Policy Implications of Driver Information Systems

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ABSTRACT

The potential impacts of driver information systems (DIS) have strong policy implications for traffic management authorities. The privacy and standardization issues are of major concern immediately in the implementation of electronic toll collection. Road pricing, a simple technical extension of toll collection, has profound policy implications in terms of political acceptability. Real-time traffic information is being provided by an increasing variety of technological systems with financial viability, and their market acceptance and dominance can strongly influence the future direction of dynamic route guidance. Public authorities will have to make policy decisions soon regarding their roles in facilitating multijurisdictional agreements on traffic diversion and in facilitating multimode transport choices to be made by travellers. In the area of driving assistance, policy decisions may help early implementation of automatic emergency signaling, while the issues of safety regulations and legal liability need to be settled before a host of technologies for driving assistance can become marketable. Those DIS functions which are to provide business and personal information do not seem to have any direct policy implications for traffic management. However, to the extent that such DIS functions affect the efficiency and regulation of transport, and affect the marketability and future standards requirement of DIS in general, traffic management authorities cannot ignore such DIS development as well. The mutual impacts between policy making and technology management are so intertwined that frequent in-depth exchange of views between policy and technology developers should be routinized through joint projects and periodic reviews.

INTRODUCTION

The rapid development and amalgamation of information technology with automobile and road technologies have given rise to new programs in Intelligent Vehicle-Highway Systems (IVHS) in Europe, Japan, North America, and other parts of the world with the objectives of improving road transport efficiency, safety, comfort, and environment. Driver Information Systems (DIS) are one of the important components of IVHS that is developing rapidly and is primarily centered on the vehicle to provide the motorist with the information of interest to him.

The newness and the evolving nature of DIS are such that the potential impacts of these systems and the associated policy implications are difficult to predict. Technology developers and promoters understandably have concentrated on the potential benefits — individual and social — of these systems. Most of the impact assessments typically raised and tried to answer such questions as how much traffic delay (in terms of percent or absolute vehicle-hours) can be reduced by dynamic route guidance, and how much such reduction would mean economically in tangible terms [e.g., see Mobility 2000's Operational Benefits Report, 1990]. Policy issues were brought up occasionally in these assessments but raised only sporadically and for the purpose of considering how to circumvent them by technology [e.g., see Mobility 2000's Advanced Driver Information Systems Report, 1990].

There have been some efforts to assess the impacts and policy implications of IVHS in Europe [e.g., Gillan, 1989; Stoneman, 1990; Karlsson, 1990], as well as in the United States [e.g., Vostrez, 1989; Chen and Ervin, 1990]. However, most of the publications have either treated IVHS in general, or discussed only a selected issue (e.g., legal liability) separately. Given the rapid development and deployment of DIS, there appears to be a need to provide a comprehensive framework for policy makers and advisors to monitor, assess, and influence the future development of DIS from the perspective of traffic management authorities. The objective of this paper is precisely the development of this needed framework. The work in this paper was based principally on the author's interviews in late 1990 with a number of organizations in Europe engaged in selected PROMETHEUS and DRIVE projects, through which considerable amount of information not available in the open literature was obtained. However, relevant information was also drawn from the author's knowledge of IVHS activities in Asia (especially through 5-week interviews in Japan in early 1991) and in North America (especially through IVHS activities at the University of Michigan). The Michigan program has been emphasizing advanced traveler information systems (ATIS), of which DIS is an essential part.

For the purpose of this paper, four categories of DIS will be considered:

(1) Toll collection and road pricing
(2) Traffic information and route guidance
(3) Driving assistance
(4) Business and personal information

On the surface, it appears that only the first three categories of DIS would have policy implications for traffic management authorities. However, as will be discussed later, even the fourth category of DIS has at least indirect policy impacts of concern to traffic managers.

Since DIS is that part of IVHS which involves a great deal of technological development within the private sector which will market DIS products with or without complementary investment by the traffic management authorities, cost estimates of marketable DIS are an essential input to the task of assessing realistic policy implications of DIS. Through interactions with a number of private firms, the author has assumed that, in the foreseeable future, the mass market for DIS will support "low-end" in-vehicle units (IVUs) in the order of a few hundred dollars, or the cost of a luxurious car radio or an automobile air conditioner. The "high-end" IVUs can probably sell for a few thousand dollars, or about 15-20% of the price of a luxurious car. For commercial vehicle operations (CVO) and for infrastructure investment by the public sector, tangible cost-benefit analyses will constitute the basis for the necessary justification for DIS investment. However, this may not be sufficient as there are other policy issues such as privacy, safety, etc. which will be discussed in this paper. The point that should be made at the outset is that many of the policy implications of DIS are intertwined with the specific technologies to be used for DIS and their costs to the users. Therefore each section of this paper will mix technoeconomic descriptions of DIS with policy-relevant discussions.

TOLL COLLECTION AND ROAD PRICING

Electronic toll collection is an IVHS technology ready for deployment. The current technology is centered around automatic vehicle identification (AVI) using electronic transponders. It may be considered the first wave of IVHS technology entering the mass market. At a relatively low cost (around 10% of the normal toll) and with high reliability (about 99% accurate), both the efficiency of road travellers and the efficiency of infrastructure toll collectors can be increased substantially. In some installations such as the Crescent City Connection bridge across the Mississippi River in New Orleans, the public authorities share their savings by offering a 30% discount of tolls for the AVI-equipped vehicles [Paisant, 1991]. In addition, the non-equipped motorists also benefit from the shortening of the queues as the equipped vehicles zip through the toll booths without stopping. It appears to be a "win-win" arrangement for all major stakeholders.

Using related but expanded technologies — not just AVI, but also automatic vehicle classification (AVC), weigh-in-motion (WIM), computer integration and communication links — the Heavy Vehicle Electronic License Plate (HELP) Program in the "crescent" states in North America, extending from British Columbia down the Pacific coast to Arizona and Texas, has reached the stage of large-scale demonstration [Walton, 1990]. With the anticipation of success, there are other HELP-like projects such as Advantage I-75, for the north-south corridor from Florida to Michigan along Interstate Highway I-75 with possible extensions to Canada [Kentucky Transportation Center, 1990].

There are two basic technologies for the AVI transponder. The ones available on the market operate at a UHF (typically around 900 MHz or around 2.5 GHz). One basic technology uses the surface acoustic wave (SAW) approach, which has the advantage of being passive (no battery on the tag) and low power emission but has the disadvantage that the code number or message stored in the transponder cannot be modified after being set during production. The maximum number of digits that can be stored in the SAW tag is also relatively small (about 10 characters).

The other basic technology uses an electronically erasable and programmable read-only memory (EEPROM) chip, which can have its code number or message modified electronically. The EEPROM chip may be passive or active. Since the passive chip requires power from the interrogator antenna to get activated momentarily, the power level needs to be relatively high, especially if the distance between the interrogator and the tag is relatively long. This high power level has caused some environmental concern [Cunningham, 1990]. For example, none of these passive tags can meet the relatively stringent Soviet standards for safe microwave environment. On the other hand, the tag may be active by having its own battery, such as a lithium battery that can last up to about 5 years. The active tags can respond with much longer messages (in the order of 100 characters) and at a farther distance, as well as operate at lower power levels.

There are other basic approaches to AVI; for example, optical bar-codes on the vehicle or video character recognition system to read numbers off the vehicle license plate. However, these systems are either much more expensive than AVI or would not work satisfactorily if the license plate or the bar code is covered with dirt or snow. Thus, some of these systems are used mainly for catching violators rather than for routine toll collection.

The existence of several AVI technologies and automatic toll collection system designs gives rise to the issue of standardization, which is getting hotter as this category of DIS application spreads and as the various vendors vie for market share and market dominance. As in the case of other information technologies such as computers, there are two general approaches to standardization. One approach is in the marketplace, where the market leader sets the *de facto* standards and compel other suppliers to go along with an obvious disadvantage since the inner working of the standards is often opaque and proprietary. The other approach is in the conference room, where committees consisting of major industrial suppliers, often with the involvement of major users, public authorities and academicians, try to agree upon a minimum set of standards that will allow multiple vendors to co-exist with mutually compatible hardware and software products. The market leader approach may be considered as an unfair practice to the dominated suppliers, but is realistic and works as fast as the market penetration. The committee approach has usually come up with more open systems that favor the users, but involves a slow process that often appears wasteful and can be overtaken by the market leader approach. Both approaches are being used for automatic toll collection in North America and in Europe. However, the market leader approach appears more dominant in North America while the committee approach has been pursued at least with an earlier start in Europe. The DRIVE project known as VITA (Vehicle Identification and Transaction Aid) seeks to define and evaluate systems for data exchange between motorway control centers and users, and is run by the motorway toll operators' associations of France, Italy and Spain, which collect tolls on about a third of Europe's motorway network. Another effort is through the European User Committee on Automatic Debiting (EUC). This committee consists of representatives from all European Governments actively interested in automatic debiting, together with other major toll facility operators, and provides a forum for the discussion of progress towards a standardized European system for automatic debiting [Catling, 1990].

Perhaps one important reason why standardization for automatic toll collection has been, and perhaps should be, slowed down is the yet-to-be-resolved issue of privacy. The functioning of the toll collection systems that have been described assume that the equipped users have no objection to their identity revealed to the system, thus allowing their whereabouts at what time knowable to those having access to the system. One way to reduce this concern is to use a technology similar to the prepaid phone cards, whose users' identity is not knowable to the telephone system. This concept has also picked up support from those who would like to see a multiple application transport card [UK Department of Transport, 1990] that can be used for public transport, parking, and transport-related expenses such as gasoline purchase. In North America, the same concept has been suggested for providing transport services to welfare recipients who need dial-a-ride or public transit vouchers [Fisher, 1990].

While phone cards have been used in Europe for a number of years with success, the adaptation of the concept to "smart travel card" for automatic toll debiting and other related applications is technically not quite straightforward. Firstly, for automatic toll collection, unlike the pay phone case, there can be no contact between the smart travel card and the interrogating system. Secondly, the required 2-way communication will be a dialog, and not a 2-way monolog as described previously, since the amount to be debited on the smart travel card will depend on the location and the time of the interrogator signal — and the complicated dialog needs to be completed within a short time if the vehicle is not required to slow down excessively.

Moreover, it has been pointed out [Queree, 1990] that the above smart travel card concept would not guarantee complete protection of privacy because of the need to catch violators, or to bill the motorists when the system is not working perfectly — the current systems have only 99% reliability, as mentioned previously. Unlike phone card violators who cannot get phone service when their credits run out, smart travel card violators can go through toll booths at high speeds without payment. The most practical way to catch them is to photograph their license plates, and this method would certainly intrude the violators', or presumed violators', privacy.

On the other hand, smart cards technology has been developed to the stage of practical applications. As automatic toll collection spreads to the general public such that there may be millions of users in a single metropolitan area, the AVI technology which needs to check the balance of each account, may not be able to handle the mass market. Under these conditions, the smart cards technology may become a necessity [Perrins, 1990]. Thus, those working toward a standard for automatic toll collection will have to balance all these factors of technology feasibility, costs, reliability, the preservation of multi-vendor competition, and the protection of privacy. These factors will be further complicated by the concern and interest in promoting, and facilitating, multimodal transport for various interest groups, including the welfare recipients and the goods moving industry.

As indicated previously, electronic road pricing in its primitive form is technically a simple extension of electronic toll collection. There are two general types of road pricing: (1) the charge for the use of a road, which has long been in practice for toll roads, regardless whether the toll is collected manually or electronically; and (2) the charge for keeping a vehicle in a particular district, no matter whether the vehicle is in motion or not (analogous to having the vehicle in a large parking structure). It is the second type of road pricing which has been seriously proposed to be put into practice recently and which has been particularly controversial.

The concept of road pricing as a means for demand management has been attractive to economists who argue that excessive congestion is a phenomenon of inefficient allocation of scarce resources. An efficient way to reduce congestion is thus to introduce a market mechanism to road transport. Without road pricing, more road building would simply attract more traffic to the new roads and the previous level of congestion returns as the system seeks a new equilibrium. In the long run, the only way to reduce congestion is by charging the less urgent users — some opponents would say the less affluent users — sufficiently to keep them off the congested routes. While this concept is not new at all, the low-cost electronic means to make road pricing practical is new and has given the concept a new life [Small, Winston, and Evans,1990].

Road pricing has many opponents. Besides those who feel that road pricing favors the rich, the strongest public sentiment against road pricing is its appearance as another tax. The general public feels that they have already paid too many taxes. Moreover, the high gasoline taxes at both the national and the state levels have not been used entirely for road construction and maintenance. Why not use some of those taxes for roads instead of charging more for road use?! All the car manufacturers and most of the highway users are against road pricing [Lamm, 1990], which is considered as a deterrent for automobile travel and another potential imposition to favor public transit versus car use. The privacy issue as discussed previously has also been raised as a negative factor by the opponents of road pricing which is to be implemented with AVI.

On a rational basis, the proponents of road pricing seem to have answers to all the objections that have been mentioned [Green, 1990]. For example, reduced rates may be charged to the poor; privacy may be protected by the use of anonymously prepaid smart cards; *etc.* Depending on the economic assumptions made, no net increased taxes or costs would result from road pricing; families would be induced to own multiple vehicles; and the automotive industry might even get a 13% increase of market [Karlsson, 1990]! While this debate continues, resolution of the key issues and consensus forming would be difficult without some field experiment.

It is interesting that the serious experiments and implementation of road pricing to date have been in Hong Kong and Singapore rather than the well industrialized world. The first attempt of electronic road pricing was made by Hong Kong in the mid-1980s, where motor traffic congestion and pollution in the central business district became intolerable. However, even after money and efforts had been spent to install such a system, it was never put to use due to political unacceptability. In a recent interview by the author, the Hong Kong authorities [Siu, 1991] attributed the public rejection to the unfortunate timing in the road pricing installation. The Hong Kong authorities did not anticipate that, shortly after the installation, UK and China signed the treaty to have Hong Kong reverted back to China in 1997. The Hong Kong populace became highly suspicious that the road pricing system might be the beginning of Big Brother watching the residents' movement. Thus, although road pricing is still an official policy in Hong Kong, the authorities resorted to an increase of car ownership taxes as the more practical means to achieve a marked, though perhaps temporary, traffic reduction in Hong Kong.

In Singapore, a manually operated road pricing system (an Area Licensing Scheme) to keep most of the motor traffic from its central business district has been in operation since the mid-1980s. The scheme was highly successful in reducing traffic congestion in the central business district. In fact, it was overly successful to the extent that the roads became highly underutilized in the district, and the price was reduced from Singaporean $5 to $3 for any vehicle to enter the restricted zone during "peak hours." [Field, 1991]. Recently Singapore has planned to convert their road pricing system from manual to electronic. A number of bids had been received from Europe, Japan, and North America before they were all rejected. The main reason for the rejection was that none of the bids could satisfy the technical requirements of reliable reading of all vehicles in multi-lane traffic as well as the concern of privacy. However, AVI on busy multi-lane city roads has been an active R&D activity [e.g., Doh, 1991] even though no such system with sufficient reliability is available on the market at the present time.

In Europe, there is a joint manual and automatic toll cordon for Oslo, Norway, and similar plans are under consideration for Stockholm, Sweden. The Dutch Government initiated the now-tabled "Rekening Rijden" (traveling accounting) project which was due to implement the first part of the road pricing system by 1992, with complete coverage of the Randstat (Rotterdam, Amsterdam and the Hague) by 1996. In the United Kingdom, serious consideration for road pricing has been coupled with very innovative ideas for its implementation. For example, a "Timezone" concept has been proposed for London, which would be ringed with roughly concentric circles representing progressively more expensive tolls as one approached the center [Green, 1990]. This approach would prevent traffic diversion at zone boundaries as has happened around the central business district of Singapore, causing congestion around its boundaries. An even more radical concept, known as "congestion metering", is under consideration by the City of Cambridge [Oldrige, 1990]. Unlike the usual road pricing scheme as in Hong Kong, where a congested zone is predetermined and a fixed fee for entry is charged whether the zone turns out to be congested or not, congestion metering will levy a charge only when a vehicle experiences actual congestion (defined by a threshold of vehicle speed and/or numbers of stops per unit distance). It is believed that such a scheme will induce a more economically rational behavior from the driver and will result in more effective relief of congestion.

It has been reported that the high-level officials in both U.K. [*Inside IVHS*, 1991a] and U.S. [Van Ness, 1991] have shown some serious interest in road pricing. Given the potentially significant impact on road congestion and the rough path taken by road pricing in the past, it would be important for any transport authorities to monitor the above-mentioned projects around the world. It is not sufficient just to see whether a proposed road pricing systems gets implemented or not, it would be important also to find out how the system will actually be operated, how the compliance will be enforced, and how much impact — intended and unintended — will result from its implementation.

If road pricing is to have a future, various scenarios of its implementation must be considered and planned for. The general public sentiment must be taken into account. One possibility is to introduce the concept as a natural extension of what the public is already familiar with; *viz.*, pay for parking, even if parking is on public roads — as alluded to previously in this paper. The joint discussion among all European governments on automatic debiting through such organizations as EUC mentioned previously would help develop a consensus towards the best approach to electronic road pricing.

Finally, the transponders used for automatic debiting may be used for other DIS communication purposes beyond toll collection and road pricing. As will be discussed in the next section, traffic information and route guidance may also be provided by these transponders doubling up as beacons, especially if two-way dialogs are to be considered for automatic debiting from smart travel cards. If a single port is to be kept for all DIS communication purposes between the vehicle and the outside environment, whatever is decided for toll collection may affect the practical choice for route guidance and other DIS functions. Thus, the early and dominant market penetration of a specific AVI approach and its *de facto* standard may pre-empt the development of other DIS applications to be discussed later in this paper.

TRAFFIC INFORMATION AND ROUTE GUIDANCE

Traditional and various new technologies have been used to provide limited but real-time traffic information to the driver for him to make timely and appropriate strategic decisions on route choices. The cost to the driver ranges from negligible (as in changeable message signs) to the order of $350 (as in some examples to be given later), depending on the degree of timeliness and relevance demanded. When the situation gets complicated and when the driver is in a strange territory, he would like to get advice on which route he should take to get to his destination. The cost for getting such competent route guidance is substantially higher — in the order of $3,500 per vehicle, although the cost could be lowered significantly if the information storage and processing is shifted from the vehicle to the road infrastructure. In general, when a driver is diverted to a better route for himself, other drivers would also benefit. However, as will be discussed later, this is not necessarily true in all circumstances. In addition, the neighborhood to which the driver is diverted may not like it. Since there are potential winners and losers, there is a distinct need for the traffic management authorities to play a role in this category of DIS application.

For years, real-time traffic information collected by traffic management authorities has been provided to the general public, including drivers on the road, through commercial and public radio and television stations at no incremental cost to the users. However, such information may not be timely and relevant enough to help drivers make strategic route choice decisions. Even dedicated traffic stations (Highway Advisory Radio or HAR) may give too much irrelevant information and the driver may not tune to these stations at the critical moments for decision making. On the other hand, the incremental cost to the driver for these services is negligible since most car radios can tune to these dedicated stations just as easily as to other stations. To assure that the driver does get new significant traffic information when it becomes available (such as after a major incident has been identified), automatic HAR (AHAR) radio has been designed to turn on the radio, or interrupt other audio devices and programs, and automatically tune to the HAR station with the latest information [Turnage, 1982]. However, the added cost of the AHAR has not made it very marketable, and most HAR stations have not been sending out the automatic interrupting signal to make AHAR work.

Over the past decade, changeable or variable message signs (CMS or VMS) have been installed at critical segments of motorways but the high cost to the traffic management authorities is such that the number of these signs is deemed insufficient. Also, the limited space on these signs has been blamed for not having given understandable and sufficiently detailed information for the driver to make new route decisions with confidence.

Recently radio data systems (RDS) have become available in Europe to provide low-rate (about 1,000 bits per second) coded information to properly designed receivers, utilizing the sidebands of the frequency spectrum assigned to the broadcaster. Originally designed to provide program identification and alternative frequencies for better reception of the desired radio program or program type, RDS is now being promoted to provide real-time traffic information through a traffic message channel (TMC), which may provide effectively 74 bits per second of traffic information codes to specially equipped radios [Thomas, 1990].

In general, North America is behind Europe in RDS implementation. As of January 1991, there were only 12 RDS stations in the U.S., of which 5 were put in Detroit by Delco Electronics in January 1991 [LeBow, 1991]. However, RDS is moving ahead in the U.S. vigorously, and RDS for traffic messages will be field tested in Detroit as a part the IVHS activities under the Michigan Department of Transportation [MDOT, 1990].

There is an active European project working on the standards of RDS/TMC [Davies and Eng, 1989]. As indicated above, the output may be in the form of textual and/or synthetic voice displays — textual display may be more distractive but would not interfere with, or require interruption of, other audio programs. For owners of high-priced (around $300) car radios, the added cost of acquiring the RDS feature is quite marginal. The cost to the stations to add RDS features would be in the order of a few thousand dollars, and the incentive for them to make the investment could be significant due to competition. To go to TMC, however, there would be additional infrastructure costs for traffic data collection and collation, and for message management systems.

While the European RDS standards have almost been set, the Japanese have not been satisfied with these standards and have been developing and testing new approaches, using more sophisticated digital modulation schemes and error correcting codes. One of their FM multiplex broadcasting approaches has been tested for mobile reception, and promises to provide much higher bit rates than the current European approach — 10 to 12kbps versus 1kbps [Yamada, 1991]. These high bit rates can be used to transmit a great deal more traffic information and even projected link times (to be discussed later under route guidance) without the need for additional frequency spectrum. Given the still fluid situation regarding RDS in North America, it behooves the traffic management authorities to work with telecommunication policy makers there to review all the competing schemes of RDS before the final standards are set.

Another way to provide traffic information at a marginal cost to owners of high-priced communication equipment in the vehicle is the use of car phones, which typically cost $350 including installation plus user charges. The number of cellular car phones in the United States is growing rapidly, approaching 10 million in the foreseeable future. A car phone owner can call a particular number for real-time traffic information relevant to him at a marginal cost if such information is collected, sorted, and distributed. The Michigan Metropolitan Transportation Center has a plan to do a field test on such cellular call-in services, along with HAR, AHAR, as well as RDS in the coming year in order to compare their relative effectiveness [Michigan Department of Transportation, 1990].

The latest technological system on the market for providing real-time traffic information is the TrafficMaster, which has been in operation for the London area since mid-1990 [Martell, 1990a]. Average vehicle speed in the fast lane of the motorways around London (M25 and a limited range of other motorways connecting to it) is automatically measured every 2 miles and reported every 3 minutes by infrared sensors. When the speed drops below a threshold of 25 miles per hour, the average speed and location of the congested segment are transmitted over a paging service frequency to owners of the TrafficMaster's simple map display unit, which may be carried by the owners as well as put on top of their vehicle dashboards. For more relevant information, the user may choose to focus on only one of the four quadrants of the M25 ring-shaped motorway. Paging service is also available as an option. The price of TrafficMaster is about $500 for the portable unit, plus about $32 per month service charge, with another $30 per month for the paging service option. By late 1990, there were about 300 customers (35-40% of whom chose the additional paging option), and the number was expected to reach 5,000 by September 1991. Since the breakeven point is only about half that number, TrafficMaster's financial viability appears very promising [Martell, 1990b].

From the perspective of the traffic management authorities, there are at least two policy issues related to traffic information. The first has to do with the fusion and authentication of traffic information, and the other is the concern about potential risk of near-term success of a specific traffic information provider pre-empting certain forms of dynamic route guidance which must use real-time traffic information.

Historically the responsibility for collecting traffic information lies solely with the traffic operation authorities. Sources of data range from loop detectors, remotely controlled television cameras, police reports from highway patrols and helicopters, and emergency calls from citizens. Each of these sources has its peculiar problems. The policy question is how to combine and fuse the new and conventional sources to provide the highest quality traffic information at the lowest cost. There is a need to consider not only technical issues, but also institutional ones, such as the fusion of information from multiple jurisdictional units (local authorities, weather bureau, etc.) and trading information with new private sources.

As in any private service-providing activities, there is a risk of "cream-skimming" so that the easiest and most profitable services are provided while the more difficult but perhaps much needed services are neglected. For example, TrafficMaster has focused on M25 not only because it is the most travelled motorway, but also because the average speed can be measured most conveniently and the operating company needs to deal with only one public authority; *viz.*, the UK Department of Transport. It is encouraging to learn that TrafficMaster has recently considered expanding to the arterials (the A roads) in the London area [*Inside IVHS*, 1991b]. Questions may still be raised, however, as to whether the future extension of TrafficMaster may never measure the traffic in other routes (the B roads as well as the A roads outside of London) which go through multiple jurisdictions and which may provide the best alternative routes for some of the drivers. Also, would the success and dominance of TrafficMaster prevent other service providers to market the more sophisticated systems? To be fair to TrafficMaster, similar questions may be raised with any of the traffic information schemes described previously.

If a driver on the road just wants to find his way to his destination under normal traffic conditions, he can use static route guidance, which does not require real-time traffic information and thus can be autonomous. However, he does need to know where he or his vehicle is located, and he needs the road network or up-to-date map information. The three basic navigation systems for IVHS are dead reckoning, LORAN (a long-range maritime navigation system which has been applied to vehicle location on land), and GPS (global positioning system) based on satellites. Each can be augmented by map matching and all can be used to complement one another. The map matching algorithm is based on a form of artificial intelligence which helps to correct navigation errors [Honey and Zavoli, 1986]. At present, Loran C is most widely used for commercial and government vehicle location and fleet dispatch in North America but is not universally used around the world. On the other hand, GPS is relatively least applied in North America since not all the satellites are in orbit for 24-hour coverage and the per unit receiver cost has been rather expensive for most users. However, commercial receivers for mass production are being developed and, with the help of low-cost offshore manufacturing, the per-unit cost can become only a few hundred dollars.

Philips' CARIN system and Bosch's TravelPilot system are capable of providing static route guidance through a combination of dead reckoning and map matching with the digital map information stored in a magnetic tape cassette or a compact disk. A major difference between the two systems is that CARIN guides the driver via a display of directional arrows while TravelPilot accomplishes the same purpose via a display of an electronic map which shows the current location of the vehicle and the destination. Most drivers find it less distractive to follow the directional arrows while driving but prefer to have the map information for an overview of the total route. To cover a wide area of possible travel (*e.g.*, Western Europe or the entire U.S.), the most practical way to store the vast amount of map information is through the use a compact disk system, which has been rather expensive. For example, TravelPilot with compact disks has just begun to sell for about $3,500 in the U.S. although the price is expected to drop with an expanding market — hopefully to below $300 after 4 years [Braegas, 1990]. This may be compared with currently available navigation systems with GPS plus dead-reckoning and map-matching for over $4,000 in Japan, where compact disk drives can be acquired for as low as a few hundred dollars, substantially below the cost of those drives in Europe. In any event, a fully functional navigation system is probably too expensive in the near future to be accepted in a "baseline" IVHS system for the mass market in the U.S. [Ristenbatt, 1991] This is an important point for the public authorities to consider if privatization of IVHS is an important goal.

Since one of the major frustrations in driving is to get caught in unexpected traffic congestion, dynamic route guidance which takes into account real-time traffic information in route guidance is highly desirable. Dynamic route guidance is by no means a new concept. Over the past 20 years, there have been three discernible generations of such systems [TARDIS, 1990]. The first-generation systems include ERGS in the U.S. [Rosen, Mammano, and Favout, 1970], CACS in Japan [Yumoto *et al.*, 1979], and ALI in Europe [Braegas, 1980] — all programs in the 1970s — using low-rate inductive loops for communication. For example, CACS transmitted 144 bits of information at each junction at a rate of 4.8 kilobits per second [Kawashima, 1991a]. The second generation is typified by Ali-Scout [von Tomkewitsch, 1991], whose development began in the early 1980s, using beacons for short-distance communication at major junctions. At each junction, the beacon transmits 8 kilobytes of information at a rate of 125 kilobits per second. (The next generation of Ali-Scout, known as Euro-Scout to be ready by 1992, will transmit 30 KB at 500 kbps [Sodeikat, 1990].) The third-generation systems include CARMINAT [Renault, 1990] (one-way wide-area communication into the vehicle via RDS), SOCRATES [Catling, 1990], and ADVANCE [Kirson, 1991] (two-way communication via a digital cellular radio link), which are systems under development in the late 1980s and early 1990s. In these systems, information will be transmitted <u>continuously</u> as well as at a relatively high rate — around 9.6 kbps in SOCRATES [McQueen, 1991]. As we progressed from the first to the third generation, the required number of equipped junctions on the infrastructure decreased while the typical cost of in-vehicle unit (IVU) increased (from $80 to $250, to an estimated $800, hopefully, for the third generation IVU at a mass production level).

It is interesting to note that the first two generations of dynamic route guidance systems are infrastructure-based while the third generation is primarily vehicle-based. The former searches for the best routes with equipment on the infrastructure (such as in the case of Ali-Scout), while the latter does that with equipment on board of the vehicle (such as in the case of CARMINAT). It is important to discuss the policy implications of these two types of systems. First is the financial implication which may affect the system viability. Infrastructure-based systems naturally put major capital investment requirements on the infrastructure side. This may be a slow process, not only because of the magnitude of the investment but also because of the need for multijurisdictional cooperation in both system installation and operation. Those drivers who are early investors in the IVUs for such systems may be dissatisfied with their limited usability for a long time. The whole system may then become unacceptable to the users, and the infrastructure costs may be too high for a government or operating company to bear. On the other hand, the vehicle-based systems require rather expensive IVUs and the early users are likely to be the more affluent drivers and the commercial vehicles. If fully functional navigation systems are considered outside the scope of the baseline IVHS, as discussed previously, then almost by definition, those route guidance systems which build on top of navigation will be only for the high-end of the IVHS market. As will be explained in more detail, there would still be a substantial amount of capital and operating costs on the infrastructure side for the vehicle-based dynamic route guidance systems. If these high costs are borne by public agencies, questions may be raised as to their justification and fairness to the less affluent non-users.

Secondly, there is a question of who is in control. The infrastructure-based systems would be more amenable to the presumption that traffic should be controlled by a central authority (public or a private surrogate) who will guide the traffic to reach a "system optimum" according to a system-wide objective (such as minimum total vehicle-hours of delays) subject to centrally determined constraints (such as no traffic diversion to schools and residential areas). On the other hand, the vehicle-based systems would be more amenable to the presumption that the driver will determine his own objective function and will search for "user optimum" (such as a weighted average between travel time and tolls paid) subject to privately determined constraints (such as avoiding subjectively perceived high-crime areas).

Of course, each of the two system types may be adapted to a mixture of system and user optima. For example, the infrastructure-based Autoguide [UK Department of Transport, 1989] and Ali-Scout do provide optimal route guidance for individual drivers as long as their objective functions fall within a small set of prototypes and the centrally determined constraints are used. However, it would be impractical to modify the constraints to suit each individual driver. Furthermore, if a vehicle fails to follow the centrally provided guidance, the vehicle may get lost until it picks up direction from another beacon since there is no map information on board. Putting digital map data on board would increase the IVU cost and defeat an original attractiveness of the infrastructure-based system. On the other hand, the vehicle-based CARMINAT and SOCRATES would need the up-to-date link time information from the infrastructure. Thus, it is possible for the central operator (public or private) to inject system-wide objectives and route constraints by artificially increasing some of the link times. However, this practice may lose the driver's confidence in the link time information and render the whole system unacceptable to the user. The appropriate balance between system-wide traffic objectives and the degree of user acceptance would be a complicated policy decision.

As an aside, this author has suggested [Chen and Ervin, 1990] the use of economic incentives for bringing the user optimum closer to the system optimum. Analogous to the situation of an overbooked airliner, economic incentives (*e.g.,* in the form of a reduction of monthly charges) may be offered to drivers to divert from a certain route. The amount of incentive may be changed depending on the actual monitored traffic which reflects the drivers' responses. This approach would impose a new load to the 2-way communication system, but can avoid the mistrust of the whole system by the users. Note that this system presumes a monthly charge for the equipped vehicles but does not presume road pricing.

Regardless of which approach to take, the projection of link time (up to about 90 minutes into the future) will be needed for dynamic route optimization and this projection must be done centrally. This implies new tasks and/or improved technologies to be used by the traffic management authorities. For example, credible and reliable projection of link time will need the speedy and accurate estimation of the duration of an incident after it is detected and verified. Such estimations are being done only haphazardly at present. Some form of simple models based on artificial intelligence is needed to predict incident duration as a function of the link location, time of the day, the number of lanes blocked, weather condition, whether bodily injuries are involved, *etc.*

At present, the projection of link times in the Ali-Scout system is done by a sort of moving average of current and historical data with modification through link models, which seem to ignore the interactions between links in a network [Janko, 1990]. A more sophisticated real-time simulation model may be needed to provide more accurate link time projections [Kaufman *et al.*, 1991]. However, the reduction of such an approach to practice is yet to be realized, and its realization might require a substantial investment by the traffic management authorities. It is reported that anticipatory route guidance was attempted by abandoned in TravTek [Rillings, 1991b] while such an approach is still the goal of Advance [Doi, 1991]. To some extent, the projected link time can also be partially controlled in urban areas where there are traffic lights, whose timing may be modified as a function of time and as a function of the traffic flow. How such timing changes should be coordinated with dynamic route guidance is a research and policy question clearly in the domain of the traffic management authorities [CARGOES, 1989].

Another important task in this area for the traffic management authorities is to provide updated information of road changes (construction, reconfiguration, new roads and roundabouts, new one-way and/or turning lane restrictions, etc.). Such road changes in Berlin, for example, are as frequent as once a day [Sodeikat, 1990]. Autonomous systems that provide navigation and/or static route guidance would need this updated information. As they get such information from the infrastructure, they may as well get the dynamic route guidance information from the infrastructure if that is available. Thus there is a strong motivation to explore dual mode systems that combine the autonomous and infrastructure-based systems [Haessermann, 1990]. One example is the combination of TravelPilot with Ali-Scout; another is the combination of CARIN with GSM (Groupe Speciale Mobile; a form of digital cellular radio scheduled to be launched in 1991 in Europe), which can provide the infrastructure-based route choice as well as road changes [Langbein, 1990]. Significantly, a number of dual mode route guidance systems, involving almost all the major European car companies, are expected to be demonstrated in Torino, Italy in September 1991.

With the coexistence of multiple basic approaches to dynamic route guidance, standardization is clearly a very important policy issue. It is interesting to note that the Japanese have abandoned the infrastructure-based approach as a result of the evaluation survey among drivers involved in the CACS program during the 1970s [Kawashima, 1991b]. The North Americans, notably through TravTek [Rillings, 1991a] and ADVANCE projects, have been working during the last few years exclusively on vehicle-based systems for dynamic route guidance. The substantive progress being made in SOCRATES may lead to a vehicle-based system in Europe that would be more congruent with the trends in Japan and North America. On the other hand, the low-cost IVU is clearly an attractive feature of infrastructure-based route guidance systems. If a sufficient number of cities in Europe and North America are convinced in the near future to make the substantial investment on the infrastructure for them, such systems as Ali-Scout may pre-empt the market for dynamic route guidance.

Besides the choice between basic approaches as discussed above, other areas of standards of relevance to route guidance include the choices of map data formats, message symbols and contents, communication frequency and protocols, and man-machine interfaces. Everyone seems to agree that standards should be minimum in order not to stifle innovation. At the same time, there need to be sufficient standards to permit users to choose products among multiple vendors and to operate their vehicles to communicate with multinational infrastructures. Well-established standards would also help manufacturers reduce cost by providing aggregated markets, and would induce manufacturers to make technical and financial commitments to IVHS. Again, as in the case of toll collection and road pricing, the traffic management authorities need to be aware of the market leader approaches and the committee approach in standard setting.

Since the social benefits of DIS are supposed to be relief of traffic congestion and increase of driving safety, not just helping a small group of users to reduce their travel times, it is important for traffic management authorities to evaluate the traffic and safety impacts of DIS. Fortunately such projects have been launched in a number of countries including the UK [*e.g.*, Stevens and Bartlam, 1990]. Preliminary assessment of dynamic route guidance has indicated that the typical reduction of vehicle-hours of delays would be in the range of 7 to 15% [JMP, 1987]. Recently more detailed evaluation using computer models has indicated some interesting but problematical results. For example, the user benefits have been shown to decrease, and may even become negative, under certain circumstances as the percentage of cars equipped with Ali-Scout system increases beyond around 15% [McDonald, 1990]. This was based on the assumption that drivers of equipped cars would follow the routes along the main roads determined by the traffic center while the drivers of unequipped cars who know the local geography would "rat race" through the small urban streets. On the other hand, research at the University of Michigan has shown that the benefit to users in a vehicle-based route guidance system [Kaufman *et al.*, 1991] can continue to rise for the equipped drivers as the penetration rate increases from zero toward 100%. There is an important policy issue here regarding the degree and the means of control that should be exercised by the traffic management authority to discourage rat race and to make dynamic route guidance attractive to those who have invested in the system.

In the area of safety, route guidance is the category of DIS that may improve on travel time at the direct expense of safety since the additional navigation and routing information may be overly distractive to the driver. One of the most significant roles of the transport authorities is to evaluate the various traffic information and route guidance systems before they are allowed to be marketed, through licensing control and other regulatory measures. Indirectly, safety may be reduced as drivers are diverted from motorways to urban streets since statistics have shown that there are more accidents on urban streets than on motorways on the basis of vehicle-mile travelled. There are multiple issues here regarding the tradeoff between efficiency and safety: who should do the tradeoff — the drivers or the traffic manager — and how the inputs and outputs of the tradeoff analysis should be conveyed to the drivers and to the general public whose safety may be affected by the drivers.

Before any large-scale implementation of traffic information and route guidance systems, the most reliable and convincing evaluation approach would be simulation. Traffic impact can be evaluated using computer simulation models, which are purely mathematical. Safety evaluation, however, can best be evaluated using driving simulators, with various human drivers connected to physical mockups. There are issues related to simulation-based evaluation as any simulation by definition can only approximate the real environment. Thus, there are questions related to the needed degree of sophistication of the driving simulator for human-factor evaluation of route guidance systems. For example, are motion-based driving simulators [Drosdol, Kaeding, and Panik, 1985] really necessary to provide sufficient evaluation results for safety regulation purposes, even though simple static display prototypes are less expensive and more desirable for initial design of man-machine interfaces? There are also questions related to the potential generation of new traffic as a result of route guidance, which would be difficult to simulate on current traffic models or on driving simulators.

In the past, manufacturers and promoters of DIS have provided their own evaluation of system effectiveness, reliability, and user acceptance. Besides the unavoidable elements of subjectivity, many of these evaluation studies have not followed the most rigorous principles of experimental design. Since sociotechnological systems are costly and time-consuming, it behooves the traffic management authorities to be involved and to insist upon the most scientific and objective evaluation of user acceptance and driver behavior, as well as technology performance, safety and reliability in the major field tests. Ideally the evaluation of various approaches should be done on alternative systems under controlled environment, which suggests that the alternative systems should all be tried in the same locale. However, the reality is that the alternative systems are all very expensive and are likely to be tested in different sites. There are ways and means to make the multiple-site field tests semi-controllable through quasi-experiments (e.g., using same survey instruments on control and experimental groups with similar profiles [Underwood, 1991]). There is a practical policy question as to the degree of rigidity of guidelines for evaluation that should be provided and enforced by appropriate authorities.

With the concept of car probes (also known as floating cars) being implemented to provide updated information about link times, the issue of privacy has been raised. However, several ideas have been generated to avoid vehicle identification in the implementation of car probes. For example, a random number may be assigned to each car being followed by the route guidance system. Alternatively each floating car can simply report to the traffic control center how much time it has taken to get to the present location from a previous location. The traffic management authorities would only need to make sure that one of these ideas is indeed being implemented.

Finally, the traffic management authorities have the responsibilities, and are in the best position among various interested parties, to promote multijurisdictional cooperation and multimodal transport usage. Central authorities will have to exercise the leadership to build consensus and foster cooperation among local authorities to work out mutual understanding regarding multijurisdictional traffic diversion or rerouting — which has been a major stumbling block in route guidance implementation. In addition, information and recommendation for alternative and multiple modes of transport — including public transit, car pooling, parking, dial-a-ride, bicycle paths, walking paths, *etc.* — can be best promoted and furnished by traffic management authorities. Eventually, even public transit schedules may be modified in coordination of route guidance in order for the entire transport network to be fully utilized to cope with the unabated traffic demand, unexpected incidents, and special events.

DRIVING ASSISTANCE

The DIS application category of driving assistance consists of new electronic devices and subsystems that will augment the functions of driving tasks. From the perspective of communications, they may be subcategorized as autonomous, vehicle-highway, and vehicle-vehicle systems. Since vehicle-highway systems involve modification of the highway infrastructure, they are of obvious and immediate concern to traffic management authorities. However, as indicated later, there are significant public policy issues in the other subcategories as well. On the other hand, although intelligent cruise control is sometimes considered as a driving assistance, it involves dilution of the driver's control function, with all of its legal liability implications [Syverud, 1990], and is generally classified under advanced vehicle control systems, which is outside the scope of this paper.

Autonomous driving assistance includes, first of all, new electronic display panels which have been designed to show only the key information of interest to the driver at the moment, thus reducing information (output) overload to the driver and saving the very limited space on the dashboard. Similar arrangements have been designed to reduce the number of driver (input) control knobs through a hierarchy of touch-screen commands. The safety as well as human-factor merits of these devices, under various external lighting conditions and driving situations, are yet to be proven by extensive tests.

Head-up displays (HUD) of key information on the windshield, a technology borrowed from military aircraft, are generally considered to be desirable as they can provide information without requiring much eye movement of the driver. The technology is still rather expensive (in the order of $300 [Spreitzer, 1991]] and is only beginning to be offered as an option on some of the most luxurious cars. There is no consensus on what kind and how much information to be displayed on the windshield (the most common ones being vehicle speed and directional arrows), and on exactly where the HUD image should be displayed on the windshield.

Another common wisdom is the desirability of synthetic voice output versus visual display since the ordinary driving is already putting heavy demand on the driver's visual channel. However, questions have been raised as to the noise interference of the motor, the traffic, and the sound associated with near accidents. Moreover, visual information may be retained and repeated more readily than audio information for review purposes. Perhaps both visual and audio displays should be used to reinforce each other, as in the superb display for route guidance in Ali-Scout. A great deal of testing will be needed to sort out the best man-machine interface for various situations. For safety regulation, traffic management authorities need to monitor the results from these tests closely.

Vision enhancement through infrared or ultraviolet system is another example of autonomous driving assistance DIS. In the case of infrared, signal processing has to be done electronically and the question is how to display the image to the driver without undue distraction. In the case of ultraviolet, signal processing is done by the driver's eyes but the vision enhancement must be through the reflection of fluorescent materials. This is the situation where the traffic management authorities can help by putting fluorescent strips on highway obstacles, road signs, and/or road edges. Such action would be justifiable only if the ultraviolet vision enhancement is proven really effective and there are enough vehicles installed with ultraviolet lights.

Another autonomous system which is quite attractive is to superimpose a red bar to the side mirror when a sensor detects a vehicle on the driver's blind spot to caution him about lane change [PROMETHEUS, 1990]. Such a system provides only warning signals with the responsibility of vehicle control remaining entirely with the driver. However, there may still be questions of legal liability in case collision occurs due to malfunction of the warning red bars.

In the subcategory of vehicle-highway communication for driving assistance is the example of in-vehicle safety advisory and warning system (IVSAWS), in which some of the radio-frequency warning signals may come to the vehicle from ground points, such as hidden stop sign, dangerous curve, construction ahead, etc. To receive such active signals at a close distance requires relative low-cost receivers on the vehicle — in the order of a couple hundred dollars [Housewright, 1991] — and can be implemented in the near future on the presumption of willing cooperation between traffic management authorities to provide the active signals and private manufacturers to make the receivers. Another example in this subcategory is highway signs coded on transponders mounted on the ordinary visible road signs. This approach, first suggested by the author

[Ervin and Chen, 1989], has been successfully demonstrated by the CAROSI (CAr ROadside SIgnalling) project in Sweden [CASROSI, 1990]. Color displays of speed limits, pedestrian crossing, and highway numbers are added to the electronic reconfigurable panel display of the demonstration car. The speed limit information has also been coupled to the set point of the cruise control unit to make the car speed follow the legal limits. Practical implementation of CAROSI is deemed difficult in the foreseeable future, not only due to the needed installation and maintenance of the transponders by the highway authorities but also because of the high-cost antenna and reader required on the vehicle. This latter barrier may be reduced for vehicles equipped with the high-end IVHS on board that already contains some of the electronics for CAROSI. Future work on this subcategory would include head-up display, various packaging and installation of the transmitters or transponders (under the pavement, on an overhead gantry, as well as on the roadside), and use of the information for other driving assisting functions, such as to provide anticipatory warning to the driver before the fast-moving car reaches a sharp curve. Traffic management authorities should consider promoting the safety and other social benefits of the highway transponders, which can also be carried by children and pedestrians. Highlighting and retaining safety and warning road sign information for the driver's review through electronic means can certainly enhance safety. Large-character display of road signs, whether head-up or on the dashboard, would help older drivers and those with eye impairment. The policy question is how much effort and investment should be devoted to this "cooperative highway" approach on the part of the government.

There are other vehicle-highway systems which the traffic management authorities may wish to promote. One of these is the automatic emergency calls (or distress signals) to be transmitted by vehicles in trouble. This would require three elements: (1) an automatic as well as manual triggering device for transmitting the signal since the driver may be unconscious in an emergency situation; (2) an automatic indication of the vehicle location with sufficient accuracy for the rescue crew to find the vehicle; and (3) cooperating traffic management authorities to take up the rescue mission. In a recent survey among American truck drivers and operators, this was considered the highest-priority function of IVHS to them [Stone and Ervin, 1990]. Daimler-Benz's ARTHUR (Automatic Radio Communication System for Traffic Emergency Situation on Highway and Urban Roads) would transmit automatically vehicle identification number, insurance policy, and any information about chemical or hazardous materials onboard to help coordinate the rescue mission. The location of the vehicle in trouble would be determined through a triangulation technique based on the handover of transmission among 3 or more GSM stations, as would be possible after the SOCRATES project is in operation. However, the deployment of GSM is still several years off. Meanwhile, there are other means for automatic vehicle location [Ristenbatt, 1991] that can be used and an early deployment of automatic emergency calls can save many lives. To speed up such applications, some government leadership is in order to get the system set up and maintained in full operation, at least in those segments of the motorways and arterials where accidents have occurred frequently and where emergency calls from telephones or from motorists are either impractical or unsafe.

Something similar to the above but applied to finding a stolen vehicle has been implemented in several parts of the U.S. The system is called LoJack (the opposite of Hijack), and the transponder installed in the car can be triggered by the authorities upon receipt of the theft report, and emitted signal from the transponder, hopefully unknown to the thief, can help the police find the stolen vehicle [Reagan, 1979]. LoJack is being sold at about $600 in the U.S. A more recently developed system, called Teletrac, would perform the same function automatically without requiring the owner reporting the theft to the authorities. The system uses spread spectrum technology for signaling, and electronic maps to show the location of the stolen car [International Teletrac Systems, 1990]. This unit is being marketed at about $700 in the U.S. Both systems have benefited from encouragement by the insurance industry through premium discounts offered to equipped vehicles. They have also relied on the interest and cooperation of selected state authorities for their successful deployment.

In the subcategory of vehicle-vehicle communication for driving assistance, the examples are fewer but quite interesting. The PROMETHEUS program seems to have emphasized communication between vehicles moving in opposite directions. The Handshake project features the provision of fog warning by vehicles just coming out of the fog zone to on-coming vehicles which are about to enter the fog zone. Similar communication schemes have been proposed for vehicles on one side of the motorway, after observing a traffic jam on the other side, to send signals to vehicles in the opposite direction upstream from the jam so that they may make timely diversion from the motorway [Prometheus, 1990]. Another recent idea that achieves similar functions, but using vehicle-highway communication rather than direct vehicle-vehicle communication, is to rely on an electronic transponder installed on the middle strip of a divided motorway as a mailbox for vehicles moving in opposite directions to deposit and pick up messages for driving assistance. One advantage of this "mailbox" concept is to avoid unreliable and mischievous messages by restricting message deposits to authorized vehicles which know the password for the electronic transponder. The implementation of this last concept would imply the acceptance or licensing of such responsibility by traffic management authorities. There are also ideas for driving assistance using vehicle-vehicle communication among vehicles moving in the same direction, such as in the overtaking manoeuvre involving three vehicles moving at different speeds. However, these ideas need further development before they can be effectively demonstrated [Williams, 1990].

It should be pointed out that all of the above vehicle-vehicle communication applications, no matter whether they are for vehicles moving in the same or opposite directions, would not be very practical until the percentage of vehicles with appropriate and compatible communication equipment becomes significant. The implementation would be difficult if everything is left to the free market due to the lack of incentives for early investment. Perhaps the way to bootstrap the market is for the traffic management authorities to install the electronic mailboxes discussed previously and provide plentiful information for driving assistance (*e.g.*, icy bridge ahead, etc.) so that early as well as late investors can receive immediate benefits. Another way is to use new vehicle-vehicle communication means that would not require installation of new equipment on both vehicles. One example is the technology of using intensive light emitting diodes (LED) on the rear bumper to provide textual messages; *e.g.*, "Slow Down", "Lengthen Headway", *etc.* [Stanley, 1988]. The permission for using such a technology (which could be distractive to the driver behind) and setting the standards for acceptable rear-bumper messages would be the responsibility of traffic managers.

BUSINESS AND PERSONAL INFORMATION

The provision of business and personal communication to drivers on the move used to be considered a luxury, at least for noncommercial vehicles. However, with the decreasing cost of information technology and the increasing demand for such services in our information society, provision for business and personal information is deemed highly desirable if not essential for long-distance commuters, tourists, high-level executives, as well as drivers of commercial vehicles — trucks, taxis, ambulances, police cars, *etc.*, some of which are not strictly "commercial".

From a policy perspective, the regulation and frequency allocation for business and personal communication seems to be entirely in the domain of telecommunication authorities. However, to the extent that the technology and communication media for this application category of DIS shares and/or overlaps with those for the other three application categories which are of central concern to traffic management authorities, the latter cannot ignore the policy implications of this fourth category of DIS as well. There are also driving safety issues in the use of some of business and personal information systems that would require evaluation and regulation activities of the traffic management authorities.

In North America, commercial vehicle operations (CVO) has been recognized as one of the four components of IVHS [Mobility 2000's CVO Report, 1990]. The tendency for commercial vehicles to be the precursor of all automotive vehicles to adopt all sorts of IVHS technologies has been acknowledged by both Europeans and Americans [Sviden, 1988; Underwood *et al.*, 1990]. Thus, in the American HELP Program, which was described previously, business information related to vehicle taxation and fleet management is communicated via the same media as that for toll collection [French, 1990]. A number of police cars in Detroit and other American cities are equipped with both Loran C and Mobile Data Terminal (MDT) for automatic vehicle location and dispatch purposes [*Fire Chief* staff, 1990]. Real-time traffic information may thus be easily conveyed to the driver via MDT, or conveyed to the central dispatcher, for the purpose of dynamic route guidance.

Personal information can now be conveyed to the motorist (driver and passenger) by car phone, facsimile, or paging — some luxurious cars, especially in Japan, even have commercial television for the passengers, or for the driver while the car is standing still. Clearly some of these communication channels may be used for traffic information and route guidance as well. As mentioned previously, TrafficMaster provides real-time traffic information via a paging service frequency [Martell, 1990a]. The cellular car phone system may be used to provide link time information for on-board route optimization, especially after the cellular system becomes digital as in the future GSM in Europe [Catling, 1990]. With the expected advent of personal communication network (PCN) which may one day replace both the home phone and the car phone, its continuing development should be monitored by the traffic management authorities as well as the communication regulatory authorities.

As mentioned previously, tourist and other "yellow page" information is expected to be provided to drivers on the move as a feature of DIS. TravTek, one of the major American IVHS demonstration projects involving 100 test vehicles in Orlando, Florida will feature the provision of tourist information around Disney World. The automobile clubs (both the AA in Europe and AAA in the United States) have libraries with rich tourist information that can be made readily available. There are strong commercial interests in making "yellow page" available in digital form to facilitate information search and to make two-way communication for yellow-page transactions such as hotel reservation practical. This growing business may have policy implications in both financing and technical decision making.

Financially the provision of both personal and traffic information may sway the purchasing decision for a traffic-oriented service. As indicated previously, 35-40% of the subscribers of TrafficMaster also opted for the paging service. Technically the provision for large volume of yellow-page information may preclude or favor certain technology. For example, it has been reported that although infrared (IR) beacons have convincing advantages of low cost and low interference (due to the incoherence of IR waves) [Von Tomkowitch, 1990], their currently low data rate capability for handling yellow-page information has hampered their acceptance by many car companies, at least in the near future [Williams, 1990].

SUMMARY AND CONCLUSIONS

The matrix at the end of this paper summarizes the potential prominent policy impacts of the four categories of DIS that have been discussed in this paper. The double-checks indicate the policy implications that demand the most critical attention. Admittedly the author's subjective judgment has influenced the results summarized in the matrix. It is hoped that this explicit judgmental results have been supported by the discussion and arguments in this paper, and will contribute to useful policy consideration and debate.

Thus, as shown in the matrix, privacy is a most critical concern in electronic toll collection if it is based on automatic vehicle identification (AVI) technology. The use of smart cards, prepaid anonymously, would go a long way toward alleviating this concern. However, smart cards technology for automatic high speed contactless debiting is more complicated than the existing AVI technology. Meanwhile AVI technology is being considered for massive-scale deployment worldwide. Such deployment not only may set *de facto* standards for toll collection and road pricing, but may strongly influence the technical direction of traffic information and route guidance in the future as well. It behooves the traffic management authorities to monitor and, if possible, to participate in the standard setting process for toll collection and road pricing on a worldwide basis.

While road pricing has been experimented or is being proposed in many cities, its political acceptability is very doubtful in the foreseeable future for most countries. However, road pricing promises to provide a fundamental long-term relief of traffic congestion and there are many innovative ideas for its implementation. The transport authorities should follow these experiments and the general debates in depth, not only watching how the various interest parties react to each other and jointly make decisions on its acceptance, but also encouraging field tests in order to assess how compliance is to be enforced and how much direct and indirect impacts the various schemes of road pricing will have on traffic congestion, land use, and urban development.

The provision of real-time traffic information and static route guidance appears to be a financially viable service that can be provided by the private sector. The challenge to the traffic management authorities here is to guard against cream-skimming so that the service can be provided for all roads and to fuse all sorts of conventional and newly available data to help provide the most timely and accurate traffic information for all.

Dynamic route guidance has so far turned out to be rather costly. A choice needs to be made soon between two fundamentally different approaches — *i.e.*, between vehicle-based and infrastructure-based approaches. This will not be easy as there are major philosophical differences and strong vested interests. This author is of the opinion that the choice be decided by free market forces and that the traffic management authorities should focus on providing the projected link times needed by either approach, and to take a strong leadership in developing multijurisdictional agreement on traffic diversion and in extending dynamic route guidance to include multiple modes of transport. Additional research should be led by traffic management authorities to assess the realistic impact of dynamic route guidance on congestion and to assess the safety of man-machine interfaces of such systems.

From the policy perspective, the most significant issues of driving assistance are the interrelated issues of safety and legal liability. The traffic management authorities should consider taking several actions. For application areas with safety as a primary objective but without much progress toward deployment — such as automatic emergency calls — the traffic management authorities should take a lead role in promoting their development and implementation. For application areas involving vehicle-highway communication — such as electronic transponders installed on the roads — the traffic management authorities should begin investing and implementing them as a way to bootstrap the market. As to legal liability, either new legislations need be introduced to set some limit for IVHS products, or the whole question should be considered as a part of a comprehensive review and debate at the highest level of government on the impact of legal liability on all kinds of technological innovation, not limited to IVHS.

Those DIS functions which are to provide business and personal information do not seem to have any direct policy implications for traffic management. However, since the same communication media may be shared between these functions and those of traffic management, the transport authorities should consider the new technology and regulation for business and personal information in order to make their own transport policies that would impinge on the technical standards, safety assurance, and financial viability of those DIS which are of direct interest to traffic management.

Finally, this author had the impression that, in all the countries he has visited in Europe, Asia, as well as North America, the DIS researchers in the private industry have not really thought very much about policy implications except in a haphazard way. Yet they are making technological choices and developmental efforts that may have profound policy implications. Similarly the policy makers are not very familiar with exactly what DIS technologies are being planned for deployment as they have been under development mainly in the private sector. Both sides can save time at the later stage of implementation and can be synergistic if they work more closely and frequently together at the developmental stage. Therefore the author would like to suggest that frequent in-depth exchange of views between policy and technology developers be routinized through joint projects and through periodic reviews.

A MATRIX SUMMARY

Policy Impacts	Toll & Rd Price	Route Guidance	Driving Assistance	Business & Pers Info
Privacy	XX	X		
Standards	XX	XX	X	X
Financing	X	XX	X	X
Political Acceptance	XX			
Multijurisdiction	X	XX		
Multimode	X	XX		
Safety		X	XX	X
Legal Liability			XX	

REFERENCES

Braegas, P., "Function, Equipment and Field Testing of a Route Guidance and Information System for Drivers (ALI)," *IEEE Transactions on Vehicular Technology*, VT-29(2), 216-225, 1980.

Braegas, P., Robert Bosch GMBH, private communication, October 1990.

CARGOES, DRIVE Project V1011, "Integration of Dynamic Route Guidance and Traffic Control," April 1989.

CAROSI, brochure available from the PROMETHEUS organization at Volvo, Sweden, 1990.

Catling, I. and McQueen, B., "Road Transport Informatics in Europe - A Summary of Current Development," *Proceedings of the 5th Jerusalem Conference on Information Technology*, 702-715, October 1990.

Chen, K. and Ervin, R.D., "American Policy Issues in Intelligent Vehicle-Highway Systems," SAE Paper 901504, Society for Automotive Engineers, 1990.

Cunningham, R. F., Port Authority of New York and New Jersey, private communication, August, 1990.

Davies, P. and Eng, C., "Radio Data System — Traffic Message Channel," *Proceedings of the 1st Vehicle Navigation and Information Systems*, A44-A48, 1989.

Doh, M.A., Ong, J.T., Chang, C.H., Ooi, T.H., and Mital, D., "Automatic Vehicle Identification on Busy Multi-Lane City Roads," *Proceedings of the 2nd Vehicle Navigation and Information Systems*, IEEE/SAE, 1991.

Doi, R. M., Motorola, Inc., private communication, July, 1991.

Drosdol, J. Kaeding, W., and Panik, F., "The Daimler-Benz Driving Simulator: New Technologies Demand New Instruments," paper presented at the 9th IAVSD Symposium on Dynamics of Vehicles on Roads and Tracks, Linkoping, Sweden,1985.

Ervin, R.D. and Chen, K., "Toward Motoring Smart," *Issues in Science and Technology*, 5(2), 92-97,1989.

Field, B. G., "From Area Licensing to Electronic Road Pricing: A Case Study in Vehicle Restraint," SAE Paper 911677, Society for Automotive Engineers, 1991.

Fire Chief staff, "Detroit DETERS System Aids Emergency Response," *Fire Chief*, 25-29, July 1990.

Fisher, R.J., "Smart Travelers of the 1990s," *ITE Journal*, 17-19, January 1991.

French, R.L., "IVHS Developments in North America," paper prepared for JSK Foundation, Tokyo, Japan, August 1990.

Gillan, W.J., "PROMETHEUS and DRIVE: Their Implications for Traffic Managers," *Proceedings of the 1st Vehicle Navigation and Information Systems*, 237-243, 1989.

Green, N., "London 'Timezone'", paper presented at the National Economic Development Organization (NEDO) Conference on Information Technology & Traffic Management, London, November 1990.

Haessermann, P, "Route Guidance Systems: Combination of Autonomous Systems with Infrastructure Based Systems," presentation at SITEV '90, Geneva, Switzerland, May 1990.

Honey, S.K. and Zavoli, W.B., "Map Matching Augmented Dead Reckoning," *36th IEEE Vehicular Technology Conference Proceedings*, New York, 359-362, 20-22 May 1986.

Housewright, K. (Hughes Ground Systems Group), "Near-Term Automatic Driver Information Systems Application," presented at the 1991 SAE Future Transportation Technology Conference, August 1991.

Inside IVHS, 1(9), "Road Pricing Debate Heats Up in U.K. amid Technical Gains," 1-4, April 29, 1991a.

Inside IVHS, 1(12), "Trafficmaster Seeks Expansion of Network onto London A Roads," 6-7, June 10, 1991b.

International Teletrac Systems, "TELETRAC: the Stolen Vehicle Locator System," Inglewood, CA, United States, 1990.

Janko, Technical University of Berlin, Germany, private communication, October 1990.

JMP Consultants Ltd., "Study to Show the Benefits of Autoguide in London," Final report to Transport and Road Research Laboratory, February 1987.

Karlsson, T., "Financing," (Working Paper k:\secfo\docs\SC0259); "Road-Pricing," (Working Paper k:\secfo\docs\SC0261); "Privacy," (Working Paper k:\secfo\docs\SC0274); DRIVE Program, March 1990.

Kaufman, D.E., Wunderlich, K.E., & Smith, R.L., "An Iterative Routing/Assignment Method for Anticipatory Real-Time Route Guidance," IVHS Technical Report 91-02, University of Michigan, May 1991.

Kawashima, H., "Present Status of Japanese Research Programmes on Vehicle Information and Intelligent Vehicle Systems," presented at the DRIVE Conference, Brussels, 6 February, 1991a.

Kawashima, H., "Two Major Programs and Demonstrations in Japan," *IEEE Transactions on Vehicle Technology* 40(1), 141-146, 1991b.

Kentucky Transportation Center, Advantage I-75 brochure, University of Kentucky, Lexington, KY, 1990.

Kirson, A.M., "RF Data Communications Considerations in Advanced Driver Information Systems," *IEEE Transactions on Vehicle Technology* 40(1), 51-55, 1991.

Lamm, L., Highway Users Federation for Safety and Mobility, Washington, D.C., private communication, September 1990.

Langbein, R., Daimler-Benz, Stuttgart, Germany, private communication, October 1990.

LeBow, G., Sage Broadcasting Corporation, presentation on Radio Data Systems at the Transportation Research Board (TRB) Committee on Communication Meeting, Washington, D.C.,14 January 1991.

Martell, D., "Navigation Systems," paper presented at the National Economic Development Organization (NEDO) Conference on Information Technology & Traffic Management, London, November 1990a.

Martell, D., General Logistics, Luton, United Kingdom, private communication, November 1990b.

McDonald, M., University of Southampton, private communication, December, 1990.

McQueen, B., Ian Catling Consultancy, private communication, August, 1991.

Michigan Department of Transportation, "Comparison of Alternative Driver Information Systems: Proposal for Phase-One Operational Field Test Program, Michigan Metropolitan Transportation Center (MTC)," October 1990.

Mobility 2000, Final Report of the Working Group on Advanced Driver Information Systems (ADIS), March 1990.

Mobility 2000, Final Report of the Working Group on Commercial Vehicle Operations (CVO), March 1990.

Mobility 2000, Final Report of the Working Group on Operational Benefits, March 1990.

Oldridge, B., "Electronic Pricing: An Answer to Congestion," paper presented at the National Economic Development Organization (NEDO) Conference on Information Technology & Traffic Management, London, November 1990.

Paisant, R., Louisiana Department of Transportation and Development, private communication, August 1991.

Perrins, K., GEC, Borehamwood, United Kingdom, private communication, 1990.

PROMETHEUS video tape, 1990.

Queree, C., MVA Systematics, United Kingdom, private communication, 1990.

Reagan, W.R., Auto Theft Detection System, U.S. Patent 4,177,466, 4 December 1979.

Renault, "CARMINAT Leads the Way," press document, October 1990.

Rillings, J. H., "TravTek," General Motors document, June 26, 1991a.

Rillings, J. H., General Motors, private communication, July 1991b.

Ristenbatt, M. P., "A Communications Architecture Concept for ATIS," *Proceedings of the 2nd Vehicle Navigation and Information Systems*, IEEE/SAE, 1991.

Rosen, D., Mammano, F., and Favout, R., "An Electronic Route-Guidance System for Highway Vehicles," *IEEE Transactions on Vehicular Technology*, VT-19(1), 143-152, 1970.

Siu, G., Hong Kong Commission of Transportation, private communication, May 1991.

Small, K., Winston, C., and Evans, C.A., *Roadwork*, Brookings Institution, Washington, D.C., 1989.

Sodeikat, H., Siemens, Berlin, Germany, private communication, October 1990.

Spreitzer, W.M., General Motors, Warren, MI, United States, private communication, January 1991.

Stanley Electric Co., Battle Creek, MI, United States, private communication and technology demonstration, August 1988.

Stevens, A. and Bartlam, M., "Safety and Traffic Impact Evaluation of Driver Information Systems," paper presented at PROMETHEUS Pro-General Workshop, London, November 1990.

Stone, B.E. and Ervin, R.D., "Survey of the Trucking Industry's Preferences for IVHS," University of Michigan, October 1990.

Stoneman, B., "The Potential Impacts of Future In-Vehicle Driver Information Systems," Working Paper WP/TO/75, Transport and Road Research Laboratory, Crowthorne, United Kingdom, 1990.

Sviden, O., "Future Information Systems for Road Transport: A Delphi Panel-Driven Scenario," *Technological Forecasting and Social Change*, 33(2), 159-178, 1988.

Syverud, K., "Liability and Insurance Implications of IVHS Technology," SAE Paper 901508, Society for Automotive Engineers, 1990.

TARDIS (Traffic And Roads - DRIVE Integrated Systems, The Total Traffic Management Environment), DRIVE Project V1018, "Dynamic Route Guidance," Working Package 2.2, November 1990.

Thomas, M., "Telecommunications: the Backbone of DRIVE," *Traffic Engineering + Control*, 209-213, April 1990.

Turnage, H., "Development of Automatic Highway Advisory Radio in the United States," *Proceedings of International Conference on Road Traffic Signalling*, 156-158, IEE, London, 1982.

UK Department of Transport, *Autoguide*, Pilot stage proposals - A Consultation Document, 1989.

UK Department of Transport, *Paying for Parking*, Approval of Parking Control Equipment and Devices - A Discussion Document, November 1990.

Underwood, S.E., University of Michigan, private communication, August 1991.

Underwood, S.E., Chen, K., and Ervin, R.,D. "The Future of Intelligent Vehicle-Highway Systems: A Delphi Forecast of Markets and Sociotechnological Determinants," TRB paper 890804, Transportation Research Board, 1989.

Van Ness, N., Federal Highway Administration, private communication, July 1991.

Von Tomkewitsch, R., "Dynamic Route Guidance and Interactive Transport Management with Infrared Beacons," report issued by Siemens AG, Munich, Germany, 1990.

Von Tomkewitsch, R., "Dynamic Route Guidance and Interactive Transport Management with ALI-SCOUT," *IEEE Transactions on Vehicle Technology* 40(1), 45-50, 1991.

Vostrez, J., "Vehicle/Highway Automation: Policy Issues and Strategies in California," SAE paper 891721, Society for Automotive Engineers, 1989.

Walton, C.M., "The Heavy Vehicle Electronic License Plate Program and Crescent Demonstration Project," *IEEE Transactions on Vehicle Technology* 40(1), 147-151, 1991.

Williams, M., Jaguar Car Ltd., Coventry, United Kingdom, private communication, November 1990.

Yamada, O, NHK Science and Technical Research Laboratories, private communication, April 1991.

Yumoto, N., Ihara, H., Tabe, T., and Naniwada, M., "Outline of the CACS Pilot Test Systems," paper presented at the 58th Transportation Research Board Annual Meeting, 1979.

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