Driving towards a Cleaner Future

A Study of Transport Policies of Road Emissions Control in China

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Driving towards a Cleaner Future - A Study of Transport Policies of Road Emissions Control in China
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Executive Summary

The atmospheric environmental pressure upon China is increasing, and so is the awareness that the launch of effective policies should be urged. Motor vehicles have become a significant source of pollutant emissions. While the motor vehicle population seems inevitable to grow rapidly in the near future, the question appears crucial that how to provide road traffic-induced emissions increasing in parallel.

Endeavors have been made both at national level and local level. Whilst national government concentrates on the general issues, e.g. establishing standards, monitoring implementation, introducing taxation, and designing future objectives, the focus at local level is mainly on the implementation of national regulations and initiation of local policies tailored by specific circumstances.

Due to the facts that there are limited resources available to devote to environmental protection issues, policy priority required setting. The evaluations of existing policies dealing with road traffic generated emissions, therefore, have been conducted based on following criteria: environmental effectiveness, economic efficiency, enforceability, equity, and dynamic effects.

The outcome of analysis and research shows that most of the existing policies, if implemented properly, are quite effective in terms of pollution reduction. Compared with the industrialized countries, the costs of controlling road emissions in China are relatively lower. However, more attention should be put on the equity and dynamic effects of the policies. Based on the results of evaluation, further recommendations are made.
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1. Introduction

It is only recently that people in China have realized they are facing serious atmospheric environmental problems. With the rapid economical and population growth in the past two decades, the air quality in most Chinese cities has deteriorated and is getting worse. Guidelines set by the World Health Organization (WHO) for the protection of human health are routinely violated. The damage to human health and well-being due to poor air quality is believed to be extensive. If current trend was not halted and converted, the atmospheric environment would soon become impossible to sustain population, economic, and industrial growth in the future.

Air pollution problems in the cities are more severe than that of rural areas due to the higher population concentration. The artificial generating sources for substances causing air pollution can be divided into two categories: Mobile generating source, e.g. motor vehicles and Stationary generating source, e.g. power plants and factories. Currently, the stationary sources remain to be the prime contributor of air pollutants, especially in the cities applying heating systems during wintertime. On the other hand, however, mobile sources appear to be responsible for an increasing share of air pollution in most cities, mainly attributed to rapid growth of vehicles population. While the expansion of motor vehicle fleet in China seems unavoidable in the foreseeable future, how to control motor vehicle generated air pollution by strong governments' interventions becomes crucial.

Various packages of policies have been developed to cope with the problem by organizations and research institutions, e.g. the World Bank. China, both at national level and local level, has also made efforts to control traffic-induced emissions and is pursuing better environmental performance. However, considering the limited social economical resources available for environmental protection, the adoption and implementation of policies require the priority setting.

1.1 Objectives of Study

The purposes of this paper are to review the environmental consequences of the increasing road traffic and to summarize the present policies used to ameliorate them both at national level and at local level. Combing with international experience and specific China's situations, analysis of present policies and further policy recommendations are to be conducted, if possible from cost-efficiency perspective. To fulfill the objectives of thesis, following questions will be addressed in the report:

- How serious the problem of road traffic-induced emissions is in present China? What's the future trend?
- What policies to relieve road emissions have been implemented and what are to be enforced, both at national level and local level?
- How effective the existing policies are, both from an environmental effectiveness perspective and from a cost-efficiency perspective?
- How to set priorities for the future transport policy of China?
1.2 Scope and Limitations

For achieving a more concise analysis, the scope of research has been narrowed down.

Firstly, although the overall transportation consists of 4 modes: road transport, aviation, maritime transport, and rail transport, only the road traffic and consequently generated road emissions will be the focus of this thesis. The reason lies in that road emissions are more significant, compared with those of other mobile generating sources. For instance, Shanghai has busiest port in China and has two international airports at present. However, looking at NOx emissions in Shanghai as example, in 1998, road traffic contributed 61% of NOx emissions from total mobile generating sources, while maritime transport, trains, and aviation shared 24%, 10%, and 5% respectively. Furthermore, the road emissions are mainly distributed in the urban areas, especially in the highly congested districts, which have more significant adverse impact on human health.

The motor vehicles used in road transport include heavy-duty vehicles ($\geq$3.5 ton), light-duty vehicles (<3.5 ton), motorcycles, and mopeds. Both passenger transport and freight transport will be taken into consideration in the thesis.

In spite of various policies available for road emissions control, transport policies, i.e. emission standards, fuel policies, fuel taxes, public transport policies, traffic restraint, etc. will be summarized and analyzed in this thesis. Other policies, especially land-use policies, concerning with emissions control will be out of this thesis’s scope.

1.3 Material and Methodology

To prepare this thesis, a study trip to China and Shanghai was made from June till August 2001. Most relevant materials were collected during this period, including the primary materials of air pollution information in Shanghai conducted by SAES (Shanghai Academy of Environmental Sciences). Some informal interviews were made with residents in Shanghai to acquire better understanding of the current situation. Other materials were mainly obtained through literature in IIIEE library and Internet resources.

The methodology used in this thesis involves a review of literature, relevant legislations and policy documents. A case study in Shanghai is made to illustrate the local situation and policies. In the analysis section, both the approach of environmental effectiveness and the approach of cost-efficiency will be applied to evaluate existing policies. The approach of environmental effectiveness used in this thesis concerns the impact on polluting emissions, measured in physical units, e.g. a reduction of so many tones of pollutant emitted. The approach of cost-efficiency concerns the comparisons of costs of different policies to attain a given targets. The costs concerned may be described as the direct economic costs of achieving the changes in pollutant emissions that policy seeks, measured in monetary terms.

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1 Shanghai Academy of Environmental Science (SAES): *Investigation and Research of NOx Emission in Shanghai*, 2000
1.4 Thesis Outline

This thesis starts in Section 2, with a short description of general atmospheric environment and followed by the history and trend of road traffic in China. The specific road emissions and its environmental consequence are detailed as well.

Series of policies coping with the problems, both at national level and local level, are summarized and introduced respectively in Section 3 and 4.

In Section 5, discussion and analysis on the existing policies are conducted in depth. Policies are evaluated both from emission control perspective and cost-efficiency perspective.

The results of Section 5 facilitate the policy recommendation in Section 6.

Finally, Section 7 concludes the thesis and raises the questions for further research.
2. Road Traffic Emissions in China

This section is intended to provide a general background for the research. The current air pollution levels in China, especially in major cities, are already unacceptably high. National air quality standards are frequently exceeded. With the rapid expansion of vehicle population, transport sector is putting more pressure on the atmospheric environment than ever. Consequently, large scales of adverse environmental and human health impacts are generated.

2.1 General Air Pollution Status in China: History and Trend

Tracing the development of national environmental report can help better understand of the air pollution problems. In Environment Report of China in 1989,\(^2\) it is reported that the general atmospheric environment was good at that time. And the pollution only existed in the large and medium-sized cities. However, Environment Report of China in 1990 has described the problem as follows: “air pollution in large and medium-sized cities\(^3\) are comparatively severe, and there is a deteriorating trend in the small-sized cities and towns”. Situation is even getting worse from then on and air pollution has extended to rural areas. Moreover, a notable trend has apparently emerged. The combustion of coal with high sulfur content used to be the main cause of air pollution in China. Consequently, smoke, suspend particulate matter, and SO\(_2\) consisted of the dominant air pollutants. Nevertheless, NO\(_x\) pollution has been put attention since the environment report in 1995. In metropolitan cities like Guangzhou, Beijing and Shanghai, problem is more severe. (Shown in Figure 2) In 1998’s report, vehicle exhausts was described as the other primary contributor to air pollution in part cities.

![Figure 1. Annual Average Concentration of TSP, SO\(_2\), and NO\(_x\) in Chinese Cities](image)

Source: CEPA, Annual Environmental Report of China

\(^2\) All the data in this section, except those which are specially marked the references, are quoted from: State Environmental Protection Administration of China: (CEPA), Annual Report on the State of Environment in China. 1989-2000.

\(^3\) In China, large-sized city refers to a city with the population of 500, 000 and above. Medium-sized city is a city with the population of 200, 000–500, 000.
As shown in Figure 1, during the period from 1989 through 1998, the yearly average concentrations of total suspend particulate matters (TSP), \(SO_2\) in Chinese cities have decreased 33 percent and 46 percent respectively. However, the density of \(NO_x\) emission remains relatively stable during the same period with the exception of 1998.

![Figure 2. Forecast of NO\(_x\) Emission in the inner city of Shanghai](image)

*Source: SAES, Investigation and Research of NO\(_x\) Emission in Shanghai, 2000*

Figure 2 has illustrated that exhausted emissions from motor vehicles play a crucial role in air pollutant emissions in urban area. In 1998, road emissions contributed 74% of total \(NO_x\) emissions within Inner-ring Roads of Shanghai. While the \(NO_x\) emission from stationary resources is predicted to increase 20% in 2010 compared with that of 1998, the \(NO_x\) emission of road traffic in 2010 will be 92% more than that of 1998.  

It is notable that air pollution problems are varied by geographical factor in China. The atmospheric environment problems in cities of northern China are more serious than those in southern China, with several exceptions of southern industrialized cities. In 1996, for instance, the annual average concentrations of SPM, \(SO_2\), and \(NO_x\) in northern cities were 0.387 mg/m\(^3\), 0.083 mg/m\(^3\), and 0.053 mg/m\(^3\) respectively, while those in southern cities were 0.23 mg/m\(^3\), 0.076 mg/m\(^3\), and 0.041 mg/m\(^3\) respectively. This factor determines that differentiated policies should be tailored by specific local conditions.

### 2.1.1 National Ambient Air Quality Standards

The current National Ambient Air Quality Standards (GB3095-1996) was initiated and enforced in 1996. Based on National Ambient Air Quality Standards, Standard I is required in the environmental protection districts, forests, beauty spots, etc. Standard III should be met in special industrial districts. Other areas are expected to reach Standard II. Thus, most of the urban and rural areas, except for the industrial districts, are obliged to reach standard II. The concrete standards have been illustrated in Appendix 1.

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4 Shanghai Academy of Environmental Science (SAES): Investigation and Research of NO\(_x\) Emission in Shanghai, 2000
According to the annual environmental report, the fulfillment of air quality standards is a huge challenge. For instance, Standard II requires the yearly average TSP concentration less than 0.2 mg/m$^3$. However, as shown in Figure 1, all the data have exceeded the standard without any exception. In the report of 2000, urban air quality data of 338 monitored cities were collected. By analyzing the data of three commonly monitored pollutants of NO$_x$, SO$_2$ and TSP, only 123 cities, or around 36.5% of those cities, met the National Standard II. For the rest of cities, at least one indicator exceeded the necessary standard. Moreover, Air Pollution Index (API) of 112 cities exceeded National Standard III, which accounted for 33.1%.

2.2 Current Status of Road Transport

Over the past two decades China has witnessed rapid increase of motor vehicle productions and registrations. In 1998, automotive vehicle ownership per capita in China is 1/100 and that of car is 1/355, which are respectively 1/13 and 1/32 of the world’s average.\(^5\) Considering the largest population denominator, the fleet of automobiles is considerably high. Moreover, the fleet has been expanding at the speed of average 10 to 14 percent per year during the past 20 years, which implies doubling the number every 6 to 7 years. As results, the number of automotive vehicles has increased from 4.22 million in 1987 to 13.14 million in 1998. (Figure 3) Besides, other types of vehicles, in particular motorcycles have increased sharply. The amount of those types of motor vehicles in 1998 is 10 times of those a decade before. Consequently, the total fleet of motor vehicles in China has climbed to 40.84 million in 1998.\(^6\)

![Figure 3. Motor Vehicle Fleet of China](source)

**Figure 3. Motor Vehicle Fleet of China**

*Source: NBS, China Statistical Yearbook of 1999, 2000*

The factor that most of the motor vehicles tend to be concentrated in or near urban areas results in the exponential growth rate of urban vehicle population. The counterbalancing factor used to be the income of households as a barrier of privately owned car

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development. According to economists' usual saying, when annual GDP per capita reaches 1000 USD, or when the annual income of a family is equivalent to half the price of a car, it signifies the arrival of the era of sedan cars entering families. Currently, annual GDP per capita in China is around 800 USD. However, many cities and regions have exceeded this standard, e.g. Shanghai has reached annual GDP per capita of 4000 USD. Presently, there are over 500,000 households in Beijing, each with a yearly income of around 45,000 RMB (equivalent to half the price of a common car). All these factors indicate that China has possessed the condition for developing family cars. Based on the prediction, the annual demand of automotive vehicles and sedans will be 5.8 million and 2 million in 2005, 10 million and 4 million in 2010, respectively. As results, the automotive vehicle population is expected to reach 49 million in 2010.\(^7\)

The current situation of motor vehicle manufactory and maintenance in China worsens the problem. Firstly, while some of the vehicles are manufactured by joint-venture enterprises and by enterprises under the license of developed countries, domestic companies using designs that are more than 20 years old take the other portion. M. Walsh found that the vehicle technology being produced tended to be primarily carburetor equipped with mechanical rather than electronic controls.\(^8\) Recently, collected emissions data in China shows that current vehicles are typical of late 60 or early 1970’s US cars. A recent investigation conducted by China National Automotive Industry Corporation (CNAIC) showed that a common domestic-produced car in 1998 emit up to 11.8 times as much CO, 3.3 times as much NO\(_x\) and 14 times as many HCs as those of U.S. 1992’s car.\(^9\) Poor vehicle maintenance as reflected in the high failure rate in the existing seems troublesome as well, relatively lenient I/M program. Many vehicles are operating with a rich air fuel mixture which produces relatively good drive-ability, but high fuel consumptions, as well as CO and HC emissions.

### Table 1. Emission Factors of Different Types of Motor Vehicles in 1997

<table>
<thead>
<tr>
<th>Motor Vehicle Type</th>
<th>Unit</th>
<th>Average Emission Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>PM</td>
</tr>
<tr>
<td>Sedan</td>
<td>g/km</td>
<td>44.2</td>
</tr>
<tr>
<td>Mini Car</td>
<td></td>
<td>24.7</td>
</tr>
<tr>
<td>Jeep</td>
<td></td>
<td>34.5</td>
</tr>
<tr>
<td>Medium-duty Cars</td>
<td></td>
<td>51.1</td>
</tr>
<tr>
<td>6BT Dongfeng Diesel Engine</td>
<td>g/kWh</td>
<td>2.87</td>
</tr>
<tr>
<td>Heavy-duty Petrol Engine</td>
<td></td>
<td>164.6</td>
</tr>
<tr>
<td>GM 6.2L Diesel Vehicle</td>
<td>g/km</td>
<td>0.35</td>
</tr>
<tr>
<td>Motorcycle</td>
<td></td>
<td>14.4</td>
</tr>
</tbody>
</table>

Source: Tsinghua Univ., Strategy Research of Motor Vehicle Emissions’ Control in China, 1997\(^{10}\)

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A research group of Tsinghua University conducted a study on the emission factors of different types of motor vehicles in 1997. The tested vehicles were really representative at that time and the result proved that those motor vehicles were highly polluting as shown in Table 1.

2.3 Road Traffic-induced Air Pollution in China

Traffic-induced air pollution in China first gained attention in the early 1980s. However, efforts to investigate the environmental impacts of transport sector have not been made until recent years. Although overall national statistics of emissions from road traffic are still lacking, relevant studies have been conducted at local level. In Shanghai, 8 monitored points near the main roads have been settled to record the data of traffic volume and NO\textsubscript{2} concentration. The monitoring results have evidently proved the consequent correlation between two factors, shown in Figure 4. It is generally believed that the increase of NO\textsubscript{x} concentration in large-sized cities is related to the rapid expansion of motor vehicle fleet. The annual growth of vehicle fleet in Shanghai is 14\% during last 10 years and the motor vehicle fleet has trebled in Beijing during the same period. Consequently, the annual NO\textsubscript{x} concentration in urban area of Shanghai increased from 0.046 mg/m\textsuperscript{3} in 1994, to 0.105 mg/m\textsuperscript{3} in 1997. There is also a significant increase of NO\textsubscript{x} concentration in Beijing.

![Figure 4. Correlation between Traffic Volume and NO\textsubscript{2} Concentration in July 1997, Shanghai](image)

Source: Xia, D., Temporal-spatial Distribution Characteristics of Nitrogen Dioxide Concentration in Shanghai Ambient Air, 2001

Moreover, the density of NO\textsubscript{x} in Central Business District is extremely high during the peak time. Recent studies prove that cyclists and traffic police stationed in intersections

\begin{itemize}
  \item Zhou, H., and Sperling, D., Traffic Emission Pollution Sampling and Analysis on Urban Streets with High-rising Buildings, 2001
  \item SAES, Integrated Protection Plan for Motor Vehicle Pollution in Shanghai, 2000
  \item Fu, L. and Yuan, Y., Beijing's Recent Efforts in Combating Urban Transport Pollution, 2001
  \item Xia, D., Temporal-spatial Distribution Characteristics of Nitrogen Dioxide Concentration in Shanghai Ambient Air, 2001
\end{itemize}
of Shanghai suffer from NO\textsubscript{x} exposure levels twice that of the National Standard.\textsuperscript{15} Based on the readings collected from 27 monitored points settled along elevated expressway in Shanghai, during April 1994 till Feb 1997, the maximum daily concentration of NO\textsubscript{x} varied 0.65~3.36 mg/m\textsuperscript{3}. Daily average concentration from all those monitored points exceeded National Standard without an exception. The situation in Beijing is even worse due to the huge number of motor vehicles. The contribution rate of NO\textsubscript{x} from motor vehicle source was 43\% in 1999. It was reported that Beijing NO\textsubscript{x} pollution was double the national acceptable air quality standard in 1998 and NO\textsubscript{x} that year became Beijing's most serious air pollutant.\textsuperscript{16}

The other notable fact is the increasing emission of CO and Hydrocarbon (HC) from motor vehicles. In 1998, 24.75 million tons of CO emission came from motor vehicles running in Chinese roads. In Beijing, 83\% of total CO emission comes from motor vehicle source.\textsuperscript{17} The contribution rates of CO and HC from motor vehicles in Shanghai were respectively 33\% and 78\% in 1990, but 64\% and 91\% in 1998. The total amount of CO and HC emissions in 1998 were respectively 191\% and 337\% of those in 1990. Moreover, the contribution rates of motor vehicle emissions are forecasted to be 70\% of CO, 88\% of NMHC and 24\% of NO\textsubscript{x} in 2005; and they will respectively reach 77\%, 88\%, and 27\% in 2010.\textsuperscript{18} Problem is more severe in the inner city areas. In the CBD of Shanghai, motor vehicles accounted for 87\% of CO, and 97\% of HC emissions in 1998.\textsuperscript{19} In the absence of other emission resources, road traffic is believed to be significant source of lead and SPM emissions in urban areas.

### 2.4 Adverse Environmental and Human Health Impacts of Road Traffic Generated Air Pollution in China

Acidification and adverse human health impacts are the two significant road emission related problems in China.

#### 2.4.1 Acid Rain

Due to enormous industrial and domestic use of fossil fuels, especially coal with high sulfur content, biomass, and heavy fuel oil, China is one of the worst acid rain polluted countries in the world. Emissions from road traffic worsen the situation. The two major air pollutants resulting in soil acidification are \(SO_2\) and \(NO_x\), of which transport sector is accounting for increased share.

#### 2.4.2 Adverse Human Health Impacts

Environment currently is one of the four major factors affecting human health and mortality in China. Different from the air pollutants emitted from chimneys, the exhausted gases from motor vehicles are emitted at the ground level which is in close proximity the breathing zones of people. Therefore, road emissions today, especially in

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\textsuperscript{15} Song, R., \textit{A Study on Exposure Level of Human to the Emission of Motor Vehicles}. 1997

\textsuperscript{16} Zhao, Y., \textit{Clear Improvement in Beijing’s Air Quality}, 2000

\textsuperscript{17} Fu, L. and Yuan, Y., \textit{Beijing’s Recent Efforts in Combating Urban Transport Pollution}, 2001

\textsuperscript{18} SAES, \textit{Integrated Protection Plan for Motor Vehicle Pollution in Shanghai}, 2000

\textsuperscript{19} Ibid.
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urban areas are responsible for enormous adverse health effects. According to World Bank, it is estimated that 178,000, or 7 percent, of deaths in China's urban areas could be prevented each year by air quality Standard II.\textsuperscript{20} Based on the census conducted by Minister of Health in 1999, cancers were the primary cause of death in urban areas and accounted for the proportion of 23.89% of total mortality, followed by cerebrovascular diseases and heart diseases. The rate of death from respiratory diseases in urban areas ranked the fourth. In rural China, respiratory diseases were the first cause of death and were followed by cancers.\textsuperscript{21} Abundant evidences have determined the consequent relationship between environmental conditions and diseases, especially cancers and respiratory diseases. Poor atmospheric environmental is considered a significant cause resulting in diseases and death.

In respect of vehicular emissions, lead and SPM are especially damaging to human health. High lead concentration in the bloodstream will increase incidence of abortion of women, impair renal function at high blood lead levels, and increase blood pressure. Most significantly it impedes the intellectual development of children and will probably result in lead poisoning. In Shanghai, Professor Shen Xiaoming, vice director of the Shanghai Children's Medical Center (SCMC) has taken a particular interest in lead poisoning in the city's children. Professor Shen and other researchers studied 1969 children between one and six years of age and found 37.8% had blood lead levels equal to or higher than the level defining lead poisoning (10 micrograms per deciliter) - a level at which IQ is known to deteriorate significantly. One factor that correlated highly with the children's lead levels with time spent on or near the city's traffic ways.\textsuperscript{22} In regard to SPM, since particles from vehicle emissions and tire wear are mainly in the submicron range, they are able to penetrate deep into the respiratory tract, cause respiratory problems, exacerbate asthma and damage lung function. Other pollutants, of course, have adverse health effects as well. CO inhibits the capacity of blood to carry oxygen to organs and tissues. SO\textsubscript{x} will probably lead to respiratory illness and premature death. NO\textsubscript{x} cause changes in lung function.

2.5 Concluding Remarks

China is confronting serious air pollution problem at present. With the rapid economic growth, the expansion of motor vehicles appears inevitable. The trend of increasing pollutant emissions from road traffic, with the increased adverse environmental and human health effects, is obvious. Effective policies are in the need to halt and convert current trend.

\textsuperscript{20} Cornell, S., \textit{Driving at a Cleaner Future}, 1998

\textsuperscript{21} Minister of Health, PRC (MOH), \textit{Annual Human Health Statistics of China in 1999}, 2000

\textsuperscript{22} Cornell, S., \textit{Driving at a Cleaner Future}, 1998
3. Road Emissions Control at National Level

With the increased consciousness of the adverse environmental and human health effects due to road emissions, rather than waiting for that to happen, efforts have been made in China to prevent the situation from becoming worse. This section is intended to trace the progress of national policies. Two basic functional mechanisms, command-and-control and economic instruments are applied to reach the environmental objectives.

3.1 Legal Framework for Control Road Emissions

During past two decades, national government, cooperating with national legislation institutions, has established a legal framework for environmental protection, which comprises three levels of legislative documents: laws, regulations, and standards. Within the framework, regulation is often specific to particular problems. The implementation consequences of regulations will be taken into account of the standard making. The state government takes charge of environmental regulations and standards, whilst the approval of environmental law requires the approval of legislation authority, which is National People’s Congress of China (NPC) in this case.

The law of the People’s Republic of China on the Prevention and Control of Atmospheric Pollution is the specific law applicable to motor vehicle emissions so far. While basic principles of environmental regulation and policy are described in this document, legal liability and the consequent punishment are also prescribed. After it was amended in April 2000, it was for the first time that an individual chapter - Chapter IV: Prevention and Control of Pollutants Discharge by Motor-driven Vehicles and Vessel, was initiated specific to traffic-induced air pollution.

The environmental standards on protection ambient air quality can be categorized into 5 kinds: basic standard, quality standard, emission standard, method standard, and reference material standard. National Ambient Air Quality Standards introduced in Section 2.1.1 is one of the quality standards. In regard to road emissions, the most important standards probably are the vehicle emission standards.

In 2001, a set of new vehicle emission standards have been put into enforcement, which include: Limits and Measurement Methods for Emissions of Pollutants from Light-duty Vehicles (I) (GB 18352.1-2001), Limits and Measurement Methods for Emissions of Pollutants from Light-duty Vehicles (II) (GB 18352.2-2001), and Limits and Measurement Methods for Exhaust Pollutants from Compression Ignition (C.I.) Engines of Vehicles (GB 17961-2001). The new standards have reached the level in accordance with Euro I emission standards (the requirements of 91/441/EEC and 93/59/EEC). Motorcycles should also reach the level equivalent to that of Europe at the first stage (requirements of 91/542/EEC). Compared with former standards, there is an 80 percent reduction in emission standards for light-duty petrol vehicle while emission standards for diesel vehicle drop 10–30 percent. In 2004 all the light-duty vehicles and cars should meet Euro II emission standards (the requirements of 94/12/EC and 96/69/EC), and
heavy-duty diesel vehicles should meet Euro II emission standards (the requirements of 91/542/EEC) since 2005. From 2010, China will synchronize its exhaust emission standards with the international one.

3.2 Command and Control Policies in National Level

Command-and-control is the traditional approach used to promote environmental performances. Due to the centralized political structure and former plan economic regime, command-and-control policies are still the main measures that central and local governments prefer. To mitigate road traffic-generated emissions, a set of policies has been developed on the basis of legal framework. Besides, central government is also assumed the responsibility of making environmental targets and plans.

3.2.1 Fuel Standards

In order to further curb air pollution problem due to tailpipe gas emission, the new State gasoline standard was enforced since 2000. It not only has a stricter limit on the amount of sulfur and lead content in the gasoline, but also adds content control indexes on olefins, aromatic and benzene. Though most content control indexes from the new State standard have been officially implemented since the beginning of 2000, the restrictions on two indexes, including sulfur content and olefin content, were initiated only in Beijing, Shanghai and Guangzhou on July 1, 2000 and will be expanded nationwide by 2003.

Lead has historically been added into gasoline as an octane enhancer. However, as was explained in Section 2.4.2, high concentration of lead will lead to huge adverse human health effects. Thus, there is now a worldwide move to ban lead in gasoline. Moreover, the use of lead free gasoline provides a prerequisite for the introduction of catalytic converters to reduce the emission of NOx, CO and HC.

Before it was banned, China’s gasoline contained 0.078 grams of lead per liter compared with 0.015 grams of lead per liter in Hong Kong, Singapore and many European countries.23 Based on Article 35 of Law of the Prevention and Control of Atmospheric Pollution, “Units and individuals shall, according to the time limit prescribed by the State Council, stop the production, import and marketing of leaded gasoline”.24 The new gasoline fulfilling standards only contains less than 0.013 grams of lead per liter and the gasoline octane number must exceed 90 Research Octane Number (RON). The new gasoline has accounted for 99% of total national gasoline consumption since July 2000 and the total reduction of lead discharge is expected to be 1,500 tons in 2000.

Sulfur content will be limited lower than 0.08 per cent and olefin content shall not be more than 35 per cent based on the new standard.

23 Cornell, S., Driving at a Cleaner Future, 1998
3.2.2 Vehicle Policy

As shown in Table 1, an obvious characteristic of existing motor vehicles in China is their high emission factors. The available measures to control the exhaust emissions, therefore, include applying new technology in the newly produced cars, replacing existing stock by more environmental friendly vehicles, and better maintenance and retrofit of the existing vehicle stock, etc. On the other hand, since all motor vehicles are subject to vehicle emission standards, the stringent emission standards play a crucial role in control the emission from the source.

Technological policy

In 2000, SEPA, Ministry of Science and Technology and State Administration of Machinery Industry jointly issued Technical Policies on Preventing and Controlling Emission Pollution of Motor-driven Vehicle to departments in charge of environmental protection, science and technology and machinery industry (automobile industry) in all regions of China. This policy gives technological standards in product development, quality control and after-sale service on newly produced motor vehicles, motorcycles and engines. It also puts forward strict technological requirements on the control of automotive and motorcycle emission as well as the production, sales and use of fuels. Technological Policies also makes clear prescription on the research and development, technology import and technology matching of emission control device and testing equipment.

Newly produced motor vehicle

All the domestic produced motor vehicles are required to take an approval test before they can get the production permission. All the motor vehicle models that have passed the test will be listed in the “Index of Enterprise-Produced Motor Vehicles and Their Products” issued by the China National Automotive Industry Corporation (CNAIC) and the Minister of Public Security and this index will be amended annually. It used to be the measure for SEPA to monitor the car manufactures to abide national standards. Since this index is now criticized as the obstacle of motor vehicle production, CEP A now is considering initiating three differentiated indexes for car production from the environmental perspective, which would include index of motor vehicles exceeding national standards, index of motor vehicles meeting national standards, and index of motor vehicles meeting Euro II standards. For the motor vehicles in the first index, production will be halted. Since 2000, all the newly produced light-duty gasoline motor vehicles are required to adopt electronically controlled ignition system and three-way catalytic converters. In a report conducted by World Bank, efficiently operated three-way catalytic converters can reduce exhaust CO and hydrocarbon emissions of gasoline vehicles by as much as 95 percent and NOx by over 75 percent.25

As one step to implement the new emission standards, four ministries issued the ban of carburetor-equipped automotive vehicles, which concerns 187 models of cars and mine vans, jointly in June 2001. The cars in the index are prohibited producing and trading.

The release of ban is due to the lagging situation that there were still nearly 100,000 newly produced cars that were not equipped with electric fuel-injection devices and catalytic converters at the end of 2000.

Existing stock of motor vehicles and scrappage programs
Because transportations could vary substantially between cities, it is not feasible for the CEPA to establish an exclusive policy applicable to the whole country. Therefore, local governments take more responsibility upon those issues. However, the general guideline of CEPA is to introduce Inspection and Maintenance (I/M) programs as the tool assuring that in-use motor vehicles are properly maintained. In respect of vehicle scrappage program, the acceleration of phasing out the motor vehicles that exceed national standards is encouraged.

3.3 Economic Instruments in National Level
Inheriting the centralized and planned management mode, economic instruments have seldom been launched in order to alleviate road traffic induced pollution. However, with the development of China's reform, several attempts have been made although the implementation effects are still open to be seen.

Economic instruments have been applied in the scheme of phasing out leaded petrol. Before it is wholly banned nationwide, leaded petrol has a period of coexisting with unleaded petrol. Because the production of unleaded petrol is more costly than the leaded, in order to encourage the production and consumption of lead-free petrol, taxes were increased to keep the price of leaded petrol at least as high as that of unleaded petrol. Although the final phase-out of leaded petrol is attributed to administrative methods, the different taxes objectively reduced the difficulties for the producers and retailers to adopt leaded free petrol.

3.3.1 Tax Incentives for Low Pollution Cars
Since 1994, China has adopted a three-tiered consumption tax on cars. Depending on the size of cylinder volume of engines, the consumption tax rates are 3 percent, 5 percent and 8 percent respectively. Since 2000, the consumption tax has been reduced by 30 percent for cars that have reached the European 2 emission standard. Therefore, a 30 percent cut will lower the tax rates to a range of 2.1-5.6 percent. The cars subject to the tax reduction include passenger cars, all-terrain vehicles and compact cars.

Although the preferential tax policy is considered a positive contribution to the country's attempt to control automobile emission pollution, especially in big cities, the real effects are still questioned by the critics. Industrial analysts said the tax cut is a step in the right direction, but that it will not significantly change the prices of vehicles on the domestic market. Compared with other arbitrary charges and fees imposed on vehicle purchasers and users, this amount of tax reduction cannot substantially stimulate the preference change to low pollution cars.
3.3.2 Fuel Tax

The progress of fuel taxation is probably the best mirror reflecting the crucial obstacle of environmental protection in China, which is the conflicting interests of different ministries, as well as those of central and local governments.

At present, a monthly road maintenance fees, as well as a number of unscheduled levies, charges and fees are charged from in-use motor vehicles. The proliferation of such fees, which are usually managed as "off-budget" income, has sparked a vast number of complaints and complicated the fiscal operation of the State. It was reported that in 1999, the total profits of auto industry was 4 billion RMB, while all the charges with the exclusion of taxes accounted for 120 billion RMB.\(^{26}\) Lots of local governments heavily depend on the charges from road transport to keep the balance of revenue. Therefore, regardless of the potential benefits which fuel taxes will have on increased fuel-efficiency and reduced vehicle emissions, the short-term interests decide the local governments negative attitude towards fuel taxes. Moreover, the fuel taxes are designed only as national taxation, which increases the resistance at local levels.

The progress of fuel taxes is comparatively rough. The Ministry of Finance decided to choose the management of toll levies and other charges on vehicles as the area in which to make a breakthrough in 1990s, because the problem of rampant levies is very serious in this area and the reform of this sector is regarded as being relatively easy. Nevertheless, it has not been approved until in October 1999, the Standing Committee of the National People's Congress passed amendments to the country's Highway Law, paving the way for the institution of the fuel tax. The tax rates of petrol and diesel are initially suggested to be 1.15 RMB/liter and 0.96 RMB/liter. Nevertheless, the institution of the fuel tax has been repeatedly delayed from then on. Earlier in 2001, the State Administration of Taxation said that the country would institute the fuel tax at an appropriate time this year. However, the continued collection of road maintenance fees in the mid of 2001 implies that the scheme will continue to be prolonged.

In the following section, policies initiated and implemented at local level are to be introduced.

\(^{26}\) The exchange rate for RMB to USD on Nov 1, 2001: 1 RMB = 0.121 USD
4. Road Emissions Control at Local Level: A Case Study in Shanghai

Three factors determine the significant role for local governments to play in controlling road emissions. First of all, effective enforcements of environmental protection laws, regulations, and standards, which are in the charge of local governments, are crucial to achieve the initial targets or goals. While central government has the monitoring rights, it is local government who concretely carry out central decisions. Experiences from other parts of the world suggest that strategies such as I/M program and alternative fuels are well suited to a local focus. Secondary, the geographical and social-economic diversity in China is significant, which makes it impossible to create a universal package of road emissions control policies. Looking at Beijing and Guangzhou as examples, as illustrated in Figure 5, the types of vehicles can differ substantially between cities. Almost two out of every five vehicles in Beijing is a light truck or utility vehicles; in contrast, almost two of thirds of the motor vehicles in Guangzhou are motorcycles. The formation of such situations is historically due to different transport development strategies. Therefore, policies specific to certain cities will be more cost effective. Finally, considering the vast social-economic costs to implement regulation reform nationwide, tentative innovations in local level are to be conducted to accumulate experiences and lessons. For instance, although the institution of fuel taxes is repeatedly prolonged in national level, it has been implemented in Hainan Island, the second largest island of China since 1999.

![Figure 5. 1992 Vehicle Population Structure in Beijing and Guangzhou](source)


In this section, policies in Shanghai dealing with road emissions will be analyzed as a case study in the local level.

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27 Walsh, M., Motor Vehicle Pollution Control in China: An Urban Challenge, 1995
4.1 Factors about Shanghai

Shanghai, the largest city in China, is located halfway down China's mainland coastline, where the Yangtze River empties into the sea. Based on the fifth national census on Nov 2000, the population of Shanghai, including the residents and floating population, has reached 16.74 million. The total administration area of Shanghai Municipality is 6,200 km² and the urban area is 3248.7 km². In 2000, Shanghai's GDP was 455.1 billion RMB and the GDP per capita had climbed to 34,600 RMB (equal to 4,180 USD).²⁸

The urban transport system has been developed rapidly during the past decade. Until the rear of 1998, the length of the roads in Shanghai added up to 4712 km. The amount of road area accounted for 72.8 km² and road area per capita reached 7.5 m². Shanghai has built a 70-kilometre long multi-tier elevated roads system that comprises of Elevated Inner-ring Road, North-South Elevated Road and Elevated Yan'an Road. Two routes of metro are in used in the city at present, whose lengths are 21 km 19 km respectively. Also, a 20-kilometre elevated light train route has been completed in 2000 and a 30-km magnetic levitation train route from Lujiazui to Pudong International Airport is to be built before 2003. 16,928 buses were in operation in 1999 and had carried 2.42 billion passengers that rear. There were 42,056 trodes running in Shanghai’s streets in 1999. The total mileage reached 4 billion km and the taxies took 0.3 billion passengers that year.²⁹

![Figure 6. Growth of Motor Vehicles Fleet and GDP per capita in Shanghai](image)


Since 1990, the average annual growth of motor vehicle fleet is 14 per cent. The correlation between GDP per capita and motor vehicle fleet has been illustrated in Figure 6. If current trend goes on, it is forecasted that the fleet of motor vehicles in Shanghai will climb to 1 million in 2005 and 1.5 million in 2010. The two dominant types of motor

²⁸ Shanghai Municipality, Shanghai's Statistics in 2000, 2001
²⁹ Transport Management Bureau of Shanghai, Shanghai Transportation Statistics, 2001
vehicles are light-duty vehicles and motorcycles, whose proportion were 49 percent and 34 percent respectively. There were other 0.23 million suburban motorcycles and 0.5 million mopeds in 1999 that had not been included in the motor vehicle fleet, which contribute enormous air pollutants as well.\(^3\)

With more stringent policies subject to industrial emissions, traffic generated emissions are expected to be the main contributor to the air pollutants in Shanghai. Effective policies are urged to halt and convert current trend. In the municipality level, the government takes two-pronged responsibilities: to implement central government policies; and to initiate and carry out local policies.

### 4.2 Enforcement of Central Government Policies

As a local government, Shanghai Municipality is supposed to be the instrument conducting unified supervision and management of the prevention and control road emissions based on national law and standards.

#### 4.2.1 Implementation of Air Quality Standards

Most areas of Shanghai are required to meet air quality standard II, with the exception of some heavy industrial districts. In order to reach the target, a daily air quality report and forecast system has been developed and in operation. Currently, air pollution index (API) is applied as the indicator to determine the status of air quality. The value of API is assigned by the calculation as follows:

\[
API = \frac{C_i}{C_o} \times 100,
\]

- \(C_i\): daily average concentration of pollutant \(i\),
- \(C_o\): national standard of daily average concentration of pollutant \(i\).

At present, the data of \(\text{SO}_2\), \(\text{NO}_x\) and \(\text{PM}_{10}\) daily concentration are collected and transferred into API in Shanghai. For instance, the daily concentrations of \(\text{SO}_2\), \(\text{NO}_x\) and \(\text{PM}_{10}\) on Nov 5 2001 are respectively 0.0675, 0.044, and 0.078 mg/m\(^3\). Correspondingly, the values of API are 45, 37, and 52. The highest value of final three API, which is 52 in this case, will be chosen as the API of Shanghai that day.

<table>
<thead>
<tr>
<th>API</th>
<th>Air Quality Standards</th>
<th>Description of Air Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ~ 50</td>
<td>I</td>
<td>Good</td>
</tr>
<tr>
<td>51 ~ 100</td>
<td>II</td>
<td>Moderate</td>
</tr>
<tr>
<td>101 ~ 200</td>
<td>III</td>
<td>Light Polluted</td>
</tr>
<tr>
<td>200 ~ 300</td>
<td>IV</td>
<td>Medium Polluted</td>
</tr>
<tr>
<td>(\geq) 300</td>
<td>V</td>
<td>Heavy Polluted</td>
</tr>
</tbody>
</table>


The different range of API value is classified into five standards as being “good,
Driving towards a Cleaner Future - A Study of Transport Policies of Road Emissions Control in China

Moderate, light polluted, medium polluted, heavy polluted”, as reflected in Table 2. Therefore, the air quality of Shanghai on Nov 5 of 2001 was moderate and met Standard II.

The function of API report and forecast system is not only to monitor the air pollution situation, but to increase the residents’ awareness of their atmospheric environment as well.

4.2.2 Fuel Policy
In respect of fuel policy, Shanghai was always going beyond the national requirements. Shanghai was one of eight cities in China that firstly banned leaded gasoline before 1998 and it was also one of three cities that adopted new stringent fuel standards since 2000. The standards for substituted fuels, such as Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) have also been established.

4.2.3 Newly Produced Motor Vehicle Policy
Shanghai is one of three largest automotive industrial bases of China. The automotive industry contributed 19.9% in the total industry product value and 30% in the industry revenue in 1997. Shanghai Automotive Industry Corporation (SAIC), which is the major auto enterprise in charge of two joint ventures with Volkswagen and GM, produced and sold 251,548 sedans in 2000, which shared about 50% of total sedans in China. The production ability of sedans is to increase to 400,000 annually. Hence, to implement national standards for new car emissions in Shanghai is quite crucial. Shanghai has adopted the new emission standards since 1999, which means the newly produced sedans will be equipped with electronic controls of air-fuel, spark management systems and three-way catalytic converters. Based on the Shanghai Municipality’s regulation, it is prohibited to produce, sell, register and use the motor vehicles exceeding national vehicle emission standards in Shanghai.

4.2.4 I/M and Scrappage Programs
I/M programs are the main method of controlling in-use motor vehicles in Shanghai. At present, two types of I/M programs concerning emission monitoring are conducted. Firstly, a periodic inspection is required once per year for every category of vehicles by 48 inspection stations in the charge of Public Security Bureau of Shanghai. Random roadside inspections will also been made by the Environmental Protection Bureau of Shanghai. On the other hand, 20 inspection stations are responsible for test the emission factors after the serving and maintenance of motor vehicles.

Although the annual inspection program has been put into practice since 1986, the effectiveness proved poor. In a random inspection conducted in June 2001, while 1294 inspected motor vehicles were tested, there were as many as 448, or 35.4 %, vehicles that failed to meet the emission standards. In regard to annual inspection program, the main

31 Shanghai Automotive Industry Corporation (SAIC), http://www.china-saic.com
32 Wu, Y., Over 30% of Motor Vehicles Exceeding Emission Standards, 2001
inspected options are emphasizing security issues rather than emission factors. Only simple idling emissions tests for gasoline-fueled vehicles and free-acceleration smoke tests for diesel-fueled vehicles are applied so far, which facilitate cheating. With the implementation of new emission standards, newly produced cars are required to equip with electronically controlled ignition system and three-way catalytic converters. Present measure methods are not able to fulfill the testing requirements any more.

In Shanghai, either the old vehicle used more than 8–10 years, or the vehicle with the mileage of above 400–500 thousand kilometers is regulated to retire and scrap. However, measures and incentives are still lacking to make vehicle renewal attractive. It is planned that more stringent emission standards will put into operation in order to accelerate phase-out of old motor vehicles.

4.3 Emission Control Policies in Local Level

Compared with policies made by the central government, local policies appear more flexible and more various. Shanghai is absolutely in the case. Realizing the existing road emissions problem and its likely worse future, Municipality of Shanghai has conducted a set of endeavors to promote environmental protection performances.

4.3.1 Public Transport Priorities

Assigning priority to public transport in Shanghai would not only improve the attractiveness of buses and metro compared with private cars, but it would also reduce the direct exhaust emissions from highly polluting buses.

![Figure 7. Bus Population, Bus Passengers and Metro Passengers in Shanghai](source: Shanghai Transport-Planning Institution (SCCTPI), 2001)

Looking at Figure 7, while the bus population has doubled from 7,000 in 1994 to 14,000 in 1997, the annual bus passenger, however, has dropped from 5.7 billion in 1990 to 2.5 billion in 1998. Correspondingly, the proportion of bus in the total passenger transport

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modes has decreased from 24% in 1986 to 16% at present. In the urban passenger transport, the proportion of bus passenger volume is 65%, which is 16% lower than that of Tokyo and Hong Kong. Shanghai residents naturally relate bus to the impression of low speed, crowded and dirty surroundings, black smokes from exhausted pipes, and high failure rates.

In order to promote bus attractiveness, the government focuses both on increasing bus speed and improving bus conditions. Several bus priority lanes have been built in the main roads of Shanghai and it is planned to establish a traffic system of bus priority lanes, in which the average bus speed is supposed to increase from currently 12 km/h to 20 km/h. Traffic lights system will correspondingly be changed to assure the bus priority. Bus routes to suburb areas will be improved as well. Aiming at provide passenger better conditions, 5,000 buses will be renewed in the following 5 years. The proportion of buses with air condition will increase from currently 15% to 50% in 2005.

As mentioned before, there have been two metro routes and one elevated light train route put into operation so far. However, the low operation efficiency has hinder their transfer ability. While the total transfer volume of these three tracks is designed for 2.5 million per day, the current daily passenger volume is only 0.7 million, which only accounts for 2.6% of total passenger transport in urban area. A better management, i.e. increase frequency in peak time and shorten waiting time, is pursued to expand the transfer ability to 2.8 million passengers per day in 2005. Metro and elevated light train are planned to be the main traffic modes in the inner city in the future. The total track length will be extended to 200 km in 2005 and 500 km in 2020.

### Table 3. Pollutant Emissions Contribution Rate from Buses in 1999 in Shanghai

<table>
<thead>
<tr>
<th>Area</th>
<th>CO</th>
<th>HC</th>
<th>NOx</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions contribution rate (%)</td>
<td>Municipality</td>
<td>22.4</td>
<td>27.1</td>
<td>35.1</td>
</tr>
<tr>
<td></td>
<td>Inner City</td>
<td>26.9</td>
<td>32.9</td>
<td>45.3</td>
</tr>
</tbody>
</table>


Another benefit of public transport priority lies in reducing pollutant emission from buses. As shown in Table 4, although the number of buses in Shanghai is only 2.4% of total motor vehicle fleet, the pollution contribution is extremely high. It appears urgent to control the bus emissions in order to improve general air pollution. Besides the strategy of 5,000 buses renewal in the following 5 years, buses using cleaner fuels are also planned to operation. In order to cooperate with APEC 2001 in Shanghai, 35 CNG buses

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34 A significant decrease of bus passenger occurred in 1996, when bus ticket price was increased from 0.1-0.2 RMB to 0.5 RMB in order to halt and reverse the enormous fiscal deficit of bus system that was 0.8 billion RMB in 1995. However, it resulted in that lots of people changed their trip modes to pedestrian, bicycle, moped, and taxi. The bicycle population increased from 4.8 million in 1994 to 6 million in 1996, whilst the moped population in 1996 was 0.5 million, 10 times more than that of 1992.

35 SAES, *Environmental Impact Analysis of CNG Bus, 2000*
produced by joint venture with Volvo have been put into operation. Detailed analysis will
be presented in Section 5.3.3.

4.3.2 Alternative Fuels
When the conventional vehicle fuels have undergone substantial modification in China, in parallel, alternative fuels such as CNG and LPG continue to receive attention in local level. Most often, these fuels are used with special groups of vehicles that can have a large impact on the environment, e.g. buses and taxies, and can be fueled at central location, thus minimizing the need for a widespread fueling infrastructure.36

In Shanghai, besides CNG buses, a tentative attempt has been made to introduce LPG to charge with taxies. In 1999, 42,056 taxies, which covered 4 billion km mileage and carried 0.3 billion passengers, were in operation. Economic leverage takes effect in the fuel substitution. In 2000, continuing hikes of gasoline prices caused more and more taxi drivers to turn to filling their sedans with LPG. The number of taxis charged with LPG increased by 40 every day in Shanghai in that summer, and there are 25,000 LPG-powered taxis in 2000. The incentive lies in the economical benefits. The taxi driver using LPG can save 30 RMB per day, compared with those driving gasoline-charged taxies. 80 gas stations have been changed in the expense of government to be able to supply LPG fuel. LPG is also regarded as a cleaner fuel with lower emissions and smokes. It is projected all the taxies will be charged with LPG in 2002. All the new taxies are required to be LPG-driven cars.

4.3.3 Phase out Moped
0.5 million petrol-driven mopeds in 1999 in Shanghai are not only the significant contributor for air pollution, but also are the main factor that increases traffic accidents and congestions. Moreover, since the moped is only allowed to run in the non-motor lanes, streams of blackness erupt from the exhaust pipes of those engines make bicyclists and pedestrians coughing and belching all the way.

In 1997, a ban on marketing and licensing petrol-driven mopeds was announced with the intention of reducing their number from 470,000 to 100,000 by the year 2000. The new regulation suggests that mopeds will be banned inside the Inner Ring Road in 2002 and a thorough ban on using will be conducted in 2005. The speed of phasing out mopeds is intended to hasten by the adoption of stringent inspection.

4.3.4 Traffic Restraint
Based on a recent investigation, the number of privately owned cars in Beijing was 8,000 in 1992 and increased to 0.18 million in 1998. On the contrary, there were only 8,700 privately owned cars in Shanghai in 1998. While the economic factors are similar in two cities, the differences of car purchase policies are determinant. Table 4 shows the different fees and charges in two cities during the purchase period. Take a Santana Gsi sedan as example. The open-market value (OMV) of the sedan is assumed 100,000 RMB.

36 Walsh, M., Motor Vehicle Pollution Control in China: An Urban Challenge, 1995
Shown in the table, to buy the same sedan in Shanghai will cost 20,451 RMB, or 20.5% more of the OMV than that of Beijing. The most significant difference lies in the license plate fee. Taking the experience of Singapore, Shanghai Municipality has adopted the auctioning of a controlled stock of certificates to purchase privately owned cars since a decade before. While it works very well in term of controlling the number private cars, this policy is increasingly criticized from the market-economic point of view. It mainly focuses on a discriminating option within the policy: for those who want to buy sedans not produced in Shanghai, the base price of license plate will be 80,000 to 100,000 RMB. Currently, the policy of private car has been changed with the intention to encourage car consumption and Shanghai Municipality has decided to cancel the base price of license plate auction since 2001. Even in the in-use phase, Shanghai’s user undertakes heavier economic burden than that of Beijing. Annual average fees in Shanghai are 16,768 RMB, 4,000 RMB more than that in Beijing.

<table>
<thead>
<tr>
<th>Options of fees</th>
<th>Beijing (RMB)</th>
<th>Shanghai (RMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open market value</td>
<td>100,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Value-added tax</td>
<td>17,000</td>
<td>17,000</td>
</tr>
<tr>
<td>Consumption tax</td>
<td>5,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Purchase Tax</td>
<td>12,200</td>
<td>12,200</td>
</tr>
<tr>
<td>Road maintenance fee</td>
<td>220/month</td>
<td>140/month</td>
</tr>
<tr>
<td>License plate fee</td>
<td>/</td>
<td>20,000</td>
</tr>
<tr>
<td>Insurance fee</td>
<td>3,000</td>
<td>3,000</td>
</tr>
<tr>
<td>Pollution fee</td>
<td>/</td>
<td>100/year</td>
</tr>
<tr>
<td>Intersection monitoring fee</td>
<td>/</td>
<td>12/year</td>
</tr>
<tr>
<td>Driving license fee</td>
<td>154</td>
<td>194</td>
</tr>
<tr>
<td>Traffic information fee</td>
<td>/</td>
<td>40/year</td>
</tr>
<tr>
<td>Vehicle usage tax</td>
<td>360/year</td>
<td>320/year</td>
</tr>
<tr>
<td>Screw fee</td>
<td>/</td>
<td>10</td>
</tr>
<tr>
<td>Picture fee</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>License plate installation fee</td>
<td>/</td>
<td>600</td>
</tr>
<tr>
<td>Storage fee</td>
<td>440</td>
<td>440</td>
</tr>
<tr>
<td>Number fee</td>
<td>20</td>
<td>/</td>
</tr>
<tr>
<td>Transfer fee</td>
<td>50</td>
<td>/</td>
</tr>
<tr>
<td>Test fee</td>
<td>11</td>
<td>/</td>
</tr>
<tr>
<td>Total</td>
<td>138,495</td>
<td>158,946</td>
</tr>
</tbody>
</table>

Source: Own Calculation based on Rao, D., 1999

Parking fee is the other economic instrument applied to cope with the traffic volume. All the parking places are classified based on its location and service condition. The highest parking fee in Shanghai, excluding those in the hotels, is 11 RMB per hour, while parking beside the road in Beijing costs 1 RMB per night. The annual average parking fee in Shanghai reaches 2894 RMB, which is double of that of Beijing.
Some command and control measures are also subject to particularly sensitive areas. East Nanjing Road, which is famous as “No. 1 Street in China”, has been built as pedestrian-only street. In respect of Huaihai Road, another crowded Business Street, a discussion of whether to apply non-stop in the street is still on the way. The scheme of exclusion of some vehicles selected by last number of license plate from CBD on particular days used to be imposed, however, it has been cancelled due to the development of road infrastructures. The heavy-duty trucks are also been forbidden to enter the urban area during the daytime.

4.4 Plan and Targets of Road Emissions in Shanghai

Through the integrated policies and strategies listed above, Shanghai Municipality intends to halt and convert the current trend of road emission in the near future. Three time scales have been identified to fulfill the task. The predictions of road emissions with and without control are shown as Appendix 3. Referring to Swedish assessments, the weight translation factors of CO and HC to NOX in terms of weight are respectively 0.01 and 0.3-1 in urban areas, i.e. 100-gram CO is equivalent to 1-gram NOX. Considering the significance of high HC density, its translation factor to NOX is assumed as 1 in Shanghai. Therefore, the data in Appendix 3 were translated in the form of NOX and the cumulative emissions, which are the consequences with control and without control, are illustrated in Figure 8. The huge gaps between these two curves on the one hand reflect the substantial environmental benefits to carry out those policies, on the other hand, imply the difficulties of implementation.

![Figure 8. Cumulative Emissions in the Term of NOX in the Future, Shanghai](source)

Source: Own Calculation Based on Appendix 3

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Of course the weight factors could be different for China, but as no such data are available the Swedish figures are used to exemplify the principle analysis.
4.5 Concluding Remarks

In Section 3 and 4, existing policies to mitigate road traffic generated emissions in China have been reviewed. While the central governments put more attention on the general legislation framework and overall emission targets, local governments, as shown in the case of Shanghai, have launched a set of policies tailored to local circumstances. However, the real effectiveness of those policies still need examination, which is to be presented in the following section.
5. Analysis of Transport Policy Measures

As the world’s largest developing country, China is still putting most attention on economic development, i.e. growth in GNP, which leads to overlooking environmental issues. There are limited political and economic resources can be devoted into control of motor vehicle induced emissions. Hence, designing an appropriate strategy to address road emissions requires careful identification of priorities. In this section, the policies adopted both in national level and local level will be analyzed from efficiency and feasibility perspectives. The analysis is also combined with international experiences and lessons.

5.1 Summary of Existing Policy

Total traffic induced emissions can be decomposed into the following factors: 1) emissions per unit of fuel; 2) units of fuel per passenger/good kilometer; and 3) passenger/good kilometers traveled. The relationship between them can be summarized in simplified form as:

\[
\text{Total emissions} = 1) \text{ emissions per liter} \times 2) \text{ liters per passenger kilometers (tonne kilometers for freight)} \times 3) \text{ passenger kilometers (tonne kilometers) traveled}
\]

Each factor is influenced by a set of determinants. The determinants of emissions per unit of fuel include fuel types, fuel quality, engine type, engine condition, temperature, and attitude, etc. As regard to liters per passenger/good km, the determinants are engine type, transport mode, fuel efficiency, vehicle load, passenger capacity, road condition, congestion, and so on. Urban structure or pattern of urbanization plays a critical role in determining the traffic volume or passenger kilometers traveled. Some determinants are related to one another.

In China’s case, with the rapid economic growth and process of urbanization, it appears inevitable that the factor of passenger/good kms traveled will increase significantly in the near future. Hence, the chance to control road traffic generated emissions mainly lies in the reduction of emissions per unit of fuel and fuel consumption per passenger/good km.

Table 5 present an array of policies adopted already in China to mitigate road emissions in the context of the framework discussed before. All the policies presented in Section 3 and 4 will be summarized and categorized into different groups based on particular policy targets. All the policies intended to control road emissions must be focused on several determinants and thus the factors. The functional mechanisms include command and control as well as economic instruments. As shown in this table, policy will take effect by modifying the behaviors of target group, which are, in this case, supplier (manufacturer) and consumer (motorist).

39 A good summary of this framework approach can be found in Heil, M. and Pargal, S., Reducing Air Pollution from Urban Passenger Transport, A Framework for Policy Analysis, 1998
### 5.2 Analysis of National Policy

With the amendment of *Law of People's Republic of China on the Prevention and Control of Atmosphere Pollution*, rights and responsibilities of national government have been defined in terms of legislation. In order to reduce road traffic generated emissions,
the measures adopted at national level mainly include: setting emission standards and fuel standards, making regulations and recommendations, monitoring policy implementation at local levels, etc. The coming fuel taxes will probably provide a powerful instrument if adopted in an efficient way.

5.2.1 Fuel Standards
In China, fuel quality control is equally important as vehicle emissions control. Not only generating large scale of emission problems, low quality fuels will significantly offset the effectiveness of engine improvement. As an extreme example, a certain model of imported sedan, which has been certified to fulfill the emission standards during a 160,000 km endurance test in the original produced country, will probably exceed emission standard only with the mileage of 80,000 km in China. Current fuel quality can only fulfill the requirements of Euro I standard. In other words, even though the newly produced cars are designed to fulfill Euro II standard, they will still exceed the standards in reality by using the present fuels. The importance of fuel quality relating to pollutant emissions can be seen in Table 6.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>CO (g/km)</th>
<th>HC (g/km)</th>
<th>NOx (g/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Santana Gsi</td>
<td>27.4</td>
<td>2.66</td>
<td>0.71</td>
</tr>
<tr>
<td>Euro I standard</td>
<td>2.72</td>
<td>0.97 (HC + NOx)</td>
<td></td>
</tr>
<tr>
<td>Santana Gsi 2000</td>
<td>7.4</td>
<td>1.01</td>
<td>1.73</td>
</tr>
<tr>
<td>Euro II standard</td>
<td>2.2</td>
<td>0.5 (HC + NOx)</td>
<td></td>
</tr>
</tbody>
</table>

Source: SAES, Environmental Impact Analysis of CNG Bus, 2000

Both Santana Gsi and Santana Gsi 2000 are sedan models produced by Shanghai Volkswagen Joint Venture Corp. Santana Gsi is announced to meet Euro I standard, while Santana Gsi 2000 has passed Euro II standard test. However, as shown in Table 6, the actual emission factors are highly above the standards, which is mainly due to the low quality of gasoline used. The test was conducted in 1998, before the new fuel standard adopted in 2000. The fuel used at that time was still leaded gasoline with high sulfur content and olefin content. Considering the critical role of fuel quality, efforts have been made in the new fuel standard.

Based on the international experiences, first priority with regard to fuels should be placed on improving those fuel qualities that are important for good combustion. In the case of gasoline, it implies improvement of Researched Octane Number (RON). China seems to have overcome this requirement with the adoption of new fuel standard. The RON of gasoline in European countries is between 91 and 98, while that of auto gasoline in China is between 90 and 98 after the year of 2000. Elimination of lower RON gasoline leads to better combustion efficiency, which will allow the use of modern engine and reduce fuel consumption substantially.

---

40 SAES, Environmental Impact Analysis of CNG Bus, 2000
The phasing-out of leaded gasoline in China has dual meanings. Firstly, lack of other significant sources of lead, particularly in urban areas, elimination of lead additive in gasoline can significantly reduce ambient lead concentration. As mentioned before, a 1,500-ton reduction of lead discharge is expected in 2000 attributed to complete prohibition of leaded gasoline. Secondary, use of unleaded gasoline is essential for the operation of catalytic converters. The current lead content in China, which is lower than 13 mg/l, will still result in chronic lead poisoning and disabling of catalytic converters. Therefore, average life of catalytic converter is only two years at present. The implementation of new standard in which the lead content is limited lower than 5 mg/l must be urged.

Due to different refining process and technologies in China, the percentages of aromatic and olefin used to raise the gasoline octane number are the opposite of most foreign countries. The actual aromatic content is between 10% and 15%, which is much lower than <45 as European standards. However, on the other hand, the olefin content is considerably high. The specified <35% olefin content is generally out of compliance in much of China, even by 40% and 50%. In the high temperature, olefin will produce carbon deposits attached within the engine, which leads to lower operation efficiency and inadequate combustion. The high content of olefin in gasoline is regarded as the main cause of deterioration of imported vehicles emission performances. While it is not feasible to reduce olefin content immediately, alternative measures are suggested to apply the additive of detergent that can both reduce fuel consumption as well as reduce exhaust emissions.

To lower sulfur content is another crucial task. High content of sulfur will not only generate emissions of SO₂ but also dramatically decrease the effectiveness of the catalyst in catalytic converters. While Euro II standard limits sulfur content less than 0.02 percent, China’s standard only set 0.08 percent as maximum. China’s ’99 survey showed that more than 60% of refineries in China could not manufacture low sulfur content gasoline meeting Euro II standard.41

The situation of diesel is more complicated than petrol. The uses of diesel comprise transport purpose, industrial purpose and household purpose. Without clear distinction of diesels by different use purpose, any changes of diesel quality should consider the likely consequences from all perspectives. Compared with world average, China has higher cetane number in diesel. However, the major problems are still sulfur content and oxidation stability, which can be solved by the deeper raffination of diesel. A research group of Beijing Univ. has made a cost-efficiency analysis of NOₓ emission control measures under different scenarios in city of Guangzhou.42 In regard to fuel quality improvement, they developed three scenarios and made a calculation of reduction potential and the costs as follows (Table 7).

41 Wang, Y., the Current Status of Fuel Quality and Development, 2001
42 Shao, M., Jumping of Vehicle Emission Standards in China and Its Related Factors, 2001
The reduction potential refers to the maximum emission reduction amount in case of certain scenario. Looking at the table, to lower aromatic content in diesel is comparatively dearer measure. Although there is not concrete data on the cost of reducing olefin content in petrol, the costs are believed to be even higher.

5.2.2 Emission Standards

Tightening emissions standards is a common measure used to combat traffic-induced emissions. As described before, current emission standards in China are in accordance with Euro I stage (the requirements of 91/441/EEC and 93/59/EEC). It is also planed to upgrade to Euro II standard (the requirements of 94/12/EC and 96/69/EC) in 2004. In 2010, China’s emission standards are expected to meet international standards at that time.

Taking full advantage of emission standards requires a carefully through-out compliance program. Two issues, manufacturer directed compliance tools and programs for existing cars are crucial with the view of making emission standards effective. In order to control newly produced cars, type approval, quality control, conformity of production, and recall should be included into one program. Economic instruments, such as tax reduction for low pollution cars, should be initiated and introduced to stimulate the incentives for the car manufactures to adopt the best available technologies. With regard to in-use vehicles, an active cooperation with local governments to apply I/M programs is also expected.

M. Walsh and his team have conducted a cost-efficiency research on the different consequences of emission standards.⁴³ Only the reduction of NOₓ has been considered, even though in most cases, substantial CO and HC reduction would also occur. Firstly, they estimated the costs and emission reductions of certain strategy respectively. For instance, in scenario that a light-duty gasoline vehicle adopts 91/441/EC standard, the amount of NOₓ emission reduction will be 0.5714 ton and it will cost 394 USD. If a heavy-duty diesel vehicle is retrofitted to meet Euro II standard, there will be a 2.2487-ton NOₓ reduction and it costs 946 USD. Then they cumulated all the factors based on two scenarios as summarized below.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Reduction potential (tons)</th>
<th>Cost-efficiency (RMB/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reducing sulfur content in petrol from 0.04% to 0.020%</td>
<td>22,000</td>
<td>7,500</td>
</tr>
<tr>
<td>Reducing sulfur content in petrol from 0.04% to 0.003%</td>
<td>34,500</td>
<td>8,000</td>
</tr>
<tr>
<td>Reducing aromatic content in diesel from 30% to 10%</td>
<td>23,000</td>
<td>31,000</td>
</tr>
</tbody>
</table>

Source: Shao, M., Jumping of Vehicle Emission Standards in China and Its Related Factors, 2001

⁴³ Walsh M., Motor Vehicle Pollution Control in China. 1998
Driving towards a Cleaner Future - A Study of Transport Policies of Road Emissions Control in China
Ming Ji
M.Sc. Thesis, LUMES

Table 8. Two Scenarios of Emission Standards and the Cost-efficiency

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Vehicle type</th>
<th>2000</th>
<th>2002</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Passenger cars</td>
<td>91/441/EEC</td>
<td>94/12/EC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Light duty vehicles</td>
<td>93/59/EEC</td>
<td>96/69/EC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy duty vehicles</td>
<td>Euro I</td>
<td>Euro II</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Motorcycles</td>
<td>ECE 40.01</td>
<td>Japan</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Passenger cars</td>
<td>94/12/EC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Light duty vehicles</td>
<td>96/69/EC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heavy duty vehicles</td>
<td>Euro II</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Motorcycles</td>
<td>Japan</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cumulative NOx reduction (10^3 tons)</th>
<th>Cumulative costs (10^6 USD)</th>
<th>Cost-efficiency (USD/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>970</td>
<td>441</td>
<td>450 (≈ 3721 RMB)</td>
</tr>
<tr>
<td>2</td>
<td>1200</td>
<td>389</td>
<td>320 (≈ 2646 RMB)</td>
</tr>
</tbody>
</table>

Source: Walsh, M. Motor Vehicle Pollution Control in China, 1998

They therefore concluded that, based on international experience, both of scenarios were very effective. Considering all the factors as well as technological capability of the domestic vehicle industry it was to recommend Scenario 1 as the minimum requirement but to allow option 2 as an alternative and to provide fiscal incentives to encourage Scenario 2 vehicles and engines. The similar results have been proved combining with local study.44

5.2.3 Fuel Taxation

Considering the factor that fuel is the largest and most visible motor vehicle operation expense, fuel price elasticity has been applied as a Transport Demand Management (TDM) strategy. In fact, fuel tax is one of few policies that can directly influence all three factors relating to total emissions as introduced in Section 5.1. Based on the past experience, increasing fuel tax is an effective energy conservation and emission reduction strategy.45

In China, replacing monthly road maintenance fee by fuel tax is the first step towards right direction. Although in the beginning stage the fuel tax is only collected as a road user fee intended to fund road construction and maintenance, consequent environment performances are also expected. Looking at Shanghai as example, current monthly road maintenance fee is 140 RMB per 10 seats for passenger cars, and 140 RMB every ton of the loaded weight for freight vehicles. On the other hand, fuel taxes are suggested to start from 1.15 RMB for gasoline and 0.96 RMB for diesel, which are respectively 37 percent of petrol price and 40 percent of diesel price. Thus, comparison of expenses can be conducted under different scenarios. (Table 10)

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44 The research group of Beijing Univ. developed two scenarios of emission standards for Guangzhou. Scenario 1 requires Euro I in 2000 and Euro II in 2004, whilst Scenario 2 requires Euro I in 2000 and Euro III in 2004. The reduction of NOx in two scenarios are respectively 21, 000 ton and 32, 000 ton. Referring to Shao M., Jumping of Vehicle Emission Standards in China and Its Related Factors, 2001
45 Victory Transport Policy Institute, Fuel Tax Increases, 2001
Driving towards a Cleaner Future - A Study of Transport Policies of Road Emissions Control in China
Ming Ji
M.Sc. Thesis, LUMES

Table 9. Comparison of Expenses between Road Maintenance Fee and Fuel Tax

<table>
<thead>
<tr>
<th>Vehicle type</th>
<th>Seats/loaded weight</th>
<th>Annual road maintenance fee (RMB)</th>
<th>L/100km</th>
<th>Mileage (km)</th>
<th>Annual fuel tax (RMB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedan (Santana Gsi)</td>
<td>5</td>
<td>1680</td>
<td>9.4</td>
<td>10,000</td>
<td>1081</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15,000</td>
<td>1622</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20,000</td>
<td>2162</td>
</tr>
<tr>
<td>Mini cars (GM Sail)</td>
<td>5</td>
<td>1680</td>
<td>6</td>
<td>10,000</td>
<td>690</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20,000</td>
<td>1380</td>
</tr>
<tr>
<td>Mini petrol bus (DHZ6330)</td>
<td>19</td>
<td>3360</td>
<td>13</td>
<td>30,000</td>
<td>4485</td>
</tr>
<tr>
<td>Light-duty petrol vehicle (EQ1030T)</td>
<td>1.5 Ton</td>
<td>2520</td>
<td>12</td>
<td>20,000</td>
<td>2760</td>
</tr>
<tr>
<td>Light-duty diesel vehicle (CA1060)</td>
<td>2 Ton</td>
<td>3360</td>
<td>18</td>
<td>20,000</td>
<td>3456</td>
</tr>
<tr>
<td>Heavy-duty petrol truck (CA3102-5)</td>
<td>5 Ton</td>
<td>8400</td>
<td>20</td>
<td>40,000</td>
<td>9200</td>
</tr>
<tr>
<td>Heavy-duty diesel truck (CA3170)</td>
<td>8 Ton</td>
<td>13440</td>
<td>22.5</td>
<td>40,000</td>
<td>8640</td>
</tr>
</tbody>
</table>

Source: Own Calculation Based on Literature Reviewing

Based on Table 9, some important trends in transport sector concerning with pollution emissions can be predicted. Firstly, the purchase of privately owned cars is expected to increase. The experience of western countries shows that the annual mileage of private cars for households is between 10,000 and 20,000 km, which allows total fuel taxes less than current road maintenance fees. Mini cars that have comparatively lower emission factors are currently charged in the same level as common sedans in terms of road maintenance fees. Considering the expense saving, it will be more attractive after adopting fuel taxes. As shown in the table, the fuel taxes of a 15,000-km mileage sedan can afford a small car to run over 20,000 km. On the other hand, however, taxi and other vehicles specific to passenger transport are confronting the significant expansion of operation costs. Looking at a taxi of Santana Gsi 2000 as example, it used to be charged 4,800 RMB per year. Only running in urban area increases petrol consumption per km of taxi to 12 L/km, 60% higher than the average. Moreover, the annual mileage of taxi in Shanghai was 95,000 km, several times than that of private car. Consequently, the total fuel taxes of a taxi will be 13,110 RMB, 2.73 times more than the road maintenance fees.

To cope with cost growth, the price of taxi has to rise. As results, the personal preference of transport mode will be changed and a number of people will likely take public transport instead, which is in favor of road emission reduction. Heavy-duty vehicles are expected to be the dominant traffic mode in long-distance freight transport due to the comparative price advantage. As shown in Table 9, a 5-ton petrol truck has to pay even more fuel taxes than an 8-ton diesel truck. The economic incentive of halting the use of
heavy petrol trucks, which is probably the most polluting vehicles, (based on Table 2) thus can be stimulated.

Based on the international experience, higher fuel prices cause a combination of reduced driving and increased fuel efficiency.\textsuperscript{46} Short-term fuel savings consist of reduced driving and a shift toward more fuel-efficient vehicles owned in multi-vehicle households. Over the long-term, higher fuel prices encourage consumers to purchase more fuel-efficient vehicles. Goodwin estimates the price elasticity of gasoline at \(-0.27\) in the short run and \(-0.7\) in the long run, meaning that a 10% price rise reduces fuel consumption by 2.7% in two or three years, and 7% over a five to ten year period.\textsuperscript{47} However, because the fuel tax is replacing the road maintenance fee in the beginning, the actual change of costs for driving are different from every transport mode. For instance, the real annual driving cost for privately owned car is decreasing, while the real fuel price for taxi has increased. Thus, the probable vehicle travel impact of introducing fuel tax in China is still open to be discussed.

In short, the positive environmental impacts of introducing fuel tax in China firstly exist in encouraging innovation and use of energy efficient technologies and vehicles. Although the change of total vehicle mileages are bit complicated, the confirmation of “Pay by Usage” Principle has set the right signal. It is estimated that the annual fuel tax would be 50 billion RMB based on 1999’ transport situation, which was 20 billion more than total road maintenance fees.\textsuperscript{48} The surplus part can be invested for better road projects and services. Besides, fuel tax implies the potential to internalize the external costs of fuel production and consumption. Further research should be followed on the social-economic costs of transport in terms of cost per unit of fuel.

## 5.3 Analysis of Local Policy

Compared with national policy, local policies aiming at traffic-generated emissions control are more specific and flexible, as reflected in the case study of Shanghai. Two major responsibilities facing local authorities are to implement national measures and to create specific policies overcoming particular local problems.

### 5.3.1 Cost-efficiency Analysis of LPG Taxi

*Liquefied petroleum gas (LPG)* is a mixture of light hydrocarbons and its main comparative advantage lies in the low sulfur content in comparison with gasoline or diesel. As described before, more than half of present taxies have been converted to run in LPG and the proportion is projected to be 100% in 2002. Although it has become a common sense in Shanghai dwellers that LPG is a cleaner fuel than gasoline or diesel, the actual environmental impacts are still requiring estimation. In order to develop a cost-efficiency analysis on LPG taxi, the calculations have been conducted as follows:

\textsuperscript{46} Victory Transport Policy Institute, *Fuel Tax Increases*, 2001

\textsuperscript{47} P. Goodwin, *Review of New Demand Elasticities*, 1992

\textsuperscript{48} Rao, D., *Impacts of Fuel Tax to China’s Society*, 1999
Santana Gsi, the dominant model of taxies in Shanghai, is chosen as the example. The emission factors of gasoline-driving sedan and LPG-driving sedan are referred to Yang, X. Other data listed in Table 10 come from relevant literature review. Referring to the same weight translation factors introduced in Section 4.4, those of CO and HC to NOx in terms of weight are respectively 0.01 and 1 in urban areas of Shanghai. Therefore, the final results are represented in the form of NOx reduction. Considering that there are two major types of LPG equipments available in the market, two corresponding scenarios are developed. (Table 11)

Table 10. Factors and Related Dominants of LPG Taxi in Shanghai

<table>
<thead>
<tr>
<th>Factors</th>
<th>Related Dominants</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_e$</td>
<td>Domestic equipment (RMB/set)</td>
</tr>
<tr>
<td></td>
<td>Korean equipment (RMB/set)</td>
</tr>
<tr>
<td></td>
<td>Depreciation of equipment (year)</td>
</tr>
<tr>
<td>$C_f$</td>
<td>Gasoline (RON 90) price (RMB/L)</td>
</tr>
<tr>
<td></td>
<td>Gasoline consumption (L/100km)</td>
</tr>
<tr>
<td></td>
<td>LPG price (RMB/L)</td>
</tr>
<tr>
<td></td>
<td>LPG consumption (L/100km)</td>
</tr>
<tr>
<td></td>
<td>Annual average mileage of taxi (km)</td>
</tr>
<tr>
<td>$N_t$</td>
<td>Number of LPG-charged taxies</td>
</tr>
<tr>
<td>$C_i$</td>
<td>Fixed assets per LPG station (RMB)</td>
</tr>
<tr>
<td></td>
<td>Current assets per LPG station (RMB)</td>
</tr>
<tr>
<td></td>
<td>Number of gas stations</td>
</tr>
<tr>
<td></td>
<td>Depreciation of fixed assets (year)</td>
</tr>
<tr>
<td>$\Delta NO_x$</td>
<td>With domestic equipment (g/km)</td>
</tr>
<tr>
<td></td>
<td>With Korean equipment (g/km)</td>
</tr>
<tr>
<td>$\Delta CO$</td>
<td>With domestic equipment (g/km)</td>
</tr>
<tr>
<td></td>
<td>With Korean equipment (g/km)</td>
</tr>
<tr>
<td>$\Delta HC$</td>
<td>With domestic equipment (g/km)</td>
</tr>
<tr>
<td></td>
<td>With Korean equipment (g/km)</td>
</tr>
</tbody>
</table>

Source: Yang, X., and Gu, A., Study Progress on Exhaust Gas Emission from Natural Gas Vehicles, 2001

Yang, X. and Gu, A., Study Progress on Exhaust Gas Emission from Natural Gas Vehicles, 2001

Yang, X., and Gu, A., Study Progress on Exhaust Gas Emission from Natural Gas Vehicles, 2001
Table 11. Cost-efficiency of LPG Taxi in terms of NOx Reduction

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Cumulative Reduction (tons)</th>
<th>Cumulative Costs (RMB)</th>
<th>Cost-efficiency (RMB/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic LPG</td>
<td>118.75</td>
<td>30.7 Million</td>
<td>258,526</td>
</tr>
<tr>
<td>Korean LPG</td>
<td>1377.5</td>
<td>49.5 Million</td>
<td>35,935</td>
</tr>
</tbody>
</table>

Source: Own Calculation based on Weight Factors, NOx=1, CO=0.01, HC=1

Based on results listed in Table 11, several important conclusions can be drawn. First of all, present converted LPG vehicles are not clean enough to make the conversion effective. The common technique in Shanghai is to convert a petrol-powered sedan to a dual-fuel vehicle. This simple conversion, especially converted with domestic equipment, has not significantly reduced pollutant emissions. Considering the enormous investments required to build and maintain a gas station which are currently afforded by the national-owned enterprises, the cost-efficiency is comparatively low. Moreover, considering other costs during LPG production, transfer, storage, etc., the real costs should be more than the number presented here. Therefore, better techniques and equipments are required to promote cost-efficiency of LPG vehicles. During the calculation, the value of C_f is always negative, which implies that taxi driver can get economical profits by converting to LPG fuel. The problem is, however, how to stimulate the incentives for them to purchase more expensive but environmental sound LPG equipments. Further research should also be conducted on the cost-efficiency of purely LPG-charged vehicles.

5.3.2 I/M Programs

Experience of European and North American show that vehicle emissions standards and technologies are not effective without proper maintenance. Today’s vehicles are absolutely dependent on properly functioning emission controls to keep pollution levels low. A relatively small number of vehicles with serious malfunctions frequently cause the majority of the vehicle-related pollution problems. Therefore, effective I/M programs are in the need to identify those problem cars and assure them repaired.

However, implementing effective I/M programs has proved difficult. Referring to the World Bank Report, recent experience in Wuhan, a city located in the center of China, showed that in roadside testing 93 percent of vehicles fell short of the standard even though 97 percent of those tested in the same period at the I/M station met it.

In order to strengthen the effectiveness of I/M programs, an I/M Programs Management System is proposed as shown in Figure 9.

The characteristic of this system is the isolation of I/M programs monitoring center, which takes charge of inspection on the separated monitoring stations. Transferring inspection responsibility from local EPA over to the contracted monitoring stations will increase the frequency of inspection and consequently raise the effectiveness of I/M programs. Technology specialization is expected in such monitoring stations and, therefore, the operation costs can be reduced and more advanced measure methods will be feasible from economic perspective.

A related research has also conducted by the same group of Beijing University combing the facts in Guangzhou. Two scenarios are stimulated based on adopting different I/M programs. (Table 12) Still, only NOx reduction has been put into consideration.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>NOx Reduction (tons)</th>
<th>Cost-efficiency (RMB/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IM 240</td>
<td>24,500</td>
<td>30,000</td>
</tr>
<tr>
<td>ASM</td>
<td>36,500</td>
<td>25,000</td>
</tr>
</tbody>
</table>

Source, Shao, M., Jumping of Vehicle Emission Standards in China and Its Related Factors, 2001

5.3.3. Public Transport Policy

Based on past experience, behavioral change in transport mode is very difficult. There is little empirical evidence on consumers switching from an automobile-oriented lifestyle to using public transport in the absence of strong policy intervention. Organization for Economic Co-operation and Development (OECD) and European Conference of Ministers of Transport (ECMT) found that improvements to public transport systems,
while bringing in more passengers, tend to have only a limited effect on the use of private cars, and therefore has little impact on congestion, \( \text{CO}_2 \) and toxic emissions. China is now experiencing a rapid social-economic transition. To attain a viable public transport system it is crucial to adjust the demand of private cars to market-economic cost conditions, before its enormous expansion makes such a policy politically infeasible. In Shanghai, public transport priority has been set as a principle of transport policy. To implement the principle, two aspects, to make public transport cleaner and to make it more efficient, should be both emphasized.

Since heavy-duty vehicles are strictly restrained in most cities of China, highly polluting buses become the significant source of air pollution. Moreover, the driving pattern of bus with frequent stops and starts and idle running of engines results in a small amount of buses being responsible for considerable emissions (Table 3). Therefore, the first step of promoting public transport system should be assigned to replace those high polluting buses. In Beijing, an ambitious project has been initiated to replace all existing buses by CNG buses. It is reported that there are 1,300 CNG buses in operation in 2000 and Beijing is the city owning most CNG buses in the world. However, the high costs of CNG buses, therefore, require a detailed research to see the real effectiveness.

The following analysis, which intends to compare the promoted diesel bus and CNG bus from cost-efficiency perspective, is based on the data of Shanghai in 1999. In respect to the example bus models, the promoted diesel bus adopts D6114 engine that meet Euro I standard, while the CNG bus is equipped with M906LAG engine. The final results are calculated by the factors listed in Table 13.

<table>
<thead>
<tr>
<th>Table 13. Factors Related to D6114 Diesel Bus and M906LAG CNG Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Emission factors</strong></td>
</tr>
<tr>
<td>Petrol bus</td>
</tr>
<tr>
<td>D6114</td>
</tr>
<tr>
<td>M906LAG</td>
</tr>
<tr>
<td><strong>Average annual mileage per bus</strong></td>
</tr>
<tr>
<td><strong>Number of existing buses</strong></td>
</tr>
<tr>
<td><strong>Energy consumption per km (kW-h)</strong></td>
</tr>
<tr>
<td><strong>Cost of new engine</strong></td>
</tr>
<tr>
<td><strong>Annual cost of new engine</strong></td>
</tr>
<tr>
<td><strong>D6114 engine</strong></td>
</tr>
<tr>
<td><strong>M906LAG engine</strong></td>
</tr>
<tr>
<td><strong>3-year depreciation</strong></td>
</tr>
<tr>
<td><strong>5-year depreciation</strong></td>
</tr>
</tbody>
</table>

Source: own calculation and SAES, 2000

---

56 The calculations are based on a discount rate of 5% in real terms, which means an annuity of 0.37 for 3-year depreciation and an annuity of 0.23 for 5-year depreciation
The environmental advantages of CNG buses have been shown in Table 13. Even compared with the "green" diesel bus with D6114 engine, a CNG bus with M906LAG engine has significant lower emission factors. Assuming all the existing buses are replaced by D6114 buses or CNG buses, two scenarios are stimulated in Table 14. Based on the same method adopted in Section 5.3.1, all three values of emissions reductions are translated to NOx as cumulative reduction.

### Table 14. Cost-efficiency Analysis of D6114 Diesel Bus and CNG bus

<table>
<thead>
<tr>
<th>Annual emissions reduction (tons)</th>
<th>Scenario</th>
<th>CO</th>
<th>HC</th>
<th>NOx</th>
<th>Cumulative Reduction (NOx)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Buses in 1999</td>
<td>93,875</td>
<td>16,320</td>
<td>22,785</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>D6114</td>
<td>3,665</td>
<td>2,008</td>
<td>18,649</td>
<td>19350</td>
</tr>
<tr>
<td></td>
<td>M906LAG</td>
<td>209</td>
<td>105</td>
<td>4180</td>
<td>31621</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Annual cumulative costs (RMB)</th>
<th>Scenario</th>
<th>3-year depreciation</th>
<th>5-year depreciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6114 engine</td>
<td>419 Million</td>
<td>226 Million</td>
<td></td>
</tr>
<tr>
<td>M906LAG engine</td>
<td>1474 Million</td>
<td>794 Million</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cost efficiency (RMB/ton of NOx)</th>
<th>Scenario</th>
<th>3-year depreciation</th>
<th>5-year depreciation</th>
</tr>
</thead>
<tbody>
<tr>
<td>D6114 engine</td>
<td>21,665</td>
<td>11,671</td>
<td></td>
</tr>
<tr>
<td>M906LAG engine</td>
<td>46,623</td>
<td>25,115</td>
<td></td>
</tr>
</tbody>
</table>

Source: Own Calculation Based on Table 13

Based on Table 14, one important conclusion can be drawn that, while CNG bus with M906LAG engine can acquire better environmental performance, the cost-effectiveness is comparatively lower than the diesel bus equipped with D6114 engine. Some other factors excluded in the results also need consideration. In regard to diesel bus, it is a significant source of particular matters (PM) emission, which is out of the system above. On the other hand, fuel consumption of the natural gas buses (recalculated to diesel equivalents) is higher than the diesel bus. This is caused by the lower average engine efficiency, by the higher curb weight of the natural gas buses (due to heavy CNG cylinders). Therefore, the average fuel cost of CNG buses is 50% more than that of diesel fuel. Moreover, while only engine price has been calculated here, the price of a new CNG buses is 650,000 RMB at present, double of diesel bus price. Enormous economic resources have to be invested for the construction and maintenance of CNG gas station, which is estimated to cost 15 million RMB per station. Considering the fiscal situation and cost-efficient factors, using clean diesel buses is recommended but CNG bus remains an alternative option.

In the worldwide, the various packages of policy measures to promote public transport attractiveness consist of increased vehicle speed, higher frequencies, improved regularity, rider convenience and comfort, better information, the provision of rapid transit systems...

---

58 PM has significant adverse human health impacts. Relative research can be found at WHO. Based on my own calculation, the annual PM emission in Shanghai will increase 7 tons by applying D6114 engine to all buses, while using M906LAG engine can reach 215-ton emission reduction.
and fare discount. Some of these measures are on the way in China. L. Zeng has conducted a study on the relationship between bus speed and the number of bus passenger trips in Beijing, as indicated in Table 15. He concludes that the higher transit speed can not only enhance the transport capacity with the same amount of buses, but also promote bus attractiveness with the higher reliability. Bus priority lanes and corresponding traffic light systems are the measures available to increase bus speed, which is in practice in Shanghai.

### Table 15. Relationship between Bus Speed and the Number of Passenger Trips

<table>
<thead>
<tr>
<th>Bus speed (km/h)</th>
<th>Headway (waiting time) (min)</th>
<th>Time consumption per bus per trip</th>
<th>Increased transport capacity per bus per day</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>13.2</td>
<td>214</td>
<td>0</td>
</tr>
<tr>
<td>15</td>
<td>8.8</td>
<td>143</td>
<td>802</td>
</tr>
<tr>
<td>20</td>
<td>6.6</td>
<td>107</td>
<td>1804</td>
</tr>
</tbody>
</table>


Although lacking of special study concerning the metro’s impact on the traffic-induced emissions in China, experience shows metro is a comparatively clean transport mode. The function of a metro route distributed in high-density corridor proves substantial to release traffic congestion. However, the high construction and operation costs are always the barrier of metro development. Furthermore, the case of Seoul suggests that the real transport volume of metro does not come up to expectation, which is also proved by Shanghai’s case.

### 5.3.4 Traffic Restraint

Traffic restraint policies have two-pronged approaches: controlling car ownerships and limiting car use. China used to pay more attention on curbing car ownerships by setting high taxes and fees, but had insufficient measures to restrain the car use.

In most industrial countries, certain amount of taxes, which usually account for 10% to 25% of car’s open-market value (OMV), are charged during purchase stage. In case of China, a custom intending to buy a new car is required to pay three different types of taxes set by national government and several kinds of fees charged by local governments. As listed in Table 4, value-added tax, consumption tax, and purchase tax, which are respectively 17%, 5%, and 12.2% of the OMV, add up to total 34.2% of the original sedan price. Local-charged fees varied from different cities and regions, however, in some extreme case, e.g. in Shanghai where has vehicle quota system, they can account for 20% or even more of the OMV.

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59 OECD & ECMT, Urban Travel and Sustainable Development, 1995
61 Ibid.
62 Teng, T., Comparison of Automobile policies between China and Western Countries, 1998
As described in Section 4.3.4, car users in China also undertake heavy economic burdens during the usage stage at present. However, the problem is that they are not correctly charged, i.e., charged according to the fuel consumption and mileage of vehicle. Most motor vehicles are still subject to the fixed amount of usage fees based on their models, which proves insufficient to achieve environmental performance. Environmental related charges must, most of all, be implemented for the usage of cars. However, car owners today, especially those running highly polluting commercial vehicles and heavy trucks, are always stimulated by the incentive of maximizing car use in order to lower the average operation costs. In other words, present car usage charges only work in the term of restraining the demand of car purchase, however, fails to calm the car use.

Although the high economic barriers set for car have successfully restrained the vehicle population, it is doubtful how long the current situation can last in the future. In order to stimulate GDP growth, national development strategy has been amended to emphasize the development of automotive industry. The Proposal made by the Communist Party of China (CPC) Central Committee concerning the 10th Five-Year (2002~2007) Plan clearly states that “the entry of sedan cars into families should be encouraged”. As part of the implementation, 238 items of administrative charges on traffic and cars were canceled in 2000. The future trend of releasing economic burdens of car purchase and use is foreseeable.

Traditional command and control policies are applied with the intention of reducing exhaust emissions and releasing traffic congestion in urban areas. While some of them prove effective, the high implementation costs are always ignored. Heavy-duty trucks are prohibited to enter urban areas in most of Chinese cities. The scheme of exclusion of some vehicles selected by last number of license plate from CBD on particular days had been conducted in Shanghai until canceled in 1999. Hangzhou has implemented a similar scheme but it is only applied to taxies during peak hours. Despite of the potential advantage of diesel fuel, in order to eliminate PM emissions Beijing has banned the registration and usage of diesel vehicle which can not meet Euro III emission standards from 2000. While it is still open to see how effective this policy will be, the costs are believed enormous. Some of local policies have produced results which are in conflict with national strategy. For instance, whilst national governments have introduced a differentiated tax rate to encourage the use of low pollution cars, several cities, including Beijing, Shanghai, and Guangzhou, have tightened limitations of small cars. In Shanghai, the small car whose engine displacement is lower than 1.2 L is prohibited from running on the elevated roads. Guangzhou has stopped registration of the car with ≤ 1 L engine displacement. The restraint of mini cars is mainly out of the consideration of releasing congestion and promoting driving security. Moreover, many carburetor-equipped mini cars are also the significant source of exhaust emissions and therefore, the stringent regulation will probably benefit the city’s atmospheric environment. On the other hand, however, these local regulations have greatly set off the national efforts to encourage small cars and hinder the potential benefits by using environmental friendly small cars.
Parking pricing is one of few economic instruments applied to constrain car use in China. However, it appears to be one of the fiscal revenues rather than an effective measure to calm the traffic, partly due to the low charge level at present. It has been proved that parking pricing can have significant transportation impacts. The price elasticity of vehicle travel with respect to parking price ranges from –0.1 to –0.3 (a 10% increase in parking charges reduces vehicle trips by 1-3%), depending on demographic, geographic, travel choice and trip characteristics.\(^\text{63}\) Further promotion of parking pricing system in China is urged.

5.4 Concluding Remarks

Most transport policies applied to control road traffic-induced air pollution, described in Section 3 and 4, have been summarized and analyzed in this section with the focus on the environmental effectiveness and the cost-efficiency of them. Probably due to the fact that China is still a developing country, the costs of emission control are still relatively lower than that in the industrialized countries. Command and control is still the main function mechanism of existing policies. While this kind of policies probably are effective in the term of pollutant reduction, their cost-efficiency is still doubtful. The problem of insufficient economic instruments appears obvious. Nevertheless, without properly implementation all these policies can only take effect in theory. In the following section, the policies will be evaluated and their further promotions will be recommended.
6. Policy Evaluation and Recommendation

There are often many policies available to address the road emission problem. The priority setting of them depends on the evaluation criteria used. Section 5 mainly focuses on the policies individually both from the environmental effectiveness perspective, i.e. reduction potential, and from the cost-efficiency perspective i.e. direct costs per unit emission reduction. However, more criteria are required to be added to form a set of comprehensive policy evaluation system, which identify whether the emission reduction strategies justify for their economic or social benefits and thus deserve implementation. In this section, the following criteria will be considered when evaluating specific transport policy, combined with the research results in former sections:64

- Environmental effectiveness.
- Cost-efficiency.
- Economic efficiency.
- Enforceability
- Equity.
- Dynamic effects

6.1 Environmental Effectiveness

The environmental consequence of certain policies is considered a central issue in policy evaluating. In section 5, the environmental effectiveness of the specific policies counteracting road traffic generated emissions is reflected in the term of the polluting emissions reduction. Command and control policies, which are still the dominant functional mechanism in China, may deliver environmental effects with greater certainty (if they are effective implemented), compared with economic instruments where the environmental effectiveness depends on polluter’s responses to market signal. Table 17 presents an array of policy effectiveness in the context of the results in Section 5.

In Table 16, the highest grades have been assigned to the policies of fuel standards, emission standards, and I/M program due to their effectiveness upon the emission reduction. Although the CNG bus case in Shanghai proves effective as well, the characteristics of CNG vehicles, e.g. unfit for long-distance trips, determine the limitation of policy application. From technical point of view, higher fuel tax level will be more effective, while it is probably not always feasible from political point of view. Simple alternative fuel conversion, e.g. to convert taxi charged with LPG, has been proved unsuccessful. Changes are urged to make traffic restraint effective.

64 The detailed discussions on the setting of environmental policy evaluation criteria can be found in e.g. Field, B.C., Environmental Economics, An Introduction, 1995; OECD, Evaluating Economic Instruments for Environmental Policy, 1994.
Table 16. Summary of Environmental Effectiveness of Transport Policy in China

<table>
<thead>
<tr>
<th>Policy instruments</th>
<th>Rating</th>
<th>Policy</th>
<th>Area</th>
<th>Emission reduction (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel standards</td>
<td>3</td>
<td>Elimination of leaded petrol</td>
<td>China</td>
<td>1,500 (Lead)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reducing sulfur content in petrol from 0.04% to 0.020%</td>
<td>Guangzhou</td>
<td>22,000 (NOx)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reducing sulfur content in petrol from 0.04% to 0.003%</td>
<td>Guangzhou</td>
<td>34,500 (NOx)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reducing aromatic content in diesel from 30% to 10%</td>
<td>Guangzhou</td>
<td>23,000 (NOx)</td>
</tr>
<tr>
<td>Vehicle emission standards</td>
<td>3</td>
<td>Euro I in 2000, Euro II in 2005</td>
<td>China</td>
<td>970,000 (NOx)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Euro II in 2002</td>
<td>China</td>
<td>1,200,000 (NOx)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Euro I in 2000, Euro II in 2004</td>
<td>Guangzhou</td>
<td>21,000 (NOx)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Euro I in 2000, Euro III in 2004</td>
<td>Guangzhou</td>
<td>32,000 (NOx)</td>
</tr>
<tr>
<td>Alternative fuels</td>
<td>1</td>
<td>Taxi with domestic LPG</td>
<td>Shanghai</td>
<td>118.75 (NOx)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Taxi with Korean LPG</td>
<td>Shanghai</td>
<td>1,377.5 (NOx)</td>
</tr>
<tr>
<td>I/M programs</td>
<td>3</td>
<td>IM 240</td>
<td>Guangzhou</td>
<td>24,500 (NOx)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ASM</td>
<td>Guangzhou</td>
<td>36,500 (NOx)</td>
</tr>
<tr>
<td>Public transport policy</td>
<td>2</td>
<td>D6114 diesel engine bus</td>
<td>Shanghai</td>
<td>19,350 (NOx)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>M906LAG CNG engine bus</td>
<td>Shanghai</td>
<td>31,621 (NOx)</td>
</tr>
<tr>
<td>Fuel taxation</td>
<td>1-3</td>
<td>Fuel taxation</td>
<td>Depend completely on the level of the tax</td>
<td></td>
</tr>
<tr>
<td>Traffic restraint</td>
<td>0</td>
<td>Strong policies are successful in vehicle ownership constraint; however, fail to limit car use</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Rating from 3 (very effective) to −3 (very ineffective). A 0 indicates no impact or mixed impacts. Source: own calculations Based on the Results in Section 5

6.2 Cost Efficiency and Economic Efficiency
Currently, a cost-efficiency analysis is usually applied as a primary policy criterion during the policymaking process. In respect to policy of air pollution control, a policy is cost-effective when it reduces the maximum possible amount of emissions for a certain amount of resources being used or, in another words; it reduces a given amount of emissions at the least possible costs. Due to the lower level of economic costs, in principle, economic instruments are more cost-effective compared with command and control regulation. Nevertheless, the case of applying command and control policies in China still proves cost-effective, as shown in Figure 10. Since most of cost-effectiveness analyses in Section 5 have been conducted in two scenarios, two scenarios differentiated from cost-efficiency are consequently stimulated as shown in Figure 10.

In both scenarios, mandated emission standards are the most cost-effective measure, followed by reducing sulfur content in petrol. Despite of unsuccessful alternative fuel policy, I/M programs prove costly, mainly due to the enormous investments needed to set up I/M stations and corresponding equipments. To promote bus emission performance could also be suggested from the cost-efficiency point of view.
**Figure 10. Cost-efficiency Comparison of Policies in Two Scenarios**

Note:

Source: Own Calculations Based on the results in Section 5

“Economic efficiency” concerns the balance between abatement costs and damages, i.e. comparing socio-economic costs and benefits. “An efficient policy is one that moves us to, or near, the point (either of emissions or ambient quality) where marginal abatement...
Driving towards a Cleaner Future - A Study of Transport Policies of Road Emissions Control in China
Ming Ji
M.Sc. Thesis, LUMES

costs and marginal damages are equal\textsuperscript{65}. However, relevant research and data in China are still lacking at present, i.e. there are not specific calculations of socio-economic benefits (the value to society) of reductions in air pollutants. Therefore, this thesis is not intended to compare economic efficiency of different policies.

6.3 Enforceability, Equity, and Dynamic Effects

Enforceability, equity, and dynamic effects of policy are not only the evaluating criteria but determinant factors of policy effectiveness in practice as well.

In spite of the facts that China has a highly centralized power system and consequently has relatively powerful political resources to ensure the policy implementation, it is still confronting the enforcement problem of environmental policies. Four factors: interests conflicting, technologic limitation, economic limitation, and weak sanction consist of the main barriers of policy implementation concerning with road emissions control. An array of policy implementation barriers is presented as follows: (Table 17)

<table>
<thead>
<tr>
<th>Policy</th>
<th>Implementation barriers</th>
</tr>
</thead>
</table>
| Fuel standards      | Interests conflicting; fuel manufacturer (increased costs); fuel retailer (storage of low quality fuels);  
                     | Technologic limitation: lack of technology to low sulfur content in diesel and olefin content in petrol;  
                     | Economic limitation: improvement of fuel refining is costly.                               |
| Vehicle emission standards | Interests conflicting: car (in particular highly polluting vehicle) users and manufacturer (increased costs);  
                           | Technologic limitation: backward manufacture technologies;  
                           | Weak sanction: low level of penalty; (tempering and corruption)                          |
| Fuel tax            | Interests conflicting; local government (revenue reduction)                              |
| Alternative fuels   | Technologic limitation: backward LPG engine;  
                     | Economic limitation: investment of gas station                                             |
| I/M programs        | Interests conflicting: car (in particular highly polluting vehicle) users;  
                     | Technologic limitation: only simple idling emissions tests for gasoline vehicles and free-acceleration smoke tests for diesel-fueled vehicles;  
                     | Economic limitation: limited economic resources to adopt advanced test equipments and conduct frequent inspection;  
                     | Weak sanction: low level of penalty; (tempering and corruption)                          |
| Public transport    | Interests conflicting: bus companies (increased operation costs);  
                     | Economic limitation: high operation costs of CNG buses                                    |
| Traffic restraint   | Interests conflicting: opponents varied with specific policy, e.g. moped rider, manufacturer, and retailer (ban of moped) |

Source: Made Based on Personal Experience and Literature Reviewing

Cited from B.C. Field, 	extit{Equity is a matter of morality and the regard that relatively well-off people have for those less fortunate}.\textsuperscript{66} Considering current facts that highly polluting vehicles, including commercial vehicles, heavy-duty trucks, motorcycles, and mopeds, etc. are mainly owned by the people with low-income, they would be more sensitive to the change of transport policy, e.g. tightened emission standards, increased fuel prices,
traffic restraint, and so on. Therefore, the crucial question of how to compensate their mobility loss deserves detailed research. Compared with command and control policies, economic instruments such as fuel tax are preferable to attain equity.

To stimulate a strong incentive for individuals and groups to adopt innovation in emission-abatement technologies has proved crucial to obtain continual improvements of the environmental performance. While most of command and control policies appear to be technology-forcing, economic instruments are, in principle, likely to have better dynamic effects through technology-following. The differentiated tax for low pollution cars is exactly the case.

### 6.4 Policy Recommendations

According to the above policy analyses and evaluations, recommendations of the transport policies in China, which intend to mitigate road traffic induced emissions are presented in this section.

- Both from environmental effectiveness perspective and cost-efficiency perspective, policies of fuel standards, emission standards should be assigned priority. In respect to fuel quality, future efforts should be made to overcome the technological barrier, i.e. low olefin content in petrol and sulfur content in diesel.

- As regard to vehicle emission standards, economic incentives should be created for the manufacturer to adopt best available technologies and for the customer to prefer environmental friendly vehicles. The effectiveness of emission standards in practice will heavily depend on the implementation of I/M programs.

- Experience from various parts of the world suggest an I/M system based on centralized, high-volume, inspection-only centers with computerized emission measurement is likely to be more effective than a decentralized system with a large number of private garages participating in the I/M.\(^{67}\)

- Fuel tax has been proved successful in reducing traffic volume and consequent emissions in the industrialized countries. Tax reform both to restrain demand for transport to an efficient and environmental acceptable level and to generate efficient incentives in the choice of vehicle and fuel type, size of vehicle and location and timing of vehicle use. To distribute fuel tax between central and local governments is suggested to lower the barriers of its introduction.

- Infrastructures of gas stations are usually costly and from the point of view of life cycle assessment, the costs of alternative fuels are also considerable. Therefore, policy of substituted fuels could be reserved as an alternative option.

In regard to public transport system, its effectiveness is not only limited at constraining privately owned car demand. It should be also applied as the policy which compensates the mobility loss due to the increased stringent transport policy, and thus helps realize the value of equity.

Current traffic restraint policies are insufficient to acquire the objectives. Successful experience, e.g. road pricing, transit improvement and rideshare programs, High Occupant Vehicles (HOV) priority, etc. should be introduced gradually.

A latest investigation in Singapore shows that the most effective way to reduce smoke emission is to carry out proper and regular servicing and maintenance of vehicles. Towards this end, vehicle fleet owners are required to attend the regular meeting in which they are educated. Such experience is also available for China.

The cases of fuel standards and vehicle emission standards show the potential benefits by jumping of standards. While there will probably be a slight decrease from the cost-efficiency perspective, the reduction potential has increased significantly. Accelerating the adoption of higher standards therefore is recommended as well.

Last but not least, in many cases mixes of different instruments may be the best way to fulfill the control targets. Comprehensive package of policies, therefore, may be more effective than single specific one.
7. Conclusion

The conclusions presented in this section are drawn based on the descriptions, discussions, and analyses in the former sections. While most of the concluding remarks have been presented, this section intends to directly address the research questions that were posed at the start of the thesis. Based on the findings and limitations of the study, further research directions are to be pointed out.

7.1 Conclusions

The question that have been posted in the beginning of the thesis are:

*How serious the problem of road traffic-induced emissions is in present China? What's the future trend?*

Present China is undertaking the increased atmospheric environmental pressure. While the pollutant emissions from stationary source have witnessed releasing, the road traffic-induced emission is responsible for a growing share in the total air pollution. The problem is more serious in the urban areas. Acidification and adverse human health impacts are two of major environmental consequences of road emissions.

Rapid economic growth in past two decades and foreseeable future enables an expanding social status purchasing privately owned cars. From the policy perspective, the phrase of “the entry of sedan cars into families” was raised as national development strategy, replacing the former stringent constraint that had successfully limited the vehicle population. The trend of rapid motor vehicle population growth is inevitable.

On the other hand, however, the exhaust emissions should not necessarily change in parallel with the number of motor vehicles. Particularly in the case of China, current motor vehicles often have high pollutant emission factors. The potential of the emission reduction through adopting cleaner vehicles allows the possibility of decreasing road emissions, even though vehicle population increases.

*What policies to relieve road emissions have been implemented and what are to be enforced, both at national level and local level?*

Proper transport policies prove crucial to mitigate road traffic generated emissions. To achieve this objective, efforts have been made to develop a package of policies in China. Command and control remains the dominant functional mechanism of policy, while several economic instruments have taken effect.

There had not been clear lines of authority and responsibility concerning road emissions until the amendment of *Law of People's Republic of China on the Prevention and Control of Atmosphere Pollution*. Whilst the polices at national level focus on the overall and general issues, e.g. vehicle emission standards, fuel standards, and taxation, etc., the local
governments take responsibility of develop countermeasures tailored to local specific situations.

How effective the existing policies are, both from an environmental effectiveness perspective and from a cost-efficiency perspective?

Most of existing policies prove both effective from a point of view of environmental effectiveness and cost-effective from economic perspective. The significant reduction potential of pollutant emissions is partly due to a large scale of highly polluting vehicles at present. The fact that China is still in the initial stage of automotive popularization determines the urgency of proper policies, before the problem is too costly and complicated to control.

How to set priorities for the future transport policy of China?

Besides the environmental effectiveness and economic efficiency, the criteria of enforceability, equity, and dynamic effects are also taken into consideration when evaluating the policies.

Fuel standards and vehicle emission standards have been assigned the first priority, considering their effectiveness and efficiency. I/M programs can control emissions from in-use vehicles effectively. Promotion of public transport can not only reduce direct emission from buses, but also calm the demand of private vehicles. Although not been put into operation yet, fuel tax is expected to reduce the total travel demand and stimulate manufacturer and customer to prefer environmental friendly vehicles. Introducing more instruments is in the need of making transport constraint policy effective. Simple alternative fuel conversion is proved unsuccessful.

The implementation of policies appears to be the obstacle that will probably offset policy effectiveness and efficiency. Current barriers concerning with road emissions control policies are comprised of interests conflicting, technological limitation, economic limitation, and weak sanction.

Equity and dynamic effects are often the criteria that would be overlooked during policy-making process. In respect to transport policies intended to mitigate road emissions, how to compensate the mobility loss, especially for the poorer remains crucial to realize the equity objective. Using economic instruments in preference to command-and-control regulation should be encouraged both from equity and dynamic effects point of view.

In principle, command-and-control policies, i.e. regulations, work well from a short-run perspective, whilst economic instruments, i.e. traffic user-charges, are preferable from long-term point of view. The problem now is that the governments in China rest heavily on the command-and-control approach. In order to attain road emissions objectives in a long-run, China has to gradually introduce traffic user-charges and get the understanding how they work in practice.
6.2 Further Study

While it is not the intended purpose of this thesis to discuss other policies, e.g. land-use policy, available to reduce road traffic-induced emissions, the probable environmental consequence of those policies deserve further research.

While transportation has many external impacts, the focus of this thesis is on the road emissions, which implies the risk of "the tail wagging the dog". In reality, however, exhaust emissions would not be either the exclusive objective or the unique consequence of transport policy.

The calculations in this document are intended to show a general picture of problems. Due to lacking of precise data and the information of the behavioral responses of different policies, the calculations are comparatively rough. Further research is suggested to carry out with more precise data and suitable model tools.
8. Reference

8.1 Printed Sources


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Driving towards a Cleaner Future - A Study of Transport Policies of Road Emissions Control in China

State Environmental Protection Administration of China (CEPA), various issues, Annual Report on the State of Environment in China, CEPA, Beijing


8.2 Web-based Sources

Cornell, S., (1998), Driving at a Cleaner Future, SINOSPHERE, 
http://www.chinaenvironment.net/sino/sino2/page3.html (08.10.2001)


### Appendix 1. National Ambient Air Quality Standards

<table>
<thead>
<tr>
<th>Pollutant</th>
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<th>Concentration Range</th>
<th>Unit</th>
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*Source: SEPA, National Ambient Air Quality Standards, 1996*

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Appendix 3. Emissions from Motor Vehicles in the Future, Shanghai (tons)

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