ENVIRONMENT AND INFRASTRUCTURE DEVELOPMENT IN MEGA-CITIES: THE CASE OF SHANGHAI, CHINA

by

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ABSTRACT

As the largest city of China and one of the world's 10 largest cities, Shanghai has experienced rapid economic growth in the recent years. But at the same time this rapid economic growth is placing a major burden on the city's infrastructure and local environment. The purpose of this thesis is to developing an understanding of the current infrastructure situation in Shanghai, its potential development in future and its impacts on the environment.

First, the thesis will describe a general picture of Shanghai including geological location, economics and its relation to the country and population growth. Then the thesis will review the current environment and infrastructure problem faced by the city. As air pollution, energy shortage, transportation congestion and poor water quality are the major three hindrances to the sustainable development of Shanghai, these will be the major concerns of this thesis. The conflict between the continually increasing demand for infrastructure facilities with the environmental and financial constraints is not a problem unique in Shanghai. Some specific comparison with other mage-cities will be made to develop a better understanding the related issues and the possible strategies to improve the environment and infrastructure performance in the city will be analyzed. Since the financing is also an important issue related to integrate infrastructure development, finally, this thesis will analyze the current infrastructure investment structure and discuss the potentially new approach for the funding of the infrastructure in Shanghai.

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Table of Contents

Table of Contents

List of Figures

List of Figures

List of Tables

Chapter 1 — Introduction

As the largest city of China and one of the world's 10 largest cities, Shanghai has experienced unprecedented economic growth in the last five years (since 1992). By the end of this century, Shanghai is poised to become a major economic, financial, and trade center in the world. At the same time this rapid economic growth is placing a major burden on the city's infrastructure and local environment. Issues related to a city's infrastructure include energy generation, transportation, water supply, waste disposal, and housing. Over the past decade, Shanghai has been taking measures to modernize its infrastructure to accommodate the requirements of economic growth. At the same time, the city confronts a range of severe environmental problems that accompany this fast growing economic development. To pursue a balanced social, economic, and environmental policy, the city should take into consideration the local ecology. The main purpose of this research is to review recent efforts concerning how to modernize the city's infrastructure, while maintaining its local ecological environment and sustaining its economic growth.

This thesis will review the current environment and infrastructure situation in Shanghai. In particular, we will examine problems related to economic growth and environmental impact. Also, specific issues related to Shanghai will be compared and understood in terms of the infrastructure development experiences in other mega-cities. A brief outline of each chapter follows:

Chapter 2 This chapter will provide a general picture of Shanghai including a historical, geophysical, and socioeconomic perspective on the urban development of Shanghai. Furthermore, this chapter will feature sections on Shanghai's natural location, city history, population, economics situation, and municipal administration. A major emphasis will be placed on the structure and development of the city's economy. To demonstrate Shanghai's unique economic status in China and its remarkable economic growth, some of its economic indices will be compared to that of China's national level and other mega-cities. Additionally, as one of the densest cities in the world, the growth of the population in Shanghai will also be discussed.

Chapter 3 This chapter will discuss the general environmental problems in Shanghai. They are covered in four sections: air pollution, water quality, solid waste, and noise. The purpose of this part is to provide a general scene of the environment situation in Shanghai.

The air pollution in Shanghai is mainly coal-smoke pollution. The prime pollutants are totally suspended particulates (TSP), nitrogen oxides, and sulfur dioxide. Poor water quality is another major threat to residential health and industrial productivity. Although air pollution and water pollution are the main concerns of this chapter, issues related to solid waste and noise will also be analyzed. This thesis will provide data on the major pollutants of Shanghai and compare them with data found on other mega-cities, as well as the Chinese national standard.

Chapter 4 This chapter will assess the past and current stages of Shanghai's infrastructure and analyze the problems faced by the city in the process of infrastructure development. It will include the following sections: energy and power generation, transportation, water supply and sewerage, solid waste management, housing.

Any energy shortage is a major hindrance to the development of Shanghai. With economic growth, the consumption of the energy is increased dramatically. But increase in energy demand has put a large pressure on the environment. Electricity requirements are increased in both the industrial and household sectors. Since coal-fired power generators meet most of the demand for electricity, changes in energy generation and consumption structure are needed to protect the environment. (Coal-fired power generators are a leading cause of severe environmental problems.) This chapter first analyzes the current energy generation and consumption structure in Shanghai. Next, the shortcomings in energy consumption of Shanghai will be demonstrated through comparison with other mega-cities. Moreover, this section discusses the severe environmental problems caused by coal-based energy generation and consumption in the city. In the end of this section, some suggestions to remedy the energy problems in Shanghai will be provided.

In addition to an energy shortage, Shanghai has suffered traffic congestion for a long time because of a high population density in the downtown area. Although the government has tried to alleviate this severe problem by implementing a decentralization plan, it has not been successful. This section first reviews the city's past and current transportation situation. The prominent urban transportation problem in Shanghai will be analyzed. The motor vehicle fleet increases rapidly, while the road construction, although impressive, fails to keep up with the growth of vehicles. Without the sufficient facility in the new dwelling area, the residents still have to go to the downtown. As more and more residents live long distances from work, it even aggravated the burden of the transporting in the commute period. The majority of the commuters depend on the public transit system, mostly is the bus. Unfortunately, the service is not efficient due to insufficient and poor vehicles. In the peak hour, the bus is too crowded to move fast. So the public transit is declining, while the private transport has a trend to increase, which even worsen the already severe transportation problem. This section demonstrates that an effective public transit system is a necessary measure to lessen the amount of traffic congestion, as well as to lessen the amount of money spent on road construction. Another problem discussed in this section is the inefficient transportation management. Finally, this thesis will try to provide some suggestions to improve the transportation performance in Shanghai by considering the transportation models of other mega-cities.

The quick increase automobile traffic will become a potential threat to Shanghai's sustained development. In the central area of Shanghai, there is very little parking available; many cars must park on the street, which further worsens the congestion. Although privately owned cars are only a small part of the total automobile fleet now, they will become a future trend. To avoid escalating the traffic congestion, we must consider how to deal with the potential private car boom at this time. Moreover, the automobile is a major contributor to the atmospheric pollution and noise. To preserve a livable environment, there are not many choices. They are basically either to limit the automobile use or to develop the technology that reduces emission. Some possible mechanism will be discussed.

With rapid economics growth, pressure to treat wastewater has increased simultaneously. Without adequate waste treatment and efficient conservation measures, the water quality of Shanghai is worsening with its industrial development. Although several rivers run through the city, Shanghai still face the problem to meet the demand of both the industrial and household sectors, since almost all the rivers are severely polluted by the directly discharged waste. As a result, the potable water quality is poor. The potential mechanism to improve the water quality will be introduced.

The sewage network in most parts of the city was set up nearly one century ago, it was far behind what is sufficient to meet the need now. So it is necessary to set up an efficient sewage system to handle the increasing volume of wastewater in Shanghai.

Although improving the water quality becomes a major concern of the municipal government, it cannot be achieved without the appropriate mechanism to treat the wastewater. Issues regarding waste and domestic sewage problem are discussed in this section, as well as what measures can be taken to improve the water quality.

Since the income of urban families has steadily risen in the past few years, the living expenses also increased. With more consumption, more solid waste was generated. The mode of disposal of the solid waste in Shanghai will be analyzed.

The housing condition in Shanghai is improved with the huge investments pouring into the housing development. The dwelling area per capita in urban districts has increased steadily. With more development taken in old area rehabilitation, a large amount of residents in the central area of the city moved into the periphery of the city. Moreover, the urban vegetation will also be discussed in this section.

Chapter 5 In this chapter, the investment in the infrastructure area in Shanghai will be analyzed first. Since the funding of infrastructure is vital to the sustainable development, this thesis will analyze the possible infrastructure financing strategies. Since the private participation is proved helpful to the efficiency of the infrastructure, the possibility and mechanism of the privatization will also be discussed.

Chapter 6 This chapter will conclude the thesis with summarizing the most important points of the research.

Chapter 2 — Basic Facts of Shanghai

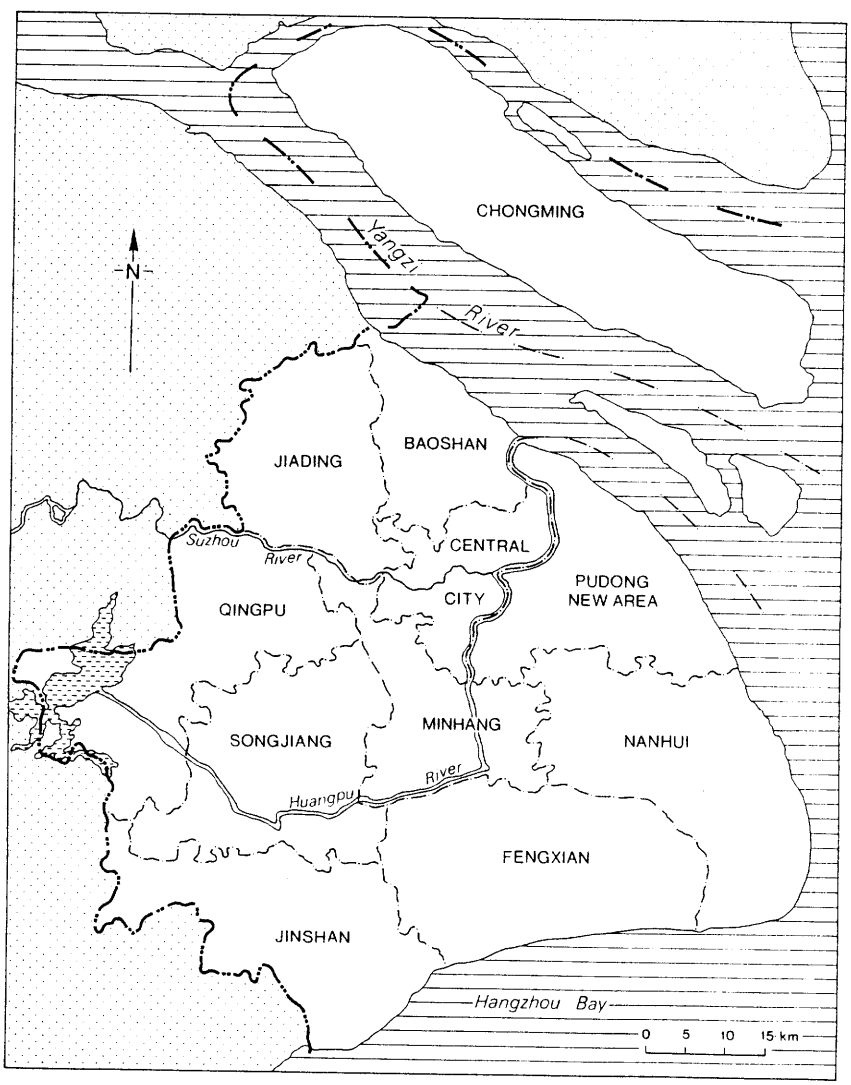
2.1 Overview

Shanghai, located at 31°41' north latitude and 121°29' east longitude, is the largest city in China. Bordering the Jiangsu province on the north and west side and on Zhejiang province on the south, Shanghai lies on a large delta plain – the Yangzi River Delta, which edged by the Yangzi River on the north and Hangzhou Bay on the south (see Figure 2-1). Because of its strategic location, Shanghai has long been the gateway to the outside world for China. Located at the middle point on China's coast, Shanghai possesses an advantageous position linking not only to other cities along China's coastline, but to other major cities in the Asia-Pacific region as well. Moreover, at the mouth of Yangzi River, it's easy for Shanghai to access the vast hinterland of China. The launching of the Three-Gorges Dam project enhance the regional importance of Shanghai even more (SMIO 1997).

With northern subtropical maritime monsoon climate, Shanghai enjoys a mild weather, generous sunshine and abundant rainfall. Its spring and autumn are relatively short compared with summer and winter. The average low temperature in January is 3°C, while the average high temperature in July is 27°C. The city has a frost-free period

The city covers an area of 6,340.5 km^2, extending about 120 km from north to south and nearly 100 km form east to west. Shanghai is divided into three parts: the central city with ten urban districts, the four suburban districts and six suburban counties. The area of the central city is 280 km^2, while suburban districts is 1777 km^2 and suburban counties is 4283.5 km^2. Most area of the city's land was formed by centuries of alluvial sedimentation, with an average elevation about 4 m above sea level (SMIO 1997).

Figure 2-1 The Administrative Division of Shanghai



2.2 Economy

2.2.1 Economic Growth

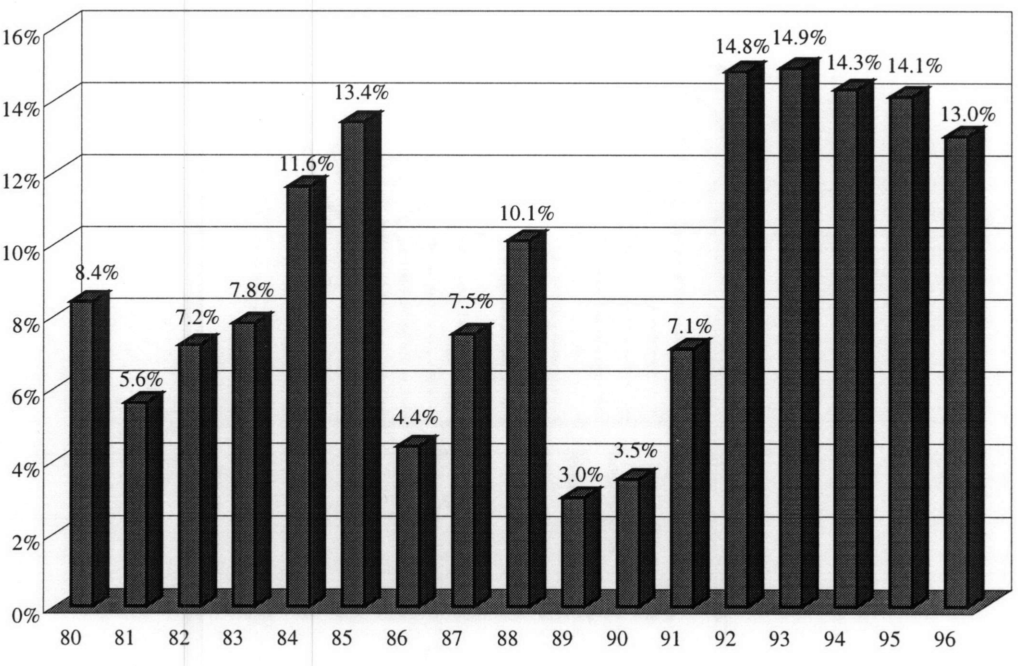
Since the time of the foundation of the People's Republic of China, Shanghai's economic development can be divided into three periods.

The first period was 1953-1978. Under the command economy, the determined factor of the economy growth was the societal distribution of resources. The annual economic growth in those 26 years was about 8.8%, clearly above that of China as a whole.

The second period was 1979-1990, when Guangdong and other southern provinces took the advantage of the China's economic reform and opening policy to race ahead the economic growth, while Shanghai was conservative to act as a safeguard of the economy reform. In that period, the average economic growth rate was 7.5%, which was far below its southern counterparts. Meantime, Shanghai's share of China's GDP declined continuously from 7.5% in 1978 to a record low of 4.1% in 1990.

In1990, the announcement of the opening and development of Pudong, the eastern part of Shanghai, activated the lagged economic growth of Shanghai. Shanghai grasped this historic opportunity to deepen economic reforms, open the city wider to the outside world, and pursue arduously social and economic progress. From 1992 to 1996, the annual GDP growth surpassed 13% in each of the five years (Figure 2-2). The GDP share of the nation also recovered and kept steadily around 4.4%. In 1996, Shanghai's GDP reached 287.8 billion RMB (27.3billion RMB in 1978), and the GDP generated by an average worker was RMB 26,572 in 1996 (4,295 RMB in 1980). At the same time, Shanghai has also achieved rapid increase in its financial income. In 1996, Shanghai's total financial revenue reached 87.4 billion RMB, including 28.849 billion RMB in local financial revenue, which was 26.9% higher than in 1995 and one of the biggest growth rates in recent years.

Figure 2-2 The GDP growth rate in Shanghai, 1980-1996.



Source: SMIO, 1997

2.2.2 Economic Importance

As the largest city, Shanghai also serves as the economic center of the nation. Although the economic proportion of the national total declined in the past two decades due to the rapid economic growth of other parts of the nation in the 80's, Shanghai still made up a sizeable proportion as showed in table 2-1.

Table 2-1 Shanghai's Proportion of the Nation's Total, 1996

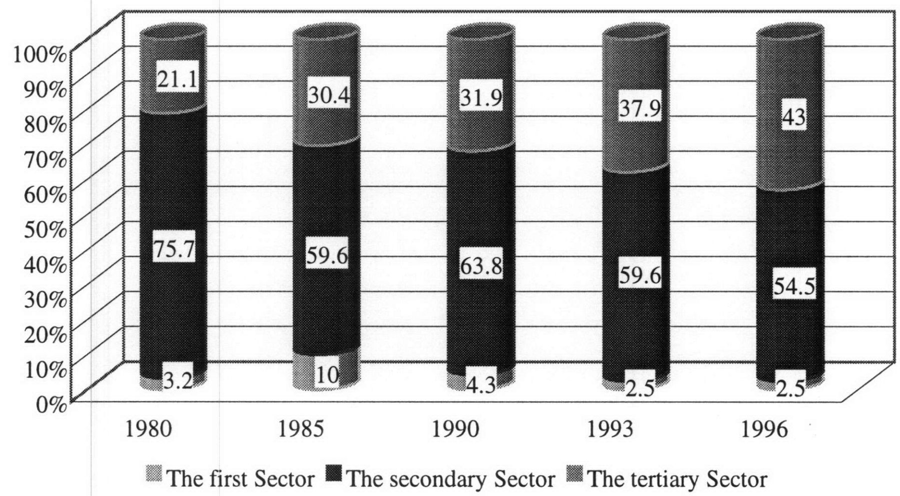
	Unit	National	Shanghai	Shanghai proportion(%)
GDP	100 million RMB	67,795	2,902.20	4.3
Social retail sales	100 million RMB	24,614	1,161.30	4.7
Financial income	100 million RMB	7,367	873.76	11.9
Total investment in fixed assets	100 million RMB	23,660	1,952.06	8.3
Total imports/exports through Shanghai customs	100 million USD	2,899	528.70	18.2
Port cargo handling volume	10,000 tons	83,500	16,402	19.6
Freight mileage	10,000 tons	36,271	3,756	10.4

Source: SMIO, 1997

2.2.3 Economic Structure

To maintain a high GDP growth rate, Shanghai has experienced significant structural change. The government began emphasizing the development of the tertiary sector, while actively restructuring the secondary sector, and steadily improving the performance of the primary sector in the recent years. As a result, the tertiary sector of the city has been growing the fastest. In the meantime, the city has made notable progress in the strategic restructuring of local industries, so the industrial structure was continuously optimized since 1978. In 1996, the output of the city's tertiary sector reached RMB124.812 billion, accounting for 43% of GDP, compared to 21.1% of GDP in 1980. Moreover, during the 1979-1996 period, the tertiary sector grew at an average yearly rate of 11.4%, 2.1 points higher than the GDP and 2.5 points more that the secondary sector (Figure 2-3).

Figure 2-3 Sector Composition of GDP in Shanghai, 1980-1996



Source: Wu, 1997

With the restructuring of the economy, the number of employed laborers in the different economic sectors has also changed. More laborers have switched from the agricultural to the secondary and tertiary sectors. Laborers in the tertiary sector made up 38% of the city's total labor force in 1996, an increase from 21.6% in 1978, while the proportion in the agricultural sector sharply decreased from 34.4% to 10%. Compared to the labor force distribution of the major cities in the developed country, Shanghai had a clear low proportion in the tertiary sector and extremely high rate in agriculture (Table 2-2).

Table 2-2 Distribution of the Labor Force in the Economy

City	First Sector	Secondary Sector	Tertiary Sector
Shanghai	10.0	52.0	38.0
Hong Kong	0.9	26.7	72.4
Singapore	0.4	35.1	64.3
Tokyo	0.6	29.6	69.8
New York	0.1	13.3	86.6
London	1.3	18.7	80.0
Paris	0.1	22.1	77.8

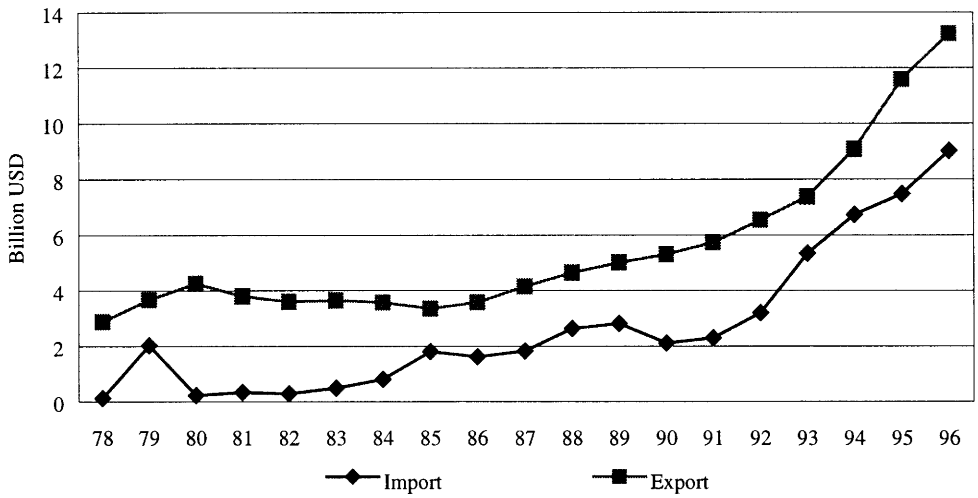
Source: Wu, 1997

Despite the rapid development of the tertiary sector, Shanghai has remained an important national industrial base. In the past decade, the industrial output in Shanghai occupied around 6% of the nation total. After 1990, Shanghai's industry has undergone strategic restructuring. Through technological import from the advanced countries and reconstruction, the industrial structure has been heavily optimized. In recent years, the investment had an emphasis in the six pillar industries. The six pillar industries are automobiles, the electronic and telecommunication equipment, power station equipment and parts manufacturing, petrochemical and fine chemical processing, the iron and steel, and the household electrical appliances. In 1996, the six pillar industries contributed 215.39 billion RMB in total industrial output, accounting for 50.7% of the city's total industrial output value. Meanwhile, Shanghai made great efforts to develop the most competitive products and new high-tech, highly marketable and high value-added products, concentrating in the development of integrated circuits, modern biology and medicine, and new materials. In 1996, the high-tech industries yielded 75.329 billion RMB, 14.8% of the city's total industrial output value (SMIO 1997).

2.2.4 Foreign Investment and Trade

In the 80's, during a the slow economic development period, direct foreign investment in Shanghai was far less than that in Guangdong and the Special Economic Zones. However, the Chinese government decided to prioritize the development of Shanghai, the amount of foreign direct investment increased rapidly after 1990. From 1991 to 1996, Shanghai had signed contracts on 16,635 overseas-funded projects with contracted investments. These total to a sum of 52.727 billion US dollars, of which 23.076 billion US dollars had already been utilized. These figures accounted for, respectively, 90% and 83.8% of the city's total since the adoption of the reform and opening policy in 1978. By the end of 1996, 73 countries and regions had invested in Shanghai. Meanwhile, the foreign trade performance in Shanghai was also similar to its rapid economic development (Figure 2-4).

Figure 2-4 Foreign Trade in Shanghai, 1978-1996



Source: SMIO, 1997

2.3 Population

2.3.1 Urban Population

To obtain a sustainable development, retaining a suitable population was very important. In spite of Shanghai's large population, population control has been a prominent policy of its development since 1978. Although the government has strictly controlled immigration and has tried to export the trained manpower to other part of China, the population still increased rapidly. In 1996, Shanghai had a population of 13.0443 million, accounting for 1.1% of China's total and 3.6% of the national urban population. Shanghai's population ranked #6 among the world cities, however, its proportion of the nation total and urban population was very low compared to other major cities (Table 2-3).

Table 2-3 Urban Agglomeration of the Mega-cities, 1996

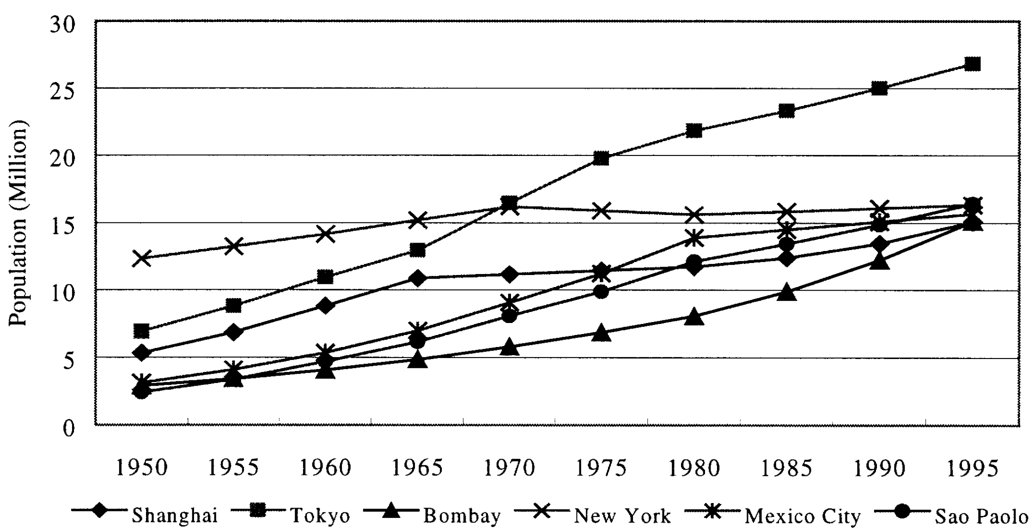
	Population	Population residing in agglomeration, 1996, as percentage of	
		Total Population	Urban Population
Tokyo	27.242	21.7	27.8
Mexico City	16.908	18.2	24.8
Sao Paulo	16.792	10.4	13.2
New York	16.390	6.1	8.0
Bombay	15.725	1.7	6.1
Shanghai	13.659	1.1	3.6
Los Angeles	12.576	4.7	6.1
Calcutta	12,118	1.3	4.7
Buenos Aires	11,931	33.9	38.3
Seoul	11,768	26.0	31.5

Source: United Nations, Department of Economic and Social Affairs, Population Division, 1996

2.3.2 Population Growth

Due to the successful execution of the birth control policy, Shanghai became the first area in China to report a negative natural population growth rate in 1994. The city's natural population growth rate was -2.3 per thousand, with the birth rate 5.2 per thousand and the death rate 7.5 per thousand. However, the population in Shanghai still grew, mainly because of immigration from the hinterland of china. In the 1990's, immigration soared. Due to the economic booming, there was a labor shortage in Shanghai, especially for labor intensive jobs, which the urban resident was reluctant to do. Lured by the high income, the rural population has continuously flowed into the city in increasing numbers. This immigrant labor force was estimated about 2.5 million to 3 million. In China, each individual was officially registered at a specific place of residence. A permanent change of residence status required permission from the appropriate authorities of the origin and destination place. Because a majority of the temporary migrant in Shanghai did not have any kind of residence permit, they were not considered as registered residents of the city. As a result, the actual population in Shanghai had already exceeded the 15 million by 1995. However, the growth rate of population in the past decades was slower than most other major cities in the world (Figure 2-5).

Figure 2-5 Population Growth of Urban Agglomerations in Mega-cities

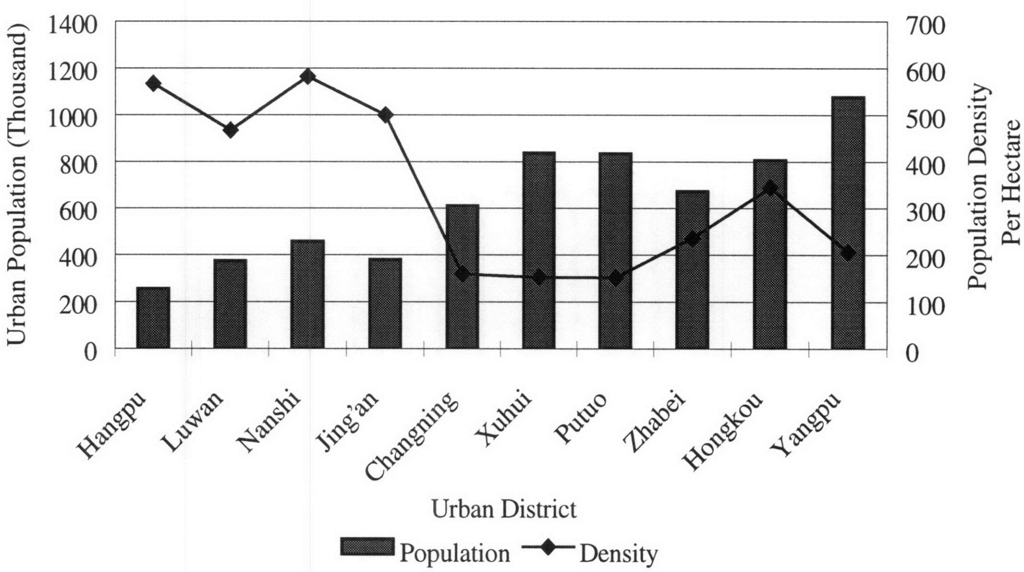


Source: United Nations, Department of Economic and Social Affairs, Population Division, 1996

2.3.3 Urban Population Density

Another important fact in Shanghai is the high population density in the urban area. The average population density is more than 22,500 per square km^2, while in the four downtown districts the average is over 50,000 per square km^2 (Figure 2-6). Such a high density, which was the result of poor planning at the early stages of the city's development, lead to an under-supplied of infrastructure and a degradation of the city's environmental quality. Thus, urban redevelopment is necessary and essential for the further sustainable development in Shanghai.

Figure 2-6 Population Density in Urban Areas of Shanghai



Source: SMIO, 1997

2.3.4 Aging Population

With its economic development, the life expectancy of Shanghai residents had reached the level of other developed countries in the world. In 1996, the average life expectancy stood at 74.07 years for men and 78.21 years for women, up 3.38 and 3.43 years, respectively, from 1978. The life expectancy of Shanghai residents was higher than the world average and that of middle-income countries. In short, the life expectance in Shanghai reached the level of major economically developed countries. As a result, the increase in the elderly population has been fast during recent years.

Chapter 3 —Environmental Situation

3.1 Introduction

In the past fifteen years, Shanghai accomplished a rapid economic growth, which has made the life for the city residents far better than it was two decades ago. But at the same time, the environment was somewhat sacrificed for the economic growth. As a result, the air and water quality deteriorated significantly during that period. Although controlling the industrial emission and switching to more clean residential fuel sources began to improve the polluted environment, the city has still suffered from poor air and water quality, which has harmful effects on the health of the city's residents. The environmental problems were also a threat to the sustainability of the accelerated development of Shanghai. Furthermore, an inadequate environmental service infrastructure places Shanghai at a competitive disadvantage when it is trying to reestablish itself as a new financial and commercial center in the Asia-Pacific area. Thus integrating social, economic, and environmental objectives to achieve sustainable development is necessary for Shanghai.

3.2 Status of Ambient Air

The rapid growth in industry and rising consumption in households has put a huge pressure on the air quality in Shanghai. However, with industrial emission control and residential switching to more clean fuel programs, the air quality in Shanghai has stopped worsening. Or one might say they have been improved a little in the past several years. But, the ambient concentrations of total suspended particulates (TSP) are still extremely high, and the sulfur dioxide concentrations, which causes acid rain, are also high, since the coal is still the primary energy source in Shanghai.

3.2.1 Main Pollutants

Air pollution is mainly caused by coal-smoke pollution. In urban areas, the air pollution is primarily caused by vehicle emission, industrial activities, and energy production and consumption.

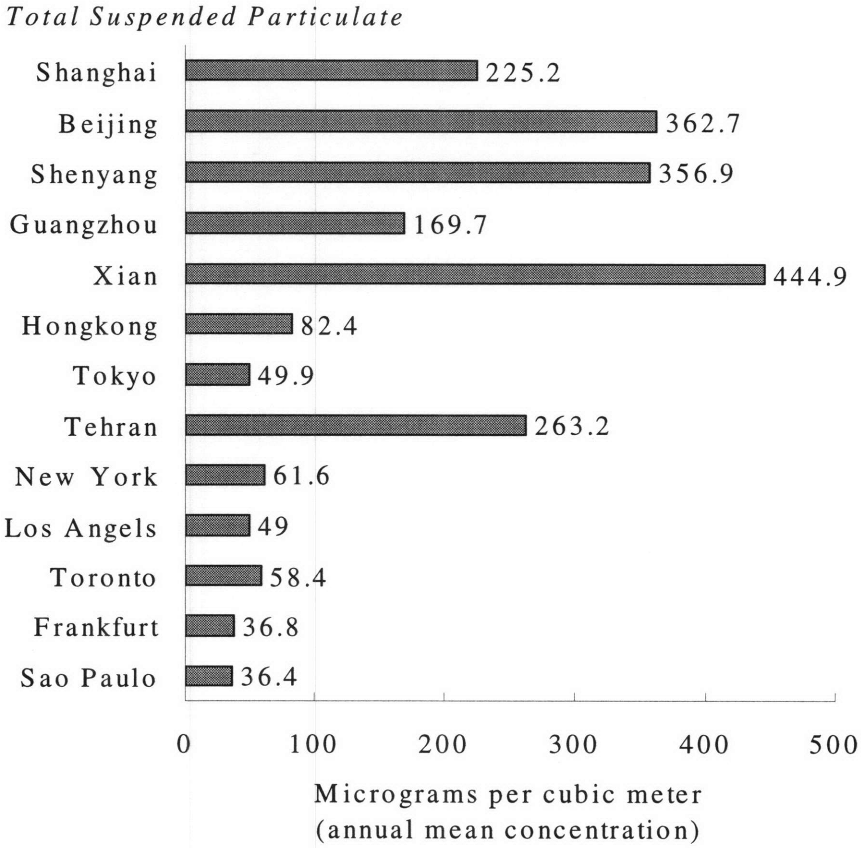
3.2.1.1 Total Suspended Particulates (TSP)

TSP is a complex mixture of organic and inorganic substances, present as both solids and liquids, which may be dispersed into the air by combustion processes, industrial activities, or natural events. The diameter of particulate can range from less than 0.1 micrometers (μm) to 1,000 μm or so (Shah, Nagpal and Brandon, 1997).

Since a particulate measures less than 10 μm, which are referred to as suspended inhalable particulate, they remain in the air longer than larger particles and are small enough to be inhaled deeply into the respiratory tract. Such suspended particulates could increase problems in pulmonary functions (Elsom 1996).

The main sources of emissions of particulate are energy consumption, such as coal, biomass, and petroleum products (Elson 1996). Since most Chinese cities use coal as their principle sources of energy, the urban area in China has recorded some of the highest pollution in the world for total TSP. Figure 3-1 shows the TSP emissions in the major cities of the world from 1989 to 1994. Because of the poor air dispersal and lower temperature inversions, the TSP emissions is somewhat higher in the cities in northern China, such as Beijing, Shenyang, and Xian, than in Shanghai. However, the TSP emissions in Shanghai were still recorded at a high level, as the TSP emissions in the cities of China were obviously higher than most major cities out of China. In the urban of Shanghai, the average level of total suspended particulate was 225.2 micrograms per cubic meter per annum from 1989-1994. The TSP emissions in Shanghai reached their peak in the beginning of the 90's, but after 1992 they steadily decreased, dropping almost a third from the peak of 347 in 1992 to 241 in 1996 (Figure 3-2). However, the emissions of TSP in Shanghai have been several times higher than the World Health Organization (WHO) average annual guideline of 60-90 $\mu g/m^3$, and the Chinese ambient air quality standard for resident urban areas of 120 $\mu g/m^3$ (see Table 3-1),

Figure 3-1: TSP Emissions in Major Cities, 1989-94



Source: WHO and UNEP, 1992

Table 3-1 Ambient Air Quality Standards of China and WHO

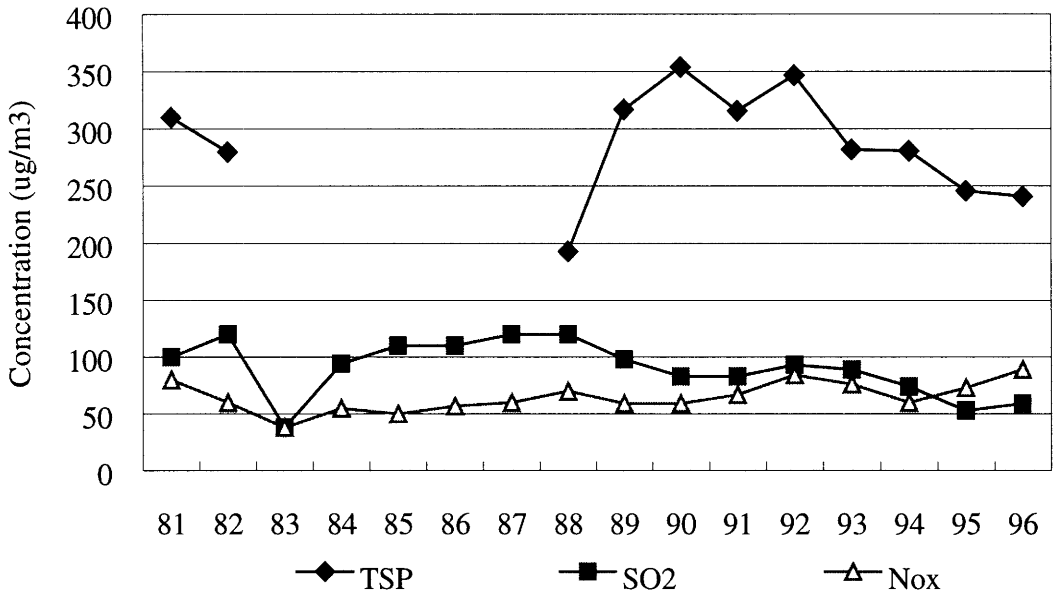
Unit: Micrograms per cubic meter

	China			World Health Organization
	Class 1	Class 2	Class 3	
TSP[a]	60	120	150	60-90
SO_2	20	60	100	40-60
NO_x	50	100	150	150

Note: *Class 1 are tourist, historic, and conservation areas.*
Class 2 are residential urban and rural areas.
Class 3 are industrial areas and heavy traffic areas.
a. Since China does not have annual standards for TSP, it has been assumed that the same ratio between daily and annual standards for SO_2 applies to TSP.

Sources: WHO and UNEP 1992 and World Bank staff estimates

Figure 3-2: Major Pollutants Emissions in Shanghai, 1982-96



Source: World Bank data and Shanghai Environment Bulletin

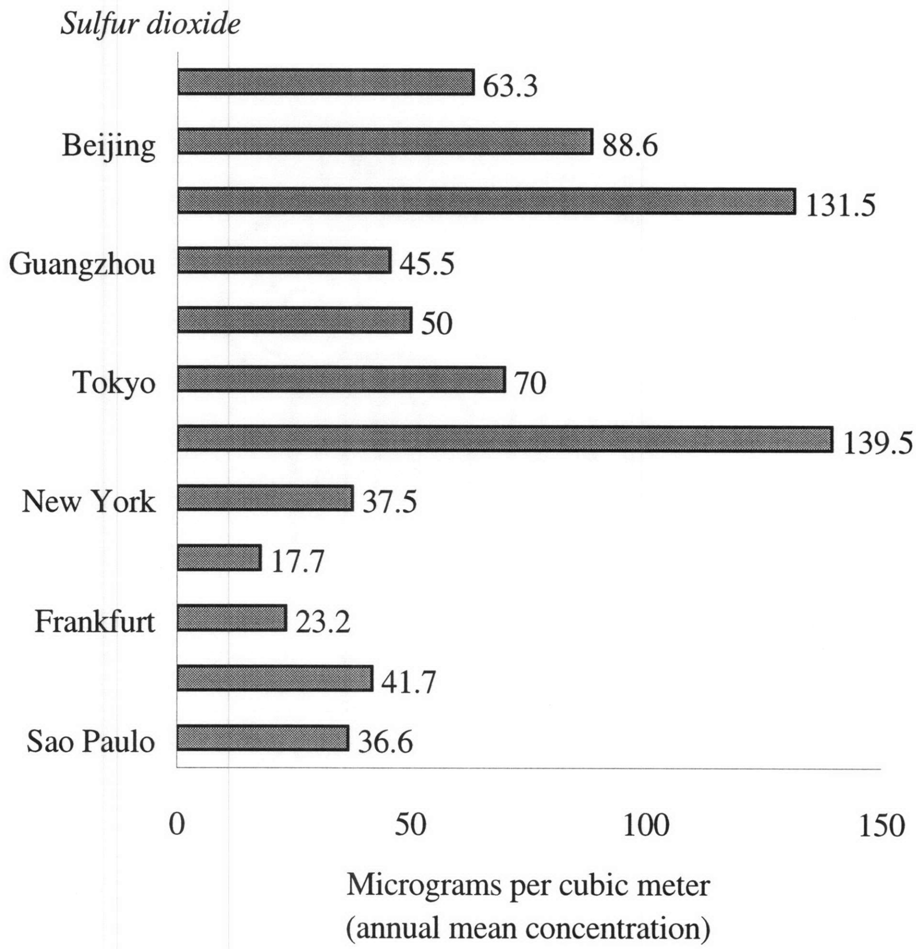
3.2.1.2 Sulfur Dioxide (SO_2)

Sulfur dioxide (SO_2) is a colorless gas. The burning of coal and petroleum products is responsible for most SO_2 emissions. SO_2 is the principal pollutant associated with acid deposition and damages the ecosystem in both direct and indirect ways. (Elsom 1996). As the largest and most industrialized city in China, the energy consumption in Shanghai is quite substantial. Unfortunately, the primary fossil fuel is coal, which has a very low caloric content and a high sulfur concentration, and is the major source of the SO_2 emission.

The Figure 3-2 shows that there were two sharp reductions of SO_2 emissions. One was in the end of the 80's in which the average emission level was decreased from 110-

120 μg/m^3 to around 90 μg/m^3, while the other was happened in the middle of the 90's in which the emission level was further deceased to below 60 μg/m^3. Although the SO_2 emissions in Shanghai had already meet the WHO emission guideline and the China Chinese ambient air quality standard for urban areas, the emissions were still higher than most other major cities (see Figure 3-3). Moreover, after a two-year decrease, the SO_2 emission in 1996 was very close to the WHO guideline and China standard.

Figure 3-3: SO_2 Emissions in Major Cities, 1989-94



Sources: WHO and UNEP

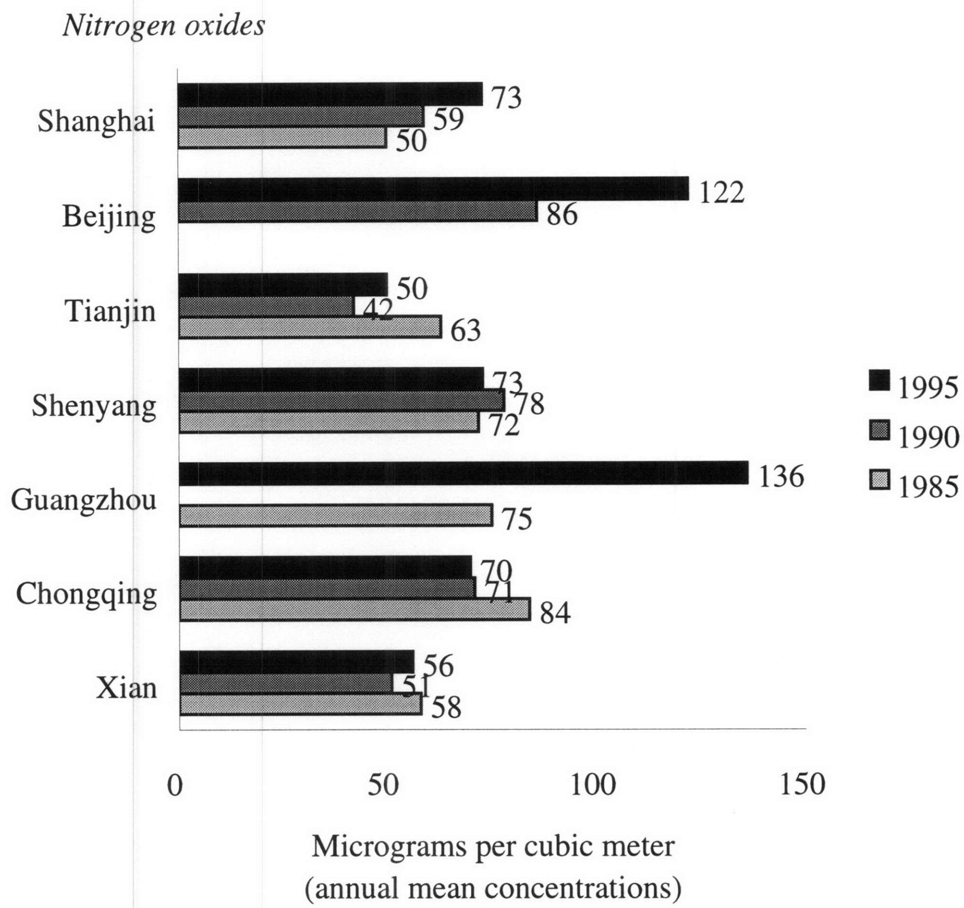
3.2.1.3 Nitrogen Oxides (NO_x)

Nitrogen oxides are also a major pollutant has a negative impact on the environment. There are several nitrogen oxides, but one mainly refers to two species of nitrogen oxides: nitric oxide (NO) and nitrogen dioxide (NO_2).

The major source of direct emissions of nitrogen dioxides in urban areas is from motor vehicles and power generators, while tobacco smoking and the use of gas-fired appliance and oil stove are the main indoor sources. Exposure to nitrogen dioxide had a variety of respiratory effects, such as a cough and sore throat. Moreover, combined with SO_2, it may aggravate bronchitis, asthma and emphysema (Elsom 1996).

The NO_x emissions in Shanghai have been below the WHO average annual guideline of 150 $\mu g/m^3$ and the Chinese ambient air quality standard for resident urban areas of 100 $\mu g/m^3$ for urban areas. However, unlike the TSP and SO_2 emissions, the NO_x emissions in Shanghai have quickly increased in the past 15 years except for several minor decreases (see Figure 3-2). The emissions of NO_x in the 1996 were almost two times the emissions in the middle of 80's. Compared to other major cities in China, Shanghai was the best city in 1985 for NO_x emission, but became one of the worst cities in 1995 (Figure 3-4).

Figure 3-4 NO_x Emissions in Major Chinese Cities



Sources: World Bank data and SMEPB

3.2.2 Waste Gas Emission

Waste gas is defined as the gas from industrial process that are exhausted to the atmosphere. With the rapid industry growth, the total waste gas emissions increased annually. The major pollutants in the waste gas were SO_2, smoke and dust, and industrial dust. There were 464,000 motor vehicles in Shanghai in 1996. It is estimated that 70% of the automobile exhaust emission was in compliance with the national standard accounted. Among the vehicles, which exceeded the emission standard limits, nearly 90% were due to CO, 25% were due to hydrocarbon, and 15% were due to both of CO and hydrocarbon (SMEPB 1997).

3.2.3 Air Pollution Control

The industry function layout and structure of Shanghai was adjusted by moving the polluting factories away from the center of the city, lowering the industrial emission in the urban areas. Highly efficient precipitators with multi-barrel were installed in use to reduce the air pollution caused by inefficiency. In households, utilization gas was popularized along with the amelioration of the housing conditions, improved the indoor air quality. Furthermore, to cut the emissions in the transportation, a plan for equipping exhaust emission purification facilities in motor vehicles was successfully executed.

3.3 Status of Water Quality

For a long time, the slow growth in urban areas has constrained the provision of essential urban water services, which are now inadequate for a city of such economic importance and size. Under the pressure the rapid industrial growth and the increased use of chemical fertilizers and pesticides, the river and groundwater in Shanghai has been worsening. Almost all the rivers around the city are heavily polluted. Moreover, the solid waste disposal facilities are overburdened, and the nightsoil system serves some 4 million people daily. The nightsoil system is seriously at risk due to a lack of disposal facilities. These problems directly affect the raw water supply for Shanghai, most of which is drawn from an intake located in the center of the city on the lower reaches of the Huangpu River. In addition to industrial and domestic wastes, water quality at this intake is exposed to the thousands of ships and barges that use the surrounding waterways daily. These ships and barges discharge liquid and solid wastes into the waterways daily. Water quality currently fails to meet WHO and Chinese standards and is deteriorating. Water passing into the supply frequently contains toxic chemicals including known carcinogens, at levels causing taste and potential health problems.

The urban drinking water is a serious problem in Shanghai now. Although drinking boiled water reduces the incidence of illness due to polluted drinking water, some problems still exist because some intestinal worms and toxins cannot be eliminated thoroughly through boiling. Moreover, poor water quality also threatens the future of industrial growth, especially the electrical and biotechnology industries, for which the clean water is a necessity.

3.3.1 Quality of Aquatic Environment

The major river in the urban area of Shanghai is the Huangpu river, which divides Shanghai into two major parts, Puxi and Pudong. The former is the old urban area of Shanghai, while the latter is the new developing zone. The city is dependent on the river as a major source of its water supply. However, most of the river is grossly polluted. According to the Shanghai Environment Bulletin, although the water qualities of Huangpu river have remained relative flat in the past several years, it was slightly worse in 1996 than in 1995. The main pollutants in the surface water of Shanghai are chemical oxygen demand (COD), unionized ammonia, total phosphorus, and petroleum (SMEPB).

Considering the major water standard such as Dissolved Oxygen (DO), the rivers in other industrialized cities all exceeded the 9 mg/L, which satisfied the Category I of the Chinese surface water quality standard. In contrast, the Huangpu River only met the standard requirement of Category III (Table 3-2).

Table 3-2 Water Quality of the River in Selected Mega-cities

Unit: mg/L

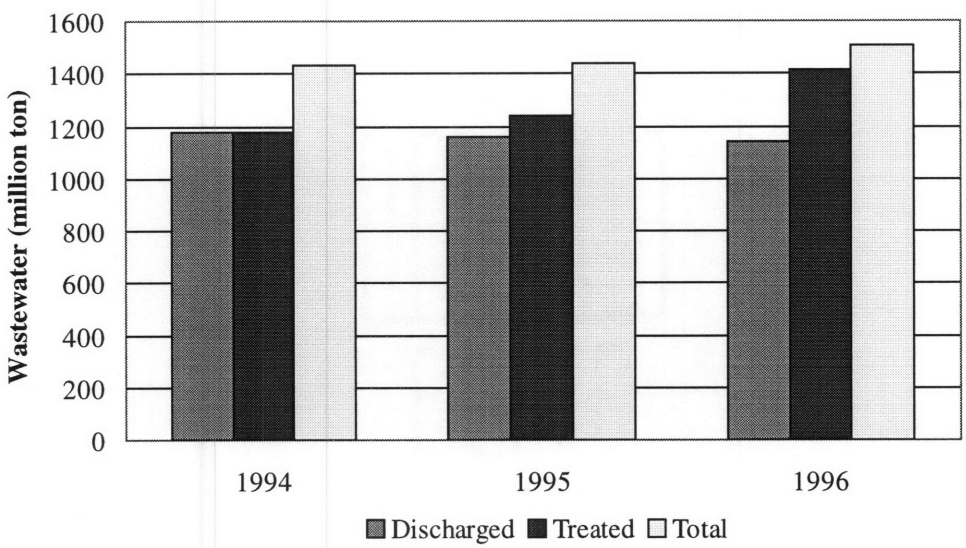
City	River	DO	BOD	Total Oxogen
New York	Hudson River	9.4		0.59
Paris	Seine River	9.8-11.0	04-Feb	
London	Thames River	9.9	2.4	7.52
Shanghai	Huangpu River	4.53	3.41	3

Source: Tian, 1996

3.3.2 Wastewater Discharge

The industrial effluent discharge in Shanghai has decreased slightly in the past three years, while the increase rate of industrial effluent subjected to treatment before being discharged amount far below the industrial growth. The rate of the treated industrial effluent has increased obviously (Figure 3-5). In 1996, the industrial effluent discharge per thousand RMB of production value was 4.32 tons, while in the city proper it was 3.89 tons. The main pollutants in the industrial effluent were Chemical Oxygen Demand (COD), Petroleum, Cyanides, Hexavalent, Arsenic, Lead, etc (SMEPB 1991-1997).

Figure 3-5: Industrial Wastewater Effluent in Shanghai, 1994-1996



Source: Shanghai Environment Bulletin

3.3.3 Water Pollution Control

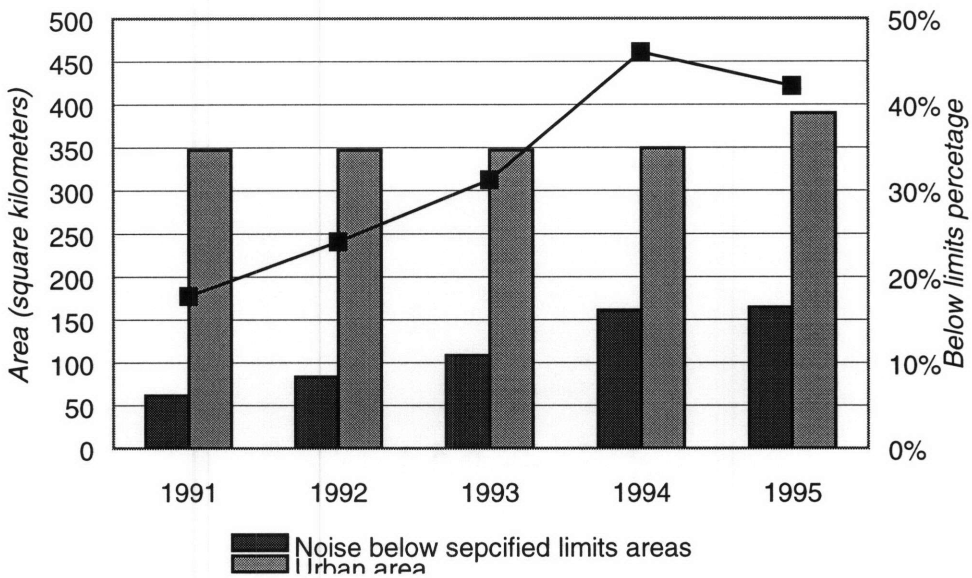
Facing the serious polluted water, the municipal intensified the supervision and management on wastewater discharging units along the Upper Huangpu River, where the major source of the drinking water for the city residents occurs. Meanwhile, the Municipal Government has intensified the comprehensive rehabilitation at Suzhou Creek, which a notorious dirty and smelly river across the urban area of Shanghai. The rehabilitation tried to solve the problem both on the surface and at the root.

3.4 Noise

Shanghai is also a noisy city. The high noise levels in the city can be ascribed to several causes. The most significant are traffic and construction noises. In 1996, the vehicle volume on the main roads in Shanghai during daytime was 1,509 vehicles per hour; at night it was 628 vehicles per hour. The average equivalent sound levels have slightly risen annually due to the increased traffic volume in the cities. Monitoring results indicate that the average equivalent sound levels during daytime were 72.6 dB(A), which exceeded the national traffic noise criterion of 70dB(A). Moreover, the night traffic noise increased to 66.7 dB(A), suggesting a high possibility of sleeping disturbances (SMEPB 1997).

The traffic noise mainly consists of horn honking, or simply “horning”. To control the traffic noise, some forbidden areas have been set up to minimize the horning occurrence by motor vehicles in the center of the urban areas. Additionally, with the dramatic increase of construction sites, construction noise has become another main source of noise. Management of construction site work has been intensified, so that construction work at night was forbidden unless a special application is submitted and officially approved by the local authorities. The areas with noise below the specified limits have steadily increased in the past five years, which now cover about half of the whole urban area (Figure 3-6).

Figure 3-6: The Noise Situation in Shanghai, 1991-1995



Source: Shanghai Environment Bulletin

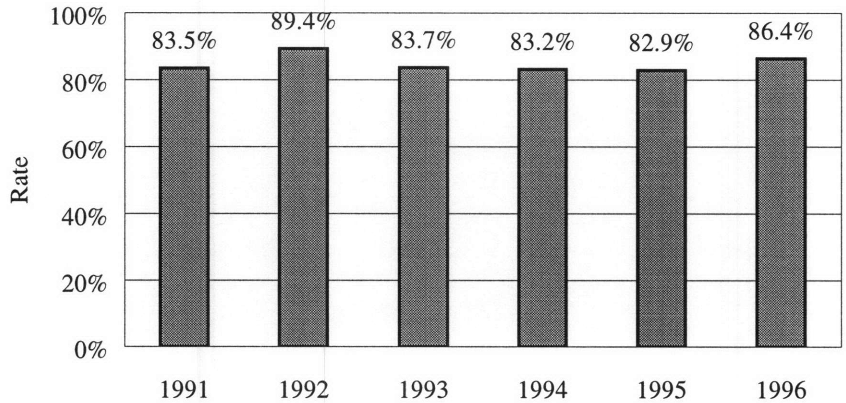
3.5 Solid Waste

3.5.1 Industrial Solid Waste

Although industry has grown rapidly, the amount of generated industrial solid wastes has begun to decrease in 1996 due to stringent industrial solid waste control.

Furthermore, the comprehensive reutilization rate increased in the past three year, with a 86.4% rate in 1996 (Figure 3-7).

Figure 3-7: The Re-utilized rate of Solid Waste in Shanghai, 1991-96



Sources: Shanghai Environment Bulletin

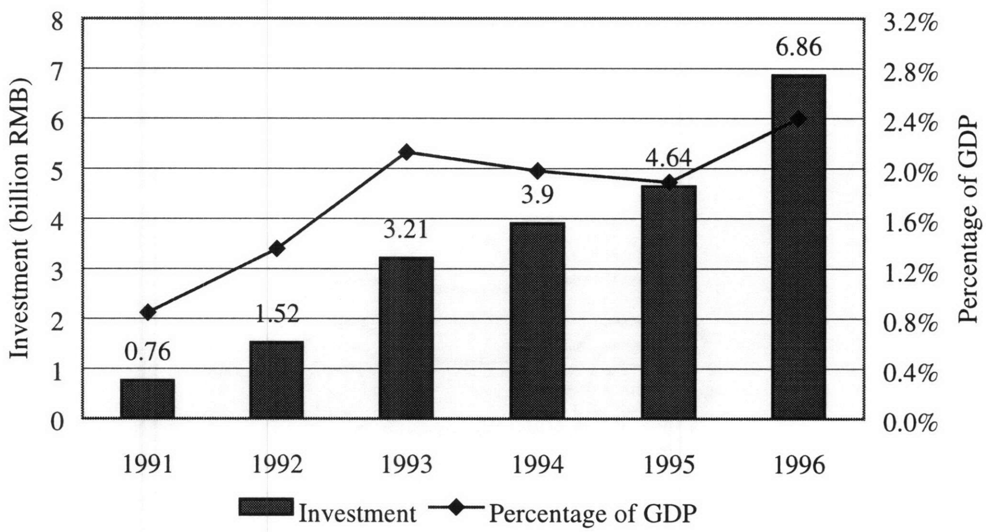
3.5.2 Household Waste

With the income growth, the residential consumption in household has increased rapidly. As a result, household refuses risen quickly, which increased over 10% annually in the past several years. The harmless disposal rate was near 80%.

3.6 Environment Protection in Shanghai

To meet the target of sustainable development, the investment for environmental protection increased quickly in Shanghai in the 90's, which has increased faster than the economic growth. Most of the funds were invested in the pollution control of existing sources such as relocation of the polluting factories, environment protection investment of new projects, urban environmental infrastructure, regional environmental comprehensive rehabilitation, and operation and development of the environmental institutions (Figure 3-8).

Figure 3-8 Investment for Environment Protection



Source: Shanghai Environmental Bulletin

After the compilation of "Shanghai Total Pollution Load Control Solution for Emission of Major Pollutants" which was finished in 1996, the municipal made clear and definite the approach to implementing pollution load control. To carry out the total loads control, pollutant discharging units all over the city were registered, which subjects to data check and collation, computer data input, etc. Moreover, one focal point of environmental protection work in Shanghai is to implement a green project. Of those listed in National Green Project of Trans-Century Program, the major green projects includes: the complementary facilities of the Combined Sewerage Project Phase I concerning Suzhou Creek, Shanghai Sewerage Project Phase II, Suzhou Creek Comprehensive rehabilitation Project, domestic refuse incineration plant, projects of district heating, desulphurization projects in power plants, comprehensive control projects of livestock wastes, secure landfill site and incineration project for hazardous wastes, etc. Meanwhile, many environmental impact assessments of major municipal projects were conducted to ensure that the projects turn a benefit to the citizens, without negative impacts on the environment.

Based on the urban environment comprehensive rehabilitation quantitative examination, which was announced by the National Environmental Protection Agency (NEPA), the total score of 20 comprehensive indices has risen up in the past several years. The ranking position of Shanghai had accordingly gone up. Meanwhile the score of pollution control index was keeping the No.1 among all of the 37 examinated cities (SMEPB 1997).

Chapter 4 —Infrastructure Development

4.1 Introduction

Infrastructure was the structures and networks that framed the modern cities and made it possible to undertake the social and economic activities. It included the energy supply and distribution facilities, the transportation networks, the water and sewage lines, the waste disposal systems, and the public buildings and parks.

Since the beginning of 1990s, Shanghai has invested an enormous amount of capital, materials and manpower resources into public infrastructure projects. During the 1978-1997 period, Shanghai pumped a total of 182.762 billion RMB into such projects, representing an average annual increase of 26.5%. For the 1991-97 period, the figures were 157.377 billion RMB and 39.9%, respectively. So, investment into infrastructure projects in the last seven years accounted for 86.1% of the city's total since the adoption of the reform and opening policy. As a result, the urban infrastructure development was promoted in Shanghai.

However, rapid economic development in Shanghai had increased demand for power and other infrastructure facilities. The energy shortage, traffic congestion, the poor drinking water quality, and outdated sewage and waste disposal systems were becoming the major threats of the sustainable development of the city.

4.2 Energy

Energy is a critical factor in the urban sustainable development in Shanghai. The demand for energy consumption is notably increased with the rapid economic growth. On the other hand, coal-based energy consumption also has important impacts on the urban environment, which is the main cause of Shanghai's air pollution and acid deposition. In 1996, Shanghai consumed 41.82 million tons of coal (SMPC 1997a). Without any coal reserves in Shanghai, all the coal needed are imported from other province, which also worsen the already serious rail transportation problem.

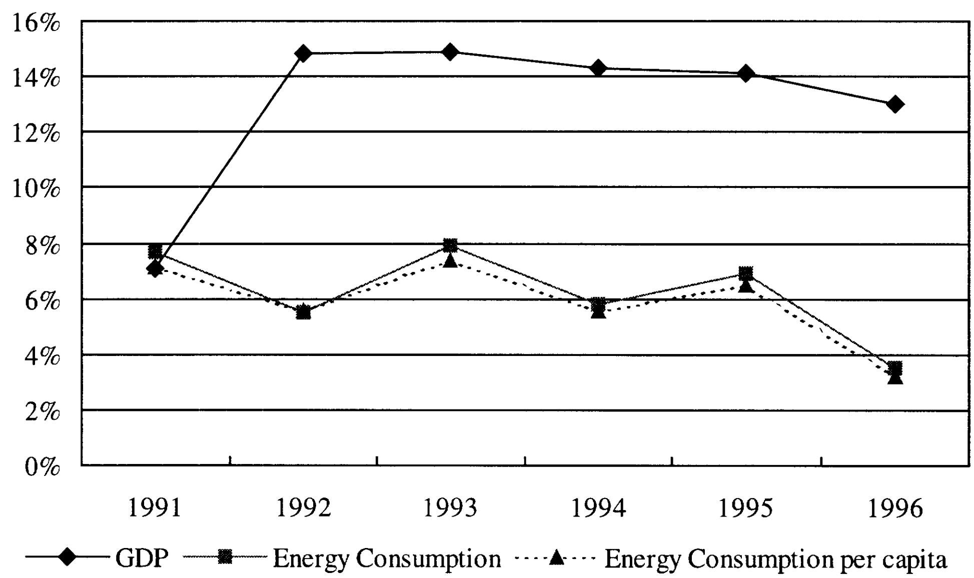
4.2.1 Energy Consumption

With the economic growth, the energy production and consumption is increasing rapidly. In 1996, the total energy consumption increased from 34.67 million tons of coal equivalents (MTCE) in 1991 to 42.66 MTCE in 1996, with the average annual growth rate of 6%. But at the same time, the average annual growth of GDP was nearly 14% (Figure 4-1). So Shanghai achieved the rapid economical development with relative low energy consumption.

The two most prominent features of energy supply and demand in Shanghai are the city's heavy dependence on coal and the industrial sector's dominance in final energy consumption.

The coal's share in primary energy consumption in the city increased from 66% in 1990 to 72% in1995. By contrast, the coal consumption accounts for only 25% in the USA and the former Soviet Union (WRI 1996).

Figure 4-1 Energy Consumption and Economical Development in Shanghai



Source: Shanghai Energy Bulletin 1997

Among the energy consumption in Shanghai, the industrial and transportation sector is the most important consumers. Their key sources of energy are electricity, coke and coal. The industry and transportation alone account for more than 75% of the total energy used in Shanghai. For energy type, electricity is the most important energy source, which is widely used by almost all sectors. Furthermore, while the commercial and services sector account for only about 15% of the total energy consumption, it used a large share of petroleum products. (Table 4-1)

Table 4-1 Final Energy Consumption in Shanghai, 1995

Unit: Millions of tons of coal equivalents

	Agriculture	Industry/ Transportation	Services/ Commerce	Household	Total
Coal		15.7%	0.6%	4.3%	20.8%
Coke		19.5%			19.5%
Fuel Oil		6.5%	3.1%		9.7%
Gasoline	0.6%	1.2%	1.6%		3.3%
Kerosene		0.1%	1.5%		1.6%
Diesel	0.5%	1.4%	3.2%	0.1%	5.1%
Other Oil		3.7%	0.1%		3.8%
Electricity	1.1%	27.7%	4.5%	2.9%	36.2%
Total	2.2%	75.7%	14.7%	7.3%	100%

Source: Shanghai Energy Bulletin 1997

Another important fact in the final energy consumption is the rapidly increase of electricity generation and consumption. The electricity shortage also becomes a major problem in Shanghai. Despite of the rapid growth, the electricity generation still cannot meet the increasing demand. In 1996, the electricity generated in the city was about 40 billion KW-hours, nearly 3 billion less than the demand.

For electricity usage, Shanghai has a large industrial share and relatively small commercial and household share, compared with the industrialized countries. However, the sector pattern of the energy usage is becoming more like that in industrialized countries, since the consumption growth in the commercial and household sectors are far more rapid than the industry sector (Table 4-2). The income of the household in Shanghai has considerably increased with the economical development, which accelerates the purchase and utilization of the domestic electric appliances, such as TV, refrigerator and air conditioners, etc. As a result, electricity becomes an important factor in daily life. On the other hand, the modernization of industrial plants has also increased the electricity demand, because more new electronic equipment installed.

Table 4-2 Electricity Generation and Consumption in Shanghai

Unit: billions of KW-hour

	1990	1995	1996
Total Generated	24,105	37,130	40,334
Total Consumed	26,474	40,327	43,040
Agriculture	0,722	1,394	1,282
Industry/Transportation	22,253	31,413	32,566
Commercial/Services	2,055	4,492	5,712
Household	1,444	3,028	3,480

Source: Shanghai Energy Bulletin 1997

4.2.2 Environment Impacts

The combustion of coal results in exhaust smokes containing carbon dioxide (CO_2), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx) and particulates. Because coal is main energy resource in Shanghai, it has caused severe environmental problems. The situation has even worsened because most coal used in Shanghai is raw coal with high sulfur content. In China, the average sulfur content of coal is 1.25-1.35%, and an average 20% ash content. Because of the high ash content, the heating value of the coal is low, less than 21 mega-joules per kilograms. By comparison, most internationally traded coal has 25% more heating value per kilogram, 25-50% less sulfur, and 50% less ash (World Bank 1997). Due to the high content of sulfur and ash, the emissions form the burning coal in industry are the main sources of ambient air pollutants. Burning one thousand kilogram coal directly will produce 4.9 kg SO_2, 0.2-2.2 kg CO, and 200-250 kg dust. It is estimated that the industries account for 81% and 78% of the total SO_2 and particulate emissions respectively (Chu and Zhao 1997).

4.2.3 Energy Development Strategies

Solving the environmental problems related to the production and consumption of energy is complex. Due to the national energy structure and economical limitation, coal as the main primary energy in Shanghai will not change in a short period. It is clear that the essential reasons of environmental problems caused by energy in Shanghai can be ascribed to the low energy efficiency, high dependence on coal, and high level of emissions.

The serious air pollution problems related to the energy in the city can be improved through improving energy efficiency, diversifying energy supplies, and controlling emissions.

4.2.3.1 Energy Efficiency

Energy inefficiency was a major challenge in Shanghai, as the city had suffered an energy shortage for a long time. To achieve a sustainable development, the city needs to pursue a more efficient use of energy. Although, the energy consumption has increased substantially in the past decade, the energy intensity in Shanghai declined sharply, with an average annual rate more than 15% (SMPC, 1997a). However, the energy intensity in Shanghai has remained higher than that of the industrialized countries. In 1996, the energy consumed per $1,000 GDP in Shanghai was 1.32 TCE, while it was less than 0.3 TCE in OECD countries (IEA 1994). This implies a considerable potential for reducing the energy intensity.

Most industries in Shanghai consumed more energy to produce a unit of final product than in industrialized countries (Yu and Shen 1997). Old equipment and the outdated technology mainly cause the high-energy intensity in the industry sector. Since industry accounts for about three-quarter of the total energy consumption, renewal of equipment and technology innovation can play an important role in the energy conservation.

The biggest wasters of energy are industrial boilers and kilns, most of which burn coal directly. While modern boilers typically operate at 75 to 80% efficient, Chinese boilers average about 55 to 60%. Chinese kilns operate at the 20 to 30% range, while 55 to 60% in the industrialized countries (Smil 1988). Replacing and refitting small and outdated industrial boilers alone could save a large amount of raw coal. Moreover, by using catalysts and changing boiler designs to reduce combustion temperatures, it is possible to abate around 90% NO_x emission (Anderson 1996).

Another potential approach is to restructure the economy. The energy saving can be achieved through further structural shifts toward high value-added and low-energy-intensity products. Although the contribution to the GDP by commercial and service sector was very close to that of the industrial sector, it only consumed one-fifth of energy as the industry did. In Shanghai, the commercial and services sector showed a substantially increase in the past years. With an increasing role for the commercial and service sector in the economy, energy efficiency will be improved.

4.2.3.2 Cleaner Coal and Diversifying Supplies

Since a large amount of the air pollutants are caused by coal burning. introducing cleaner coal and diversifying the energy supply with cleaner resources can have a positive affect on the urban environment.

Among the total coal used, about a quarter coal used in Shanghai is washed coal, while most is used in metallurgy. As a result, very few steam coal is washed in Shanghai, compared with about 45% in USA and more than 75% in Europe (SMPC, 1997a). Encouraging the use of washing coal for industrial boilers can bring major reductions in air pollution.

Meanwhile, since electricity generation accounts for almost half of the total coal consumed, importing coal for electricity production and transmitting electricity directly from other provinces is another feasible approach to cut down the coal consumption in Shanghai. According to research made by the Shanghai Environment Protection Institute, the ambient air quality will have a notable improvement, if the coal share is cut down by 50% (Chu and Zhao 1997). By participating in the investment of the large-scale nuclear and hydroelectric power station projects in adjacent provinces, (e.g. the Qing shan nuclear power station and three gorges project), Shanghai can share the generated electricity. Assuming half of the electricity demand is met by the external sources, it can save 25% of the total coal consumed in Shanghai. Thus the coal share in the total primary energy will drop to nearly 50%.

Another efficient measure to improve the air quality in Shanghai is introducing the use of much cleaner energy, such as natural gas and liquid petroleum gas (LPG). Natural gas is the cleanest burning fossil fuel. When natural gas is burned, it emits less CO_2 than oil or coal, almost no SO_2, and only small amounts of NOx. Since about 10% of the coal is used to produce the gaseous fuels, a large amount of the coal could be saved by substituting with natural gas or LNG for such fuels. Considering that the cost of purchasing the natural gas or LPG in the international market is very close to the cost of the gaseous fuel production in Shanghai, it is financially feasible.

4.2.3.3 Controlling Emissions

Since Shanghai is located out of the central heating area delimited by the central government, heating in most buildings is provided by small and medium-size industrial boilers, most of which burn coal directly. With the average heating efficient of only 55%, such boilers have consumed 4.6 million tons of coal, which causes much of the air pollution. Since a central heating system can increase the heating efficiency to 70%, a large amount of the coal consumption will be reduced by updating the boilers with such systems.

Although coal consumption has been reduced, emission from the household sector still plays an important part in emissions control. Indoor air pollution could be almost entirely eliminated by substituting gas for the fuels now used in cooking (Anderson 1996). Enhancing the gaseous fuel usage in households is perhaps the most feasible and efficient means to improve the indoor and ambient air quality. Although the household gaseous fuel usage soared from 57% in 1990 to 87% in 1995, about 450,000 families still use coal for cooking now. If gaseous fuel replaces coal in all such families, the result may be a decrease of 32.1 thousand tons of SO_2 emission and 73.8 thousand tons of ash dust per year. The heating efficiency reaches 55%-60% (Wu 1997).

4.2.4 Energy Pricing and Tariffs

Although Shanghai suffers from an energy shortage, much energy is wasted. On one hand, the shortage of energy, particularly that of electric power, has already affected the city's economy and residents' living standards; on the other hand, due to inefficient management, low levels of technology, and low energy prices, there is considerable waste in utilizing energy resources. The setting of appropriate energy prices and tariffs can have a strong impact on reducing pollution by giving the right signals to customers in terms of energy conservation and rational use of energy (OECD 1995). Energy consumption has subsidized by the government for a long time, especially electricity. Due to the subsidies, the fixed electricity price in Shanghai is well below the cost of production, which has exacerbated electricity shortage and waste. With increasing household electricity consumption, the government suffered a huge financial burden. Moreover, with the current quota policy for industrial users, the energy accounts for a negligible part of the total operation costs. Thus, there has been little incentive to consume less than the full energy quota (Levin, Liu and Sinton 1992). Eliminating irrational subsidies and increasing energy prices to reflect actual economic and environmental costs is necessary to promote energy conservation.

4.3 Transportation

Urban transportation is a key area of infrastructure investment, construction and management, which is closely linked with the urban economic development. The movement of great numbers of people and the increased circulation of goods and materials, combined with an increase in the number of motor vehicles, traffic problems are becoming a major issue in Shanghai. Although the urban roads have been significantly improved during the past years, Shanghai find it increasingly difficult to deal with the rapid traffic growth, which has lead to the problems of congestion and long travel times. Furthermore, transportation is also critical to the urban environment, as motor vehicles are a significant source of urban air pollution.

4.3.1 Transportation Situation

In the mid-80's, transportation problems became the major obstruction to the economic development of Shanghai. The transportation infrastructure in Shanghai was initially not designed for mostly motorized traffic, since only a small percentage of the city's urban area was devoted to roads. Moreover, the urban area of Shanghai almost had the highest population density in the world. The road area per capita was only 2.2 m^2, which was relative low in comparison of the cities in the industrialized countries, while the road area per capita is 10.5 m^2 in Tokyo and as high as 28 m^2 in New York city (Sun 1997).

Driven by the economic growth, Shanghai's motorization has been gathering momentum. The city's entire motor vehicle fleet has almost tripled in the past 10 years (Table 4-3). Among the motor fleet growth, the passenger vehicle fleet has grown far more rapidly than the goods vehicle fleet. In 1994, more than half of the city's motor vehicles were passenger vehicles, while only one-third belonged to this category ten years ago.

Meanwhile, due to the poor public transit system, the demand for private automobile ownership and use will rise. Privately owned automobiles have had a steep rise in recent years. However, compared to other major cities in China, the car ownership is somewhat lower in Shanghai, with about 15 cars per 1,000, while it is more than 24 per 1,000 in Beijing and 21 in Guangzhou (Stares, Stephen and Liu 1996).

Table 4-3 Shanghai's Vehicle Fleet

Year	Total Vehicles	Passenger Vehicles	Other Vehicles	Private Automobiles
1985	94,400	26,000	68,400	60
1990	147,700	54,600	93,100	1,500
1994	270,200	141,700	128,500	4,000

Source: Shanghai Municipal Statistics Bureau

Another important aspect of the growing motorization in Shanghai is the dramatic growth of the petrol-driven moped, which has become a favorite transportation mode over the past three years. As a result of the reconstruction of the urban area, millions of people moved from the downtown to the urban fringe. Without sufficient public transportation, the private transportation has increased. With a price tag ranging from $400 to $1,500, a moped is much cheaper than a car or motorcycle and does not require the rider to have an automobile license. The moped has become a popular replacement of bicycles due to its fast speed, small size and easy operation. It has become another important transportation mode in just three years.

The rapid vehicle fleet growth has increased the demand of the transportation facilities, especially the roads and parking spaces. Since the end of the 1980's, the municipal government has substantially increased the investment on road construction. The total length of urban roads increased to 3008 kilometers in 1995, which was almost doubled the 1631 kilometers in 1990. During the same period, the total urban road area reached to 34.34 millions m^2, which represents an impressive annual average growth of nearly 14%. The road area per capita also rose from 3.38 m^2 to 3.59 m^2 (SMCC, 1996). Furthermore, with the building of the new ring roads and widening the important street, the road network was initially set up.

However, the expansions of the transportation infrastructures have been generally outpaced by the explosive increase of the vehicle fleet. Because of the urban land constraints, the growth of length and area of urban roads will not be higher than that of the previous years.

Consequently, road construction has not kept up with the growth of vehicle usage, leading to increased congestion and much lower average driving speeds. Moreover, most roads in the center area are narrow, so motor vehicles have to share them with mopeds and bicycles, which further worsens the situation. In the downtown area, the average speed of motor vehicles is around 15 kilometer per hour, while it is 5-7 kilometer during rush time traffic.

In recent years, the municipal government has become zealous in the investment of large-scale, high-standard transportation facilities, such as elaborate interchanges, viaducts, large bridges and urban ring roads. Such projects are helpful to meet the demand of economic development and traffic growth. However, expanding the road network is rarely an adequate solution. In very dense cities such as Shanghai, additional road construction in urban areas requires destroying existing buildings and displacing informal settlements. Therefore, road construction implies not only huge construction costs but also enormous relocation costs. For example, the newly constructed ring road has only two lanes in each direction, instead of three lanes as many transportation planners proposed. There are fewer lanes because the relocation cost would be too high for the municipal government to afford. More importantly, any increase in road capacity tends to be quickly swamped by new travel. Hence, with this policy, the government has not solved the current congestion problems.

4.3.2 Public Transit vs. Private Transportation

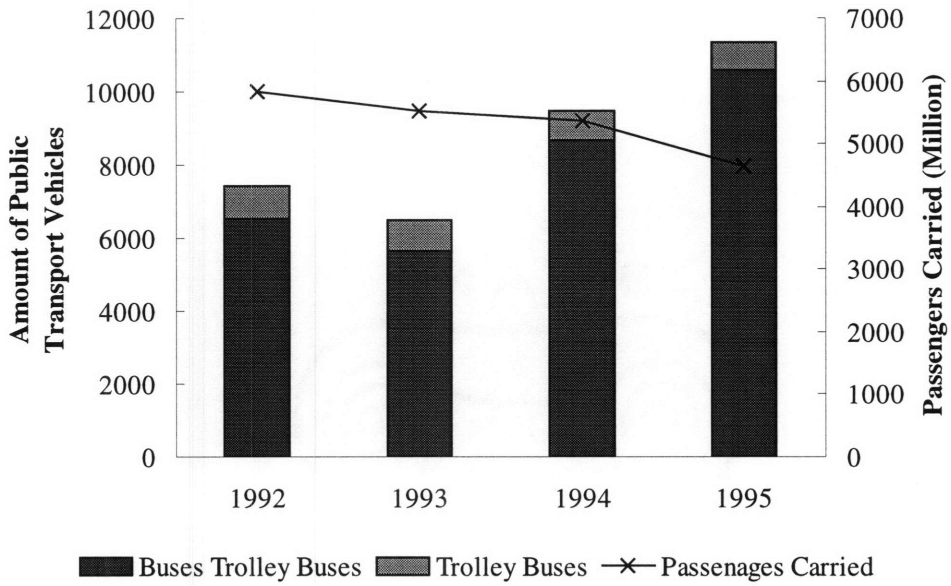
To solve the escalating urban transportation problems in Shanghai, development of the public transit system is the perhaps most effectively strategy to alleviate the transportation pressure.

In Shanghai, a large scale of urban public transit is the state-owned bus service system (including trolley buses). In the mid-80's, they once carried 75% of the total ridership of the city, with almost 15 million person-time per day. Although the municipal government made the policy that the urban public transit should have the priority, the total public transportation vehicle fleet increased about 50% in three years, from less than 7,500 in 1992 to more than 11,000 in 1995. While the total ridership continued to increase, the passengers carried by the bus services declined more than 20% over three years. By 1995, they held only about a quarter of the total flow till1995 (Figure 4-2).

Several factors caused the decline of the bus services. Because of the low fare, public transportation largely depends on government subsides. Thus, it lacks the incentive to improve its service. Congested urban roads also erode the performance of the public transportation, with long delays between buses and unpredictable travel time. The average speed of the public buses now is only about 5-10 kilometer per hour, while it was 14 kilometer in 1995 and 19.1 kilometer in 1985. The increased capacity was almost offset by the declining efficiency. Due to poor operation efficiency and service quality, people are lured away from the public transit by automobiles, mopeds, and bicycles.

Meanwhile, taxi services have become an important alternative transportation mode. In 1995, there are about 37,000 taxis, compared to only 18,000 three years ago. With the increase of income, taxis have become affordable and popular, which has further accelerated the decline of the public transit services.

Figure 4-2 Public Transportation Vehicles and Passengers Carried, 1992- 1995



Sources: China Statistics Yearbook, 1993-1996

As congestion is frequently the result of an insufficient road network, expanding the current road capacity in Shanghai is necessary. Yet, the construction of the new road facility cannot solve the traffic problem completely. Even the planned road network with elaborated roads and ring roads in the urban area completed, it would only meet the demand of the motor vehicles in the short run. However, since the motor vehicle fleet increased almost 50,000 annually, the road facility will find it difficult to deal with the continually expanding fleet. On the other hand, there are more than 7 millions bicycle and 460,000 mopeds on the streets, which have occupied a large part of the already limited road resource and affected the operation of automobiles. Since efficient public transit could result in less dependence on private transportation, it is very important to develop an efficient public transit system to attract the resident away from the private transportation mode. The experience in U.S. cities indicated that the higher the urban density, the greater the share of the work trip was made by public transportation. In New York, which is the densest city in U.S., the public transportation accounts for more than half of the total work trips (U.S. Bureau of the Census, 1994). Since the population density in the central area of Shanghai is far more than that of New York, it is important to expand the public transportation.

Moreover, private transportation modes are much less efficient in the use of road capacity, more expensive and more harmful to the urban environment (see Table 4-4). According to the observations made in Shanghai, the road capacity required for each automobile can accommodate roughly 4-5 bicycles or 15-20 transit riders (Shen 1997). Thus, developing an efficient public transit system, which uses less road space and emits fewer pollutants, should be a priority In Shanghai.

Table 4-4 Capacity, Cost and Emission of Various Transportation Modes

Mode of Transportation	Persons per Hour per Lane	Total Cost per Passenger Kilometer (US$)	Total Emission per Passenger Kilometers (grams)
Walking	1,800	Negligible	-
Bicycle	1,500	-	-
Motorcycle	1,100	-	27.497
Car	500–800	0.12–0.24	18.965
Bus			
Mixed traffic	10000–15000	0.02–0.05	1.02
Bus-only lane	15000–20000	0.02–0.05	0.89
Separate bus way	30,000	0.05–0.08	-
Rapid rail transit	50,000		
Surface (coal)	70,000	0.10–0.15	4.9651
Elevated (gas)	70,000	0.12–0.20	0.2307
Underground (fuel oil)		0.15–0.25	0.7102

Source: United Nations, 1994;The World Bank, 1986;.Asif Faiz, 1990

Facing intolerable traffic congestion, Shanghai needs to improve its traffic management and support the development of an efficient public transit system. Among all transportation modes, the rapid rail transit, such as subway, appears as the most attractive solution to the traffic congestion, because it can carry more people with high mobility and can be built underground which involves a relatively small displacement of residents. Furthermore, it is an environment-friend choice, as it emits relatively fewer pollutants.

Considering the advantage of such system, the municipal government in Shanghai has planned to build a rapid rail network, which features seven lines. The first subway line was completed in 1995 and the second one is under construction now. But the subway length in Shanghai far below that of other mege-cities (Table 4-5).

Table 4-5 Operating Subway Length in the Mega-cities

City	Shanghai	Tokyo	New York	London	Paris
Length in km	16	246	420	394	302

Source: Iwai, 1998

Although the subway system is an efficient transportation mode, the construction costs of such system are huge, while is even higher in Shanghai due to the complicated underground condition. Meanwhile, even if the financing sources are secured, it will take perhaps 20 years to complete the entire subway system as proposed (Pendakur 1993). For now, the contribution of the subway to the total transit supply has been quite limited because the small capacity.

Consequently, the feasible public transit development in Shanghai has been primarily based upon buses now. But, as long as buses run on the same congested streets as other vehicles, they will never be an attractive alternative for those who can afford a taxi or even a car. An effective way to increase bus ridership is to give buses priority in traffic. By giving buses priority over private traffic, more people will turn to buses as a fast and efficient alternative.

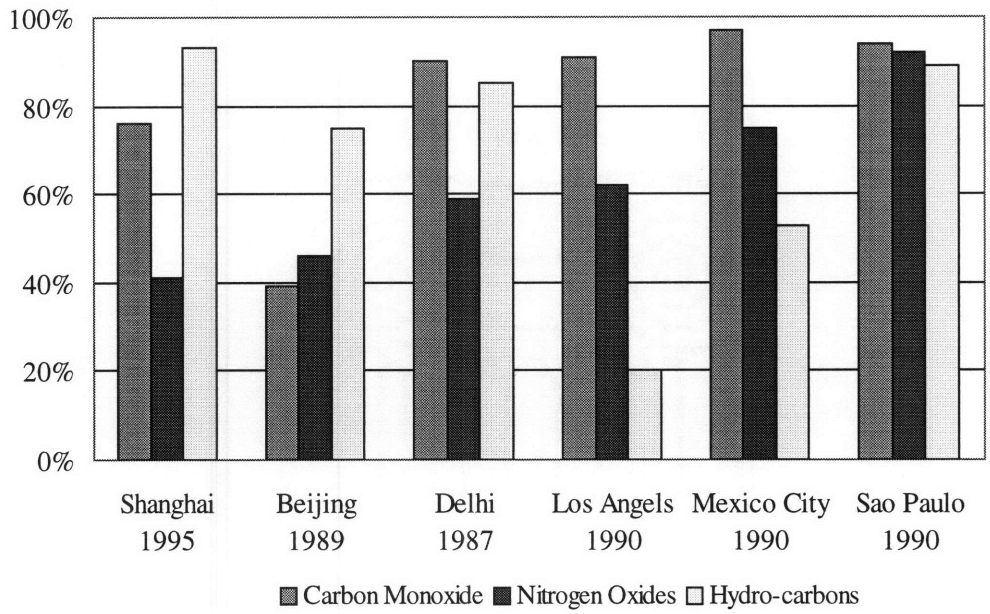
One of the potential approaches is reforming the current mixed traffic system. Although most roads in downtown area in Shanghai are too narrow to implement the bus-only lane, separating buses from other traffic is possible to increase the speed of the bus services. It is estimated that a separated bus way can move twice as many people per hour as buses operating in mixed traffic and 40 times as many people per hour as cars.

Cutting down the total traffic flow in the congestion area is another possible approach. Shanghai had tried license number restrictions to reduce the number of cars in the city and thereby reduce congestion and air pollution. But, such a plan has not been effective as proposed, since many drivers have switched license plates to meet their mobility needs. The experience of the other cities has indicted that a type of area pricing may be the most practical solution, in which drivers must pay to enter a specific area. The goal is to encourage people to use public transportation modes. Singapore's area licensing scheme is a well-known practice, which seeks to reduce traffic into the city center by charging vehicles a fee when they enter the area. Since its inception in 1975, the plan has both reduced congestion and stimulated the use of public transportation, at a modest cost. Meanwhile, the practice in Hong Kong and Singapore showed that license fees and gasoline tax are another effective economic incentive to discourage the use of personal vehicles. Thus, the municipal government in Shanghai should use an economic incentive such as road pricing rather than the regulatory one.

4.3.3 The Threat to Environment

Pollution in the city is getting worse due to discharges from vehicles and industries and dust from construction sites. Exhaust emissions from road traffic have become one of the main factors detrimental to the local air environment in most large cities, and its contribution will increase without new effective policies (Figure 4-3).

Figure 4-3 Contribution of Motor Vehicles to Urban Air Pollutant Levels



Sources: 1. Shanghai Environmental Bulletin, 1996
2. Faiz, Sinha, Gutam, 1995

The current vehicle fleet in Shanghai is highly polluting, in part because of outdated vehicle designs and inadequate emission standards for new vehicles. Vehicles do not require catalytic converters to meet current standards. Moreover, Chinese standards for cars allow forty times more carbon monoxide, six times as many hydro carbons, and eight times as many nitrogen oxides than U.S. Motor cycle standards. They are even more lax for cars, and standards for mopeds are similar to those for trucks (World Bank 1997b). Although some of the vehicles are manufactured under the standard of developed countries, a large portion of domestically manufactured Chinese cars are designed and built with the technologies that are more than 20 years old. As the result, they may emit 10 to 20 times as much CO, hydrocarbons (HC), and nitrogen oxides as those controlled vehicles in the United States or Japan. The slow vehicle speed caused by the road congestion also results in high fuel consumption, leading to high levels of emissions.

Another threat to the urban environment is the trend of increased diesel engine buses. Recently, in order to increase profits, a lot of bus companies have replaced the gasoline bus with a diesel engine, because diesel is cheap. Since the quality of China's diesel fuel is poor – with low stability and high aromatic content – diesel buses emit high levels of particulate and smoke. Also, the emission standard for diesel-fueled engines is weak, covering only tailpipe smoke and not particulate and nitrogen oxides.

Besides the automobiles, the petrol-driven moped has become another major source of the air pollution and noise. As mopeds are classified as non-motor vehicles, they are confined in the low speed lane, which is close to the sidewalk. Because of its proximity to people, its emission is more harmful to the health of the pedestrians than motor vehicles. In consideration of the pollution caused by the mopeds, the city government announced last year a total ban on issuing moped licenses and hope to reduce the number of the vehicles in the street. But without the severe punishment, such a policy may not constraint the growth of the moped traffic effectively.

4.3.4 Emission Control

As cities try to discourage private transportation and shift travel to public transit, they can also take a number of measures to improve air quality by reducing vehicle emissions.

4.3.4.1 Unleaded Fuel

Motor vehicles are a significant factor in lead emissions. Introducing the unleaded gasoline will reduce the chances of lead poising. Besides being a direct health threat, lead in gasoline prevents the use of catalytic converters, which help limit vehicle emissions of hydrocarbons, carbon monoxide, and nitrogen oxides. Unleaded fuel makes it possible to introduce a new environmental standard, which only can be met by the vehicles with catalytic converters. Shanghai has announced a ban on the use of leaded fuel in Oct. 1,1997. Just after the enforcement of the policy, the lead emission reduced 30 tons in the forth quarter of 1997 and half of the decrease was in the downtown area.

4.3.4.2 Inspection and Maintenance

Vehicles that are not maintained according to emission requirements have significantly higher emissions than properly maintained ones. According to U.S. data, a well-run inspection and maintenance program can reduce the carbon monoxide and hydrocarbon emissions of an individual vehicle by up to 25% (Faiz 1990). Such programs are especially critical in Shanghai, because much of the vehicle fleet is composed of older and generally more polluting cars. Assuring the repair of such vehicles is helpful to eliminate excess emissions.

4.3.4.3 Eliminate the Outdated Vehicles

Another effective mechanism that can be used to reduce vehicle emissions is to accelerate the disposal of old and inefficient vehicles. The elimination standard of the outdated vehicles in Shanghai is mainly based on the mileage or age of different types. Normally, the lifetime limit of automobiles is 500,000 kilometers of mileage or 15 years of age, while it is about 10,000 miles or 5 years in developed countries. Because of economic constraints, Shanghai cannot reach the high turnover rate of developed countries. Enhancing the turnover standard to accelerate the elimination of the outdated automobile is beneficial for the urban environment, since the old automobile usually emits more pollutant than the new one.

4.3.4.4 Alternative Clean Fuel

The possibility of substituting cleaner-burning alternative fuels has drawn increasing attention in the past years. Principal alternative fuels include natural gas, LPG, CNG, electricity and methanol.

4.3.5 Transportation Planning and Management

Since urban transportation is an integrated and dynamic system, traffic planning and management is very important. Without a good understanding of the nature of the transportation problems, it is impossible to solve the problems only through building new facilities.

Planning and management of the network will be crucial to optimizing the efficient use of road space. Traffic management should be designed to make the best use of space to accommodate demand with minimal investments in new infrastructure. Using traffic control and traffic enforcement to manage traffic flow, traffic management gives priority to the movement of people rather than vehicles. Street capacity can be increased by installing junction improvements and traffic signals, creating bus lanes, limiting and otherwise controlling on-street parking, and introducing one-way streets and other traffic flow measures.

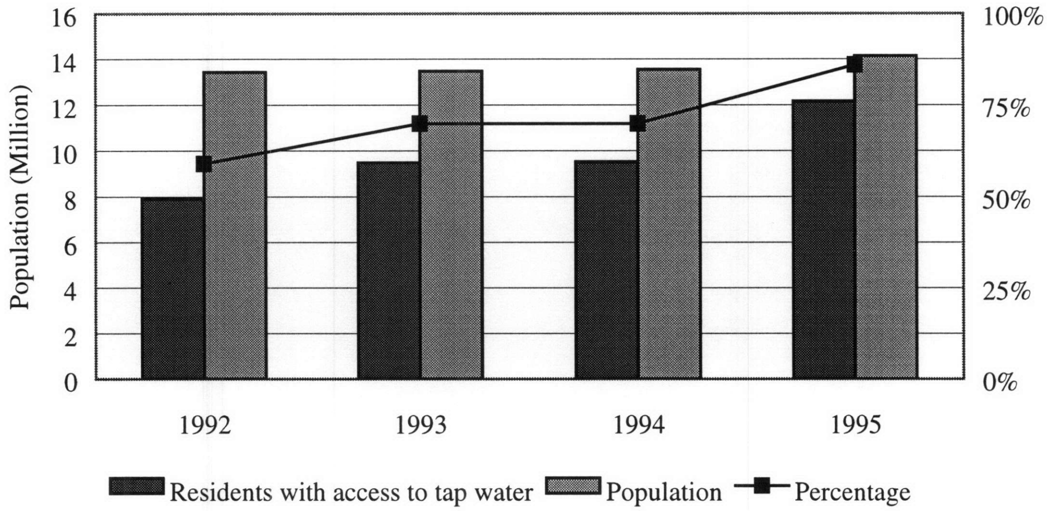
4.4 Water Supply and Sewerage

4.4.1 Water Supply

Shanghai, although surrounded by plenty of rivers, suffers from a water shortage and poor drinking water quality because of the serious water pollution. Since the rapid economic growth, the demand for water has increased steadily. Statistics shows that the total water consumption in the city reached 1.5 billion tons in 1996.

Since the water supply and drainage has long been deemed as a basic government service, increasing the water supply capacity and improving the drinking water quality enjoys a fairly high priority in the consideration of municipal government among the environmental problems. In recent years, the municipal government has invested huge sums in order to improve the water supply and sewerage facility. The infrastructure related to water issues witnessed an impressive improvement in the past few years. The percentage of the resident with access to tap water reached 86% in 1995, which is close to most advanced cities (Figure 4-4).

Figure 4-4 Residents with Access to the Tap Water in Shanghai, 1992-1995



Source: China Statistics Yearbook, 1992-1995

However, since almost all the rivers around Shanghai are severely polluted due to waste, the potable water quality is poor. The 14 million residents in Shanghai have to rely on drinking water supplies that are contaminated with oil, ammonia, nitrogen and an assortment of other potentially dangerous organic compounds. Only a portion of the population of Shanghai have a source of clean water, and the rest need to protect themselves by disinfecting, boiling their drinking water, or by buying their water in containers.

The quality of drinking water supply affects the health of urban residents. Drinking water quality is largely determined by sources of incoming water, modes of water supply, and the level of water treatment. To improve the drinking water quality, separating the drinking water supply from the water supply for other uses is a possible approach.

Due to its high quality, the groundwater could be the major source of the drinking water for urban residents. According to the statistics, about 140-150 million tons of groundwater is exploited every year in Shanghai. Over exploiting the ground water results in continuous earth subsidence; so restricting the usage of groundwater is necessary. However, among the total groundwater exploited, only 20% was utilized by the domestic sector, while only 200,000 tons was for drinking. Assuming that the average daily drinking water consumption per capita is 5 liters, urban residents need about 40,000 tons of ground water every day. So the annual groundwater for drinking is nearly 1.5 million tons, only a very small portion of the current exploitation, which will not cause the earth subsidence. The current mineral water filter facility and bottle water supply network is sufficient to guarantee the reliable supply to urban residents.

Although the city has been struggling with the water shortage, a large amount of the water has been wasted because it has been underpriced. In 1996, the daily tap water consumption reached to 281.54 liters per capita. If one included industrial water consumption, the average water consumption per capita is much higher than that of most developing countries. So it is necessary to thoroughly adjust the water supply policy.

Because of government subsidies, the prices in Shanghai have not reflected the true value of the water, which has lead to the widespread inefficiency in water consumption. Removing such subsidies and letting water prices rise can not only provide incentives for water conservation, but also raise the funds to finance the needed infrastructure. One good example of using price leveraging to manage the water supply is Bogota, Colombia.

From 1975 to 1990, the actual water price increased 88%, while the daily water consumption per capita decreased from 203 liters to 160 liters in the same period (World Bank and DCC).

4.4.2 Sewerage

A large part of the municipal water becomes wastewater after utilized. An integrated sewage system and a sufficient capacity to handle the wastewater generated in the city are a necessity to protect the river body. Yet, the drainage and sewage service is a weak fraction in the infrastructure development in Shanghai. The main sewage network was set up several decades ago, which is now obsolete to deal with the continued increasing effluents. With huge investments, the sewage service of the city improved in the past few years. However, it far below the level of the cities in industrialized countries (Table 4-6).

Table 4-6 Wastewater Disposal in the Selected Cities

City	Sewage available rate	Municipal waste water disposal rate	Daily waste water Disposed (10^3 M^3)
New York, 1990	100%	100%	6230
London, 1989	100%	100%	
Paris,1989	100%	100%	2100
Seoul,1989	99%	55%	3060
Tokyo,1989	84%		5660
Shanghai, 1995	70%	41%	514

Source: Tian, 1996

Due to the serious lack of sewage treatment facilities, only 70% of industrial wastewater received treatment in 1995, but only 30% were up to the government standards. As to the municipal wastewater, only 30% are treated (SMEPB, 1996). As a result, a large amount of effluents has been discharged directly into water bodies without effective treatment, which have become the major threats to the water quality of the surrounding rivers, causing serious pollution of potable water sources and threatening the health of urban residents.

To decrease the impact on the water environment, the city should have an integrated sewage system for municipal and industrial wastewater. Industries should have in-plant treatment to remove the toxic materials and heavy metals before discharging into the municipal sewage system. However, water transfer projects require huge investment, and take years to complete. Increased water supply and water consumption will only lead to greater waste water emissions, if effluent treatment does not catch up. The city will face increasing shortages of drinkable water if the quality and quantity of wastewater treatment does not rise. Safe drinking water is already a serious problem in Shanghai.

Furthermore, the increasing water pollution has also wasted huge investments. For example, the city had to move its water intake 40 kilometers upstream at a cost of $300 million because the river waters around the city had become too polluted (The Economist 1998).

Thus, it is important to use water more efficiently and to intensify efforts to stop the deterioration of aquatic environments caused by municipal and industrial effluents. One possible approach is the reuse of municipal wastewater in industry, which provides companies with a cheap and reliable source of water and at the same time protects the environment. A study in Beijing showed that a combination of strategies could reduce industrial water consumption by about one third, at a cost substantially less than that of investing in new supplies (WRI 1996). Meanwhile, effluent can also be used to recharge groundwater supplies, which can solve the problems caused by over exploiting local groundwater.

In Shanghai, although fees have been imposed for the discharge of sewage and for industries usage of sewage treatment facilities for their effluents, without the effective enforcement, such regulation is meaningless.

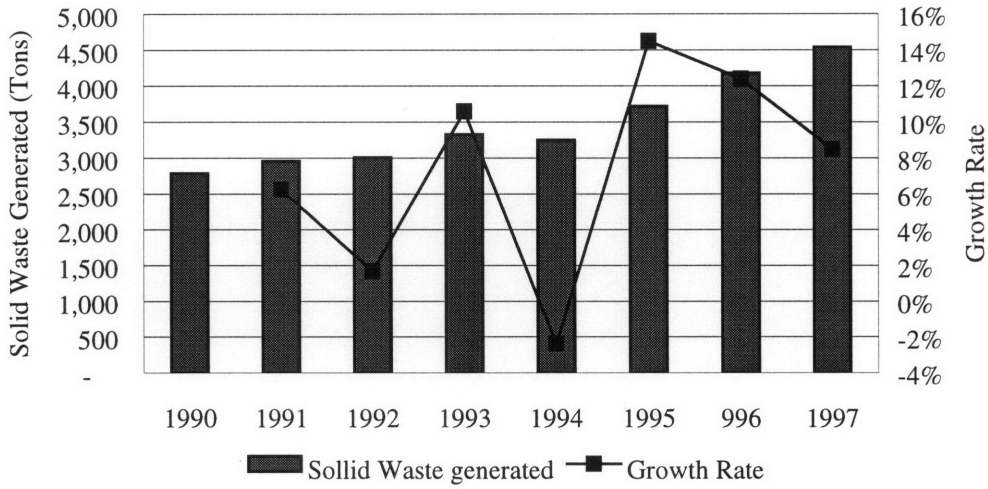
4.5 Solid Waste

4.5.1 Municipal Solid Waste

With the income of the household, the ever-increasing amount of solid waste is becoming one of the major challenges in Shanghai. In 1997, Shanghai households generated more than 4.5 million tons of solid waste, about 0.7 kg per person per day, which is close to 0.87 and 0.85 kg per person per day in Singapore and Hong Kong, respectively, but far below 1.8 kg in New York City (Stren, White and Whitney 1992).

Also, the city also produced nearly 6,500 tons of night soil every day. In the 90's, the average annual rate of increase rate of solid waste is about 7.2% in the past decade, which is far more rapid than the population growth (Figure 4-5).

Figure 4-5 The Municipal Solid Waste in Shanghai, 1990-1997



Source: Shanghai Environmental Bulletin, 1990-97

4.5.2 Waste Disposal

Although the collection of the solid waste almost reaches 100% of the population, the disposal of even greater quantities of waste has become the main challenge to the municipal government.

As the total waste collected by the municipal governments continues to increase, the methods of treatment and disposal of waste remain the same in the city. Landfill, a relatively easy and cheap way of disposing of waste, absorbs almost all of Shanghai's waste. The problem is critical in Shanghai, as it does not have sufficient space for solid waste landfills. As a result, there is only one landfill facility in Shanghai now, which can dispose about 5000 tons of solid waste per day. The city generated more than 10 thousand tons of municipal solid waste every day. Only about half of those were safely landfilled, while large amounts of the remainders were transported to the periphery of urban areas for open dumping. Although the government pours a large amount investment to expand the landfill capacity, it has not met the requirement of the continual increasing municipal solid waste.

Incineration is a potential method to reduce the total volume of waste to be landfilled and avoids sanitation problems. Incineration is the major approach to handle the solid waste in Tokyo and Paris. Among the total solid waste produced, kitchen waste accounts for more than 70%, while paper, plastic and glass make up the major remainder (Chen 1998). Since a majority of the municipal solid waste in the city is burnable, incineration can dramatically reduce the volume and weight of waste to be landfilled. Moreover, incineration also produces waste heat, which can be converted to generate electricity and heat.

However, both the construction of the incineration facility and expand the current capacity of landfill required huge investment. Moreover, both landfill and incineration are extremely wasteful of energy as well as other resources, particularly in comparison to recycling. The experience in the city Lilli showed a feasibility to recover 50% of its solid wastes, by composing 25% and recycling a further 25% of the total wastes (Gilbert, Stevenson, Girardet and Stren, 1992). Because the wastes are being recycled and composed rather than dumped, the resources may be efficiently used and the environmental impacts reduced. Pollock indicated that recycling is a much cheaper strategy in comparison to other methods. To handle the waste, recycling requires less than one third of the cost of landfill and incineration (Table 4-7).

Table 4-7 Comparison of Waste Management Costs (USA)
Unit: Dollars per ton

Method	Collection	Processing	Total
Recycling[1]	-	-	30
Composting	50	15	65
Current landfill	70	20	90
Incineration	50	40-60[2]	90-110
Future landfill	70	25-30	95-100

Notes 1=Collection+processing-revenues
2=Includes revenues from electricity sales
Source: Pollock, 1987

To facilitate the incineration disposal and to increase the recycling of the solid waste, the traditional mixed collection should be replaced by a separate collection, where the solid waste is separated into paper and cardboard on the one hand, and bottles and cans on the other two separate conveyors. Additionally, the city should provide incentives for residents to reduce waste generation and increase recycling.

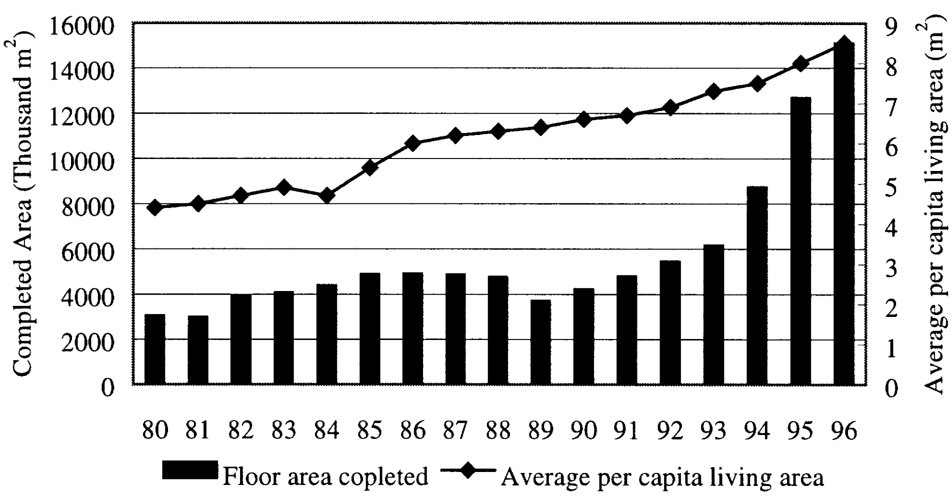
Among all the methods to solve the municipal solid waste problem, most experts suggested that the most desirable approach is to reduce the amount of waste generated. Kitchen waste accounts for nearly 70 percent of the total municipal solid waste, whereas such wastes occupy a small share of the total waste in most advanced cities such as New York and London. Providing clean vegetables to urban residents can considerably cut down the food waste. Since coal is the main energy source for the city, increasing the supply of coal gas and natural gas and developing district central heating systems to reduce solid residues generated from direct coal combustion is another possible measure to minimize the generation of municipal refuse will also include.

4.6 Housing

Due to the extremely high population density in the downtown area of Shanghai, most residents have suffered from a housing shortage. In 1980, the average floor area per capita was only 4.4 m^2. Without sufficient transportation and other infrastructure facilities, residents are reluctant to move to relatively spacious apartment on the periphery of the city. On the other hand, the municipal government has lacked the fund to build more resident house and necessary infrastructure facilities.

The introduction of land and housing reforms in China has made an urban renewal possible, as land leasing can help raise the funds for urban redevelopment. From 1992 to 1995, the land leasing record showed that US$8.27 billion and 9.85 billion RMB was raised from the leasing of land. This provided the funds for urban facilities and infrastructure development. As a result, the housing conditions have been improved. With 52.9 million m^2 being completed from 1991 to 1996, the average per capita living space among urban residents had expanded to 8.5 m^2 in 1996 (Figure 4-6).

Figure 4-6 Housing Development in Shanghai, 1980-1993



Source: 1. Tian, 1996
2.Shanghailinvestment Report, 1996

Another important improvement of the urban housing system is the squatter areas in the city. In 1985, the total squatter area was 4 million m^2. This figure decreased to 1 million in 1995.

Urban vegetation is an important symbol of the ecological level in modern cities. By the end of 1996, the city's total urban green area were 7,231 hectares, including 2,008 hectares of public green areas, 5.2 times that of 1978. However, compared with other major world cities, Shanghai has much fewer parks and green areas. Although the coverage of vegetation in urban areas has been increasing dramatically in the recent years, the vegetation coverage rate is only 17% in 1996. Moreover, the per capita green space stands at only 1.92 m^2, which was only about a quarter of that of Singapore (1982) and far less than the level in European cities (Table 4-8).

Table 4-8 The Park and Public Green Area in Selected Cities

	Year	Per Capita Park Area ($m^{2)}$)	Year	Per Capita Public Green Area (M^2)
Shanghai	1992	0.56	1996	1.92
Tokyo	1987	2.9	1990	4.2
New York	1988	14.4	1978	21.6
London	1984	25.4	1978	22.8
Paris	1982	24	1984	12.4
Singapore	1984	4.6	1982	7.2
Moscow	1980	19.1	1980	22.6

Source: Tian, 1996

Chapter 5 — Infrastructure Investment and Financing

5.1 Introduction

Integrated urban infrastructure development is an approach, which is being tried out in a wide range of Asian countries for more than a decade. However, in Shanghai, because of the inadequate investment, the infrastructure development has been stagnant for a long time. According to the statistics, the investment in the urban infrastructure facilities was only 6 billion RMB from 1952 to 1978. As a result, the basic infrastructure facilities, such as energy supply, transportation, drinking water and waste disposal, have been difficult to meet increasing demand of economical development.

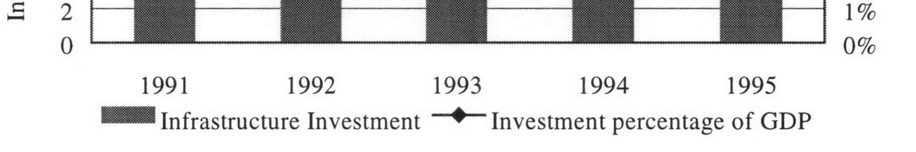
5.2 Infrastructure Investment

5.2.1 Infrastructure Invest

Urban infrastructure is invariably linked with a productive urban economic development. The experience of the newly industrialized East Asia was indicated that economic development could be made more effective through appropriate investments in infrastructure. Compared with an average infrastructure investment of 4 percent of GDP among all developing countries, infrastructure investment by the newly industrialized East Asian economies rarely fell below 4 percent of GDP and was often higher, reaching 7 or 8 percent in several years (World Bank, 1994).

The infrastructure investment level was low in Shanghai for a long time, which was less than 2 percent of the GDP before the 1990's. The municipal government in Shanghai has become increasingly concerned with the adequacy of infrastructure as it plays a crucial role in determining the overall productivity and development of the city's economy, as well as the quality life of the city residents. Consequently, the infrastructure investment has increased sharply in 1990's, especially after 1992. The public infrastructure investment proportion of the GDP almost doubled from 1990 of 1995, with an average 6.41 percent of GDP in the five years (Figure 5-1).

Figure 5-1 Public Infrastructure Investment in Shanghai, 1991-1995



Source: SMCC, 1996

5.2.2 Infrastructure Improvement

With massive investment, the municipal government's endeavor to improve the city's investment environment has markedly upgraded the infrastructure facilities (Table 5-1). In 1995, the total gas supply capacity increased to 4.90 million m^3 per day, the total gas pipes length was 4,527 kilometers, and nearly 85 percent of the families in the city used gas while cooking. From 1991 to 1995, 49 key roads were completed, the total road length in urban area reached 3,008 kilometers and the road area was 47.55 million m^2. Also, 37 water drainage systems were renovated or newly built and the length of sewerage pipelines extended to 2,536 kilometers, while the sewage treatment capacity reached 1.89 million tons per day.

Table 5-1 City Infrastructure Facilities in Shanghai

	Unit	1980	1990	1995	2000*
Cooking gas use	1,000 Household	660	1,430	3,470	4,200
Length of gas pipeline	kilometers	1,414	2,700	4,527	5,500
Length of city roads	kilometers	907	1,631	3,008	3,975
Area of city roads	1,000 m^2	8,940	26,480	47,550	64,250
Waterworks production capacity	1,000 m^3/day	3,720	5,990	8,230	13,070
Length of water pipeline	kilometers	2,318	3,483	4,754	6,080
Length of sewage pipeline	kilometers	1,370	1,892	2,536	2,792
Sewage treatment capacity	1,000 tons/day	150	410	1,890	4,700
Average living area	m^2	4.4	6.6	8	10
Urban green area	hectares	1,738	3,570	6,561	10,166

Source: 1.China Statistics Yearbook
2.SMCC, 1996

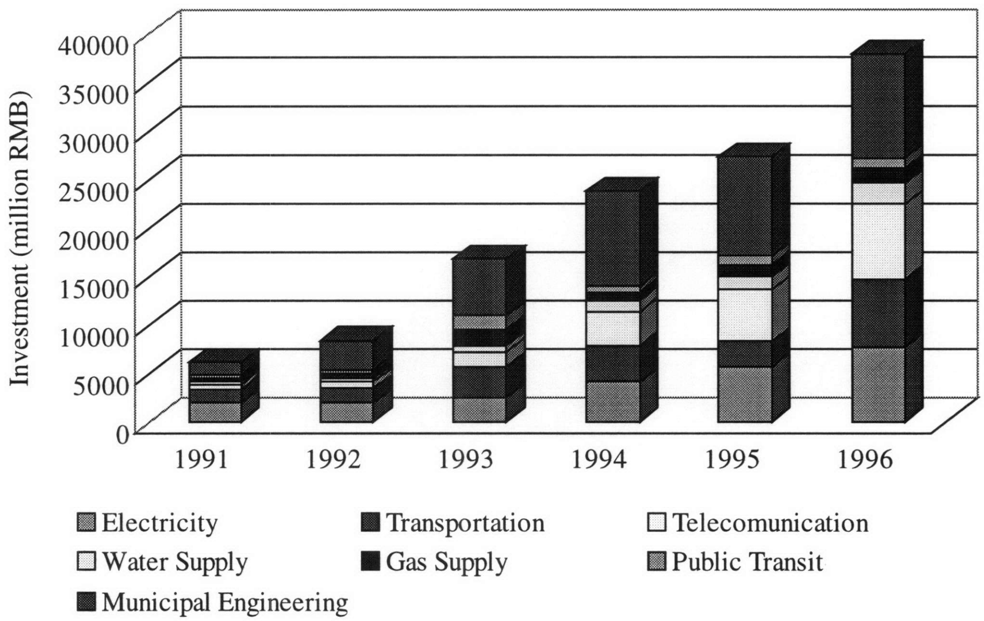
According to the government plan, by the end of this century, the urban transportation in Shanghai will become an integrated, vertical, network and large volume system with a "3 horizontal and 3 vertical" and "3 rings and 10 radiation" road mainstay network. The running water supply capacity in the city proper will reach 13 million tons per day, while city wastewater treatment capacity will reach 4.7 million tons per day. In the urban area, the average living space will be 10 square meters per person, while the green land of the whole city will reach 10,166 hectares and 20 percent green land coverage (SMCC 1996).

5.2.3 Sectors of Infrastructure Investment

In the 1990's, the investment in infrastructure facilities and housing increased dramatically, which focus on the improvement of the urban transportation system, public utilities and residential housing condition. From 1991 to 1996, the infrastructure investment increased more than six times, which reached 37.8 billion RMB in 1996 (Figure 5-2).

Just like most other Asian cities, electricity, transportation and telecommunications have received the major part of the investment, which together accounted for almost sixty percent of the total investment in Shanghai. Another important fact in the issues of infrastructure in the city was the rapid growth of the investment in the water supply sectors. While the infrastructure investments are increased dramatically in all the sectors related, the investment growth in water supply sector has been far faster than other sectors. Although it was only shared a small part of the total investment, the investments in water supply in 1996 was almost 10 times that in 1991. It was clear that energy, transportation and telecommunications are still the prime concerns of the municipal government, and the water supply is also an important issue considered by the government.

Figure 5-2 Infrastructure Investment by Sections in Shanghai, 1991-1996



Source: Shanghai Investment Report, 1996

5.3 Infrastructure and Environment

In Shanghai, the city's environment has suffered from the lagging of the infrastructure development for a long time. Electric power generation, highway construction, and heavy traffic have become a major contribution to pollution. Meanwhile, efforts to increase water supply have led to water pollution, while the wastewater and solid waste disposal facilities suffered from inadequate investment.

Since nonpolluting sources of power, better management of the urban traffic, clean water and safe disposal of waste all provide environmental benefits, investing to improve the infrastructure services will contribute to the environmental sustainability of the city.

5.4 Infrastructure Financing

Shanghai is facing a major challenge in the provision of infrastructure with its rapid economic growth. As the World Bank has pointed out, the provision of the infrastructure plays a crucial role in facilitating economic growth and international competitiveness. Infrastructure capacity grows step by step with economic output. An 1 percent increase in the stock of infrastructure is associated with a 1 percent increase in GDP (World Bank, 1994). Thus, long term economic growth requires a modern and efficient infrastructure.

To maintain a rapid pace of growth over the next decade, a large amount of investments will be needed in Shanghai to provide the sufficient services to sustain productivity and improve the quality of residential life. These investments include not only the capital costs of upgrading existing infrastructure facilities, but also the corresponding costs of maintaining such facilities.

Traditionally, nearly all the infrastructure projects have been financed by state revenue, while the municipal government own and operate the infrastructure facilities. After the reform of the fixed capital investment system, the sources of the infrastructure investment diversified. As shown in the statistics, the direct investments from the state decreased, while the domestic loan and funding has been the main sources for infrastructure finance. Moreover, foreign investment will also become an important alternative source of the infrastructure finances in Shanghai. For example, the inner ring highway was financed by the World Bank loan, the metro system by a government loan from France, Germany and the U.S., and the natural gas project in the East Sea by the Asian Development bank. The land readjustment scheme also played a part in funding the infrastructure facilities. This has opened up the new land in the urban periphery for urban use and thus helped to increase the supply of the housing and raising the fund through auction the downtown land.

However, the local government revenue and borrowing still are the predominant infrastructure finance source. Almost all bank loan and fund raising for the infrastructure are backed by the government. Hence, the government virtually bears all the risks associated with infrastructure finance.

Inadequate services often result from poor pricing policies, which also place a heavy weight on the fiscal authorities. Indiscriminately subsidized facilities and services often lead to a level of demand that exceed the supply capacity (Linn and Wetzel, 1995). User charges should be an equitable and efficient means of recovering costs of construction and maintenance of the infrastructure facilities. Moreover, the user charges are also an effective pricing scheme to control the demand for urban utilities (Kim, 1995).

The private participation in the infrastructure is another possible mechanism to raise the needed funds and improve the performance of the urban infrastructure facilities. By the early 1990s, as the importance of providing efficient telecommunications, transportation, power, and other infrastructure services in maintain a competitive edge is realized, it have been clear that private involvement would be necessary in infrastructure development. It was widely agreed that the private provision of goods and services is more efficient than its public competitors. The most popular strategy for private sector participation in the infrastructure finance is build-own-operate (BOT) scheme.

BOT scheme made it attractive for private participation in the financing of infrastructure, especially in energy and transportation projects. Under the scheme, the private operators undertake the risks of construction and operating infrastructure facilities. After a given period of time, the infrastructure facilities will be turn back to the government. The BOT scheme provides the advantage for the government with shortage of development fund. Moreover, it also transfers the construction and operation risks to the private sector. On the other hand, as the private sector operates the infrastructure facilities on a commercial basis, it also improves the efficiency (Pahlman, 1996).

Chapter 6 — Conclusion

As one of the mega-cities of the world, Shanghai has experienced unprecedented economic growth in the recent year. At the same time, the city confronts a range of severe environmental problems that accompany this fast growing economic development. Moreover, the insufficient infrastructure has become a major hindrance to the further development of the city, which also has lead to the negative environmental problems. The expansion in infrastructure in the city will benefit not only the economic development, but the local environment as well.

As coal burning is responsible for a significant part of the air pollution, the serious air pollution problem in the city can be improved through diversifying the route energy consumption by emphasizing hydroelectric and gas burning promptly. Vehicle emission is another important contributor to air pollution. Expanding the road facilities can reduce the congestion. But it also encourages the vehicle use and increases the emission. Therefore, improvement of the road capacity cannot solve the related environment problems. So developing an efficient public transport system, which is efficient and environment-friendly, should be a priority option in Shanghai. Moreover, the improvement of the urban sewage and waste disposal system, where the wastewater and solid waste can be appropriately treated, is helpful to improve the quality of the city's water reserves.

In the recent years, the municipal government in Shanghai has become increasingly concerned with the environmental protection and adequacy of infrastructure. It ia slao concerned with determining the sustainable development of the city's economy, as well as the quality life of the city residents. an enormous amount of capital, materials and manpower resources has been invested into the infrastructure projects. However, without implementing appropriate policies, urban environment and infrastructure problems will be exacerbated. Almost all the sectors in the infrastructure facilities receive some kind of subsidies from the government. Although the city has suffered from the shortage of the infrastructure, a lot of resources are wasted, as the prices of the infrastructure utility are distorted by the subsidies. So eliminating these irrational subsidies and set a reasonable user charge to reflect the real economic and environment costs is necessary to improve the efficiency of the infrastructure.

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