EMERGING VEHICLE TECHNOLOGY AND IMPLEMENTATION BARRIERS

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Contents

INTRODUCTION

In all of the world's cities, the most acute transportation problems of congestion, accident and air pollution are severe today and growing worse rapidly. In the US, today as many as 120 million residents live in areas with unhealthy air.[1] Motor vehicle crashes accounted for 90 percent of all transportation fatalities and even larger percentage of injuries during the last two decades.[2] Most of rich literatures illustrate that these severe problems in US are principally the results of excessive use of cars rather than poorly designed and operated public transportation.

However, people are not dissuaded from using cars because they recognize cars as the most convenient, comfortable and quickest mode of making trips. But environmentalists often criticize transportation infrastructure investment as a misguided policy worsening transportation problems. In addition, more and more communities are stubbornly opposing the new construction of roadway. On the other hand, there have been also no absolute evidence that public transportation is much more efficient way to handle the problems. Thus, increasing is the level of expectation that new vehicle technologies can produce positive effects in all parts of urban transportation.

These technologies are regarded as a potential solution for reducing auto-dependence and urban congestion over time which is a goal of great importance to the achievement of more sustainable cities. They also offer a way to help ease the global climate change problem. In particular, Intelligent Transportation Systems is expected as a unitary source that achieves dramatic improvement of quality of urban transportation, as its influence on transportation and society is increasing gradually.[3]

Principal barriers to introduce, implement and commercialize these innovative technologies still remain, however. These barriers relate not only to technical issues but also to economic, political, and legal ones. One of the most serious hurdles to implementation of the technologies is caused by the speeding gap between technological innovations and social and institutional changes.[4] As vehicle technologies develop rapidly, the socioeconomic circumstances associated with urban transportation activities are different from the past ones. But social regulations and people's perception and behavior still lag behind the pace of the technological changes.

A variety of public-private partnership programs, strongly supported by federal and state governments, are flourishing in order to jump over technical barriers in introducing vehicle technologies. Subsidies and tax incentives are now beginning to be designed to

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[1] Web site for *Next Generation Transportation Vehicles, Magnitude of the Problem.* Transportation Science and Technology, U.S. DOT. *http://scitech.dot.gov/partech/nextsur/nextgensurface.html*

[2] Web site for *Intelligent Vehicle Initiative: Magnitude of the Problem,* Transportation Science and Technology, U.S. DOT. *http://scitech.dot.gov/partech/intelveh/intelveh.html*

[3] *The National Intelligent Transportation Systems Program: Where We've Been & Where We're Going,* Report No. FHWA-JPO-97-0027. U.S. DOT. March 1997.

[4] McKnight, Scott A., Clarence W. Mosher, David J. Bozak. "Issues Encountered in Implementing Technologies", Ch 4. Summary. In *Evaluation of Emerging Technologies Traffic Crash Reporting.* Report No. FHWA-RD-97-023. February 1998. *http://ntl.bts.gov/DOCS/97023/ch04/ch04_07.html*

incubate these ambitious programs. However, automobile industry is still struggling with a lack of information about the new customers who are willing to buy new technologies. Government is not yet able to predict what the social and economic consequences of social reception of new technologies will be.[5] Therefore, the questions on what kinds of regulation and how should be transformed to adapt to new technological and social environment are seriously raised among policy-makers.

If transportation has to be more than marginally improved, it is meaningful to address current efforts and issues toward developing new technologies trying to deal with diverse urban transportation problems such as air pollution, safety and congestion. By addressing technological and non-technological issues facing vehicle technologies to be implemented, it is expected that increasing affluence of new technologies and a combination of the technologies will make it possible to meet environmental as well as travel capacities.

EMERGING VEHICLE TECHNOLOGIES

There is an adequate justification for explaining currently flourishing researches on vehicle technologies. T.R. Lakshmann indicated three classes of solutions to achieve sustainable transportation in the 1997 Asilomar Transportation and Energy Conference: demand, supply, and change in the context of the problem.[6] If demand can be changed by altering price structure (i.e. incentive), supply solutions are represented by efficiency improvements including a number of solutions that technological development can promote. Changing the context is represented by land use policy. Even though technology is not the only way to resolve the transportation troubles, it can be obviously thought of a powerful means of solution, since it can not only increases the efficiency of supply of transportation service, and it also impacts tremendously on the context – land use.

Currently, it is difficult to define where the margin of vehicle technologies is, because the vehicle technology area is so broad and researches on it are numerous, yet fragmented and many specific areas are independently treated. In addition, as newly emerging information technology is recently combining with other conventional and innovative vehicle technologies, the area has been rapidly expanding far beyond ordinary people's imagination. Hence, vehicle technology it self, as a unit of analysis, has not been under a comprehensive study or review. Also, such a study must entail a careful scrutiny of the technology's social and economic impact on society as well as possible implementation barriers and obstruction. In this paper, based on the major function of the technologies, the discussion will be focused on a few mainstream vehicle technologies: vehicle control, safety, and driving assistance and "green" vehicle technology attempting to address environmental problems.

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[5] *A Report to Congress: Nontechnical Constraints and Barriers to the Implementation of Intelligent Transportation Systems*. U.S. DOT, Joint Program Office for ITS. January 1997.

[6] Lipman, Timothy, Danilo Santini, Daniel Sperling. *Policies for Fostering Sustainable Transportation Technologies*. *Conference Summary.* UCD-ITS-RR-98-8. Institute of Transportation Research, University of California, Davis. May 1998. pg.2.

The recent smart car technology is mainly driven by safety concerns and the technologies are more rapidly advanced particularly by the recent development of information technologies. The safety-related technologies (e.g. air bags, antilock brakes, adaptive cruise control, crash warning device, navigation assistance system) are widely used as a touchstone of market acceptance of more innovative technologies and sophisticated systems. "Green" vehicle technology mainly cares about environmental concerns such as energy efficiency and pollution-reduction. It is also the area that is recently the most actively paid attention to by a variety of researches of government and public-private partnerships. New engine technologies and fuel technologies are the rapidly growing areas.

In the following, I will briefly describe the newly emerging areas of smart vehicle technology and "green" vehicle technology, and also discuss the federal vehicle technology development programs. Furthermore, the discussion will primarily address non-technical barriers to deploy and commercialize the technologies and implementation dilemma this technological innovation faces.

Intelligent Vehicle Technologies: Control, Safety and Driving Assistance

Each year, more than 41,000 people die in highway crashes, with a total economic loss estimated at over $150 billion/year.[7] In addition, 30,000 bus crashes over the past 5 years resulted in 17,000 deaths and injuries.[8] Although driving has become safer for the last 50 years through public education, developing safety equipments, and improving highway design, driver error still causes not only 90 percent of crashes involving cars, buses, and trucks but also serious pedestrian casualties and injuries.[9]

The Intermodal Surface Transportation Efficiency Act (ISTEA) era (1991 ~ 1997) allowed the US government and industries to make a rapid progress for developing the technologies on crash warning and avoidance device, in-vehicle information systems, and automated highway system. In this period, three Intelligent Transportation Systems (ITS) programs, Advanced Collision Avoidance (ACA), Automated Highway System (AHS), and Driver Vehicle Interface (DVI) programs, had been continued to conduct research and development in order to improve driving safety and efficiency.[10]

The programs initiated the foundational researches on rear-end, lane-change, and roadway departure crash avoidance systems that take the form of warning drivers, recommending control actions, and introducing interim and limited control of the vehicle in dangerous situations. The Driver Vehicle Interface (DVI) program has also completed

[7] *Intelligent Vehicle Initiative Business Plan*, U.S. DOT, Intelligent Transportation Systems Joint Program Office. July 2000. pg.1.
[8] Web site for *Intelligent Vehicle Initiative: Magnitude of the Problem.* Transportation Science and Technology, U.S. DOT. *http://scitech.dot.gov/partech/intelveh/intelveh.html*
[9] ibid.
[10] *Intelligent Transportation Systems Projects Book.* U.S. DOT, Intelligent Transportation Systems Joint Program Office. pg.343.

design guidelines for advanced traveler information systems, allowing the way of more realistic simulation for studying the driver-vehicle interface.[11]

Since the beginning of the Transportation Equity Act for the 21st Century (TEA-21) in 1998, the US DOT integrated these research and development efforts into one program, called the Intelligent Vehicle Initiative (IVI). The program has been focused on eight major problem areas: Rear-End Collision Avoidance, Lane Change and Merge Collision Avoidance, Road Departure Collision Avoidance, Intersection Collision Avoidance, Vision Enhancement, Vehicle Stability, Driver Condition Warning System, and Safety Impacting Services.[12]

The Intelligent Vehicle Initiative (IVI) Program

Intelligent Vehicle Initiative (IVI) principally aims to accelerate the development and commercialization of the safety- and mobility-enhancing driver assistance systems. The program merges all previous vehicle-focused ITS activities, with two major goals: to reduce the number of highway crashes and pedestrian casualties and the resulting injuries and fatalities; to improve the effectiveness of intelligent systems to assure safe vehicle operation in residential and pedestrian activity centers. In particular, it challenges to develop and deploy "human-centered" vehicle systems that completely consider the driver's capabilities and limitations. "Human-centered" means here not just the ergonomics in vehicle design but also the infusion of human sensibility into the design process.[13]

Intelligent Vehicle Initiative (IVI) is a multi-agency research and development effort between US Department of Transportation (DOT), the Federal Highway Administration (FHWA), the National Highway Traffic Safety Administration (NHTSA), and the Federal Transit Administration (FTA). It is also a government-industry partnership, endeavoring to build alliances with the private sector such as auto-manufacturers and suppliers. These alliances are essential since driver-centered smart vehicles cannot be created, deployed and commercialized without strong industry support.[14] In addition, the program can obtain synergies in research and economize its resources by coordinating activities among U.S. Department of Transportation's agencies.

The ongoing vehicle-related projects under Intelligent Vehicle Initiative have investigated technical elements of smart vehicles such as crash avoidance, obstacles sensing, intelligent speed control, and individual driver information systems. The program also expands its researches on human factor and user acceptance. Predicated on the foundational efforts, the initiative has defined eight major problem areas that are currently under study, and those areas will be briefly discussed in the next section.

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[11] ibid. pg.344.
[12] *Intelligent Vehicle Initiative Business Plan*, U.S. DOT, Intelligent Transportation Systems Joint Program Office. July 2000. pg.2.
[13] *The Human-Centered Transportation Systems of the Future*, Presentation of the National Science and Technology Council at ITS America's 7th Annual Meeting in Washington, D.C. June 1997.
[14] Little, Cheryl. "The Intelligent Vehicle Initiative: Advancing "Human-Centered" Smart Vehicles", *Public Roads,* Vol. 61, No.2. Sep/Oct 1997. *http://www.itsdocs.fhwa.dot.gov/jpodocs/periodic/2QF01!.htm*

Major researches under the Intelligent Vehicle Initiative program indicate that one of the primary efforts by the program, collision-avoidance systems, offers the potential for significantly reducing motor vehicle crashes. In particular, preliminary NHTSA estimates show that rear-end, lane-change, and roadway-departure crash-avoidance systems have the anticipated benefits, collectively, to reduce crashes by one-sixth, or about 1.2 million crashes a year.[15]

However, the development of a safe and affordable intelligent vehicle will be a long and difficult task in which IVI must triumph over numerous technical hurdles and non-technical barriers. A primary technical obstacle is developing technologies that complement the human visual and higher cognitive abilities through better understanding of the complexities and idiosyncrasies of human behavior.[16] There are also challengeable non-technical issues that should be overcome to achieve the programs' goals and are extended over different kinds of institutional barriers and market barriers. One of the critical issues is to shape cooperative relationships with industry, since it is impossible to accomplish the program's strategic outcomes without the automotive industry's ongoing support and consumer interest.[17] Major non-technical barriers will be discussed in detail later.

Eight Major Problem Areas[18]

Rear-End Collision Avoidance – There are approximately 1.8 million police-reported rear-end crashes annually which accounted for about 855,000 injuries and 1,570 fatalities in 1998.[19] Rear-End Collision Avoidance systems are being designed to detect and classify the presence and speed of vehicles and stationary objects up head. Determining the level of threat from vehicles in front, it warns drivers to avoid collisions.

Lane Change and Merge Collision Avoidance – Lane change and merge crashes occur most frequently in metropolitan arterial streets, accounting for 600,000 crashes in 1998.[20] This collision avoidance systems watch the lane position and relative speed of other vehicles beside and behind the equipped car and advise drivers of the potential for collision.

Road Departure Collision Avoidance – According to police-reported crash data, more than 937,000 crashes of this type occur each year, and it leads to more than 500,000 injuries and 13,000 fatalities.[21] Road Departure Collision Avoidance Systems warn

[15] Web site for *Intelligent Vehicle Initiative: Requirements,* Transportation Science and Technology, U.S. DOT. *http://scitech.dot.gov/partech/intelveh/intelveh.html*
[16] Web site for *Intelligent Vehicle Initiative: Technical Challenges and Implementation Issues,* Transportation Science and Technology, U.S. DOT. *http://scitech.dot.gov/partech/intelveh/intelveh.html*
[17] *Intelligent Vehicle Initiative Business Plan*, U.S. DOT, Intelligent Transportation Systems Joint Program Office. July 2000. pg.3. pg.10.
[18] Appendix A discusses the specific definition of technology and the anticipated benefits.
[19] ibid. pg.6.
[20] ibid.
[21] ibid. pg.7.

drivers when his/her car is likely to deviate from the lane of travel. They also track the lane of road edge and recommend safe speeds for the road ahead and adjust vehicle speed for the shape of the road. However, due to the diverse cause of these types of crashes including weather, vision, driver impairment, and driving behaviors, the development of systems has significant technical challenges.[22]

Intersection Collision Avoidance – 1.7 million crashes, 22 percent of total crashes, happened at intersections in 1998. Intersection Collision Avoidance Systems check a vehicle's speed and location relative to intersection and the speed and position of other vehicles in the surrounding area, and inform the driver of appropriate actions to avoid a right-of-way violation or probable collision. U.S. Department of Transportation identifies that this area is more technically challenging than any other areas and viewed it as a long term program area.[23]

The above-mentioned collision avoidance and warning systems include several fundamental technologies such as adaptive cruise control, map database, and navigation system. The combination of these technologies is applied to complete user services taking on three different levels of control. The lowest level suggests to the driver what action to take. The middle level takes limited control of the vehicle so that it can respond to safety-compromising positions. For example, intelligent cruise control could slow a vehicle down if approaching a front vehicle too quickly. The highest level of control would be when the system takes precedence over the driver and therefore, the system can take absolute control of the vehicle.[24]

Vision Enhancement – Approximately forty percent of all crashes and fifty-three percent of fatal crashes take place during degraded visibility conditions including night. Vision enhancement for drivers can be provided via in-vehicle system detecting infrared radiation from pedestrians, animals, and roadside features to give drivers an enhanced view. Infrared reflective lane-edge markings will also be brought into the future vision enhancement version. Manufacturers already introduced night vision enhancement products.[25]

Vehicle Stability – While rollovers are involved in only 6 percent of all crashes for combination trucks, it was a factor in over half of all fatal crashes of combination trucks.[26] The technology enables vehicles to be stabilized on the road by controlling braking and steering systems.

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[22] *Intelligent Transportation Systems Projects Book.* U.S. DOT, Intelligent Transportation Systems Joint Program Office. pg.344.
[23] *Intelligent Vehicle Initiative Business Plan*, U.S. DOT, Intelligent Transportation Systems Joint Program Office. July 2000. pg.7.
[24] Proper, Allen T. *Intelligent Transportation Systems Benefits: 1999 Update.* Report No. FHWA-OP-99-012. Prepared by Mitretek Systems Inc. May 1999. pg.65~69.
[25] *Driving Safely Into The Future With Applied Technology*. Publication No. FHWA-OP-99-034. U.S. DOT, Intelligent Transportation Systems Joint Program Office.
[26] *Intelligent Vehicle Initiative Business Plan*, U.S. DOT, Intelligent Transportation Systems Joint Program Office. July 2000. pg.7.

Driver Condition Warning System – Fatigue is a 3 to 6 percent of fatal crashes involving large trucks and also a factor in 18 percent of single vehicle, large-truck fatal crashes.[27] Driver condition warning systems can alert drivers' drowsiness and fatigue by measuring the degree of a driver's pupils covered by eyelids and present overall drowsiness status through feedback mechanisms. This service will probably be introduced first on commercial vehicles.

Safety Impacting Services – since more than 90 percent of crashes are the result of human error, the effective integration of various driver assistance systems and its impact on the driver are seriously being reviewed. In particular, the effect of in-vehicle information systems, or the way presenting information to the driver without distraction, has been greatly taken care of. Examples of safety-impacting services include Route-Guidance and Navigation System, Automatic Collision Notification, Cellular Phone, Adaptive Cruise Control, In-Vehicle Computing, and Commercial Vehicle Diagnostic/Prognostics.[28]

Some of ITS services assisting in the driving task are currently beginning to make their way to the market place and are noticed as a yardstick to measure how future vehicle technologies can be adopted by consumers. In-vehicle vision enhancement is evaluated as a promising technology, since it can improve driving conditions from inadequate lighting, fog, and snow. Navigational systems are also being deployed, providing assistance to the driver in unfamiliar surroundings. However, there are no clear evidences that these technologies will easily penetrate markets, since the technologies are not sophisticated enough not to interrupt human driving and not affordable yet to mainstream technology buyers. Technology should be both more affordable and more refined to bridge the "Chasm"[29] so that mainstream buyers can visualize the application and benefits of these smart vehicle technologies. The detail discussion on market barriers of vehicle technologies will be followed later.

"Green" Vehicle Technologies

The U.S. DOT has tried to address the problems of petroleum dependence, global warming, and air pollution by achieving significant advances in vehicle technologies. As the world's reliance on motor vehicles has grown, so have concerns about concurrent increases in petroleum consumption, carbon emissions, and air pollution. In the U.S., transportation consumes two-thirds of all petroleum used and produces one-third of greenhouse gases.[30] To tackle these problems, Office of Transportation Technologies in

[27] *Driving Safely Into The Future With Applied Technology*. Publication No. FHWA-OP-99-034. U.S. DOT, Intelligent Transportation Systems Joint Program Office.
[28] ibid.
[29] Dr. Geoffrey Moore defined in 1991 "chasm" is a time lag of market adoption between early/expert technology buyers and mainstream buyers, suppliers should overcome this period to have commercial success of technology products. For specific, see Geibel, Jeffrey P., *How to Bridge the Chasm, Not Just Cross it.* GEIBEL Marketing & Public Relations. *http://geibelpr.com/chasm.htm*
[30] Web site for *Next Generation Transportation Vehicles, Magnitude of the Problem.* Transportation Science and Technology, U.S. DOT. *http://scitech.dot.gov/partech/nextsur/nextgensurface.html*

the Department of Energy is now working on more than 30 specific technologies and operating more than 40 programs supporting the technical development and market acceptance of the technologies.

Main efforts focus on gasoline and diesel engine improvement, alternative fuels and hydrogen, hybrid vehicles, fuel cells, batteries, hypercars and weight reduction of vehicles. The major technical concerns are achievement of certain level of energy efficiency and reduction of emission without sacrificing safety and vehicle performance. In addition, the development of manufacturing techniques to reduce the time and cost of vehicles is another crucial technical challenge at present.

The Next Generation Transportation Vehicles Partnership responds to this need through research leading to the development of highway vehicles, locomotives, and ships that are better designed, more efficient, and less polluting.

Partnership for a New Generation Vehicles (PNGV)

The partnership, announced in September 1993, is a unique collaboration between the Federal Government and the United States Council for Automotive Research (USCAR), which represents Chrysler, Ford and GM. The partnership is aimed at strengthening US industries by developing vehicle technologies for a new generation of energy-efficient and environmentally friendly vehicles. The PNGV pursue three specific, interrelated goals: 1) reduce manufacturing production costs and product development times for car and light truck production; 2) pursue advanced technologies for near-term vehicles improvements that increase fuel efficiency and reduce emissions of standard vehicles; and 3) within the next decade, develop a new class of vehicle that will achieve up to three times the fuel efficiency of today's automobile, maintain performance, size, and utility of comparable vehicles, and meet or exceed safety and emission requirements.[31]

PNGV has been expected to be a departure from the historical regulatory relationship between government and the U.S. automobile industry. The support for the program from the both is essential to target the results of joint research and development to commercial vehicle technology development. Since the current oil price in U.S. does not encourage consumer demand for high efficiency automobiles, government support of long-term research and redevelopment for the development of fuel efficiency technologies is necessary to spur activity and accelerate progress in the absence of market full. The leadership of the U.S. automobile industry is also critical for these new technologies to be successfully deployed and implemented in the market.[32]

The advanced vehicle technologies pursued by the PNGV focuses on compression ignition direct injection (CIDI) engines, gas turbines, fuel cells, lightweight materials and high-power energy storage such as batteries, flywheels, ultracapacitors. For the PNGV,

[31] *PGNV Program Plan.* U.S. DOC, Partnership for a New Generation of Vehicles. November 1995. pg.ES-2. *http://www.ta.doc.gov/pngv/goals/pp_es.htm*
[32] ibid. pg.ES-1.

the most critical issue is to develop a new class of automobiles that achieves a tripling in fuel economy without a penalty in emissions, performance, utility, or life-cycle cost.[33]

U.S. DOT expects that the PNGV will lead to significant energy, environmental, and economic benefits to the nation. The nation imported in 1993 about 50 percent of its oil at a cost of more than $40 billion. If vehicle fuel efficiency can improve significantly, U.S. can reduce its reliance on foreign oil supplies, thereby diminishing the economic burden created by related balance-of-trade deficit. In addition, by developing a new generation vehicles, U.S. can improve its economic competitiveness in the world's automobile industry, since it can establish technical leadership in producing competitively priced, high fuel efficiency, and low-emission automobiles.[34]

It has been identified that there are several technological challenges that the partnership must overcome to achieve its strategic goals. Three broad issues appear prominent currently. 1) dramatic reduction in body and chassis mass, while meeting safety standard; 2) dramatic increase in energy-conversion efficiency, while meeting emissions standards; and 3) recovery of kinetic energy normally lost during braking, while meeting cost target.[35]

Beyond the technical challenges, non-technical issues will become more critical, as next generation automobiles will be deployed. For example, it will be an important issue to supply alternative raw materials and the infrastructure required to produce finished materials at commercially viable costs. In order to deliver new technologies to market affordably, advanced manufacturing technique should also be guaranteed, because it can shorten product development times, lower costs and improve product quality and durability.[36]

Types of Environmentally-friendly Vehicle Technologies[37]

Gasoline Engine – The conventional gasoline engine equipped cars reduce its fuel consumption by 50 percent since the 1970s.[38] New direct injection engines being developed under the Office of Transportation Technologies is anticipated to reduce the consumption by 30 percent. Even though many automobile producers are developing

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[33] Web site for *Next Generation Transportation Vehicles: Technical Challenges and Implementation Issues.* Transportation Science and Technology, U.S. DOT. *http://scitech.dot.gov/partech/nextsur/nextgensurface.html*

[34] *PGNV Program Plan.* U.S. DOC, Partnership for a New Generation of Vehicles. November 1995. pg.ES-1. *http://www.ta.doc.gov/pngv/goals/pp_es.htm*

[35] Web site for *Next Generation Transportation Vehicles: Technical Challenges and Implementation Issues.* Transportation Science and Technology, U.S. DOT.

[36] ibid.

[37] Information in this section comes mainly from both Dudson, Brian. "When Cars Are Clean and Clever: A Forward-Looking View of Sustainable and Intelligent Automobile Technologies". *Transportation Quarterly*. Vol.52. No.3, Summer 1998. 103 ~ 120. and Web site for *Office of Transportation Technologies: Technologies*, U.S. DOE. *http://www.ott.doe.gov/technologies.shtml*

[38] Dudson, Brian. "When Cars Are Clean and Clever: A Forward-Looking View of Sustainable and Intelligent Automobile Technologies". *Transportation Quarterly*. Vol.52. No.3, Summer 1998. 103 ~ 120. pg.107.

these technologies, the Japanese auto manufacturers are becoming a market leader of this kind of technology. The New Honda Accord uses a sophisticated system of catalytic converters to surpass California's Ultra Low Emission Levels and its exhaust is actually cleaner than the air of the polluted parts of some cities in U.S.[39]

Hybrid Vehicles – Hybrid vehicles have equipped with both combustion and electric engines. Especially, electric engine is designed to operate efficiently at constant speed. These vehicles are currently in production, and Toyota recently first introduced a hybrid into the market. The price of this vehicle is approximately 30~40 percent more than a comparable conventional vehicle, but it is projected that the extra cost will be regained over its life time in places like Japan and Europe, where fuel is expensive.[40]

Fuel Cells – Fuel Cells produce electricity to power automobiles by chemically combining hydrogen and air. Some vehicles will produce hydrogen on-board from gasoline or methanol. Both Toyota and Mercedes have demonstrated prototypes of fuel cells vehicles and vehicles adopting this technology are planned to be on the market by 2004. These vehicles are expected to reduce fuel consumption up to 50 percent.[41]

Weight Reduction Materials – Weight reduction is another powerful way of improving fuel efficiency. Current efforts address to develop ultra-light, carbon fiber materials in order to produce lightweight vehicles that can improve fuel efficiency about two times.

Alternative Fuels – The alternative fuels being tested at present are Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), Methanol, Ethanol, Hydrogen, etc. These are designed to reduce emission and release fewer green house gas emissions. However, the effectiveness of some of these technologies are still controversial due to its limited availability and its performance on pollution reduction, so the technologies are mainly applied in niche market such as buses and service vehicles.[42]

Batteries and Energy Storage – Since conventional batteries are too heavy, fleeting, costly, and most seriously, limited in capacity, energy storage devices are key to the optimal performance of electric and hybrid electric vehicles. Electric Vehicles (EV) and Hybrid Electric Vehicles (HEV) require different battery power to energy ratios and make use of battery power differently. Auto manufacturers are evaluating Flywheels and ultracapacitors in hybrid test performed through Department of Energy's HEV program.[43]

Currently, as shown previously, a variety of "green" vehicle technologies are being reviewed as the subject of research and development efforts. And some of them are already shown in the market. However, the effectiveness of some of these technologies is

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[39] ibid.
[40] Web site for *Hybrid Electrical Vehicle Program in Office of Transportation Technologies,* U.S. DOE. *http://www.ott.doe.gov/hev/what.html*
[41] Web site for *Fuel Cell Demonstration Program*, DOD. *http://www.dodfuelcell.com/fcdescriptions.html*
[42] Dudson, Brian. "When Cars Are Clean and Clever: A Forward-Looking View of Sustainable and Intelligent Automobile Technologies". *Transportation Quarterly*. Vol.52. No.3, Summer 1998. 103 ~ 120. pg.107.
[43] ibid.

controversial due to different technical and non-technical reasons. Some alternative fuels are limited in terms of availability and skeptical in their performance for reducing pollution and greenhouse effect. In addition, these environmentally friendly technologies are expensive to maintain as well as costly to produce. Manufacturing cost to produce specific parts is still extremely expensive and only small numbers of mechanics can deal with these new technologies, and hence the technologies are not affordable in general for mainstream buyers yet. In addition, some of new fuels and technologies raise health and safety issues and equity issues caused by its unaffordability.[44] Because of these non-technical and institutional problems, the technologies cannot yet be introduced in mass market, although some of them are applied in niche market such as buses and service vehicles. The following chapter will address more specific non-technological, institutional barriers in implementing and commercializing these new technologies.

NON-TECHNOLOGICAL ISSUES AND IMPLEMENTATION BARRIERS

Although the programs motioned above have been pursued actively at the federal level, a variety of other efforts are also being made at the state and local level. However, those efforts are developed mainly in a technical perspective. The fundamental socioeconomic issues have been in some degree of oblivion. The situation is that attention is too much paid to technical development, but there is not enough study on social constraints for implementing a certain technology, economic impacts of adopting it, and the way for society to use and administer vehicle technologies.

It is required to change people's behavior, or market behavior, organizational behavior, inflexible regulation in order for vehicle technology to be viable in the market. Given this situation, it is meaningful to look at what non-technical barriers exist currently in developing, deploying, and commercializing technologies.

Industry Behaviors: Barriers to Public-Private Partnership

Fragmented Interest and Lack of Consensus

The formation of public-private partnerships has been encouraged, because the technical expertise needed to deploy and implement many vehicle technologies is beyond the current ability of many state and local governments. The private sector's experience in developing and commercializing new products and services may be essential to the successful implementation of new vehicle technologies. If vehicle technology products are going to be widely adopted, the private sector could help pay a large share of the potential public agency costs of providing vehicle technology products. Instead, it obtains a return on its investment in the market they can preoccupy. Successful partnership can share the risks and the rewards.

[44] *Clean Fuels: An Overview.* Report No. EPA-400-F-92-008. U.S. Environmental Protection Agency. August 1994. *http://www.epa.gov/oms/06-clean.htm*

However, U.S. DOT addresses that the areas in which partnerships are now appearing and successful are limited, although partnerships were initially thought possible in all areas of ITS.[45] FHWA also notices that forming partnerships has often been more time consuming than originally anticipated.[46] One of the reasons for this is that public and private entities have different objectives and concerns about sharing information to develop and implement vehicle technologies. Furthermore, there is widespread interest within the private and public sectors. According to FHWA, as of June 1996, ITS America has 824 members including private sector, Federal, State, and local government, and academic organizations. It is a challenge to generate a correspondence in this kind of broad community.

The lack of consensus arises not only in ITS area but also in the area of "green" vehicle technology. There is insufficient consensus on what future technology should be. All kinds of engine technologies are developing in the private sector in order to serve the interest that each industry has. Each industry has different view depending on its own profit-maximization objective. In addition, less agreement exists on the goals of reducing oil use and increasing the use of renewable fuels. Some such as oil industries feel that such changes in fuel use and mix would likely result from pursuing emissions reduction targets but were not valid as stand-alone targets. They lobby against the Electric Vehicle program because they fear the risk of loosing market-shares and focus more on new engine and fuel cell technologies relying on gasoline use. They argue that there will not be much competition with gasoline as an internal combustion engine fuel over the next 10 years, and improvements in fuel economy for conventional vehicles are still possible through such measures as friction reduction and improved warm-up procedures. [47]

Avoidance of Risk Taking

Although auto manufacturers are now more active for developing new environment-friendly vehicle technologies, they initially expressed skepticism toward the overall objective of the technology development. Automakers thought that it is difficult to develop a market for the new technologies. Due to the nature of the industry, there are also potential risks in not innovating: the loss of markets or a decrease in competitiveness and productivity. It makes some of major auto manufacturers rush into the partnerships of the technology development. On the other hand, the costs and risks of technology innovation and commercialization are greater than those in other fields. Developing new ideas through research, development, testing, and demonstration require a great investment of time and money. Given the environment that many companies focus primarily on near-term issues and bottom-figures, their inertia and limited resources make them avoid investing in the technologies that possibly fail along the path to

[45] *A Report to Congress: Nontechnical Constraints and Barriers to the Implementation of Intelligent Transportation Systems*. U.S. DOT, Joint Program Office for ITS. January 1997. pg.E-3
[46] *Key Findings From the Intelligent Transportation Systems (ITS) Program: What Have We learned?*. Prepared for the Federal Highway Administration by Mitretek Systems. U.S. DOT. September 1996. pg.32.
[47] Finizza, Anthony. "The Future of Alternative Fuel Vehicles: An Oil Company Perspective". Presentation at Asilomar Transportation and Energy Conference in Pacific Grove, CA. In *Policies for Fostering Sustainable Transportation Technologies: Conference Summary*. UCD-ITS-RR-98-8. Institute of Transportation Studies, UC, Davis. May 1998. pg.31.

commercialization.[48] In addition, many companies are unwilling to bear the legal liability associated with adopting new and unproven technologies. For example, in developing new infrastructure technology, many companies in construction and auto industry fear health, safety, or environmental hazards issues which are often great enough to deter them from adopting new materials, technologies, and processes.

U.S. DOT argues that one of the most critical non-technical issues is the need for the ongoing support of the automotive and other related industries.[49] The active role of automakers and their suppliers is important for achieving the all the technology development implementation programs' strategic goal and outcomes.

Institutional Barriers

Institutional issues are the main barriers for implementing vehicle technology. Many vehicle technology experts say that there are no technical barriers viewed as being "easy" when compared to the magnitude of institutional problems that need to be addressed.[50] The paper will mainly discuss three main institutional barriers: public organization, financing, and regulation. I will address the organizational problems of many state and local agencies, as a player of partnership, and focus on financial dilemma on the vehicle technology deployment and finally discuss current legal dilemma the technology innovation faces.

Organizations

Lack of Intergovernmental and Inter-Jurisdictional Coordination[51]

It has been found that one of the most significant barriers is the inability for states and local governments to work in a coordinated, multi-jurisdictional fashion because of a lack of common goals and shared vision. Since vehicle technologies should be integrated eventually with intelligent infrastructure to be completely effective in tackling current transportation problems, a lack of inter-jurisdictional cooperation prevents effective exchange of information across political boundaries in large metropolitan areas. Inter-departmental cooperation within the same jurisdiction is also insufficient and hence synergy is hardly produced for integrating a variety of vehicle and highway technologies. State, localities, and other public entities are only slowly addressing the need for cooperation. For example, the responsibility for managing highway traffic in most metropolitan areas has evolved over time in response to public needs, resources, and prevailing institutional and political arrangements. Within each political jurisdiction these

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[48] *Commercializing Infrastructure Technologies: A Handbook for Innovators*, Civil Engineering Research Foundation. 1997. http://www.iti.northwestern.edu/clear/infr/cerf2/cerf_ch1.html

[49] Web site for *Intelligent Vehicle Initiative: Technical Challenges and Implementation Issues,* Transportation Science and Technology, U.S. DOT. *http://scitech.dot.gov/partech/intelveh/intelveh.html*

[50] *Key Findings From the Intelligent Transportation Systems (ITS) Program: What Have We learned?*. Prepared for the Federal Highway Administration by Mitretek Systems. U.S. DOT. September 1996. pg.29.

[51] ibid. pg.27. and *A Report to Congress: Nontechnical Constraints and Barriers to the Implementation of Intelligent Transportation Systems*. U.S. DOT, Joint Program Office for ITS. January 1997. pg.50~56.

managerial responsibilities are often dispersed among separate public agencies. If cooperation is not possible among public agencies, this fragmentation will inhibit chances for the successful implementation of certain elements of the vehicle technology development program.

A DOT-sponsored report insists that some public transportation agencies and political jurisdictions worked together effectively to introduce and operate traffic management systems. Some metropolitan areas have adopted coordination committees to deploy and operate these technologies. However, it should be acknowledged that many state, local agencies, and MPOs are still struggling with self-interested conflicts and pay only small attention to constructive dialog and new relationships with other public entities.[52]

Shortage of Trained Worker[53]

A shortage of trained workers could generate negative impact on the deployment and implementation of vehicle technology products and services. U.S. DOT sponsored study shows that it is quite possible that under current budget constraints, state and local transportation departments may not be able to hire enough workers with the profession and technical skills to operate and maintain the technologies. It is estimated that ITS-related employment will rise from 21,000 in 1996 to 219,000 in 2011.[54] Although all levels of government will possibly have the difficulties in fulfilling and training their staff, these difficulties are present particularly for local government and transportation agency, which often lack the funding. For the successful implementation of new vehicle technologies, existing employees must be retrained or individuals with new skills must be hired.

Financing

Innovative Vehicle Technologies vs. Conventional technologies

A 1997 GAO report[55] indicates that the competition for inadequate financial sources between ITS and conventional transportation projects will restrict the deployment of new technologies. For example, Philadelphia urban area have plans representing more than $100 million in ITS projects, but since needs on their conventional infrastructure are urgent, it was uncertain whether they would implement many of their planned intelligent vehicle and highway technology projects. As they need to repair their deteriorating roads and bridges in the area, it would leave little funding for these projects. In addition, it is doubtful that transportation planners can make large capital investments in innovative

[52] Todd Goldman and Elizabeth Deakin, "Regionalism Through Partnership?: Metropolitan Planning Since ISTEA". *Berkeley Planning Journal.* Vol.14. 2000. pg.46~75.
[53] *A Report to Congress: Nontechnical Constraints and Barriers to the Implementation of Intelligent Transportation Systems*. U.S. DOT, Joint Program Office for ITS. January 1997. pg.5~14.
[54] *A Report to Congress: Nontechnical Constraints and Barriers to the Implementation of Intelligent Vehicle-Highway Systems.* U.S. DOT. June 1994. pg.viii.
[55] *A Report to Congressional Committees: Challenges to Widespread Deployment of Intelligent Transportation Systems*. Report No. GAO/RCED-97-74. U.S. GAO. February 1997. pg.10.

vehicle and infrastructure technologies, given that there is not enough funding for maintaining these technologies.

The report shows that the majority of local government and transit agencies believe that the funding levels for the technology need to increase and be earmarked in order to successfully deploy new technologies for both auto and transit.

Regulation

Privacy

Some have indicated concern on the loss of privacy resulting from extensive data collection of vehicle technologies using cutting-edge information technology. The potential for collecting this type of information may reduce the public's willingness to support the development and adoption of various vehicle technologies. Although some of recent studies[56] show that only 25 percent of the public is totally opposed to any loss of privacy regardless of social good which may result, there possibly would be serious constitutional and statutory challenges to the use of vehicle technologies in the future.

Liability

There are conflicting reports of the height of the liability issues. The increased automation resulting from the adoption of certain new technologies could shift liability to the developers and operators of automated systems. It concerns the resolution of who is to be responsible for accidents and consequent claims: the non-driving driver, the auto-highway authority, or the auto manufacturer. Some legal experts theorized that this issue would produce a "chilling-effect" on the entry of the private sector into the development of technology. Although 1997 U.S. DOT report[57] shows that there is no evidence that fear of liability has deterred industry involvement, concerns still exist. In the future, liability will be a significant issue, as potential liability would arise out of the failure of proposed systems for advanced vehicle control in which the control of the vehicle is transferred from the driver to the automatic system (e.g. automatic braking system and automated highways).

Intellectual properties

Continuing concern is the question of allocation of potentially valuable rights in intellectual property developed with public funds. Some worries that disputes over the retention of intellectual property rights by a government agency could deter the technology developers from not only participating in research but also implementing the technologies. Unless project participants address these issues early in the process, negotiation of the allocation of rights in intellectual property and clauses protecting preexisting data and trade secrets can cause significant delays in implementing vehicle

[56] *A Report to Congress: Nontechnical Constraints and Barriers to the Implementation of Intelligent Transportation Systems*. U.S. DOT, Joint Program Office for ITS. January 1997. pg.33~40.
[57] Ibid. pg.22~26.

technologies.[58] However, the problem is not simple, because it is difficult to define what can be the subject of the intellectual properties in the future. As society becomes more complex and information is more footloose, the target of intellectual properties becomes more ambiguous, and hence a decision on what should be had by whom will be very hard to make.

Design and performance standards

Some private sector technology developers argue that they need assurances that any products they develop will be technically compatible with vehicle technology products developed by other firms. They believe the adoption of industry design and performance standards could promote the development, adoption and implementation of large and complex systems of vehicle technologies. If properly designed and introduced, industry standards could reduce market uncertainty, promote acceptability among users, limit liability, improve safety and performance, and therefore promote technological development and implementation. However, the premature adoption of industry standards or protocols could also stifle competition and innovation among vehicle technology developers.[59]

Industry design and performance standards, to the maximum extent feasible, should accommodate the broadest possible range of interest and technological alternatives. However, the process of developing standards was inflexible in the past. The process should become flexible and consultative with more public involvement, with the broad discussion of technical and non-technical issues.[60]

Socioeconomic and environmental impacts

The impact of vehicle technology on society and environment is unclear. Careful deployment of vehicle technology may yield socioeconomic as well as environmental benefits in terms of boosting industry and economy, improved air quality and reduced fuel consumption. However, it is needed to conduct a further study on the relationship between vehicle technology and travel behavior, transportation system performance, vehicle emissions, fuel consumption, air quality, and economic equity in order to address the consequences of the technology implementation.[61] Without completing these studies, we cannot have the answer for the question of what particular technologies should be chosen for implementation. The researches must also consider impacts on the community and social environment, as well as the underlying forces and the potential supporting role

[58] Ibid. pg.27~32.
[59] *A Report to Congress: Nontechnical Constraints and Barriers to the Implementation of Intelligent Vehicle-Highway Systems*. U.S. DOT. June 1994. pg.vii~viii.
[60] Lipman, Timothy, Danilo Santini, Daniel Sperling. *Policies for Fostering Sustainable Transportation Technologies*. *Conference Summary.* UCD-ITS-RR-98-8. Institute of Transportation Research, University of California, Davis. May 1998. pg.II.
[61] *A Report to Congress: Nontechnical Constraints and Barriers to the Implementation of Intelligent Transportation Systems*. U.S. DOT, Joint Program Office for ITS. January 1997. pg.62~68. and Dudson, Brian. "When Cars Are Clean and Clever: A Forward-Looking View of Sustainable and Intelligent Automobile Technologies". *Transportation Quarterly*. Vol.52. No.3, Summer 1998. 103~120.

of vehicle technology in enhancing mobility, promoting community cohesion, and enhancing the quality of life.

Market barriers and acceptance

Demanders: Consumer Inertia

Consumers are often reluctant to purchase new technologies, because they hardly accept the risks associated with unproven technologies and thus have inertia to rely on what they have used in the past. Buyers do not want to pay for the technologies alone unless they offer a significant improvement of vehicle performance. For example, private travelers find traffic information an attractive feature when bundled with for-pay services such as stock quotes, weather, and sports scores. However, if it does not supply a substantial improvement over traffic information that is currently available free of charge, they would be unwilling to pay for it.[62] For route choice decisions, travelers are generally more interested in having Advanced Traffic Information System (ATIS) for long distance trips or for travel in unfamiliar areas, but they are less interested in having ATIS for local or familiar trips. Thus, many people who mainly travel daily familiar trips or commuting do not actually want to pay for it. As another example, in-vehicle voice-alert systems, reminding drivers to buckle their seat belts, was rejected in the 1980s, since the people is extremely picky about what goes in their vehicles.[63]

In the area of environment-friendly vehicle technologies, similar circumstances often happen. Many recent surveys show that there is high level of support of clean air by the public. However, it is also clear that consumers prefer improvement of technology to lifestyle changes. Many marketers focused on younger groups as prospective green vehicle technology buyers and dismiss baby boomers and traditionals. The youth group is recognized as being more receptive to environmental products because of the emphasis that is being placed on the environment schools, from grade school onward. However, despite the concern expressed by young member of society, most seem unwilling to make big sacrifices for these concerns. A study[64] shows how concern differs from action among the youth segment. It argues that the young expressed purchase intention based on value and convenience, despite the fact that they had been screened to be pro-environment. They expressed that they expect safety, service, performance, reliability, range, and affordability, and that alternative fuel vehicles would need to meet the same criteria met by the traditional family car.

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[62] *Key Findings From the Intelligent Transportation Systems (ITS) Program: What Have We learned?*. Prepared for the Federal Highway Administration by Mitretek Systems. U.S. DOT. September 1996. pg.28.
[63] Little, Cheryl. "The Intelligent Vehicle Initiative: Advancing "Human-Centered" Smart Vehicles", *Public Roads,* Vol. 61, No.2. Sep/Oct 1997. *http://www.itsdocs.fhwa.dot.gov/jpodocs/periodic/2QF01!.htm*
[64] Beseda, Jane. "Factors that Influence the Successful Introduction of New Technologies". Presentation at Asilomar Transportation and Energy Conference in Pacific Grove, CA. In *Policies for Fostering Sustainable Transportation Technologies: Conference Summary*. UCD-ITS-RR-98-8. Institute of Transportation Studies, UC, Davis. May 1998. pg.21.

It also argues that eco-friendly households will pay more and will consider alternative fuels, but these households make up only 8% of intender households. Furthermore, the eco-friendly consumer group is more conservative and practical than the early adopter group, preferring safety over price and being more willing to wait for a vehicle to become established in the market before buying. These findings suggest that market is still pretty conservative and today's decision appear to be traditional. Although the issue of global warming is likely to grow in importance with public awareness, but it is found that at least among this group of young people, there is little awareness or concern for the subject.

Suppliers: Lack of Market Understanding and Need Assessment

The biggest challenge researchers and inventors typically face is developing a through understanding of the market for their idea or invention. Invention does not necessarily lead to technology commercialization and innovation. In fact, oftentimes the knowledge gained by research never leaves the laboratories or institutions in which it was developed. Government, academic researchers and engineers often fail to realize that engineering or scientific success does not always result in business or commercial success, because they have traditionally far removed from the market. They, as a supply-oriented people, tend to place less emphasis on the critical business, management, market issues that lead to success, and instead focus primarily on technical research and development.[65]

To make a success, user needs are clearly defined and prioritized. Currently, a variety of different vehicle technologies are researched and developed by the public, private, and partnership at state and federal levels. However, there are not many public officials who can clearly understand what user requirements are urgent and which technology should be prioritized to penetrate market successfully. In addition, researchers and governments often do not know how to begin the process of commercialization, how to obtain market information, or where to turn for assistance with their questions or needs.

Technological innovation can serve a new revolution when it occurs. However, without well-defined market demand and understanding market push and pull, innovation rarely forces change in a mature automobile industry. Current trends of encouraging public-private partnership try to ease these difficulties. The government research should address whether the market requires a new product and prioritize what needs are more urgent and crucial. This review can be a guide for government and the private sector to determine the status and potential for innovative technologies in their particular vehicle technology component.

Market complexity: Interrelationship with Socioeconomic Barriers

[65] *Commercializing Infrastructure Technologies: A Handbook for Innovators*, Civil Engineering Research Foundation. 1997. http://www.iti.northwestern.edu/clear/infr/cerf2/cerf_ch1.html

Market penetration of the technologies is closely associated with other institutional and economic issues such as cost, privacy and economic impacts. A DOT report[66] shows that for transportation managers in all sectors, major ITS buyers, the biggest obstacle to ITS purchase is the Operation & Maintenance costs. As another example, commercial drivers are receptive to vehicle technology for safety and security, but would not actively use the service because of concerns on privacy about its use for surveillance purposes as well as cost.

There are also economic issues involved in establishing automated highway system and commercializing smart vehicles. While roads existed when people first bought autos at the beginning of the century, automated highways have not constructed yet enough for automated vehicles. People are reluctant to purchase smart cars until smart highways are produced. On the other hand, when few vehicles would be equipped to use automated highways, it is difficult to justify and pay for the construction of the high-cost highway system.[67] Thus, the conflicting economic arguments have been continuing. Some argue that it is easier to introduce automated highway systems by constructing new facilities or converting existing lanes on all fronts, because it produces economic benefits by boosting construction and other related industries. Others insist that more evolutionary process is needed to avoid the risk that this technology cannot be commercialized in the market. They argue that many "advanced safety vehicles", with advanced air bags and intelligent cruise control, can be the platform for the fully automated vehicle and highway system equipped with collision warning and avoidance systems.[68]

In the area of "green vehicle technology", similarly, two conflicting strategies are discussed for the commercialization. For example, to bring fuel cells into market, one way is that niche markets would be the focus where the unique attributes of the product allow it to be used despite its high costs. Then a gradual diversification strategy could be followed. But the problem of this strategy is that the company would not be having much liquidity to attract investors. Another way is to go all out to change power systems of all vehicles on all fronts. This strategy has also problems of requiring considerable capital and managing patents protection. Furthermore, some leading companies would not want to give up autonomy in the market by having partners.[69]

These institutional and economic issues are always interrelated with marketing issues. Technology-push innovation is less likely to occur, unless complex social and market barriers are substantially removed from market.

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[66] Radin, Sari and Jane Lappin. *ITS User Acceptance Research on Transportation Managers*. John A. Volpe National Transportation Systems Center. Working Paper Prepared for U.S. DOT. March 1996.
[67] Dudson, Brian. "When Cars Are Clean and Clever: A Forward-Looking View of Sustainable and Intelligent Automobile Technologies". *Transportation Quarterly*. Vol.52. No.3, Summer 1998. 103~120
[68] Lay, Rodney K., Gene M. McHale, William B. Stevens. The U.S. DOT Status Reports on the Automated Highway Systems Program. Mitretek Systems. July 1996. pg.8-1~8-2.
[69] Ballard, Geoffrey. "Perspectives on Ballard's Development of the Fuel Cell for Use in Transportation". Presentation at Asilomar Transportation and Energy Conference in Pacific Grove, CA. In *Policies for Fostering Sustainable Transportation Technologies: Conference Summary*. UCD-ITS-RR-98-8. Institute of Transportation Studies, UC, Davis. May 1998. pg.20.

Actual applications

In addition to all institutional and market barriers discussed before, one more inherent risk is that the technology will not work as expected. For example, while green vehicle technologies are making great strides, with new electric vehicles, hybrids and fuel cells, the opposite market direction are observed from sport utility vehicle and pick-up truck. These vehicles were not originally designed for day-to-day trips. But they became popular in actual market because of its advantages: high visibility from the driver's seat over traffic, a sense of collision safety, and personal security. From this perspective, the actual application of the technology can be often different from the original expectation.[70] When private goals are in conflict with social goals, problems would be much more serious. As more and more households have multiple vehicles, it can possibly encourage the Electric Vehicle market. However, concerns have been raised. Most of households want to have dissimilar body types, people will be more preferable to have Sports Utility Vehicles, when they had an Electric Vehicle already or will have an Electric Vehicle in the future. Thus, it is hard to guarantee, as the Electric Vehicle market are larger, the pollution can be reduced. Even though this is only one of possible scenario, it makes it clear that any technology implementation may not actually apply to market as originally anticipated.

CONCLUSION

The US transportation sector faces important challenges. Foremost among these challenges is the need to enhance the safety and to ameliorate the environmental problems related to traffic congestion. Developing diverse vehicle technologies is an innovative attempt to reach a goal of sustainable transportation. Many technicians and policy makers believe that rapidly developing technologies will achieve great success for easing current transportation problems.

However, technology is not a panacea resolving all kinds of transportation problem. The concept of technological "legitimacy" is important in a sense that a technology can become legitimate by capturing the ideology of given society. This ideology defines what is good and acceptable, and it shifts with time.[71] Therefore, technology must follow social and environmental constraints. As this "legitimacy" screens technology, it always interacts with not only social institution but also market absorbing people's thought. Therefore, the technology innovation is stimulated or sometimes stalled by regulation,

[70] Turrentine, Tom. "Redefining the Market". Presentation at Asilomar Transportation and Energy Conference in Pacific Grove, CA. In *Policies for Fostering Sustainable Transportation Technologies: Conference Summary*. UCD-ITS-RR-98-8. Institute of Transportation Studies, UC, Davis. May 1998. pg.36.

[71] Ballard, Geoffrey. "Perspectives on Ballard's Development of the Fuel Cell for Use in Transportation". Presentation at Asilomar Transportation and Energy Conference in Pacific Grove, CA. In *Policies for Fostering Sustainable Transportation Technologies: Conference Summary*. UCD-ITS-RR-98-8. Institute of Transportation Studies, UC, Davis. May 1998. pg.20.

organizational behavior, and multiple players in market. If technology is not sufficiently embedded in the ideology of society, technology cannot be viable.

To solve transportation problems using vehicle technologies, or even less ambitiously, to let the technology viable in market, it is required to change not only people's behavior but also context, constraining it, such as regulation, urban form and land use pattern. Policy makers must avoid technology optimism. They must keep in mind that technology would be widely adopted only if there were policy, government and behavioral change. Also, they should have enough capacity to deal with side effect produced by this technology innovation such as privacy invasion, information monopoly. It is time to think education, pricing instruments and new organization structure to implement emerging vehicle technologies.

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