

INTELLIGENT VEHICLE HIGHWAY SYSTEMS (IVHS) ISSUES AND RECOMMENDATIONS

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Abstract Intelligent Vehicle Highway Systems (IVHS) is the integration of various pieces of information and computer technologies to the transportation elements in order to obtain a more productive transportation system. The five major components of IVHS are the Advanced Traffic Management Systems (ATMS), Advanced Vehicle Control Systems (AVCS), and Advanced Public Transportation systems (APTS). This paper examines the different macro level issues such as socioeconomic, legislative, financial, environmental and international as well as micro level issues such as insurance and liability related to IVHS. It then identifies the obstacles that potentially hinder the implementation and growth of IVHS. After examining the implications of these issues it attempts to make suitable recommendations to help resolve different IVHS issues. The issues concerning the applicability of IVHS in developing countries are also examined in light of the current situation and suggestions on the applicability of specific technology areas are included.

Key Words Intelligent Vehicle Highway Systems, Computer and Information Technology, Developing Countries

چکیده سیستم های حمل و نقل باهوش (IVHS) مجموعه ای از تکنولوژی های جدید اطلاعاتی و کامپیوتری است که برای بهبود دادن حمل و نقل و ترافیک داخل شهر و بین شهرها بوجود آمده است. سیستم های حمل و نقل باهوش به پنج بخش تقسیم شده اند: سیستم های مدیریت ترافیک، سیستم های اطلاعاتی راننده، سیستم های مربوط به ماشین های صنعتی و تجاری، سیستم های کنترل ماشین و سیستم های حمل و نقل همگانی. این مقاله موضوع های مهم مثل مسائل اجتماعی، اقتصادی، قانونی و بین المللی که مربوط به سیستم های حمل و نقل باهوش میباشد را تشریح میکند. بعد از تشریح کردن این مسائل، یک سری از موانعی که برای بکار بردن سیستم های حمل و نقل باهوش وجود دارد مورد بررسی قرار گرفته است. مسائلی که برای پیاده کردن این سیستم ها در کشورهای در حال توسعه وجود دارد نیز مورد بررسی کامل قرار گرفته است.

INTRODUCTION

In the past decade several factors have contributed to a renewed interest in IVHS. Among the positive factors contributing to this increased interest are rapidly decreasing cost of information and computer technology and also the need felt by advanced countries to develop the technology make the best possible

use of existing infrastructure at very little additional cost. Among the negative forces are increased congestion, air and noise pollution, and lack of funds to meet the ever growing demand on the transportation infrastructure.

It is expected that IVHS, when implemented, will play an important role in reducing congestion, improving safety and increasing the ease and conve-

nience of travel. In the U.S. alone, a Texas Transportation Institute study [1] indicates that the losses due to congestion in thirty-nine major metropolitan areas are expected to be in the order of \$41 billion a year. The implementation of IVHS is expected to reduce travel time by 13-45% resulting in tremendous savings. IVHS is also expected to have a large impact on the safety of the highway system. The baseline estimates of IVHS safety benefits are 11,259 lives and 442,000 injuries saved by the year 2010 [1].

Mobility 2000, a non-profit cooperative organization involved in promoting IVHS research, has grouped the emerging IVHS technologies into five functional areas: Advanced Traffic Management Systems (ATMS), Advanced Driver Information Systems (ADIS), Commercial Vehicle Operations (CVO), Advanced Vehicle Control Systems (AVCS), and Advanced Public Transportation Systems (APTS).

ATMS is a group of technologies/techniques to control and optimize traffic flows on networks. ADIS would provide travelers with certain pieces of information such as location, traffic conditions, route guidance and parking control. CVO deals with the operation of commercial and emergency vehicles. AVCS is the application of computer technology to driver assistance, providing warning signals which identify the relative position of vehicles. Such pieces of information are helpful in the prevention of high speed collisions. APTS encompasses the application of advance technologies in information and communication systems to High Occupancy Vehicles (HOV), ride-shared vehicles, conventional buses, commuter and light rail and para-transit.

CURRENT IVHS ACTIVITIES IN THE UNITED STATES, EUROPE, AND JAPAN

Currently, IVHS activities in the United States are supported at the federal, state and local government

levels as well as universities and industry. The Federal Highway Administration (FHWA) is actively supporting IVHS research in the public sector. In fiscal year 1991, \$20 million was spent on these activities. The National Highway Traffic Safety Administration (NHTSA) provides funds for safety and human factors research. The Urban Mass Transit Administration (UMTA) sponsors research connected with application of IVHS technologies to mass transit.

Among the State Departments of Transportation (DOT's), the California Department of Transportation (CalTrans) has been seriously involved in IVHS activities. The Program on Advanced Technology for the Highway is conducted under CalTrans and the University of California, Berkeley. The Pathfinder demonstration project co-sponsored by CalTrans, FHWA and General Motors (GM), to be conducted on a twenty-four mile freeway stretch in Santa Monica, California, is expected to demonstrate traveler information systems technology [2,3]. Minnesota Department of Transportation (MnDOT) is sponsoring Guidestar, a field test on the applicability of advanced traffic management technology [3,4].

One of the major IVHS programs in Europe is PROMETHEUS, which stands for Program for European Traffic with Highest Efficiency and Unprecedented Safety. It began in 1986, and will be in operation until 1994. It is a multi-governmental, multi-organizational collaborative effort, and primarily involves auto manufacturers from five European countries [5,6].

Another major activity is the European Dedicated Road Infrastructure for Vehicle Safety Program, also referred to as DRIVE. It emphasizes on-board vehicle systems and is divided into four functional areas: general approach and modeling, behavioral aspects of traffic safety, traffic control and services, and telecommunication and databases [7].

The Japanese approach to IVHS could be identi-

fied as project based, as opposed to the systems based approach of Europe and the U.S. Two of the major IVHS projects in Japan are Road/Automobile Communication System (RACS) and the Advanced Mobile Traffic Information and Communication System (AMTICS). RACS has focused on on-board navigation systems, roadside beacons for simple traffic information, and semi-microwave beacons for individual and business communication. AMTICS focuses on on-board navigation systems and digital cellular radio for traffic management [8].

IVHS ISSUES

The implications of some of the most important macro level issues, both positive and negative, are described below.

Socio-Economic Issues

Although there are several issues to be considered in the implementation of IVHS, the socio-technical

impacts of IVHS in terms of reduced congestion and increased safety continue to be a driving force towards its implementation [10]. Researchers at the University of Michigan asked thirty-two experts to rank the socio-economic effects of IVHS for different IVHS technologies. The survey pointed out that positive effects like reduced congestion and improved safety play an important role towards implementation, whereas negative effects such as increased commuting play only a marginal role in hindering the implementation. The survey results are presented in Table 1, and the proposed IVHS benefits due to safety in Table 2.

Government and Legislative Issues

In the U.S., coordination between governmental agencies like the Environmental Protection Agency (EPA), Federal Highway Administration (FHWA), National Transportation Safety Administration (NTSA), and the budget office is very important to IVHS implementation to avoid unnecessary duplication of work

TABLE 1. Cross-cutting Sociotechnical Impacts (1= highest rating)

SOCIAL IMPACTS	ATRP	AVL	MI	CRG	AVN	CW	CA	SHK	AH	AG
Reduced Congestion	1		1	1	1					
Improved Safety	6	6	3	3	2	1	1	2		1
Consumer acceptance		10	6	7			5	7		
Increased automobile commuting	7						3	8		
Smoother flow of traffic on toll roads	3		9					3		

(Source: Steven Underwood, "Social and Institutional Considerations in IVHS," *Automated Highway/Intelligent Vehicle Systems: technology and Socioeconomic Aspects* (sp-833), special publication of the society of Automotive Engineers, August 1990).

Legend:

ATRP- Automatic Tolls and Pricing
AVL- Automatic Vehicle Location

AVN- Automatic Vehicle Navigation
MI- Motorist Information
CRG- Cooperative Route Guidance
CW- Collision Warning
CA- Collision Avoidance
SHK- Speed and Highway Keeping
AH- Automated Highway
AG- Automated Guideway

TABLE 2. Baseline Estimates of IVHS Safety Benefits

ELEMENT	By 1995	By 2000	By 2010
Lives Saved	88	927	11,529
Injuries Saved	3,060	35,500	442,000
Dollars Saved (in millions of dollars)	167	1800	22,200

(Source: "Intelligent Vehicles and Highway Systems" by Mobility 2000, executive summary of the proceedings of the National IVHS Workshop, in Dallas, Texas, March 1990, published by the Texas Transportation Institute.)

[11]. Another important issue facing the government is the question of limiting the liability of public and private sector providers and manufacturers. Even if the technology is affordable, it will not be in the market as the manufacturers are always vulnerable to potentially damaging law suits. Still another role of

government in support of the rapid progress of IVHS is the standardization of specifications to assure requisite levels of horizontal and upward compatibility [9,12].

A University of Michigan survey among experts revealed that liability limitations, appropriate funding, leadership and direction are among the major issues facing the government in the implementation of different technologies. The survey results are shown in Table 3.

Institutional Issues

The 1989 policy resolution by American Association of State Highway Transportation Officials (AASHTO), resolutions of the Motor Vehicle Manufacturers in 1989, resolutions of IVHS America, and Mobility 2000 have all called for federal initiative and leadership in formalizing the structure of IVHS

TABLE 3. Cross-cutting Government Policy Initiatives (1= highest ranking)

Government Initiatives	ATRP	AVL	MI	CRG	AVN	CW	CA	SHK	AH	AG
Liability Protection		11	6		2	1	1	1	2	3
Establishing standards	3	6	2	3	5	3	2	2		
Federal funding or incentives for R&D		8	5		1	5	5		1	1
DOT leadership, initiative and commitment		3	9	4	4	4			9	5
Provide the necessary public infrastructure		5		2	3	6	9			
Appropriate adequate funding			1	1			4	3	10	
Local, state and federal legislation to implement	1			5		10				
Dedicated lanes and roadways					9		3	8	3	

(Source: Steven Underwood, "Social and Institutional considerations in IVHS," Automated Highway/Intelligent Vehicle Systems: Technology and Socioeconomic Aspects (sp-833), special publication of the Society of Automotive Engineers, August 1990).

and promoting the development of IVHS [13].

Since the federal government is a vast conglomerate of agencies, institutional obstacles have the potential to directly and indirectly block IVHS efforts. In addition to the problem of inter-agency coordination, a lack of expertise for advanced communication and electronics technologies among key personnel may be an impediment to IVHS development.

Since the federal government is expected to play a key role in IVHS, the institutional obstacles are a cause for genuine concern about the feasibility of a proposed design or organizational arrangement that places heavy reliance on government operation of technically advanced systems.

As a result of these concerns and the efforts of the Highway Users Federation (HUF), AASHTO, and other concerned organizations formed a nonprofit educational association called "IVHS America" in July 1990 [14], with the purpose of coordinating IVHS goals, promoting cooperation at the national and international levels, and operating as center for IVHS related research.

Financial Issues

The development and deployment of an advanced technology based highway system, which leads to

immediate opportunities for reduction in congestion, improved safety, and increased utilization of transportation infrastructure, call for many financial commitments from both the government and private sectors. Mobility 2000 has predicted that the major expenditure in IVHS development will be mainly in 1) Research and development of different IVHS technologies, 2) Field operational tests, and 3) Deployment. The financial commitment or the aggregate funding required for R & D, field operational tests, and the total investment levels of IVHS are shown in Tables 4,5, and 6, respectively.

Environmental Issues

Environmental considerations have become an integral part of any major project implemented in the United States. Environmental considerations assume more significance in the case of highway projects since U.S. consumption of gasoline is about 25% of total world production [15].

Since carbon emissions are a major source of pollution, research efforts are currently underway to develop pollutant free hydrogen based fuels for cars. A significant amount of research is also being carried out on the viability of electric cars. Once implemented, it is expected that IVHS technologies will

TABLE 4. Aggregate Funding: Research and Development (\$ millions)

	1991-1995	1996-2000	2001-2010	Total
Applications	70	60	-	130
Systems	135	20	15	170
Dynamics and Control	300	335	160	795
Human Factors	122	108	70	300
TOTAL	\$627	\$523	\$245	\$1395

(Source: "Intelligent Vehicles and Highway Systems" by Mobility 2000, executive summary of the proceedings of the National IVHS Workshop, in Dallas, Texas, March 1990, published by the Texas Transportation Institute.)

TABLE 5. Aggregate Funding: Field Operational Tests (\$ million)

	1991-1995	1969-2000	2001-2010	Total
ATMS	158	315	-	483
TRANSIT	15	20	25	60
ADIS	160	237	511	908
CVO	96	48	24	168
AVCS	75	670	795	1510
TOTAL	\$504	\$1290	\$1325	\$3119

(Source: "Intelligent Vehicles and Highway Systems" by Mobility 2000, executive summary of the proceedings of the National IVHS Workshop, in Dallas, Texas, March 1990, published by the Texas Transportation Institute.)

TABLE 6. Recommended IVHS Investment Levels (in millions, using constant 1990 dollars)

ELEMENTS	1991-1995	1996-2000	2001-2010
R&D	627	523	245
Field Tests	504	1,290	1,325
Deployment	3,105	10,880	15,950

(Source: "Intelligent Vehicles and Highway Systems" by Mobility 2000, executive summary of the proceedings of the National IVHS Workshop, in Dallas, Texas, March 1990, published by the Texas Transportation Institute.)

assist in decreasing harmful environmental effects of vehicle congestion. In addition to the above mentioned macro level issues, there are some problems at the micro level. Some of the most important micro level issues are discussed in the following paragraphs.

Promotion/Resistance by Industry and User Groups to IVHS

By its very nature, IVHS spans industries, and it is imperative that the views, (both positive and nega-

tive) of the industry be taken into consideration before the implementation of IVHS. The position of some of the major industry groups and also the users are given below.

Motor Vehicle Industry

The motor vehicle industry is eagerly looking towards IVHS as a possible solution to the growing problem of traffic congestion [16]. They feel that motor vehicle manufacturers have a tremendous stake in how the congestion problem is addressed since increasing congestion, with its attendant loss in productivity, efficiency and competitiveness, will negatively affect the motor vehicle industry in the long run.

Electronics and Communications Industry

The advent of IVHS is bound to have a tremendous impact on the electronics and communications industries. The first major shift in automotive electronics is the integration of various electronic subsystems so that they can facilitate information interchange. The second major shift in automotive electronics is the development of sophisticated electronic systems such as voice recognition and a host of driver information systems. To capitalize on the tremendous growth potential, the electronics manufacturers are calling for increased cooperation with automobile manufacturers, and towards that end, they are being actively supported by their respective labor groups.

Trucking Industry

The trucking industry expects to benefit to a great extent from less congestion and the existence of safe highways. Due to the expected benefits, the trucking industry is actively campaigning and eliciting support for IVHS implementation.

Parts Manufacturers

To the extent that IVHS changes the motor vehicle

and highway industries, parts manufacturers will be asked to modify their products. This expansion might involve a large number of new firms who may be asked to provide components. The more this particular industry is fragmented, the more varied industry opinions, will be .

Users

Since the users are expected to be the major beneficiaries of IVHS implementation, the Highway Users Federation (HUF) is actively supporting the development of IVHS. However it is very likely that a large number of users might resent the idea of a general tax increase to fund the capital intensive IVHS developmental activity.

Liability and Insurance Issues

The liability issue to be dealt with in the implementation of IVHS concerns the fact that the IVHS technology represents a gamut of new systems with the potential to produce "public risks" outside consumer control. Further, it has the potential to shift liability towards manufacturers and high way owners, thus increasing their liability risks and decreasing their incentives to promote the technology [17].

The technologies with the potential risk to the providers of IVHS technology are Driver Information Systems and Driver-Control Systems [17]. Driver Information systems include applications that provide information to the driver but leave the control in the motorist's hands. Driver-Control Systems are those applications that sometimes over-ride driver control. Examples of this type could include collision avoidance systems and emergency brake controls, etc.

Despite many issues confronting IVHS, it offers many benefits to the user community. Figure 1 shows qualitatively the benefits derived from IVHS.

IVHS IN DEVELOPING COUNTRIES

The transportation and traffic problems of developing countries are quite different from those of developed countries. Even among developing countries there are wide disparities the main reason for such differences is that many developing countries face the situation of increasing population and also a recent trend in economic growth, which places an increased pressure on the existing infrastructure.

Further more, in the transportation system in the developing countries there are several modes which use the same right-of-way at widely different operating speeds. In general, average speeds are lower and travel times are higher than those in developed coun-

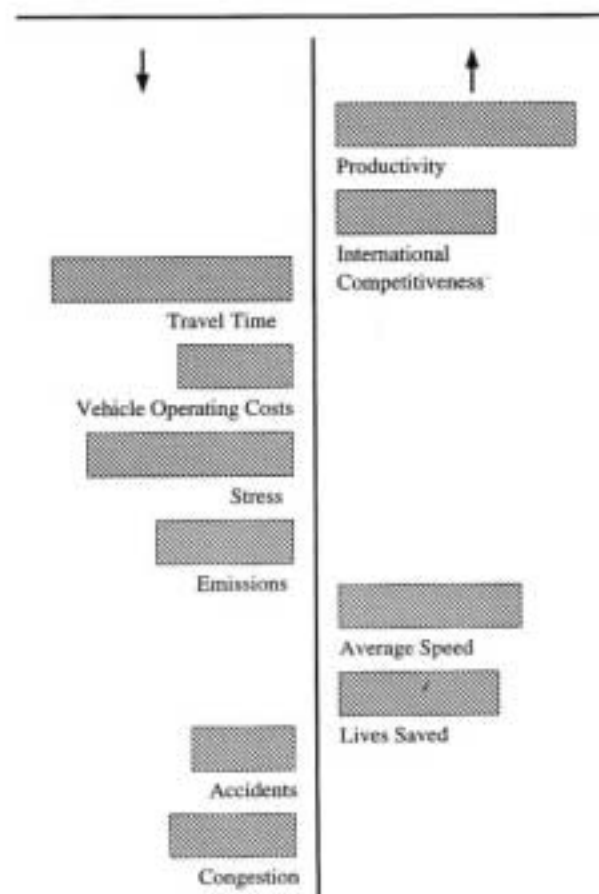


Figure 1. Potential Benefits of IVHS (Source: Mobility 2000, National IVHS workshop, in Dallas, Texas, March 1990, published by the Texas Transportation Institute.)

tries. High pollution levels owing to vehicles of different types and the use of leaded fuel are also critical issues in some developing countries. In short, with a significantly lower proportion of the population owning a private automobile, public modes of transportation are much more important and accommodate the bulk of the population and goods.

Unlike the industrialized nations, where the increasing number of vehicle-miles is a problem, in the developing countries, it is generally a case of demand on the system exceeding supply and a greater dependence and utilization of public transportation. Thus the total vehicle-miles is not as high as the total person-miles traveled.

Applicability of IVHS Technologies to Developing Countries

IVHS is under consideration to be applied in developed countries to improve the speed and efficiency of the transportation network which is relatively well developed and established. In the face of the high costs of adding infrastructure, IVHS offers a solution in optimizing the existing network.

In many developing countries the infrastructure development process is still operating and the highway network is less extensive. Buses and commercial vehicles are seen in a larger proportion in the highways. Increasing average speeds and reducing travel times is a minor objective than providing mobility to the growing population and also expanding the infrastructure to expand service and accommodate all users. The problem is more of over-crowding, less capacity and pressure on the system, mainly bus and rail services. In the face of tight financial situations, and considering infrastructure development, IVHS can offer alternative solutions in optimizing and increasing the efficiency of the existing networks.

Since the number of users of private cars is a smaller proportion of the population, the benefits of the installation of ATMS and ADIS technologies

such as driver information and traffic management systems on a wide basis is not expected to outweigh costs, at least in the foreseeable future. The cost of vehicle-vehicle and vehicle-roadside communication, route guidance and on board computers [18] could be prohibitive. The application of ATMS and ADIS technologies could be considered for densely populated urban areas only. Real time monitoring and control and availability of real time traffic information to drivers, not through on board computers but through electronic variable message displays on urban roads is a possibility.

In the face of financial limitations, concentration on driver information and ATMS technology development poses equity questions also as only a small portion of the population benefits. Financial, legal, and institutional issues must be carefully evaluated and financing arrangements must be such that auto owners pay for these developments to make it more equitable.

AVCS technologies can be considered for deployment because of the safety benefits of the application of these technologies. Some of the enabling AVCS technologies aimed at driver perception enhancement and automation of controls like obstacle detection and lane sensing, electro-mechanical control systems like electronic steering control and electronic fuel injection and transmission, and antilock braking and traction control [18] can be considered for incorporation into indigenously designed and manufactured vehicles.

Since the application of these technologies is expected to push the vehicle costs up, the full automation and application of these systems may not be viable. However partial deployment of at least some technologies that have significant safety benefits must be considered. With public transit being important in developing countries, the application of APTS and CVO technologies is expected to yield maximum benefits and is most suitable among the IVHS func-

tional areas.

Real-time fleet monitoring and tracking using satellite or sign post-odometer systems can enable real time planning or optimization and dispatch of fleet resources [18]. Significant benefits can be expected by the application of these technologies with more flexibility and real time optimization of resources. Keeping operational costs low is critical to the success of public transit in developing countries and the fuel and cost savings in the long run could justify the investment in these technologies.

Electronic Driver Assistance and Information, and Computerized Real Time Fleet Monitoring and Fleet Dispatch can be expected to yield significant gains [19]. The availability of real time information for the passenger at the terminal, intermediate stops, and in the public is feasible and must be considered for implementation [19].

Applicability of CVO technologies is also possible to a greater extent, with truck freight operations forming an important portion of the vehicle mix on the highways. Electronic record keeping and monitoring of freight vehicles at the dispatch center, and coordination of freight trips can enable the freight trucks to pick up freight for delivery on return trips and thus result in further trip optimization and fleet utilization.

On the part of the enforcement authorities and the highway administration, electronic record keeping vehicle condition monitoring, toll collection and weigh-in-motion can result in less delays, speedy data processing, better enforcement and increased efficiency. The applicability of these CVO technologies is a viable proposition [18].

Issues of IVHS Deployment in Developing Countries

There are several factors that have to be considered for IVHS deployment in developing countries. Deployment of IVHS technologies raises legal, finan-

cial, institutional and technical issues.

In those developing countries, where infrastructure is not fully developed and in which there are financial limitations, the applicability and extent of expensive communication systems based on IVHS technologies may be questionable. As many of the currently available technologies are beneficial mainly to auto owners, the equity issue of investing such large amounts in IVHS development must be considered.

Another important factor is that some of the developing countries are in hot, tropical or equatorial areas and the operational viability of sensitive electronic hardware has to be tested. Some modifications may be necessary to make them work in hot, humid, and dusty environments, which can further raise the cost of these technologies.

SUMMARY AND CONCLUSION

IVHS is basically the integration of various advanced computer and information technologies to improve the efficiency of the transportation system. The five major components of IVHS are ATMS, ADIS, CVO, AVCS and APTS. Currently, international research efforts are focused on ATMS and ADIS technologies.

While IVHS research is being conducted all over the world, the United States, Europe and Japan have established a commendable lead in these activities. The Santa Monica freeway project, Travtek, and Guidestar are among the prominent U.S. activities, whereas prominent European activities include PROMETHEUS and DRIVE. The Japanese follow a project based approach as opposed to the concept based approach used in the United States. The prominent IVHS activities in Japan are the RACS and AMTICS projects.

Several important issues dictate whether IVHS based system will or will not be successful. These

issues include macro level issues as well as micro level issues. Among the macro level issues are the socio-economic issues, government and legislative issues, institutional issues, financial issues, environmental issues, and international issues. Among the micro level issues are the resistance by different user groups, legal and liability issues and the private/public sector partnership issue.

A national strategic plan is essential for the successful implementation of IVHS. Suitable legislation must be enacted, creating an apex coordinating body to oversee the developmental activities of IVHS and also to promote the standardization of the nascent technologies. This will help in the commercialization of the different technologies, thus furthering private sector participation.

Though transportation infrastructure development in developing countries is still a major part of the investment in transportation, the applicability of some of the IVHS technologies especially those under the umbrellas of APTS, CVO and AVCS can be considered. The potential benefits could be seen in the form of better access to the public, increased information availability, better organization and planning of the system, and an increase in the overall efficiency of the system. The development of an extensive communication backbone would be critical to the application of IVHS in developing countries. Legal, political, financial, technological, and equity issues will have to be examined carefully before IVHS is deployed in developing countries.

The exciting aspect of IVHS is that it promises an entirely new concept in using information technology to solve transportation problems. Although a lot of issues still need to be resolved, the recent technological developments and the commitment, will and drive of all the personnel involved in transportation and the participation of the government seem to suggest that IVHS as a concept has come to stay, and could very well be the forerunner of transportation in

the next century.

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