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Moving Transportation toward Sustainable Development: The Need for a Paradigm Shift

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MOVING TRANSPORTATION TOWARD SUSTAINABLE DEVELOPMENT: THE NEED FOR A PARADIGM SHIFT

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ABSTRACT

Despite progress in controlling exhaust emissions, the increase of cars on the road will surpass progress in emission control technology. The automobile is currently **responsible for 50% of world fossil fuel consumption**, 15-20% of CO_2 emissions worldwide and overwhelming particulate air pollution in many urban centers. Current efforts in emissions control have been focused on improving the efficiency of fuels and automobiles and their emissions. However, as a mode of transportation, the automobile is one of the most inefficient, both in environmental and economic costs. Even the most efficient cars developed today will still significantly contribute to the amount of global greenhouse gases based on the current rate of increase in automobile usage. Current trends in automobile development and research are not sustainable. This paper describes some novel approaches to offset and reduce automobile emissions that are currently under study.

INTRODUCTION

In recent years, as the public has become increasingly concerned with environmental problems, air has come to be regarded as a resource within the public domain. Hence air pollution is considered a public problem, a concern not only of those who discharge the pollution, but also of those who may suffer as a result. However, in the past, industry, agriculture, and individual polluters have found it more economical to discharge waste products into the atmosphere than to exercise waste control. In general the organization or activity causing the pollution did not suffer the consequences of the pollution. As a result, those who benefited from a reduction in air pollution from the installation of control equipment did not directly bear the cost of the equipment.

The rational for the control of air pollution rests on four basic assumptions [2]:

1. *Air is in the public domain.* Such an assumption is necessary if air pollution is to be treated as a public problem, of concern not only to those who discharge the pollution but also those who may suffer as a result.

2. *Air pollution is an inevitable concomitant of modern life.* There is a conflict between man's economic and biologic concerns; in the past, this conflict was recognized only after air pollution disasters. We need a systematic development of policies and programs to conserve the atmosphere for its most essential biological function.

1. *Scientific knowledge can be applied to the shaping of public policy.* Information about the sources and effects of air pollution is far from complete, and a great deal of work must be done to develop control devices and methods. Man does not have to abandon either his technology or his life, but he must use his knowledge.

2. *Methods of reducing air pollution must not increase pollution in other sectors of the environment.* Some industries reduce waste in the air by dissolving them in water and by pouring the polluted water into streams. For example, one proposal to reduce the sulfur dioxide emitted by coal burning electrical power plants results in the formation of large quantities of either solid or liquid wastes. Such methods are not true solutions to air pollution problems.

There are many definitions for air pollution. One such definition is the following: "air pollution may be defined as the presence in the outdoor atmosphere of one or more contaminants or combinations. Therefore, in such quantities and of such duration as may be or may tend to be injurious to human, plant, or animal life, or property or which unreasonably interferes with the comfortable enjoyment of life or property or the conduct of business "[8]. It is very important to establish a definition to begin the process of looking at and defining air pollutants. It covers all aspects of life and how air pollution can interfere with our lives and property.

The need for protecting our air quality is essential. It is also of concern for the entire public domain to recognize and protect. Garrett Harden wrote an article titled "The Tragedy of the Common." In this article Harden argued that "a society permitted perfect freedom of action in activities that adversely influenced common properties was eventually doomed to failure [1]. Authors are not proposing that we are destined to failure soon, but the air quality must be protected. It would not be wise to allow companies and individuals to emit air pollutants that are harmful to others and society [1].

THE AUTOMOBILE PROBLEM

There are 500 million cars on the world's roads today, ten times as many as 50 years ago. By 2030 there could be a billion, plus another 500 million lorries and motorcycles [3]. This is excellent news for automobile manufacturers and consumers. More people will be able to afford and ride in cars. However, the increase in the number of automobiles will bring heavy costs in air pollution and congestion. Figure 1 is a presentation of the factors affecting transportation demand in the US.

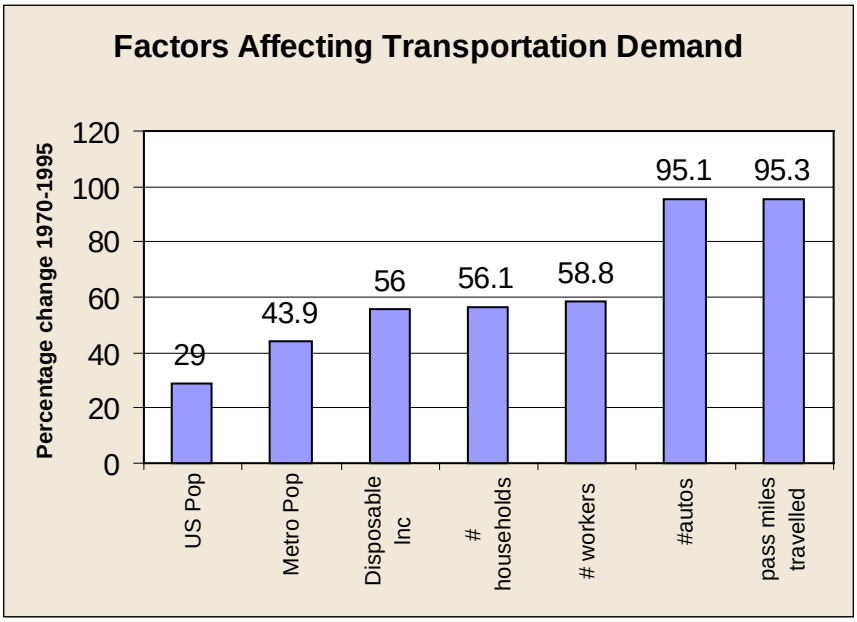

FIGURE 1, SIGNIFICANT FACTORS IMPACTING AUTOMOBILE DEMAND. (Source: The US Department of Transportation)

On a national basis in 1977, highway vehicles were responsible for 75 percent of the carbon monoxide, 35 percent of the hydrocarbons, and 29 percent of the oxides in nitrogen [5]. It is evident from this report that in the absence of control, the hydrocarbon emissions would have increased by a factor of over 2 by 1980.

A modem version of the tragedy of the commons has been discussed by Harvey Brooks of Harvard University. Brooks points out that the convenience, privacy, and safety of travel by private automobile encourages each individual to drive to work, school, or stores [2]. At low levels of traffic density, this is a perfectly logical approach to the demands of modem life. At some critical density, however, the road network commons is incapable of dealing with the traffic, and the smallest disruption (a stalled vehicle, a delivery truck, and a minor accident) dooms drivers to minutes or hours of idleness [1].

Congestion of traffic also increases the levels of air pollutants from automobile exhaust. "But now congestion is considered a menace for another reason too: it makes pollution much worse. "Cars in jams cause three times the pollution they do when they are flowing freely," explains Mr. Kramer of Daimler-Benz [4]. There are two problems. The first is the actual emission from the automobile and the second is the concentration of the emissions from congestion. Both of these problems will be analyzed.

AIR POLLUTANTS AND CONGESTION

Modern automobile engines operate by burning fuel in an engine system. These fuels, diesel or gasoline, are mixtures of hydrocarbons. The engines operate when oxygen in the air combines with the hydrogen and carbon. One hundred percent efficient and pollution free engines operate by converting all of the engine’s oxygen and the hydrogen to water, and all of the carbon to carbon dioxide. Unfortunately, today’s engines are neither efficient nor pollution free because a typical combustion produces several pollutants [5].

FUEL + AIR => UNBURNED HYDROCARBONS + NITROGEN OXIDES +
CARBON MONOXIDE + CARBON DIOXIDE + WATER

Some of the major air pollutants come from automobile exhaust emissions. Automobile exhaust emissions have the potential to increase dramatically with the expansion of automobile markets in the future. This paper will discuss the need for preserving the world's air, illustrate the extent of the problem, and provide some possible solutions to automobile emission air pollution and congestion.

Why do we need to save our air? Because, the quality of our air is one of the essential elements we need to sustain human life on earth. It is from the oxygen that we are able to breathe and live. All pollutants affect the quality of the air and impact the quality of our lives.

Air pollution is a waste remaining from the ways we transport our goods and ourselves. It is a by-product of the automobile. The major cause of air pollution is combustion. In a perfect world, the hydrogen and carbon in the fuel combine with oxygen from the air to produce heat, light, carbon dioxide, and water vapor. However, impurities in the fuel, poor fuel to air ratios, or too high or too low combustion temperatures cause the formation of air pollutants [6].

AUTOMOBILE EMISSION CONTROLS

The first problem is that automobiles emit air pollutants. Table 1 illustrates the adverse effects of automobiles without emission controls on the environment [7].

TABLE 1. IMPACTS OF AUTOMOBILES WITHOUT EMISION CONTROL ON ENVIRONMENT

	% POLLUTANT			
Source	**CO**	**HC**	**NO**	**Particulate**
Exhaust	100	62	100	90
Crankcase Emission		20		100
Fuel Tank Evaporation		9		
Carburetor Evaporation		9		

The State of California has taken the lead in dealing with automobile emissions. In 1960, the Motor Vehicle Pollution Control Board of the State of California was created to establish specifications on vehicle exhaust and evaporative emissions. The first automobile emission requirement was for the reduction of crankcase blow-by. The Control Board adopted a resolution requiring that a positive crankcase ventilation system be installed on all new cars sold in California beginning with 1963 models.

However, California State action wasn't enough. Automobile emissions were a national problem, and required federal action. The federal government, by an amendment to the Clean Air Act in 1965, specifically authorized the writing of national standards for emissions from all motor vehicles sold in the United States. Many factors went into achieving the emission standards. Advances in technology were essential to reduce the amount of emissions from automobiles. The result has been increased standards and enforcement of the federal laws [8].

The tragedy of the commons illustrates that the air is common to use and only through government action will automobile emissions be reduced. "But the air and waters surrounding us can not readily be fenced, and so the tragedy of the commons as a cesspool must be prevented by different means, coercive laws or taxing devices that make it cheaper for the polluter to treat his pollutants than to discharge them untreated [6]. This is a key point. Legislation and enforcement of laws are the primary means of reducing automobile emissions.

Legislation and taxes force compliance, thereby causing a dramatic effect. Unless there is a reason to change the automobile emissions, manufacturers will continue to produce automobiles that emit air pollutants. The cost associated with reducing the amount of emissions from an automobile is the manufacturers' profits margin. As a result, the costs are passed on to the customers. However, who can put a price on the quality of clean air especially since it effects our existence on earth? As a result we must acknowledge that air is in the pubic domain which is the first of our four basic assumptions for air pollution control [1]. Figure 2 is a presentation of the changes in automobile emissions since 1970.

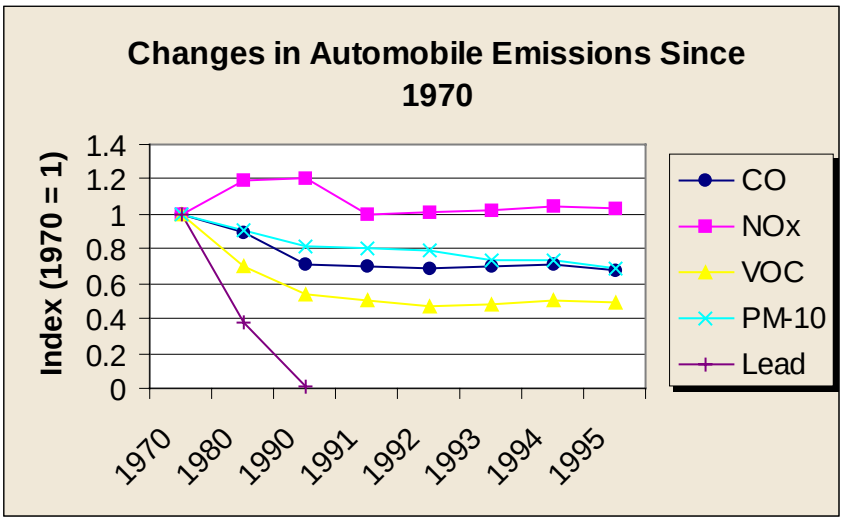

FIGURE 2, VARIATIONS IN AUTOMOBILE EMISSIONS.
(Source: The US Department of Transportation, Highway Statistics, Summary to 1995)

Future control of automobile emissions will continue to in the hands of the federal government. In particular the Environmental Protection Agency (EPA) will regulate, and enforce automobile emission standards. The need for the federal government to take the lead will continue. It needs to be this way to ensure that the laws have a strong backing. A 1987 ranking of United States Environmental Protection Agency major problems listed its top three problems as the following [3]:

- Criteria air pollutants
- Hazardous air pollutants
- Other air pollutants

CURRENT OPERATING ENVIRONMENT

With an extreme growth in the number of cars utilized in today's society, the current levels of automobile emissions polluting the air is at an all time high. Automobile emissions became a public issue in 1970 with the Clean Air Act. This act, along with the Clean Air Act Amendments in 1990, have attempted to regulate and enforce emissions standards and improve air quality for major metropolitan areas throughout the United States. The regulations set forth by the Environmental Protection Agency have met with great scrutiny by both state level agencies and major car manufacturers [5].

In an attempt to satisfy EPA guidelines, preserve the environment and satisfy the general public, several actions need to occur simultaneously. First, the EPA must relax strict regulations that dictate to states how to achieve the required air quality. Second, states should implement a mandatory annual decentralized testing program utilizing the IM 240 for emissions testing. Third, major car manufacturers must continue researching new technology, including electric cars and cars that operate using alternative fuels. These strategies will preserve the rights of states and individuals while improving the air quality and meeting EPA guidelines. However, other strategies are also worthy of investigation and are discussed in this paper [7]. Figure 3 is a comparative study of automobile emissions for various engine emission products.

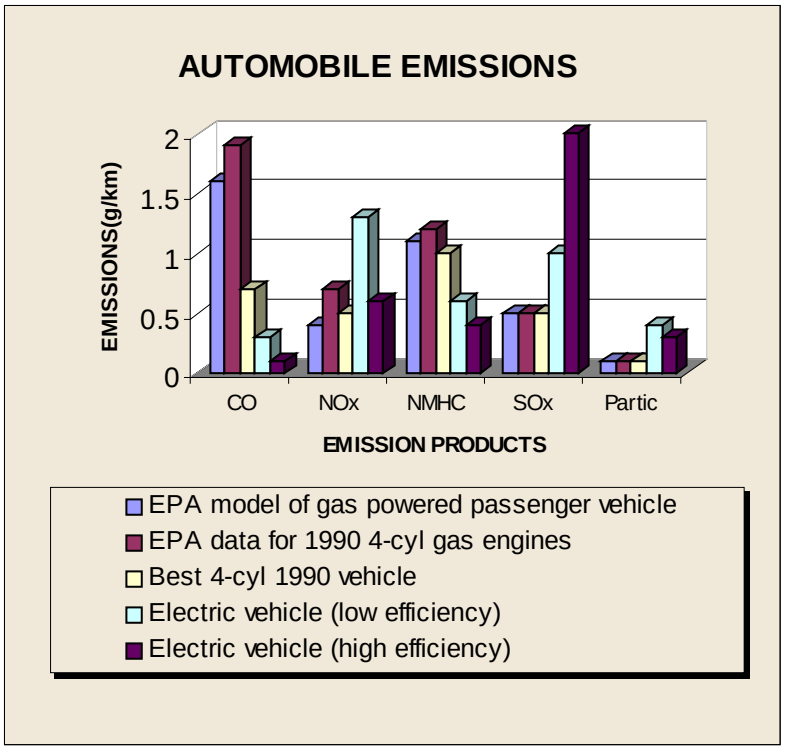

FIGURE 3, COMPARATIVE ANALYSIS OF AUTOMOBILE EMISSIONS IN US.
(Source: The US Department of Transportation)

THE CONGESTION PROBLEM

The problem of congestion is an entirely different concern of major cities. It has to do with the fact that many people prefer to drive their cars to work. Traffic delays are common and accidents are bound to occur. Many attempts have been made to reduce the number of automobiles traveling in and out of cities but none have been to effective. The two assumptions made are that people will continue to drive automobiles on a daily basis and that emissions will continue to be emitted. A solution must be found to solve this problem of congested automobile emissions [2].

Cities have tried numerous techniques to reduce the amount of automobiles on the roads. City planners recommend that drivers share a ride and carpool with other workers. This causes a problem with people who are on different work schedules or people that might have to wait on others. Another technique is using public transportation. The problems are frequency of schedules with work times and proximity of the transportation to the user. Cities have also tried park and ride shuttles and express lanes. Although these techniques have been somewhat successful they do not solve the problem of congestion on the highways [4].

Figure 4 illustrates the increase in US annual automobile fuel consumption since 1960 to 1995. Figure 5 is a comparative analysis of the US annual vehicle miles traveled from 1960 – 1995. Even though these figures seem to show a leveling trend, pollutants and emissions are still a significant issue [6].

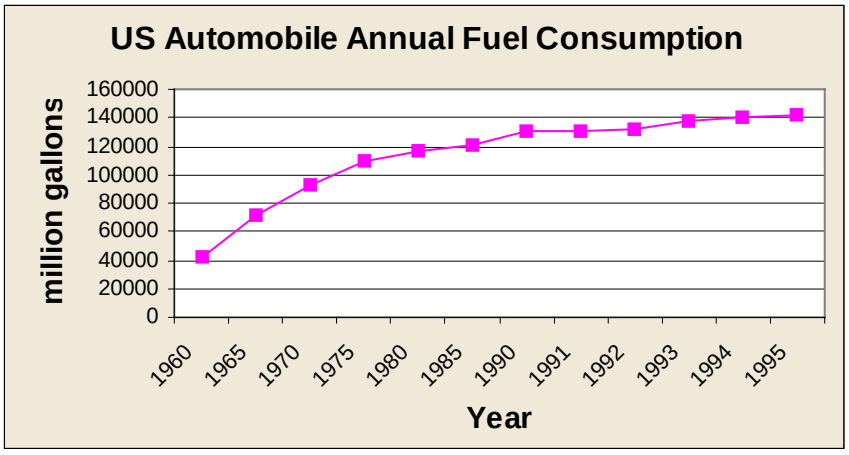

FIGURE 4, ANNUAL FUEL CONSUMPTION IN THE US.
(Source: The US Department of Transportation)

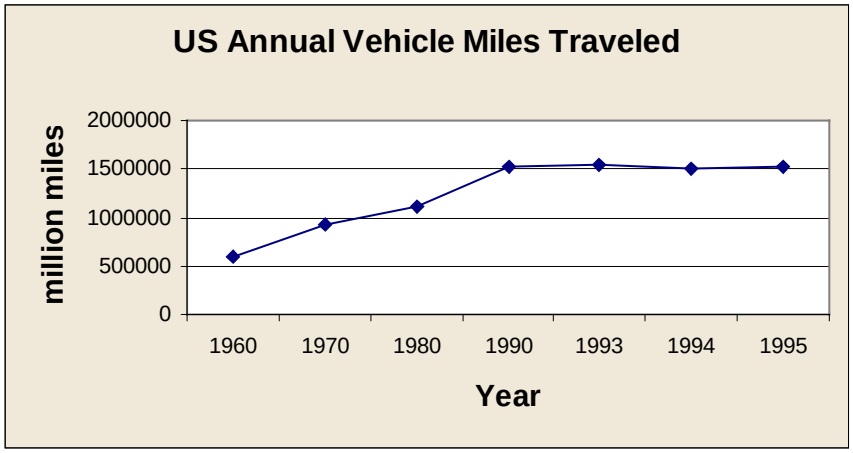

FIGURE 5, ANNUAL VEHICLE MILES TRANSPORTED IN THE US.
(Source: The US Department of Transportation)

SOLUTUION

The solution may lie in technology and electronics. The concept is called telematics. It is a way of managing traffic in cities. Telematics started with linking traffic lights by computer so that they always optimize traffic flow. The telematic systems can also be connected to operation control centers with access to online information about problems such as accidents. Displays alert drivers to problems ahead on the roadways so they can divert to another road. The telematic systems take advantage of navigation systems such as the global positioning services (GPS). This is the basic system of telematics [8].

A case study for telematics was conducted in Los Angeles, California. The experiment was simple and only involved installing traffic signals. Traffic signals and controls were installed at 800 intersections. The signals and controls cut delays by 50,000 hours **per day and eliminated 8** million stops by cars [6]. This traffic management technique is not noticeable to drivers but it cut down on congestion.

There are also doubters to the telematics approach. Many transport economists and planers damn telematics with faint praise. Katsutoshi Ohta of Tokyo University puts the technique's potential for cutting congestion at only 15% [4]. Mr. Ohta even worries that some applications might make matters worse. For example the GPS systems encourage drivers to use back street bypasses to traffic jams. As a result, congestion is spreading to the residential districts. This is true but it prevents the concentrated congestion of many cars stuck on the main highway.

Car companies are avid supporters of telematics. They love telematics for two reasons. The first is that the more electronics that a car has, the more profit car companies can get per car. Surveys suggest that within four years some 10- 15% of the cost of a new car will go on various electronic navigation and control systems. These systems talk to the telematics infrastructure to reduce delays [5].

The second reason that car companies like telematics is that technology that keeps traffic moving should sell cars. Some market cars already carry telematics devices such as navigation aids that use satellite signals and on board digital maps to plot the best route to a destination. The latest systems have a disembodied voice that tells the driver when to turn left or right. Some systems even incorporate live, up to the minute information on the state of traffic. In Japan over a million cars use a navigation system. In Britain, a simple system called Trafficmaster, based on roadside sensors and radio waves broadcast to the car, is being installed to cover the entire motorway network [3].

INTELIGENT VEHICLE SYSTEM

The idea of telematics has spread into the intelligent-vehicle highway system (IVHS). IVHS makes the cars smarter and able to deal with traffic congestion. Transportation planners say that IVHS will improve highway systems by steering drivers away from bottlenecks, as well as reducing air pollution caused by congestion. Advanced traffic management technology and systems, which IVHS supplies, are the keys to dealing with congestion. The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) authorized 659 million dollars for IVHS through 1997. Potential clean air benefits were the major selling points of the IVHS system. This act shows again the need for government to be involved in the air pollution solution [6].

The idea for IVHS started many years ago. Thirty years ago transport researchers at the Massachusetts Institute of Technology had a special room with a toy car layout. The layout showed how traffic could be completely automated to have safe, high speed, high-density traffic flow. This summer, the toy layout will become a fact on Interstate Highway 15 near San Diego, California [3].

The experiment in San Diego will conduct tests to find out what level of automation will work best. A small squad of cars, trucks, and vans will use the middle two lanes of Interstate 15 with electronic devices that will talk to each other and a control center. The cars will have sensors, radar scanners, and on board computers. The computers will be able to interpret all the information and drive the car. The experiment is designed to allow platoons of 10-12 vehicles, each of them separated by two meters, to drive safely at highway speeds [8].

There are three stages of the automated highway that will be tested. The first stage is to have each vehicle operate independently but with its own automated lane keeping, cruise control, and collision avoidance systems. The next stage is the "cooperative vehicle" stage where each car would talk electronically to those around it so they could slow down, speed up, or change lanes to accommodate actions planned by another vehicle. Drivers would still be necessary to supervise and oversee the actions of the planned moves [1].

The third stage of the automated highway eliminates the need for drivers. Traffic would be taken care of from a central control room. Fully automated platoons of vehicles would follow each other down dedicated lanes. The control room would tell the car’s electronics how and when to join the next platoon. Cars would simply slide into position while the driver watched. The car would be programmed to get out of the platoon and off at a pre-set highway exit [3].

There are those who doubt and are concerned about the automated highway. They are concerned about reliability, safety, and credibility. Another issue is a failure in a car's radar system with automobiles only 2 meters apart. In a world filled with lawsuits over accidents, it would seem unrealistic that people would rely solely on a radar system. The doubters say that telematics is at best only good for providing information to drivers. The doubters contend that cars should not be connected and able to talk to each other [7].

Another major concern is cost. The automated highway system with its infrastructure has a high cost. The key questions are: who will build these systems and who will own them? According to the *Strategic Plan for Intelligent Vehicle Highway Systems in the U.S.,* a report from the public/ private group IVHS America, $200 billion could be spent over the next 20 years to develop and deploy IVHS technologies. The costs would be broken down with 80% borne by the private sector and 20% borne by the public sector. For the most part, individuals will pay for in vehicle technology, while public spending will be used in research and development and to determine the system architecture [2]. Federal, state, and local governments will likely be responsible for the needed infrastructure- building traffic management centers and installing hardware to collect and transmit real-time data- although private industry may also invest in this area. Eventually, the hope is that vehicles, communicating information back to the center, will serve as probes, eliminating the need for expensive in road sensors in some areas. This is especially difficult in a time that is against expanding public sector activity [4].

When will the automated highway become a reality? Americans think that by the end of this year they will have figured out the best way to make it happen with the San Diego experiment, and by December of 2001 they will have a fitly tested prototype system up and running. Toyota has been working on another version of the automated highway with one vehicle. This vehicle has radar and special video cameras, on a private test track. Toyota is not talking much about its project and research. However, the developments of its research might be beneficial to all researchers in the IVHS field [6].

CONCLUSIONS

The battle over the automated highway is just about to begin. The results of the war might not be known for some time. There is a lot at stake with the experiment in San Diego this summer. If the pessimists of the automated highway win out, telematics will remain a limited tool, cutting congestion by enabling roads to handle around 15% extra capacity. If the enthusiasts win out, capacity on the main inter city roads suitable for automation may double or triple and reduce congestion as well as automobile air pollution significantly.

Americans love their automobiles. The love affair between automobiles and Americans has been going on for over 50 years and looks strong to continue for some time. The automobile was a revolution in the transportation field but the inventors did not know about the harmful effects of automobile emissions on the quality of air. They also didn't expect the growth of automobiles to have such an impact on our lives. The two major problems with automobile emissions are the pollutants and concentrations. The use of telematics and the automated highway can greatly reduce the effects of automobile emissions on the air.

The need for preserving the air quality is essential for our existence on earth. The projected estimates of the number of automobiles in the future depend on solutions now to counter the increased emissions that will result. Technology, like IVHS, will definitely play a major role in finding solutions to control emissions while the federal government will still need to enforce and control air pollution.

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BIOGRAPHY

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Dr. Bahador Ghahramani is an Associate Professor of Engineering Management in the School of Engineering at University of Missouri-Rolla (UMR). Prior to joining UMR he was a Distinguished Member of Technical Staff (DMTS) in AT&T-Bell Laboratories. His work experience covers several years of academics, industry, and consulting. Dr. Ghahramani has presented and published numerous papers and is an active participant and officer of various national and international organizations and honor societies. He holds a patent, "Eye Depth Testing Apparatus", has filed for two Bell Laboratories patents "A Method for Measuring the Usability of a System" and "A Method for Measuring the Usability of a System and for Task Analysis and Re-Engineering".

Dr. Ghahramani received his Ph.D. in Industrial Engineering from Louisiana Tech University; MBA from Louisiana State University; MS in Industrial Engineering from Texas Tech University; MS in Applied Mathematics from Southern University; and BS in Industrial Engineering from Oklahoma State University.

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