CICERO Working Paper 2001: 09

Globalization of the automobile industry in China

Dynamics and barriers in the greening of road transportation

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August 2001

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Tittel: Globalization of the automobile industry in China: Dynamics and barriers in the greening of road transportation

Forfatter(e): Lin Gan
CICERO Working Paper 2001: 09
18 sider

Finansieringskilde: Norges forskningsråd

Prosjekt: Promoting sustainable road transportation in China: The greening of the automobile industry

Prosjektleder: Lin Gan

Kvalitetsansvarlig: Knut Alfsen

Nøkkelord: bærekraftig utvikling, transport, bilindustrien, teknologisk utvikling, Asia, Kina

Sammendrag:. Artikkelen beskriver tilstanden i bilindustrien og i styringen av veitransport i byer i Kina. Den gjør rede for hvordan bilindustrien utvikler seg for å møte utfordringer fra den økonomiske utviklingen, miljøreguleringer og teknologisk endring. Dynamikken og barrierene som følger av teknologisk endring i biler med sikte på reduksjon av eksosutslipp og økt energieffektivitet analyseres. Det hevdes at eksterne kostnader bør tas i betraktning ved utvikling av offentlig politikk for bilindustrien og samferdsel. Artikkelen stiller spørsmålstegn ved myndighetenes politikk som i dag oppmuntrer til anskaffelse av privatbil, og foreslår at forbedret kollektivtransport og sterkere utslippsbegrensninger ville være relevant for Kinas arbeid for bærekraftig utvikling av transportsektoren.

Språk: English

Rapporten kan bestilles fra:
CICERO Senter for klimaforskning
P.B. 1129 Blindern
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Eller lastes ned fra:
http://www.cicero.uio.no

Title: Globalization of the automobile industry in China: Dynamics and barriers in the greening of road transportation

Author(s): Lin Gan
CICERO Working Paper 2001: 09
18 pages

Financed by: The Research Council of Norway

Project: Promoting sustainable road transportation in China: The greening of the automobile industry

Project manager: Lin Gan

Quality manager: Knut Alfsen

Keywords: Sustainable development, transportation, automobile industry, technological development, Asia, China

Abstract: This article describes the state of the automobile industry and urban road transportation management in China. It reviews how the automobile industry is evolving to respond to challenges in economic development, environmental regulations, and technological change. The dynamics and barriers resulting from technological change of the automobile in response to reduction of exhaust emissions and energy-efficiency improvement are analyzed. It is argued that consideration of externality costs should be integrated in automobile industrial policymaking and transport management. This paper questions the current government policy of encouraging private car ownership, and suggests that improvement in public transportation systems and stronger emissions control would be relevant to China's drive toward sustainable transportation development.

Language of report: English

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Acknowledgements

This research is financed by a grant from the Research Council of Norway (NFR). Its support is greatly appreciated. The author is grateful to Lynn P. Nygaard for her editorial assistance.

1 Introduction

Transportation is one of the major contributors to air pollution problems at the local, regional and global levels. Transportation accounts for 27% of total global energy consumption. It relies on fossil fuel burning, primarily oil, and is now the fastest-growing source of greenhouse-gas emissions, particularly in developing countries. Analysis of how to manage the transportation sector and reduce its environmental effects is closely related to works on climate change, technology choice, regulatory frameworks, as well as to issues of sustainable consumption and social equity.

The greening of the road transportation sector and the automobile industry is a highly debated issue in international energy and environmental policy arenas, and has attracted the attention of the media (*Financial Times*, December 3, 1998) as well as researchers and policymakers. It has been argued that development and dissemination of new automobile technologies, e.g., fuel cells, energy efficient engines, electric cars, and the use of alternative fuels,[1] will have profound impacts on economic, political and market structures in developing countries (IIEC, 1996). Employing innovative and alternative automobile technologies will also affect patterns of energy production and consumption and trade relations, as well as bring about changes in social behavior and lifestyle.

The greening of road transportation, through improved energy efficiency and use of alternative fuels, will affect the way industries respond to market change. This is a complicated process, through which various dynamic factors shape directions and courses of action and interaction. Since developing countries are able to not only draw on past experiences of industrialized countries but also benefit from new techno-logical innovations, there is no reason why they should repeat the mistakes of the industrialized countries in developing their transportation systems.

A high degree of dependence on private cars for transportation puts pressure on natural the resource base, particularly on the fossil fuel energy supply, and increases pollution from auto emissions. What must be considered are alternative options for modes of sustainable transport and technology choices that both provide cost-effective solutions for the increasing demand for mobility and minimize the negative environmental effects of automobile use. Therefore, promoting the development and dissemination of energy-efficient automobile technology is a preferred policy option.

Traditional transportation planning emphasizes increasing traffic capacity, traffic flow, and parking capacity. This is usually realized through heavy government investment in highways and road infrastructure. Private car ownership is encouraged through policy incentives that aim to increase consumption as means to stimulate economic development. This mode of development is being challenged because of concerns about sustainability and social equity. Transportation sustainability can be assessed by measuring automobile dependency: the greater the dependence on automobiles, the more unsustainable the transportation system. Sustainable transportation incorporates a broader range of goals, including economic, technological, social and environmental considerations (Litman, 2001, p.1).

[1] The US Department of Energy has defined the following fuels as "alternative" to gasoline: biodiesel, electric fuel, ethanol, hydrogen, methanol, natural gas (CNG/LNG), propane (LPG), P-series, and solar fuel.

1.1 Development Challenges

China has made considerable progress in its economic development over the past two decades. During 1980–1999, average GDP growth rate was 10.4% annually. The industrial growth rate was at 12.7% per year in the same period. The average annual growth rate of GNP per capita was 8.3% during 1985–1995. Although China is still classified as a low-income developing country, the estimated per capita purchasing power parity (PPP) was at US$ 3,550 in 1999, which is comparable to the group of the "lower-middle-income" economies (The World Bank, 1997, p.214, 2001, p.12). In addition, China has the highest gross domestic savings rate in the world at 40.1% of GDP in 1999. The increase in living standards has led to a growing demand for quality transportation services and more convenient and flexible transportation systems. Use of private cars is often the preferred choice of wealthy people and the middle class. This trend is similar to that in many industrialized and some developing countries.

One of the sectors that shape development paradigms and consumption patterns is road transportation, automobile use in particular. It can be argued that China, in building its transportation systems with a high dependency on road transportation, is currently following a development trajectory similar to that of many other newly industrialized countries, such as Thailand, where the extensive use of automobiles has led to traffic congestion and severe environmental problems (Phipott, 1995).

On the one hand, increasing globalization of the Chinese automobile industry has had considerable impacts on international trade, domestic employment, and structural changes in the economy (Hirabayashi, 1997). On the other hand, the increasing use of private cars has mostly benefited wealthy groups and marginalized the poor and disadvantaged social groups in their access to public transportation. Public health has been significantly affected by exhaust emissions from automobiles (Xu, 1994, pp.216–2; 1998), which has led to increased social inequity, mostly affecting the poor and disadvantaged social groups in mega-cities.

China is undergoing rapid changes in its road transportation sector and the automobile industry development. This can be seen in two aspects: First, improved urban transportation management has increased the mobility of urban residents.[2] This improvement is largely a result of government policy to promote economic development through automobile sector growth and infrastructure development. It puts emphasis on the increased private car ownership as means of stimulating personal consumption for economic growth; Second, the greening of automobile production and use has reduced environmental impacts of automobile emissions. This development stems more from industrial and market competition rather than from government emission regulations. This is basically the result from the "policy lag" phenomenon, which characters the public policy systems in China. The reasons will be explained in later sections.

Rapid development of road transportation systems in China has had considerable impacts on energy use by increasing the pressure on oil production, distribution and consumption as the country becomes increasingly dependent on imported oil. From 1993, China became a net oil importer, and by 1997, imported oil increased to some 4 billion tons (Gan, 1998, *China Statistics Yearbook*, 1999). This is an important change in energy trade, indicating that China will become highly dependent on imported oil to sustain its industrialization and economic growth in the coming decades (*China News Digest*, Jan.14, 1997).

[2] The effort to improve public transportation networks in Shenzhen is an example (www.chinautc.com, May 2, 2000). Shenzhen maintains one of the highest rates of private car ownership because of its high income level and the policy of encouraging private car purchase.

The growth in the transportation sector is the main driving force behind the increased demand for oil. Passenger transportation by road increased 7.4 times during 1978–1998. This growth implies an increasing dependency on the automobile as means of passenger transportation. A similar trend is seen in freight transportation: 76% of all goods were transported by road in 1995, which is an increase from 69% in 1980 (National Statistics Bureau, 1996, pp.94–95).

With the acceleration of urbanization in China during 1980–1999, the urban population as a percentage of the total population of 1.3 billion increased from 20% to 32% (The World Bank, 2001, p.162). This implies an increasing exposure of people to pollution in urban areas. The central government policy to promote urbanization will intensify this process, as sustainability goals in urban planning are often undermined by other objectives, such as economic growth, employment, housing, etc (Zhou, 2001).

In the 1990s, there were growing concerns within China about the increasing concentration of the greenhouse gases (GHGs) in the atmosphere that may lead to unexpected climate changes. It is estimated that 33% of the greenhouse gases that cause global warming originate from transportation sources. Damages caused by CO_2 emissions accounted for 2.5% of GDP in 1999 (The World Bank, 2001, p.180).[3] Evidently, this issue has evolved from mere scientific debate into the policy arena at various institutional levels in China, including the government, international organizations, multinational corporations, scientific research institutions, non-governmental organizations (NGOs), and the mass media. However, the most pressing concern of the government is to reduce the impacts of urban environmental pollution problems, as almost all of China's big cities are affected by severe air pollution problems caused by high levels of such pollutants as sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and total suspended particulates (World Bank, 2001, p.174). Air pollution problems in large cities are often debated in the mass media, as pollution levels far exceed national and international emission standards.

China has already become one of the world's leading car-manufacturing countries. By 1998, China was ranked number 10 in the world in terms of total automobile production. China produced 1.63 million vehicles in 1998 out of the total world output of 52 million vehicles. This rapid industrial development represents both opportunities and challenges for China's integration into the global economy and efforts to protect the environment.

2 Road Transportation Development

There have been four phases in the development of the automobile industry in China over the past 50 years.[4]

1953–1965: In this initial phase, the state government acted as the main promoter and investor. During this period, the state government invested about 1.1 billion yuan and produced about 60,000 vehicles per year. As part of the technology collaboration program between China and the former Soviet Union, automobile industry development was very much shaped by the Soviet technology import, product development, management styles, and institutional set-up. By 1960, 16 automakers and 28 assembly companies were established. In this period, automobile production at the regional level also became feasible and profitable, driven by profit-making initiatives of provincial governments. "Self-reliance policy" was the

[3] Carbon dioxide damage is estimated at US$20 per ton of carbon (the unit damage) times the number of tons of carbon emitted.

[4] Some information is taken from an unpublished report (Hu, XJ, Zhang, XL and He, JK, 2001).

main philosophy behind this massive industrial development. There were basically no international contacts with automakers in industrialized countries apart from the solo technology collaboration with the former Soviet Union.

1966–1980: This period marked a phase of modest growth and periodic turbulence in the industry. From 1965, driven by security considerations, the state government invested heavily in automobile production capacity development in the western regions, particularly in the Sichuan, Shanxi and Hubei provinces. Because these plants were built in remote areas where there was a lack of infrastructure, materials and energy supply, the strategy misfired and created many difficulties in the industry. Production was mostly focused on heavy vehicles for military use, and over-capacity and weak demand characterized the industrial development in these regions. By the early 1970s, demand for passenger cars started rising and production could no longer meet the demand. The government decentralized automobile production, which led to a peak in capacity development in different regions. By 1980, there were 58 automakers, 192 assembly companies, and about 2,000 spare parts suppliers. The state invested 5.1 billion yuan in increasing production capacity to 160,000 vehicles. The policy of decentralized production limited China's ability to increase economies of scale and reduce costs in the auto industry.

1981–1998: This period was a phase of adjustment and high-speed development. The open-door economic policy from 1978 provided an opportunity for the auto industry. By the early 1980s, boosted demand for auto products led to shortages in production capacity. Provincial governments stepped in for further investment, facilitated by the decentralization policy. From 1983 to 1985, automakers almost doubled from 65 to 114, which intensified market competition. From the mid to late 1980s, major international automakers came to establish themselves in the Chinese market, encouraged by the open-door government policy and the large market potential for the passenger car business. The industrial development was characterized by an increase in joint ventures, which led to the establishment of seven major corporations. Together, these corporations accounted for more than 60% of the market share in products in this period. By 1998, total investment amounted to 120 billion yuan and production output accounted for 262 billion yuan, or equivalent to 0.8% of the GDP.

1999–present: Over the last two years or so, important changes have been observed in urban transportation management and the auto industry. In late 1998, the central government introduced a policy of encouraging private ownership of passenger cars. The various incentives resulting from this policy – including low interest loans and reduced tariffs and fees – is leading to an increase in the demand for private cars. On the other hand, concern about the environmental impacts of motor vehicle pollution has led to policy changes for sustainable urban transportation management and increased fuel efficiency in the passenger car industry. Stronger environmental regulations and market competition become major driving forces behind improving the energy efficiency of newly produced cars. Most of the new products in the market can meet the Euro II emission standards, while China is still applying Euro I standards. Cities such as Beijing and Shanghai have introduced stricter measures.[5] In major cities, public buses have been encouraged to use LPG (liquefied petroleum gas) or CNG (compressed natural gas).

There is also an increasing amount of research on the use of Intelligent Transportation Systems (ITS) in urban transportation management. A government sponsored research group was established in Beijing in early 2000 to work on this matter. However, transportation

[5] Started in early 1999, Beijing and Shanghai municipal governments imposed stricter regulations on auto producers and required them to follow the Euro I emission standards for the production of new cars. Euro II emission standards should be followed by January 1, 2004. Nationwide, Euro I emission standards started implementation in January 2000.

management planning is a new issue in urban management, as only 30 cities out of 668 have undertaken comprehensive transportation and traffic surveys, and only a fraction of these have employed advanced transport planning methodologies. Cities like Beijing, Shanghai, Tianjin, Shenzhen and Nanjing have begun to introduce Traffic System Management (TSM) and Transport Demand Management (TDM) in the attempt to tackle urban transportation problems.

3 Mega-trends in the Automobile Industry

With the start of the 21st century, the Chinese automobile industry is facing growing challenges: pending membership in the World Trade Organization (WTO), intensified market competition, stricter environmental regulations, increasing consumer demand for quality products and services, oil price increases, and mergers within the industry.

The automobile industry has been heavily subsidized by the government. During 1995–2000, state investment in the automobile industry totaled 58.8 billion yuan, of which 80% were invested in 13 major state-owned companies (*China Daily*, May 15, 2001, p.5). These companies control 90% of the automotive market with an anural production output of some 2 million vehicles. **Table 1** shows that between 1980 and 1988 the output value of the automobile industry increased by some 33 times, the fixed assets increased by 26 times, and the work force more than doubled. During this period, he number of companies almost unchanged, which implies an increase in the scale of production. Large-scale mergers are resulting in a consolidation into three main industry groups: First Auto Works, Shanghai Automotive Industry Corp., and Dong Feng Motors. Small automakers are losing ground to larger ones, which receive support from the state and collaborate with capital-rich and technologically advanced international giant automakers.

Table 1. Automobile Industry Development in China (1980–1998)

Year	Enterprises	Employees (million)	Output Value (million yuan)	Fixed Assets (million yuan)	Equipment (1,000)
1980	2,379	0.91	8.84	5.36	201.1
1985	2,904	1.41	23.53	9.62	318.7
1990	2,596	1.57	46.81	17.99	394.8
1995	2,479	1.95	204.27	64.54	541.5
1998	2,426	1.96	298.76	141.88	636.9

Source: Chen, 2001, p.3.

In terms of strategy, automakers in China can roughly be divided into two groups. The first group includes Volkswagen, General Motors (GM), Toyota, Ford, Peugeot Citroen, Nissan, Daimler-Chrysler, and Suzuki. This group of enterprises is attempting to establish themselves in the Chinese market mostly through joint ventures with Chinese counterpart companies. Their strategy is to maximize their domestic market shares. By utilizing the skilled and cheap labor force in major Chinese automakers, these foreign companies can reduce production costs and maximize profits. Volkswagen, for example, has from the mid-1980s established itself as a key passenger automaker with more than half of the market share in its passenger cars sales in China.

GM is another example of a firm that engaged itself in China with a long-term vision and an entry strategy focusing on quality service and infrastructure development. GM has predicted that 40% of car industry growth in Asia will come from China. By 2025, China will surpass the US to become the largest automobile market. As its long-term market strategy, GM invested some US$ 2 billion in four joint venture enterprises, one spare parts sales center, and two research institutes that cooperate with universities. The first manifestations of what may be called GM's constructive engagement policy has led to the $1.52 billion joint venture Shanghai plant, which is now producing a version of the Buick Regal/Century. The Buick Regal/Century is a luxury-class car, retailing at some $40,000, and targeted at wealthy entrepreneurs. A minivan based on the Pontiac Montana will be the next product, and other vehicles will follow. In addition, Jinbei GM, another 50/50 joint venture company in Shenyang, will start production of the Chevrolet Blazer SUV and S10 pickup soon (Mccormick, 1999).

The strategy of the second group of automakers is to first export their products to China. This group includes primarily luxury automakers, such as Volvo, BMW, and Mercedes-Benz. These manufacturers are taking a cautious approach in their market entry strategy, but they remain open to large-scale engagement in the future. Mercedes-Benz will establish a production plant in China if China joins the WTO this year (*People's Daily*, May 14, 2001, p.5). BMW has been performing well in its sales, and has set a target of 5,000 units by 2001. Joint venture plant development is currently under negotiation. Currently, these automakers are trying to expand their service and spare-parts supply networks. With their potential capacities in market development and expansion, it is expected that they will soon apply more aggressive operations. Their objective is to serve the wealthy income group with the purchase power to buy luxury cars in the price range of 400,000–600,000 yuan (48,190 to 72,280 U.S. dollars).

4 What Drives the Globalization of the Automobile Industry?

Over the past two decades, the open-door economic policy has had a massive impact on the automotive market. China's development in the automobile industry is part of the drive towards integrating key industries into the global marketplace. There are several interrelated driving forces behind the globalization of the industry, including market competition, technological change, and environmental regulations. (See **Figure 1** below.)

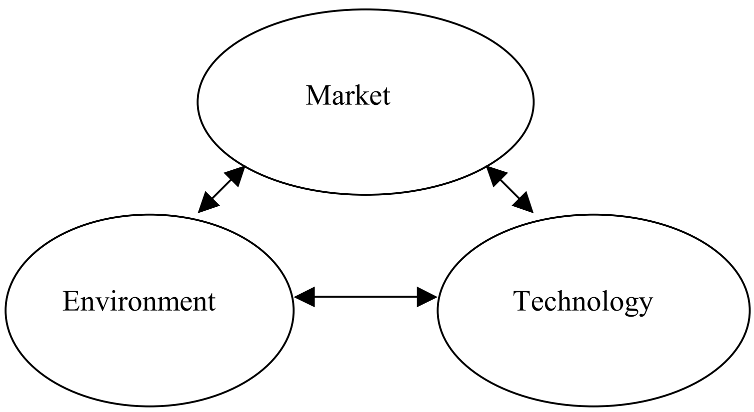

Figure 1: Market Competition

Globalization of the automobile industry implies the integration of the domestic market into the international market with increased circulation of goods and services. It is clear that the high growth rate in China's economy and the increasing purchasing power of the wealthy social groups have attracted all the major international automakers to China. By 1998, there were more than 600 international investors from the auto industry that established their businesses in China. Among them, about 40 are brand-name automakers. The first company to enter the Chinese market was Volkswagen of Germany, which established a joint venture business in Shanghai in 1985 and soon established itself as a key player in the auto market. Volkswagen now accounts for 54% of the passenger car market with 300,000 units of annual output.

The Chinese automobile products are dominated by foreign automakers, except products made by First Auto Works. Government policy works to give a competitive edge to domestic manufacturers. First, the policy of indigenization of foreign technologies and products aims to localize the production of cars and spare parts, which is intended to reduce costs. Second, protectionism applies high tariffs to keep foreign products less competitive than domestic products. So far, 40%–80% of the parts can be supplied within China, depending on the products. However, this policy of protecting the domestic spare parts industry also removes the incentive for investing in improving its know-how and technical competence.

Currently, competition for market shares in the car market is strong among 148 automakers with 4,593 models under sale. Private passenger car consumption is up. In 1985, private car sales only accounted for 9% of the total automobiles sold; in 2000, the figure was 60%. Private car ownership is increasing at the rate of 25% per year. The main concerns from consumers include price, safety, reliability, emissions, and post-sales service. Energy efficiency improvement is reflected in concerns about fuel economy. Price is still the main signal of market competition. With the increasing gasoline prices, users—especially taxi drivers—are becoming more sensitive to fuel economy than ever before. They are also becoming more interested in switching to alternative fuels.[6]

To promote market competition, the government has relaxed price regulations for automobile sales. Automakers are trying to bring the best of their products and services to the market. However, China's imminent entry into the WTO will bring about a great uncertainty in their business. Over the past half a century, protectionism has, to a large extent, kept the domestic auto industry out of international market competition. Deregulation of the automotive market to increase competition will attract foreign automakers to China with their quality products and services. The domestic auto industry will find it difficult to survive without considerable improvement in management techniques and technology. The government has recently taken measures to reduce tariffs on imported automobiles to put more pressure on domestic carmakers.[7]

On the other hand, globalization of the auto industry will provide better opportunities for Chinese enterprises that target the rural market, domestically and internationally. In the last few years, the increasing export of China produced commercial light-weight vehicles, minivans, and motorcycles to other developing countries is a good example (Chen, 2001, p.10). Apparently, this export strategy fills a gap left by international automakers.

[6] For example, taxi usually drives about 300 km per day in Beijing. Taxi drivers are very much concerned about fuel price increase, and alternatively shift to use cheaper alternative fuels, such as LPG (interviews with taxi drivers by the author in early 2001).

[7] Tariff reduction for automobiles above 3.0 litres from 100% to 80% and below 3.0 litres from 80% to 70%.

The issue of promoting private car sales has become a matter of public debate. The main arguments for and against private car purchase are listed in **Table 2**. It is notable that the environmental and health impacts of automobile use are not mentioned in the public debate.

Table 2. Arguments For and Against Private Car Purchase

For	Against
Increased mobility	Lack of parking space
Economically affordable	Too expensive and can't afford it
Increased transportation efficiency	No particular need
Easy to get loans	Safety concerns
Status symbol	Not satisfied with current products
Access to more forms of enjoyment	Difficult to acquire permits
Following examples of others	Difficult to obtain credit
	Health concerns (better to use bicycles)
	High maintenance costs

Source: *Shenzhen Business Daily*, April 1, 2001.

4.1 Technology Advancement

In the Chinese auto industry market, most technologies are imported. Chinese carmakers have comparatively weak research and development (R&D) capacity for product innovation and new designs. Joint venture companies dominate in terms of technology transfer, adaptation, and product innovation. In terms of fuel economy, domestically developed cars consume some 10–30% more of energy than those products made by foreign technologies and designs (*Life Daily*, Feb.6, 2001).

Driven by the desire to dominate the market, major automakers are attempting to introduce new technologies into the Chinese market. This is a new phenomenon compared with that in the 1980s and 1990s. Volkswagen plans to tap into the diesel car market in China with its latest technology. This intention is signaled by the "3-liter/100km" Lubo car. Volkswagen's plan to introduce models with low operating costs is based on its prediction that the purchase of private cars in China will grow steadily in the coming years. Concerns about fuel economy and the environment will drive up the demand for super energy efficient and cleaner cars.

One of the emerging areas for technical innovation and market development will be in energy efficient cars. A driving force behind the growth in this area is the government desire to clean up the environment and to reduce China's dependency on oil. In April 1999, 13 key government organizations under the support of the State Council started implementation of the "Air Clean-up Program: Clean Automobile Action Plan," which involves programs to promote R&D on fuel cells, electric and hybrid cars, and dissemination of mature alternative fuel technologies.

China's R&D efforts on electric cars started in the early 1990s. The government invested more than 350 million yuan for R&D and demonstration projects. However, no commercialization has been realized in these projects. Vehicles using alternative fuels, particularly LPG and CNG, increased from 5,000 in 1998 to 80,000 in 2000, and filling stations were increased from 40 to 228 in the 12 cities where clean vehicle demonstration projects were implemented (*Science Daily*, May 2, 2001).

The main obstacles to manufacturing more fuel efficient cars are the weak R&D capacity in industrial enterprises, underdeveloped marketing networks, and a low rate of technology dissemination. The government has been the major promoter of R&D efforts conducted at universities and government research institutions, but disseminating research results to the market has been unsatisfactory. So far, there has been little market demand for electric cars, mainly because the technology has not developed sufficiently, particularly in battery life. In contrast, alternative fuel technologies have found a market niche and are being disseminated rapidly in some large cities such as Beijing,[8] Shanghai, and Shenzhen. Some of the key technologies are imported from abroad, such as the American gas engines used in public buses . This wide market acceptance is assumed to be demand driven with the objective of reducing vehicle emissions. Government subsidization of infrastructure development, e.g. filling stations, also plays a role in technology dissemination. However, there have been some problems in adapting to technology change. For example, many taxi drivers are reluctant to shift to alternative fuels because of the reduced acceleration.[9]

The trend of switching to alternative fuels is driven by a number of factors: stricter environmental regulations, rising gasoline prices, and an increasing supply of natural gas (Logan and Chandler, 1998). However, there are debates about the effectiveness of using alternative fuels.[10] It has been argued that alternative fuels do not drastically reduce pollution, particularly with respect to NO_x emissions. These fuels are considered by some to be an intermediate technology. Advanced research is being conducted with regard to the application of fuel cell technology.[11] Hybrid cars have not yet been given enough attention yet, although they have recently become a hot topic internationally.[12] To a large extent, China has not yet developed a high level of research expertise in auto industry innovation. This will require further investment in capacity building, particularly in training of experts and technicians.

4.2 Environmental Regulations

In the past, the Chinese government paid inadequate attention to assessing, or adjusting, its policies on road transportation in relation to reducing the environmental impacts of automobile emissions.[13] There are contradictions in governmental policy with regard to prioritizing the use of private cars versus relying on the development of public transportation systems to satisfy demands for mobility and flexibility. On the one hand, the government intends to boost the use of private cars to stimulate economic development; on the other hand, critical issues, such as environmental effects of automobile use, constraints in oil production and road transportation capacities, have forced the government to reassess its policies on public transportation systems, and to readjust automobile industrial policy. The policy shift to regulating the use of leaded gasoline is a clear example. Use of leaded gasoline was banned

[8] Methanol as an alternative fuel has become applicable for public buses in Beijing. It is a demonstration project supported by the state government.

[9] Based on interviews conducted by the author.

[10] Comments by experts in a number of workshops held in China.

[11] A research center has been established in Shanghai to develop advanced fuel cells for transport use.

[12] The First United Nations and US Department of Energy Conference on Hybrid Power Systems was held in California, USA, May 24–25, 2001.

[13] According to a comment by Mr. Jin Fengjun, senior researcher at the Chinese Academy of Sciences.

nationwide by July 2000. There has thus been a push to produce energy efficient and environmentally friendly cars.[14]

Recently, the Chinese government realized the importance of pollution control from urban transportation and became determined to take action. According to Deng Nan, Vice Minister of the Ministry of Science and Technology, “China attaches great importance to the development of alternative-fuel vehicles (AFVs), primarily because of air pollution and a need to replace oil imports with domestically produced natural gas…Developing environmentally friendly motor vehicle technology in line with China's resources is highly significant for ensuring the sustainable development of the nation's automobile manufacturing industry."[15]

It was estimated that Beijing would demand at least 200,000 units of motor vehicles during 2000–2002, stimulated by new environmental protection measures in the city. It was stipulated that by the end of 2002 all motor vehicles then in use must meet the new exhaust emission standards that took effect in early 1999. To strictly implement the emission criteria, more than half of the more than 1.6 million units of vehicles now in use in the city need to be re-fitted or replaced. It is believed that strict environment regulations will both encourage people to trade in old polluting vehicles for cleaner cars and help improve the production technology of China's automotive industry (China Carguide Corp., July 12, 1999).

The Chinese government has used regulatory instruments relatively effectively to regulate industrial behavior. The command-and-control policy approach is more widely used in China than elsewhere in the world. This approach may stimulate rapid changes in technology applications and dissemination of new technologies and products, but is less cost-effective in economic terms as it brings high marginal costs in transformation of production facilities and management systems. In the past few years, Beijing regulated the taxi market and ordered the demolition of some 40,000 highly polluting Dafa minivans to replace them with more energy efficient and cleaner models. The costs of this substitution were mostly borne by private taxi drivers and their affiliated companies.

5 Perceived Barriers

There are several barriers for China to be able to shift to the development path that supports sustainable road transportation. These barriers are primarily institutional and relate mostly to government policies.

5.1 Costs of Externalities

There has been little integrated assessment about the external costs of road transportation for society, despite a number of studies on vehicle pollution and related health problems (Xu, 1994; Xu, et al. 1995, pp.286-89; James and Polenske, 1998). These external costs include the

[14] Eighteen cities and provinces, such as Beijing, Shanghai and Guangzhuo, imposed local laws to ban the use of leaded gasoline in 1998. The State Council decided to ban the use of leaded gasoline in 46 cities by July 1999, which was further imposed on the whole country by July 1, 2000. It was required that gasoline producers stop production of leaded gasoline by January 1, 2000. It is also required that all car manufacturers install catalytic converters and electric-ignition systems in all newly produced cars. These regulations have been proven effective in implementation, particularly with regard to the actions taken by the oil refinery industry.

[15] Speech at the opening of the Second Beijing International Seminar and Exhibition on Electric Vehicles and Alternative Fuel Vehicles held in Summer 1998.

increased costs of health care insurance, hospitalization, and environmental damages to infrastructure, property, cultural heritage, and land use, which result from accidents, noise, climate impacts, and exhaust emissions. Integrated and comparative studies of road transportation could provide a better understanding of the economic aspects of sustainable transportation management and prevent policymakers from designing policies that support inefficient use of resources.

In a recent OECD report, it is estimated that the externality costs of road transportation and aviation could amount to 8% of GDP in OECD European countries. Life-cycle assessments of the externality costs should include not only the impacts from road transportation operations, but also the costs of vehicle production and maintenance, construction of infrastructure, fuel production and distribution, and disposal of used vehicles. This will add additional costs of 15–30% to the operational costs (OECD, 2000, p.28).

5.2 Land Use

Land use is a perceived problem in urban planning. In Beijing, the density of the population is 714/km^3. In some areas of the city center, population density may reach 100,000/km^3. The average road per capita is 3.5 km^3 in Beijing and 1.8 km^3 in Shanghai, compared with 28.3 km^3 in New York and 45.9 km^3 in Chicago, respectively. In major US cities, vehicle use occupies about 30–50% of the land, while it is about 13–15% in Beijing. Each year, the growth rate of road construction in Beijing is about 3%, while motor vehicle population is growing by 12% and use of passenger cars by 25% (Chen, 2001). It is clear that infrastructure development cannot keep pace with the increase in motor vehicle use. China uses only 7% of the world's arable land to feed 22% of the world's population. Increasing land use for road transportation will increase uncertainty with regard to food production, which is of strategic importance for national security. It will also not be realistic for China to devote much of its scare land resources mainly to improving the mobility of motor vehicle users—particularly because most infrastructure development in urban areas benefits private car owners.

In late 1990s, traffic speed in key streets was at 10km/h in Shanghai. Traffic congestion is being perceived mainly as an infrastructure problem rather than a management one. Therefore, more roads are being built to cope with the growth in vehicle population. But this will not provide a solution, as long as the growth of vehicle population far exceeds infrastructure development. **Figure 2** illustrates the dilemma.

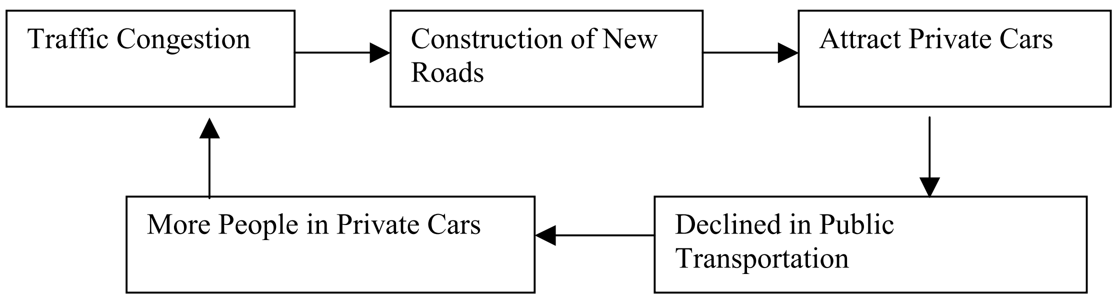

Figure 2. Dilemmas in Traffic Management

5.3 Change in Consumption Patterns

China has long been known for its widespread use of bicycles in urban transportation. This situation has changed to a considerable degree with the increasing use of automobiles to go to work and leisure activities. China is experiencing a rapid expansion in road transportation, which has now surpassed other transportation systems, such as air, water, and railroad transportation. Motor vehicle ownership increased from 5 vehicles per 1,000 people in 1990 to 8 vehicles in 1999. From 1980 to 1995, the total number of registered motor vehicles has increased more than eleven times from 2 million to 25 million. In 1995, road transportation accounted for 89% of the total passengers in the transportation sector, compared with 65% in 1980 (National Statistics Bureau, 1996).

It is projected that road transportation per passenger kilometer will increase by 3.5 times during 1991–2010 (International Energy Agency, 1994, p.184). Before the 1980s, private cars were rare. Economic reforms begun in 1978 have resulted in a dramatic increase in the purchasing power of the affluent social groups and the middle class. From 1985 to 1995, the total number of private-owned cars has increased from 285,000 to 2.5 million, or almost eight times. In the same period, road transportation capacity only increased by 23%, even though public investment in road transportation doubled from 13% to 26.5% of the total investment in infrastructure development.

With the rapidly changing consumption patterns, what needs to be stressed is the inequity in income distribution. According to the World Bank (2001, p.70) 30% of the population in China with the highest income represented 77% of the total income or consumption, while 30% of the population with the lowest income represented only 8.3% of the total income or consumption. It is clear that the majority of the population cannot afford to purchase private cars but is increasingly being affected by exhaust emissions from private automobiles that rich people can afford to buy. Clearly, with the rising income and living standards, more and more consumers will consider using private cars instead of bicycles because bicycles are becoming more inconvenient (few bicycle lanes are being developed) and public transport systems are not well developed.

5.4 Energy Consumption

According to the International Energy Agency, the overall energy demand for road transportation is projected to increase from 25 Mtoe (million tons of oil equivalent) in 1991 to around 95 Mtoe by 2010, corresponding to an annual growth rate of over 7% (1994, p.185). With regard to energy efficiency of automobile use, there are two contradictory trends: 1) due to increasing use of new motor vehicles, energy efficiency per 100 vehicle kilometers has improved from 30 and 26.9 liters with gasoline and diesel engines in 1985 to 27.7 and 23.1 liters in 1992; 2) energy efficiency per 100 passenger kilometers has decreased by more than 10% in the same period (International Energy Agency, 1994, p.183). The second trend is related to increasing individual use of automobiles and related traffic congestion that tends to reduce overall fuel efficiency. Clearly, advancement in technology and improvement in urban transportation management and infrastructure will help increase energy efficiency in the long run, but declining use of collective transportation will certainly lead to inefficient use of energy resources and more pollution, which may off-set the gains from adopting new vehicle technologies.

5.5 Tensions in Transportation Systems Development

The government is the main investor in road projects intended to build up the infrastructure to meet growing demand. Public investment in road transportation infrastructure totaled 217.5 billion yuan. However, there are tensions in road transportation systems development. Such issues as transport effectiveness, road accidents, air and noise pollution, and increased dependency on oil-powered motor vehicles have all become targets for skepticism and policy reform concerns.As a result, the central government has set up a policy to encourage increased private car ownership, while at the same time giving priority to public transportation development. Market competition has pushed the automobile industry to reduce product prices in order to boost demand. Few alternative measures are being developed to strengthen public transportation systems, although at the regional level there is growing concern about green alternatives in vehicle production and use.[16] Adopting alternative fuel technologies will have a profound impact on the market. However, difficulties remain with regard to establishing the infrastructure, i.e., refueling stations, and reducing costs for technology adaptation and dissemination.

China is already the world’s third largest producer of motor vehicles, following only the USA and Japan. Even though the use of automobiles, particularly passenger cars and motorcycles, has increased dramatically, China is still in the early stage of road transportation development. Passenger car ownership in China was 3 per 1,000 people in 1999, compared with 478 in the USA (World Bank, 2001, p.170–72). With a total population of 1.3 billion, there is a tremendous potential for problems related to road transportation in terms of energy use and environmental impacts. If China reaches a level of 24 passenger cars per 1,000 people, which is average for low- and middle-income countries, by 2030, the number of passenger cars could reach as many as 33.6 million,[17] or the equivalent of 25% of the current US level. The pressure on China’s oil resource base and world energy markets would be enormous, as would be the problem of air pollution.

The government developed the “1994 New Automobile Policy,” which provided the guideline for the automobile industry up to the year 2000 and beyond. Moreover, the “China Science and Technology Policy Guidebook” (SSTC, 1992, p.48) proposed that the fuel efficiency of motor vehicles should increase 5% by 2000. Research and dissemination of alternative fuels, e.g., natural gas and alcohol, should be implemented in some regions of the country. It is by no means clear how cost-effective policy measures could be established to accomplish these objectives. The fast growing population of private cars has not only provided competition for public transportation, but has also made it less effective in operation.

5.6 Technological Change and Innovation

By 1999, some 15 million motor vehicles (excluding military vehicles) were in use, of which 6 million were passenger cars. About 2 million motor vehicles (excluding motorcycles) were produced in 2000. However, the majority of the motor vehicles in use are old and technologically out-dated. For example, most motor vehicles are not equipped with catalytic converters, and fuel efficiency is much lower than international standards dictate. By the mid-1990s, most of the vehicles produced employed technologies from the 1970s and the 1980s, which had been transferred from industrialized countries. Japanese automakers were the early players with the market entry strategy to transfer outdated auto technologies and products.

One example is the Dafa minivan, which was produced by a joint venture between Daihatsu and Tianjin Automobile Industrial Corp. in the early 1980s to the late 1990s. The Dafa minivan was based on an old model produced in Japan in the 1970s, and was used as taxi in Beijing extensively for about ten years from 1985–1995. It is still being used today in Tianjin

[16] Currently, more than 6,000 vehicles operate on cleaner-burning natural gas, and the vehicles refuel at more than 70 refuelling stations. China has also developed the national electric vehicle (EV) standards, formed a panel of experts from the scientific and business sectors, established an EV research and demonstration zone, and is involved in joint EV and AFV programs with Italy, the United States, and Australia.

[17] This figure is based on the expectation that China’s population will be around 1.4 billion by 2030.

as the result of the local protectionism. The Daja minivan has been characterized as a major polluter and low quality product. According to one report, automobiles in China emit up to ten times as much harmful exhaust pollutants as those in developed nations, and they are the main source of pollution in large cities, responsible for 80% of all carbon monoxide emissions (*China Online*, December 16, 1998).[18]

From early 2001, competition has intensified in the auto industry. Some automakers have modified their market development strategies. Major automakers, such as Toyota, GM, VW, are investing heavily in new models and products. Vehicles using new technology, which makes them cleaner and more energy efficient, are entering the market. This development can be seen as the result of intensive market competition among major automakers. It seems to be a positive trend in terms of improved fuel economy and emissions reduction. Increasing competition will push automakers to use more advanced technologies to meet consumers' demands. However, in some cases, pressure for cost reduction may also push automakers to select cheaper products or lower standards, as long as they meet the minimum requirements in emission standards. It seems that the current emission standards of Euro I lags behind the state of the market, as most of the new vehicles produced can reach Euro II emission standards.

The reason that the industry has responded positively to meet strict emission standards is twofold: both market competition and emission regulations for new products have played a role. State tax authorities have provided an incentive for the automobile industry to employ stricter environmental standards by giving the consumer a 30% tax reduction on the purchase of new products that meet Euro II emission standards.

5.7 Environmental and Health Effects of Auto Emissions

Although China follows the Euro I standards for urban automobile emissions, actual emissions often exceed the standards because of the lack of monitoring stations, advanced equipment, law enforcement measures, and so on.[19] According to the World Resources Institute (WRI), Chinese vehicles emit 2.5 to 7.5 times more hydrocarbons, 2 to 7 times more nitrous oxides (N2O), and 6 to 12 times more carbon monoxide (CO) than foreign vehicles. In Beijing, Shanghai, Hangzhou, and Guangzhou, up to 70% of CO emissions have been attributed to motor vehicles (WRI, 2000). As a result, although China's vehicle fleet is small compared to that of industrialized countries, its mega-cities are already blanketed with heavy smog. **Table 3** compares the situation of air pollution in mega-cities in the world.

The number of motor vehicles on China's roads has tripled since 1984, climbing from less than 2.4 million in 1984 to 13.2 million in 1998 (Chen, 2001). By 2020, the urban vehicle population is expected to be 13 to 22 times greater than it is today (Stares and Liu, 1996). This trend will have a major impact on China's future air quality. The shift toward private vehicle use is most apparent in mega-cities. For example, from 1986 to 2000, the number of private vehicles in Beijing increased more than five times, from 260,000 to 1.65 million. Although this is less than one-tenth of the number of private vehicles in Tokyo or Los Angeles, the pollution from Beijing's motor vehicles is significantly greater.

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[18] See: http://www.chinaonline.com

[19] According to interviews with government officials conducted by the author during a trip to Shenzhen in early 2001.

Table 3. Air Pollution Indicators in Mega-cities of the World

City	Population in Millions (2000)	Total Suspended Particulates* (1995)	Sulfur Dioxide* (1998)	Nitrogen Dioxide* (1998)
Beijing	10.8	377	90	122
Shanghai	12.9	246	53	73
Tokyo	26.4	49	18	68
Osaka	11.0	43	19	63
New York	16.6	61**	26	79
Los Angeles	13.1	49**	9	74
São Paulo	17.7	86	43	83
Rio de Janeiro	10.6	139	129	n.a.
Mexico City	18.1	279	74	130
Delhi	11.7	415	24	41
Mumbai	18.0	240	33	39
Calcutta	12.9	375	49	34
Manila	10.9	200	33	n.a.

*Micrograms per cubic meter **Data from1989-94, in *World Resources (1996-97),* pp.154.
Source: The World Bank. 2001. *World Development Indicators (2001)*, pp.174–75.

Table 4 shows the air pollution situation in major cities in China. If we take into account that the World Health Organization's (WHO) annual mean guidelines for air quality standards are 90 micrograms per cubic meter for total suspended particulates, and 50 for sulfur dioxide and nitrogen dioxide, it is clear that air pollution levels in China's major cities have reached critical levels.

Table 4. Air Pollution Indicators for Major Cities in China

City	Population in Millions (2000)	Total Suspended Particulates* (1995)	Sulfur Dioxide* (1998)	Nitrogen Dioxide* (1998)
Chongqing	5.3	320	340	70
Guangzhou	3.9	295	57	136
Guiyang	2.5	330	424	53
Harbin	2.9	359	23	30
Jinan	2.6	472	132	45
Lanzhou	1.7	732	102	104
Shenyang	4.8	374	99	73
Taiyuan	2.4	568	211	55
Tianjin	9.1	306	82	50
Urumqi	1.6	515	60	70
Wuhan	5.2	211	40	43
Zhengzhou	2.1	474	63	95
Zibo	2.7	453	198	43

*Micrograms per cubic meter
Source: The World Bank. 2001. *World Development Indicators (2001)*, pp.174–5

5.8 Social Impact of Government Subsidizes

Subsidizing the provision of infrastructure is sometimes defended on the grounds that such infrastructure provides goods and services to the poor and stimulates economic growth. However, the World Bank (1994) concludes that price subsidies to infrastructure in developing countries almost always benefit the more affluent social groups more than the poor. In the case of road transportation, subsidies mostly benefit richer social groups, car owners, at the expense of the poor and disadvantaged social groups.

Pollution problems from road transportation have affected the health and well-being of old generations, children, and the working class, who are marginalized in society. Not only do these groups not benefit from the government policy to subsidize infrastructure and support private car ownership, but this policy results in restricting or reducing their access to public transportation service. Moreover, they have to pay their own hospitalization and health care costs resulting from auto emissions and accidents. This inequity issue stemming from public transportation policy has not yet been addressed by policymakers. At the current stage of economic development, it is hard to deny the need for infrastructure development. The important policy consideration for the government is to reassess its policies and make the social equity issue relevant to economic growth.

6 Conclusions

China's transportation sector and the auto industry are in the middle of a rapid transition. Both government policies and market demand have contributed to the growth in road transportation. Although still an infant industry by international standards, there is an observed convergence of key elements, such as capital investment, research and development, technology transfer and merges within the industry. They all contribute to the globalization of the industry and transportation management modes. The dynamics come from three interrelated fabrics: desire for economic prosperity, environmental regulations to reduce impacts of emission, and technological change/innovation to increase efficiency and reduce costs. Transportation sector development is shaping the country's development in many aspects, including energy supply and security, employment, social equity, and life style change. Conflicts remain as to what extent benefits from improved transportation networks and mobility can be distributed more equally among various income and social groups, and between urban and rural areas. Meanwhile, policies should be adjusted and adapted to keep automobile use and expansion from putting unnecessary pressure on natural resource base and harming the environment.

From 1980 to 1997, total CO_2 emissions in China increased 1.4 times from 1.5 to 3.6 billion tons. China contributes 15% to global CO_2 emissions. If the trend of CO_2 emissions continues at the current rate, China may become the world largest CO_2 emitter by the mid-21st century. The problem of acidification is also spreading rapidly (*Associated Press*, December 7, 1998). Increasing energy security concerns also call for policy adjustment towards sustainable transportation development.

With the increasing domestic demand for energy consumption and services, which result in uncertainty in energy supplies and increased pollution problems, China is meting challenges in its industrial and environmental policies. This could lead to drastic changes in its transportation policy to encourage sustainable production and use of automobiles. The key issue will be how to establish cost-effective regulatory frameworks for emissions reduction and incentives for technological innovation to satisfy demand for transport services, and at the same time minimize the harmful environmental impacts of automobile emissions. To reach these objectives, barriers for sustainable transportation sector development—such as protectionism in import of foreign made automobile —should be reduced. Adjustment of corresponding policy frameworks and instruments will be necessary.

Technological change plays a central role in emissions reduction and energy efficiency improvement. New automobile technology development and innovation will become a major driving force in China's transportation sector development. China has the advantage of being able to select from the latest technologies to jump over the technology gap.[20] Policies need to be designed to encourage private sector investment in technology development and innovation, for which venture capital market should be established to provide finance and credits for industrial innovation and research. Research centers in universities should be encouraged to establish closer links with the industry in order to market their research results more effectively. Through such initiatives, China should be able to reduce its dependency on foreign technology imports and increase its domestic R&D capacities.

There are encouraging indications that the government is willing to explore new auto technologies and promote industry innovation. Energy efficient vehicles and alternative fuels are perceived as solutions to urban environmental problems. To promote vigorous policy changes in urban areas in support of new technology innovation and market dissemination, strict environmental regulations are needed, such as mandatory implementation of Euro II emission standards in major cities before 2004. Measures should also be undertaken to strengthen monitoring stations and emission inspection facilities.

The current policy of encouraging private passenger car ownership will not be sustainable in the long run because of China's particular situation: high population density, shortage of land resource, limited oil reserves, environmental impacts and health effects of automobile use, etc. Although China needs to improve its transportation networks, as growth in automobile use is inevitable, policy changes should be encouraged to support public transportation systems development. Efficient and convenient public transportation networks will be in line with China's development objectives: to satisfy the majority needs for improved mobility. It is important to introduce changes in the design of vehicles, considering the safety of the passengers and use of eco-friendly fuels, such as CNG, hydrogen, and electricity. Wider mandatory use of devices such as catalytic converters to neutralize poisonous gases is also recommended.

Singapore, Curitiba in Brazil, and Freiburg in Germany, for example, have all been able to develop sustainable urban public transportation systems (*Our Planet*, Vol.12, No.1, 2001, pp.8–14). China would do well to draw from these experiences in the planning of urban transportation systems. It is vital to introduce new concepts of urban transportation management when new development is designed in small and medium sized cities to avoid future traffic congestion and related environmental pollution problems.

Compared with Western nations, which have had the benefit of a century of experience and know-how development in the automobile industry, China only has gained substantial experiences in modern auto industry development over the last 15 years or so. This gap will not be overcome in a short-time span. However, it is possible for China to narrow the gap in newest technology breakthroughs, particularly by adopting advanced clean vehicle technologies and products. This will require adequate policy support and measures that can simultaneously accelerate industrial innovation and rationalize resource use.

[20] This has already been seen in the telecommunication sector development, for which China utilizes the most advanced broadband technology for network build-up.

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