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Potential Contributions of Intelligent Vehicle/Highway Systems (IVHS) To Reducing Transportation's Greenhouse Gas Production

by

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ABSTRACT

The road transportation system (including automobiles, buses and trucks) has not yet made significant use of modern electronics technologies to enhance system operations. Intelligent vehicle/highway systems (IVHS) is the label currently applied to the nascent attempts to use advanced technologies to enable travelers, vehicles, and the roadway infrastructure to function as an integrated system. IVHS technologies influence both the supply and demand sides of transportation, to promote enhanced operational efficiency and reductions in vehicle miles traveled. These changes can reduce the contribution of the transportation sector to global warming in ways that are explained qualitatively in the paper. Quantitative evaluation of the global warming implications of IVHS must follow from further research on the technology and travelers' responses to it, and from development of the policy framework for IVHS implementation.

1. INTRODUCTION

Intelligent vehicle/highway systems (IVHS) is the term that has recently been coined to describe the application of modem computer, communications and control technologies to aid in the observation, guidance and control of vehicles operating in a traffic system. IVHS has become a popular concept among a variety of constituencies, while at the same time incurring the displeasure of other constituencies. This polarization is unhealthy and unnecessary, and is to a considerable extent based on misconceptions about what IVHS is. Much of the problem stems from the name IVHS itself, with the unfortunate emphasis on the word "highway". A more appropriate name might be "intelligent transportation systems".

The significance of IVHS lies in its use of information technologies to help make travelers, road vehicles and the road infrastructure work together as an integrated system. Virtually all other modes of transportation have already been operating in such an integrated fashion for years (railroads with their signal and train control systems, aircraft with air traffic control and ships with vessel traffic systems in ports). The road transportation system and its vehicles
(automobiles, buses and trucks) have to date only been connected where the rubber tires contact the pavement surface. The potential improvements in operational effectiveness that can be gained from the integrated systems approach are at the least considerable and in some cases very dramatic.

Much of the harshest criticism of IVHS has come from the "environmental" constituency, which has viewed it as "a way of making it easier for people to drive" and hence an incentive for people to travel in an environmentally unsound way. This perspective overlooks the multimodal character of IVHS (making transit and ridesharing services more attractive) and its potential for real improvements in system productivity. One of the purposes of this paper is to attempt to bridge the gap between the proponents and opponents of IVHS by discussing its potential impact on global climate change in qualitative terms. The discussion cannot yet proceed to quantitative evaluation because of many gaps in current understanding of how the technologies will be used and even more serious uncertainties about the policy environment in which they may be applied.

The place of IVHS relative to other elements of the transportation-global climate change "system" is illustrated schematically in Figure 1. Transportation planning is based on the general economic paradigm of supply-demand equilibrium illustrated on the upper part of Figure 1. IVHS can influence both the supply and demand sides, leading to reductions in transportation "consumption" (most commonly measured in terms of vehicle miles traveled, VMT, but in reality including other metrics as well). After the "consumption" is defined, improvements in vehicle energy efficiency can lead to reductions in the use of energy for transportation, while choices of unconventional sources for the vehicle energy can further reduce the contribution of transportation to global warming. Most consideration of the global warming issue focuses on these later stages, for understandable reasons. However, the problem is large enough that it is likely to be necessary to bring all available tools to bear on it. Therefore, the potential contributions of IVHS technologies deserve consideration as well.

The specific ways in which IVHS technologies influence the supply and demand sides of road transportation will be discussed in more detail later. At this point it is important to raise the distinction between short and long-term effects of IVHS. The short-term effects are unambiguously favorable for addressing the global warming problem, in that a more efficient and smoothly operating transportation system is preferable to an inefficient one. The long-term effects are subject to additional uncertainty, however. The uncertainties are associated with the potential effects of latent (sometimes termed induced) demand and changes in land use patterns that could result from major improvements in the transportation system. The latent demand is
Figure 1. Role of IVHS in Mitigating the Transportation Contribution to Global Warming.
represented by trips that people would like to be able to take, but that they forgo because of the
cost in terms of time and/or money. Significant improvements in the transportation system
would cause more of these trips to be made, leading to increases in the consumption of
transportation services, with the concomitant potential for increases in production of greenhouse
gases. Similarly, the long term effects of major transportation system improvements could
include significant new land developments further away from existing development centers,
leading to the consumption of more transportation services. This potential reinforces the
importance of coupling transportation policy with land use development policy in order to avoid
producing counterproductive results.

2. IVHS AS AN "EXPANSION OF THE ENVELOPE"

Fighter aircraft pilots are accustomed to thinking in terms of the performance "envelope"
of their aircraft. This envelope is the multidimensional space incorporating all the relevant
measures of performance, which must be traded off against each other in the design of a
particular aircraft (velocity, range, altitude, maneuverability, etc.). For any given level of
technological sophistication, it is necessary to give up performance along one or more of these
dimensions in order to gain performance along another dimension. Technological advancements
(new engine technology or lighter weight structural materials, for example) permit that
performance envelope to be expanded, so that improvements may be gained along one or more
dimensions without sacrificing performance in the other dimensions. The same concept of the
performance envelope can be applied usefully to the transportation system.

The relevant dimensions for evaluation of the effectiveness of the transportation system in
the broadest sense are assumed to be:

- mobility
- safety
- energy conservation
- environmental protection
- affordability
- ability to meet the needs of the economy
- compatibility with lifestyle desires.

Requirements for a major advance in any of these dimensions, in the absence of major
technological advances, are bound to impose serious costs in some or all of the other
dimensions. For example, major reductions in the greenhouse gas production of the road transportation system are bound to have adverse effects on all of the other measures of effectiveness with the exception of energy conservation. Expansion of the performance envelope of the system in as many directions as possible is therefore going to be necessary in order for transportation to be able to make a contribution toward reducing global warming.

It is important to be realistic about the public's tolerance for changes that will adversely impact their lifestyles when we consider the range of alternatives available for reducing the greenhouse gas contributions of transportation. Most of the "demand side" alternatives that are offered for consideration are likely to be extremely unappealing to most of the public:

- restrictions on automobile use
- large increases in fuel taxes
- mandatory use of transit or ridesharing
- substitution of high-density housing for low-density housing
- restricting or prohibiting new development
- requiring use of low-performance vehicles
- mandatory reductions in travel
- significant increases in all travel costs.

The American public is particularly resistant to making changes such as these unless there is an unambiguously clear and present threat to survival. There have been several "shocks" to the body politic within the last few decades that have been strong enough to at least produce a temporary willingness to consider changes in lifestyle or the acceptance of higher costs: Rachel Carson's Silent Spring, the 1973 oil embargo, Love Canal, Three Mile Island/Chernobyl. However, even these tend to fade from memory after a while and people revert to their former ways of doing things. Unfortunately, it is hard to see how global climate change can generate a level of public urgency comparable to these earlier examples, simply because the process of climate change has such a large inherent dynamic lag. By the time it becomes an emergency readily apparent to the "man in the street", it may well be too late to take effective corrective action. The magnitude of the problem and the severity of the corrective actions that would be called for appear to make this a more difficult issue than the other energy and environmental issues cited above.

In order to avoid having the global climate change issue collide with economic and lifestyle concerns that it cannot realistically hope to overcome, it appears to be preferable to rely on technological improvements that can help reduce transportation's production of greenhouse gases
without imposing pain on the public. The IVHS improvements in particular work to improve the productivity of transportation system operations. To some extent, these are more technologically sophisticated versions of the Transportation System Management (TSM) options that were discussed with such enthusiasm in the 1970s but were not very widely applied.

3. **HOW IVHS CAN HELP AMELIORATE GLOBAL WARMING**

The contributions of IVHS to ameliorating global warming (as well as to reductions of pollutant emissions and energy consumption) can best be explained by considering its effects on the supply and demand sides of the ground transportation system. The discussion begins with the demand side effects, and then proceeds to the supply side.

3.1 Demand Side Effects

The development of the demand for transportation services is illustrated schematically in Figure 2. The basic interaction demand arises from economic activity and people’s individual propensities to associate with each other or go places. This interaction demand can be reduced by the substitution of telecommunications for some transportation (telecommuting, teleconferencing) and by spatial reorganization of cities or regions, leaving the actual travel demand as the remainder. The spatial reorganization would require activities that associated with each other to be located closer together, which normally means at higher density. This could apply to industrial production and distribution functions, as well as personal choices of living places relative to work and recreation places. Spatial reorganization is extremely hard to accomplish for existing activities because of its cost and the long economic life of buildings, but it should be achievable for completely new developments.

Travel demand can be reduced by a variety of demand management measures such as those that were discussed in Section II, leaving the constrained travel demand to be served. The IVHS technologies of automatic vehicle identification and vehicle-roadway communication can be used to implement road use pricing, including congestion pricing, in ways that do not perturb traffic operations (not requiring stops at toll booths), and therefore do not impose the additional travel delays and energy and emissions impacts of conventional toll collection. Punitive demand management measures (i.e., those that arbitrarily restrict activity or impose costs exceeding the marginal social cost of an activity) are difficult to implement politically and impose their own set of hard-to-evaluate costs by constraining economic activity. These should therefore be viewed only as last resorts, for consideration when the problem to be solved is serious and too large to be solvable by technological improvements.
Figure 2. Demand Side Effects of IVHS (ATIS).
IVHS improvements generally enter the picture once the constrained travel demand is reached. The important advantage that IVHS offers here is the availability of up-to-date information about all of the available travel alternatives. This enables travelers to choose the most effective mode, departure time and route for a trip, or to choose to forgo the trip if the current travel conditions are sufficiently unfavorable (a particularly bad traffic jam along the way). The availability of comprehensive information about transit and ridesharing services should make these alternatives significantly more attractive than they are today, eliminating many of the uncertainties that now surround their use. This can lead to the reduction of vehicle miles traveled (VMT) without imposing a loss of mobility.

The transit and ridesharing potential of IVHS technologies should not be discounted lightly. The current general unavailability of reliable transit service schedule information is an impediment to more widespread transit use. The total unavailability of real-time information about schedule adherence is an even more serious impediment. IVHS technology makes it possible for accurate bus arrival times to be posted at bus stops, together with information about projected arrivals at destination stops and connections to other buses. The fear of missed connections and uncertain arrival times should be overcome. Availability of real-time bus information via audiotext or videotext in homes, workplaces and commercial enterprises should enable travelers to choose exactly when to leave for the bus stop in order to catch the next bus. This is particularly valuable on bus lines that have infrequent service and in locations with climates that make extended outdoor waits at bus stops burdensome. IVHS technologies also can make dynamic ridesharing and demand-responsive transit services work much more effectively than they have ever been able to in the past, giving them the potential to attract more users and provide service at a moderate cost.

Once a vehicle (single-occupant, shared ride, transit or truck) has embarked on a trip, IVHS technology can provide the driver with comprehensive information about travel conditions on a multitude of alternate routes so that he can choose the one with the least delay. This capability offers the individual vehicle the minimum travel time (or minimum energy or minimum emission) alternative, and at the same time makes the entire traffic system function more efficiently by preventing bottlenecks from getting worse. This means that when an accident or breakdown occurs, blocking a lane, many of the vehicles that would otherwise get stuck in a queue behind it could be diverted to alternate routes, avoiding the added delays, energy waste and emissions. Many drivers try to do this as best they can today, using existing commercial radio reports or information from their dispatchers or fellow fleet drivers. However, the available information is often inaccurate and is almost always too late to be of maximum utility. The availability of up-to-date traffic information about incidents can enable IVHS-equipped
vehicles to significantly reduce their wasted time, energy and emissions, since it has been estimated that more than half of the current congestion is attributable to incidents [1]. The extent of the saving is extremely difficult to estimate prior to the implementation of any extensive systems, but the Mobility 2000 group made an initial estimate of a 35% reduction in delay due to incidents [2]. Equipping buses and vanpools with IVHS in advance of general private vehicles gives these modes an advantage analogous to what they gain now from the availability of separate HOV lanes, increasing their attractiveness relative to single-occupant automobile travel.

Travelers often do not make the most efficient choice of route, even when congestion and incidents do not complicate matters. People may not be aware of shorter or easier routes in their own areas, but the problem of route choice becomes much more significant when people are in unfamiliar territory and can easily become lost. It has been estimated that from 6 to 20% of the distance traveled by road vehicles is wasted because of navigational errors [3,4]. The availability of IVHS navigation devices in vehicles makes it possible to nearly eliminate this source of wasted energy, emissions and time. The effects should be particularly beneficial for rental car drivers in cities away from home and for commercial drivers who need to stop at many destinations in the course of a normal day. The elimination of their extra mileage not only benefits them, but also further reduces congestion in the system as a whole and probably has an even greater benefit in reducing accidents (since a driver who is preoccupied with trying to find an unfamiliar destination is more likely than average to get into an accident because of his preoccupation).

This section has indicated several ways in which IVHS technologies can reduce the demand for vehicular travel (VMT), thereby saving emissions, energy and time:

- making transit and ridesharing services more attractive
- convincing travelers to forgo trips when traffic conditions are particularly bad
- convincing travelers to delay trips until conditions improve
- enabling travelers to find "best" routes to avoid traffic problems
- reducing wasted travel produced by navigation errors.

The IVHS technologies that produce these effects are often characterized as Advanced Traveler Information Systems (ATIS). Their potential for reducing greenhouse gas emissions from transportation will vary greatly from location to location. In relatively small urban areas with little congestion, the improvements may only be in the reduction of navigation errors, and could therefore be only a few percent. In larger areas with significant congestion and well-
developed transit services, the improvements could be anywhere from 10% to 30% as a rough guess, assuming that a large percentage of the vehicles and travelers make use of the ATIS services.

3.2 Supply Side Effects

IVHS technologies can produce significant improvements on the supply side of the transportation system, as explained schematically in Figure 3. These improvements can be gained largely without the addition of any steel or concrete, although they can ultimately have effects comparable to the construction of additional lane-miles of roadway. The nearer-term IVHS technologies enable more efficient use of the existing system infrastructure capacity in a variety of ways, including reduction of accidents and smoothing of traffic flow disturbances. In the longer term, vehicle automation technology can enable the existing freeway infrastructure to handle its current traffic burden virtually without delays, or to even carry much more traffic than it does now, again without delays. The potential for large capacity increases is, not surprisingly, the most controversial aspect of IVHS.

The right side of Figure 3 depicts a variety of IVHS actions that facilitate more efficient use of the present roadway infrastructure. These begin with such seemingly mundane issues as improving the operation of traffic signals. Current traffic signal systems vary widely in their Operations and effectiveness, so the potential for improvement will also vary widely. New technologies for collecting traffic condition information and for optimizing network performance should make it possible to eliminate most of the inefficiencies of current signal operations. For example, the City of Los Angeles has already implemented their Automated Traffic Surveillance and Control system (ATSAC) and has measured improvements of 13.2% in travel time, 14.8% in average speed, 35.2% reduced stops and estimated 12.5% in energy use and 10% in HC and CO emissions [5]. More advanced traffic control approaches than this are under development, so the potential for further improvements is very real.

It has been demonstrated that freeway operations can be improved by limiting the volume of traffic entering at ramps (ramp metering) and by providing advance warnings of problems to be encountered ahead (by changeable message signs). These technologies have been used on a limited basis in a number of cities, but are not yet the norm throughout the country. Observed improvements from ramp metering alone have covered a wide range, including a speed increase of 35% while throughput also increased 32% in Minneapolis-St. Paul and a travel time reduction of 48% with throughput increases of 62% to 86% in Seattle [6]. The warning signs can divert some of the traffic to adjacent streets that have capacity available when incidents occur and can...
Figure 3. Supply Side Effects of IVHS.
also provide enough advance warning to eliminate some of the rear-end crashes that occur when drivers suddenly encounter a bottleneck.

Traditionally, freeway and arterial operations have been handled entirely separately because of jurisdictional differences (freeways being state responsibilities, while arterials are local). IVHS is seeking to break down those jurisdictional barriers so that integrated corridor and areawide traffic management can be applied to produce system-level optimum traffic flows. This will mean the balancing of flows so that the system no longer suffers the inefficiency of having an underutilized roadway running parallel to another one that is being pushed beyond its capacity. The result should be an overall reduction in delay, energy consumption and emissions for the same total traffic volume.

As already mentioned, incidents have been estimated to account for more than half of the delays now encountered on freeways. The impacts of incidents can be mitigated, once they occur, by having the affected vehicles removed from the traffic lanes as soon as possible. IVHS technologies for traffic surveillance and incident detection, as well as communications, make it possible to have emergency response teams dispatched sooner than before so that the duration of the incidents can be reduced. This will permit the full capacity of the system to be restored sooner, cutting down on the delays and excess energy consumption and emissions associated with each incident.

The IVHS capabilities described above for enhancing the efficiency of current operations are normally labelled as Advanced Traffic Management Systems (ATMS). The overall impact they can have on production of greenhouse gases will depend in large part on how inefficient the current operations are. In locations where the current operations are already reasonably good, the improvements may only be of the order of 10%. However, there are many places where the current traffic operations are quite poor and there could be improvements of as much as 20% or 30% with full application of the ATMS technologies [2].

IVHS technologies have already been used in a limited fashion by various large fleet operators, with their two-way communications between vehicles and dispatchers (transit buses, taxis, delivery trucks, emergency services, etc.). Areaize IVHS systems will make these fleet operations even more effective, particularly by providing them with real-time traffic condition information so that they can really optimize their routing and scheduling. The benefits of large fleet operations information can also become available to even the smallest fleets. The effects of this should be more efficient operations, requiring fewer vehicle miles of travel to satisfy the needs of all their customers. For interstate truck operators, further benefits of IVHS technology
can be gained by electronic waybilling, nonstop border crossings, weigh-in-motion and two-way communication with dispatchers. All of these help to eliminate unnecessary stops, which cause significant delays and frustrations for drivers, while also wasting energy and emissions as truck engines idle unproductively. This special class of IVHS capabilities for fleet operations is normally referred to as Commercial Vehicle Operations (CVO).

The significant contribution of accidents to our urban congestion problems has already been cited several times. One class of IVHS technologies is aimed specifically at avoiding accidents by giving the driver a warning of an impending collision so that he can take corrective action, and then taking the corrective action itself if the driver does not respond. Widespread use of such systems could eliminate some of the accidents we have now and could therefore also eliminate the congestion resulting from those accidents. This would make the "full" capacity of the existing road system available for more of the time than it is now.

The peculiarities of drivers' vehicle-following behavior tend to make disturbances in vehicle flow propagate upstream when traffic density is high. This means that a modest brake application by one vehicle to accommodate a lane change by another vehicle becomes a harder brake application by the next vehicle, and so forth until some vehicles further upstream are brought to a dead stop. Driver control assistance systems, such as "adaptive cruise control", may be able to damp out these disturbances so that they do not lead to the "stop and go" phenomenon we experience so frequently nowadays. The resulting smoothing of traffic flow should save time, energy and emissions, as well as probably reducing the rear-end collisions that sometimes result from the propagation of flow disturbances.

The warning and control assistance systems just described are normally referred to as the first stage of Advanced Vehicle Control Systems (AVCS I). With significant market penetration, they should be able to reduce rear-end and sideswipe collisions and thereby eliminate a significant portion of the nonrecurrent urban freeway congestion we now experience, with a consequent reduction of greenhouse emissions. In large and congested urban areas, this may amount to a reduction of as much as 10%, although considerable research will be needed to determine the magnitude of the reduction with any degree of confidence.

The driver's perceptual and motor response inaccuracies and sluggishness are the primary limitations in the performance of the current roadway-vehicle-driver system. Any dramatic improvement in the capacity, productivity or safety of the system will require the driver to be supplanted by electromechanical systems with higher performance. Modern control technology can be used to steer a vehicle and control its throttle and brake systems as well, so that it
follows the intended lane and maintains the proper spacing relative to all other vehicles on the roadway. Research is in progress to refine and demonstrate these more advanced vehicle control capabilities (termed AVCS II and III) [7]. Preliminary feasibility studies indicate that application of these AVCS II and III technologies could double or triple the capacity of a freeway lane, while significantly improving safety as well. The implications of such a dramatic change are obviously significant to the transportation supply system.

The immediate effect of application of AVCS II and III technologies to one (existing) lane of a freeway could be comparable to the effect of adding one or two new lanes. Severe congestion can be replaced by free-flowing traffic immediately. If parallel routes in the immediate area are also congested, the new freeway capacity may cause some of that traffic to divert, diminishing the benefit to the freeway users but improving the situation on those parallel routes. Stop-and-go arterial trips could become smoothly flowing freeway trips, with consequent reductions in production of greenhouse gases (as well as reducing energy consumption and other pollutants). The magnitude of the improvement is difficult to evaluate, and will vary significantly from one vehicle to another, but could be viewed as analogous to the difference between the EPA city and highway fuel economy ratings.

The significant increase in available road capacity should produce a readily apparent short-term reduction in congestion. This can lead to an increase in trip making, as people decide to take trips that they would have formerly forgone because of excessive congestion. Satisfaction of this latent travel demand confers a societal benefit in terms of increased mobility and potential contributions to economic activity, but it also leads to increases in VMT, energy use and emissions. The net effect is likely to vary significantly from place to place, depending on local conditions, making it difficult to say whether the improvements gained on all of the pre-existing trips will outweigh the contributions of the new (formerly latent) trips.

3.3 **Long-Term Supply Side Effects of Major Capacity Increases**

The development of urban regions has always been inextricably tied to the development of transportation systems. The transportation-land use interaction is extremely complicated and has yet to be modeled with sufficient fidelity to produce useful predictive tools. However, the basic trend of real estate development following transportation system improvements is well documented. Improved accessibility obviously makes land more valuable and useful. This means that if we were to implement AVCS II and III systems to dramatically increase freeway system capacity, we could expect new land developments to be stimulated in the areas served by those systems, generating more trips and perhaps eventually saturating their expanded
capacity. If the effective speed on the new systems were twice the speed on the existing congested system, people might choose to live up to twice as far from their workplaces without having to spend more time traveling. This could open up new areas on the urban fringes to development, where people could afford more space to spread out and enjoy a less crowded lifestyle. Of course, this is exactly the formula for the development of the suburban sprawl that we have experienced during the past four decades of automobility. It could also lead to significant further increases in transportation energy consumption and emissions.

The foregoing argument makes it appear virtually impossible to achieve net transportation system improvements over the long run. That is a consequence of permitting unconstrained land development to follow transportation system improvements and of pricing individual travel below its marginal social cost. In one sense, the damage is already done in the modern American cities of the West, which have developed in response to the kind of mobility afforded by the automobile and the freeway. Their essentially low density development pattern cannot be effectively served by less wasteful modes than the private automobile. New development patterns can only be expected to arise in response to insurmountable problems with the old pattern or the availability of new, superior transportation modes. The very high capacity AVCS II and III systems offer the latter possibility.

Implementation of AVCS II and III systems needs to be coupled with careful land-use planning and regulation, so that unchecked sprawl is not encouraged. AVCS systems with a limited number of access points at the urban fringe can be combined with zoning for high-density cluster development at those access points to encourage a more efficient pattern of land use, rather than continuous sprawl. The access points within the developed part of the region can also be targeted for higher density development to discourage growth in VMT.

4. CONCLUSIONS

Attempts to limit the transportation system's contribution to greenhouse gas emissions are in direct conflict with economic development and people's desire for mobility. This conflict can be eased by technological improvements that "expand the envelope" of feasible alternatives. IVHS technologies can provide these improvements on both the supply and demand sides of the transportation system, but in general the IVHS improvements are measured in the tens of percents, not in factors of two or ten. The one aspect of IVHS that offers the potential for dramatic improvements in transportation system performance is not necessarily beneficial on the energy and environment side because the improvements are so dramatic that they could lead to
increases in tripmaking.

This dilemma reinforces the importance of taking an integrated approach to addressing the coupled problems of congestion, safety, energy, air quality and global climate change. Focusing on only one or a subset of these is likely to produce distortions with respect to the others. Broadly-conceived system engineering work is needed to evaluate the impacts of competing alternatives on all of the problem areas.

The institutional environments surrounding the different problem areas are quite distinct from each other, and they even involve different agencies that do not communicate very effectively among themselves (at the federal level, Federal Highway Administration, National Highway Traffic Safety Administration, Environmental Protection Agency and Department of Energy). The issues become even more complicated at the state and local levels, where jurisdictions overlap in often bewildering ways.

The environmental problem solutions have been driven very strongly by regulatory pushes, while the energy and safety problems have had somewhat less vigorous regulatory pressure. In contrast, the mobility or productivity problems have had almost no regulatory involvement, but have had to rely on market pull (or the potential of future market pull) to encourage activity. The result has been that, in an era of limited financial and technical resources within the U.S. automotive industry, the environmental problem solving has taken first priority. The safety and mobility issues, which have stronger potential to influence consumers’ market choices of vehicles, have had to receive lower priority. In contrast, European and Japanese companies have viewed these issues as significant marketing opportunities and have concentrated considerably more effort on IVHS than their U.S. counterparts.

This serves to reinforce the need for broad-scale system thinking, so that the regulatory and market incentives can be rationalized and so that the complete set of coupled transportation problems can be addressed together rather than in competition with each other. Only by explicitly recognizing the inescapable coupling of the different problems do we stand a chance of developing solutions that make sense for all of the problems.
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REFERENCES


