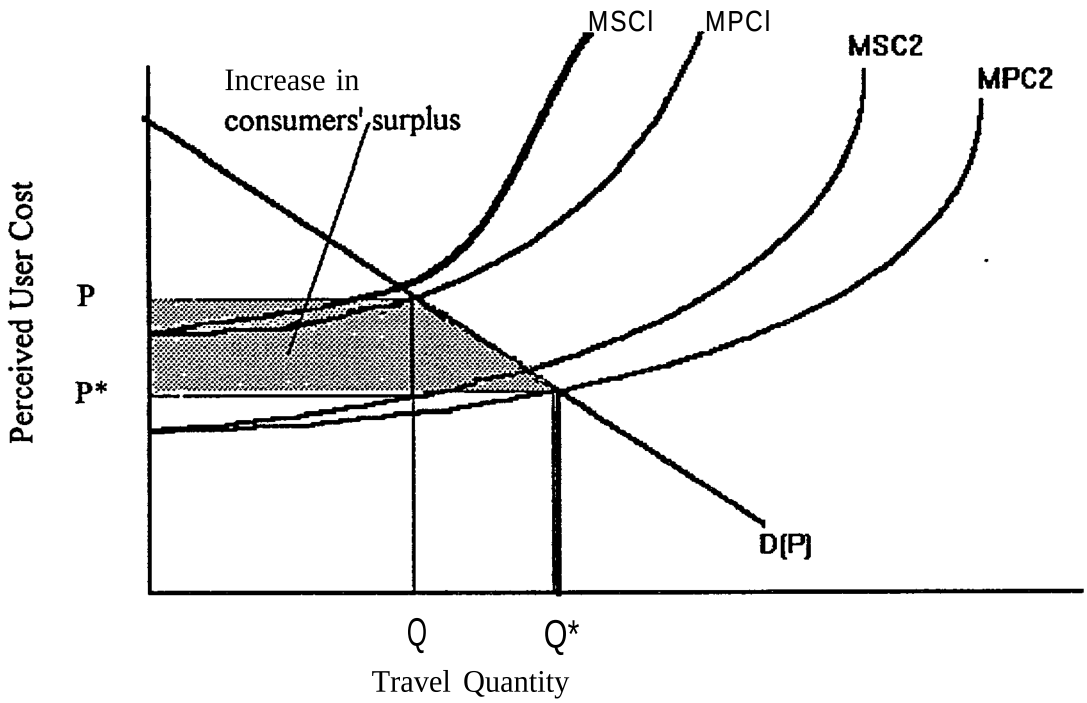
a) Deployment of headway control systems allows decreases in spacing without changes in speed.

b) Translates into increased density at all speeds.

c) Effect on density increases potential volume at given speeds and capacity.

d) End result is a decrease in user costs and shift of supply curve, increasing throughput capacity.

Exhibit 10
Sample Impact of IVHS on the Equilibrium Level of Travel



Development of automatic headway control systems, for example, reduces the equilibrium price and increases the equilibrium quantity. The fall in price generates an increase in consumers' surplus.

Q*-Q represents "induced" traffic resulting from development of technologies.

When combined with the travel demand curve for that lane or roadway (at a given point in time), the effect of the shift in supply translates into a new equilibrium quantity of travel as demonstrated in Exhibit 10. The increase in travel reflects induced traffic resulting from decreases in marginal user costs, or the increase in facility utilization that is prompted by the resulting reduction in the user cost per unit of service that the facility provides (e.g., cents per vehicle-mile traveled on the facility at a point in time). Several observations are in order.

- Induced demand should be regarded as an indication that an investment such as IVHS is generating benefits, rather than as evidence of an unforseen or unintended side-effect that can only be avoided by eliminating the investment. As shown in Exhibit 10, at the new equilibrium quantity (Q) and marginal perceived user cost (P) consumers' surplus is larger. The magnitude of the change in consumers' surplus depends on the relative elasticities of supply and demand. Therefore, where travel growth induced by the deployment of IVHS projects generates external costs, it also produces substantial benefits to users of the transportation system.
- Where travel growth induced by IVHS deployment produces external costs, it is important to deal with externalities directly (e.g., by improving emissions technology, increasing gasoline taxes, implementing road pricing, etc.), rather than to sacrifice the benefits of investment in order to minimize external costs.

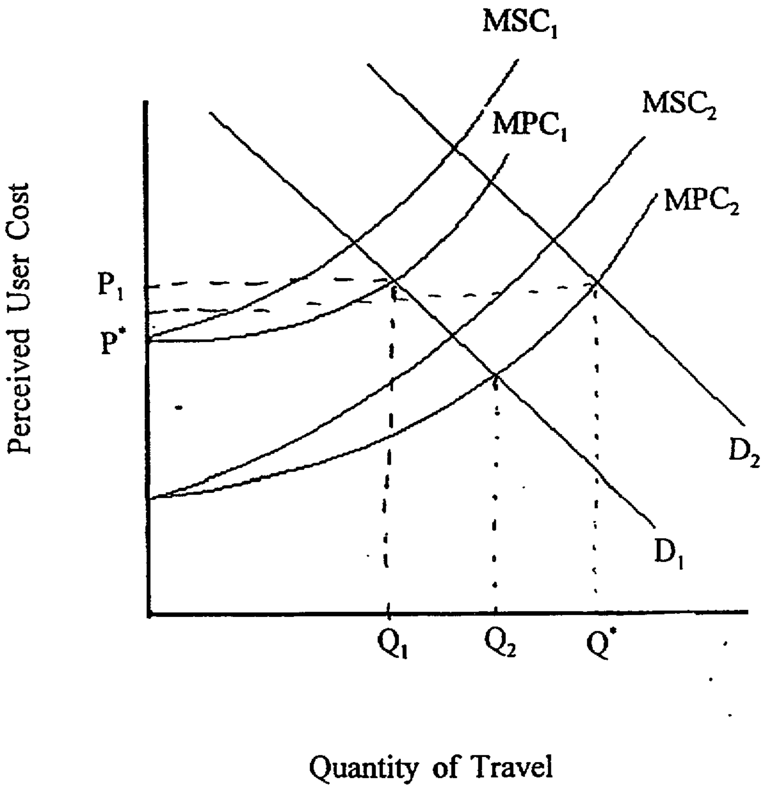
Moreover, induced demand resulting from the deployment of-IVHS should be distinguished from increases in travel and facility utilization that originates from secular growth. The dynamic nature of the market for motor vehicle travel represented by continuous shifts in demand that represent secular growth and periodic increases in supply — through either capacity expansion or in the future IVHS deployment — is depicted in Exhibit 11 Induced demand is associated with reduced user cost since the outward shift in the supply curve implies that more travel can be accommodated at ever level of cost. Outward shifts in the demand curve result in higher user costs — since as congestion sets in speed decreases and travel time increases. In fact, increases in supply are often undertaken in exactly the places where demand is growing most rapidly. This creates difficulties in separating the component of observed travel growth resulting from demand growth from the component that is induced by increases in supply. Finally, at the level of an individual facility, much of what is referred to as induced demand actually may be diverted traffic from competing facilities rather than newly induced traffic.

POLlCY IMPLICATIONS

This paper has presented an analytical framework for evaluating the potential effects of IVHS products and user services on the quantity of travel. IVHS will undoubtably have supply effects as a result of

EXHIBIT 11

Simultaneous Shifts in Demand and Supply



Initially, equilibrium is given by P_1, Q_1. As demand increases (i.e., shifts from D_1 to D_2), supply increases to accomodate the secular growth. The end result is a new equilibrium level of travel given by Q^*. $Q_2 - Q_1$ is the induced component of travel growth, while $Q^* - Q_2$ is the growth intravel associated with secular growth.

improvements in level of service that may result from more efficient traffic operations, reduced congestion, and better interface between the road and the vehicle. What has been termed as the induced demand repercussions of IVHS is simply represented by a movement along the demand curve for travel that results from reductions in perceived user costs in response to increases in facility performance (i.e., supply). Although it is true that many IVHS strategies will decrease user cost and increase travel, the external costs of increased travel must be weighed against the benefits that are accrued by users of the system. Policies that discourage highway investment projects (e.g., advanced traffic management systems) to address the externalities of motor vehicle travel restrict growth in social welfare by restricting growth in consumers' surplus. It is important to implement policies that directly deal with external costs.

Various IVHS technologies are also well suited for enhancing the effectiveness and logistics of transportation demand management programs, such as road pricing, that can help to internalize the external costs associated with motor vehicle travel. IVHS can play an integral role in programs that attempt to change the price signals sent to users of the transportation system. Through automatic vehicle identification, for example, fees can be set to vary over time and distance so that higher charges at peak periods and over longer trips can compensate for the higher congestion and environmental costs of peak period and long distance travel.

Similarly, on-board diagnostics, that monitor a vehicle's emissions, and remote sensing devices, that measure exhaust pollutants from moving vehicles, are examples of IVHS technologies that can facilitate the identification, repair, or removal from service of super-emitting vehicles and that can supplement conventional control strategies such as inspection and maintenance programs. In this manner, policies that directly address external costs can be formulated with the assistance of IVHS.

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ENERGY CONSUMPTION IMPLICATIONS OF TELECOMMUTING ADOPTION

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Abstract

Telecommuting, advocated as a promising transportation management strategy, is intended to substitute a portion of physical commuting trips during peak hours by information flow, thereby reducing energy consumption and air pollution. This paper discusses the potential for energy savings from telecommuting and its implications for the transportation planning process.

Although several pilot telecommuting projects have demonstrated a reduction in commuting trips, a network-wide assessment has not been reported in the literature, partly due to the lack of mathematical models to predict telecommuting adoption. This paper applies recent telecommuting adoption models to predict adoption. The commuting trips substituted by telecommuting are then taken into account in the network-wide estimate of potential reduction in travel and energy consumption. Results suggest that about 14.5% of total workers in Austin will work from home about twice per week under a "salary neutral" program scenario; this is equivalent to 5.8% workers telecommuting every day and will save about 2.5% (18,400 gallons) of total fuel consumed by vehicles. The predicted values of telecommuting adoption in Dallas and Houston are 5.9% and 5.0% (on a everyday equivalent basis), and fuel savings are 2.6% (126,700 gallons) and 2.1% (94,400 gallons), respectively.

The estimation results also have implications for telecommuting program design. For example, the results confirmed that both employee participation and employer support are influenced by the economic implications of the program design. While employees are not willing to sacrifice salary to work from home, employers are not inclined to favor a program that decreases the telecommuter's salary, either, implying that a salary-neutral telecommuting program design may be acceptable to both employees and employers. In addition, both models reveal that the effect of changes in salary is stronger than responsibility for bearing additional telecommuting costs.

ENERGY CONSUMPTION IMPLICATIONS OF TELECOMMUTING ADOPTION

1. INTRODUCTION

Advances in information technology during the past decade have two primary types of implications for transportation planning strategies, with potentially significant impacts on environmental concerns such as energy consumption and air pollution. The first is intended to improve transportation system performance through the use of information technology, such as advanced traveler information system (ATIS) functions under the IVHS umbrella, where drivers are provided real-time network information to improve network utilization. The second, focusing on transportation demand management, is telecommuting, which is intended to substitute part of physical commuting trips during peak hours by information flow and therefore reduce energy consumption and air pollution. This paper discusses the potential energy savings resulting from telecommuting and its implications for the transportation planning process.

Although several pilot telecommuting projects on the west coast have demonstrated a reduction in commuting trips during peak hours, few attempts have been reported on estimation of aggregate impacts at the network level. For example, energy savings have been estimated primarily as the product of individual trip savings (due to telecommuting) and the average fuel consumption per trip. A network-wide assessment has not been addressed in the literature, partly due to the lack of mathematical models to predict telecommuting adoption. This paper applies the results of telecommuting adoption models developed by the authors to predict adoption. Commuting trips substituted by telecommuting are then incorporated in a network-wide estimate of potential reduction in travel and energy consumption.

The interactions between telecommuting and its environment are discussed in the following section. Models of the telecommuting adoption process by employees and employers, respectively, are then presented along with their implications for telecommuting program design. The estimated models are used to predict the extent to which telecommuting will be adopted, a key determinant of the impacts of telecommuting on energy consumption and air pollution. The prediction then forms the input to a model to estimate network-wide travel and energy savings due to telecommuting. Additionally, telecommuting implications for the transportation planning process are discussed.

2. TELECOMMUTING AND ITS ENVIRONMENT

The interactions between telecommuting and its environment are illustrated in Figure 1, which indicates that telecommuting adoption, a joint outcome of employee and employer decisions, is influenced by four external factors: telecommunications technologies, transportation systems performance, public policies, and land use patterns. The consequences of telecommuting adoption typically include three different levels of impacts. Short-term impacts refer to changes in travel behavior and activity patterns of telecommuters. Medium-term impacts include household activity allocation and car ownership. Long-term impacts involve possible relocation of telecommuting households and offices of organizations .

Telecommuting is one of a range of telecommunications applications (e. g. teleconferencing and teleshopping) that have potential impacts on transportation and the environment. The availability of telecommuting is influenced by the penetration of telecommunications related facilities in the community of interest. In addition, increasing concerns over urban traffic congestion and air quality have heightened interest in telecommuting as a promising transportation demand management strategy. Other external factors, such as land use patterns and public policy also have a bearing on telecommuting adoption, primarily on employer decisions. Pacific Bell's first telecommuting program, for example, was initiated when the local government asked businesses to reduce traffic during the 1984 Summer Olympics in the Los Angeles area (Bailey and Foley, 1990). On the other hand, the Interactive System Corporation, a computer software company in Santa Monica, California, adopted telecommuting because it could not afford to lease an office (SCAG, 1985).

The impacts of telecommuting derive primarily from the changes in travel behavior (e.g. frequency, departure time, trip chaining) and activity patterns of the telecommuter. Some pilot projects indicate that such changes may also be experienced by household members of the telecommuting adopter (Kitamura *et al.*, 1990), as telecommuting households reallocate activities among members in order to adapt to the new work and travel pattern of the telecommuter. For example, a former commuter who usually drops a child off at school on the way to the office and purchases groceries on the way back home would no longer do so during telecommuting days, unless he/she makes morning and evening trips specifically for these purposes. These duties may be transferred to other household members who still drive to work, or the pattern of some activities (e.g. shopping), namely frequency, time of day, or day of week may change. The reallocation of household activities may interact with the relative priority of car use among household members and perhaps lead to a reduction of household car holdings.

The changes described above may also cause eventual reconsideration of household residential location, as well as organizational office location. A household might move closer to the workplace location of a non-telecommuting household member. Insufficient evidence is available to confirm the impact of telecommuting on household residential location. During a two-year telecommuting pilot project in California, about 50% of the respondents who either relocated or were considering it reported that telecommuting influenced their residential location decisions. However, a formal statistical test did not reject the hypothesis that household shift patterns are not significantly different between telecommuters and non-telecommuters (Nilles, 1991).

It is mainly the short-term and medium-term impacts (i. e. changes in travel patterns and activities at individual and household levels) that affect transportation system performance. To the extent that work trips have been recognized as the major determinants of energy consumption by vehicles, the change in commuting travel behavior has a bearing on energy savings as well. Thus, the aim of this paper is to investigate network-wide energy savings due to the substitution of work trips by telecommuting.

3. TELECOMMUTING ADOPTION MODELS AND POLJCY IMPLICATIONS

Tables 1 and 2 show the parameter estimation results of two models of telecommuting adoption by employees and employers, respectively. These models are based on an ordered-response formulation derived by the authors and estimated using employee and executive stated-preference data, respectively, obtained from three Texas cities (Austin, Dallas, and Houston) (Mahmassani *et al., 1993; Yen et al.* 1994A, 1994b, and 1994c). The ordered-response model maps the range of a continuous latent variable onto a set of discrete outcomes. For a given decision situation, the latent variable represents the decision maker's perceived utility or attractiveness toward the decision object of interest (telecommuting in this research). A set of ordered thresholds for the latent variable associated with each decision maker define ranges corresponding to each discrete decision outcome. The decision-maker's choice then depends on the corresponding interval within which the perceived utility or attractiveness lies. In the present models, choice alternatives are ordered from lower preference for employee participating in and employer support for telecommuting to higher preference. It follows that for a given set of utility thresholds the greater value of the perceived attractiveness of telecommuting (the latent variable), the more likely are employees (or employers) to adopt telecommuting. On the other hand, for a given latent variable, the higher the thresholds are, the less likely are employees or employers to adopt telecommuting.

Readers interested in model development and specification are referred to other papers by the authors (Yen et *al.*, 1994b and 1994~). This section interprets the estimation results and their policy implications. Please note that only estimated coefficients of variables specified in the systematic components are indicated in the Tables; estimates of the variance-covariance structure aimed at capturing autocorrelation among observations are not shown.

With respect to the employee model, Table 1 shows that salary increase (S15) has a positive effect on the latent variable, and thus will increase the probability that employees choose telecommuting, for a given set of utility thresholds. On the other hand, the coefficients of salary decrease (SD5 and SD10) imply that employees are less likely to choose telecommuting if they have to sacrifice part of their salary. Similarly, responsibility for additional costs to work from home (ANL, BPC, and PART) negatively affects employee preferences, with all estimated coefficients being negative.

The relative magnitudes of estimated coefficients reveal useful information on employee preferences from the standpoint of program design and public policies. For instance, coefficients of SD5 (- 1.311) and S15 (0.293) indicate that salary decrease exerts a stronger effect on employee preferences than a comparable increase. Additionally, the coefficients of both dummy variables for 10% salary decrease (-1.909) and 5% decrease (-1.311) confirm that the former has a stronger effect but suggest a non-proportional relationship between the amount of salary decrease and its influence on the latent variable, with a decreasing marginal effect of further salary decrease. Significant differences among the coefficients of variables ANL, BPC, and PART (-0.643, -0.901, and -0.807, respectively) indicate that requiring telecommuters to buy a personal computer (BPC) is a stronger deterrent to telecommuting than other additional cost items. The coefficients of SD5 and SD10 are statistically less than those of ANL, BPC, and PART, indicating that salary sacrifice has a stronger negative effect than having to acquire additional equipment. This finding has important implications on telecommuting program design for organizations willing to provide such work arrangement.

Other variables that exert positive effects on employee telecommuting adoption include number of children under age 16 (CHIL16) or personal computers at home (HOMEPC), employee computer proficiency (SKILL), number of hours in which employees use a computer on work each day (HRCOMP), distance from home to the workplace (DSTRIP), as well as employee attitudes toward job suitability for telecommuting (FJOBSU) and effect of telecommuting on family. Variables that have negative effects include amount of time employees need to communicate face-to-face with co-workers (HRFACE), average number of stops (STOPS) on commuting trips (a proxy of employee activity pattern) and employee attitude toward the importance of social interactions with co-workers (FSOCIO).

Table 2 shows the estimation results of the employer adoption model parameters, based on stated preference information supplied by executives and managers. As expected, employer responsibility for some (ES) or all (ET) additional telecommuting costs has a negative effect on executive preferences. Similarly, the negative coefficient of variable S15 indicates that an increase in the telecommuter salary reduces the probability that executives will support such a program, all else being equal. Interestingly, a decrease in telecommuter salary (SD5) also exerts a negative influence on executives' willingness to support telecommuting, indicating that a program that reduces telecommuters' salary will not necessarily increase the likelihood of executive support. This result might be contrary to the *a* priori speculation that executives would support any program that could cut the organization's costs. Executives undoubtedly believe that it would be unfair to penalize a telecommuter if he/she could have the same job performance, and that reducing telecommuter salary would not be viewed favorably by employees, and would therefore lead to a poor public image of the organization.

The relative values of the coefficient estimates of S15 (- 1.031) and SD5 (-0.676) indicate that an employee salary increase exerts a stronger negative effect on executive support than a decrease. Though executives may not wish to decrease the telecommuter salary, they find it less tolerable to increase telecommuting employee salary. As expected, the significant difference between the coefficients of ES (-0.414) and ET (-0.572) indicates that the executive is less inclined to support a program when the organization incurs all rather than only part of the additional costs. The results also imply that an increase in telecommuter salary is less tolerated by executives than having to assume some or all telecommuting costs.

Other variables that affect executive telecommuting adoption include educational achievement (EA), job title (IT), management span (SOM), awareness of telecommuting (AW), as well as attitudes toward the effect of a telecommuting program on data security, the performance and morale of telecommuting workers, and management concerns such as executive work load and ability to supervise telecommuters.

The models presented in this section provide a methodology for predicting telecommuting adoption, which in turn forms the basis for predicting trip reduction and fuel savings potential of telecommuting, as described next.

4. IMPACTS OF TELECOMMUTING ON ENERGY SAVINGS

Four methods have been used previously to estimate fuel savings from telecommuting. The first calculates fuel savings as the product of the average fuel efficiency and average number of miles saved from each telecommuting occasion. The second takes into account differences among individual vehicles and aggregates individual savings, obtained from self-reported fuel efficiency and reduced travel distance due to telecommuting. The third method goes a step further to consider trip characteristics that influence fuel efficiency, including travel speed and whether it is a cold or hot start (Handy et al., 1993). None of the three methods considers network effects in the estimation of energy savings.

The fourth method, developed by Sullivan et *al.* (1993) and used in this paper, relies on the "two-fluid model" of traffic in an urban network (Herman and Prigogine, 1979), which provides a macroscopic network-level description of traffic interactions in a network. It is used in this analysis to translate the fractions of vehicular trips substituted by telecommuting into total savings in vehicle-miles traveled (VMT) in a network. Fuel savings are then calculated based on a calibrated fuel consumption model. The two-fluid model takes into account network attributes such as average speed, concentration, and directional factors. The procedure also recognizes the possible increase in speed experienced by non-telecommuters that continue to commute.

To assess fuel savings due to telecommuting, it is essential to predict the extent to which telecommuting will be adopted. Recognizing that telecommuting adoption is the joint outcome of employee and employer decisions, both models presented in the preceding section are used. Since the probability of employee participation is conditional on the provision of such a program by employers, the probability of joint adoption is the product of the conditional probability of employee participation and the marginal probability of employer support. Because employees apparently do not want to sacrifice salary in order to telecommute, and employers are generally disinclined to increase telecommuters' salary, the reasonable program scenario for the prediction of possible telecommuting adoption is the one under which telecommuters' salary remains the same. Detailed procedures for aggregate telecommuting prediction are given elsewhere by the authors (Yen *et al.,* 1994d). Table 3 lists the separate and joint predictions for employees and employers in three Texas cities under the program scenario with neutral telecommuter salary and employers incurring all additional telecommuting costs (such as a new phone line).

For employee participation, results in Table 3 are intended to represent possible adoption by the target group of potential telecommuters, namely information related workers. To facilitate aggregate prediction, the population of information workers is stratified into two groups of employees: those having computer proficiency at the medium or high level as group 1, and others as group 2. The composition of groups 1 and 2 are obtained from the telecommuting survey sample (83% vs. 17%, 87% vs. 13%, and 83% vs. 17% for Austin, Dallas, and Houston, respectively). The values of exogenous variables specified in the estimated adoption models used in the prediction are obtained through the following rationale. First, it is assumed that the distributions of variables such as commuting attributes and the number of children under 16 among members of the target group is the same as the whole population. Therefore, the former are based on surveys with random observations in Texas (Jou *et al.*, 1992), and the latter is based on the U. S. census data (1990). Finally, other job attributes for the target group are based on information from the televommuting survey conducted to calibrate the adoption models.

Predicting employer adoption is fraught with even greater uncertainty, especially with regard to the characteristics of the population of pertinent decision-makers in information-related organizations. Recognizing this uncertainty, employer adoption is predicted under three alternative scenarios: optimistic, middle, and conservative, as illustrated in Table 3, reflecting different composition of the underlying executive population. For aggregate prediction, the population of "representative" decision makers is conveniently stratified into two groups. Members in group 1 do not hold titles of president or vice president, have a management span of less than 6, and possess awareness of telecotntnuting. Members in the second group hold president or vice president titles, with management spans of at least 6 subordinates, and are not aware of telecommuting. The optimistic scenario assumes that the population of representative decision makers for employer adoption consists of 80% in group 1, and 20% in group 2. The population compositions for the middle and conservative prediction scenarios are 50% vs. 50% and 20% vs. 80%, respectively. Employee adoption (conditional on employer sponsorship) is assumed to be the same across the three prediction scenarios for each city. For each scenario, while employee adoption is predicted by city to reflect differences in transportation system performance and demographic data in the three cities (Table 4), employer adoption levels are assumed to be the same in the three cities. Under the optimistic scenario, about 42% of information workers in Austin will choose to work from home about twice per week, with 42% and 36% for Dallas and Houston, respectively. These probabilities decrease to 29%, 29%, and 25% for the middle scenario, and 16%, 17%, and 14% for the conservative scenario, respectively.

To predict fuel savings due to telecommuting, the middle scenario prediction is used as the base case. According to Woods and Poole (1990), 50% of total workers are information related in these cities. Assuming that telecommuting occasions are uniformly distributed across five work days per week, the predicted percentage of total workers who work from home every day is equivalent to 5.8% in Austin, 5.9% in Dallas and 5.0% in Houston, respectively, as listed in Table 5. These equivalent percentages of telecommuters are then applied to predict network-wide fuel savings due to telecommuting using the method proposed by Sullivan et *al.* (1993). Table 5 shows that predicted adoption of telecommuting will save about 18.4 thousand gallons of gas in Austin per day, 126.7 thousand gallons in Dallas, and 94.4 thousand gallons in Houston. These savings are equivalent to 2.53%, 2.62%, and 2.08% of the total fuel consumed by vehicles every day in each city, respectively. Table 5 also indicates that vehicle fuel savings during peak hours (7-9 A.M. and 4-6 P.M.) on arterial are 3.6 thousand gallons in Austin per day, 23.3 thousand gallons in Dallas, and 22.0 gallons in Houston, which are equivalent to 5.73%, 6.17%, and 5.05% of total fuel consumed by vehicles everyday in the peak on arterial in each city, respectively. As expected, results reveal that fuel savings in terms of percentage in peak are higher than on the daily basis.

To reflect the variation of fuel savings according to different levels of employer adoption, which is believed to play a relatively more important role than employee adoption to date, fuel savings are also predicted under the conservative and optimistic prediction scenarios. In Austin, the conservative prediction indicates an equivalent 3.3% telecommuting penetration every day, resulting in 1.44% savings of daily fuel, or 3.26% fuel savings in peak hours. These numbers increase to 8.3%, 3.62%, and 8.19% under the optimistic scenario, respectively. Overall, the equivalent telecommuting penetration under the conservative scenario is about 3.0% in the three cities, 5.5% under the middle scenario, and 8.0% in the optimistic case. In terms of fuel consumed, daily savings range from about 1.5%, 2.5%, to 3.5% under three different prediction scenarios. Peak savings are about 3.0%, 5.5%, to 8.0%. The results show that fuel savings highly depend on the level of employer telecommuting adoption, and suggest that executives may need to be targeted by public policy makers to promote telecommuting acceptance and penetration.

5. SOME TELECOMMUTING IMPLICATIONS FOR TRANSPORTATION PLANNING

The implications of telecommuting on the transportation planning process can be illustrated in Figure 2. Conceptually, the aggregate travel demand on transportation systems derived from each individual's activities motivates capacity addition to the transportation infrastructure and/or policy measures to manage the resulting congestion. These changes in the transportation system influence the land use pattern in the community, which in turn affects individuals' activities. Empirically, in order to predict travel demand and the associated performance of the transportation system, traditional transportation planning procedures use different types of land use models to predict future economic activities in-the area of interest. The results of land use models and demographic data then provide the input to the four-stage transportation planning process intended to project the performance of the transportation system for the particular land use pattern under consideration (Manheim, 1979; Paquette *et al.*, 1982; Meyer and Miller, 1984).

Although a plethora of critiques of the traditional four-stage procedure can be found in the literature, it remains well entrenched in transportation planning practice. Recent policy concerns such as air quality, congestion management and advanced technologies have led to renewed interest in alternative transportation planning methodologies. In practice, activity-based approaches to travel demand analysis appear particularly attractive. Their basic premise is that activity and trip patterns rather than individual trips should be at the center of demand analysis procedures, Activity-based approaches are particularly appropriate to analyze the transportation impacts of telecommunications technology applications. The latter can directly and indirectly influence activity patterns as they have the potential to transform the movement of people and goods on transportation networks by information transmission.

The development of telecommunications technologies may affect land use patterns and hence the economic and social activity system. For example, Kutay (1986) argued the importance of communication networks as a determinant of office location, paralleling the role of transportation systems in regional economic development (Adler, 1987). To the extent that telecommunications networks might be a substitute for transportation systems in the future, they may be expected to play a role in the growth of economic activities and spatial distribution of industry. Thus businesses today with high information-related activities may be located where easy access to telecommunications networks is available (Salomon, 1988).

The impacts of telecommuting on transportation system performance are due to the substitution of commuting trips by information flow. The reduction of travel ultimately mitigates traffic congestion and air pollution. It has long been recognized that transportation infrastructure improvements tend to generate additional demand for travel that is attracted by better service levels (Adler, 1987). Therefore, it may not be unreasonable to expect at least part of the potential savings from telecommunications applications to be offset by induced demand. Additionally, the impacts of telecommuting on activity patterns at the individual and household levels have been discussed in section 2. As a result, the implications of telecommuting on transportation planning have to be recognized through its impacts on land use, activity, and transportation systems. Finally, policies and regulations enacted by the public sector may target telecommunications technologies, the transportation system, or the land use pattern. Intervention by governments is primarily on the supply side of these factors, and may include control of pricing and level of service. Such supply side actions will affect demand side as well.

6. CONCLUSION

This paper predicts potential savings in fuel consumption resulting from telecommuting in three cities in Texas. The prediction procedure relies on the "two-fluid model" of traffic in urban networks, and calculates fuel savings based on a calibrated fuel consumption model. Results indicate that for the middle prediction scenario about 14.5% of total workers in Austin will work from home about twice per week under the salary neutral program, which is equivalent to 5.8% workers telecommuting every day, and will save about 2.5% (18,400 gallons) of total fuel consumed by vehicles per day. The predicted portions of telecommuting adoption in Dallas and Houston are 5.9% and 5.0% (on a everyday equivalence), respectively. Fuel savings are 2.6% (126,700 gallons) and 2.1% (94,400 gallons), respectively. However, alternative prediction scenarios reflect considerable uncertainty regarding the levels of employer adoption and support of telecommuting, suggesting that executives form a critical target group for public policy action aimed at encouraging telecommuting.

The above prediction is based on two models of telecommuting adoption by employees and employers, respectively, and a set of assumptions to derive reasonable values for the explanatory variables from exogenous data source. The estimation results also have policy implications in terms of telecommuting program design. For example, estimation results found that both employee participation and employer support are influenced by economic implications of the program design. Specifically, both changes in employee salary and the costs incurred by telecommuters (or employers) significantly influence these two decision makers' adoption decisions. While employees are not willing to sacrifice salary to work from home, employers are not inclined to institute programs that decrease the telecommuter's salary, either. In addition, both models reveal that the effect of changes in salary is stronger than the responsibility for assuming additional telecommuting costs. The results imply that a salary-neutral telecommuting program design may be acceptable to both employees and employers.

While the fuel consumption savings potentially achievable through telecommuting are meaningful, they are not likely to be the primary motivation for greater telecommuting adoption and support through public policy. Ultimately, it is the benefits that both employees and employers might derive in terms of enhanced lifestyle options and eventually greater productivity that will determine the degree of penetration. Employees benefit from the decrease in the time and cost spent commuting, and the resulting increase in discretionary time and scheduling flexibility. Employers benefit by reducing overhead cost of offices and employee turnover. It is only incidental that society also benefits through reduced congestion and fuel consumption savings.

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Table 1 Estimation Results of Employee Telecommuting Choice Model

Variables		Parameter estimates*	
Specified in the latent variable			
Constant		-0.190	
(Economic implications)			
S15:	Change in telecommuter salary (1 if increase 5 %; 0 otherwise)	0.293	(30.0)
SD5:	Change in telecommuter salary (1 if decrease 5 %; 0 otherwise)	-1.311	(-4.9)
SD10:	Change in telecommuter salary (1 if decrease 10 %; 0 otherwise)	- 1.909	(-9.8)
ANL:	Additional phone costs assumed by employee (1 if need to add a new phone line at home; 0 otherwise)	-0.643	(-31.0)
BPC:	Additional computer costs assumed by employee (1 if need to buy a personal computer; 0 otherwise)	-0.90 1	(-7.3)
PART:	Additional partial costs assumed by employee (1 if need to pay part of the costs; 0 otherwise)	-0.807	(-8.9)
(Employee personal and household characteristics)			
CHIL16:	Number of children under age 16 at home	0.142	(3.2)
HOMEPC:	Number of personal computers at home	0.202	(9.6)
SKILL:	Index of computer proficiency (1 if at least one skill at medium or high level; 0 otherwise)	0.272	(16.0)
(Employee job characteristics)			
HRFACE:	Number of hours communicating with co-workers face-to-face per day	-0.344	(-18.0)
HRCOMP:	Number of hours using a computer on work per day	0.175	(17.0)
(Employee commuting attributes)			
DSTRIP:	Distances from home to the workplace, miles	0.028	(15.0)
STOPS:	Average number of stops on the way to work and back home per week	-0.124	(-14.0)
Specified in the utility thresholds			
Utility threshold 2			
Constant		2.270	
FJOBSU:	Regression score of employee attitudes toward job suitability for telecommuting	-0.436	(-33.0)
FFAMIL:	Regression score of employee attitudes toward telecornmuting effect on family	-0.577	(-31.0)
FSOCIO:	Regression score of employee attitudes toward the importance of social interactions with co-workers	0.568	(14.0)
Utility threshold 3			
Constant		2.864	
FJOBSU:		-0.318	(-3.4)
FFAMIL:		-0.126	(2.0)
FSOCIO:		0.820	(8.4)
Number of observations	545		
Log likelihood value at zero	-5228.7		
Log likelihood value at convergence	-3909.0		

* Numbers in parentheses are t-values

Table 2 Estimation Results of Employer Telecommuting Choice Model

Variables		Parameter estimates*	
Specified in the latent variable			
Constant		0.229	
(Economic implications)			
S15:	Change in telecommuter salary (1 if increase 5 %; 0 otherwise)	-1.031	(-3.5)
SD5:	Change in telecommuter salary (1 if decrease 5 %; 0 otherwise)	-0.676	(37.0)
ES:	Employer responsibility for partial additional telecommuting costs (1 if some costs; 0 otherwise)	-0.414	(-32.0)
ET:	Employer responsibility for all additional telecommuting costs (1 if total costs; 0 otherwise)	-0.572	(-22.0)
(Executive personal characteristics)			
EA:	Executive's educational achievement (1 if a master or Ph.D. degree; 0 otherwise)	0.493	(12.0)
AW:	Awareness of telecommuting (1 if the executive knows someone who telecommutes; 0 otherwise)	0.537	(19.0)
(Executive job characteristics)			
JT:	Executive's job title (1 if president or vice president; 0 otherwise)	-0.772	(-38.0)
SOM	Number of subordinates directly supervised by the executive (1 if <= 5; 0 otherwise)	0.451	(23.0)
Specified in the utility thresholds			
Utility threshold 2			
Constant		3.923	
FIELE	Regression score of executive attitudes toward telecommuting effect on telecommuters and public image of the organization	-0.488	(-60.0)
FMANG:	Regression score of executive attitudes toward the management impacts of telecommuting	-0.118	(-22.0)
Number of observations		80	
Log likelihood value at zero		-791.0	
Log likelihood value at convergence		-407.1	

* Numbers in parentheses are t-values

Table 3 Predicted Probabilities of Telecommuting Adoption for Information-Related Workers

Cities	Predicted Choice Probabilities		
	Employee	Employer	Joint
Optimistic Scenario			
Austin	.650	.641	.417
Dallas	.657	.641	.421
Houston	.556	.641	.356
Middle Scenario			
Austin	.650	.446	.290
Dallas	.657	.446	.293
Houston	.556	.446	.248
Conservative Scenario			
Austin	.650	.251	.163
Dallas	.657	.251	.165
Houston	.556	.251	.140

Table 4 Mean Values of Explanatory Variables Used for Telecommuting Prediction

Variables		Austin	Dallas	Houston
Specified in the latent variable				
(Employee personal and household characteristics)				
CHIL16:	Number of children under age 16 at home	0.64	0.71	0.82
HOMEPC:	Number of personal computers at home	0.56	0.53	0.48
(Employee job characteristics)				
HRFACE:	Number of hours communicating with co-workers face-to-face per day	1.56	1.44	2.17
HRCOMP:	Number of hours using a computer on work per day	4.48	3.90	3.91
(Employee commuting attributes)				
DSTRIP	Distance from home to the workplace, miles	10.80	13.00	13.90
STOPS:	Average number of stops on the way to work and back home per week	4.25	4.10	4.92
Specified in the utility threshold				
FJOBSU:	Regression score of the employee's attitudes toward the job suitability for telecommuting	3.98	3.90	4.29
FFAMIL:	Regression score of the employee's attitudes toward the effect of telecommuting on family	2.65	2.38	2.67
FSOCIO:	Regression score of the employee's attitudes toward the importance of social interactions with co-workers	3.42	3.33	3.38

Table 5 Fuel Consumption Savings from Telecommuting Under Realistic Network Data (Conservative Scenario)

	Austin			Dallas			Houston		
	C	M	O	C	M	O	C	M	O
portion of total workers working from home twice per week (%)	8.2	14.5	20.9	8.3	14.7	21.1	7.0	12.4	17.8
equivalent portion of total workers working from home everyday (%)	3.3	5.8	8.3	3.3	5.9	8.4	2.8	5.0	7.1
fuel savings, thousand gallons per day	10.5	18.4	26.3	71.1	126.7	180.4	52.7	94.4	132.2
fuel savings, percentage (%)	1.44	2.53	3.62	1.47	2.62	3.73	1.16	2.08	2.91
fuel savings, gallons, peak on arterial	2.1	3.6	5.2	13.0	23.3	33.1	12.3	22.0	31.2
fuel savings, percentage (%), peak on arterial	3.26	5.73	8.19	3.45	6.17	8.78	2.83	5.05	7.17

Prediction scenarios: C, conservative
M, middle
O, optimistic

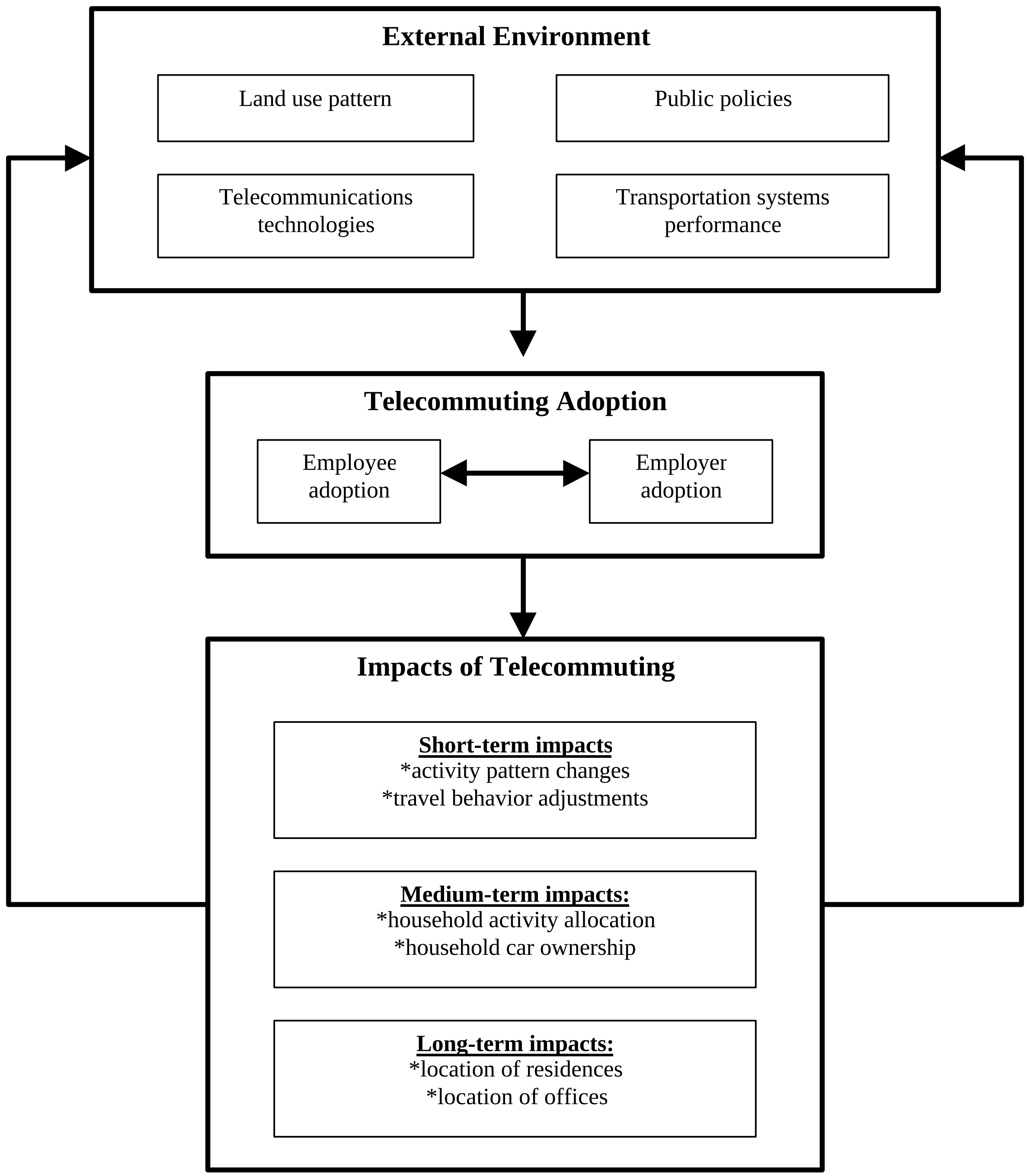

Figure 1: Interaction between Telecommuting Adoption Process and External Environment

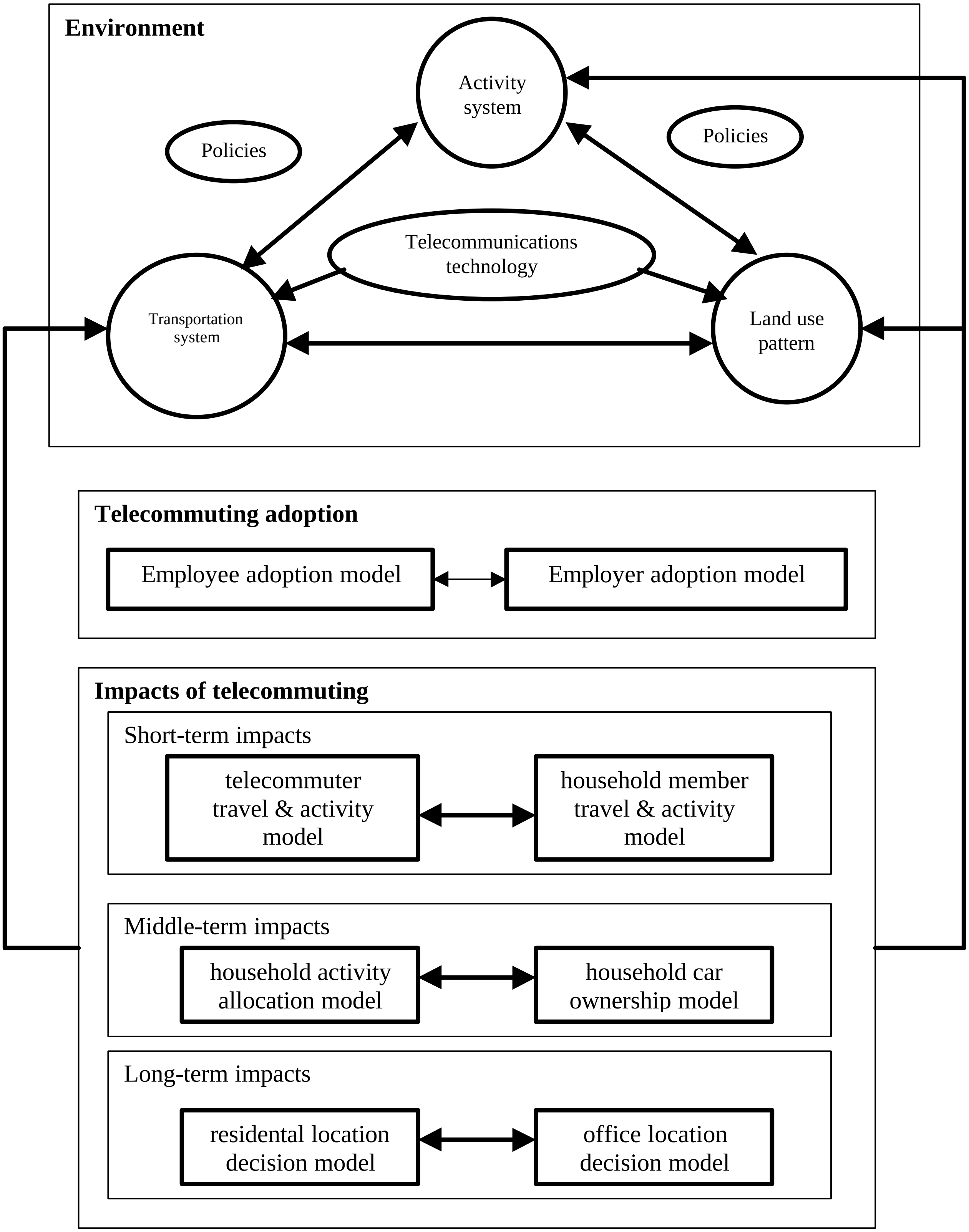

Figure 2: Implications of Telecommuting on Transportation Planning

CARBON MONOXIDE IMPACTS OF AUTOMATIC VEHICLE IDENTIFICATION APPLIED TO VEEIICLE TOLLING OPERATIONS

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INTRODUCTION

Intelligent transportation technologies (ITT's) are being promoted as a means of reducing congestion delay, improving transportation safety, and also as a means of making vehicle travel "...more energy efficient and environmentally benign (USDOT, 1990)." In theory, IVHS technologies will increase the efficiency and capacity of the existing highway and roadway systems to reduce congestion (Saxton and Bridges. 1991; Conroy 1990; Shladover, 1991; Shladover, 1989). We are not confident, however, that vehicular emissions will be reduced by the full range of proposed ITT's.

The transportation-air quality community has in the past lacked the appropriate tools in which to predict the effects of microscopic changes to vehicular activity induced by ITT's. The currently used emissions models. EMFAC in California. and MOBILE in the remainder of the US, are unable to provide the resolution needed to quantity the effects of these changes. Research at UC Davis is focusing on estimation of a statistical 'modal' model capable of simulating the emissions impacts from individual vehicles under various operating scenarios. The emissions model, currently a significantly modified version of the mathematical algorithms employed in the CALINE 4 Line Source Dispersion Model developed by Paul Benson and others at Caltrans (Benson, 1989), predicts emissions based upon individual vehicle speed-time profiles and laboratory measured emission rates. The model, therefore, can quantify vehicular emissions under various ITT scenarios.

This paper examines the carbon monoxide (CO) emission impacts of one such applied lTT, namely Automatic Vehicle Identification (AVI) used to implement automatic tolling. AVI used in lei of conventional toll booths has previously been identified as an ITT that is likely to offer air quality benefits (Washington, Guensler, & Sperling, 1993a). By allowing vehicles to be tolled either through a windshield displayed debit card, or by some other mechanism, vehicles could forgo the deceleration, stop-delay, and ensuing acceleration that results from an encounter with a conventional tolling station. The results presented here are preliminary, and represent the beginning stages of an ongoing research effort. More substantial and complete results will be provided as they become available.

BACKGROUND

The six basic ITT "technology bundles" (Jack Faucett Associates, 1993) include: Advanced Traffic Management Systems (ATMS). Advanced Traveler Information Systems (ATIS). Advanced Vehicle Control Systems (AVCS), Commercial Vehicle Operations (CVO). and Advanced Public and Transportation Systems (APTS). Each of these technology bundles is designed to achieve the same general goal; improve the efficiency of the transportation system through the application of communications and computational technologies. However. the efficiency objectives targeted by each technology bundle are distinctly different, and will have different potential effects upon the parameters that effect vehicle emissions (Washington, Guensler, Sperling, 1993a).

Previous research has concluded that one of the most likely technology bundles to improve air quality is Advanced Traffic Management Systems (Washington, Guensler, Sperling, 1993b). As the name implies, ATMS employ computer control technologies to 'optimize' or smooth traffic flows on a transportation network. Examples of ATMS technologies are real-time traffic signal network optimization, real-time ramp metering, and automatic vehicle tolling via automatic vehicle identification technologies (AVI). These computer controlled systems are designed to reduce congestion levels; minimize system-wide delay levels, and generally smooth vehicular flows. ATMS technology bundles also include various signal actuation bundles, incident detection, rapid accident response, and integrated traffic management.

Automatic toll collection, the topic of this paper, aims to smooth traffic flows by implementing advanced communications technologies between roadway and vehicles. If conventional tolling operations performed on bridges or tolled turnpikes were replaced with automatic and transparent vehicle identification and debiting, for example, then toll plaza delays experienced by motorists could be eliminated. The elimination of these activities would further result in fewer declarations, idling, and acceleration events prevalent under conventional tolling operations. These 'modal' activities, representing high load and power conditions, have been shown to contribute significantly to the production of emissions from motor vehicles (LeBlanc, et al., 1994; CARB, 1991; Benson, 1989; Groblicki, 1990; Calspan Corp., 1973a; Calspan Corp., 1973b; Kunselman, et al., 1974). In fact one sharp acceleration may cause as much pollution as does the entire remaining trip (Carlock, 1992). This suggests that a small percentage of a vehicle's activity may account for a large share of it's emissions (LeBlanc, et. al., 1994). In addition, longer enrichment events are more highly correlated with large emission excursions than are shorter events (LeBlanc, et. al., 1994), and furthermore, deceleration events are capable of producing significant emissions (Darlington, et al., 1992). In contrast to cold start emissions that occur over a period of minutes, acceleration and deceleration related emissions occur over a period of a few seconds.

Using a preliminary 'modal' model that accounts for relative contributions of CO emissions from acceleration. deceleration. cruise, and idle events, we assess the impacts of automatic tolling using AVI. The goal is to quantify the expected CO emission differences between a toll-plaza and AVI scenario. In addition, the expected variation in these benefits is approximated given current limitations of the vehicle emissions data. The results provided represent preliminary research findings, and will be supplemented with further findings when they become available.

DESCRIPTION OF THE MODAL MODEL

The preliminary 'modal' model employed in these analyses is a derivative of the CALINE Line Source Dispersion Model that has been developed over many years by the California Department of Transportation (Benson, 1989). The model is different from the CALINE model in several very important respects. First. individual vehicle 'FTP BAG 2' (Washington, Guensler, and Sperling 1994) emission rates are used in the model, rather than an 'approximated' average values applied to the vehicle fleet. Second individual idle emission rates are used in the model, rather than 'approximated' average values applied to the vehicle fleet. Finally, the 'dispersion' portion of the CALINE model is not employed, but rather, only the algorithms used to determine the emissions inventory are used. These differences result in a statistical model that can explain approximately 70% of the variation in emissions for individual vehicles tested on 14 different emission testing cycles. This is in comparison to both the current EMFAC and CALINE models, while employing fleet average FT'P Bag 2 and idle emission rate values, explain about 13% and 2% of the variation in emissions for individual vehicles respectively (Washington, Guensler, and Sperling, 1994).

The latest version of the CALINE4 model is similar to the Colorado Department of Highways (CDOH) model released in 1980. The data used to estimate model coefficients were derived from 37 discrete modes driven by 1020 light-duty vehicles ranging from 1957 model year to 1971 model year. In both the Caltrans and CDOH model development efforts, a strong relation was noted between modal emissions and the average acceleration speed product (AS) for the particular acceleration mode. Consequently, AS is one of the explanatory variables used in the CALINE4 model (Benson, 1989).

The CALINE4 model is descriptive and not deterministic. This means that the model is estimated using observed emissions and vehicle behavior, rather than using more causal variables such as fuel volatility, cylinder size, mechanical efficiency losses, etc. The model employed in this research effort is identical to the functional form contained in CALINE model, except for the significant and important differences noted earlier (and described below).

The modified CALINE model can be written as:

$TE_{ik} = EI_{ik} + EA_{ik} + EC_{ik} + ED_{ik}$ where;

TE_{ik} = Total CO emission estimate for vehicle i on cycle k in grams,
EI_{ik} = CO emissions from idle events for vehicle i on cycle k in grams,
EA_{ik} = CO emissions from acceleration events for vehicle i on cycle k in grams,
EC_{ik} = CO emissions from cruise events for vehicle i on cycle k in grams,
ED_{ik} = CO emissions from deceleration events for vehicle i on cycle k in grams.

The emission contributions from modal events are defined as:

$EI_{ik} = (IR[grams/sec])\ (t_i[secs])$. where;

IR is the measured individual vehicle idle emission rate,

t_i is time in the idle operating mode.

$EA_{ik} = [(FTPB2_{[grams/min]}) * (C1) * EXP\ (C2 * AS)] * t_{a\ [secs]} * 1_{[min]}/60_{[sec]}$, where;

FTPB2 is measured emission rate on FTP Bag2 for individual vehicles,
Coefficients C1 = 0.75 and C2 = 0.0454 for acceleration condition 1,
Coefficients C1 = 0.027 and C2 = 0.098 for acceleration condition 2,
AS is the acceleration speed product based upon average speed and average acceleration rate of the accel mode,
Acceleration condition 1 is for vehicles starting at rest and accelerating up to 45 mph,
Acceleration condition 2 is for vehicles starting at 15 mph or greater and accelerating up to 60 mph,
ta is the time in the acceleration mode.

$EC_{ik} = (FTPB2_{[grams/min]})) * [(0.494 + 0.000227 * S_{[mph]})^2)] * (t_{c\ [secs]} * 1_{[min]}/60_{[sec]}$, where;

FTPB2 is measured emission rate on FTP Bag2 for individual vehicles,
t_c is the time in the cruise event.

$ED_{ik} = (IR_{[grams/sec]}) * (t_{d[secs]})$, where,

IR is the measured individual vehicle idle emission rate,
t_i is time in the deceleration operating mode.

The modified CALINE model is used in conjunction with summed emissions from steady-state modal events for a vehicle on any cycle. For example, a given speed-time trace is parsed into discrete model events of idle, cruise, acceleration, and deceleration. The emissions from these events are then summed over the cycle to obtain the total emission estimate.

EXPERIMENTAL DESIGN

To estimate the difference in CO emissions between a vehicle encountering a conventional toll plaza, and the 'no delay' experience by automatic vehicle identification tolling operations, the modified CALINE model is employed. To perform these comparisons, a toll plaza is first simulated on a typical transportation link. The link could be a typical tolled bridge entrance, or could be the entrance to a tolled freeway. The toll plaza design follows that described by Lin (1994), representing a Gate type 'C' operating at level of service A. Under these conditions, the average vehicle experiences about 6 seconds of delay waiting for previously queued vehicles (Lin, 1994). Since the emissions estimates from vehicles encountering toll plazas are done on a per-vehicle basis, and because level of service A is assumed in these initial analyses, the traffic volume is not important (congestion delay induced by toll plazas and high traffic volumes will be covered in subsequent analyses).

To simulate vehicular activity under the two different scenarios, speed-time profiles were developed four different vehicle trajectories. Table 1 displays some characteristics of these speed-time profiles. Two speed-time profiles were developed for vehicles entering a toll plaza, one for drivers exhibiting 'aggressive' driving behavior and one for drivers exhibiting 'normal' driving behavior. All vehicles were assumed to begin and end their speed-time trajectory at a speed of 60 mph (other speeds will be covered in subsequent analyses). Aggressive driving

Table 1. Characteristics of Assumed Vehicle Speed-Time Profiles Under both Toll-Plaza and AVI Scenarios

Cycle Description	Maximum Acceleration Pate (mph/sec)	Length of Cycle (seconds)	Distance of Cycle (miles)	Deceleration Time in seconds (60mph to Omph)	Acceleration Time in seconds (60mph to Omph)
Toll Plaza, 'Aggressive' Driving	45	37	0.249	14	15
Toll Plaza, "Normal' Driving	2.0	66	0.517	30	30
AVI, 'Aggressive' Driving	1.0	15,31	0.249,0.517	n/a	n/a
AVI, 'Normal' Driving	0.5	15,31	0.249,0.517	n/a	n/a

includes acceleration and deceleration rates of about 4.5 mph/sec, while normal driving includes acceleration and deceleration rates of 2 mph/se-c. These rates agree with current car following and instrumented vehicle research that has substantiated acceleration and deceleration rates as high as 6 mph/sec (Cicero-Fernandez, et. al., 1993).

Two more speed-time profiles were developed for the non-toll plaza scenario. Again, one for drivers exhibiting 'aggressive' driving behavior and one for drivers exhibiting 'normal' driving behavior. In the former case, aggressive drivers 'floated' around their 60 mph target speed by 3 mph with 1 mph/sec maximum acceleration and deceleration rates. 'Non-aggressive' drivers were assumed to 'float' around their 60 mph target speed by 1 mph with 0.5 mph/sec maximum acceleration and deceleration rates. Both of these cycles were 'length corrected' so cross-comparisons could be made between all categories of driving.

A BASIC computer program was used to 'parse' cycles into discrete modes of acceleration, deceleration, cruise, and idle (see Washington, Guensler, and Sperling, 1994). The program is also used to apply the modified CALINE algorithms to estimate the CO emissions estimates from generated speed-time profiles.

All of the vehicles contained in the current Speed Correction Factor Data Base (see Guensler, 1994) were used to estimate CO emissions from a 'fleet' of vehicles passing through the toll plaza and AVI scenarios. After several outlying test results were discarded, 436 remaining vehicles were used to approximate the vehicle fleet. The appropriateness of the vehicle fleet represented will be treated in subsequent analyses.

Since the modal model can predict CO emission contributions from acceleration and deceleration events, the resulting emissions predictions reflect the effect of microscopic traffic flow adjustments under the two different scenarios. The results of the modeling runs can be seen in Table 2. The model predicts that 'aggressively' driven vehicles will emit about 52 fewer grams of CO with AVI (on average) than with a toll-plaza. The median difference is about 11 grams of CO, which suggests that the distribution of CO emissions from this fleet of vehicles is non-normal and heavily skewed by influential dirty' vehicles. The standard deviation under the same scenario, about 123 grams, illustrates the extreme influence of these high emitting vehicles.

Table 2. Carbon Monoxide Emission Prediction Differences Between Toll Plaza and AVI Scenarios.

Driving Behavior with Toll-Plaza	Driving Behavior with AVI	Mean Carbon Monoxide Difference (grams / vehicle)	Median Carbon Monoxide Difference (grams / vehicle)	Standard Deviation in Carbon Monoxide Difference (grams)
Aggressive	Normal	53.68	11.04	127.10
Aggressive	Aggressive	51.67	10.59	122.66
Normal	Normal	12.17	2.97	27.85
Normal	Aggressive	8.03	1.87	18.52

The table also illustrates that ‘ normal’ driving behavior, i.e. vehicle activity incorporating moderate acceleration and deceleration rates, results in much smaller CO emission rate differences. These findings agree with current literature that has identified high emission rates with extreme modal activity.

DISCUSSION

These findings suggest that a large reduction in CO emissions can be realized through the application of an Intelligent Transportation Technology (ITT’). This limited scenario, the replacement of conventional toll plazas on a freeway link with automatic vehicle identification technologies to debit passing vehicles, has been previously identified as an application of ITT’s with likely benefits to air quality. If we could implement this scenario for 6 months on a freeway segment for example, with an average daily traffic volume of 15,000 vehicles per lane, in approximate numbers we could expect a reduction in CO emissions from about 33 to 140 metric tons per lane. The uncertainty in these estimates, however, need to be addressed.

Although it is a significant improvement over currently employed models in terms of individual emissions estimations, the statistical model employed here still needs improvement and refinement. This research is currently underway at UC Davis.

The representativeness of the vehicles contained in the Speed Correction Factor data set are not likely to be representative of the current vehicle fleet (Guensler, 1994). There are several methods in which to approach this deficiency. Subsequent analyses will incorporate a random sampling scheme, which will provide a means to mimic actual sampling from the real-world population of vehicles (from an emissions standpoint). Furthermore, we need to test new vehicles and sample the existing fleet to determine which fleet characteristics are truly ‘representative’.

The impact of high-emitting vehicles and aggressive driving behavior is extremely important in these analyses. Subsequent analyses will address this effect, and will try to quantify the influence these vehicles and activities have on estimated emissions.

We need to look at many different implementation scenarios. Different approach speeds need to be considered, as well as different levels of congestion. In the above analyses, congestion is assumed not to exist, but practical experience shows that toll plazas are generally bottle-necks during peak periods, and we need to consider these congestion effects on emission estimates. We will address some of these issues in subsequent analyses.

Finally, we need to address the behavioral changes that might be induced by application ofITT's For example, previous peak-period congestion induced by toll-plazas, now eliminated by application of automatic tolling using AVI, might make the travel route more attractive to motorists. If this short-term increase in peak period level of service attracts 'new' motorists to the facility, then the projected emissions reductions may be partially or fully offset by increased traffic and congestion.

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USER ACCEPTANCE OF IVHS
AN UNKNOWN IN THE ENVIRONMENTAL EQUATION

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USER ACCEPTANCE OF IVHS: AN UNKNOWN IN THE ENVIRONMENTAL EQUATION

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Intelligent Vehicle Highway Systems (IVHS) have been characterized as both a boon and a bane to environmental quality (1). On the one hand, proponents see IVHS as a means to achieving a more efficient transportation system that will lead to less wasted fuel and fewer vehicle emissions. On the other hand, a fear of latent travel demandunleashed by IVHS-improved traffic flows has others doubting the long-term benefits. Still others see environmental promises being realized if IVHS is applied to manage travel demand through road pricing, modal shifting and other such measures which employ IVHS technology.

Running through this debate are assumptions, expectations, and projections about the users of IVHS technologies. These IVHS users will, by virtue of the travel behavior they exhibit, have an impact on environmental quality. Despite this fundamental linkage between users and the environment the truth is that a good picture has yet to be painted about IVHS users. Basic questions remain unanswered, such as how many people will use IVHS technologies, how will they change their travel behavior, what motivates those changes, and what are the impacts of those changes on environmental conditions?

This paper examines the role that one set of users, individual travelers, plays in the assessment of IVHS and the environment. First discussed are points of entry for IVHS in travel decisions. Next, a selection of research to date is examined for the likelihood of penetration of IVHS technology and services among traveler markets. In the final section, observations are made on implications for the marketing of IVHS among travelers and how that activity plays into the environmental equation.

IVES TECHNOLOGIES AND TRAVEL DECISIONS

IVHS has the potential to enter into travelers' decision-making at several points in the decision process. A useful framework capturing those relationships has been presented by Shaldover [2]. Figure 1 represents a modification of Shladover's framework for the purposes of this paper.

The demand for transportation arises from an individual's desire to satisfy certain needs (economic, social, recreational, etc.) that can be met at another location. In the long run an individual may reduce or eliminate the spatial separation of desired locations by such means as changing jobs or relocating his or her residence. In the near term, other factors come into play that determine whether a trip takes place and the characteristics of that trip. Travel behavior research [3] has shown that individual and household characteristics such as employment status, gender, residential location, and household structure are important determinants to number, length, and mode of trips.

While traditional travel behavior research has helped to identify the underlying structural determinants of travel demand, the application of IVHS technologies and services takes a dynamic view of tripmaking. In this view an individual has the opportunity to consciously decide whether, when, where, and how each trip is made. The technologies of communications and information processing, upon which IVHS is based, enable this constant reassessment process to take place.

IVHS technologies and services can come into play in an individual's travel decision-making in several ways. As shown in Figure 1, and described in the following section, IVHS points of entry are represented by the following boxes:

Substitution of telecommunication alternatives
Demand management policies
Pre-trip travel information
En-route travel information

The end result of the trip-making process shown in Figure 1 is a trip and, with it, all the environmental effects that trip entails. There are several potential environmental benefits of a traveler's use of IVHS services that results in a change in trip-making behavior:

IVHS-BASED TRIP-MAKING CHANGE	ENVIRONMENTAL IMPACT
avoidance of traffic congestion & stop/go traffic	improved fuel efficiency, reduced emissions
efficient routing	fewer vehicle miles of travel
elimination of trips	fewer vehicle miles of travel
increase in persons per vehicle	fewer VMT/person

This paper looks at the traveler's decision-making process, how IVHS fits into it, and reviews a selection of research to date that suggests how soon IVHS-based travel changes and their environmental impacts are likely to be realized.

USE OF IVHS IN TRAVEL DECISIONS: WHAT RESEARCH HAS SHOWN

Substitution of Telecommunication Alternatives. The first decision a potential traveler has to make is whether to travel at all. Increasingly, travelers are being offered opportunities to substitute telecommunications for trip making in overcoming the spatial separation between traveler and the desired destination. Telecommuting to work, distant learning for education, and teleshopping are some examples of how individuals can substitute the capabilities of telephones, televisions, facsimile machines, and data modems for the trip to work, school, and store.

Certainly eliminating trips altogether has the greatest positive impact on the environment. How significant an impact are telecommunication substitutions likely to have? The answer appears to be a limited amount, based on current trends. Data cited by Hopkins et al. [4] indicate that, while positively perceived by workers, telecommuting will be used by less than 5% of the labor force by 1997. Moreover, in one study they cite, even among employees who had tried telecommuting, the attrition rate was high (33%). In the Los Angeles area, a survey of workers in 1993 [51 found that while 90% took advantage of the opportunity to telecommute a few days each month, only 10% actually had been given that opportunity.

The behavior described in these studies suggests that telecommutingwill continue to have a persistent but modest effect on work trips and hence on their environmental impact. Additional impacts may be realized if telecommunication substitutions become significant for shopping, education, and leisure-time pursuits, as proponents of the Information Superhighway are envisioning. Until then, substitution of telecommunications for trips is unlikely to be very great.

Demand Management Policies. Once an individual makes the decision to travel, demand management policies represent the next opportunity for IVHS to affect travel behavior. IVHS technologies enable traffic managers to apply incentives and enforce regulations aimed at smoothing traffic flow and optimizing the transportation network. For example, technologies such as automatic vehicle identification, electronic payment, personal telecommunication devices, software and databases facilitate implementation of congestion pricing plans and programs to reduce the number of single occupancy vehicles through use of HOV lanes, ridesharing/ridematching programs, and modal shifts to transit.

Has research to date indicated how effective the application of IVHS to demand management will be in getting people to change their trip making behavior? While the literature on congestion pricing is scant, one study [6] based on data on tolls at the Golden Gate Bridge indicates that pricing can reduce traffic during peak periods. Either modal shifts occurred or travelers gave up trips altogether; the data are silent on this point. Getting people out of their single-occupant vehicle represents perhaps the greatest challenge for IVHS. One study, based on a survey of Virginia commuters, found that casual car-pooling (a.k.a. dynamic ridesharing) was projected to attract 18% of Beltway commuters, if time savings for both driver and passengers were a prerequisite. On the other hand, a test of a dynamic ridematching service in Bellevue, Washington, has found more people offering rides than accepting [7] Koppelman et al. [8] found in suburban Chicago, that direct disincentives for single occupancy vehicles need to be combined with incentives for ridesharing to produce substantial increases in ridesharing. For example, fees at employee parking lots were needed to equalize the relative attractiveness of transit and van pools with driving alone.

While these data are far from conclusive, one might speculate that IVHS-based demand management will need to rely heavily on economic signals to induce significant changes in trip-making behavior, such as time or mode changes. Ridesharing in the abstract may sound attractive to travelers, even with dynamic ridematching that IVHS enables, but observedbehavior suggests major hurdles must be overcome for it to succeed.

Pre-trip Travel Information. The third point at which IVHS enters the traveler's decision-making process is in having information available before the trip commences, or pre-trip travel information. Such Advanced Traveler Information Systems offer the traveler the opportunity to base the time, mode, destination, and route of a trip on information about the status of the transport network at a particular point in time. The technologies providing these services include the end-user devices for access (PCs with modems, televisions, telephone, personal digital assistants, kiosks, etc.); wireless and wired communication networks; the software and databases for collection and delivery of information; and a variety of sensor technology by which information is collected.

What do we know about the use of pre-trip information in changing travel behavior? A Southern California survey [9] revealed that 36.5% of commuters seek traffic information before leaving home, but of these less than 20% change their route. In New Jersey, 72% of commuters would prefer to use a potential incident information service to change route, 20% to change mode, and 8% to change time of departure [10]. In Washington State, 75% of surveyed commuters showed a willingness to use information to make changes in their commute [11]. However, even among those willing to make a change, few would change modes.

Results from the single actual field test of a traveler information service, the fifteen-month test of Boston's SmarTraveler service [12], paint a more conservative picture for pre-trip information services than the other studies might suggest. Overall usage was low relative to the total Boston market that had access to the service. Noticeable peaks in usage did occur during severe weather conditions, when traffic conditions were at their worst. Travelers who used the service said they made changes to their trip in 29% of the cases, with change in departure time and using a different route the most frequent types of changes. Canceling a trip altogether and switching modes were much less common, 2.2% and 1.0% respectively.

To have significant beneficial environmental results, many travelers will need to make use of pre-trip information. Surveys indicate that travelers are interested in taking advantage of such information and make changes in trip decisions. As yet, modal shifts are unlikely to occur based on information services alone. Moreover, to achieve significant penetration pre-trip information services may need to be provided at no charge. In New Jersey and in Boston, interest in the service dropped dramatically as prices were introduced.

<u>En Route Travel Information</u>. The final stage of trip decision-making where IVHS comes into play is en route. En route travel information allows a traveler to alter a trip once it has commenced. Technologies similar to pretrip travel information services are used, with the exception that communications tend to be wireless. Also, in-vehicle navigation units and routing systems track a traveler's progress through the transportation network and provide real-time route guidance.

What do we know about the potential usage of such systems? Results from a couple studies are available. Among cellular network subscribers in Boston, the SmartTraveler service cited earlier [121 was used in much higher proportion than among land-line subscribers, suggesting a greater perceived value for en-route usage. In the TravTek trial in Orlando, Florida, drivers experienced a perceived and actual travel time savings with the route guidance system [13, 14]. Moreover, drivers thought the system helped them drive more safely.

These positive findings suggest that en route information will be well received in the market, assuming that price and other factors are satisfactory to travelers. As the experience to date has been with in-vehicle devices, the potential for modes other than a traveler's own vehicle is not known. Besides the benefits of reduced time and stress for the traveler, potential environmental benefits may be achieved by avoiding traffic tie-ups and more efficient routing.

OBSERVATIONS ON THE RESEARCH AND CONCLUSIONS

The environmental benefits of IVHS depend in large part on the decisions that individual travelers will make regarding their trips and the use of IVHS in those trips. The studies cited in this paper indicate that the penetration of most IVHS technologies and services among travelers in general may be low for quite some time. To achieve greater user acceptance, aggressive market promotion will need to be undertaken, but it will need to be based on users' perceptions of the real benefits they can obtain. However, there is reason for optimism, since greater potential for penetration may exist within certain segments. Some of the studies revealed correlations among demographic or other characteristics of the traveler [e.g., 8, 9, 10, 111, such as gender, income, attitudes about independence, or length of commute. A successful marketing approach would seek to identify these segments, develop technologies and services that meet their needs, and institute an effective campaign for winning their acceptance of IVHS services. Such an approach might well be more effective in seeing that IVHS is part of the travel decision making process for those travelers where it can make a difference. The result will be a greater likelihood that the environmental benefits of IVHS can be achieved.

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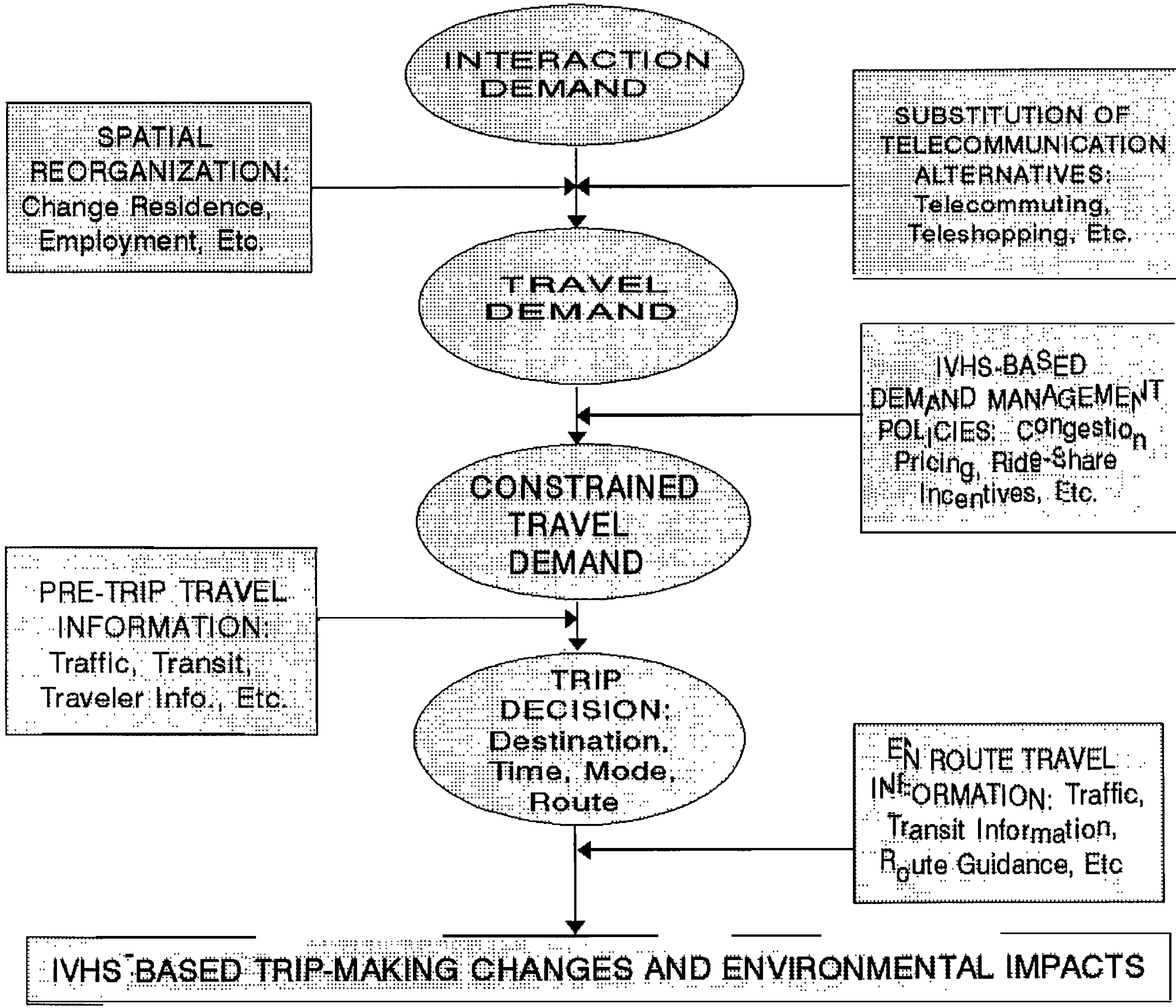
FIGURE 1. IVHS IN THE TRAVEL DECISION-MAKING PROCESS



Based on Shlacover, 19∞ [2].

Evaluating the Impact of IVHS Technologies on Vehicle Emissions using a Modal Emission Model

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ABSTRACT

One of the key goals of Intelligent Vehicle/Highway Systems (IVHS) is to improve mobility through the reduction of traffic congestion and increased throughput on today's road network. As congestion decreases and traffic flow is smoothed, associated air quality should improve. However, roadways with improved mobility and better throughput may induce an increase in traffic, resulting in a negative air quality benefit. In order to determine the impact of IVHS on air quality, models must be developed that can: 1) accurately predict vehicle emissions reductions due to smoother traffic flow; and 2) predict the induced demand for roadways when their throughput is increased due to M-IS. We are currently developing and applying a set of transportation/emission models in addressing this first issue. Current emission inventory models (e.g. MOBILE, EMFAC) simply relate vehicle emissions to average traffic densities and speeds on a specific network, and are not adequate for analyzing traffic at the microscale level required for M-IS evaluation. However, by using transportation simulation models that can accurately simulate dynamic vehicle activities (e.g., accelerations, decelerations) and integrating this information with detailed modal emissions models, precise emissions inventories for various IVHS scenarios can be achieved. Using a power demand-based modal emission model, we are currently evaluating total vehicle emissions associated with Automated Highway System (AHS) designs. Preliminary results indicate that with AHS's approximate four-fold increase of capacity, emissions will increase over current manual conditions by a factor of two if the system **is** used at full capacity (-8000 vehicles/hour-lane), stay the same at half capacity (-4000 vehicles/hour-lane), and **will** decrease by half at current traffic volumes (-2000 vehicles/hour-lane).

INTRODUCTION

Two central research questions pertaining to air quality exist for IVHS: Potential vehicle emission reductions through the application of advanced technology, and potential induced traffic demand.

Potential Vehicle Emission Reductions-IVHS has the potential to reduce vehicle emissions through several of its "technological bundles'* (see, for example, [l] for an IVHS overview). Advanced Vehicle Control Systems (AVCS) implemented at the vehicle level are intended to safely smooth traffic flow on the roadways by minimizing the stop-and-go effect of vehicles in congestion, and increase overall throughput. The heavy acceleration and deceleration components of vehicle trips can be eliminated, minimizing energy consumption and associated emissions of these vehicle operating modes. Advanced Traffic Management / Information Systems (ATMJS) will allow dynamic re-routing to take place on the roadway network, minimizing congestion and subsequently emissions. Further, navigational systems will allow users to reduce unnecessary driving and will aid in trip-chaining practices [2].

Potential Induced Traffic Demand-In contrast, the implementation of some IVHS technologies may lead to an increase of total vehicle miles traveled (VMT). If IVHS allows smoother flow and higher speeds on the roadways, people may choose to live farther away from work while still commuting in the same amount of time-thereby increasing VMT. Farther, attractive trip-ends will become reachable, again increasing VMT. Further, advanced navigational technology may divert travelers from higher-occupancy modes such as buses and carpools to single-occupant vehicles. In general, if travel becomes easier due to advanced technology, VMT will likely increase.

In order to determine the impact of NHS on air quality, significant improvements must be made in traffic simulation and travel demand models by closely integrating vehicle emission models. Existing traffic, emissions, and planning models have been developed independently of each other and are diffkult to integrate together when determining accurate air quality impacts. Current emission models (i.e., MOBILE, BMFAC [3]) functionally relate emissions to average vehicle speed and density, and are not appropriate for analyzing IVHS scenarios. Under IVHS conditions, the dynamic behavior of vehicles will be very different compared to today's traffic conditions, upon which the current emissions models are based. As a result, modal ***emissions data*** (i.e., emissions data associated with vehicle modes, e.g., idle, acceleration, cruise, deceleration, etc.) should be used with microscale traffic simulations to obtain more realistic results.

In this paper, a power demand-based vehicle emissions modeling approach is first described, followed by a discussion of its application to evaluate emissions associated with automated highway system designs.

POWER DEMAND-BASED VEHICLE EMISSIONS MODELING

Second-by-second emissions data that are registered with vehicle dynamic operation are often referred to as *modal emissions data*—emissions data that correspond to a vehicle's operating mode, e.g., acceleration, deceleration, steady state cruise, idle, etc. Using modal data in an emissions model is in sharp contrast to the current driving cycle-based emission inventory techniques (i.e., the Federal Test Procedure, FTP [4]), where emissions are collected in bags over long periods of time (on the order of 500 seconds), and then analyzed as a whole.

Second-by-second emissions data can be combined with an analytical model of the instantaneous power requirements placed on a vehicle's engine. A vehicle's acceleration performance (in the longitudinal direction) is limited by the engine power and the traction limits on the drive wheels. Given the instantaneous power requirements placed on a vehicle (at the wheels) for it to move depend on three types of factors: 1) *Environmental factors* (e.g., mass density of air, road grade), 2) *Static vehicle parameters* (e.g., vehicle mass, rolling resistance coefficient, aerodynamic drag coefficient, cross sectional area), and 3) *Dynamic vehicle parameters* (e.g., commanded acceleration, and velocity). Given these parameters, it is possible to first determine the demanded tractive power, as shown in figure 1. Further, the power demand on the engine can be determined by modeling the power transfer through the vehicle's drive system and incorporating other variables such as use of accessories (e.g., air conditioning, power steering).

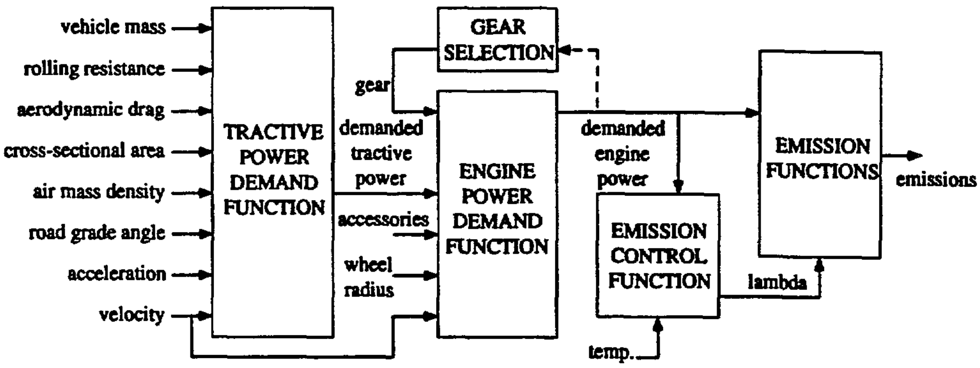

Figure 1. Load-based modal emissions modeling methodology.

One of the most important aspects of this power demand-based method for estimating emission output is modeling the vehicle's emission control system. Modern vehicles have complex emission control systems that include as the primary component a catalytic converter. An electronic engine controller regulates the air-fuel ratio to the engine so that the ratio is as near as possible to the stoichiometric ratio where the catalytic converter operates most efficiently. During normal operation of the vehicle, the air-fuel ratio is kept at the stoichiometric ratio (lambda = 1). However, there can be cases when the conversion efficiency of the emission control system is reduced. One example is during cold-start events, when the catalytic converter is not at its proper operating temperature and thus is not operating at its peak performance. Another important example includes power enrichment events. When a vehicle has a high engine power demand (which may be induced by a hard acceleration or steep grade), it has been shown that the emission control system can go "open-loop" and the air-fuel ratio is commanded rich for peak demand power and protection of engine components. Recent studies have shown that power enrichment events can contribute significantly to overall emission production (e.g., [5, 6, 7]). As a first approximation to modeling power enrichment events, a simple thresholding technique is used. When the demanded engine power exceeds a particular threshold, the emission control system goes into an open-loop state, and the air-fuel ratio is rich, producing significant emissions. When the demanded power is below that threshold, the system maintains the air-fuel ratio at stoichiometry, resulting in low emissions. The emission output of carbon monoxide (CO), hydrocarbons (HC), and oxides of nitrogen (NOx) can be measured and correlated to demanded engine power induced under numerous operating conditions. The emission output can then be approximated by a function that relates emission species output to demanded power.

For use in our traffic simulations, the vehicle dynamics equations and load-based emissions were calibrated to a 1991 Ford Taurus, using data received from Ford Motor Company. As further modal emission data becomes available for other vehicles from Ford and other sources, they can easily be incorporated into this type of model when determining a more complete, comprehensive emission inventory.

AUTOMATED HIGHWAY SYSTEMS

IVHS technology in the form of AVCS can be applied to control vehicle motion so that vehicles can operate in "platoons", i.e., follow each other very closely at high speeds, while still maintaining a high safety margin. This has several implications: 1) traffic flow will increase dramatically over current highway conditions due to denser traffic traveling at higher speeds; 2) congestion should decrease since the stop-and-go effect caused by relatively long human reaction delays will be eliminated and accidents will be minimized.

Current highway traffic (i.e., uninterrupted traffic flow) can be characterized by the traffic volume (v), average vehicle speed (S), and vehicle density (D). These terms are generally related by the product $v = S \times D$ [8]. Further constraints operate on these parameters which restrict the type of flow conditions on a highway link. The general form of these constraints is shown in figure 2, which illustrates some key points of uninterrupted traffic flow:

- Zero rate of flow occurs in two distinct cases: 1) when there are no vehicles on the roadway, and 2) when the density is so high that all vehicles are stopped and can not move. In the first case, the density is zero, thus the flow rate is zero, and the speed in this case is assumed to be the driver's desired speed (i.e., vehicle free speed). In the second case the density is at its maximum and the vehicle speed is zero. The density at which this occurs is called the jam density.

- As density increases from zero, the traffic flow increases due to the increased number of vehicles. The average vehicle speed is reduced to maintain safety during higher density conditions.

- Traffic flow is maximized at a specific critical density. As density increases above the critical density point, speed drops off at a faster rate. Traffic flow tends to become unstable in this region due to perturbations from lane change maneuvers, merging, or any external variables (e.g., debris in roadway, accident in adjoining roadway, etc.). These perturbations can create disturbances that are not damped or dissipated in the flow. These unstable, forced flow regions in the curves are characterized by stop-and-go congestion.

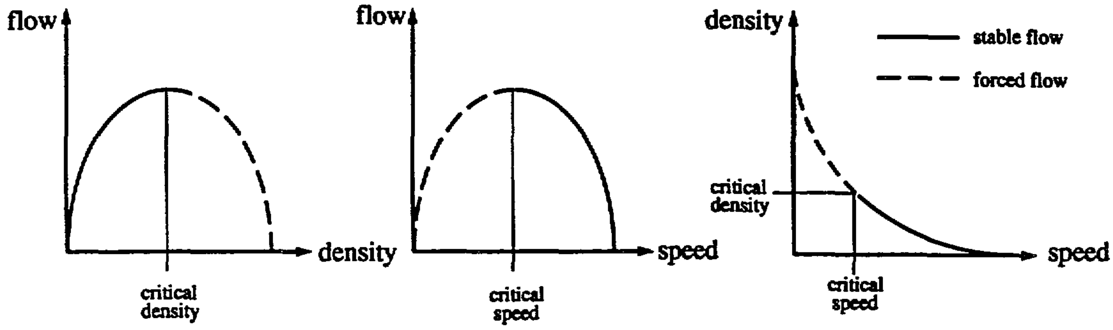

Figure 2. Flow, density, and speed relationship of traffic flow.

Human driver flow-density-speed relationships can be approximated mathematically by specifying the headway, or gap, between vehicles required for safe stopping if one car suddenly brakes, and after a time lag, the second car also brakes without collision. The lower flow-density curve in figure 3 was produced for the case when the first car brakes at 0.9 g (8.82 meters/second^2) and the second car brakes at 0.6 g (5.88 meters/second^2) after a one second time lag. This curve (after [9]) is for a single lane and is similar to curves predicted by the Highway Capacity Manual [8].

A similar mathematical formulation can be developed for the flow-density-speed characteristics of an automated highway system. Within a platoon of vehicles, the headways are much smaller, closely regulated by automated controls. Therefore, platooned vehicles can travel faster at higher densities, thus improving the traffic throughput. Again, if we consider a single lane of platooned traffic as shown in figure 4, we can mathematically approximate the flow-density-speed characteristics.

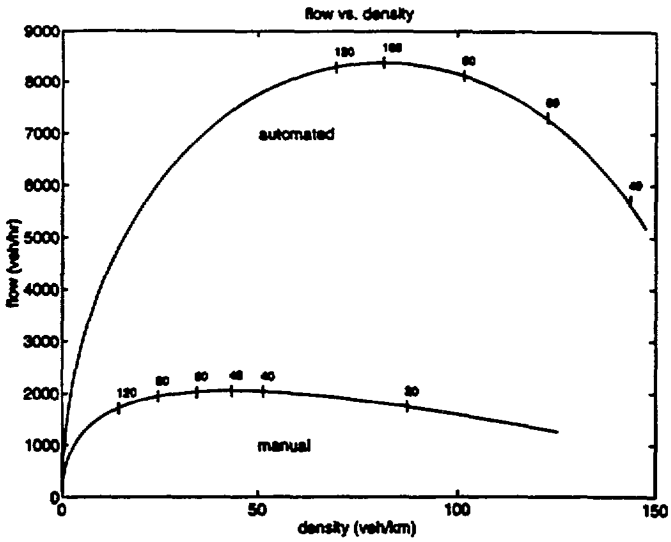

Figure 3. Flow-density relationship of traffic for both manual driving and automated driving. Velocity values (km/hr) are annotated on the curve.

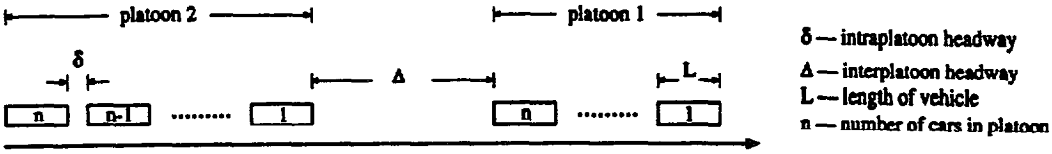

Figure 4. Platoons of vehicles on a highway.

Using the notation given in figure 4, the vehicle density for an automated lane is given as: $D = \frac{n}{\Delta + n(L+\delta) - \delta}$

The interplatoon headway is determined as before, i.e., requiring safe stops if one platoon suddenly brakes, and after a time lag, the second platoon (leader) also brakes. In the automated scenario, the time lag is much shorter than for human behavior. The upper flow-density curve in figure 3 was produced for the more restrictive case when the first platoon brakes at 2 g (19.6 meters/second^2), and after a 0.3 second time lag, the second platoon (leader) brakes at 0.3 g (2.94 meters/second^2). It is assumed that the intraplatoon headway is precisely controlled and can also perform safe stops under these specified stopping conditions. In the mathematical formulation, the intraplatoon spacing is set to one meter, the car length is five meters, the number of vehicles in each platoon is 20 vehicles, and the vehicle free speed is 120 km/hr. The difference between these two curves is substantial. The maximum traffic flow for the automated case is roughly four times that of the manual driving case. The maximum flow for the automated case occurs at an average speed of 103 km/hr, and for the manual case it occurs at 48 km/hr.

STEADY-STATE VEHICLE EMISSIONS

Emissions produced by traffic (manual or automated) will depend on several factors. In general, large variations in velocity (i.e., numerous acceleration, deceleration events) lead to higher emissions, therefore to minimize total emissions, traffic should be kept as smooth as possible. In this preliminary analysis, we only consider steady-state vehicle speeds and the associated emissions.

Using the power-demand emissions model described above, several microscale platoon simulations were carried out to determine average emission rates at different steady-state velocities. The motion parameters, engine power demand, and associated emission rates were calculated for each modeled vehicle in the simulation. Because the follower vehicles within a platoon have very small intraplatoon headways (e.g., on the order of one meter), the aerodynamic drag coefficient of each follower is significantly reduced due to the "drafting effect". Using preliminary aerodynamic drag reduction data for vehicles in platoons [10], the calculated power demand on the engine is significantly smaller at higher speeds. Based on the data, even the lead vehicle of a platoon has its aerodynamic drag coefficient reduced due to the vehicle following closely behind. A comparison between constant velocity CO emission rates* for 20 vehicles that are platooned and non-platooned is shown in figure 5. In both cases the traffic density is low, and the vehicles are traveling near their free speeds. It is apparent that 20 vehicles traveling independently with no interaction have greater emissions at higher velocities than platooned vehicles that benefit from the drafting effect.

In order to determine total steady-state emissions of an automated lane within an AHS, these emission data were applied to the flow-density curves shown in figure 3. It is important to note that the curves in figure 3 reflect traffic density and flow associated with specified safe headways. Thus to generate flow values at lower densities, vehicle speeds greater than the free speed (i.e., the maximum speed a driver will go on the freeway without interference from other traffic) were used in the calculations. For purposes of generating total link emissions at lower densities, the flow values were adjusted so that the vehicle velocities at low densities were at the constant free speed.

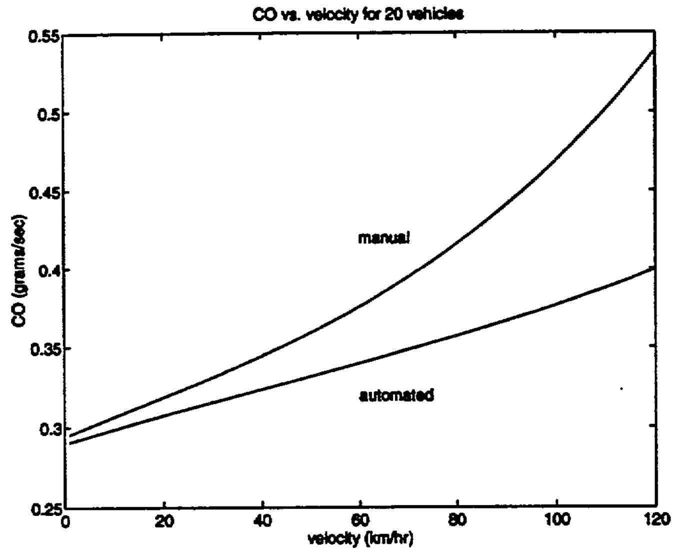

Figure 5. Constant velocity carbon monoxide emission rates for 20 vehicles platooned and non-platooned.

The total CO emissions for a one kilometer lane are shown as a function of traffic flow for both the manual and automated (platooning) cases in figure 6. There are several key points to note in this figure:

1) The maximum traffic flow for a manual lane is 2053 vehicles/hour at a average vehicle speed of 48 km/hour. At the same traffic volume, the automated lane produces roughly *half* as much emissions as in the manual case (manual: 0.76 grams/second, automated: 0.34 grams/second).

2) Given the emissions rate for maximum manual traffic volume of 0.76 grams/second, roughly *twice* the traffic volume can occur in the automated lane to produce the same amount of emissions (manual: 2053 vehicles/hour, automated: 4565 vehicles/hour at 0.76 grams/sec).

3) The maximum traffic flow for an automated lane is 8286 vehicles/hour at an average speed of 103 km/hour. The associated emissions at this point is roughly *twice* that of the maximum flow rate of manual driving.

It is important to point out that the emissions associated with higher traffic densities and lower average speeds are underestimated in these curves. Remember that these emissions are calculated based on steady-state velocities, and the

* Results of hydrocarbon (HC) and oxides of nitrogen (NOx) emissions also were obtained for all the experiments and are similar in shape to the CO emissions and are not presented here due to limitations in space.

negative slope region of the flow-density curve is inherently unstable, leading to stopand-go traffic. The accelerations associated with stop-and-go traffic will lead to a greater amount of emissions,

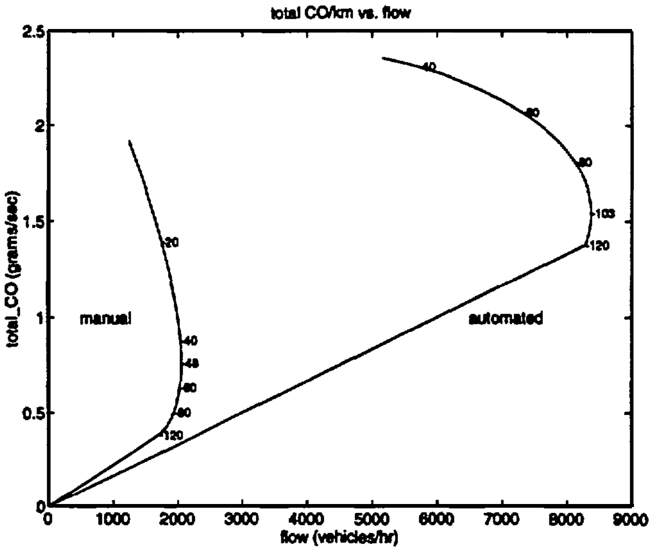

Figure 6. Total CO emissions versus traffic flow for manual and automated traffic for a one kilometer lane.

CONCLUSIONS

Based on microscale simulation models and modal emissions data for a modem, closed-loop emission controlled vehicle, steady-state (i.e., constant velocity) emission rates have been estimated for both manual and automated lanes. An automated lane using platooning can improve the traffic flow by a factor of four, and at maximum flow values, the total emissions increase is by a factor of two. If only half of the automated lane capacity is used, the traffic flow improves by a factor of two, and the associated emission rates are roughly the same as the full-capacity manual case. If the automated lane carries the same traffic volume as in the manual case, the emissions are reduced by a factor of two.

This analysis ignored transient emissions, i.e., emissions due to accelerations and decelerations associated with unstable traffic flow. We are currently using our models to predict the emissions associated with stop-and-go traffic in the unstable traffic flow-density regions. If congestion is to be avoided, the traffic should be kept in the positive slope region of the flow-density curve (see figure 3). When in the positive slope region, interaction between vehicles in traffic is minimal, leading to smoother traffic flow. It can be seen that the extent of the positive slope region is much greater for the automated lane when compared to the manual lane.

This analysis assumed a constant platoon size of 20 vehicles, however, platoons will vary in length due to vehicles dynamically entering and leaving platoons as they travel from their specific origins to destinations. Shorter length platoons will lead to lower automated lane capacities and higher average vehicle emissions. Also, emissions associated with platoon maneuvers such as ***splitting*** and ***merging*** have not been analyzed here, but is currently under investigation.

Finally, the emission rates used in this analysis were for a single vehicle. For current manual driving, the vehicle population is quite varied, and to more accurately predict total emissions, emission rates for different vehicle classes must be incorporated. For an automated scenario, however, the vehicle population will be somewhat more restricted. Vehicles that have automated platoon technology will tend to be. newer passenger vehicles with closed-loop emission control systems, similar to the vehicle modeled here.

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III.

Socio-Economic and Institutional Issues

SOCIO-ECONOMIC ISSUES AND INTELLIGENT TRANSPORTATION SYSTEMS

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INTRODUCTION

The transportation system is an integral part of the societal - economic system of every group of people on earth. It is through transportation that people gain access to the things they need to do to be functioning members of society. While other means of access (e.g., tele-commuting, tele-conferencing, television shopping) are developing and will become more common in the future, the need for transportation will remain dominant for any planning horizon that we can conceive. To plan a transportation system without explicit inclusion of the societal and economic factors that affect and are affected by transportation would be unwise.

In tbe United States as we have planned and implemented transportation systems over the last 200 years, precedence has been given to the technological factors of importance. Those rail transit systems that we have are functional; our Interstate Highway System is excellent; and our vehicles compete in the world market. In planning and executing the provision of transportation services, we have focused on the technology and all too often have not addressed the larger social issues. As we laid rail track across the country and built highways that would divide neighborhoods, we did not ask the local people what they thought of these innovations. With rare exceptions, the voices of individuals were not heard in the transportation planning process. (Weiner 1992). In the 1960s and 1970s, the building of the Interstate Highway System began to be questioned by people who would be most negatively affected by it. Many would lose their homes or their neighborhoods. Their concerns began to be addressed through such forums as the Boston Transportation Planning Review in which citizens participated in the planning process through public meetings. Academics began looking at ways to incorporate societal concerns explicitly in the planning process. (Richardson 1973).

Even with these efforts, major time and cost delays occurred in the completion of the Interstate

System. We reached the point of enormous expenditures per mile of construction of roads in our urban areas – time and expenses that could have been markedly less had major societal and economic issues been addressed early in the process. Not only is it important to address societal and economic issues for what we may consider as altruistic reasons, but it is also important to do so because it is good business. (See Underwood and Streff 1992 for a discussion of the items that need to be considered in evaluating Intelligent Vehicle-Highway System (IVHS) technologies.) It will save time and money in the long run and produce a product that will better serve society. Noting, in 1972, how important it was to address societal issues in their business planning process, the Business Environment Studies component in General Electric noted "Without a proper business response, the societal expectations of today become the political issues of tomorrow, legislated requirements the next day, and litigation the day after." (Wilson 1985)

PURPOSE OF THIS PAPER

The goal of this paper is to raise for discussion the concept that it is more cost-effective and less expensive for both the public and private participants in the Intelligent Transportation Systems community to start planning and implementing intelligent transportation systems with societal and economic issues included in the planning process from the very beginning. There are several objectives that support this goal. These are:

1) to explain transportation systems as part of the larger social / economic / political / environmental system;

2) to identify many of the societal and economic factors that impact or are impacted by transportation systems;

3) to present "forecasts" of several of these factors; and

4) to suggest ways of analytically incorporating these factors into the planning process.

METHOD AND DATA

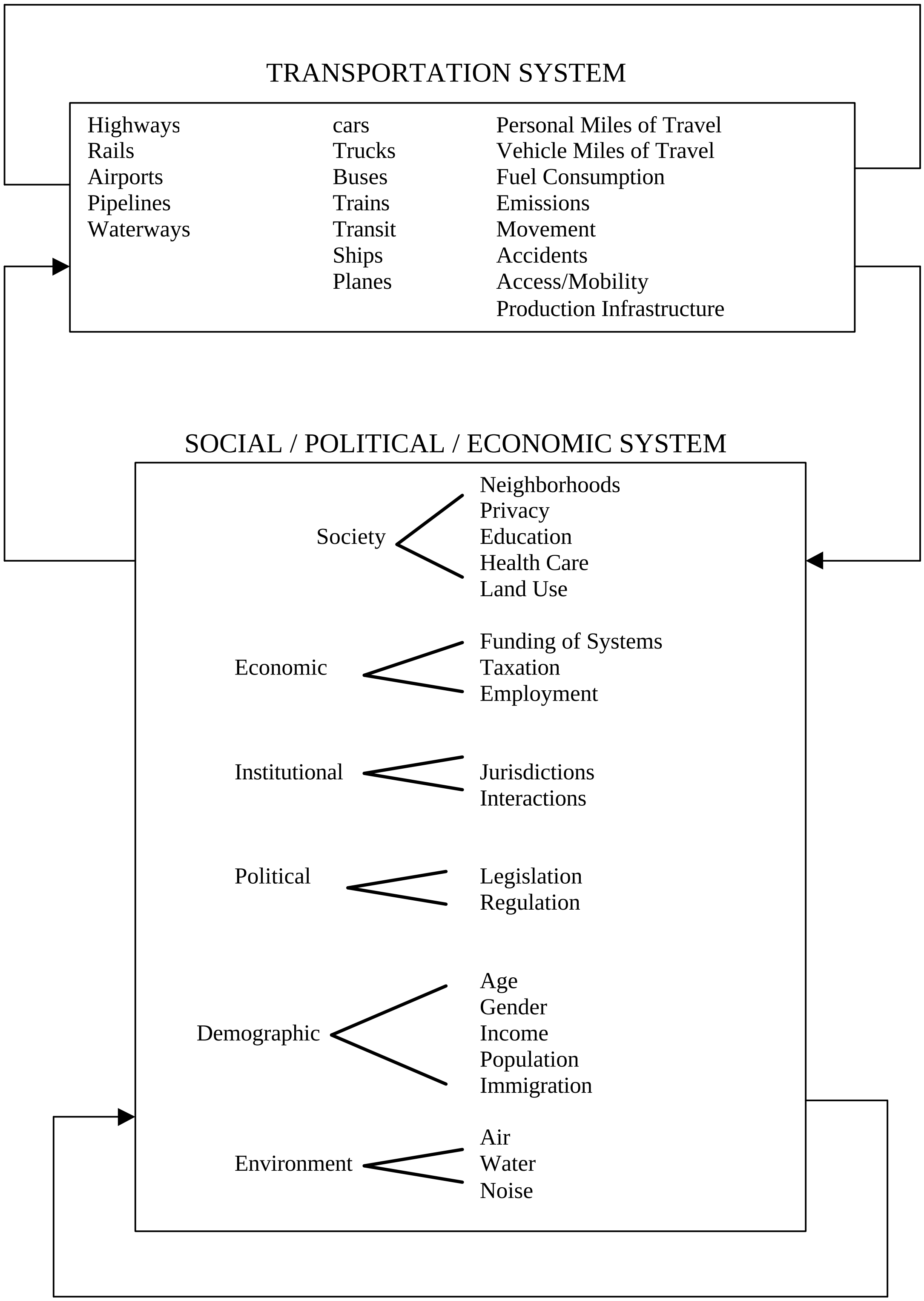
The analysis presented in this paper is supported by several sources of data. It draws together forecasts of the Bureau of the Census, experts in traffic safety, and key representatives of the automotive and supplier industries. In addition, it draws on some of the organizational methodology of influence diagrams and scenario development. Because of restrictions on the development of this paper, it was not possible to fully implement any of these methods or others that are available. Rather, the paper represents an introduction to the challenges ahead coupled with suggestions on how to address them.

TRANSPORTATION AS AN INTEGRAL PART OF THE SOCIO-ECONOMIC SYSTEM

In any discussion of a transportation system -- intelligent or otherwise – it is useful to begin with a placement of it in the larger social system. The transportation system is not a stand-alone system and caunot be studied in isolation. Economists refer to the demand for transportation as a derived demand. By this is meant that there is practically no demand for transportation in and of itself. With the exceptions of those of us who like to drive cars, fly planes, or ride in buses or trains (thrill seekers, those enchanted by movement, machines, or the lure of the sky or road), we use transportation for the purpose of meeting some other need – that of getting to some place of business, social, educational, shopping, or other activity.

The social / economic activity system – employment, housing, schooling, health care, shopping, socializing, etc. – has a vibrant life with its own changes and interactions. The transportation system is planned and built by a combination of public and private enterprise and, to some extent, changes through the impetus of those responsible for planning and implementing such systems. In addition, the transportation system is affected by changes in the social / economic system and, in turn, the availability of transportation directly affects the function of the social / economic system. For example, a rural community begins; roads are built to the area; industry relocates because of transportation availability; housing is built to house workers and their families; schools and shopping centers are built to serve those families; more roads are built to accommodate the growing commercial and personal travel; and so on. Figure 1 illustrates the relationship of the transportation

FIGURE 1 - INTERACTIONS OF THE TRANSPORTATION SYSTEM
WITH THE SOCIAL / POLITICAL / ECONOMIC SYSTEM



system and the larger social / economic / political system. It lists just a few of the social, economic, political, and other factors that interact with the transportation system such as neighborhoods, privacy, taxation, employment, regulation, age, gender, and immigration. Note in the figure that the two systems change as a result of activity within themselves (including the actions of planners and engineers responsible for transportation systems) and that each changes as a result of the activity in the other.

Waller (1994), Sobey (1990), and others have suggested many of the societal and economic factors that might be of relevance in the planning of a transportation system. Table 1 lists some sixty-one of them. This list is not meant to be exhaustive, but rather a glimpse into some of the complexity and challenges that exist in implementing transportation systems.

As growth of social / economic and transportation systems continues, there are major benefits that are experienced including economic prosperity, better access for some members of society to life's necessities, etc. At the same time, there may be many negative consequences of growth including air, noise, and water pollution, the deterioration of inner cities, the loss of open laud, congestion in cities and in the residential and commercial areas surrounding them. There are many other social indicators such as increasing crime rate, lack of access to health care for people living in the inner cities, increase in the teen birth rate, increase in drug use, inability of inner city residents to get to employment in suburban areas, destruction of urban neighborhoods, a tearing of the social fabric, benefits for the haves and costs for the have-nots, health effects from air pollution accompanied by a decrease in the quality of life for those who live in smog-enclosed areas, an inability to swim in or drink polluted waters, etc. It is not clear that there is a direct relationship between transportation services and these conditions, but they cannot simply be written off when planning a new type of transportation system. Consideration of them can be made by use of any of several analytical methods, some of which are listed below.

SOCIETAL AND ECONOMIC FACTORS AFFECTING AND AFFECTED BY TRANSPORTATION

There are many societal and economic factors that affect transportation systems and/or are affected by

Table 1

A POTPOURRI OF SOCIETAL AND ECONOMIC FACTORS

Access of disadvantaged groups such as the poor, the young, the aged, and the physically disadvantaged

Access to employment	Isolation of population in rural or urban areas
Access to education	Land use
Access to health care	Legal issues
Access to housing	Jurisdictional issues
Access to shopping	Market forces
Affordability	Minorities
Air pollution	Modal choice
Availability of food and energy	Movement of goods
Crime	Neighboorhocd viability
Competing social goals	Noise pollution
Congestion	Non-users of transportation system
Consensus process	Quality of life
Cross-organizational cooperation	Participation in society
Cyclists	Privacy
Day care	Product and tort liability
Defense industry refocus	public / private interactions
Demographics	F&creation
Economic growth	Regulation
Economic stabiity	Retail sales
Education	safety
Employment availability	security
English as a second language	Societal attitudes
Equity	Tele-commuting
Funding - privately	Teleconferencing
Funding - publicly	Transit availability and use
Gender	Truckers
Health care availability	Unemployment
Immigration	Vehicle ownership
Income	Water pollution
Intermodal transfers	Who pays / who benefits

them. Several efforts have been made to identify these, although not specifically for the purposes of intelligent transportation systems planning. The Bureau of the Census provides demographic forecasts for several years into the future. A set of symposia on critical issues in traffic safety in the year 2010 provides another source of "forecasts". A third source of data is a Delphi study of the future of factors related to the automotive industry. Data from each of these are presented below.

Census Forecasts

It is useful for planning purposes to look at the current population level and composition and Census estimates for the future. Table 2 lists 1995 population estimates for the United States for men and women, disaggregated into those greater than or equal to 16 years of age and those greater than or equal to 65 years of age. This breakdown gives us the numbers of people who are eligible to have drivers' licenses and those who are in the pool to be elderly drivers. Total U.S. population is also included, as is the ratio of women to men and the percent of the population (disaggregated by gender) that is elderly (greater than or equal to 65).

Tables 3 and 4 provide the same information for the years 2005 and 2050. The data for 2005 are a base for a relatively near-term planning forecast, while the 2050 data give us a view of time when most of us will be either very old or no longer alive. Even though we may not be able to reap the benefits of our planning ourselves, perhaps our great-grandchildren will. Of note are the increasing numbers of the population, the elderly (both men and women), with the population of older men increasing at a higher rate than that of older women. Note that by 2005, almost 13% of the population will be elderly, with about 1.5 million more elderly women and about 1.8 million more elderly men than in 1995. By 2050, 20% of the population will be over 64 years of age. This has direct implications for both time horizons for access to societal activities, ergonomic design of vehicles, safety, intermodalism, etc.

Critical Transportation Issues

When traffic safety experts convened in 1992 under the sponsorship of American Iron and Steel Institute and The University of Michigan Transportation Research Institute to identify critical issues in traffk safety in 2010, they hypothesized what the future would hold in terms of driver behavior,

Table 2 - CENSUS FORECASTS - 1995
US Population (Thousands)

AGE	TOTAL POPULATION	MALES	FEMALES	FEMALE/ MALE
$16	201,543	96,964	104,579	1.08
$65	33,649	13,699	19,950	1.46

Total Population	263,434
Elderly Males/Tot. Pop	0.052
Elderly Females/Tot. Pop	0.076
Elderly People/Tot. Pop	0.128

Table 3 - CENSUS FORECASTS - 2005
US Population (Thousands)

AGE	TOTAL POPULATION	MALES	FEMALES	FEMALE/ MALE
$16	223,469	107,880	115,589	1.07
$65	36,970	15,534	21,436	1.38

Total Population	288,286
Elderly Males/Tot. Pop	0.054
Elderly Females/Tot. Pop	0.074
Elderly People/Tot. Pop	0.128

Table 4 - CENSUS FORECASTS - 2050
US Population (Thousands)

AGE	TOTAL POPULATION	MALES	FEMALES	FEMALE/ MALE
$16	310,626	150,350	160,275	1.07
$65	80,109	36,092	44,016	1.22

Total Population	392,031
Elderly Males/Tot. Pop	0.092
Elderly Females/Tot. Pop	0.112
Elderly People/Tot. Pop	0.204

Source U.S. Bureau of the Census (1992)

vehicle occupants, vehicles, and the highway environment. (Richardson 1993) They suggested (but did not agree on) the following scenario:

"Drivers will:

- continue to drive drunk and drugged
- continue to want personal transportation, greater speed, and perhaps more vehicles per person
- include more older, female, immigrant, and minority people
- demand different types of vehicles from now, e.g., vans vs. muscle cars
- expect that the vehicle and the highway infrastructure should protect them in the event of a crash
- demand more socially responsible vehicles
- not change their attitudes about vehicles
- not buy safety for safety's sake
- change their driving patterns because of working at home, living in rural work communities, use of alternative vehicles such as motorcycles and bicycles, and changes in the types of vehicles available.

Vehicle occupants will:

- change in terms of their size, physical condition, demographics, out-of-position locations in the vehicle, and ergonomic requirements
- have more disabling injuries in relation to fatalities
- have high medical costs due to injuries.

Vehicles will:

- have greater differences and incompatibilities among them technologically because of the aging of the fleet
- contain new technology such as intelligent vehicle highway systems (IVHS) or alternative fuels with uncertain safety impacts
- be subject to different regulations such as stricter Corporate Average Fuel Economy (CAFE) standards

- be designed for ease of assembly, disassembly, recyclability
- contain light-weight materials such as composites and aluminum
- have airbags front, rear, and side; obstacle detection systems; ABS; speed control; enhanced vision systems
- have higher prices due to the built-in expense of vehicle manufacturer employee health care coverage.

The highway environment will:

- contain more vehicles of various sizes and technologies
- not increase significantly in terms of new miles of highway built
- have more travel and congestion
- deteriorate due to poor maintenance of the infrastructure
- not safely accommodate drunk and drugged drivers
- have more hazardous materials carried on them.

Given these future characteristics, tradeoffs will exist between:

- safety and other vehicle design goals
- safety and other public goals
- safety and mobility
- infrastructure maintenance and other goals
- police resources for enforcement of speed, alcohol use, and other safety factors vs. other crime needs
- impairment detection and willingness to pay.

Further, without concerted thinking, planning, and implementation, <u>no one</u> will:

- provide coordination among the plethora of data bases available, e.g., police data bases and medical facility data bases
- reduce or eliminate actions on the part of politicians, the media, and industry (particularly alcohol) that are potentially counterproductive to efforts to promote safety

- provide effective integration of transportation into the larger society, e.g., locations of places of employment, shopping, alcohol-licensed establishments
- modify product and tort liability legislation so as to enable the development of new products and practices to facilitate the efficiency of the transportation system and to enhance safety
- coordinate and facilitate the intermodal transfer of both people and goods
- coordinate the efforts of local, state, and federal governments and other organizations in improving safety
- control the growth of medical costs through preventive measures, including primary, secondary, and tertiary prevention."

Although traffic safety was the area of focus for this scenario, the symposia participants are also experts in the broader field of transportation, and their insights can be applied directly to the situation surrounding the planning and implementation of intelligent transportation systems. For example, drivers will have similar attitudes pertaining to their transportation, whether planners are thinking of safety or IVHS. Therefore, it can be anticipated that drivers will expect that they will be taken care of by forgiving vehicles and environments; have different driving patterns; and not voluntarily curtail their drinking and driving. These drivers will be carrying passengers who will be different from today's passengers in terms of size, age, physical condition, demographics, and ergonomic requirements. Vehicle occupants will be older, more likely female, and larger and smaller than they are today. Vehicles are expected by this group to offer new technology and therefore be in potential conflict on the roadway with older, not so well equipped vehicles; have more safety equipment; and cost more than they do today. At the same time, it is expected that the roadway infrastructure will deteriorate. All this will occur in a time of a lack of cooperation across organizational entities. The warning is given by this group of experts that it is now past time to consider how to address many of the societal issues that come to bear on the transportation system and to coordinate transportation planning and implementation activities across organizational boundaries. In fact, of the over fifty issues identified by this group of experts as being important in traffic safety in 2010, the vast majority of them had to do with the people and institutional aspects of the transportation system rather than the technological ones.

Some of these same societal and economic issues are raised by Pisarski (1994). He indicates that there are societal forces of stability such as population, labor force age, drivers' licenses, vehicles, women workers, and vehicle miles of travel (VMT) "ceilings". Also, there are forces of change including women, immigrants, the young and old, low income, and the inner city. Although the traffic safety experts did not address forces of stability, these forces of change are totally consistent with those raised by them.

Delphi Forecasts of the Automotive Industry

A Delphi survey conducted by the Office for the Study of Automotive Transportation at The University of Michigan (Cole et al. 1994), contained the following opinions on circumstances in the year 2003. There were over 200 Delphi panel members who participated in one of three panels: Marketing, Materials, or Technology. These people are in senior management in the automobile manufacturing industry or the automotive supplier companies, or are practicing scientists or engineers. The views expressed are their current opinions of what the future will be like in about ten years. The responses reported here are based on the median scores of the panel members for the questions asked.

Political and Economic Factors Affecting Business Strategy

The forecasts of several of the political and economic factors affecting automotive business strategy (and therefore also other economic conditions) showed little change the next ten years. Among these are the personal taxation rate, business taxation rate, federal budget deficit, personal savings rate, trade value of the U.S. dollar, the trade deficit, and the unemployment rate. On the other hand, increases were expected in manufacturing competitiveness, annual GNP change, and energy prices.

Economic, Social, and Consumption Factors

Economic, social, and consumption factors that influence the level of new vehicle demand that were expected to increase slightly over the next ten years include the age of the operating fleet, real transaction price of new autos, used car prices, vehicle insurance premiums, personal loan interest rates, use of mass transportation, and real disposable personal income. None of the economic, social, nor consumption factors were expected to decrease.

Fuel Prices

Compared to a baseline of $1.10 in 1992 for a gallon on unleaded regular gasoline, panelists estimated that the equivalent real retail price of gasoline per gallon in the U.S. in 2003 will be $1.70.

Federal Regulatory and Legislative Activity

It is anticipated that the following U.S. federal regulatory and legislative standards will be somewhat more restrictive in 2003 than they are in 1994: fuel economy standards, occupant restraint / interior safety, product liability, vehicle integrity / crashworthiness, and vehicle emission standards.

Manufacturers Suggested Retail Price

Compared with a model year 1993 Manufacturers' Suggested Retail Price of $16,186 for an intermediate / family car, panelists expected the equivalent car prices in 2003 to increase as follows: Big 3 at $19,000, Japanese nameplate at $19,600, and European and others at $22,000.

Vehicle Age and Ownership Periods

Delphi Study panelists estimated that the average age of passenger cars in the United States will increase from 7.9 years in 1992 to 8.5 years in 2003, and that the length of ownership by new car buyers will grow from 5.5 to 6.0 years over the same time period.

Vehicle Sales Smart Vehicle Features

Panelists estimated the following total U.S. passenger new-car market, domestic and import, penetration rate (in percent) for the following "smart" vehicle systems for 2003:

Near-object detection (back-up warning)	3
Adaptive cruise control	7
Collision warning (front, rear, and side radar)	5
Night vision enhancement	5

Radio call for help locator	10
Automatic toll collection	5
Navigation	5
In-vehicle message system	10

CAFE Standards

The Delphi panel members expect that the CAFE standards that can be reached by the different manufacturer groups by 2003 are:

Traditional domestic	32 mpg
Japanese - foreign and domestic	35 mpg
European - foreign and domestic	30 mpg

The expectations provided by the Delphi panelists give us some insight into what the future of factors affecting intelligent transportation system technology might be. If we aggregate the expectations pertaining to these factors, we can suggest the following scenario of the future. This scenario would have increasing vehicle and fuel prices and average age of vehicles on the road causing a dampening effect on the increase in demand for new vehicles, somewhat offset by a growing population needing cars and a modest increase in real disposable income. One indicator of this trend will be the increasing average age of new-car ownership. The new cars sold will be more energy efficient, safe, and environmentally friendly, although only a very small portion of them would be equipped with "intelligent" technology, perhaps because of the cost of the new technology. Because of the higher cost of cars and fuel, those people needing transportation may buy less expensive cars or switch to other, less expensive, modes of transportation. However, there would not be a decrease in vehicle miles of travel if the effects of higher fuel and vehicle prices are counter-balanced by the greater fuel efficiency of new vehicles and an increase in population.

Travel Trends

In 1992, 98% of the vehicle miles of travel (VMT) in the United States were on the highway. (U.S. Department of Transportation 1993) Between 1983 and 1990, VMT in the United States grew by

4% causes for this increase were distributed among the following factors by the percent noted: population increase (13%), person trips per capita (18%), mode shift (16.6%), vehicle occupancy (16.6%), and trip length (35.9%). Much of the increase in trip length was due to longer work trips which increased by 29% over the seven-year period. (U.S. Department of Transportation 1992) To the extent that work trips continue to grow in the future as they have in the recent past, there will be definite implications for increased congestion in the non-traditional work-trip commute areas.

Implications of Factors for Intelligent Transportation Systems

Table 5 contains a listing of the IVHS User Services. (IVHS America 1994). It includes twenty-eight technologies that may be offered over the next several years. For the purposes of presentation in this paper, they are aggregated into their service groupings and presented in Figures 2 and 3, respectively, along with some of the societal and economic factors that may affect them or be affected by them (in a positive, negative, null, or uncertain way). These figures represent a preliminary and speculative attempt, without specific analysis, to synthesize the forecasts of several groups and individuals into influence charts. These charts are not meant to represent the ultimate "truth" on the relationship between societal factors and transportation systems, but rather are offered as discussion starters. Although the charts do not address the locational issues, it is important to recognize that every impact of an intelligent transportation system is felt at the local level. At the same time, it is necessary to consider regional, national, and international impacts that may occur. Note that the first row of Figure 2 shows the expected penetration rates of various intelligent transportation technologies into the new-car fleet. These are based on the expected penetration of one or more of the technologies in the user service group as estimated by the Delphi study panel members. The charts show a wide range of types of relationships, and future research aimed at establishing and quantifying these relationships is necessary.

ANALYTICAL METHODS TO ADDRESS SOCIO-ECONOMIC ISSUES

There are many analytical methods available to address the societal issues attendant to the deployment of an intelligent transportation technology. Albers and others (1994) presented several of these at the 1994 SAE International Congress and Exposition. He and others on a subcommittee of the Societal

Table 5

IVHS USER SERVICES

Travel and Traffic Management

- Pre-trip Travel Information
- En-Route Driver Information
- Traveler Services information
- Route Guidance
- Ride Matching and Reservation
- Incident Management
- Travel Demand Management
- Traffic Control

Public Transportation Management

- En Route Transit Information
- Public Transportation Management
- Personalized Public Transit
- Public Travel Semxrity

Emergency Management

- Emergency Vehicle Management
- Emergency Notification and Personal Safety

Commercial Vehicle Operations

- Commercial Vehicle Electronic Clearance
- Automated Roadside safety Inspection
- Commercial Vehicle Administrative Processes
- On-Board Safety Monitoring
- Commercial Fleet Management
- Hazardous Material Incident Notification

Electronic Payment

- Electronic Payment Services

Advanced Vehicle Safety Systems

- Longitudinal Collision Avoidance
- Lateral Collision Avoidance
- Intersection Collision Avoidance
- Vision Enhancement for Crash Avoidance
- Safety Readiness
- Pre-Crash Restraint Deployment
- Automated Vehicle Operation

Source: IVHS America (1994)

FIGURE 2: SOCIO-ECONOMIC FACTORS AFFECTING INTELLIGENT TRANSPORTATION SYSTEMS

+ Positive Impact - Negative Impact o No Impact ? Uncertain	Advanced Vehicle Safety Systems	Emergency Management	Commercial Vehicle Operations	Electronic Payment	Public Transportation Management	Travel & Traffic Management
Likelihood of Penetration (2003) (%)	3-10	10		5		5
Population Growth	o	o	+	+	+	+
More Elderly	o	o	o	?	+	+
Highway Constraint	o	o	+	+	+	+
Regulation	+	+	+	?	+	+
Drunk Driving	o	o	o	o	+	+
Ergonomic Changes	o	o	o	o	?	?
CAFE	o	o	+	+	+	+
Clean Air Regulations	o	o	+	+	+	+
VMT Increase	o	+	+	+	+	+
Poor Highway Maintenance	o	+	?	?	+	?
Little Coordination Across Institutions	-	-	?	?	-	-
Litigation	-	-	-	-	?	-
Energy Price Rise	o	o	?	+	+	+
GNP Growth	+	+	+	+	?	+
Increasing Age of Fleet	o	-	?	?	?	?
Increase in Car Price	-	-	?	+	+	?

FIGURE 3: SOCIO-ECONOMIC FACTORS AFFECTING INTELLIGENT TRANSPORTATION SYSTEMS

Advanced Vehicle Safety Systems	Emergency Management	Commercial Vehicle Operations	Electronic Payment	Public Transportation Management	Travel & Traffic Management	+ Positive Impact - Negative Impact o No Impact ? Uncertain
-	-	o	o	+	+	Access by Disadvantaged
-	-	o	o	?	-	Affordability
o	o	+	+	+	+	Air Pollution
o	o	?	+	?	?	Crime
?	o	+	+	+	?	Congestion
+	?	?	?	?	o	Cyclists
o	o	o	o	+	o	Health Care
+	?	o	o	+	-	English as Second Language
o	o	o	-	+	o	Intermodal Access
o	o	o	-	+	+	Isolation
-	-	?	-	?	-	Legal Issues
o	o	o	-	+	o	Neighborhood Viability
o	o	+	+	-	o	Noise Pollution
-	-	?	-	-	?	Non-Users of System
-	-	-	-	?	?	Privacy
o	o	o	o	?	+	Recreation
+	+	+	o	?	o	Safety

Implications Task Force of IVHS America are in the process of compiling an inventory of such methods. It is expected that the inventory will be completed by the end of 1994. Among these methods are decision analysis, conflict resolutions techniques, focus groups, Delphi studies, futuring, scenario development, influence diagrams, scanning and monitoring the environment, econometric analysis, epidemiological techniques, and expert systems. These methods have been used widely in many sectors of the economy, but not extensively in the transportation systems analysis arena. Other methods, such as the "direct legitimacy approach" rely on direct system user input. (Hauer 1994) All these methods represent fertile ground for exploratory research for application of methods and the opportunity to incorporate into the planning process the societal issues with a rigor that exceeds simple acknowledgement and discussion.

FUTURE RESEARCH NEEDS

In order to begin to address the societal and economic factors that interact with the transportation system, there is an abundance of work that must be done. First, the issues that are not considered to be technical issues must be identified and categorized in some logical way. Second, some attempt must be made to quantify the impact of those factors on the transportation system and the effects of changes in the transportation system upon them as well. To do this properly, an identification of the available analytical techniques needs to be made followed by demonstrations of their applicability to the societal / economic arena in transportation systems analysis and planning. Some will prove to be useful, while others may not. There is every reason to pursue this line of research, and few reasons not to begin now.

SUMMARY AND CONCLUSIONS

This paper represents an identification of many of the societal and economic issues attendant to transportation systems, a summary of several efforts to forecast the future pertaining to transportation systems and the environment surrounding them, an effort to link them together in a relational way, and a call for attention to be focused on addressing this issue as analytically as possible as early as possible in the planning for the implementation of intelligent transportation technology.

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INTELLIGENT VEHICLE/HIGHWAY SYSTEMS (IVHS): ECONOMICS AND ENVIRONMENTAL POLICY

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ABSTRACT

This paper considers the environmental impacts of IVHS from an economic perspective. It discusses the potential public and private benefits of IVHS technologies and the role of the public sector in the development of smart cars, smart streets and smart transit. It concludes that some IVHS technologies can promote technological efficiency but that ***economic*** efficiency requires the use of policies that target the externality costs associated with automobile use.

1. INTRODUCTION

Intelligent Vehicle Highway Systems (lVHS) are intended to offer a variety of technological solutions to the nation's growing surface transportation problems.[2] IVHS are a set of potential, new technologies designed to alleviate congestion and, in effect, increase road capacity, primarily by in-routing and smoothing traffic flow. Currently, IVHS activities are in various stages of research and development, operational testing and deployment (FHWA and FTA 1992). Federal legislation has allocated well over $100 million annually to these projects and eventual cost of IVHS deployment may reach the hundreds of billions of dollars (Horan and Gifford undated).

The public sector has traditionally accepted responsibility for transportation infrastructure investment because of the public services provided However, although IVHS deployment involves large infrastructure investments, including traffic surveillance and communications systems, the benefits provided will be both private and public to varying degrees. In addition, because successful deployment of IVHS technologies require the financial base, marketing capabilities and technological expertise found in the private sector, a partnership is developing between the public and private sectors for the purpose of achieving IVHS deployment (FHWA

1992). These facts raise policy questions concerning the role of public sector involvement in lVHS deployment.

This paper discusses the potential, public and private benefits of lVHS technologies and discusses the role of the public sector in the development of smart cars, smart streets and smart transit.3 The stated purpose of IVHS is to effectively expand roadway capacity, allowing more people to use the roads and travel faster than before, a public benefit. But the surface transportation system as a whole imposes large public costs, including congestion and environmental externalities, that might be exacerbated by the increased automobile use that IVHS is expected to encourage, This paper addresses the policy implications of IVHS implementation, particularly with respect to environmental quality.

The next section discusses two concepts in the economics of transportation that are relevant to this discussion: externality costs and latent demand. Section 3 draws on this discussion as well as theoretical research about the travel behavior implications of IVHS technologies and empirical evidence about travel behavior to assess the public and private benefits of smart cars, smart streets and smart transit. It asks whether public sector investment is appropriate for the IVHS technologies considered here. Public sector investment is appropriate when public benefits are sufficiently large relative to the cost of program implementation. As we consider IVHS implementation, we must also address the external costs associated with the potential increase in automobile use. Section 4 focuses on environmental policies for transportation and discusses their relationship to IVHS policy. Section 5 summarizes the key points of the paper.

2. ISSUES IN TRANSPORTATION POLICY

The Social Cost of Driving

According to economists, the problem with automobile use is that automobile users do not pay for the time delay and environmental costs they impose on others. The costs of automobile use can be divided into two categories: private costs and public (external) costs. Private costs are those actually borne by the driver and consist of gasoline costs, parking fees, road tolls, wear and tear on the automobile and the opportunity cost of travel time. External costs include congestion costs (the increased time spent by others on the road as a result of the marginal increase in congestion created by an additional car), air, water and noise pollution, increased risk of traffic accidents and increased deterioration of the roads. The sum of private and public costs is the full social cost of driving. Individuals weigh their own, private costs against the benefits they anticipate from driving to determine how much driving they will do. Because their driving produces external costs, the result is a market inefficiency where total social costs exceed total (mostly private) benefits. A recent estimate suggests that time delay costs alone exceed $22 billion annually (Hanks and Lomax 1991).

Latent Demand

The question of how IVHS will affect the social burden of environmental and congestion costs is a complicated one. IVHS is targeted at the congestion problem and is intended to decrease travel delays. This effect decreases part of the privately-borne cost of driving and promotes automobile use, increasing both vehicle miles traveled (VMT's) and number of trips. This is a phenomenon known as ***latent demand.***

Latent demand refers to the additional, unanticipated vehicles that appear on new roads because people switched routes, modes or travel times, or because they decided to take trips they had previously not taken. Latent demand is present when congestion is severe enough to deter people from taking trips using their most preferred routes, modes or times of day. When new road capacity becomes available, these people switch to their more preferred trip plans and might even cause congestion to return to its previous level.4 Note however, that although travel times may not improve, more people are taking more convenient trips than before. This is an economic gain that should not be ignored when evaluating plans to increase road capacity. From an environmental quality perspective, however, more cars, which might be traveling at the same slow speeds as before, generally means more emissions.

A full assessment of the costs and benefits of using IVHS to reduce congestion therefore requires an understanding of the extent to which latent demand will offset travel time gains. Most reports of latent demand have been based on ***ex*** post studies. For example, Sherret (1975) found that after the Bay Area Rapid Transit (BART) opened in the San Francisco Bay Area, 8,750 transbay trips were diverted to BART, but 7,000 new automobile trips were generated. Using the ***stated preference*** approach to estimating latent demand, Kroes et al. (1987) found that latent demand in western Holland would add 27% to the existing evening peak hour traffic.

To date, Henk (1989) seems to have provided the most comprehensive study estimating and predicting latent demand for the state of Texas. Using data from before and after new roads were introduced in 34 selected study sites in Texas, Henk (1989) finds that the existing volume to capacity ratio (an indicator of the severity of congestion) and nearby population density positively affect the magnitude of latent demand. For example, in his study, a percentage increase in volume to capacity increases latent demand by around 90 vehicles. Latent demand can be as high as 13.8 times the population density depending upon whether the new road crosses a natural barrier, is a freeway and is radial rather than circumferential.

It is impossible to make a general assessment of how much latent demand IVHS would induce because latent demand is clearly a location-specific phenomenon. However, Henk's (1989) model and the BART example suggest that in areas where congestion is particularly severe, latent demand is likely to be high enough to offset a large percentage of the travel time gains created by new road capacity.

3. ECONOMIC IMPACTS OF IVHS

This section summarizes the main types of IVHS technologies and evaluates the primary expected impacts based on the incentives created. A convenient way to review IVHS technologies is to refer to three general categories: "smart cars," "smart streets," and "smart transit." Smart car technologies refer to privately owned technologies that are installed in individual automobiles such as Advanced Traveler Information Systems (ATIS) and Advanced Vehicle-Control Systems (AVCS). ATIS are intended to provide the driver with real-time information about traffic conditions and optimal route-planning. AVCS are intended to provide automatic steering and braking controls that allow closer following distances and faster speeds. Smart streets refer to Advanced Traffic Management Systems (ATMS) which are infrastructure-based monitoring systems intended to be used for traffic smoothing and accident detection. Smart transit technologies include real-time transit schedule information and high-tech fare cards which are intended to make transit systems more attractive relative to automobiles.

Smart Cars

Smart cars are intended to reduce congestion by providing people with real-time information about road conditions and better vehicle control systems. Implementation of ATIS involves large infrastructure investments in traffic monitoring and communications systems as well as individual information dissemination units which may take the forms of at-home telephone subscriber services or in-vehicle technologies. AVCS are primarily in-vehicle technologies.

Some ATIS owners, upon learning of congested conditions, will presumably choose to travel using alternate routes, modes or times of day, or maybe even forgo their trips altogether. The intended result is that overall travel times are reduced. Amott, de Palma and Lindsey (1991) have shown, however, that this might not be the case. They use a general equilibrium framework to consider how providing information to travelers will affect expected travel times and find that there are many potential outcomes depending on the number of travelers receiving information, how they react to information, how they expect others to react and how reliable the information is. One possible outcome, for example, is that when people learn of congested conditions, they postpone their trips only to cause congestion when they all get on the road at a later time. Arnott, de Palma and Lindsey (1991) also find that the per vehicle, private benefits are greatest when information is provided to only a few individuals and private benefits decrease as the number of individuals receiving information increases. When all individuals are equally informed, travel times can even increase.

It is important to point out that during periods of recurring congestion people will have already optimized their trip routes and timing to deal with congestion. In other words, people will have already sorted themselves out so that those who experience the highest costs from congestion have found ways to alter their routes or timing and those who are more willing to bear the congestion costs stay on the congested roads during these times. Adding new information to this long-run equilibrium might not alter the amount of congestion that exists.

It is estimated that as much as 60% of congestion is non-recurring (Lindsey 1989); but non-recurrent (incident-related) delays occur because highways are overloaded to start (Hall 1993). Traffic diversion therefore requires surplus capacity on nearby alternate routes. During congested times, this capacity might not be available. Al-Deek and Kanafani (1993) show that although guided traffic is better than unguided traffic in situations of non-recurring congestion, the benefits associated with traffic diversion are mitigated by the congestion that is bound to form on the alternate routes. In fact, they suggest that there are little, if any, benefits associated with guiding traffic during peak periods, the most important periods to target.

The results in the literature seem to suggest that smart cars are most effective in situations where only a few individuals have them. If this is true, then there will be few public benefits associated with smart cars and the marketplace can take care of optimizing total net (private) benefits. Drivers who see potential benefits exceeding the costs will purchase the technologies.[5] The purchasers of smart cars will be those who place the highest values on time, and as more smart cars appear and benefits diminish, purchases will slow down. The result. should be an optimal allocation of smart car technologies that maximize net private benefits. Because smart car technologies offer primarily private benefits, they should be produced and sold as private market goods that may have a small public benefit associated with them.

Some might argue that although it is practical for the private sector to provide individual units of smart car technologies, it is still public sector responsibility to provide the traffic monitoring infrastructure (see FHWA 1992). This, however, is not the case. If the private benefits of smart car technologies exceed the full cost of implementation, then private firms will find it profitable to invest in infrastructure as well as equipment development. If they do not find it profitable, then it would be a poor investment for the public sector as well. The potential public benefit does not appear to be large enough to warrant government subsidization of smart car technologies.

Smart Streets

ATMS are sometimes called "smart streets." They include technologies for on-road surveillance and control of traffic flows through signal synchronization and ramp-metering systems, among other things. Preliminary testing of these systems has found time savings in several cities. For example, estimated improvements from ramp metering systems have shown increased speeds of 35% with increased throughput of 32% in Minneapolis-St. Paul and reduced travel times of 48% with increased throughput of 62-86% in Seattle (Federal Highway Administration 1989, cited in Shiladover 1993). The automated traffic surveillance and control system (ATSAC) in the City of Los Angeles has measured improvements of 13.2% in travel times, 14.8% in average speed and 35.2% in fewer stops (Rowe, Okazaki and Hu 1987, cited in Shiladover 1993).

As mentioned earlier, improving traffic flows will induce latent demand which, over time, might counteract the congestion and emissions benefits measured in these examples. Still, there are benefits associated with getting more people where they want to go at the times of day they prefer.

Because ATMS are intended to accomplish travel time reduction by traffic re-routing and smoothing, one of their side effects might be a reduction of VOC emissions ***per VMT. The*** anticipated result is that we have more cars traveling at faster and less-erratic speeds, perhaps producing fewer emissions per VMT than before. Unfortunately, we do not yet fully understand the relationships among VMT's, number of trips (cold starts), speed and emissions so we cannot unequivocally say whether or not emissions or other automobile-related externalities increase or decrease as a result of ATMS implementation (Sperling et al. undated). Smart streets appear to promote system efficiency, a public benefit, but the overall externality impacts, especially environmental impacts, remain an empirical question.

It is useful here to distinguish between technological and economic efficiency. Technological efficiency refers to the engineering aspects of a system rather than the allocative aspects. If there are bottlenecks in the system, then there are potential gains associated with alleviating these bottlenecks. These gains are separate from the question of whether we have too much traffic to start. We do not promote economic efficiency by maintaining the bottlenecks and allowing excessive travel times to discourage people from driving.

ATMS are meant to target technological efficiency, and when evaluated on this basis, they seem to potentially offer substantial, public benefits, warranting public sector investment. In light of the potential increase in automobile use these technologies encourage, however, it will become even more important to pursue policies that target enviromnental externalities.

Smart Transit

Smart transit is intended to improve the attractiveness of transit primarily by providing real-time information to travelers about transit schedules. This should reduce wait times which are known to be considered negative attributes of transit Smart cards will offer riders convenient payment methods without having to carry exact change. Smart transit is often used as the primary example of how IVHS will help diminish transportation's negative environmental impacts. The idea is that increasing the attractiveness and accessibility of transit increases its use and decreases automobile use and VMT's.

Unfortunately, expectations in this regard are probably overly optimistic.6 It is clear from the results of research on mode choices that transit is considered an inferior option compared to the automobile for most transportation users. Most transit systems presently make up less than 2% of the mode share in their respective cities. Inducing a significant reduction in automobile use would require a more than tripling of transit use in such cities, a difficult goal to achieve.7

Because the primary benefit of smart transit is reduced transit wait time, we can look at empirical models of mode choice that include transit wait time or transit headway time (the scheduled time between transit vehicle arrivals; wait time is often assumed to equal one-half of the headway time) in order to get an idea of how smart transit could increase transit ridership. Train (1980) for example, estimates mode choice and vehicle ownership for work trips in the Bay Area using a multinomial nested logit model (McFadden 1973,1978) and includes separate variables for transit headway and in-vehicle times. We can estimate an elasticity representing the percentage change in the probability of choosing transit with respect to a percentage change in transit headway time (Train 1986, p. 40). This elasticity is a function of the probability of choosing transit, the transit headway time and the estimated coefficient on transit headway. Using Train's (1980) estimation results, we find that the elasticity is -0.21 when the transit headway time is 10 minutes. For example, the probability of choosing transit increases 2.1% when headway time is reduced from 10 minutes to 9 minutes (a 10% change). Transit use in the Bay Area sample is estimated to be 19% of work trips (an unusually large mode share), so a 2.1% change in the probability of transit use would increase the transit mode share by 0.4%.8 Note that if we applied the same elasticity to a low-transit-use city, the magnitude of the increase in transit use would be much smaller than this. Reducing transit wait time through smart transit will increase transit use but not by amounts large enough to significantly reduce VMT's.

Nevertheless, improviug transit, if coupled with a policy that provides a disincentive to drive, can offer substantial benefits. Price elasticities for automobile use have been shown to range between -0.1 and -0.5 (Goodwin 1992, Oum, Waters and Yong 1992). Improving the attractiveness of transit could increase the magnitudes of these elasticities by offering more viable substitutes for the automobile. Smart transit could be au important policy complement to environmental pricing.

Summary of Results

Table 1 summarizes the potential public and private benefits anticipated from investments in smart cars, smart streets and smart transit and the appropriate role of public sector investment.

This section has argued that the three broad categories of IVHS will have differing economic and environmental impacts. Smart cars will primarily offer private, time-savings benefits and should therefore be developed and sold in the private sector without public support. Smart streets will offer public benefits by allowing more people access to the roads at peak times, but in the absence of countervailing pricing policies, might negatively affect the environment by increasing VMT' s and number of trips.Smart transit will offer marginal public benefits, including environmental benefits, by encouraging transit use instead of automobile use. The effectiveness of smart streets and smart transit could be enhanced by policies that discourage automobile use. Some potential policies are mentioned in the next section.

4. IVHS AND ENVIRONMENTAL POLICY

The stated purpose of IVHS is to effectively expand roadway capacity through the use of technology. This is indeed an important goal given the high and growing costs that congestion imposes on society.[9] But because the surface transportation system as a whole harms the environment, this stated purpose seems to be directly at odds with the environmental goal of reducing emissions.[10] Even if IVHS does not adversely affect the environment, it is probably not the most effective policy for pursuing environmental improvement. A basic notion in economics is that the best way to pursue a policy goal is to target that goal directly (Baumol and Oates 1988). In the case of transportation policy, we seem to have two opposing goals: to move people as efficiently as possible given the present transportation infrastructure (technological efficiency) and to reduce transportation-related externalities (economic efficiency).

Ideally, the notion of moving people as efficiently as possible would incorporate both goals simultaneously. Efficiency implies least cost, and if we forced people to pay the full cost of driving, we would indeed obtain an efficient solution that balances the benefits associated with automobile use with the full social costs, including congestion and environmental externalities (Baumol and Oates 1988). But the present system is far different from this economically ideal world. People do not pay the full cost of their driving and it is not clear that they will do so anytime soon.[11]

In our non-ideal world, it makes sense to pursue the goals of technological and economic efficiency using a mix of policies where each goal is targeted directly using the appropriate mechanism. Following this prescription, it can be argued that some IVHS technologies show promise in promoting technological efficiency (reducing travel times or increasing throughput) while other policies such as congestion pricing or emissions testing can be used to combat the serious environmental problems created by the system as a whole, promoting economic efficiency. In other words, the idea of getting more people where they want to go faster than before is a public benefit[12] The fact that at present, people are not paying for the costs they impose on society when they drive generates a large public cost. These costs must be addressed using appropriate policies, especially as we consider introducing IVHS technologies which might exacerbate some of these costs.

There is a growing literature evaluating emissions-related policies including reformulated gasoline, enhanced inspection and maintenance programs, alternative fuels, congestion pricing, gasoline taxes and accelerated vehicle scrappage programs (Alberini et al. 1993, Geoghegan et al. 1994, Harrington, Walls and McConnell 1994, Krupnick 1992, Krupnick, Walls and Hood 1993, Walls 1992). Harrington et al. (1994) find that, in general, policies that rely on economic incentives, such as emissions rate-based vehicle registration fees, and target high emissions rates, such as vehicle inspection and maintenance programs, are more cost-effective than technology-based policies, such as alternative fuel vehicles and California emissions standards.

If we are interested in targeting automobile-related emissions we must &sign policies that create the appropriate incentives. The cost-effectiveness of a program depends crucially on the ability of a program to target high-emitting vehicles, especially those that are heavily used. In addition, to maximize benefits, it is important to focus on critical areas, at critical times of day, during critical seasons. It may be impossible to develop one program to satisfy all of these criteria at once, but it is clear that certain programs are more likely to create the appropriate incentives for high-emitting vehicle owners. For example, Harrington et al. (1994) recommend an emissions rate-based vehicle registration fee coupled with a VMT-based fee, which would focus both on emissions rates and amount of vehicle use and encourage owners of these vehicles to maintain them properly and/or drive less.

Pricing policies such as gasoline taxes and congestion pricing are advocated by economists because they directly target externalities by increasing the privately borne costs of automobile use. Gasoline taxes, however, do not focus on congested areas and times and therefore might result in more diffuse emissions and congestion reductions that might not bring large marginal benefits (Krupnick et al. 1993). Congestion pricing is primarily intended to reduce congestion costs but also has the benefit of reducing the higher VOC emissions associated with congested conditions. Recent empirical work by Geoghegan et al. (1994), Mohring and Anderson (1994) and Repetto et al. (1991) has shown that optimal congestion fees can substantially reduce congestion and emissions costs and produce significant public benefits.

It is beyond the scope of the present paper to review the aforementioned environmental policies in detail. They are mentioned here as policies that directly target emissions and can be used in conjunction with certain system efficiency-enhancing IVHS programs. It should also be noted that IVHS technologies can be used to facilitate implementation of some of these environmental policies. Advanced Vehicle Identification (AVI), for example, can facilitate road tolling for congestion pricing. AVI might also be used in association with remote emissions-sensing devices to fully automate an emissions rate-based pricing scheme.

5. CONCLUSIONS

The purpose of IVHS is to effectively expand roadway capacity through the use of technology. Based on preliminary test results and theoretical reasoning, it appears that the programs with the highest potential for improving public benefits are ATMS. Preliminary tests show potential for improving system efficiency by increasing throughput and possibly, reducing travel times (depending on the amount of latent demand induced). ATMS, like most IVHS technologies, will encourage automobile use so that total VMT's will increase, making it possible that congestion will return to its original level. But the external costs associated with VMT's and congestion should be addressed using policies targeted directly at these problems.

Smart transit technologies are said to enhance the attractiveness of transit and encourage its use over the automobile. Based on mode choice estimation results and existing mode shares, however, it is not clear that these technologies alone will achieve significant reductions in automobile use. But when combined with pricing policies that discourage automobile use, smart transit might be appropriate and even necessary, depending on the cost of implementation.

Smart cars seem to offer mostly private benefits. These technologies should therefore be developed and sold in the private sector without public participation in their development.

The approach taken in this paper is to consider IVHS technologies in a broad sense. Within the categories discussed, there are specific ideas, not mentioned here, that might warrant special consideration, such as smart vanpools or smart communities. There might also be complementarities associated with particular combinations of technologies.

The purpose of the present paper is to discuss IVHS in a policy context, looking at public and private costs. IVHS will not solve all of our transportation problems and might even exacerbate some, especially environmental costs. We must therefore begin to think comprehensively about an overall transportation policy mix that addresses both system inefficiencies and economic inefficiencies.

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Table 1: Potential Benefits of IVHS and Role of Public Sector

IVHS Technology	Description	Potential Public Benefits	Potential Private Benefits	Appropriate Role of Public Sector
Smart Cars	- Route guidauce (to avoid congestion) - automatic vehicle controls	- Small reduction in congestion and travel time - Uncertain effect on total VMT's and emissions	Large travel time savings by avoiding congestion	Leave all investments to private sector
Smart Streets	Infrastructure-based systems to control andsmooth traffic	More road capacity that allows more people to travel when and where they want	Latent demanders get access to roads	Invest when public benefits are greater than implementation costs
Smart Transit	- Real-time transit schedules - Easy payment methods	Very small improvement in congestion and emissions	More convenience for transit users	- Invest only where potential transit ridership might substantially iucrease - Consider as complement to a pricing policy

ENDNOTE

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2 See Downs (1992) and Small et al. (1989) for discussions about trends in transportation use, congestion, environmental costs and infrastructure constraints.

3 Unfortunately, because IVHS technologies are new and untested, it is impossible to make a reliable quantitative assessment of the economic and environmental impacts of IVHS Instead, many researchers have evaluated aspects of the IVHS program on a qualitative basis, or recommended research directions or methodologies to aid in making quantitative assessments in the future (Horan and Gifford undated, Shiladover 1993, Underwood and Gehring 1992). This paper performs a qualitative analysis.

4 In the long run, people may choose where to live or work based on new road capacity, so the full extent of increasing road capacity may not be seen until many years after implementation.

5 The high cost of smart cars will prohibit most people from purchasing them. This has led to concern about equity issues. This concern is valid when the public sector is subsidizing development and production, but would not be an issue should ATIS become a purely free-market good.

6 Shiladover (1993) for example, suggests that smart transit could improve greenhouse gas emissions by 10% to 30%.

7 Furthermore, an inordinate increase in ridership might require larger transit operations which might impose increased environmental costs in some cities.

8 The elasticity decreases as the headway time decreases, so multiplying the 0.4% effect by 10 minutes would overestimate the amount of transit use resulting from a complete elimination of wait time. Thus, 4% is an upper bound of the increase in transit mode share.

9 Congestion has been estimated to be roughly equal to one-third of the total social cost of driving (Small 1992, p. 84)

l0 The nation's surface transportation system presently contributes 70% of carbon monoxide (CO), 39% of nitrogen oxides (NO,), and 30% of volatile organic compound (VOC) emissions (USEPA 1992). In urban areas that violate the National Ambient Air Quality Standards (NAAQS) the shares of automotive emissions are even higher.

11 There has been increased interest in the idea of congestion pricing which would charge drivers for the congestion externality they impose. The Intermodal Surface Transportation Act (ISTEA) of 1991 includes funding for congestion pricing pilot projects. At present though, there is only one pilot project underway (in the San Francisco Bay Area) and it may be years before implementation occurs.

l2 Small (1992, pp. 36-45, 77) suggests that travel time for work trips is typically valued at 50% of the wage, or approximately $4.80 per hour for the U.S. in 1989. This information, in association with a location-specific estimate of latent demand, can be used to approximate the public value of increasing road capacity and possibly reducing travel time in a particular location.

INTELLIGENT TRANSPORTATION SYSTEMS

Building Consent for Post-Cold- War Transportation Initiatives

By Peter Roudebush and Harry Mathews

Introduction

Its the Summer of 1945, you call a friend in a small town in Vermont (Summer population 3000), and your call is transferred to where he is having dinner, because the town telephone operator is everyone's friend and often has been told or has heard where her subscribers are planning to be. Today, if you call Area code 617-951-1433 in Boston, you'll hear "Good Morning, you have reached the Boston Society of Architects "(population 11, not all full time). " "This is our user-friendly voice mail system. Please bear with me and I'll guide you where you wish to go. If you have a rotary or crank phone hold on, we can handle that too. If you know the extension of the person you want, push that extension now and I'll vanish. If you don't know their extension, push the pound or star key."

Does voice-mail answering really help your business? Does this technology save you and your client time and money? Is the value of that time more or less commensurate with what you would pay a receptionist? Should your business communications be entrusted to a machine or to someone answering the telephone?

The telephone operator who connected the caller with my father was doing something everyone thought normal in 1945. The country was at war. Everyone was helping one another (and the country) in a time of stress. People were planting their own vegetables; car-pooling to save gas; and helping one another cope with every imaginable problem. Today this feeling of cooperation seems to have disappeared. Many people seem to think, it can only exist in time of war. I am about to describe a way those feelings were evoked in peacetime around a transportation planning event which occurred twenty years ago. This may be a model for achieving consent for intermodal transportation systems today.

The planning event took place in Boston in 1971, and became one of the intellectual cornerstones of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). The Boston Transportation Planning Review (BTPR) was an enormously successful transportation planning experiment in public participation, which spontaneously conceived a locally initiated Metropolitan Area Intermodal Transportation Plan.

The BTPR was successful because its open public participation was integrated with broad interdisciplinary professional expertise. This allowed the public and the experts to explore transportation investment options together in detail. This enabled informed debate and the creation of common solutions. The review formulated holistic solutions no single person nor group could have conceived independently as accurately or as richly. It was not only a planning exercise, but an educational experience. Its results instilled deeply felt confidence on the part of everyone who participated. Participants sincerely felt their recommendations fully addressed their mandate carefully and accurately. The BTPR set the agenda for transportation planning for the Boston region for the next twenty years and has been followed with little controversy ever since.

The BTPR found out where Boston's constituency wanted to be led, and organized a plan leading in that direction. I will describe this process in more detail. It indicates one way seamless intermodal transportation could be achieved today. Such systems depend upon being made and run by people **wanting** to have them, wanting them to work, and wanting to work together to conceive, implement and operate them. The BTPR did that. But this kind of planning is not unique; similar techniques are now being used by major international corporations. These same techniques are helping businesses and manufacturers planning and building a myriad of post-Cold War facilities, tools and systems for a sustainable future.

The Boston Transportation Planning Review

In 1969, Massachusetts officials were having trouble acquiring public consent for an Interstate Highway "Inner Belt" for the Boston Region. Governor Francis Sargent instigated a review of the situation. The resulting BTPR, directed by Alan Altshuler, was designed with the help of Lowell Bridwell, former Federal Highway Administrator and representatives of state agencies, cities and towns, and interested citizens of the region. The review addressed a full spectrum of cross disciplinary criteria and interests including economics, social, environmental, historical, and landuse values, and urban as well as transportation design.

The BTPR's participatory process was very carefully constructed, and even began as the design for the study was being devised. Participation was made central to the actual planning taking place and made an integral part of it. No one was barred from participating. A special "Community Liaison" work element was separately funded to emphasize this and to help translate the concerns of interested citizens in case their contributions were not clearly understood by the professional team.

Citizens and experts saw their suggestions incorporated into the plan or amended as work progressed, perceived differently or accomplished through other means. Everyone who worked with the plan as it evolved were thus able to understand its implications. As a result, everyone connected to the plan - citizens, professionals and politicians - genuinely felt its product represented their own informed and considered opinions, hard work and self criticism. Their interaction generated mutual respect and even sometimes admiration. Ideas emerged which transcended groups or persons; it was extraordinary what wit and imagination came from voices which theretofore had been silent, including those of staid, well-seasoned engineers, who thought it not their place to make suggestions, nor that they might ever have an opportunity to do so even if they had a good idea.

Participants viewed themselves not as decision-makers, but as advisors to the Governor and the body-politic, providing technical and political information and feedback to and from citizens and government at all levels, defining ranges of possible decisions, the Governor, The Congress, the FHWA and FTA, the legislature and city mayors could take. "Alternative Program Packages" were carefully developed and evaluated, considering carefully everyone's interests. Because the process was ***inclusive*** and open, no one's agenda was excluded, nor were solutions based upon lack of information. Unknowns were treated in an informed manner leaving as many future options open to future decisionmakers as possible.

A clear statement emerged from the plan: that the people in Greater Boston wanted to reduce traffic congestion by using public transportation more and highways less to access the City. The plan, accordingly, schematically designed the systems to accomplish this objective in a thoughtful, detailed, specific, richly informed and well documented way.

Doubts persist about whether the BTPR was predisposed against Interstate Highways. The Inner Belt plan was openly evaluated along with other transportation alternatives, and its supporters were listened to very carefully. What emerged was recognition of the problem inherent to Interstate Highways in urban areas. In the country, building highways with four times the capacity of the traffic on surrounding streets is possible, but in cities, highways built to that same criteria, immediately fill to capacity. Urban Interstate highways are instantly too congested to serve for evacuation; its unimaginable how they could practically be constrained to work in an emergency. In non-emergencies, they increase congestion, because they allow more vehicles to use them than can access local streets. BTPR participants found so many more opportunities emerging from their mutual interaction, they put defense criteria in context, and went on to seek more rewarding solutions.

The BTPR recommended Massachusetts transfer some of the Interstate Highway funds apportioned to the Boston Region to transit instead of highway purposes, and that no additional highway capacity be built into the region's radial commuter road network. It recommended building a Third Harbor Tunnel to take through traffic out of the heart of downtown. This allowed north/southwest through traffic to connect directly with the Massachusetts Turnpike. It also recommended depressing a section of elevated highway built in the mid-1950's, which severs Boston's Business District from its historic waterfront, called the Central Artery. In the 1980s, even before the depressing the Central Artery had been approved, anticipation of the Project inspired a major economic renewal of the buildings surrounding the Artery corridor.

The principal transportation benefit of depressing the Artery was a rail link, to be built as part of it, between the two railroad systems serving north and south of Boston. This filled in the only missing track in rail service along the Atlantic Coast from Florida to Maine, and allowed commuter trains to traverse the city instead of terminating at separate stations. It opened new regional markets for labor and business activity by increasing City accessibility via public transportation, and made the use of interconnecting bus, transit and commuter rail systems dramatically more attractive through reduced transfers.

While the rail link didn't guarantee people would leave their cars at home or in suburban stations, it provided an attractive and affordable alternative means of travel into and out of Boston, and helped people walk to destinations in a restored historic waterfront through an environment designed for pedestrians. The rail link allowed highways serving Boston to be constrained, if the public wanted to reduce congestion, without sacrificing affordable accessibility to those who chose to enter or leave by rail.

The BTPR planning event and its resulting intermodal plan were so powerful, its recommendations were pursued with confidence. The excitement which had been created in Boston soon brought national attention and special focus to implement the plan temporarily eclipsing attention to other areas across Massachusetts.

Because the federal government had not yet approved ISTEA, the Central Artery Project became an Interstate Highway improvement under FHWA rules in 1983. I will say more about the Interstate Program in a moment. Under these rules, the design grew to carry three times more traffic. The rail link was dropped, because it was perceived to be in competition, and the project doubled in cost. As people found themselves less clearly associated with it and concerned about values they felt were being dismissed, the project further began to accumulate a staggering list of additional costs to "mitigate deficiencies".

Last year, Massachusetts Governor William Weld formed a Task Force to determine whether the rail link could be returned to the Project. After three months, that Task Force found it could, and that rather than interfering with the Artery, it made it consistent with ISTEA and could possibly help its construction. Congress approved $4 million to start the rail link's environmental impact statement, and the Massachusetts Legislative Transportation Committee approved $60 million in state funds to match federal preliminary funding. A full Legislative approval is pending approval of funds to help people all across the state. A Rail Link Caucus for members of the Massachusetts Legislature attracted the participation of 183 of the state's 200 legislators last year, who recognized the rail link both as good politics and as good business.

There is strong business support for building the Central Artery Project and the Rail Link. Congestion constraints will be necessary to achieve mandated compliance with the national Clean Air Act Amendment. Constraining some of the traffic, built into it for defense reasons, may enable some of the Project's costs, disruption and contention to be reduced. This could update the Project to make it even more consistent with national transportation policy and the BTPR master plan. It could also speed its implementation.

Disillusion and Cold War Spending Policies

That same summer of 1945, when you might have reached my father with Georgette's help at a friend's house in Vermont, America dropped the bomb on Hiroshima. It was as if I took a revolver from my briefcase, and fired it at the ceiling. The bomb captured permanent world attention in a single day. The waves caused by this explosion are still being felt now, fifty-years later, and are unlikely to subside any time soon.

That August day in 1945 changed an age of almost delirious optimism into one of almost equal cynicism within the space of fifty years. The dreams of unrestrained power and wealth resulting from a new age of machines had turned from good to evil. The powerful conviction that man's inventiveness could lead to whole new paths of life and great societies was shattered. Moral judgment and authority, the very foundations of American Democracy, were sorely and severely challenged. 200,000, mostly innocent people died in five days, and 150,000 more were to die in the next five years.

The excitement of discovery, and the energy gleaned from new sophisticated machines had started a race for world supremacy among industrial nations at the turn of the century. By World War II, most of this energy was focused on war preparations to control who would oversee its power. People had been preparing for or waging war for 30 years. Everyone had sacrificed time, energy, and money in the spirit of the nation's best interests and national defense, and had helped build the tools to win it. Then, that August day showed these same tools could unwittingly annihilate all life on Planet Earth.

It stopped World War II. The initial response at home was pure panic. We built bomb shelters, so some of us at least, would survive if a bomb landed on the United States. The "Doomsday Project" at the Pentagon, to sustain the country's leadership in the event of nuclear war, is only now being phased out.

The price of war had already taken its toll, the country was recovering from a severe depression, and money was scarce. Congress enacted a series of focused, single purpose, military-like programs to reinspire national reinvestment. These included massive federally subsidized and controlled programs in transportation, urban renewal, housing, banking, health and social security, everyone of which proved unsustainable.

Popular misconceptions about Cold War economic policies abound. Some of these programs might have been more sustainable had they focused upon longer-term objectives, but it was considered mandatory to regain government respect and quickly revive credibility, thus people's attention was riveted on short-term engagements. These inspired a wave of short-term profit taking, and nearly bankrupted the American economy.

Marketers, for example, made products specifically designed to wear out more quickly, on the theory that would persuade customers to repurchase. This idea quickly opened the doors to foreign competition. The oil industry created a cartel with automakers, steel producers, rubber, asphalt and concrete plants which regulated what could be sold and soon controlled highway construction. It was convinced this was how progress was made. It thought interconnected businesses were the wave of the future, which they might be if used less exclusively and less defensively. It mistakenly thought wealth came from keeping it from people who were not part of the cartel. The cartel thought our national defense highway system was helping our automobile industry, when in fact, it was keeping it from competing with German and Japanese manufacturers, who soon took over the industry.

Many people today believe conflict is inevitable and people can only work together in times of crisis. As a result, many people today are out-of work, profoundly skeptical, and the costs of doing business have skyrocketed. Some wonder if all new technologies are dangerous. The Cold War with Russia may be over, but the Cold War between people here is still raging furiously.

These circumstances made fertile ground for the environmental movement. Born in reaction to short-term thinking and the consequences of that August day, it spread like red blood cells to a wound. As one might expect, it interfered with progress, and some of its soldiers still do. But it started to change our thinking to consider expediency differently, to look into long term consequences more fully, and to seek new ways of doing business.

Many people today don't understand why major public works should be stopped to preserve endangered species, while others are wondering if man isn't one of them. Neither crisis view is very useful in itself. But what the BTPR demonstrated was that both views have merit if both are pursued and refined together. As opposed to discarding views as too extreme to be important, the BTPR used opposing views to discover new solutions which sustained both action and long-term objectives more efficiently.

If we take a century-long overview of our progress this past century, we may not have progressed quite as radically as everyone expected and discovered that most of the problems and conflicts which have confounded man before persist. At the same time, our optimism and struggles to build new frontiers have driven us to discover amazing new ways to help confront these conflicts more knowledgeably, and we may be realizing for the first time that planning ahead might enable us to progress more fruitfully.

Post Cold War Intermodalism

Intermodalism is a new transportation term narrowly interpreted to mean improving the interrelationships between modes. But it is a concept which can and should be interpreted more broadly. Turning intermodalism from a challenge into an opportunity means allowing it to address not only travel modes, but the multiple social, economic, and environmental values which influence transportation choices and decisions. Many transportation research investments can be made narrowly, but will gain value and purpose if linked to other interests through cross-modal, cross-disciplinary thinking. These are considerations, which all levels of government and private industry must now address to achieve more sustainable economic systems, tools, and jobs.

I was impressed last year by an address given at the New England Museum Association's Annual Meeting by W. Richard West, the director of the National Museum of the American Indian. I think what he said about his museum can be usefully said about the transportation industry. I have therefore. with his permission, transposed some of his speech in a cross-disciplinary manner. In his speech, W. Richard West begins by quoting Robert McCormick Adams, the Secretary of the Smithsonian Institution, who wrote the following statement about the new museum:

As "This national museum (that) takes the permanence, the authenticity, the vitality and the self-determination of Native American voices as the fundamental reality it must represent, we move decisively from (an) older image of the museum as a temple with its superior, self-governing priesthood to a forum which is committed not to the promulgation of received wisdom, but to the encouragement of a multi-cultural dialogue".

A transposed statement about the transportation industry might read:

As America's transportation industry takes the permanence, the authenticity, the vitality and the self-determination of American voices as its fundamental reality, it must move decisively from an older image of the industry as a temple with its superior, self-governing priesthood to a forum which is committed not to the promulgation of received wisdom, but to the encouragement of a dialogue with all citizens.

No one will likely ever succeed in controlling solely for themselves or their group many of the multiple new inventions which continue to be made as we move into a new century. The notion that these are the dominion of a select aristocracy was shattered fifty years ago. We are now bound together, by that accident, into sustaining our existence by assuring that future inventions are not used to exclude or coerce for short-term gains, but to open more universally sustainable opportunities. The century just behind us has dealt a profoundly humbling message: the tools we invent must be used constructively and not to destroy. Outmoded systems must be replaced with constructive alternatives, not simply destroyed. The machines we have discovered are not ends in themselves, but simply tools which provide opportunities to envision progress differently. This hardly means we dare no longer act any more than it ever did before. On the contrary, the exciting work has just started.

Planning events such as the BTPR may help us reach detente in the Cold War we seem to be having with each other, and make it easier to accept change from Cold-War to new growth policies:

1. Design Sustainable Planning Systems

ISTEA calls for integrated statewide and Metropolitan Planning Organization plans.

If these plans are drawn considering the full range of social, economic and environmental values and all known externalities of each state or region, they can acquire the similar solid backing for their common wisdom the BTPR achieved. When they do, this will enable subsequent project EIS submittals to draw upon this information with confidence rather than to require repeating studies with each subsequent project application.

Consider EIS planning not as an impediment required by bureaucrats or as an invitation to disagree, but as a vital educational experience. Realize the ripples the bomb made are the harbingers of change. A statewide or MPO plan may make smaller ripples, but its decisions will influence what happens for better or for worse, for the next fifty to one hundred years. This means making decisions which support long and short-term opportunities, and using all available resources to act as wisely as possible. This means not discarding information or rules, but thinking constructively beyond them. It means cross-disciplinary thinking; acting the way Georgette did, using personal knowledge to connect people to new ideas or new ways to look at old ones beyond the information now listed in most books.

2. Design Sustainable Transportation Systems and Tools.

Population characteristics are changing. Unlike what was fashionable during the Industrial Revolution, industrialized countries are having smaller families. We recently discovered we were overfishing George's Bank. The view that economic health is necessarily linked to increasing everything must change and the benefits of longer-term qualities in smaller quantities must begin to be appreciated.

Helping cities build systems so people can live healthy, safe urban lives depends upon both changing urban living habits, and building sustainable communities. Both objectives can create good business. Skyscrapers and suburban sprawl are more energy consumptive and less easily sustainable than more moderate densities. More sustainable densities vary from place to place and are less expensive to build and maintain. But above all, these densities can be built with human-scaled designs which make people proud of them and want to care for them.

W. Richard West talks more about museums, saying: "America's educational system desperately needs our assistance, and we represent remarkable bundles of human and material resources that contain substantial stores of information, knowledge, and potential educational impact. Let me be very blunt about the reverse side of this coin----I am extremely doubtful that either the public, or, for that matter the private sectors, come the next century, will be agreeable to supporting these very expensive institutions unless the public perceives that they have a far more general and democratized educational presence and impact".

Many existing transportation systems of the past were not planned for the future. It is said Boston's streets were planned by a cow. New criteria and the tools to more accurately recognize the consequences of planning decisions keep being invented. However they need a context in which to be understood and evaluated constructively. This context might be envisioned as an ongoing educational system, in which everyone participates, out of which come experiments in progress, systematically helping discover how we can treat the Earth and ourselves more gently.

Consistent with this approach are transportation tools which help to accurately educate travelers about systems choices and tools which expand their choices: cars which don't pollute, ways of using existing resources, such as rail systems more effectively, ways to preserve older buildings and build new tree-lined streets which remind us that many of the best examples of sustainable accomplishment have been around a long time. These are places which, centuries later, sustain admiration and respect. They increase in value by inspiring pride and care. They are typically full of human wisdom, human scale, delight and creativity for everyone. The more we build of these, the easier it becomes to inspire more confidence in the future.

3. Design Systems which use people and machines to do what each do best

Enormous amounts of useful planning information exists, but lots of it is seldom used. Planning has not been popular; people assume the information gathered will be used against them. The predictions of surveillance in the book “1984” have already taken place. We have already experienced “Big Brother” surveilling us as cold, inhuman, statistics. Few people in western societies have escaped being recorded. No city, nor state in the world has not been mapped. The data is there to enable us to drive up any street in the world via computer graphic systems, ***but not yet to look peacefully into the faces of those who live there, to ask how they feel, how we could help them and what ideas they have to help us***. At least for the moment, this can be done with better results, face to face.

Images can now be projected on a computer screen, for most localities, showing where the transportation systems, police and fire stations are, where all the traffic goes, and where the crimes and fires have taken place. That traffic and those crimes and fires can be related unbiasedly to age, income, race, sex, marriage, mortgages, social security, insurance, and health care, if we want it to. This data, if we want it to, can be used to help the people living on those streets together with people in business and government, to make constructive, creative, useful plans and market new inventions.

The binary system of computers, while remarkable in its ability to manage extraordinary volumes of complex data, remains an impoverished fool next to man whose memory of sight, hearing, smell, touch, and feelings provide hugely more information. Creativity, I think, comes from individual thought and observation made by people alone with their thoughts, derived from connections they are able to draw from individual experiences. Great ideas emerge from all levels of intellect, age, and education; most ideas go unheard. Ideas grow strength by people building upon someone’s creativity, adding to it respect and value and adjusting it to help it grow. Computers can help. Our diversity is the major source of our creativity. It may be our best assurance too that creativity will always eventually be constructively used. Our diversity expands our common vision to initiate new understandings of common “realities”.

Jane Jacobs, the renown observer of cities, notes that cities are, and have always been the breeding grounds of economic resurgence; the places where ideas are formed through the interactions of people talking face to face and inventing new ways of doing things. Cities behave this way because they are places where people from everywhere come to meet, where their ideas can compete and cross associate and generate new vision.

Services are needed to design and support transportation planning concepts. Clear and sustainable concepts need less support. More services are needed, the more there is disagreement. Extending this analogy, the more sustainable we make development, the more easily we can shift growth from services back to manufacturing, thereby reducing the costs of doing business and increasing wealth.

I have unabashedly quoted Richard West previously, in a cross disciplinary effort to correlate what is happening in museums with what is happening in the transportation industry. Here is another of his comments:

“Finally, I remain convinced that if we can accomplish all the foregoing, museums can be transformed into the vital forums for the exchange of cultural ideas and information and of debate that the Secretary of the Smithsonian Institution, Bob Adams, so elegantly described in my opening presentation. At that point I believe that museums, as social institutions will have the potential for assuming a role that ascends to an entirely new plane, which seems so logical, but which they have not achieved in any systematic way to date. Specifically, they will become far more important and pivotal- far more integral--to the continuing evolution of American culture. More important, they become not only the venues for debate but, perhaps, genuinely proactive instruments of the cultural reconciliation that this country appears so desperately to need. ”

My thesis today has been focused upon using people's words and connections the way Georgette used the telephone in 1945. Most businesses today are actively pursuing programs which involve employee participation aggressively. Most top executives agree, without employees buying into them, their plans do not work. Most everyone going to Home Depot today expect to find good products or return them for cash. With unemployment, for example, in France reaching 15 % , overseas governments must also find ways to employ more people more usefully. Planning more openly and constructively, sharing ideas, building upon their cross-fertilization and respecting contributions more freely are effective ways to reduce both the deficit and unemployment and eventually of sending new inventions like clipper ships to span the globe for new adventure.

W. Richard West concludes his speech by quoting his Deputy Director who said " And museums will become different in a way that will, in the future, seem logical and self evident. I predict we will not be able to recreate what all the fuss was all about."

"From the longer view", W. Richard West states", "however, I have confidence approaching the serene that her prediction will prove absolutely prescient. And it is that long view which the National Museum of the American Indian, by history and perhaps destiny, is constrained to take. For us it is not only an option - it is no less than a cultural imperative."

The Transportation Industry may not envision itself as a cultural institution, nor that its options for future action are as imperative. Nevertheless, you may find sharing some of the cross-disciplinary thinking of the National Museum of the American Indian and of the Boston Transportation Planning Review worthwhile exploring further.

Thank you very much for your kind attention.

I am indebted to Harry Mathews of Arthur D. Little, who has mentored and co-authored this writing, helping compare ideas with emerging international business practices. I am also indebted to W. Richard West whose speech about the National Museum of the American Indian I have quoted so frequently, and to the following author's papers, whose words were food for thought:

Richard Barrett The World Bank	Environmentallv Sustainable Urban Transport Defining a Global Policy
John B. Hopkins	Discussion Paper: Aspects of Sustainable Transportation
Unsigned	Sustainable Transportation Proposal for a Transportation Research Board Study
Arnold Howitt Alan Altshuler	The Challenges of Transportation and Clean Air Goals
VNTSC	Charting A New Course in Transportation Transportation Strategic Planning: Seminars January 1993