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IVHS

Intelligent Vehicle-Highway Systems

Intelligent Vehicle-Highway Systems (IVHS) for Newly Industrialized Countries (NICs)

Kan Chen and Young-Shin Hyun

Department of Electrical Engineering and Computer Science
University of Michigan
Ann Arbor, Michigan 48109

Paper Prepared for
Society of Automotive Engineers
The 6th International Pacific Conference
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UNIVERSITY OF MICHIGAN
TRANSPORTATION RESEARCH INSTITUTE • (313) 936-1066
2901 Baxter Road, Ann Arbor, MI 48109-2150, and
COLLEGE OF ENGINEERING • (313) 764-4333
4112 EECS, Ann Arbor, MI 48109-2122

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Abstract

Intelligent Vehicle-Highway Systems (IVHS) are based on the amalgamation of information technology with automotive and highway technologies to help relieve traffic congestion, improve safety, and reduce pollution and energy wastes. IVHS have been developing rapidly in the past few years in industrialized countries around the world -- Europe, Japan, and North America. On the other hand, the needs for IVHS in the newly industrialized countries (NICs), and the possible roles that these countries may play in the IVHS development, have not been well recognized.

Available data suggest that the problems of traffic congestion and fatalities in the large cities of NICs are just as bad as, if not worse than, those in the industrially mature countries. NICs are therefore potential users of IVHS. The city of Singapore has actually gone ahead of the rest of the world in applying IVHS technologies to implement road pricing as a practical means for automotive traffic demand management. Because of geographic and cultural diversity, there are significant differences in the timing, variety, and emphasis of IVHS applications in the NICs.

The NICs have been successful in recent decades to export manufactured goods to the world market. To the extent that IVHS products are primarily for the large-volume and low-cost market, it behooves the industries in both the industrially mature countries and the NICs to consider strategic alliances on the supply side to cater to the global market. The new emergence of venture capital and massive road construction projects in selected NICs may also make them attractive potential partners to the industrially mature countries.

An Overview of IVHS

Intelligent Vehicle-Highway Systems (IVHS) are based on the amalgamation of information technology with automotive and highway technologies to help relieve traffic congestion, improve safety, and reduce pollution and energy wastes. The genesis of IVHS began over two decades ago. With the dominant role played by motor vehicles in the total North American transportation system, the efficiency and safety of highway travel have been of continuous concern to the American society. Advanced vehicle-highway systems, ranging from electronic route guidance systems [Stephens *et al.*, 1968; French and Lang, 1973] to automated highways [Gardels, 1960] have been an area of research and development in the United States for decades. Before the substantial reduction of the Federal Government's role in civilian technology development during the early 1980's, U.S. research activity in advanced vehicle-highway systems in the Electronic Route Guidance Systems (ERGS) [Rosen *et al.*, 1970] had inspired corresponding work in the Japanese Comprehensive Automobile Traffic Control System (CACS) Program [Yumoto *et al.*, 1979] and the European Autofarer Leitung und Informationsystem (ALI) Program [Braegas, 1980]. While the U.S. activities were curtailed in the 1970's and most of the 1980's, the efforts to advance the application of information technology to vehicle/highway interactions in Europe and Japan accelerated, perhaps as a result of the more pressing needs of domestic transportation there, especially in the urban areas, as well as different government policies.

The announcements of the billion-dollar DRIVE [DRIVE 1991] and PROMETHEUS [Glathe *et al.*, 1990] programs in Europe and the comparable AMTICS and RACS programs in Japan [Kawashima, 1991] during the past few years, along with extensive prodding by the California Department of Transportation (Caltrans), have jolted the U.S., leading to a revival of its activities in advanced vehicle-highway technology. However, with the passage of time, the revived activities are now taking on characteristics which differ, both technically and institutionally, from that seen through the 1960's and 1970's. For example, more emphasis is now put on the nearer-term use of information systems for driver-advisory functions than on the longer-term use of control

technologies for automation purposes. There is also a wider range of organizations working in concert from both the private and public sectors than in the past to link the vehicles and highways through information technology -- hence the emerging program title, Intelligent Vehicle-Highway. Recent U.S. studies [USOTA, 1989; USDOT, 1990] have adapted Mobility 2000's [Mobility 2000, 1990] grouping of IVHS technologies into four generic functional areas. These are listed below along with examples.

- * Advanced Traffic Management Systems (ATMS):
Adaptive traffic signal controls, automatic incident detection, automatic toll billing, etc.
- * Advanced Traveler Information Systems (ATIS):
Automatic vehicle location, automatic vehicle navigation, motorist information, cooperative route guidance, collision warning and in-vehicle signage, etc.
- * Advanced Vehicle Control Systems (AVCS):
Collision avoidance, speed and headway keeping, automated highway, automated guideway, etc.
- * Commercial Vehicle Operations (CVO):
Weigh-in-motion, automatic vehicle classification, automatic vehicle identification, etc.

In general, most ATMS technologies are in the deployable stage, although ATIS technologies will need near-term research and development, and AVCS technologies will require longer-term research before they can be applied reliably. All of these three categories of IVHS technology are likely to penetrate the commercial vehicles and their fleet operations first before they are applied to the majority of passenger cars, as illustrated in Figure 1 [Underwood *et al.*, 1990]. Thus, in North America, there are already a few automatic toll billing and automatic vehicle locator systems in operation or under installation, and one of the most active IVHS projects to date has been the Heavy Vehicle Electronic License Plate (HELP) Program started in 1984 which applies CVO technology with a networked data communications and processing system for improving trucking productivity along the Pacific Coast (from

British Columbia to California) and into Arizona and Texas [Walton, 1991].

The renewed movement in IVHS in North America has been supported by a convergence of interests from private industry, government agencies at all levels, and academic institutions through an informal group known as Mobility 2000, which began in 1987 and whose recommendations [Mobility 2000, 1990] have led to the formation of a nonprofit legal entity called Intelligent Vehicle-Highway Society of America (IVHS America) in 1990. This groundswell support for IVHS is expected to lead to a substantial and continuing federal funding for IVHS through the 1991 Reauthorization of Surface Transportation Assistance Act by the U.S. Congress.

Table I. Major IVHS Programs and Developments

Geographic Regions	Early Programs	Year	Recent Programs & Developments	Year
North America (IVHS)	ERGS	1968	Mobility 2000	1987
			IVHS America	1990
Europe (RTI)	ALI	1979	PROMETHEUS	1986
			DRIVE I	1989
			DRIVE II	1992
Japan (IVHS/RTI)	CACS	1976	RACS	1986
			AMTICS	1987
			NeGHTS	1989
			SSVS	1992?

Meanwhile the European IVHS programs are moving ahead with a number of research and demonstration projects under both the PROMETHEUS Program and the second phase of the DRIVE Program (DRIVE II), the latter to begin in 1992. In Japan, the combined implementation of RACS and AMTICS Programs is

being discussed in a new organization known as Vehicle Information and Communication Systems (VICS), while advanced research may be launched under a new program called Super Smart Vehicle Systems (SSVS) following a two-year feasibility study [Kawashima, 1991]. Another advanced program evolving in Japan is the Next Generation Highway Traffic System (NeGHTS) [Kawashima, 1991], which is designed to realize the concept of "info-mobility" [Tsugawa *et al.*, 1991], integrating various ideas to improve road traffic management, driver safety and convenience.

The IVHS movement in the three country blocs in the industrialized world are summarized in Table I. The expanding activities in the these countries have not been taking place without being noticed by other parts of the world. In fact, some of the early development and pioneering trials or applications of IVHS technologies have taken place elsewhere; e.g., electronic road pricing (ERP) in Hong Kong [Chan and Catling, 1986] and Singapore [Field, 1991], and the traffic signal control system known as the Sydney Co-ordinated Adaptive Traffic System (SCATS), originated from Australia [Lowrie, 1982; Luk *et al.*, 1982], is one of the most advanced systems of its kind in the world [Longfoot, 1991].

Needs for IVHS in NICs

The accelerating development of IVHS in North America, Europe and Japan can be attributed to the converging forces of social needs to reduce automobile transportation problems in these countries, their maturing technical capabilities of information technology, and international competition [Chen and Ervin, 1989]. In terms of social needs, the increasing problems of traffic congestion and automobile accidents are most frequently cited as the main problems which demand new solutions that might be offered by IVHS, which also provide new hope for reducing air pollution and energy waste. For example, the typical urban commuter suffers in the order of 15 minutes of delay due to congestion on U.S. freeways at present, and it has been predicted that an average delay of one hour is more likely by 2005 [Lindley, 1987]. Highway fatality that subsided from a peak of around 50,000 per year a decade ago shows a tendency of climbing back to that abominable level. The conventional ways of combating these problems by building more and wider roads have found

increasing difficulty as urban land becomes rapidly scarce and exorbitantly costly. One indicator of this difficulty is the rate of increase in motor vehicles versus the rate of increase in highways. Recent statistics indicated that while the number of licensed motor vehicles in the U.S. had grown 7.5% between 1984 and 1987, the interstate highway system had increased only 5% in the same period. This means that, in terms of vehicles per kilometer, the ratio increased by a factor of 1.023 ($=1.075/1.05$), or by a growth rate of about 5% over a decade.

If traffic congestion, automobile accidents, and increase in vehicles per kilometer are indicators of social forces behind IVHS needs, then the newly industrialized countries (NICs) would have at least equal, if not substantially greater, need for IVHS. Although statistics are lacking in traffic delays during commuting periods in the large cities of NICs, those who have traveled to such cities as Rio, Seoul, and Taipei would readily testify that the traffic jams there during rush hours are just as bad and perhaps more frustrating as in New York and Los Angeles. Statistics which do exist seem to indicate a worse need for IVHS. For example, the following table shows the data for the number of vehicles per kilometer, and the number of deaths from automobile accidents.

<u>Country</u>	<u>Vehicles per Kilometer</u>			<u>Auto Fatality Rate</u>		
	<u>Year of 1978</u>	<u>Year of 1988</u>	<u>Growth in 10 yr</u>	<u>Year of 1978</u>	<u>Year of 1988</u>	<u>Annual Peak</u>
Hong Kong	190	226	19%	437	301	477 (1981)
Korea	88	127.8	45%	5,114	11,563	11,563 (1988)
Brazil	5.63	9.92	76%	3,933	5,683	6,757 (1986)
South Africa	17	24.4	44%	6,550	10,691	10,691 (1988)

[Source: International Road Federation, 1989]

Note that the annual growth rates of vehicles per kilometer in these above countries, ranging from 19% to 76%, are all much higher than the U.S. rate of 5% over the same decade. In other words, road building in all these countries fell far below the increase of

automobiles, and there is a dire need for reducing automobile transportation problems by untraditional means beyond building more highways. Parenthetically, the absolute figures of vehicles per kilometer have less significant meaning as the geography of each country is quite different. For example, with most of its business on a tiny island, Hong Kong has a much higher number of vehicles per kilometer as compared to the other countries listed. The fatality rates do not show identical trends but are all of relative concern in terms of deaths per vehicle-kilometer traveled.

As to air pollution and energy waste related to automobile traffic, again the general impression of world travelers is that these problems in the large cities in NICs as well as in other developing countries are much worse than those experienced in the industrially mature countries. Accurate data relevant to automobile emission and energy waste have not been collected from all countries. However, available data show that the number of days exceeding reasonable air pollution limits has averaged 8 per year in New York, 15 per year in Hong Kong, and 87 per year in Korea. The U.S. Department of Energy estimates that all the increase in global oil demand between 1986 and 2010 is expected to come from developing countries, and half of the increase in oil used in 15 developing countries used between 1970 and 1984 was for transportation [World Resource Institute, 1990]. Improvements in traffic congestion through IVHS can reduce travel time, which can in turn reduce energy waste and emission. Although IVHS alone would not be sufficient to alleviate these problems significantly, it does provide a new avenue to approach these problems, in concert with the more conventional measures such as antipollution and energy conservation technologies and regulations.

Applications of IVHS in NICs

Given the needs for IVHS in the NICs, one would expect to see applications of IVHS in these countries now and in the future. This is indeed the case. By and large, IVHS applications in the NICs follow the same general trend in the industrially mature countries. Specifically, IVHS applications or market penetration would begin with ATMS, followed by ATIS, and eventually by AVCS, as discussed previously in this paper. However, because of geographic and cultural diversity, there are significant differences in the timing, variety, and emphasis of application within each IVHS category.

Beginning with ATMS, one can find applications of computerized traffic light controls in many NICs. In fact, partly due to the "late-comers' advantage," some of the developing countries are installing the most advanced adaptive traffic control systems. The late-comers' advantage exists for those countries or cities which do not have modern (or even any) traffic control systems to begin with. Without the need to write off the capital investment in such systems, they may as well go for the most advanced systems if there is a need for them. For example, Shanghai and Beijing have acquired respectively the SCATS [Lowrie, 1982] and SCOOT [Robertson and Bretherton, 1991] traffic light control systems, which are responsive to real-time traffic demand. These are among the most sophisticated traffic control systems which are not in widespread use even in the industrially mature countries.

Electronic toll and traffic management (ETTM) is an area which is in between ATMS and ATIS. This area appears to be the first wave of IVHS applications in the industrially mature countries. The same basic technology can be used for electronic non-stop toll collection and for road pricing. Yet we see here an interesting dichotomy between NICs and the industrially mature countries. Because there are more toll roads, bridges, and tunnels in the industrially mature countries than in most NICs, automatic toll collection does not seem to take on as much momentum in the NICs. On the other hand, due to the extremely high density of population and motor vehicle traffic in certain NICs, electronic road pricing (ERP) has been attempted in Hong Kong and actually implemented in Singapore [Catling and McQueen, 1990]. By contrast, due to political and institutional barriers, ERP has not been accepted in Japan and the Western world even though the concept has been advocated by research economists [Small *et al.*, 1990] and has been proposed in United Kingdom [Green, 1990], the Netherlands [Catling and McQueen, 1990], and other Western countries. In all these cases, the main public objections have stemmed from the reluctance to pay an extra tax for road use and from the concern about the potential loss of privacy. At present, Singapore is the only country that has several years of experience of road pricing -- a manual system which is going automatic through IVHS.

In the ATIS category, autonomous navigation systems are taking off in Japan, with hundreds of thousands of units already in the market; and several dynamic route guidance systems have been

designed and/or demonstrated in Europe and North America. In either case, the availability of accurate and up-to-date digital maps is a rather important prerequisite. Thus, although the need for navigation and route guidance exist in the NICs, the interest in these ATIS systems is not great and will probably remain low until either the appropriate government authorities or some private concerns take the leadership and make the necessary investment to develop the map database. There seems to be a chicken-and-egg dilemma in this situation. Without the map database, nobody would want to buy a navigation system. Yet until a sizable market is sufficiently certain, nobody wants to invest in the development of the database. This may be a case for some government role to break the deadlock.

Once the map database is available, navigation and real-time traffic information systems would be natural IVHS applications to follow. Although navigation can be accomplished by a variety of technologies (dead reckoning, Loran, and satellite global positioning system), the combination of dead reckoning augmented by map-matching, with possible supplementation by GPS, seems to be the likely approach for NICs, most of which do not have extensive navigation system infrastructure such as Loran. Dynamic route guidance, the logical step beyond dynamic traffic information system, may be difficult to implement in NICs because of a combination of factors -- relatively high costs, lack of practical alternative routes, and multijurisdictional problems. Many of the luxurious vehicles that can afford dynamic route guidance are probably driven by chauffeurs, who are expected to know the best routes once the dynamic traffic conditions are available. In such vehicles, the higher priority investment may be for such devices as car phones, facsimile machines, televisions, and special sound systems, which would make the traffic jam more tolerable for the passenger.

As to AVCS technologies, they are in the long-term development category even for the industrially mature countries, and are therefore rather remote for applications in NICs. Moreover, the existence of a greater variety of vehicles (bicycles, motorcycles, wagons, etc.) on a wider classes of roads in the NICs would make the application of AVCS even more difficult in these countries. On the other hand, the institutional issue of legal liability may be less of a problem, making NICs possibly more attractive from the standpoint of field experiments for AVCS.

NICs' Capabilities for IVHS

Although no IVHS technology on record has originated from the NICs, these countries do have certain capabilities that can contribute to future IVHS development. First of all, IVHS development needs not only technical strengths, but also a number of nontechnical capabilities. Even in the technical category, fundamental breakthroughs in *de novo* technologies are not the most critical factor for success. Therefore NICs can make certain contributions to IVHS development based on their own capabilities, which can become even more effective if they are coupled to appropriate capabilities of the more industrially mature countries. A few examples are presented below.

It has been pointed out [Chen, 1990] that some of the most advanced technologies for IVHS have been borrowed from the defense and space industries; e.g., satellite global positioning system, image processing, and spread spectrum communications. The Western companies which have developed these modular technologies are geared mostly toward low-volume high-cost production. In contrast, the IVHS market is for high-volume low-cost products, for which the industry of the NICs are particularly adept. The challenge to the NICs is for their manufacturing firms to find the right partners in the industrially mature countries and form strategic alliance with them for the IVHS market.

It has also been pointed out earlier in this paper that, for various reasons, some of the NICs have pioneered in certain IVHS applications. The most visible example is the road pricing system in Singapore. As an early user or implementor of the system, the experience should be a valuable asset for advising other countries or for international consulting in IVHS. There is evidence that the lesson learned from Singapore road pricing project has already led to new ideas for road pricing being proposed elsewhere. Specifically, it has been observed that the traffic around the Singapore core city has become congested as vehicles try to drive around the periphery of the core city to avoid paying the road price. This observation has led to the idea of London Timezones which are concentric circles around the city center, the road price for each zone being gradually reduced as the vehicle moves away from the center [Green, 1990].

Still another capability of selected NICs, somewhat surprisingly, is the abundance of venture capital for new technologies. For example, Taiwan has become first in the world in per capita foreign exchange holding because of its rapid economic growth and its enormous international trade surplus. The central government has promulgated venture capital regulations which strongly encourage channeling the investment to advanced technology, both domestically and internationally. About half of such investment has gone overseas [*Asian Venture Capital Journal*, 1990], and thus potentially these capital funds could be used for IVHS development. It is reported that Taiwanese investment in the U.S. has been doubling every year recently and amounted to \$1.32 billion at the end of 1990 [*Korea Herald*, 1991]. Their investment in Europe has been about half as much as in the U.S. Korean investment in North America has been comparable although their investment in Europe has been much less [Balk, 1991]. As expected, some of the investors are trying to couple overseas investments with strategic partnership, e.g., providing venture capital startups with the understanding that a significant portion of the manufacturing be done in the future in Taiwan as the venture matures.

While highway construction in most industrially mature countries has slowed down, that in the NICs is continuing unabated. For example, the U.S. Interstate Highway Program which began in the 1950's under the Eisenhower administration is officially coming to completion in 1991. In contrast, Taiwan has launched a new 6-year National Construction Plan (1990-96), with a budget of U.S. \$300 billion, almost half of which is earmarked for transportation infrastructure. Even a small percentage of this budget can go a long way in applying IVHS technology. Thus, the potential market for IVHS in NICs can be quite significant. Conceivably this market may be used as another strategic instrument by the NICs.

Conclusions

The three converging forces behind the acceleration of IVHS activities in the industrially mature countries are societal needs for new approaches to automobile travel problems, new technologies and capabilities for developing these approaches, and international competition for the new products and services in the IVHS market. This paper has examined IVHS for the newly industrialized countries (NICs) in the context of these three kinds of forces. It may be

concluded that the social needs for IVHS in these countries are no less than those in the industrially mature countries. The NICs have certain relatively unique capabilities to contribute to future IVHS development. Given the appropriate incentives and opportunities, the private sector in selected NICs can play a significant role either in international competition or in international cooperation through strategic alliances with their counterparts in North America, Europe, and Japan.

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