The Future of Personal Transport in China: Summary of a Symposium, January 12, 2001

Michael Greene, National Research Council

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This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. The author wishes to thank the following individuals for their review of this report:

Dr. W. Dale Compton, Purdue University; Dr. Kong Hui Guo, Jilin University, China; Dr. Claude C. Gravatt, Jr., Department of Commerce; Dr. Lester A. Hoel, University of Virginia, and Dr. Dennis Shuetzle, Ford Motor Company.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of symposium presenters, , nor did they see the final draft of the report before its release. The review of this report was overseen by Dr. Harold Forsen, Foreign Secretary, National Academy of Engineering. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the author and the institution.

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INTRODUCTION

In August 1999 a delegation from the Chinese Academy of Engineering (CAE) led by Professor Guo Konghui visited The National Academies in Washington to discuss opportunities for collaboration on a study of the future of personal use vehicles in China. Barely motorized at present, China is confronted with the prospect of a massive increase in demand for automobiles. The question of how to address that demand involves consideration of existing infrastructure, including roads, parking areas, alternative public and personal modes of transport; availability of high quality fuel, and ability to control the pollution and congestion of Chinese cities. The CAE has been asked to provide advice to the Chinese government on this issue, and the delegation invited the National Academy of Engineering (NAE) and the National Research Council (NRC) to collaborate on a study with them.

The study will be carried out by a Committee on the Future of Personal Use Vehicles in China. The members were nominated by both the NRC and the CAE, and the membership has been approved by both organizations. The committee had its first meeting during January 11-13, 2001, at the National Academy of Sciences (NAS) in Washington, D.C. On Friday, January 12, the committee invited a group of experts to join some members of the committee to review the issues surrounding rapid motorization in China and the world experience in confronting similar problems in other countries. This symposium was designed to serve as the initial technical presentation to the committee and enabled some of the more difficult issues to be introduced by non-member experts in a setting outside of the committee room where they would be debated. This summary was prepared by Michael Greene, staff director of the committee, as an attempt to capture the presentations and the subsequent discussion. The author takes responsibility for all errors and omissions.

OPENING REMARKS

Dr. C. William Colglazier, executive officer of the NRC, opened the symposium. He described the functions and activities of the National Academy of Sciences (NAS), chartered by Congress during the Lincoln Administration in 1863, and its two sister organizations, the NAE and the Institute of Medicine (IOM), and the NRC (the operating arm of The National Academies). The NRC conducts about 250 studies a year, mostly at the request of the United States Government. Dr. Colglazier gave some examples of recent studies and distributed the Report to the Congress and other materials.

Dr. Zhu Gaofeng, vice president of the CAE, described his organization. The CAE was founded in 1994 as the highest advisory institution in engineering. It now has 542 members. Its mission is to promote the progress of engineering to facilitate economic development in China. Since its establishment, it has carried out 50 activities related to national goals in engineering and 16 projects for state commissions and ministries. Among them have been a strategy for water resource development, a paper on subway system construction, and a proposal for reform of engineering education. These policy papers have played an important role in government decision making. In the case of the water report, the government sent copies to all provincial governments as a basis for policy making. The CAE was invited for direct discussions with the Development Commission during the preparation of the Tenth Five-Year Plan for China.

The CAE is also active in industrial development through an initiative on industrial relations.

Groups of experts are sent into factories, especially state enterprises, for consultation to improve management and encourage innovation. It also assists local economies by consulting on local projects in cities. There is also international cooperation: the CAE has memoranda of understanding with nine sister engineering academies, including the NAE.

Recently the CAE sponsored an International Conference on Engineering and Engineering Sciences. Dr. William Wulf, president of the NAE, gave a keynote speech, and Jiang Zemin, President of the People's Republic of China, spoke on the importance of engineering science to development.

Professor Dale Compton, home secretary of the NAE and co-chair of the Committee on the Future of Personal Use Vehicles in China, next described the nature of the CAE initiative and joint study to explore opportunities and issues. The focus will be on personal transport technology, the societal implications of rapid motorization, and the effect on infrastructure, land use, and the environment. The committee will explore the experiences of other countries with regard to new technologies, their socioeconomic impact, emissions, petroleum dependence, and use of alternative fuels. He said the NRC does not claim to have the answers, but can help to identify and understand the options facing China and try to avoid some of the problems that the United States has experienced.

Professor Guo Konghui, Jilin University of Technology and CAE co-chairman of the Committee spoke next on "Issues We are Facing." The number of personal use vehicles* (PUVs) in China has been growing by 20 percent per year since 1985. In 1999 the number was 14.52 million, or about one PUV per 90 persons. Of those vehicles that are personal use cars (PUCs) there is about one car per 350 persons. (In the United States the number is nearly one per person.) The car market was 0.56 million sales in 1999; if the Chinese demand were equal to the world average for its population, the market would be 10 million sales per year. It is forecast that China will attain this level in 15 to 20 years, and at that time it will cause a serious impact—not only on China but on the world as well.

What forces are restricting the Chinese market? Guo listed seven.

1. *Government policy*. There is a high tax on cars, at 20 different levels. For example, for a business vehicle like a taxi, the total tax is more than 100 percent of the price, and for non-business vehicles the total tax is up to 50 percent of the price. Other payments or "donations" must be made under different names. This is a serious burden for car owners.

2. *Low personal incomes*. In 1999, the average personal income for urban dwellers was 58,590 yuan (about $7,000), rising from 51,550 yuan in 1998. In rural areas, the average income was 2,205 yuan in 1999 and 2,116 yuan in 1998. The average personal income increase between 1998 and 1999 was 9.3 percent in cities, 4 percent in the countryside. Even so, there are many families that are able to buy a car but are discouraged by the high taxes and complex procedures associated with its purchase.

3. *Environmental issues*. Air pollution is a serious issue in the cities, and this exerts a social pressure on the government to restrict new car sales.

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* Personal use vehicles (PUV's) are defined as motor vehicles that are owned by individuals rather than government or private organizations. The number includes cars, buses, taxis, trucks, and tractors. The number of vehicles that are used by individuals for their personal business is probably higher, since many company and government vehicles are used as PUVs at least part of the time.

4. *Energy sources*. China's oil imports are growing rapidly, comprising 50 million tons in 2000. At the same time, the quality of the fuel is not satisfactory for low emissions or advanced technology vehicles. The gasoline contains a high proportion of olefins, and the diesel fuel is high in sulfur. Increasing dependence on imports is considered a national security issue.
5. *Infrastructure problems*. China has low road capacity, and average speeds in cities are below 20 km/hr.
6. *Controversy over PUC development*. Some believe the government must constrain the expansion of PUCs, while others consider expanded motorization inevitable. (A similar debate involved expanding the use of air conditioning 10 years ago when energy was in short supply. Despite initial constraints, air conditioning is now widely used in China.)
7. *The auto industry as a "pillar" industry*. Some see development of an auto industry as an engine of growth for China, while others believe there is no need to develop a Chinese capability in automobiles in an era of globalization.

Professor Guo then described what the CAE hopes for from the study.

- Achieve a proper understanding of the implications of the development of PUVs in China.
- Profit from world experience in solving the problems of congestion, pollution, energy consumption, technology choice, urban planning, and traffic management.
- Clarify the social and material costs and benefits of development of a new vehicle that would be affordable to large numbers of middle class Chinese families. (To emphasize the prospect of involving advanced technologies, China has developed an initiative called the Chinese New Generation Vehicle [CNGV].) Explore opportunities for international cooperation in developing the CNGV.
- Advise the Chinese government on removing barriers to reasonable development of a personal use transport system and the automotive industry, and on encouraging cooperation between government and industry for promotion of the CNGV and related technologies.

The CAE has already taken some steps to promote the study. They have visited several enterprises to exchange views and gather financial support for the joint study. They have organized some workshops on market and the economy, energy, environment, transport problems, and technological choice. The outcome of the workshops is a consensus that the government should facilitate the development of PUVs, and specifically the CNGV, by including the issue in the Tenth Five-Year Plan. China also should develop its own automotive industry in cooperation with the world industry, utilizing technologies from other countries. The results of the workshops were transmitted to decision-makers via various media channels.

Recently, the automotive industry has been selected by the Chinese government as one of seven key traditional industries for reform. A policy to encourage PUVs has been announced. Progress and innovation in science and technology, especially in information technology, advanced materials, and other technologies applicable to automobiles, will be supported. Investment in highway construction and oil and gas pipelines will be emphasized.

Professor Guo expressed the hope that cooperation with the NRC will lead to reasonable development of a CNGV and sustainable development for China in the 21^{st} century.

SESSION I: THE CHINESE TRANSPORT SECTOR AND ENVIRONMENT IN 2001

Dr. Zhu Gaofeng, vice president of the CAE, moderated the morning session that focused on the status of motorization in China and the response to problems that have arisen.

<u>Issues related to Personal Vehicle Expansion in China</u> - Liu Zhi, World Bank

Dr. Liu has been long involved in World Bank work on urban transport strategy in China. In 1995 he organized the symposium that led to the first official recognition of the problem.

The automotive industry in China has been designated a pillar industry, characterized by forward and backward linkages throughout the national economy. The designation is premised on the recognition of the sheer size of the potential domestic market for personal vehicles based on rising incomes, and it is motivated in part by the desire to prevent control by local governments. But the designation brings with it some concerns:

- For the auto industry—how to produce an affordable, popular family car that is competitive with foreign-made cars before China's admittance to the World Trade Organization.
- For the environmentalist—how to prevent pollution, energy shortages, and land shortages. The voice of environmentalists is becoming stronger.
- For municipal governments—how to provide the necessary road infrastructure and parking spaces, while limiting air pollution, traffic accidents and maintaining equity in land use and transport access. This issue has provoked a major World Bank project on urban transport.

Liu said there are also important social issues. Personal vehicle use expansion will change lifestyles—with winners and losers. Vehicle owners will benefit from increased mobility, while non-vehicle owners will suffer from increased congestion. At the same time there is new decentralization and more democracy in public policy decision making in China that will have a large impact on how the issues are resolved.

Dr. Liu showed graphs of motor vehicle ownership in the largest cities in China. The graphs showed clearly that Beijing has by far the highest proportion of vehicles to population, followed by Tianjin, Shanghai, and Guangzhou. Unlike the others, Shanghai has almost no private passenger vehicles. He then pointed out that 70 percent of the air pollution in Beijing is from auto emissions. Road congestion rises with car density, and Beijing leads the other cities in road traffic fatalities. In 1998 Beijing had nearly twice as many as fatalities as Shanghai.

Dr. Liu called this a "macro policy without the support of the micro environment." A 1994 study predicted that the demand for passenger cars would reach 1.3 million to 1.6 million in the year 2000. The actual vehicle sales numbered 700,000. Some urban governments continue to exercise controls on vehicle ownership and use through taxes, surcharges, and other devices. Some use these instruments as devices to raise revenue.

A recent World Bank study showed that, world wide, personal incomes are the most important determinant of private car ownership. The income elasticities of PUV ownership are greater than 1 in the long run and less than 1 in the short run. The price elasticity is smaller than the income elasticity. Governments can still exert control with fees but as income grows, car ownership will rise.

Liu said that in China, the length of paved roads is expanding as fast as incomes are rising. At the end of 2000, the total length of expressways reached 12,000 km. There is a surcharge on vehicle sales for road construction paid directly to the ministry, so highway financing is linked to vehicle ownership and use.

Urban transport is most problematic. The rise in the number of personal vehicles is linked to land use changes, congestion, and decline in public transport and bicycles. Some public officials view the bicycle as a cause of road congestion and are trying to "build their way out" of congestion. In the long run this is impossible because of increasing urbanization of the population.

Dr. Liu then discussed the evolution of the urban land use pattern in China. Municipalities tend to cover large areas and include the central city and the suburban counties. Traditionally this encouraged a compact form of land use suitable for walking and bicycling. Newer cities like Chungqing, whose urban development is similar to Western cities, are characterized by rapid urban sprawl and declines in overall population density.

What are the options available to Chinese cities to deal with motorization? They can build new roads, build or expand a subway system, give priority to public transport, tighten traffic and parking management, and control access to vehicles.

Liu noted it is instructive to compare Beijing with Shanghai to see the efficacy of some of these policies. Beijing has over 1.5 million vehicles and a traffic pattern with four circumferential roads. Shanghai has fewer than 600,000 vehicles, one circumferential, a subway, and more extensive control and management of vehicles. By all measures, Shanghai has better control of its vehicle population.

Liu said for smaller cities, control of equity and land use change may be easier. There are hundreds of cities in China with populations between 0.2 million and 2 million that will have to confront these changes. He said they should be encouraged to think small, plan carefully, and manage prudently. Automobile ownership is not the same as auto use, and a comparison of the cases of Bangkok, Thailand, and Curitiba, Brazil, can point the way to some effective strategies. Dr. Liu urged the committee to consider two questions: (1) what is a useful definition of "popular family car," and (2) what would be the impact on world fuel prices if car ownership were to reach 100 million in China.

Dr. Liu was asked how motorcycles fit into the equation, since China is the world's largest producer and user of them. He replied that the contrasting examples of Italy, where motorcycle use is declining, and Taiwan, where it is increasing, show that motorcycles have a deservedly bad safety image. He said motorcycles will not replace cars because they are not good for commuting.

Dr. Liu was then asked (1) how China is preparing to control vehicle emissions and (2) how the World Bank and others are lending assistance. He replied that China has adopted "Euro II" standards for air quality. The World Bank will finance vehicle inspection and maintenance facilities, and a non government organization (NGO) will publish the daily pollution level for every city.

A committee member asked Dr. Liu for recommendations for a case study, and whether the World Bank has carried out projections of increased motorization in China. Liu said that there were no projections, but he suggested that a look at a smaller city, perhaps in the Pearl River Delta area, would be valuable.

Dr. Liu was questioned on his concern about the impact on world fuel prices of a hypothetical 100 million Chinese vehicles when the United States already has twice the number of vehicles. Dr. Liu stated that ownership is different from use, and that second cars are not used as much.

Current air quality problem and control strategies for vehicular emissions in China - Professor Shao Min, Center for Environmental Sciences, Beijing University

Shao stated that China has long suffered from serious air pollution characterized by high ambient concentrations of SO_2 and particles. The reason is that more than 75 percent of China's primary energy source is coal combustion. Ambient concentrations of SO_2 and total suspended particles (TSP) in most big cities are much higher than national air quality standards (NAAQS) and the guidelines of the World Health Organization (WHO). In 1995, total SO_2 emissions in China reached 23.7 million tons, and one third of China's territory suffered from serious regional acid deposition.

Since 1980, great efforts have been made to abate SO_2 and particles emissions from coal combustion. Ambient SO_2 concentrations, especially TSP concentrations, have dropped gradually. However, in the process of economic development within the last two decades, the vehicle population increased dramatically. Pollution from traffic exhaust has worsened in some big cities. In 1995, the total number of vehicles in China was more than 20 million, with an average annual increase rate of 15 percent, and most of the vehicular increments are in mega-cities such as Beijing, Shanghai, and Guangzhou. Pollutants such as NO_x, CO, volatile organic compounds (VOCs) and fine particles are emitted in large amounts from vehicles and have deleterious effects on human health and ecosystems. More important, under favorable conditions such as intensive sunlight, low humidity and low wind speed, ambient NO_x and VOCs will react and produce oxidants such as ozone and H_2O_2, creating photochemical smog. These secondary pollutants are more harmful and present great threats to human health and agricultural ecosystems.

Shao said photochemical smog will be of increasing importance in next decades in China. Ground-level ozone concentrations are already very high in some big cities, and it is foreseen that this problem will rapidly spread across China as other regions, especially in central and western parts of the country, develop economically. Ozone pollution may become a regional, rather than a local, issue. High levels of oxidants in both urban and rural areas will cause heavy negative impacts on human health and also on agricultural yields, and this is going to be a critical issue for the sustainable development of China.

Shao said the major environmental problems of China are water pollution and water shortage, acid deposition, urban pollution, eutrophication of offshore seas, ozone-depleting substances, and global climate change.

Historically, the pollution problems are accumulating. In the 1970s the major problem was dust from coal burning. In the 1980s, SO_2 and acid rain were added. In the 1990s, concerns also included NO_x and greenhouse gases. SO_2 concentrations declined in 1990, but even though industrial sources were leveling off, they increased again in 1996 because the pollution from vehicles was rising. The reason was increasing urbanization of the population. The Chinese population is now 70 percent urbanized, but the present growth rate is over thirty percent. The pollution level is growing rapidly, although less so than the gross domestic product (GDP). The corresponding increase in the vehicle population is reflected in an increase in the ratio of SO_2 from industry and an increase in the ratio of NO_x from exhausts.

Shao said particulate matter is also a problem. The $PM_{2.5}$ index (referring to a certain size of particle) is four to five times higher than the U.S. standard, but the source is unknown.

Dr. Shao next described a United Nations Development Program-funded case study of Guangzhou city. The study includes an air pollution source inventory and measurement of SO_2 and NO_x, the latter being the fastest growing component. The study estimates the costs of control and concludes that adoption of Euro I and II standards along with the elimination of older vehicles is necessary to reach the established targets.

Dr. Shao concluded by stating that China must not retrace the path of other countries, with its rise and later fall in pollution. It must adopt the appropriate technology to reduce pollution at an early date.

Features of Chinese Vehicular fuels - Qiu Yansheng, Deputy Chief Engineer,

Research Institute of Petroleum Processing

Dr. Qiu described the close relationship between the automotive and petroleum industries and environmental groups in the United States where environmental interests advocate changes in the automotive industry and lead the industry to seek new, cleaner technologies. The most important objective is to reduce emissions. This depends in part on advanced engine design, but advanced engines also require cleaner and more technologically advanced fuels to achieve this objective.

China has the tenth greatest crude oil reserves in the world, but these reserves constitute only 2.4 percent of the world's petroleum reserve; Asia in total has 4 percent of the world supply. By 2010 China will need 270 million to 310 million metric tons (Mt) per year, but it will produce only 170 million to 200 million Mt per year, and it will need to import around 100 million Mt of crude oil to meet the domestic demand. Chinese petroleum has a low content of naphtha, which is needed for gasoline production.

Qui noted one of the features of the Chinese petroleum refining industry is that the catalytic cracking capacity is much greater than the capacities for catalytic reforming and catalytic hydrotreating. Chinese gasoline has a high content of olefins and sulfur and a low content of aromatics. In recent years, environmental protection regulations have become more stringent, and consequently, the quality of Chinese fuels has improved markedly. The olefin content of gasoline and the sulfur content of diesel fuel have been reduced. The updating of gasoline and diesel fuel specifications is underway. The highest priorities are to decrease sulfur content and control olefins and aromatics. Chinese industry must improve the catalytic reforming process and install catalytic hydrotreating facilities to produce products with low olefins.

China presently produces more diesel fuel than gasoline, most of which is used by agriculture. Fifty percent of the total fuel is used by the transport sector and a third of that is used by automobiles. There are separate specifications for diesel fuels for use in cities. These "SINOPEC" (China Petroleum & Chemical Corporation) specifications are under review, and the cetane number is rising while the limits on sulfur are declining. The new generation of specifications will be based on EU-II of the European Union.

Dr. Qiu was asked about new oil exploration. He replied that there is prospecting underway in northeast China and also off shore. Only 30 percent of the known reserves, however, are of low sulfur content. Since 1993, China has been importing oil, especially the Middle East. Most of the imported petroleum is high sulfur, however, and this presents a catalytic problem for the refineries.

The next question was about lead content. Dr. Qiu explained that last year China phased out lead additives in gasoline, but some refiners are using small amounts of MMT (methylcyclopentadienyl manganese tricarbonyl, a manganese-based additive) in the blending composition, which has a negative effect on engine performance.

Predicting the development of personal vehicles in cities of China - Lu Ximing, Director, Comprehensive Transportation Planning Institute, Shanghai City

Lu stated the increasing urbanization of China is putting new demands on the transportation system. At the same time the degree of mobility in Chinese cities is increasing. The number of PUCs exceeds 6 million and taxis exceed 800,000 units. Local governments are putting heavy emphasis on massive infrastructure construction. Even so, traffic is increasing, with a corresponding increase in pollution and decrease in average vehicle speed. The Japanese experience shows that with every ten percent increase in the number of vehicles on a road, average speed declines by one percent.

A study was carried out to compare the experiences of ten cities in different countries, including Los Angeles, Bangkok, Tokyo, Singapore, and Hong Kong. The relation between average speed and emissions level was tested, with low speed signifying high emissions, particularly of particulates and NO_x.

PUVs exact significant costs on the city. Each vehicle requires 1-1.4 parking berths, or about 40 square meters. In Paris, two-thirds of the available road area is used for parking. Shenzhen has developed a stereotype parking garage that is required for each residence area.

PUVs also require a highly efficient transportation management system. Strict traffic management is necessary to keep traffic flowing smoothly. Traffic management must deal with high volume traffic three times a day. In order to keep traffic moving, many cities attempt to cut traffic volumes at peak times and to shift them to off-peak hours by instituting flexible working hours, vehicle pooling, and land use reorganization.

The social cost of PUVs high and includes greater energy consumption, environmental damage, and more traffic accidents.

Lu explained that in order to prepare for the increase of PUCs, cities have adopted three strategies. Strategy A allows for unlimited numbers of PUCs, using the model of Los Angeles and Bangkok. Strategy B introduces PUCs in a gradual way to maintain a stable situation, as is done in Seoul and Tokyo. Strategy C puts more long-term control on the use of personal cars, drawing on the models of Singapore and Hong Kong. The predicted results of these strategies for China were analyzed by time series modeling and correlation and the experience of the model cities. Some results were:

- Based on an estimated growth rate of 30 percent per year, the number of PUCs will reach 42 million in 2010.
- Based on an economic growth rate of 8 percent per year, per capita GDP in cities will increase to $4,000, and PUC ownership per 1,000 population will rise from 10 to 100 vehicles. For the 300 million urban residents, the number of cars will reach 30 millions. Meanwhile the capacity of the roads in China will reach 42 million vehicles.
- Overall, it is predicted that the number of cars will increase from 3.04 million in 1999 to 30 million-42 million in 2010, with most of the increase being in the cities.

The policy options development process will draw on urban planning policies, traffic engineering policies, traffic management policies, and transport services policies. The policy options will have three aims: to allow a rapid growth in the number of PUCs; to enable PUCs to operate effectively; and to achieve a balance between the transport needs and the health of the city. The ultimate objective is sustainable development for the cities of China.

Dr. Lu said that in city planning, land use should conform to group type forms along a city's axial directions in order to increase the utility of PUCs, in long and middle distance travel and reduce centripetal traffic flows. An example is the experience of Tokyo, with its possible application to Guangzhou.

For traffic engineering, the aim is to classify roads in terms of function so that road capacity can be optimized. Vehicle operating conditions must be improved and controlled to maintain a reasonable vehicle speed. Singapore and Bangkok will be the models, to be applied in Shanghai, Beijing, Tianjin, Urumqi, and Harbin.

He said traffic management plans should seek to adopt intelligent traffic (IT) techniques to divert the traffic flows in real time, to disperse the congested areas, and to assure smooth working of the road network. Seoul is an example to be examined, with applications to Shanghai, Shijiazhuang, Changsha, and Zhaoqin.

For transport services, Dr. Lu said a high standard, multi-mode coordinated transport system should be adopted for passenger services in order to create a rational transfer regime between the transit system and PUC users. International examples are Curitiba, Brazil, and Kuala Lumpur, Malaysia, and Beijing, China.

Dr. Lu concluded by stating the rapid development of the Chinese economy has brought China rapid urbanization and mobility. An increase in the number of PUCs is an inevitable outcome of these forces. The massive increase in PUCs is placing great pressure on the cities, for which society must pay a cost. Nevertheless, the trend for development of PUCs in China is clear, with a great potential demand that must be met. It is necessary to adopt suitable policies, so that PUCs will play a positive role between urbanization and mobility in sustainable development.

During the discussion period, a questioner noted that the best policy seemed to be to get people to purchase cars and then not use them. He asked whether ownership restriction or congestion tolls were under consideration. Dr. Lu noted that use control policies are ad hoc. When traffic volume gets too high, the government considers issuing permits for odd and even day use. But some people park cars outside of the city and thus avoid control. The World Bank has promoted electronic congestion pricing in Singapore and Hong Kong, but in China the car users are a powerful elite, and the political will to limit use is not present.

Another questioner asked if public-private partnerships to capitalize road construction had been attempted. Dr. Lu replied that many methods have been attempted. The central government may allow local governments to build highways. Sometimes highways are built and then sold on the stock market. There is a great variety of financing methods for highways, but in urban areas, it is hard to collect revenue from roads, except on toll roads and toll bridges. License fees seem the only option.

A questioner noted that road area is increasing as a proportion of city land area, and asked if there is a practical limit. Dr. Lu said that the problem is not the lack of roads but traffic management. Road area per vehicle is comparable with London. But most of the roads are local access. The Chinese government puts emphasis on freeways, but freeway ramps are congested.

SESSION II: ADVANCES IN AUTOMOTIVE AND OTHER TRANSPORT TECHNOLOGIES

Dr. Wm. A. Wulf, president of the NAE, moderated the second session. The session focused on the experience of the United States and other nations in dealing with the growth of the automobile industry.

Lessons learned on the road to more efficient transport systems - Martin Wachs, University of California, Berkeley

Wachs said that today in the United States there are about 770 automobiles per 1,000 people. That means we literally could have every man, woman, and child on the road at the same time, and still have room in the back seats for their pets and baggage. The rate of increase in automobiles per capita in the United States is now very low and finally approaching saturation, though vehicle miles of driving per capita is still increasing.

In China, in 1998 there was around one personal vehicle per 90 persons, up from one per 200 persons in 1995. The United States had one vehicle per 90 persons around the year 1910, but Chinese growth in automobiles will clearly be more rapid than the United States—already the estimate for 2000 is one vehicle per 70 persons. China has the benefit of being able to adapt knowledge, technology, and management strategies that many other countries have perfected over the last 95 years, though rapid motorization will be demanding and disruptive even given China's ability to leap-frog over several stages of development. It is important to observe the policies that worked well and those that failed.

Wachs said the automobile has influenced American life as profoundly as any device in history, but it is not alone. Other technologies like the telephone, radio, television, and other telecommunications also have had profound effects. Also, the impact of the automobile on the interactions among people was matched by the effect of the motor truck on the movement of goods. The effects of all these innovations were complementary and additive. In the United States, the full adaptive process took around 100 years, and in China it will take place in a much shorter time.

Wachs said there are five major themes to consider:

1. *The automobile as a fundamental element of the economy*. One worker in six finds automobiles and trucks the source of their employment: building, repairing, driving professionally, insuring, licensing, testing, building and maintaining highways, etc. This fact has a large political impact in the United States, affecting the economy and foreign policy. A change in the world price of petroleum can throw the U.S. economy into recession, and our intense interest in the Middle East and our rejection of the Kyoto accords are direct results of this fact. The entire U.S. trade deficit with respect to balance of payments with other countries is accounted for by our imports of petroleum for transportation. Creating an automotive industry involves far more than building and selling cars; it changes the entire economic and employment structure of the nation.
2. *The importance of roads and highways and parking and infrastructure in support of the automobile and truck*. In United States cities today, 30 percent of the land area is devoted to

streets and highways, and parking area comprises another 10 percent. Ninety five percent of this area constitutes local streets and rural roads that carry 5 percent of the traffic, and 5 percent of the area is dedicated to highways and freeways that carry 95 percent of the traffic. These two types of roads are financed in very different ways. The local streets and roads that provide access to property are paid for from local property taxes and local sales taxes. The other five percent of roads is financed by user fees in the form of gas taxes or tolls. This has been very successful because it provides more money as traffic increases, and that money is used exclusively to build and maintain the roads. There is far less competition for resources than would be the case if government were to pay for roads out of general funds.

3. *The environmental impacts of the automobile*. The automobile has had a mixed effect on health. Access to health care facilitated by the automobile is one of the most important variables for increasing life expectancy. But air pollution caused by exhaust emissions and water pollution caused by runoff from roads have had a negative effect, and disposal of old automobiles, tires, parts and motor oil cause additional environmental problems. But over the past few decades, enormous progress has been made, mostly through new technologies, and the United States is on its way toward creating a sustainable transportation system.

4. *Relationships between mobility or travel and urban form*. The automobile has profoundly affected the form of cities. Earlier, city population densities were much higher, with resulting disease, fires, accidents, and other disasters. Public transit, the automobile, the creation of suburbs, and decentralization have lowered the densities and made the cities much more livable. Now this solution has given rise to new problems—sprawl, congestion, energy waste, pollution and even racial segregation—and proposed solutions include a return to higher densities in the urban centers. However, it is now politically more difficult to redesign the cities, and only a few places, like Portland, Oregon, have been able to make significant gains in this direction.

5. *The impact of the transportation system on the distribution of well-being in society*. Modern land use patterns are designed with the automobile as part of the system, and those who have no cars (the elderly, poor, minorities, and the disabled) are left out of some benefits. Automobiles also cause 41,000 deaths a year in the United States, including pedestrians and cyclists, more than all the wars in its history. It is the leading cause of death for those under 35 years of age. Important improvements have been made in vehicle design, seat belts, etc., but there has been less progress in traffic management. Some of the proposed innovations in this area involve applications of information technology to control traffic flow and charge for road use.

Wachs concluded by stating that in the United States, automobile use has had a generally beneficial effect on society. However, urban design and community planning has not been sufficiently sophisticated in coping with the automobile. Automobile users should be charged a greater proportion of the full social costs of their travel, and other modes of travel, like cycling, walking and transit need to be treated more fairly in transportation planning. While adequate roads and parking facilities should be provided, those who benefit from them should pay their full social costs, with due regard for the needs for sidewalks, bicycle paths, and transit facilities. It is possible to integrate urban transit and pedestrian facilities safely and economically with streets and highways and to protect urban parks, waterfronts, landmarks, and tourist attractions from being overrun by parked cars. Much of the criticism aimed at the automobile itself should be directed at the poor urban design decisions that have been the root of many of the inequities that characterize mobility in urban areas.

<u>New developments in engines, fuels; emission controls, and the role of electronics</u> - John Heywood, Massachusetts Institute of Technology (MIT)

Heywood stated the major vehicle-related social, economic, and environmental issues are urban and regional air pollution, energy consumption by source, greenhouse gas emissions, noise, and safety.

The technology options available to address these problems in the future include:

1. *Improved mainstream technologies*
   - For vehicle structure: better conventional materials (e.g. high strength steel), reduction of weight, lower drag resistance
   - For the engine: higher power and volume, improved efficiency, lighter weight
   - For the transmission: more gears (automatic/manual, continuous variable)
   - For fuel: cleaner gasoline and diesel

2. *Available alternative technologies*
   - For vehicle structure: lightweight materials (e.g. aluminum, magnesium), lowest drag designs
   - For the power train: hybrids (engine plus energy storage) and fuel cells (hydrogen fueled, or liquid fueled with reformer)
   - For fuels: natural gas, biomass (alcohol), and hydrogen.

Table 1 compares spark-ignition and diesel engines:

TABLE 1 – Spark-Ignition Engine Compared with Diesel

	Power Density	Efficiency	Cost Density	Emissions	Fuel
Spark-Ignition Engine	Good	Lower	Low	Effective catalyst technologies	Low cost; knock resistant
Diesel: Naturally Aspirated	Lower	High	Higher	Catalyst technologies	Lowest cost; high sulfur
Diesel: Turbo-charged	Higher	Higher	Higher	Not Available*	Aromatics

*Selective catalytic reduction effective with large stationary engines.

The gasoline engine is not as efficient, but there is no emissions treatment available for the diesel engine which uses cheaper fuels but has a higher initial cost.

Heywood noted that engine efficiency has been improving almost linearly over time as a result of incremental innovation. Toyota and Honda have been the leaders in engine innovation, while the

U.S. has been better in innovating the manufacturing process.

In a recent MIT study, “On the Road in 2020: Life Cycle Analysis,” technological options for the year 2020 are assessed and compared. The study can be seen at http://web.mit.edu/energylab/www/. A sample of the results are shown in Table 2 below.

He said this discussion can be summarized in four points.

1. Sizeable improvements in internal combustion engine performance and efficiency are feasible, on the order of one percent per year, over the next two decades.
2. If engine, transmission, and vehicle performance are considered together, long term total energy consumption improvement may be as large as a factor of two.
3. The effect of alternative fuels on engine performance, energy and emissions will be modest, except for hydrogen.
4. Total system (“well to wheels”) energy and CO_2 emissions for the best internal combustion engine and fuel cell-based systems are similar in magnitude.

Table 2 Peformance Potential in 2020

Propulsion system Advanced vehicle below	Date	Vehicle gas equiv. mpg	Total system Energy use MJ/km	Total system CO_2 gC/km	Price increase $
Gasoline ICE	present	28	3.6	72	0
Evolving Baseline ICE/Vehicle	2020	43	2.3	47	800
Gas, ICE, Adv. Vehicle	2020	49	2.1	42	2200
Diesel, ICE, Adv. Vehicle	2020	56	1.8	37	3300
Gas, hybrid ICE, Adv. Vehicle	2020	71	1.5	30	4400
CNG, hybrid ICE, Adv. Vehicle	2020	73	1.5	24	4500
H_2 fuel cell hybrid, Natural Gas	2020	94	1.7	34	5000
Gas reformer fuel cell hybrid	2020	42	2.4	49	6200

Status of the Partnership for a New Generation Vehicle (PNGV) -

Trevor O. Jones, Biomec, Inc.

Jones said that in 1993, President Clinton and the chief executive officers of the three major U.S. automobile companies announced PNGV. The private-public partnership was to carry out the research and development necessary to produce a midsize vehicle at a current affordable price that would get eighty miles per gallon and conform to the emissions standards in force at that time. The target date for the concept cars was 2000 and for the vehicle itself 2004. The NRC was asked to form a committee to peer review the research and assess the technology choice. In terms of collaboration, the partnership as such was successful. Around one billion dollars was contributed annually by industry and $300 million by the government.

Jones asked: why is a PNGV needed? There is continuing global increase in population, and a parallel increase in the vehicle population. At the same time, the fuel economy is not improving, which will eventually put pressure on a finite petroleum fuel reserve. (By 2015, it is projected that there will be one billion vehicles in use with a fuel consumption of 10 billion barrels per year.) Global greenhouse gas emissions are increasing. The cost of importing oil to the United States is a national security concern. Further, it was believed that the joint development of the new generation vehicle would enhance the competitiveness of the U.S. automotive industry.

The economy of the new car fleet is improving because of adherence to corporate average fuel economy (CAFE) standards, first passed by Congress in 1975. In 1992, an NRC study on technically achievable fuel economies had predicted up to 37 mpg for midsize cars by 2006 on the basis of current progress, far from the PNGV targets. A radical change in technology was needed to achieve greater efficiency.

The PNGV program has three discrete goals:

1. Significantly improve national competitiveness in manufacturing for future generations of vehicles.

2. Implement commercially viable innovations from ongoing research on conventional vehicles.

3. Develop vehicles to achieve up to three times the fuel efficiency of comparable 1994 family sedans, or 80 mpg.

Many parts of the U.S. government became involved, including the national laboratories. Many universities became involved, and on the industry side, many suppliers participated. Overall, 300 institutional participants became involved. The U.S. Council for Automotive Research (USCAR), was to coordinate the efforts of the big three auto manufacturers. The Under Secretary for Technology, U.S. Department of Commerce, was appointed by the President to coordinate the federal government's participation.

The PNGV program began by analyzing the energy distributions in all functions of an automobile, from engines to accessories. The objective was to make major improvements in all powertrain and vehicle characteristics. Typical objectives were to double thermal efficiency, reduce weight by 10 to 40 percent, capture 50 to 70 percent of braking energy, reduce drag by 20 percent, reduce rolling resistance by 20 percent, and lower accessory loads by 30 percent.

The major areas of development were hybrid electric systems, fuel cell-electric powertrains, energy storage by flywheel and battery, light weight material, drag reduction, and lower rolling resistant tires.

It was soon realized that the gasoline engine and the electric vehicle programs would be unable to meet the timetables. With its weight reduced by nearly 50 percent, only the direct injection diesel hybrid made the cut for 80 mpg. All concept cars unveiled in 2000 were lightweight direct injection diesel hybrids with nickel metal hydride or lithium ion batteries.

Jones said issues for the next phase of the PNGV are:

- The added cost of a hybrid powertrain—nearly $7,500 over today's vehicles
- The added cost of lightweight materials over steel
- The added cost of a compression ignition, direct injection, or CIDI (diesel) fuel injection system
- The control and reduction of NO_x and particulate matter
- Development of low cost and low weight energy storage systems
- Availability of low sulfur fuels.

Jones noted that for the long term, the fuel cell hybrid is promising. Problems include the cost, size, and weight of energy converters with reformer, the start-up time and transit response, overall efficiency with the reformer, low vehicle range with stored hydrogen, and the availability of a hydrogen fuel infrastructure.

The PNGV program has demonstrated the integration of cultures among the government, the universities, and USCAR. Of the three vehicles themselves, only the General Motors car has met the fuel efficiency goal for gasoline equivalent. The emissions standards, which have become more stringent since 1993, have not yet been met.

Actions on Urban Transportation Problems: Possibilities for China - Ralph Gakenheimer, Massachusetts Institute of Technology (MIT)

Gakenheimer said that rapid motorization in China is becoming an incontrovertible fact, and it is clear that it is in the interest of Chinese industry to help municipalities lighten the burden of congestion by better planning and traffic management. It will be useful to examine the experience of other rapidly motorizing cities around the world.

The parameters that define the problem faced by urban areas are the time evolution of the increase in the proportion of automobile trip making and its rate of acceleration, the percentage and distribution of local automobile ownership, changes in urban structure, and the existence and reach of subways and other forms of public mass transportation.

Some of the most instructive experiences in other parts of the world have been:

A. *Evolution of modal shares under rapid motorization*. Some of the interesting data come from Santiago, Chile, where as the number of autos grew by 50 percent between 1977 and 1991, the share of trips by auto grew by 61 percent and the trips per capita by 86 percent. The biggest decline in mode share was in buses, while subways and walking increased. However buses are still the dominant mode for commuting to work.

B. *The use of light rail in Quito, Ecuador*. Single articulated trolley-buses, operated at low cost, have become popular. The break-even fare is U.S.$0.27 per ride.

C. *Public transportation and restricted areas in Curitiba, Brazil*. Corridors of development were planned along the lines of the mass transit system. Curitiba boasts a modern bus system, coordinated with traffic control systems, with wide bus doors and prepayment stations. It has helped to control the development of the city, and the population density is declining.

D. *The collaboration of government agencies in Houston, Texas*. Houston covers a large area with an overall density of two persons per hectare. There are 55 separate subsystems of the regional transportation system, from traffic signal control to tollway management, railroad crossings, and emergency management systems. An "intelligent transport system" has been developed through a consortium among different municipal agencies called TRANSTAR. It is based on agreement among the participating agencies that action is necessary for planning and congestion relief. In the new system, traffic is controlled from a single room by staff seconded by all agencies.

E. **Licensing and vehicle access restrictions in Singapore**. Singapore has established electronic licensing, and no vehicle may enter the central city during rush hour without a costly license. This system has been supplemented by electronic road pricing, with automatic charges through a debit card located in the vehicle. The result has been lower revenue, but flexible management of traffic, reduced numbers of downtown entries, and traffic speeds increasing to 45 km per hour.

F. **Automobile traffic management in Bogota, Colombia**. Bogota, it seems, is trying several options. There are "no drive" days, in which 40 percent of the vehicles rest each day. This has reduced congestion, numbers of accidents, and air contamination, and it has increased the flexibility of traffic scheduling. A subway was proposed by the national government, but the mayor chose the Curitiba system of buses instead.

Gakenheimer said the shared goal of the municipality and car owner to reduce congestion, buses should not be seen as the enemy of car sales.

Health implications of increased motorized transport - Dan Greenbaum, Health Effects Institute (HEI)

Greenbaum said that concerns about ambient air pollution and public health first rose to broad public attention in the 1950's, following significant air pollution episodes in London, England, Donorra, Pennsylvania, and elsewhere, that were linked to noticeable increases in hospitalization and premature mortality. These incidents, which involved air pollution largely from industrial sources and home heating, presaged public policy action for the past four decades to reduce air pollution and improve public health. Increasingly during that time, as vehicle travel has grown dramatically, attention has focussed on air pollution from transport and its impacts on human health.

Beginning in the 1970s in the United States and in the 1980s in Europe, there has been substantial progress to reduce the emissions from individual vehicles, and, more recently, to make improvements in the quality of fuel that have resulted in reductions of some emissions by greater than 90 percent. Meanwhile, traffic volume has grown substantially, offsetting much of the improvement achieved. Also, scientific knowledge has increased, with scientists finding health effects from vehicle emissions at lower levels of exposure. Thus there has been, and there continues to be, significant public attention to reducing the emissions from vehicles and fuels and their attendant effects on human health.

Greenbaum said that since 1980, HEI has been producing extensive research on the health effects of air pollution from motor vehicles and other sources. He said HEI had learned much during that time about the emissions from vehicles, personal exposure to those emissions, and the resulting effects.

Greenbaum said his paper attempts to review briefly what we know about *emissions, exposure and effects*, and to discuss *current and likely future trends*.

Emissions. The combustion of petrol (gasoline) and diesel fuel in vehicle engines produces a number of emissions of potentially harmful substances. These emissions are not solely the result of the combustion process, nor do they come only from the tailpipe of the vehicle. Evaporative emissions—from refueling, leaks in the fuel system and engine, etc.—can equal emissions from the tailpipe.

The emissions from motor vehicles come in two primary forms: major gaseous and particulate air pollutants, which can be found in relatively high amounts in the atmosphere, and air toxins which usually are found in lower amounts in the atmosphere but can have important health impacts. The gaseous and particulate pollutants to which motor vehicles contribute include carbon monoxide, H_2O_2 and ozone (through their atmospheric precursors volatile organic compounds [VOCs] and nitrogen oxides [NO_x]), fine particulate matter PM_{10} and $PM_{2.5}$ (particles smaller than 10 and 2.5 microns in aerodynamic diameter respectively), and nitrogen dioxide. The air toxins emitted from motor vehicles include aldehydes (acetaldehyde, formaldehyde, and others), benzene, 1,3-butadiene, and a large number of substances known as polycyclic organic matter (including polycyclic aromatic hydrocarbons, or PAHs). All of the types of emissions from motor vehicles also come from other sources, such as industrial processes, electric power generation, and home heating. As a result, the contribution of motor vehicles to ambient levels depends on the pollutant. In most cases, motor vehicles contribute between 25 percent and 40 percent of the ambient levels, although in a few cases (e.g. carbon monoxide, ultrafine particles ($PM_{0.1}$), and 1,3-butadiene) motor vehicle contributions are noticeably higher.

*Exposure and Effects***.** While, in general, motor vehicles contribute a significant portion, although not the majority, of most air pollutants, there are certain circumstances in which motor vehicles can contribute a substantially higher amount to personal exposure. In particular, in urban centers, along roadsides, and especially in urban street canyons in crowded business districts, mobile source contributions can contribute 2 to 10 times as much as the general background. Research over the past several decades has found a variety of effects from the different pollutants, including effects on the respiratory, neurologic, and cardiac systems, and the promotion of several different types of cancer. One of the challenges of understanding these effects is that they are usually the result of a complex mixture of pollutants, and it is often difficult to disentangle the specific effects of one pollutant from the effects of other pollutants that follow similar spatial and atmospheric patterns. At the same time, it is apparent that not all members of the population are equally sensitive to such effects, and that some subgroups (e.g. the elderly, asthmatics, children, people with heart disease) may be at more risk from exposure to air pollution. Overall, the effects of these pollutants on public health tend to be relatively small in comparison with other risk factors such as cigarette smoking, but because of the large number of people exposed the effects are of public concern. Formal analyses of these overall effects are limited by ability to accurately estimate exposure and to calculate the risk per unit exposure. Within these limitations, one recent European analysis estimated that approximately six percent of mortality (40,000 deaths annually) in three European countries (France, Austria, and Switzerland) could be attributed to air pollution, about half of that due to exposure to emissions from vehicles.

Despite some uncertainties, there is much known about the effects of *carbon monoxide, ozone, particulate matter, and air toxins:*:

- *Carbon monoxide* is a gas emitted directly from vehicles. When inhaled it replaces oxygen in the bloodstream, forming carboxyhemoglobin and interfering with the normal transport of oxygen to the heart and brain. High levels of exposure are known to be lethal; low levels found in ambient settings are not likely to have effects in healthy individuals but can advance the time of angina (chest pain) in people with coronary artery disease and may cause increased incidence of cardiac effects. Some recent epidemiologic studies have found relationships between increased CO levels and increases in mortality and morbidity.

- *Ozone* is a gas formed in the atmosphere from combinations of nitrogen oxides and volatile organic compounds (both emitted from vehicles) in certain meteorological conditions normally found in the summer time. It is known to reduce the lung function of some individuals, and epidemiologic studies have found evidence of increased asthma attacks and hospitalization related to increased ambient levels. It may also increase the lung's reaction to allergens and other pollutants. Although recent studies have found associations of daily increases in ozone with increased mortality, there is not comprehensive evidence that long-term exposure causes chronic health effects, and some evidence suggests that the lung may develop a form of tolerance after repeated short-term exposures.

- *Particulate matter (PM)* in the form of PM_{10} and $PM_{2.5}$ is material than can be inhaled that is emitted directly from motor vehicles and other sources, and that also formed in the atmosphere from atmospheric reactions with gaseous emissions (e.g., nitrogen oxides become nitrates). Although PM has been of concern for many decades, new short term and long-term epidemiologic studies published in the United States and Europe in the 1990s found associations of PM with increased mortality and morbidity at ambient levels below then-established national air quality limit values. It is these studies that have been the basis for recent action in both the European Union and the United States to establish more stringent standards for PM. These studies, some of which find the highest mortality effects for any air pollutant, also provide the basis for the estimates of population risk in Europe discussed above. In the past several years, several new epidemiologic studies have begun to strengthen the understanding of the relation between exposure to PM and mortality and morbidity. Diesel exhaust PM has been cited as a probable human carcinogen by several national and international bodies. Ultrafine particles (less than 0.1 microns), particles containing metals (e.g., iron) may be the most toxic components of the mixture. To date these studies have not identified one component or characteristic that is significantly more toxic than others.

- *Air toxins* have a variety of characteristics and effects. Most of those emitted from motor vehicles are animal carcinogens. Benzene is a known human carcinogen. Butadiene, for which vehicles are the dominant ambient source, was recently designated as a probable human carcinogen by the International Agency for Research on Cancer, and as a known human carcinogen by the U.S. National Institutes of Health. Several aldehydes (including formaldehyde and acetaldehyde) have also been designated as probable human carcinogens. In addition, several of the mobile source air toxins, especially the aldehydes, have exhibited evidence of acute respiratory effects. Recently, the U.S. Environmental Protection Agency identified a total of 21 air toxins emitted from motor vehicle exhaust.

***Trends and the Future*.** The U.S. Environmental Protection Agency took action in 1999 to further improve fuel formulation and reduce emissions of light duty vehicles, and has currently proposed stringent new fuel and emissions standards for heavy-duty vehicles. The European Union (EU) is on a similar path, which is expected to substantially reduce emissions over the coming 20 years. However, continued growth in travel is expected to offset a portion of these reductions. As a result, continued attention to reducing emissions is likely in the future.

GENERAL DISCUSSION

Pollution Standards

Dr. Greenbaum was asked how China might set effective regulatory pollution standards. He replied that Chinese standards are already high by worldwide measure. In order to design appropriate standards it is necessary to measure ambient pollution levels and calculate the contributions from different sources. The problem is then how to achieve the most effective reductions in emissions. That requires deciding how to reduce levels at the present time, how to anticipate fuel and technology use in five to ten years, and how to adjust the standards as fuel use changes and new technologies become available. Dr. Heywood pointed out that the United States has had standards for 30 years, and they have been based on analysis that is able to convince more than the specialists. In the United States, the demanding standards have forced the pace of technological development. But realistically, the country must be prepared to adjust standards if they are not effective, and this has generally inspired political controversy.

PNGV

Speakers were asked about PNGV goals for 2004, and whether there would be a prototype ready for the market. The answer is that program management is still unsure. The 2000 concept vehicles essentially met performance goals, but not cost goals. If production prototypes are produced in the next stage, it is unclear what the fuel economy goals will be. Similarly, U.S. emission standards were tightened during the PNGV program, and the concept cars do not meet current standards. Still, some of the technologies can be incorporated into other products, and the new vehicles can appear in the market incrementally. The program can thus be successful, even though an 80 mpg vehicle does not appear suddenly in the market.

A questioner pointed out that there is another view that the PNGV program has been less than successful in accelerating advanced technology. Some smaller foreign companies, like Toyota, have gone further, while the existence of the program has undermined public regulatory initiatives to improve fuel consumption. In some cases, the new technology has been used to make vehicles larger by, for example, being incorporated in sport utility vehicles. Further, the technology chosen by PNGV, diesel hybrid, is not the cleanest. These cars do not meet current emissions standards, which was entirely predictable from well known trends.

China's PUV Strategy

A question on Chinese strategy was posed. Over the next 20 years, there will be significant growth in the number of Chinese vehicles, which is already having an impact on oil imports, national economic security and air pollution. Should China proceed systematically like the United States over 40 years, or like the EU in 20 years, or jump ahead and adopt state of the art technology?

Dr. Heywood pointed out that in order to leap-frog, there must be somewhere to land, a viable technology to go to. Today there are opportunities, but no certainties. Dr. Wachs summarized the benefits to Chinese industry and the benefits to the public of increased mobility. China should take the best guess and build in financial incentives alongside standards. Others claimed that automotive technologies developed in other countries easily can be transferred if the engineering capability is present. The difficulty will be the fuel supply. The sulfur must be removed, and that may take a while. The maintenance industry also will need support.

Conclusion

Dr. Liu concluded the session by pointing out that the increase in fuel efficiency in the United States is offset by the preference of consumers for heavier vehicles. But the relationship of size to safety, as compared to the relationship of weight to safety, is not well understood. Possibly, a new vehicle can be developed with the safety of conventional vehicles and the benefit of weight reduction.

APPENDIX A

Committee on the Future of Personal Transport Vehicles in China

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Purdue University

GUO Kong Hui, Co Chairman (CAE)
Director, the State Key Lab for Automobile
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APPENDIX B

Symposium Agenda for the Future of Personal Transport in China

Friday, January 12, 2001
Room NAS 150

9:00 AM Opening. Introduction to National Academies, the Chinese Academy of Engineering, and the Joint Study. Speakers: C. William Colglazier, Zhu Gaofeng, Dale Compton, Guo Konghui

Session I: The Chinese Transport Sector and Environment in 2001

Moderator: Zhu Gaofeng, vice president CAE

10:00 Keynote: Issues related to Personal Vehicle Expansion in China. Speaker: Liu Zhi, World Bank

10:30 Current Air Quality Problem and Control Strategies for Vehicular Emissions in China. Speaker: Prof. Shao Min, Center for Environmental Sciences, Beijing University

11:00 Features of Chinese Vehicular Fuels. Speaker: Qiu Yansheng, Deputy Chief Engineer of Research, Institute of Petroleum Processing

11:30 Predicting the Development of Personal Vehicles in Cities of China. Speaker: Lu Ximing, Director of Shanghai City Comprehensive Transportation Planning Institute

12:00 Discussion

12:30 Lunch

Session II: Advances in Automotive and Other Transport Technologies

Moderator William Wulf, President NAE

2:00 Keynote: Lessons Learned on the Road to More Efficient Transport Systems. Speaker: Martin Wachs, University of California, Berkeley

2:30 New Developments in Engines, Fuels, Emission controls, and the Role of Electronics. Speaker: John Heywood, Massachusetts Institute of Technology

3:00 Status of the Partnership for a New Generation Vehicle. Speaker: Trevor Jones, Biomec, Inc.

3:30 The Urban Experience. Speaker: Ralph Gakenheimer, Massachusetts Institute of Technology

4:00 Health Implications of Increased Motorized Transport. Speaker: Dan Greenbaum, Health Effects Institute

4:30 Discussion

5:30 Adjourn

APPENDIX C

Symposium on the Future of Personal Transport Vehicles in China
Friday, January 12, 2001
Speakers List

LIU Zhi, Senior transport economist with the World Bank. He is extensively involved in the Bank's urban transport operations in China. He co-edited a Bank report on China's urban transport development strategy. Before joining the Bank, he was a research associate with Harvard Institute for International Development (1993-95), and a faculty member of Nanjing University (1984-87). He received his Ph.D. from Harvard University.

SHAO Min, expert in Environmental Sciences. Professor of Center for Environmental Sciences. He received his Ph.D. from Center of Environmental Sciences, Beijing University. The projects he has completed includes: Studies on modern nuclear sciences and applications to environmental sciences (National natural Sciences Foundation Key Project); Acid deposition Characteristics and control strategies in Qingdao (The Eighth-Five-Years State project); Regional validation of methane emissions (National natural Sciences Foundation Project for Youth); Cost effectiveness analysis of vehicular NO_x emission control in Guangzhou (UNDP project). He has published 20 papers in national and international journals.

QIU Yansheng, expert in Petroleum Processing. deputy chief engineer of the Research Institute of Petroleum Processing (RIPP). His academic backgrounds are petroleum products, petroleum additives and tribochemistry. In the past 30 years, he has completed a variety of researches, including metalworking lubricants, gear lubricating oils, rust inhibition oils, rest inhibitors, extreme pressure additives, tribochemistry studies, etc. He has studied tribochemistry as a visiting scholar in Swansea College, Wales University, U.K. from 1985 to 1987. He has published several papers in the domestic and foreign journals, possessed several patents, and got awards from SINOPEC administrations.

LU Ximing, expert in Transportation Planning. director of Shanghai City Comprehensive Transportation Planning Institute. He completed his MA Program in City transportation Planning in Shanghai Tongji University in 1989. He received his MA from Sydney University in Australia, majored in Transportation Planning and Management in 1993. He has presented dozen of papers in International Conferences, more than 300 papers in the various domestic magazines and several special books. The Majors are covered in all fields of transportation system, such as the transportation planning, transportation development policy, city planning, computer mathematics model and transportation economy, etc. He completed dozen of key research and study projects in the past two decades.

Martin Wachs is Director of the Institute of Transportation Studies at the University of California Berkeley, where he is also Professor of City and Regional Planning and Professor of Civil and Environmental Engineering. Until 1996 he was Professor of Urban Planning at UCLA for 25 years, where he served three terms as Department Chair. He was the Chairman of the Transportation Research Board during the year 2000, and has written four books and 140 published articles about transportation and land use, the environmental impacts of transportation, and transportation finance.

John B. Heywood is director, Sloan Automotive Laboratory and Sun Jae Professor of Mechanical Engineering Massachusetts Institute of Technology. Research Interests Transportation technology, and especially engines, is his primary area of engineering interest. Much of his research, writing and teaching have focused on understanding and explaining the processes which govern the operation and design of internal combustion engines (both spark-ignition and diesel engines), and their fuels requirements. Major research themes include engine combustion, pollutant formation processes and engine and vehicle emissions, factors affecting engine performance and efficiency, engine friction, lubrication and wear. He is a member of the National Academy of Engineering and the NRC Committee to Review the Research Program of the Partnership for a New Generation of Vehicles.

Trevor O. Jones, is chairman and founder of BIOMEC, Incorporated, a biomedical device company. He was formerly chairman of the board of Echlin, Incorporated, a supplier of automotive components primarily to the after-market. Mr. Jones is also chairman and CEO of International Development Corporation, a private management consulting company that advises automotive supplier companies on strategy and technology. He was chairman, president, and CEO (retired) of Libby-Owens-Ford Company, a major manufacturer of glass for automotive and construction applications. Previously, he was an officer of TRW, Incorporated, serving as vice president of engineering in the company's Automotive Worldwide Sector and group vice president, Transportation Electronics Group. Prior to joining TRW, he was employed by General Motors (GM) in many aerospace and automotive executive positions, including director of GM Proving Grounds and director of GM Advanced Product Engineering Group. He is a member of the National Academy of Engineering (NAE) and a former commissioner of the National Research Council (NRC). Mr. Jones was chairman of the NRC Standing Committee on the Partnership for a New Generation Vehicle (PNGV) from 1993 to 2000. Mr. Jones has served on several other NRC study committees, including the Committee for a Strategic Transportation Research Study on Highway Safety, and chaired the NAE Steering Committee on the Impact of Products Liability Law on Innovation.

Ralph Gakenheimer, Department of Urban Studies and Planning, Massachusetts Institute of Technology. Ralph Gakenheimer is an urban planner interested in urban infrastructure and transportation in the developing countries and in the United States, with an emphasis on planning process, institutional development, and the relationship between methodologies and decision making. He has lived about seven years abroad, working on problems of urban planning in the developing world for public agencies, universities, foundations, international agencies and consultants. The countries include: Peru, Chile, Egypt, Indonesia, Saudi Arabia, Colombia, Lebanon, Honduras, Costa Rica, Bolivia, Venezuela, Argentina, Thailand, Mexico, Sri Lanka, China and El Salvador. He has headed an MIT faculty team on strategic planning for Bangkok. He is researcher in the MIT-based Cooperative Mobility Program in search of solutions attractive to all mobility stake-holders. He is currently a member of a research group examining alternative policies for the Pearl River

Delta of China, and a research group examining options for future mobility and air quality improvements for the Mexico City Metropolitan Area.

Dan Greenbaum joined the Health Effects Institute as its President and Chief Executive Officer on March 1, 1994. In that role, Greenbaum leads HEI's efforts, supported jointly by US EPA and industry, to provide public and private decision makers with high quality, impartial, relevant and credible science about the health effects of air pollution. Greenbaum recently chaired the EPA Blue Ribbon Panel on Oxygenates in Gasoline which issued its report Achieving Clean Air and Clean Water in July, 1999. Greenbaum also serves on the National Research Council Committee for Research Priorities on Airborne Particulate Matter and the Clean Air Act Advisory Committee. Greenbaum has nearly three decades of governmental and non-governmental experience in environmental health. Just prior to coming to HEI, he served as Commissioner of the Massachusetts Department of Environmental Protection from 1988 to 1994, where he was responsible for the Commonwealth's response to the Clean Air Act, as well as its efforts on water pollution and solid and hazardous waste. Greenbaum holds Bachelor's and Master's degrees from MIT in City Planning.