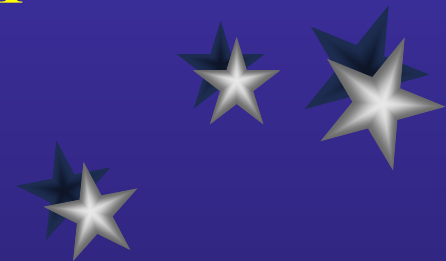


Integrated Analysis of Transportation Development and Air Quality Strategy in China

Professor Kebin He

**Institute of Environmental Science & Engineering,
Tsinghua University**

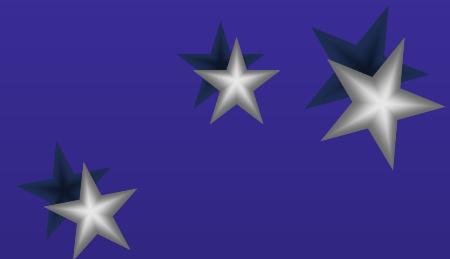
Harvard University, March 19, 2001





Outline

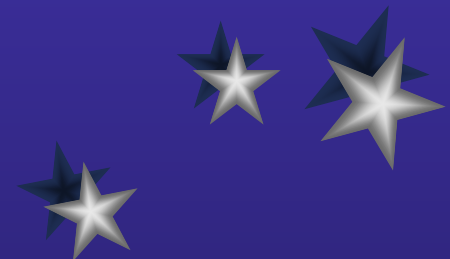
- **Overview of urbanization**
- **Overview of motorization**
- **Air pollution from urban transportation**
- **Beijing Case**
- **Future Consideration**





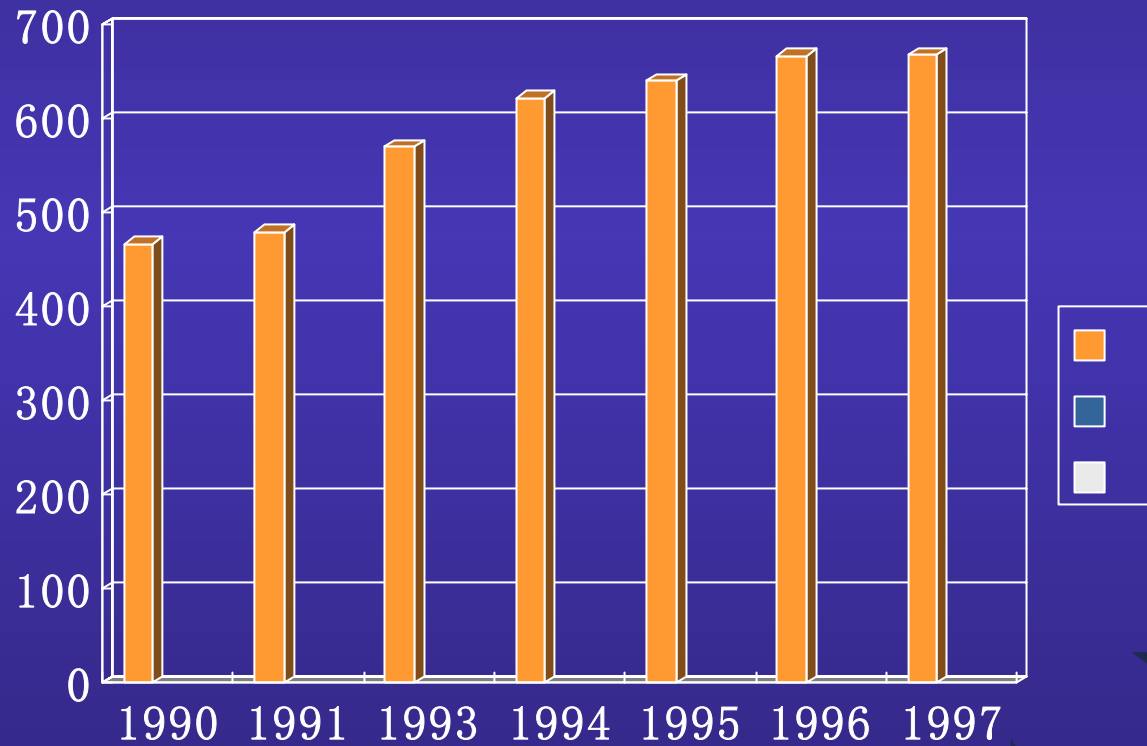
Outline

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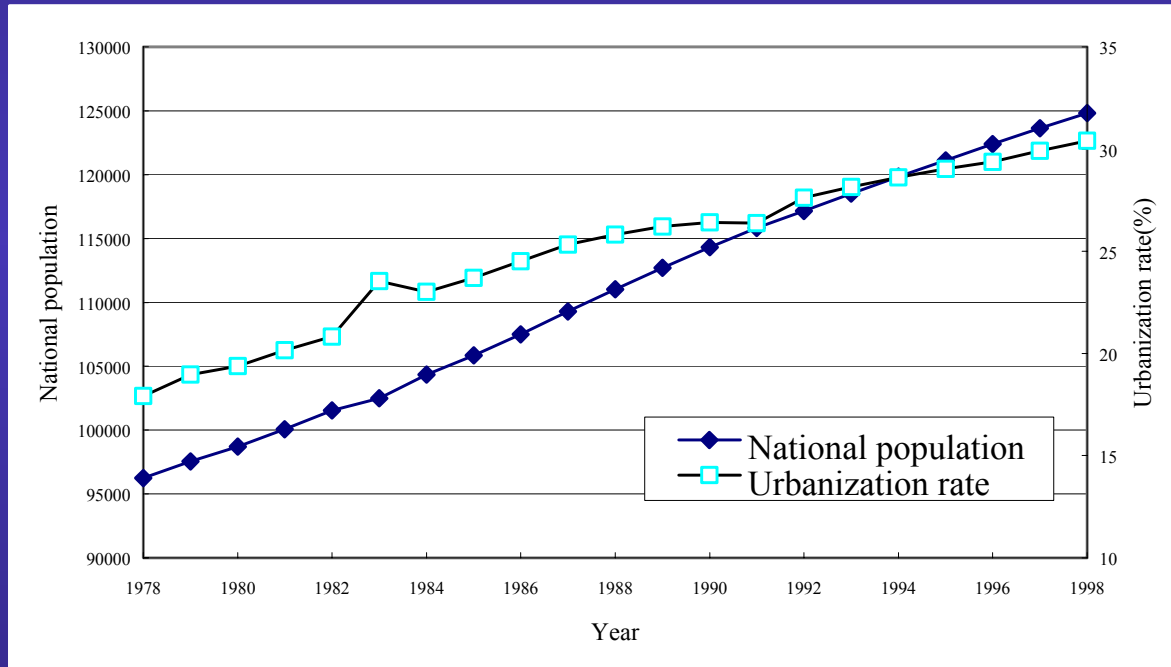
Overview of urbanization

• Increase of number for Chinese cities

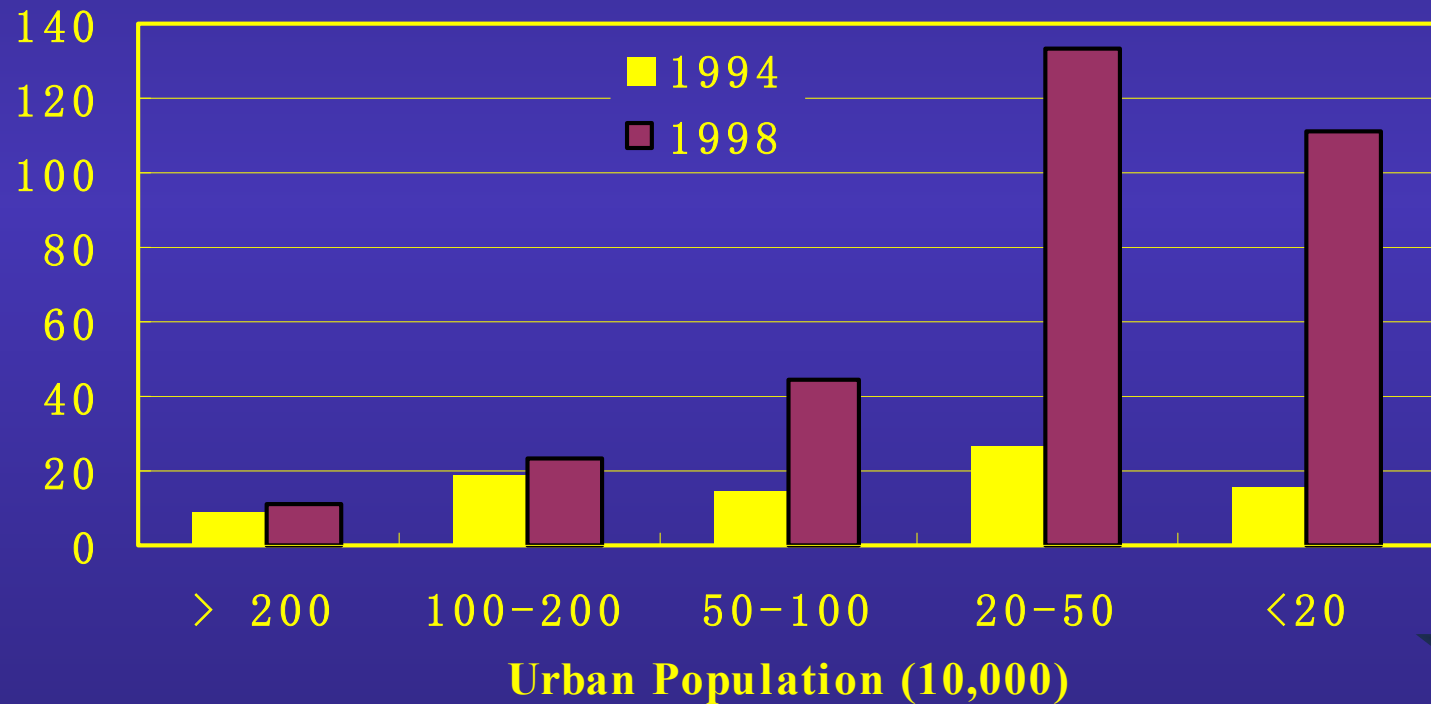


Overview of urbanization

•Development of Chinese population and urbanization



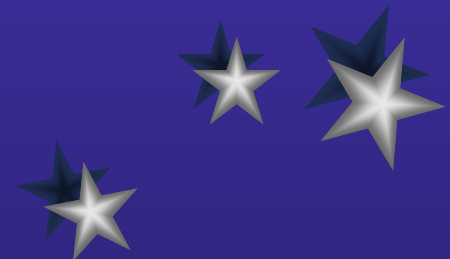
Urbanization Trends in China





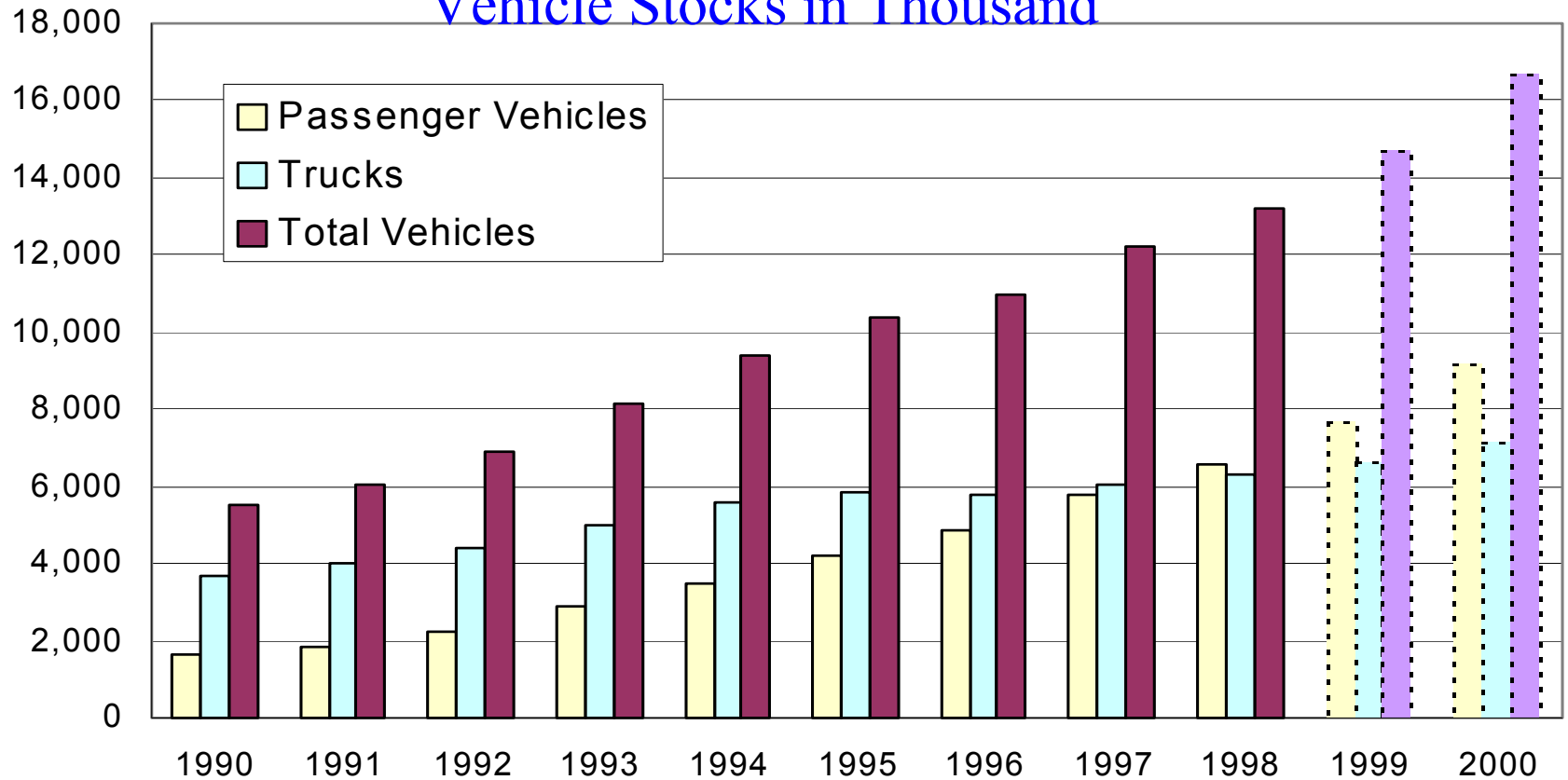
Outline

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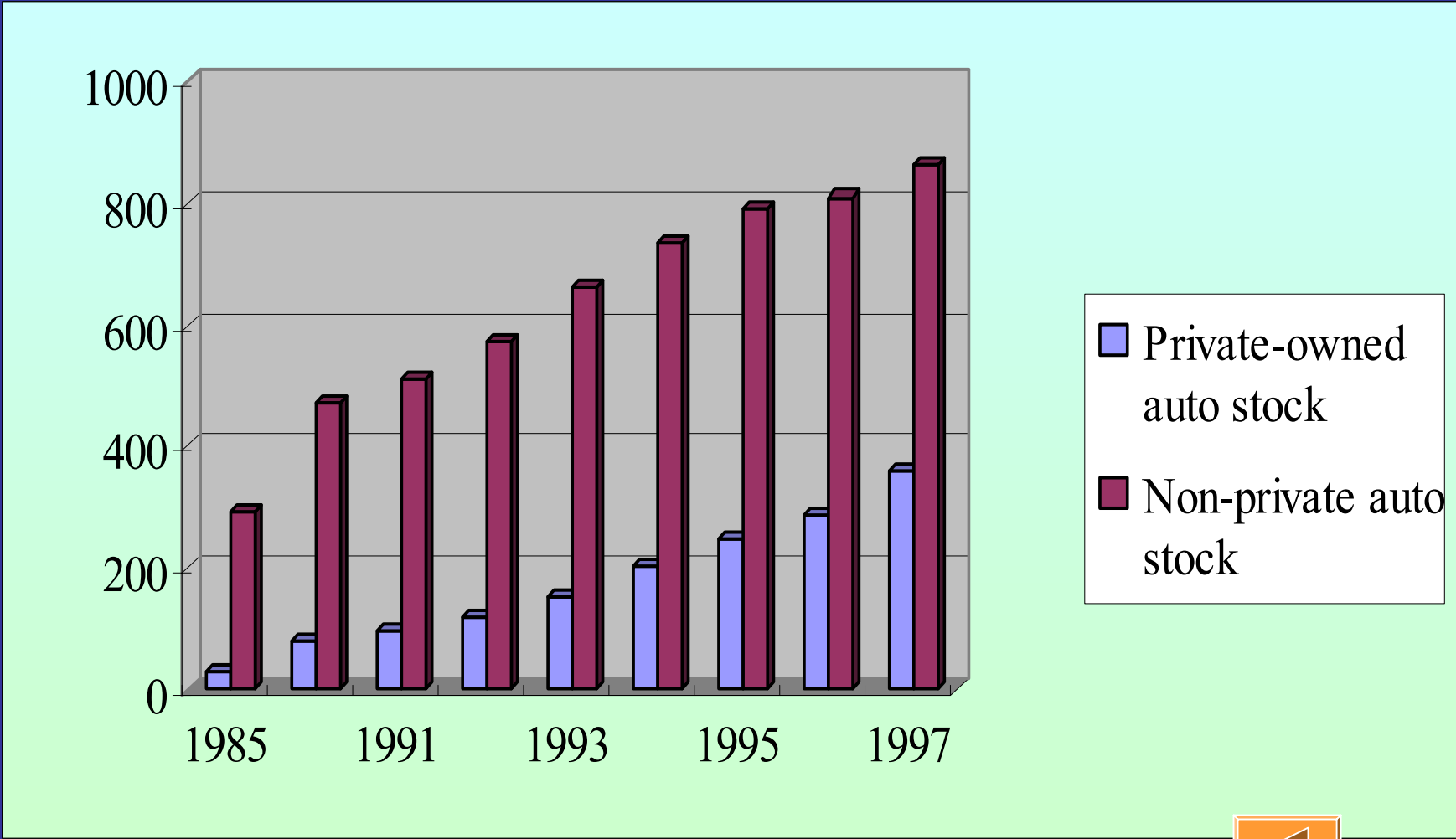


Overview of motorization

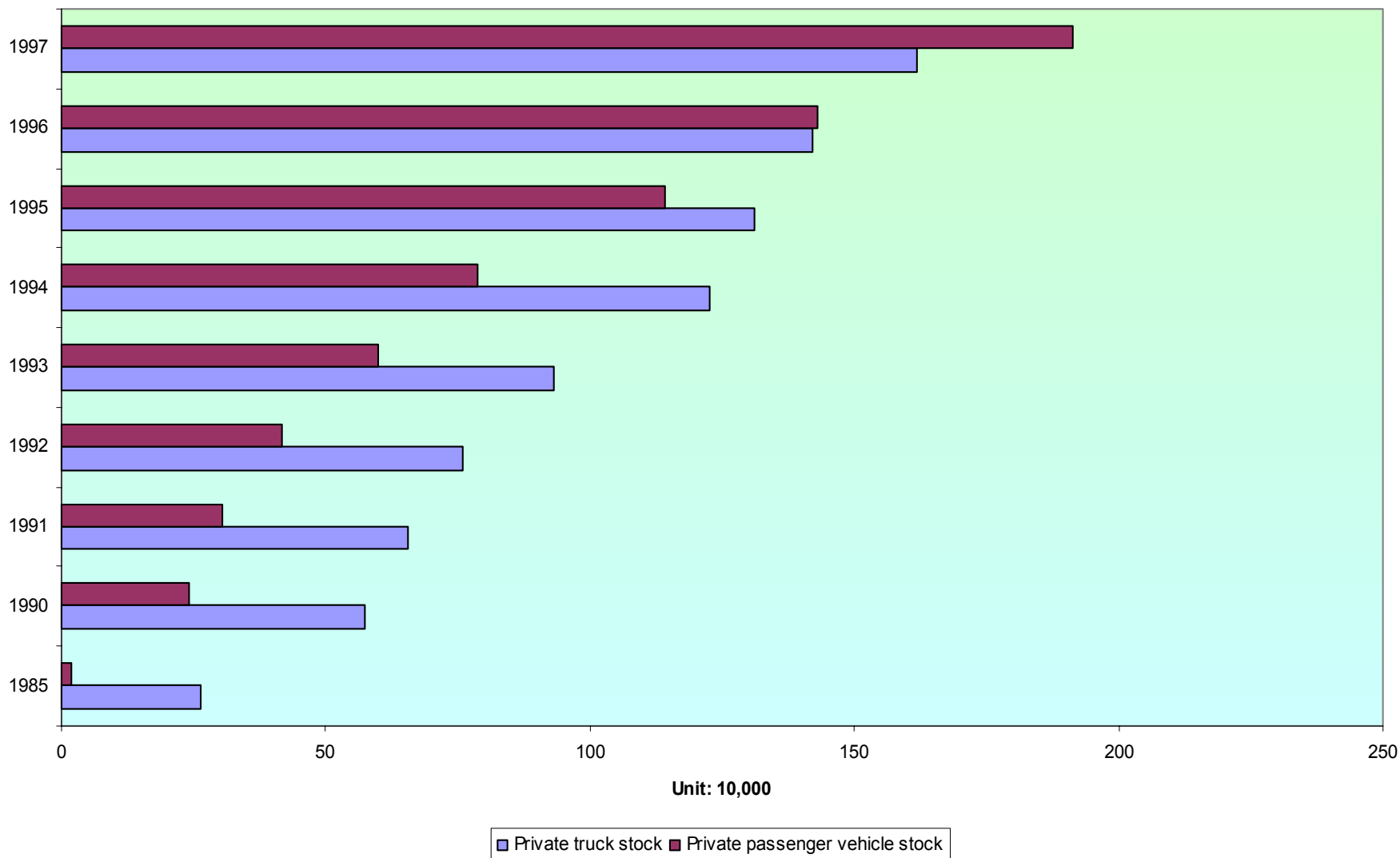
Vehicle Stocks in Thousand



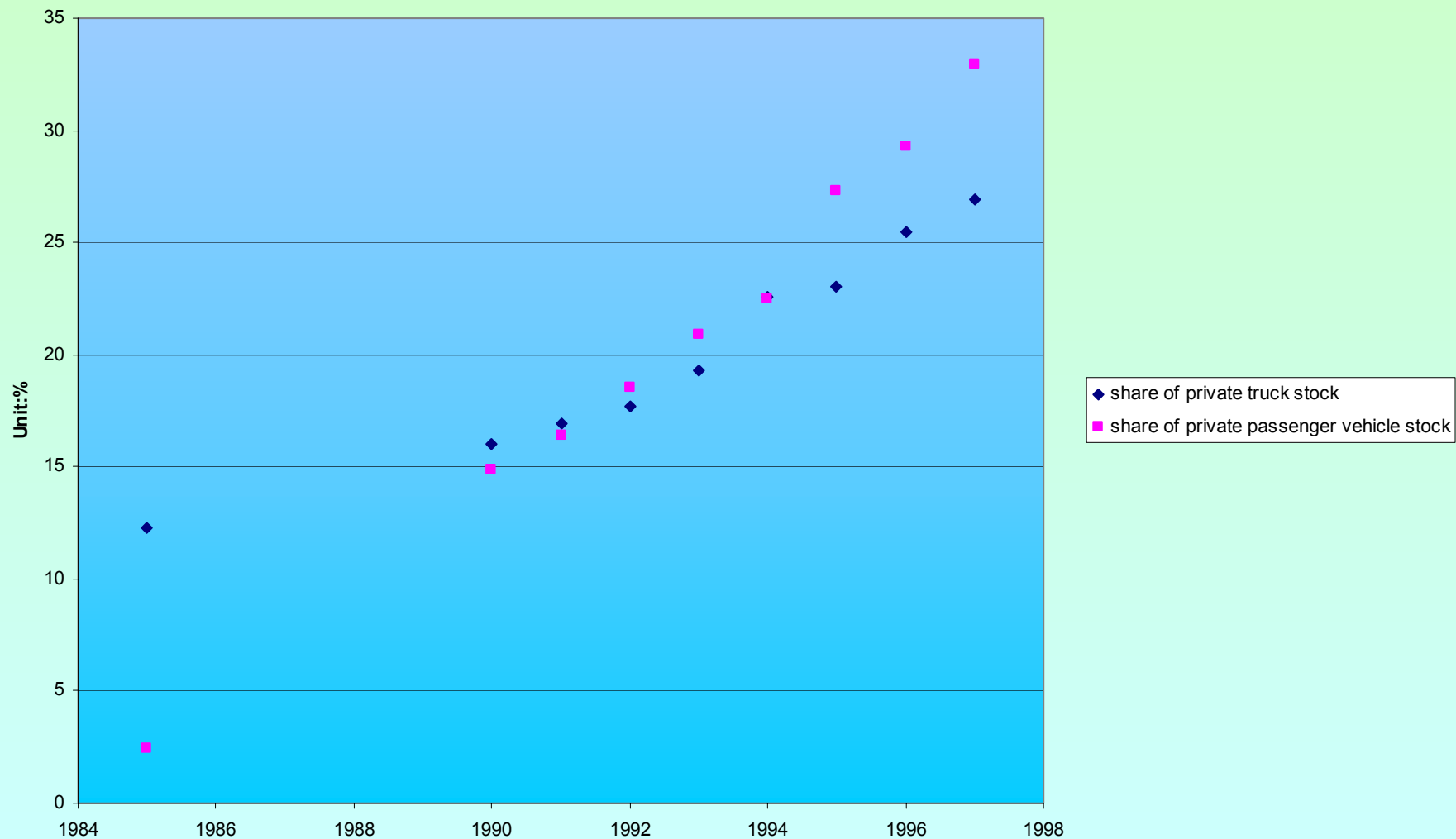
Stock of civil autos by ownership, 1985~1997



Private-owned vehicle stock by purpose (1985~1997)

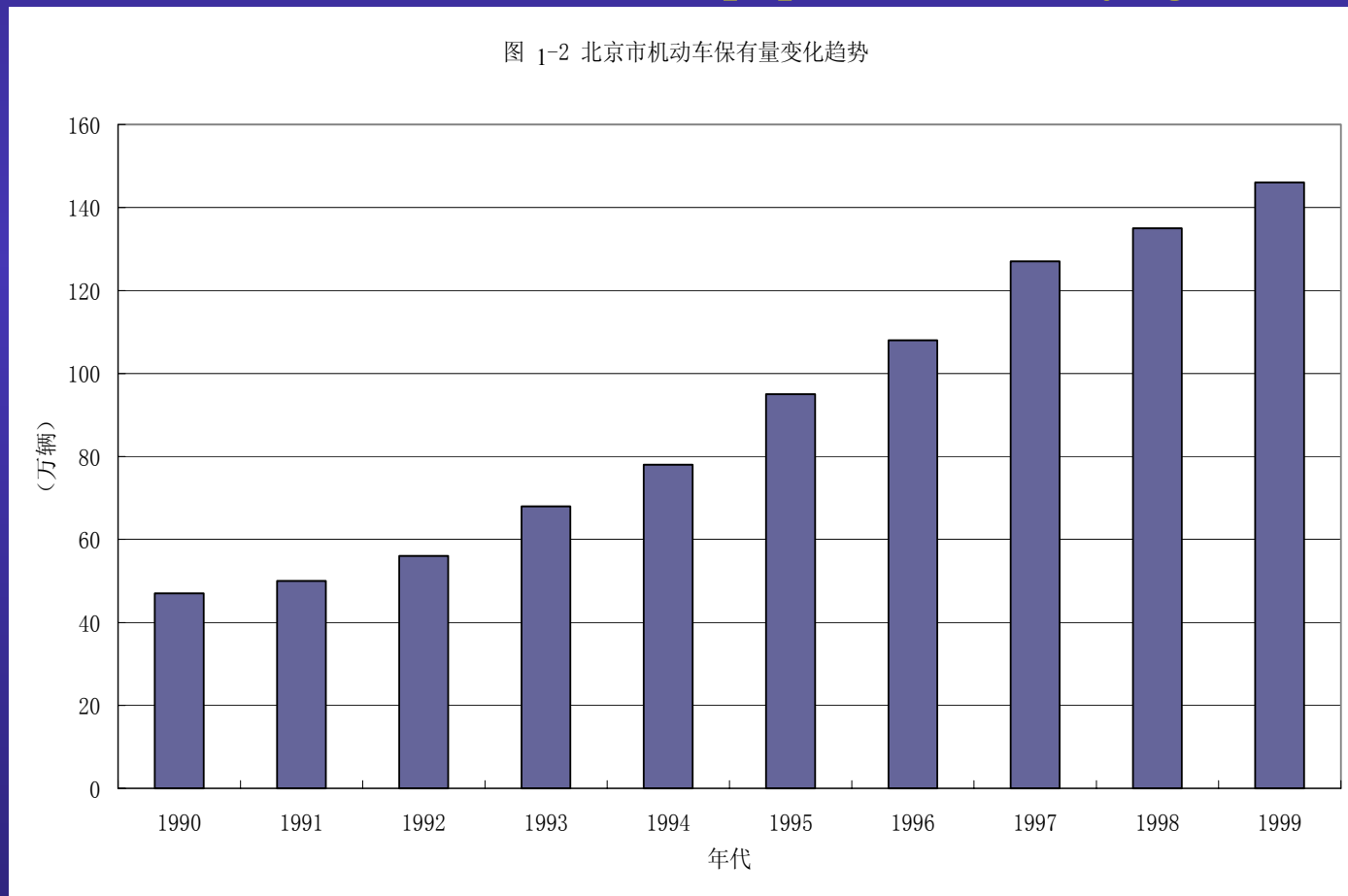


Share of private-owned vehicle stock by purpose (1985~1997)



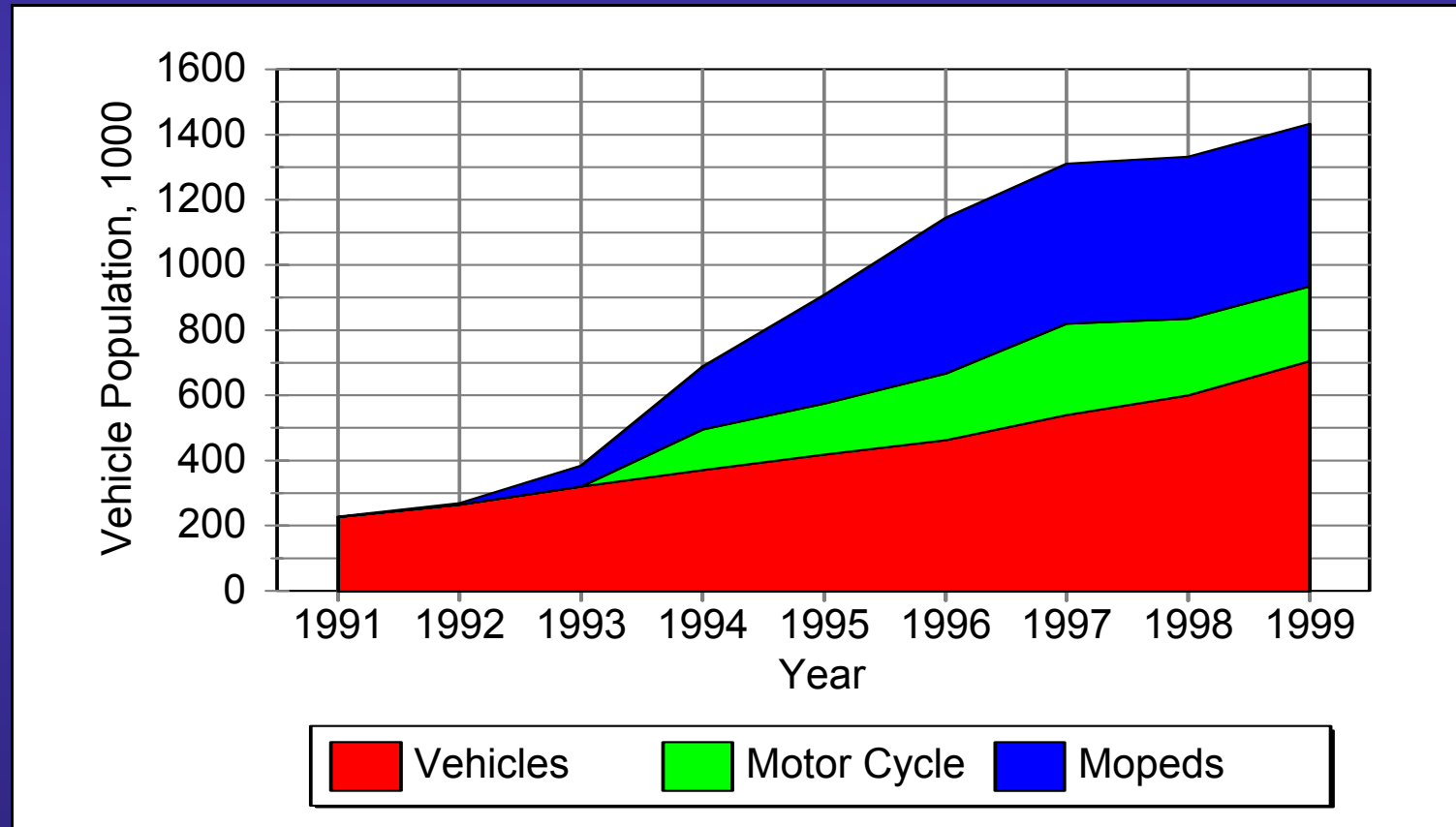
Overview of motorization

•Growth of total civil motor vehicle population in Beijing



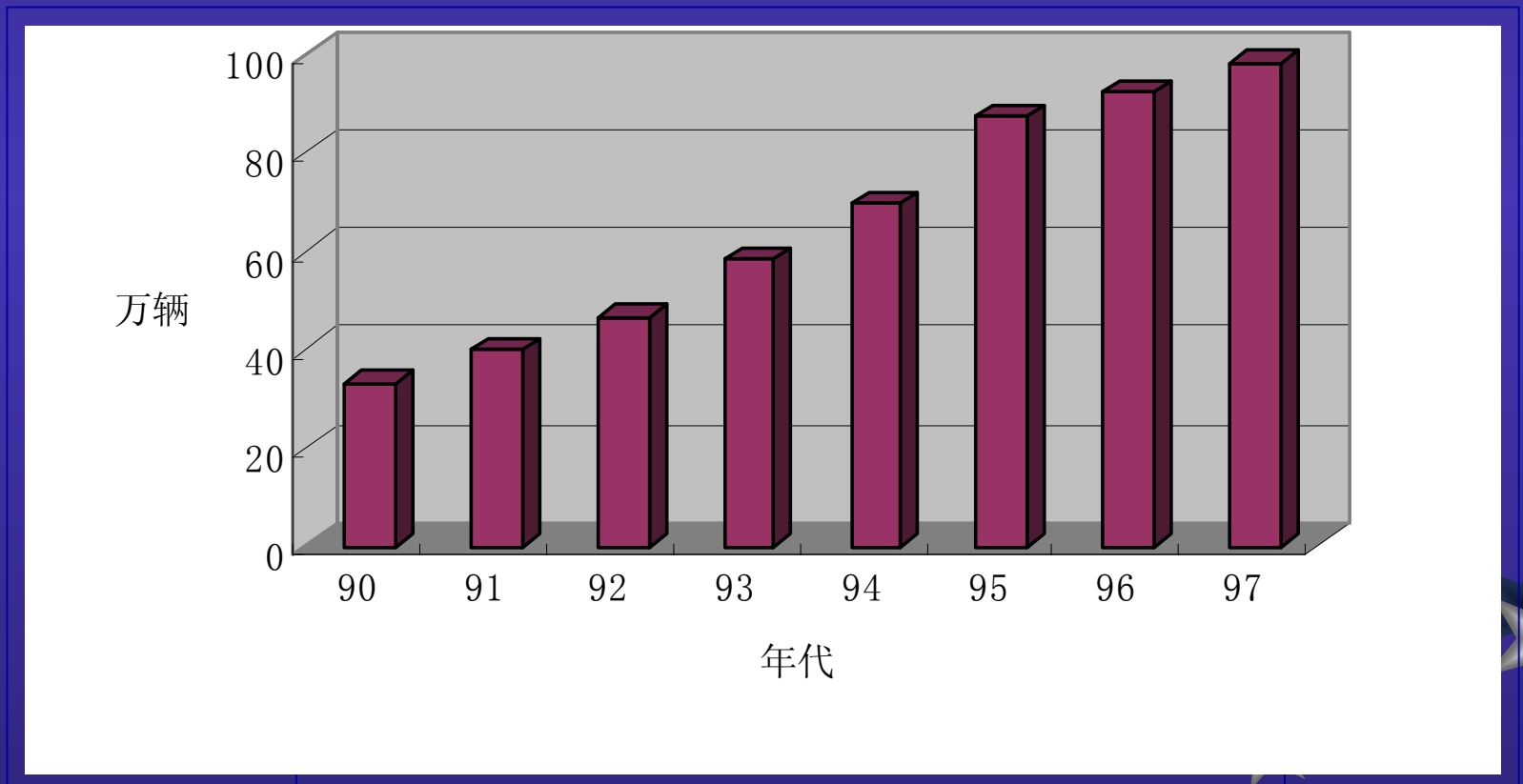
Overview of motorization

•Growth of total civil motor vehicle population in Shanghai

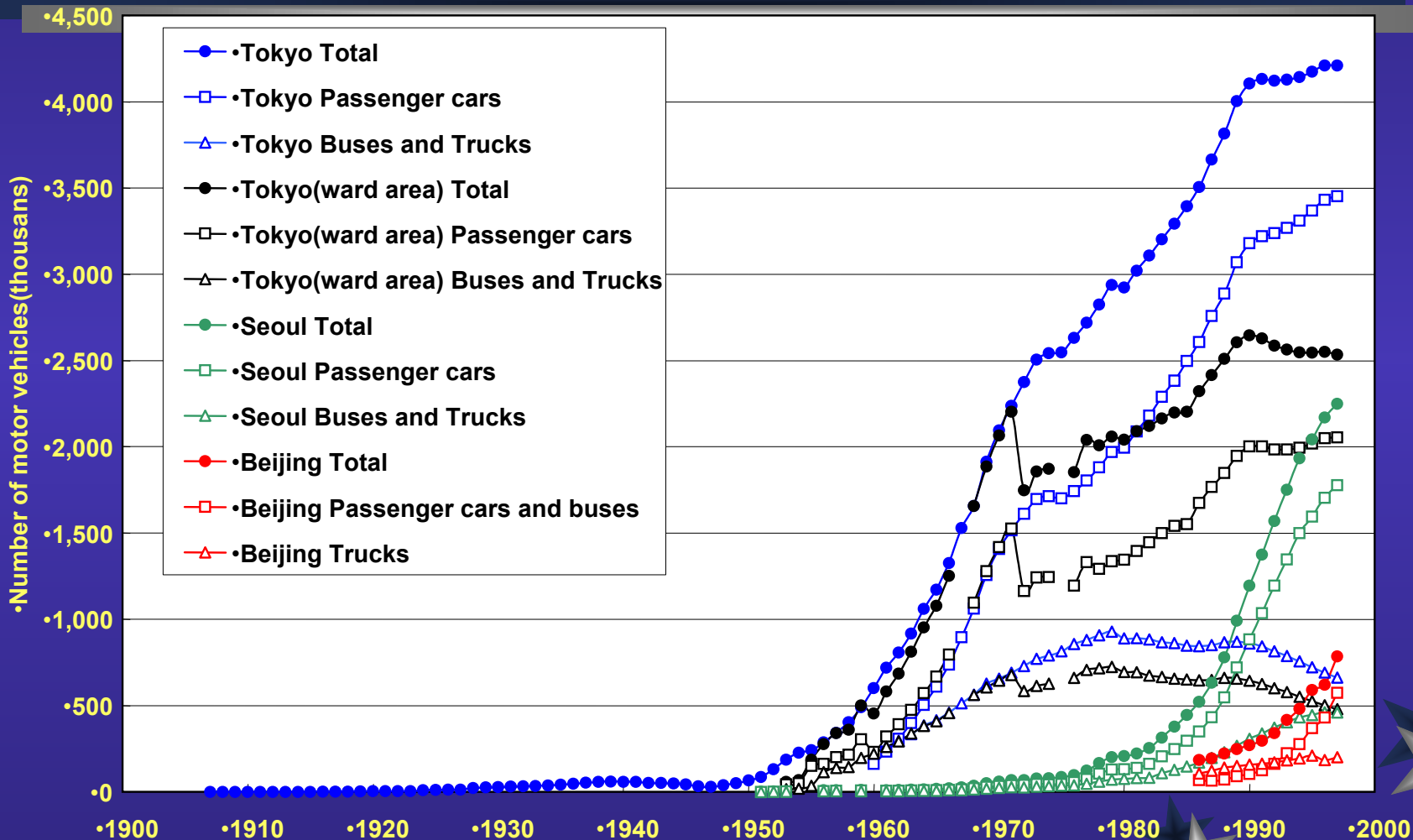


Overview of motorization

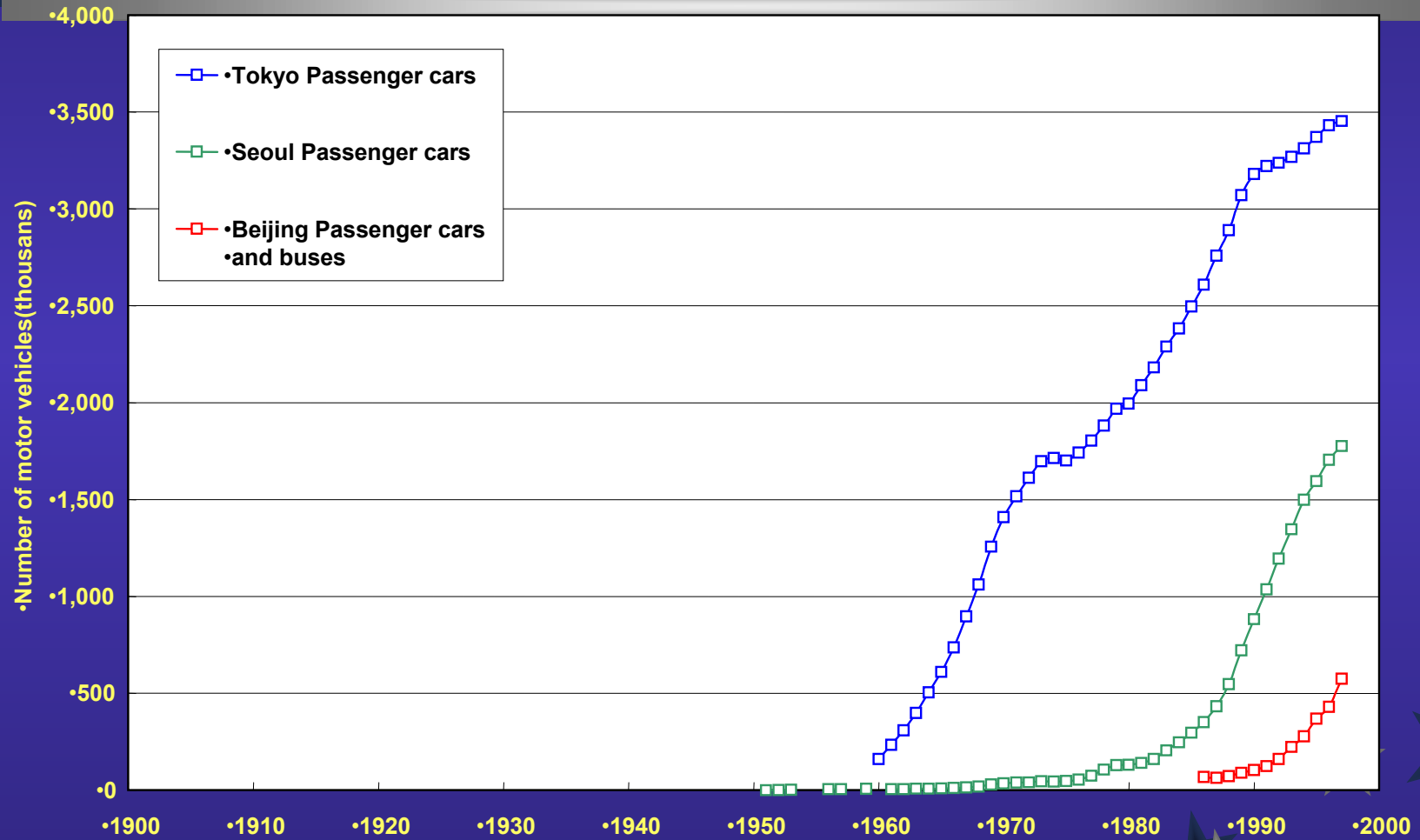
•Growth of total civil motor vehicle population in Guangzhou



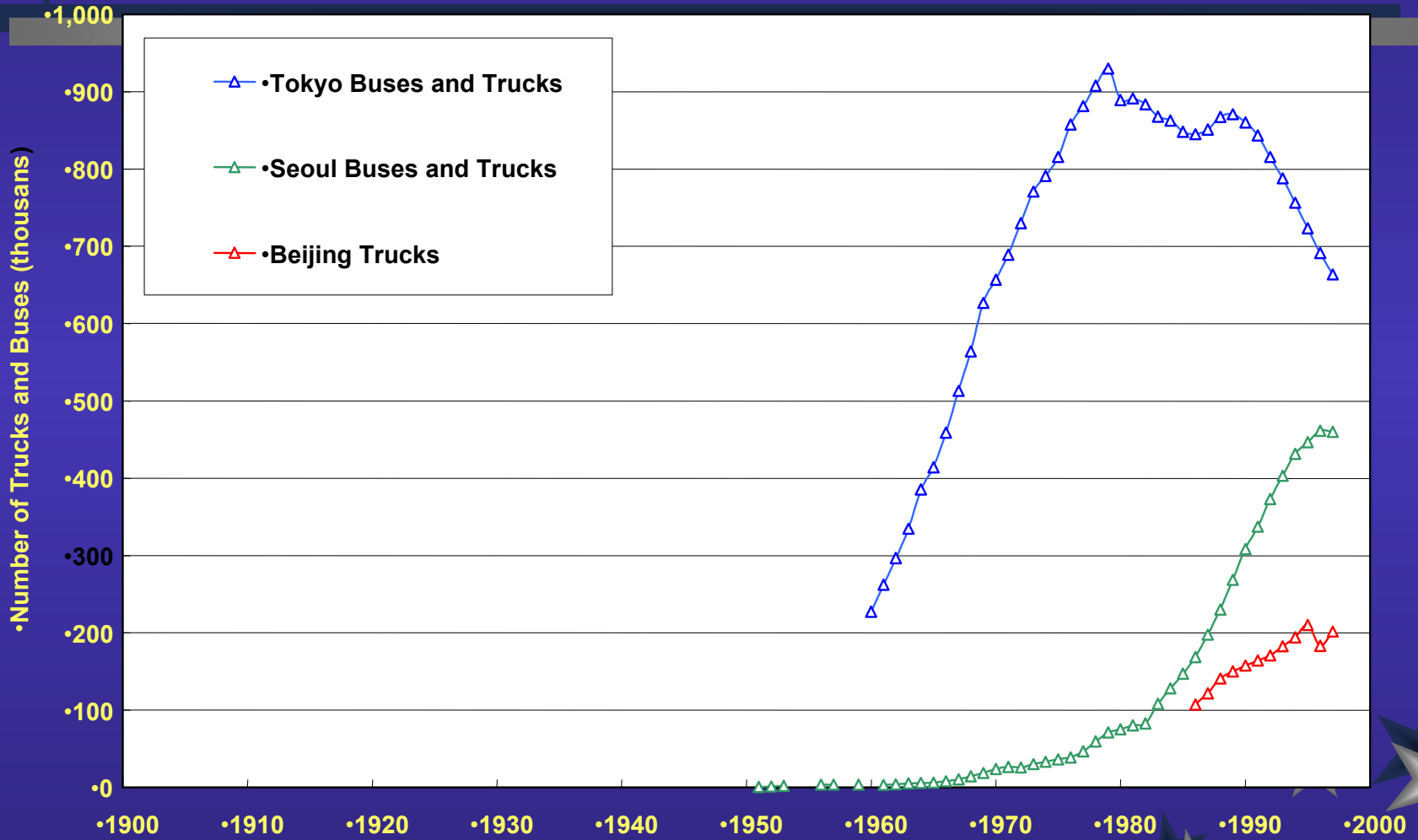
Number of Motor Vehicles



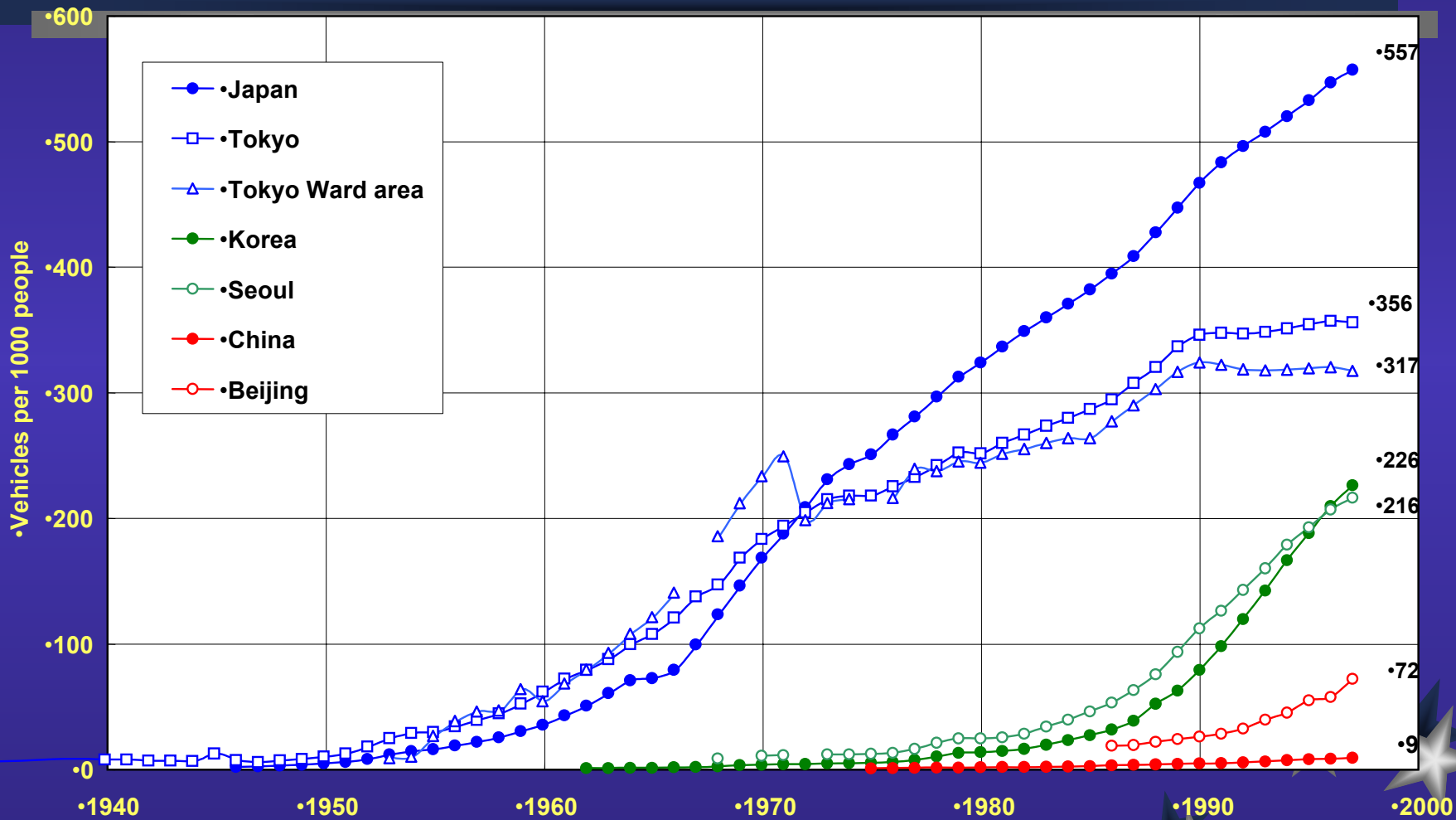
Number of Passenger Cars



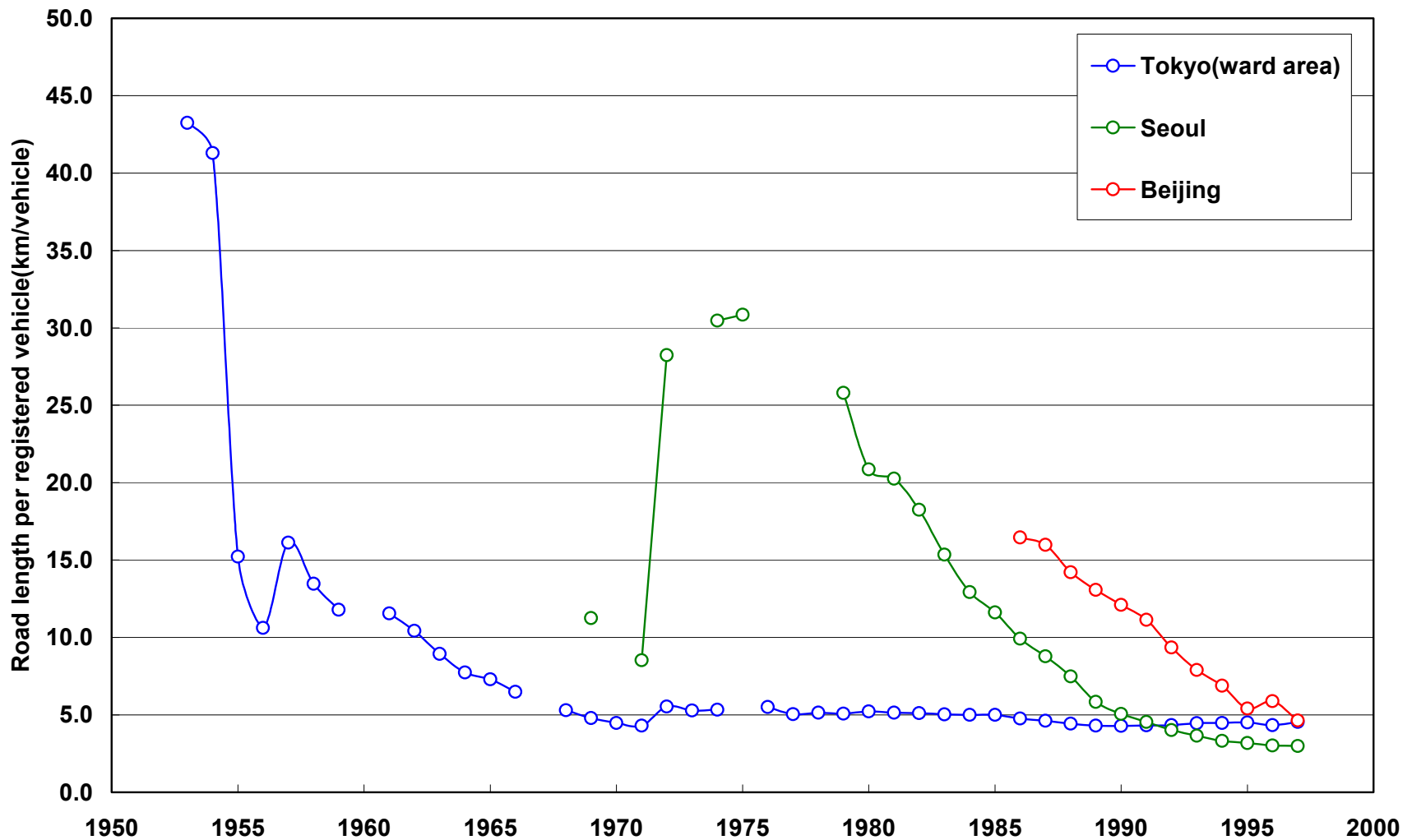
Number of Trucks and Buses



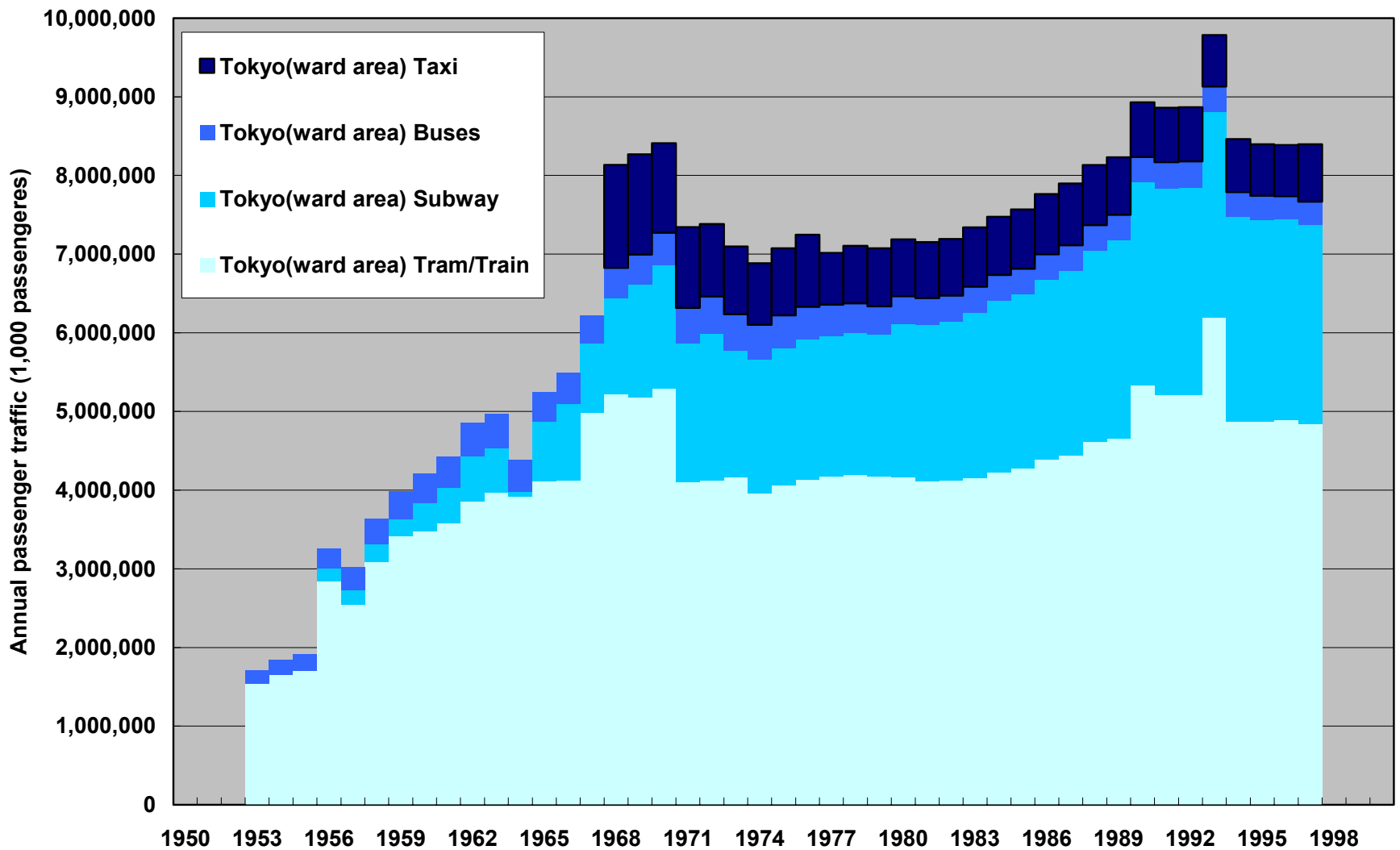
Motorization (Vehicles per 1000 people)



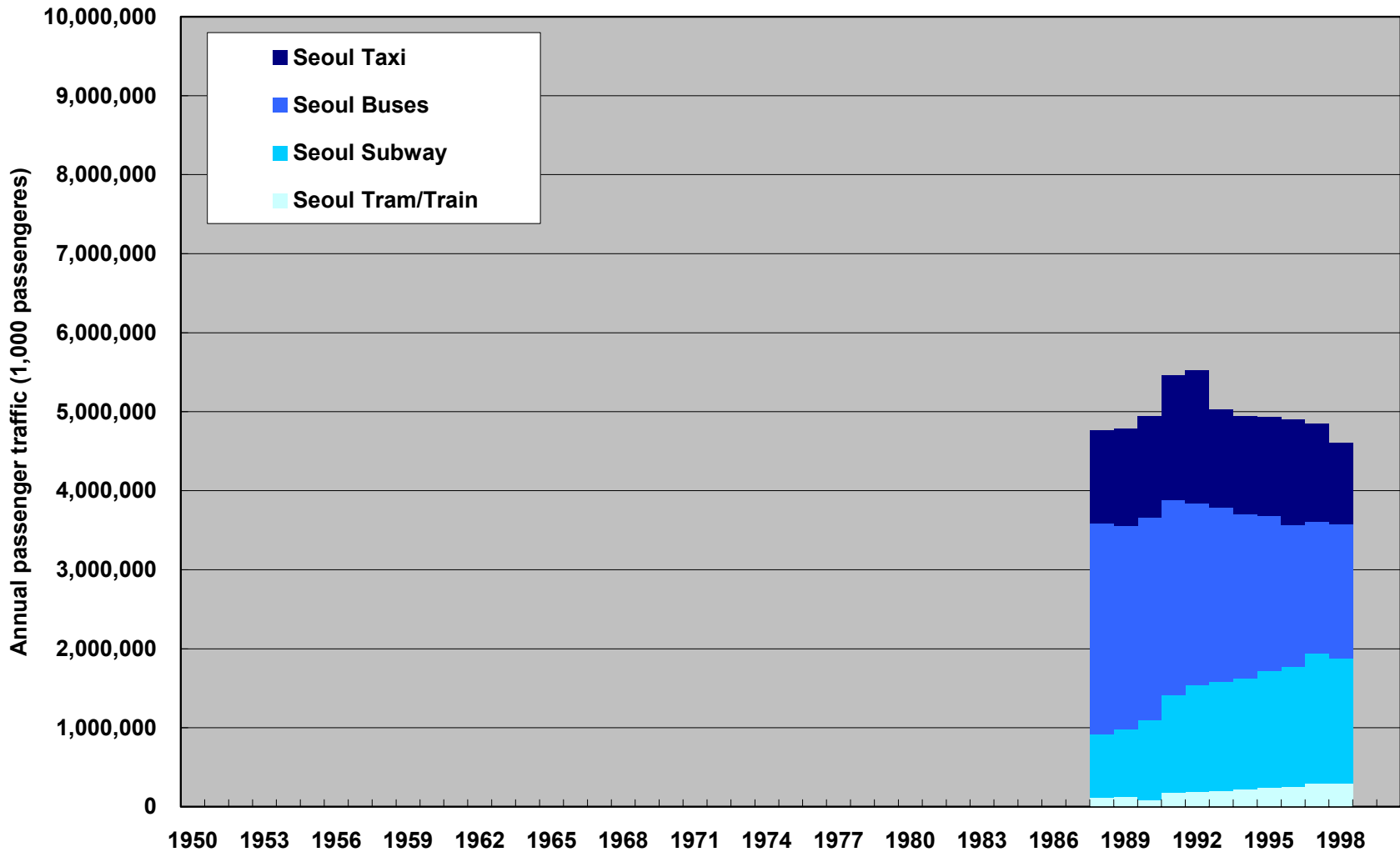
Road Provision per Registered Vehicle (length of paved road/vehicle)



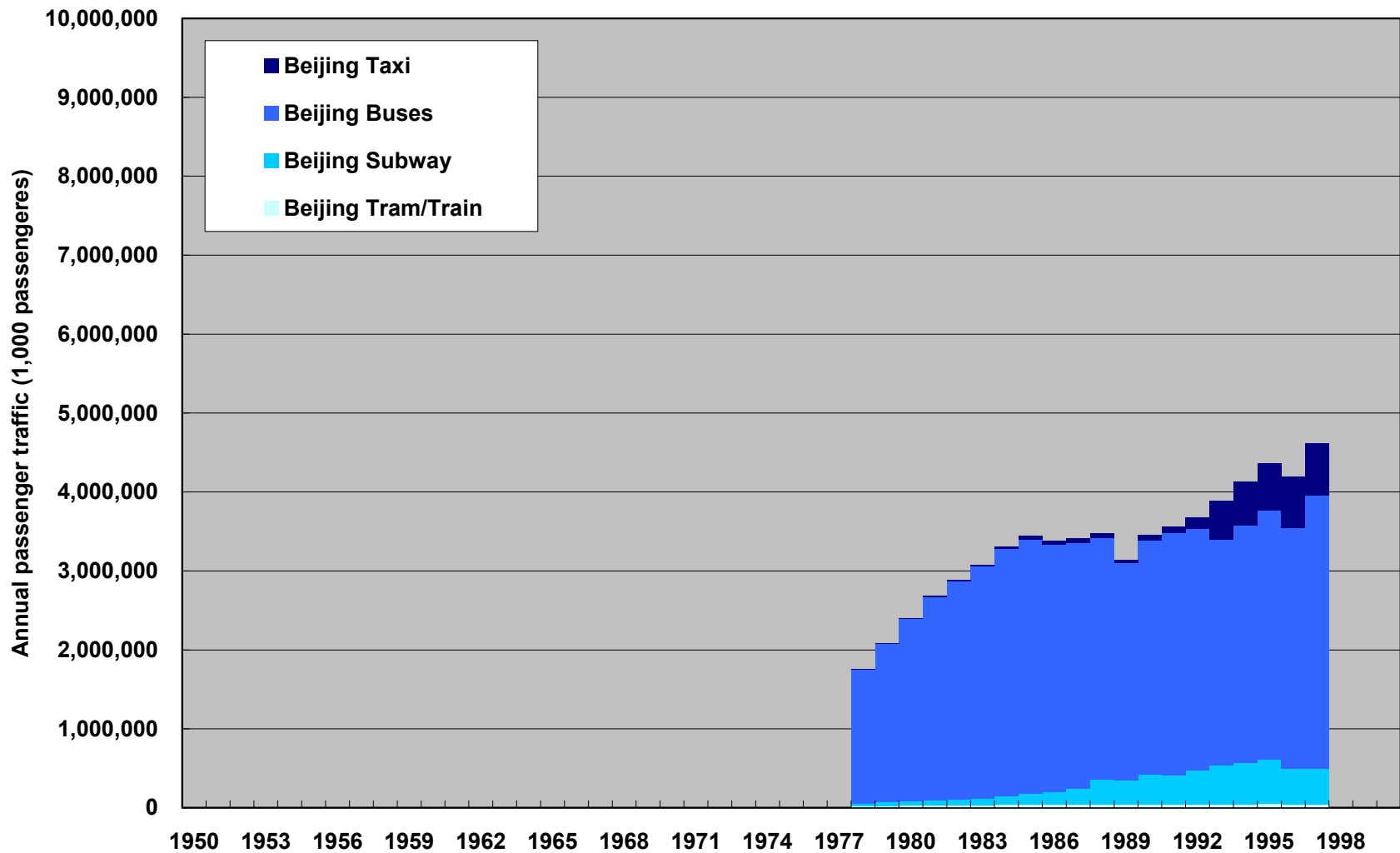
Passenger Traffic by Public Transportation Mode in Tokyo



Passenger Traffic by Public Transportation Mode in Seoul



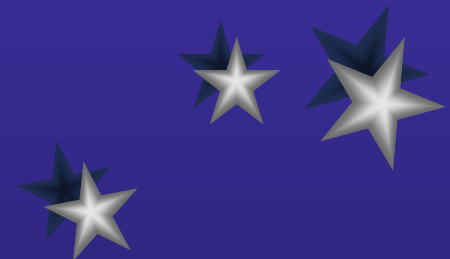
Passenger Traffic by Public Transportation Mode in Beijing



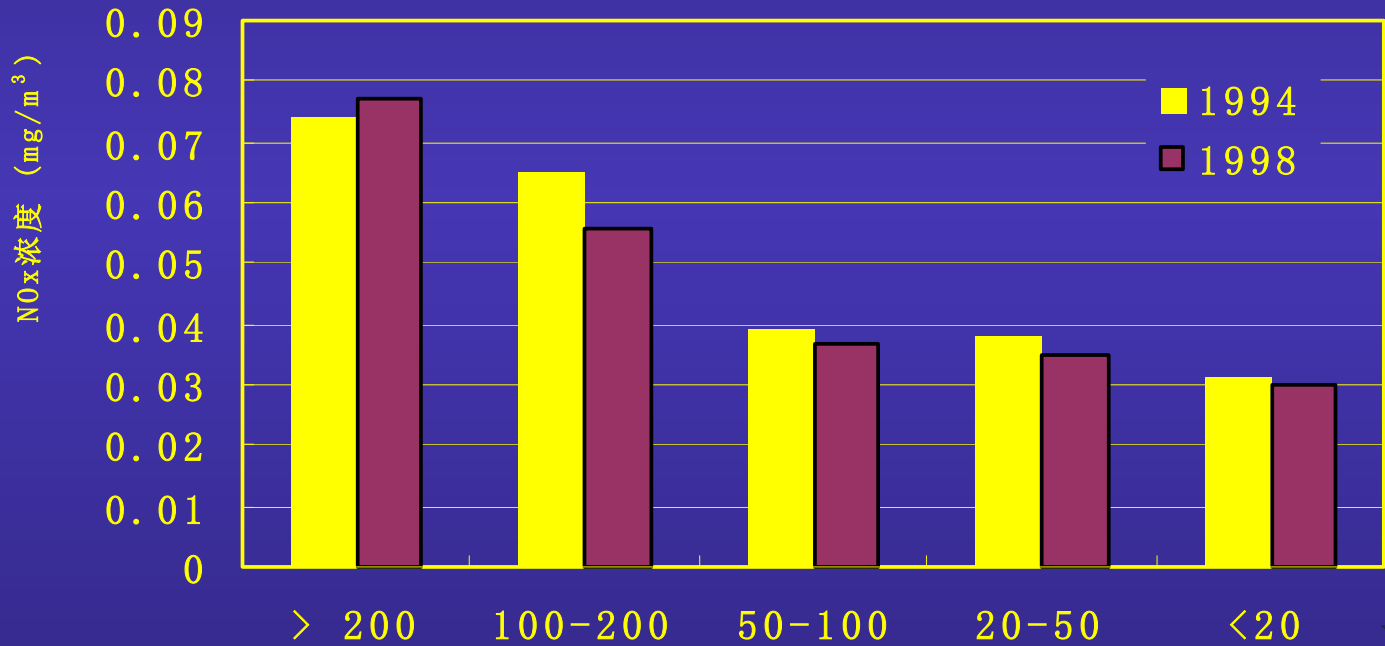


Outline

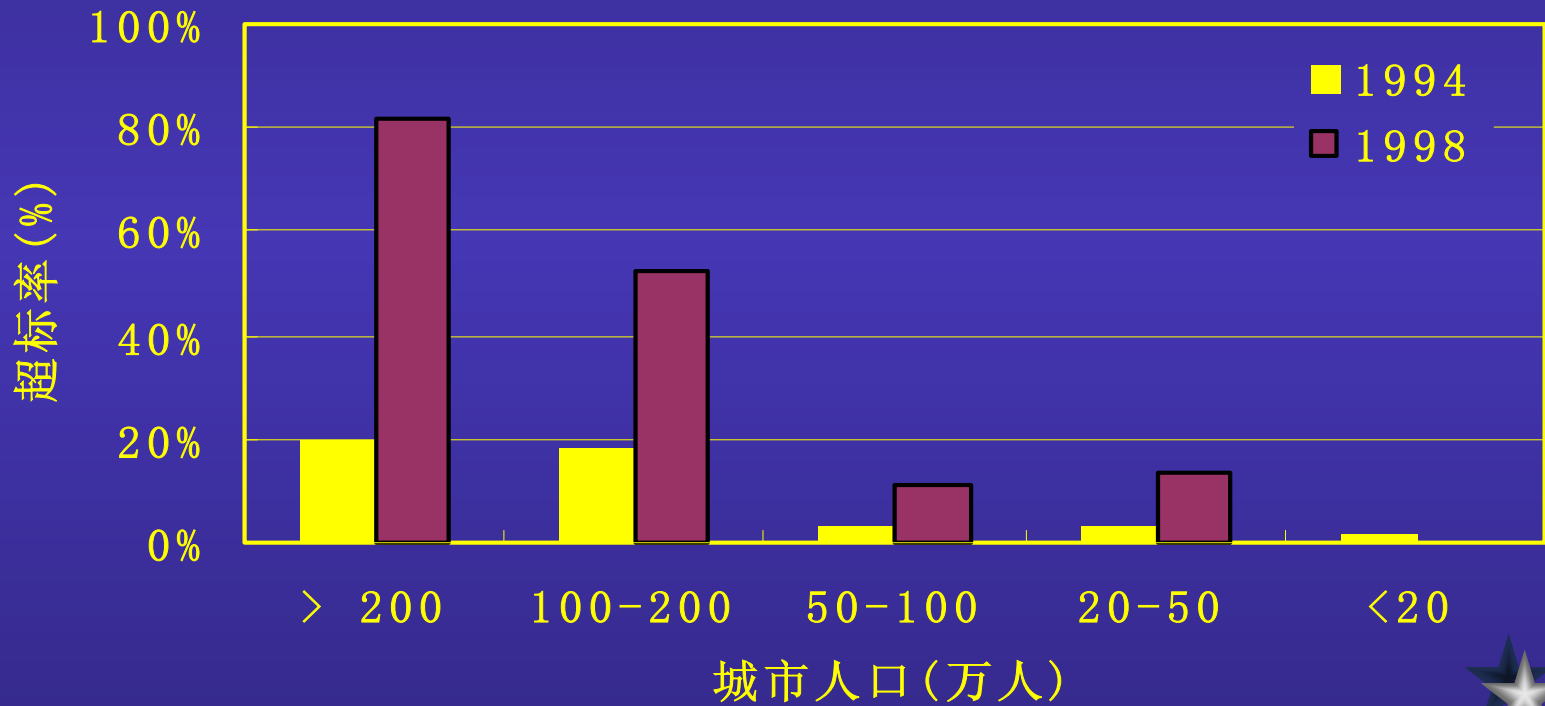
- **Overview of urbanization**
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NOx Concentration for Different Scale Cities



Rates of NOx exceeding standard





China: Urban NO_x Concentration

NO_x Concentration in Chinese cities

year	No. Of cities	Non-attainment cities		Non-attainment for Class II standard		Non-attainment for Class III standard		Non-attainment cities for Class III
		number	rate (%)	number	rate (%)	number	rate (%)	
1995	88	32	36.4	3	3.4	0	0	Beijing, Guangzhou, Lanzhou
1996	88	27	30.7	25	28.4	2	2.3	Beijing, Guangzhou
1997	94	32	34.1	29	30.9	3	3.2	Beijing, Guangzhou, Shanghai
1998	96	32	33.3	29	30.2	3	3.1	Beijing, Guangzhou, Shanghai



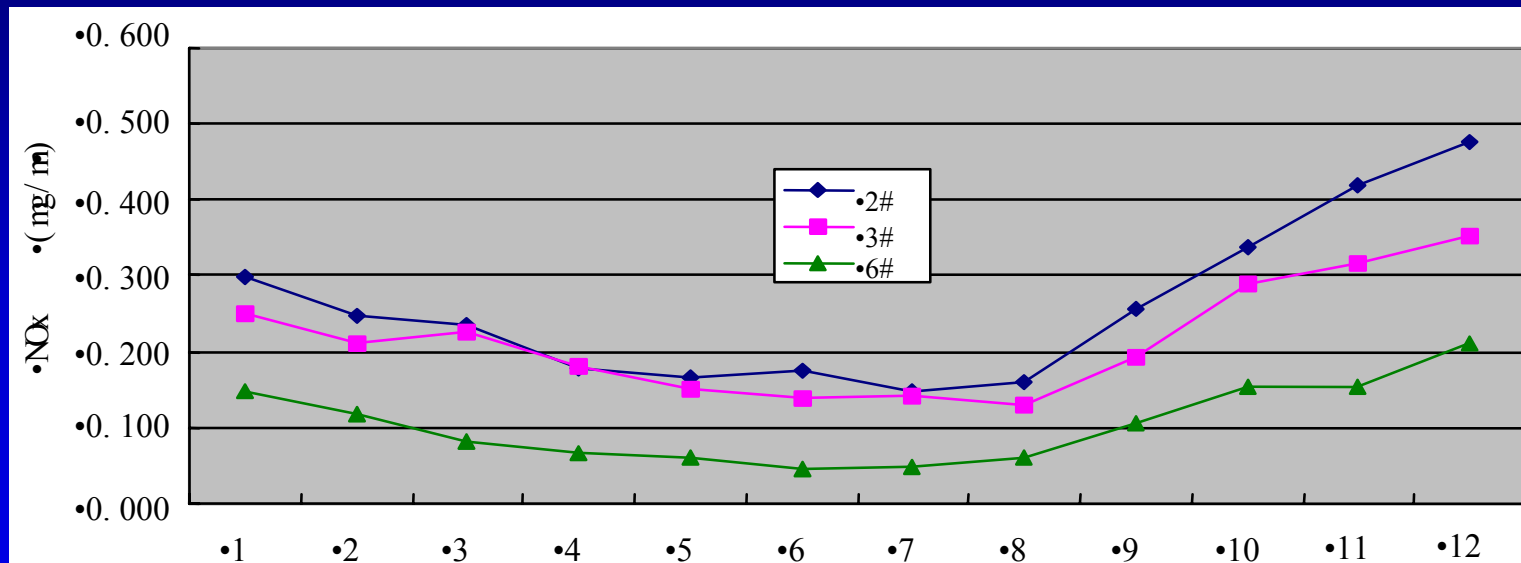
Beijing: Air Pollutant Concentrations

Air Quality in Beijing from 1997-1999 (mg/m³)

year	SO ₂	NO _x	CO	TSP
1997	0.125	0.133	3.0	0.318
1998	0.120	0.152	3.3	0.378
1999	0.080	0.140	2.9	0.364

BEIJING: NO_x Concentration In 1998

Monthly NO_x concentration distribution in 1998



2# and 3# monitoring stations are near to the arteries, and 6# monitoring station is far away from the arteries.



BEIJING: O₃ Concentration in 1997-1999

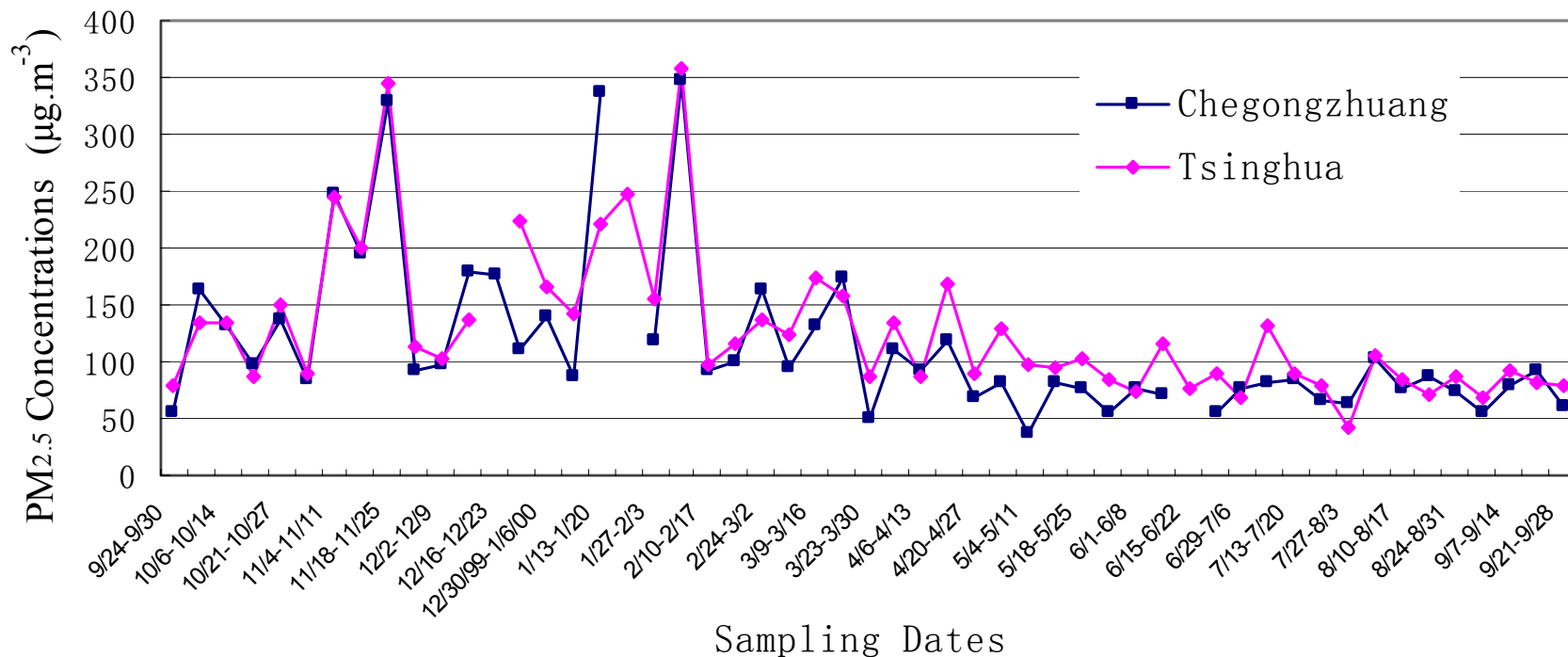
Ozone concentration in Beijing

O₃ Concentration in Beijing

	Number of non-attainment days	Number of non-attainment hours	Max. Hourly concentration (μg/m ³)
1997	71	434	346
1998	101	504	384
1999	119	777	

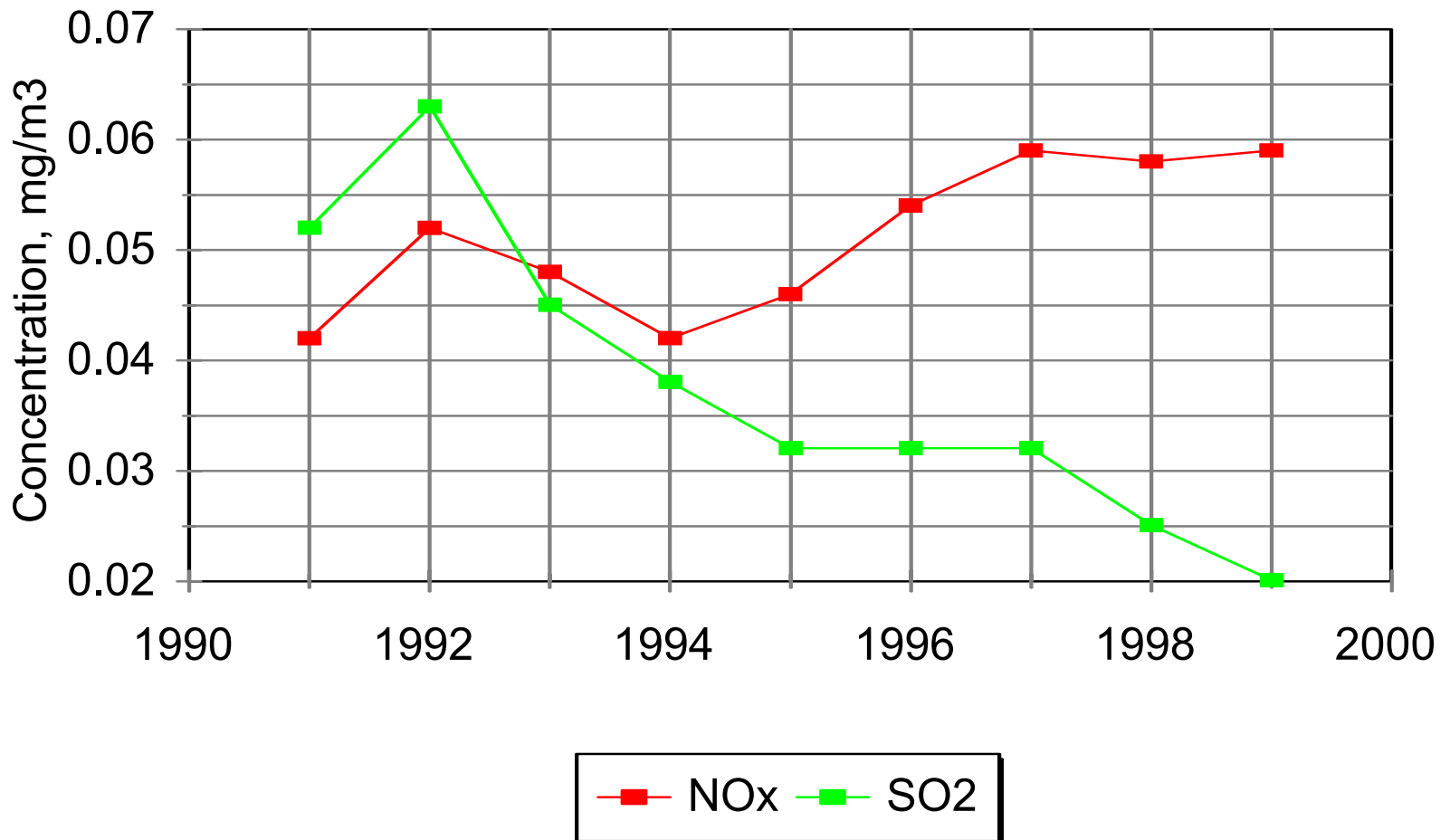
Beijing: $PM_{2.5}$ Mass Concentration Levels in 1999-2000

Weekly variations



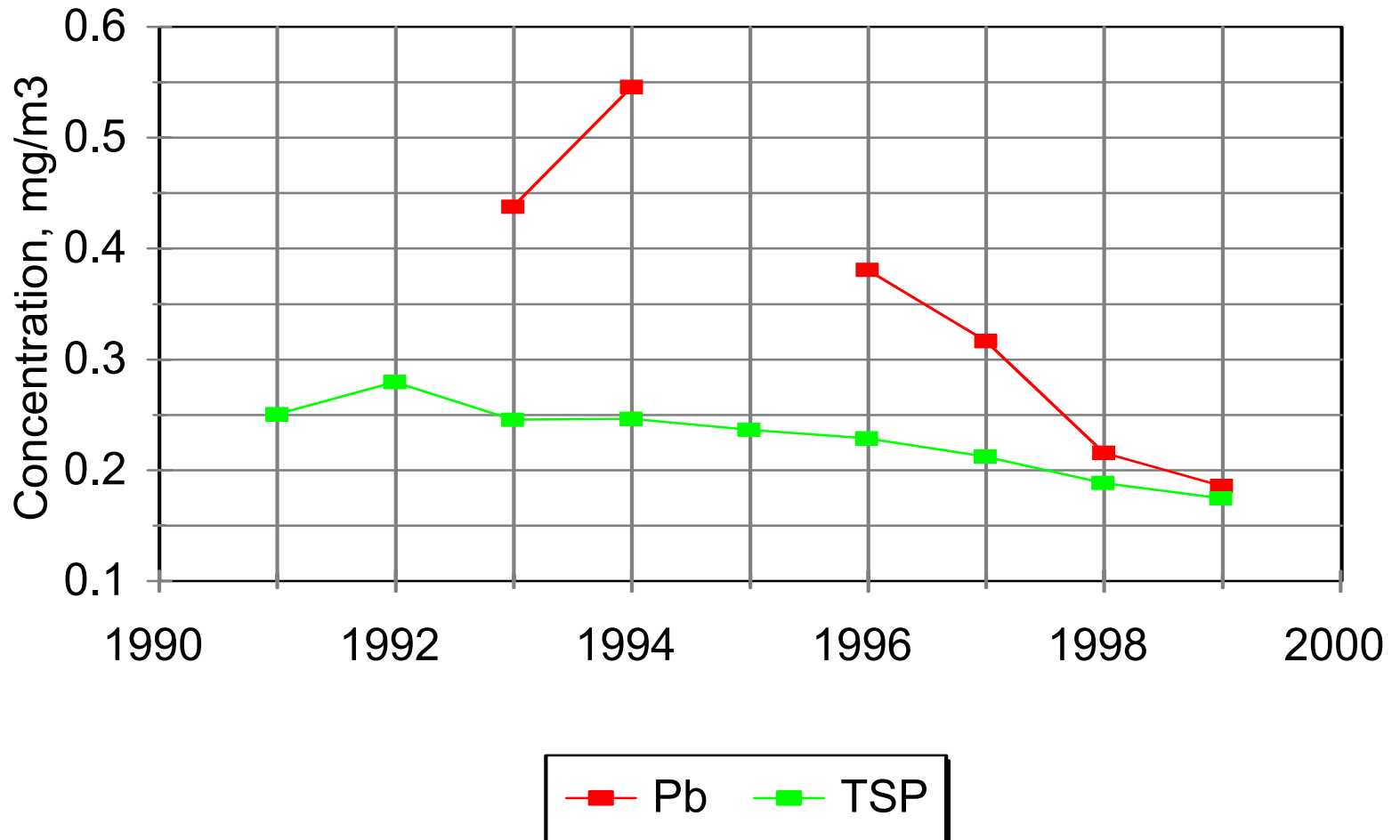
- Similar temporal variations at the two sites
- Strong weekly variations: *max difference for two consecutive weeks is 2.5 times*

Shanghai: NOx and SO2 Concentrations from 1990 to 1999





Shanghai: Pb and TSP Concentration



Shanghai: CO Concentration

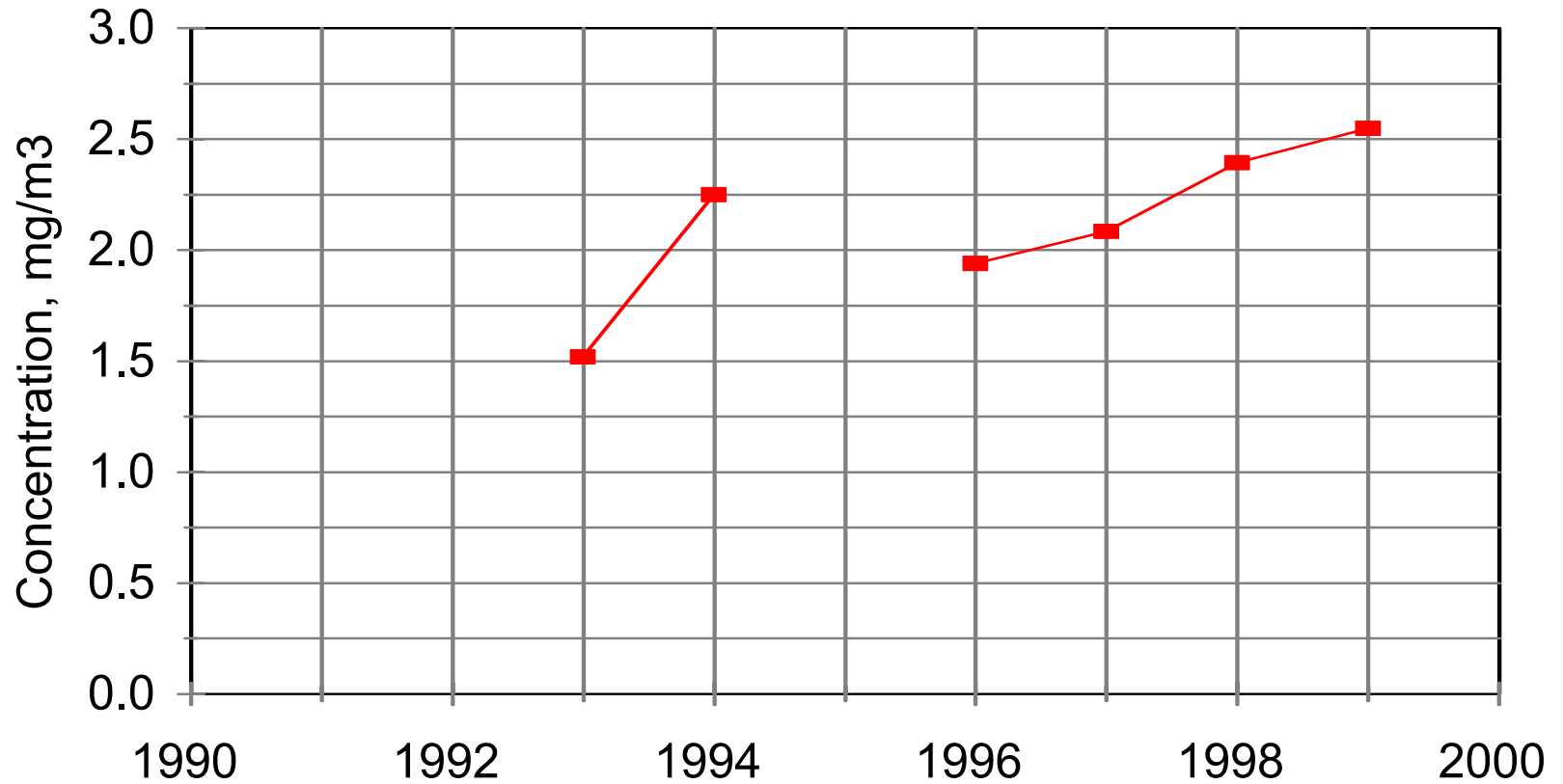
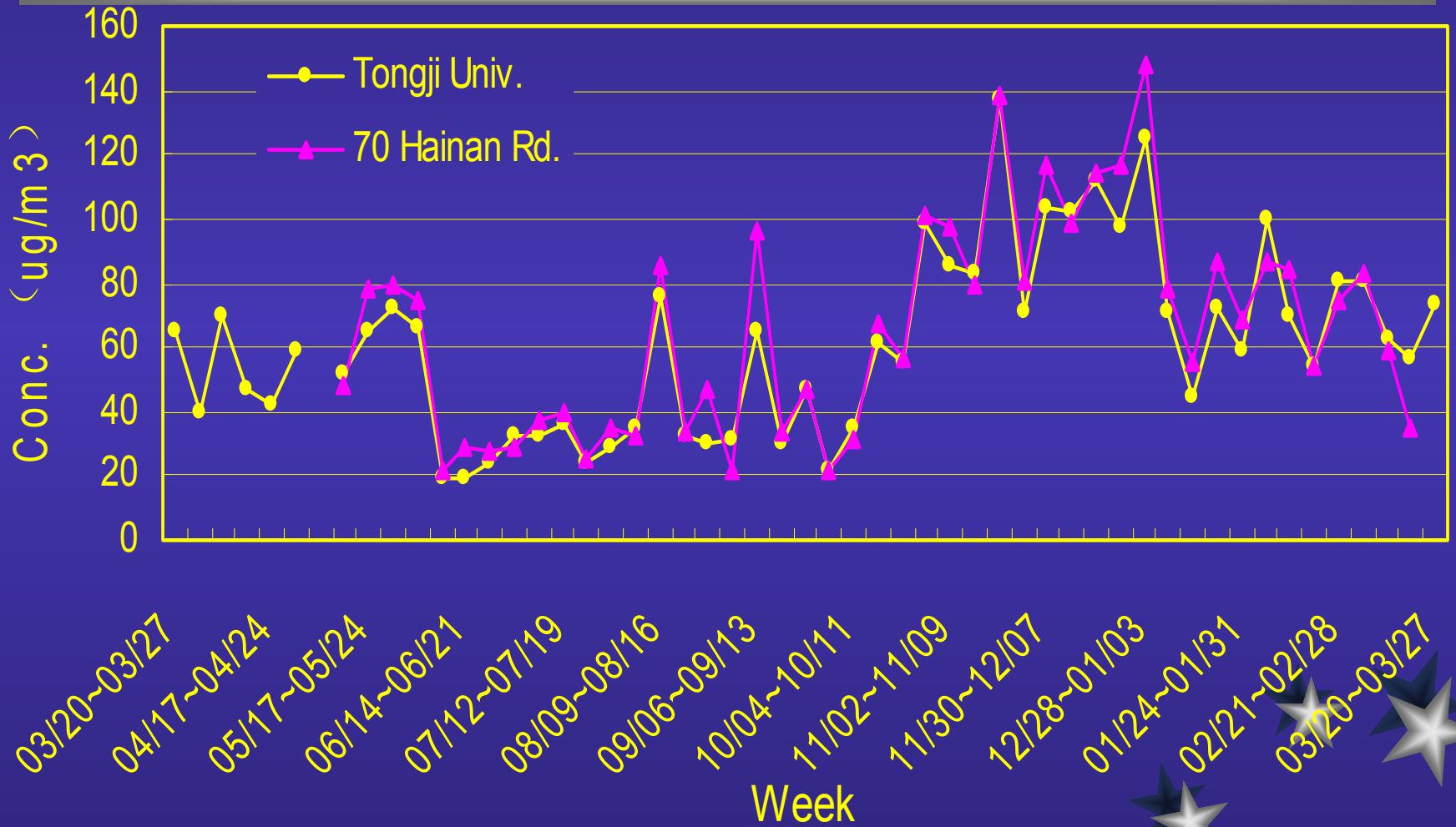


图1 PM2.5周平均浓度的变化曲线

Fig. 1 Weekly PM2.5 variations at two sampling sties

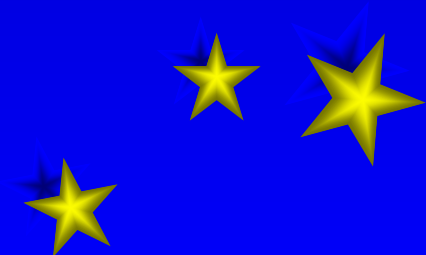


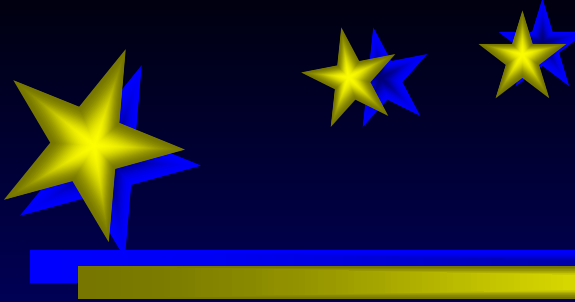


Guangzhou: Air Quality in 1997-1999

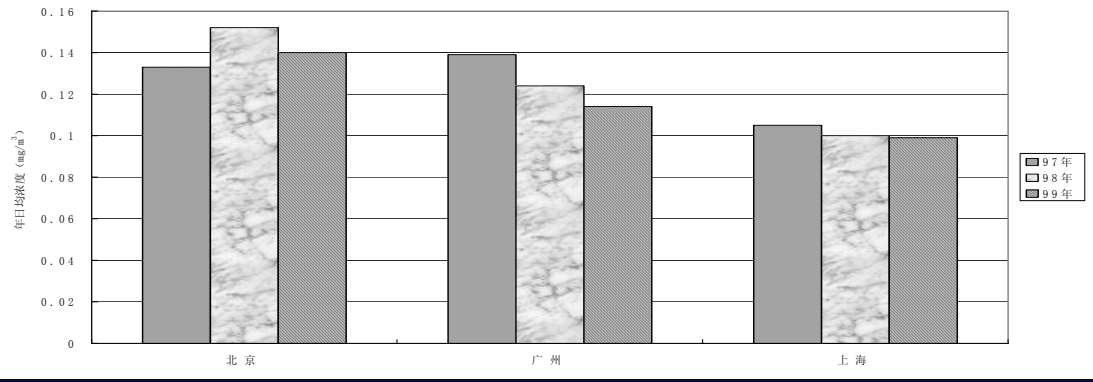
Guangzhou: Air Quality from 1997-1999 (mg/m³)

year	SO ₂	NO _x	CO	TSP
1997	0.07	0.139	2.54	0.217
1998	0.061	0.124	2.42	0.202
1999	0.054	0.114	2.29	0.182

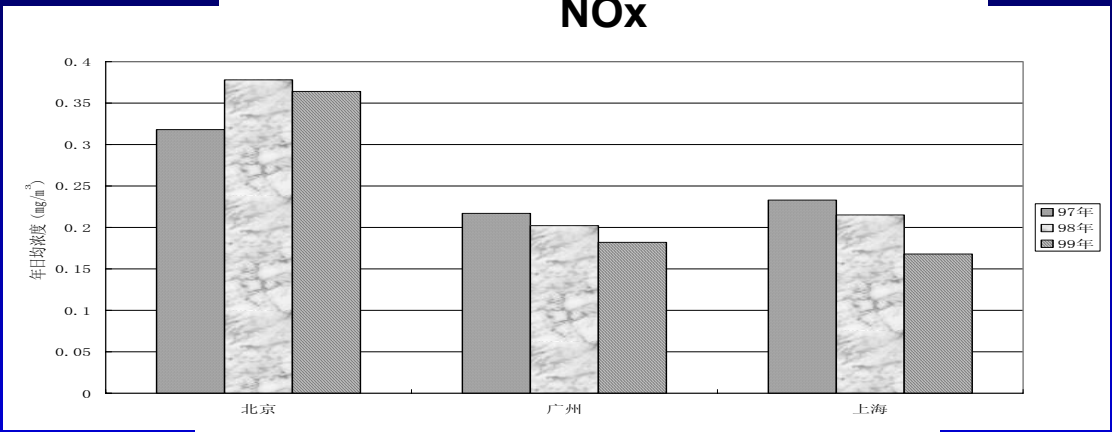




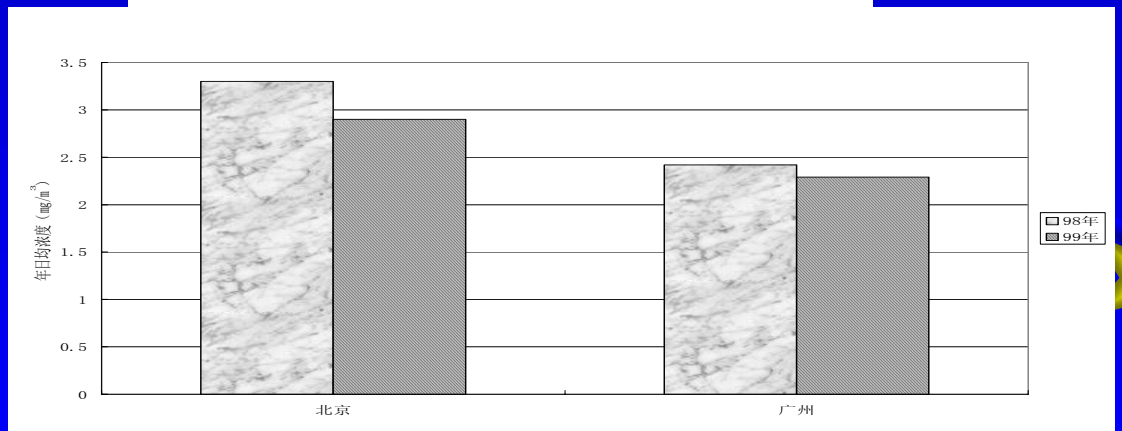
Air Pollutant Concentration in Three cities



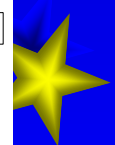
NOx



TSP



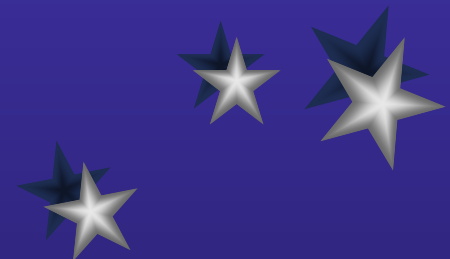
CO





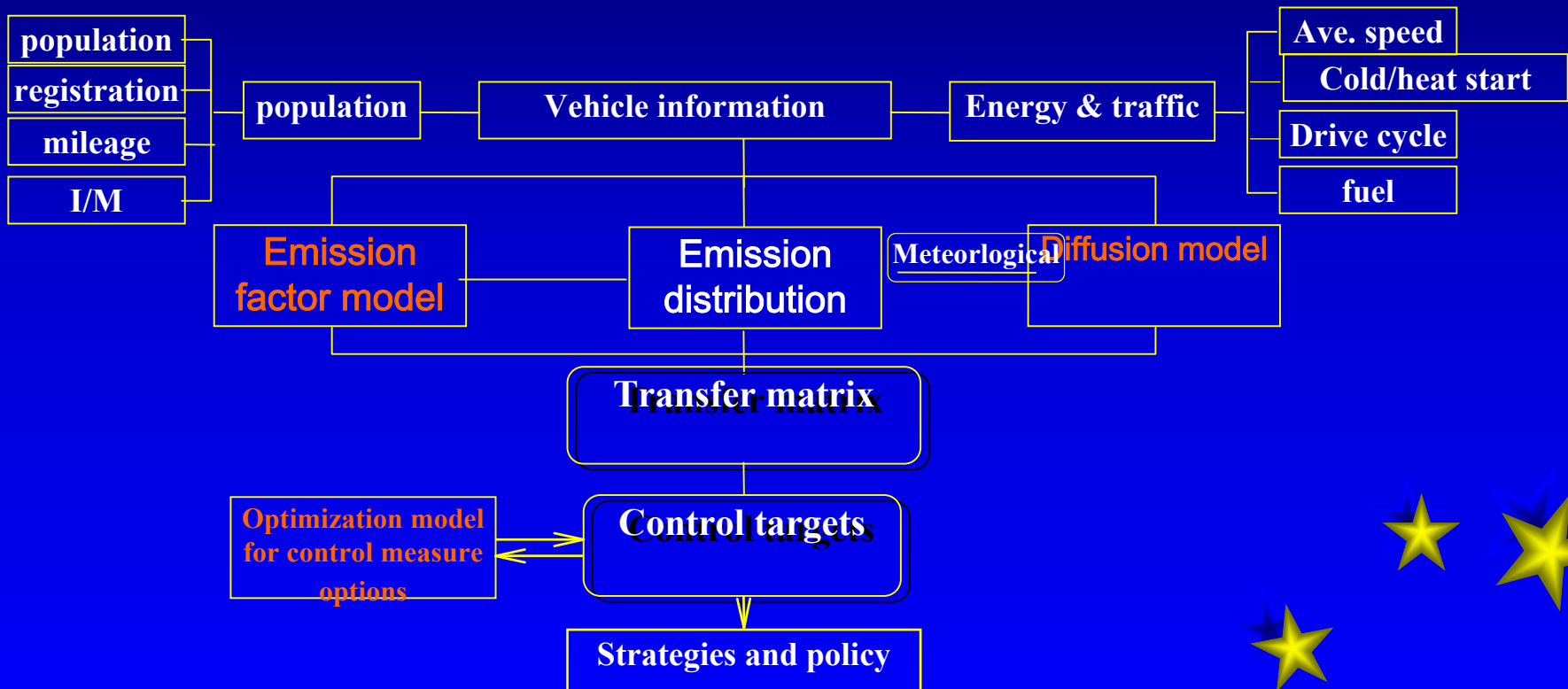
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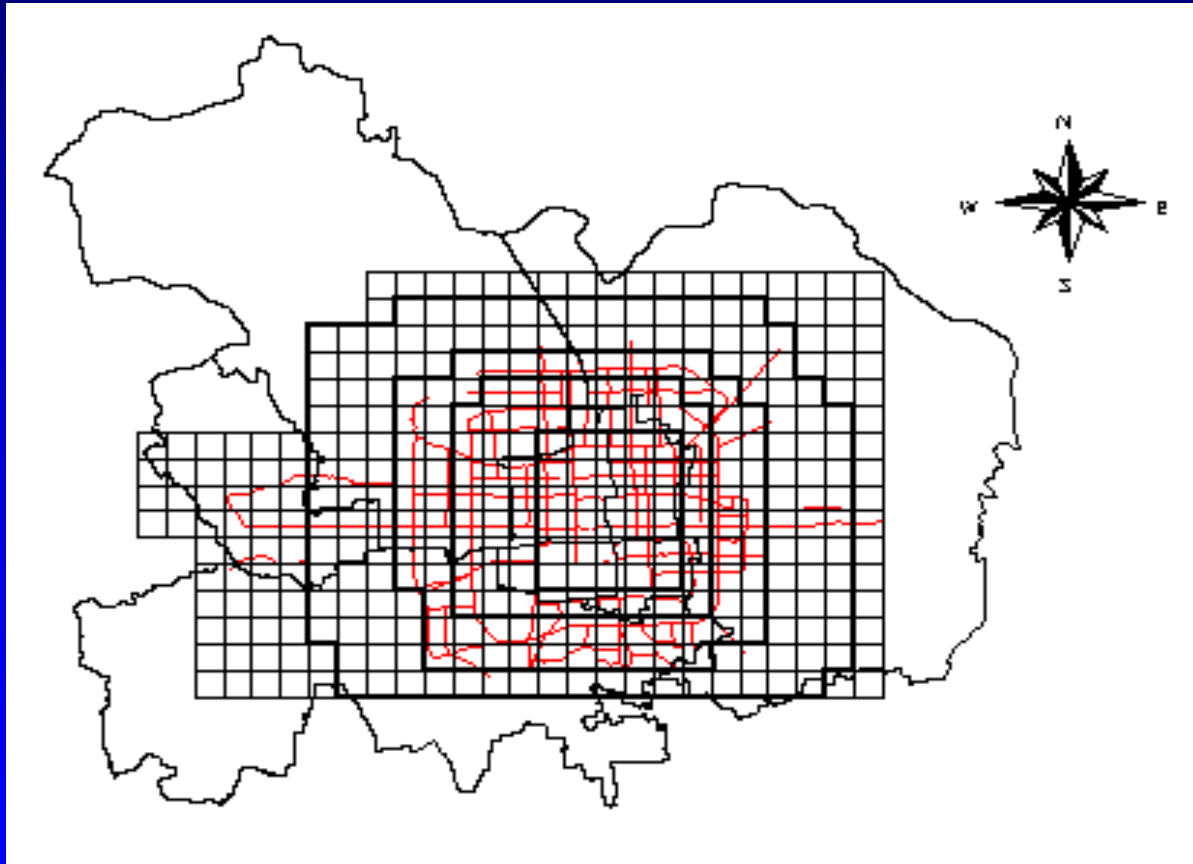


Methodology: Model Description



Methodology: Grid system

grid system is needed (364 , 1.5km*1.5km grids)



In Beijing, the road system can be described briefly as a network, with ring roads (thick solid lines) and radial roads (fine red lines) as its arteries.



Calculation of Vehicle Emission Factors

☆ **Modified Mobile5 model was used to calculate emission factors**

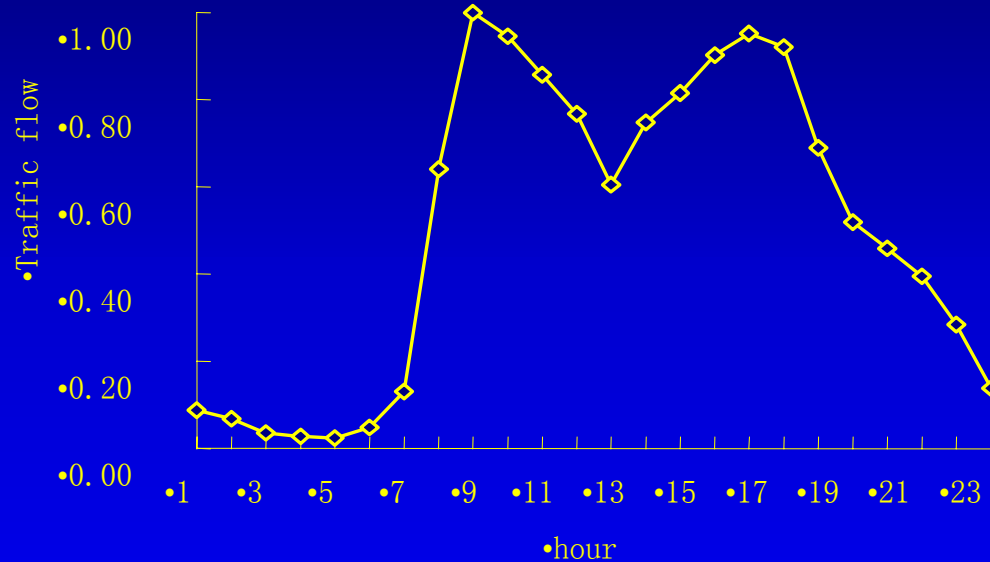
- **Modification items**

- **RVP**
- **Temperature**
- **Driving cycle conditions**
- **Speed**
- **I/M**
- **Other factors (air conditioning used, overloaded and so on)**

$$EF = FUN (CMFA L UH)$$


MOBILE SOURCE CONTRIBUTION TO AIR POLLUTANT CONCENTRATIONS

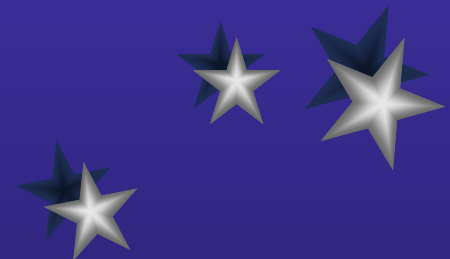
Hourly traffic flow variation





Three cases in Beijing

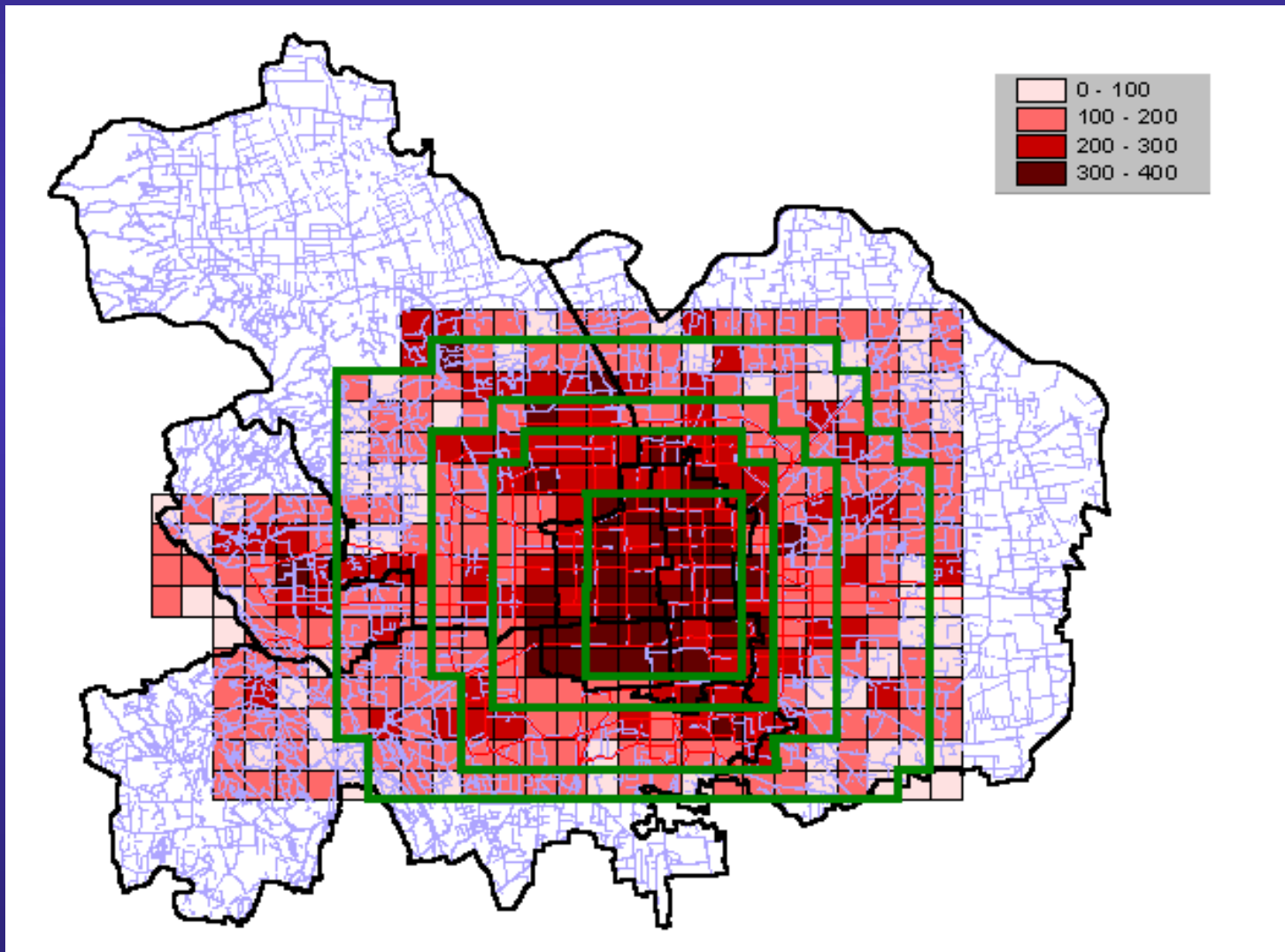
- **Formulating mobile source control strategy from 1995 to 2010**
- **Evaluating the effectiveness of air pollution control measures since 1998**
- **Prediction of air quality in 2008**



Case I:

Mobile Source Emission Inventory

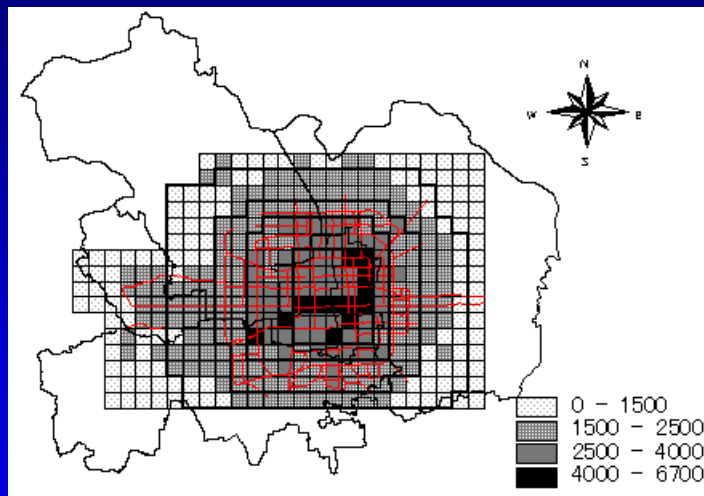
(NO_x, 1995, t / y)



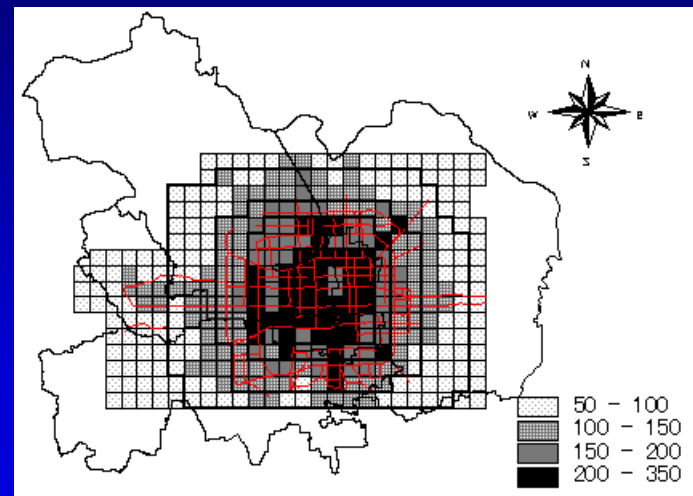
Case I:

MOBILE SOURCE CONTRIBUTION TO AIR POLLUTANT CONCENTRATIONS

- Spatial distribution of annual average concentrations in 1995



CO



NO_x

Case I: MOBILE SOURCE CONTRIBUTION TO AIR POLLUTANT CONCENTRATIONS

	Year	Emissions,(t)	Pollution Share for Emission (%)	Pollution Share for Concentration (%)	
				Urban Area	Downtown
CO	1995 年	107.5	76.8	76.5	86.3
	1998 年	129.0	82.7	84.1	89.5
NO _x	1995 年	9.38	40.2	68.4	72
	1998 年	11.5	42.9	72.8	73.6




Case I: Scenarios for control option

• Mobile source control strategies (Scenario 2)

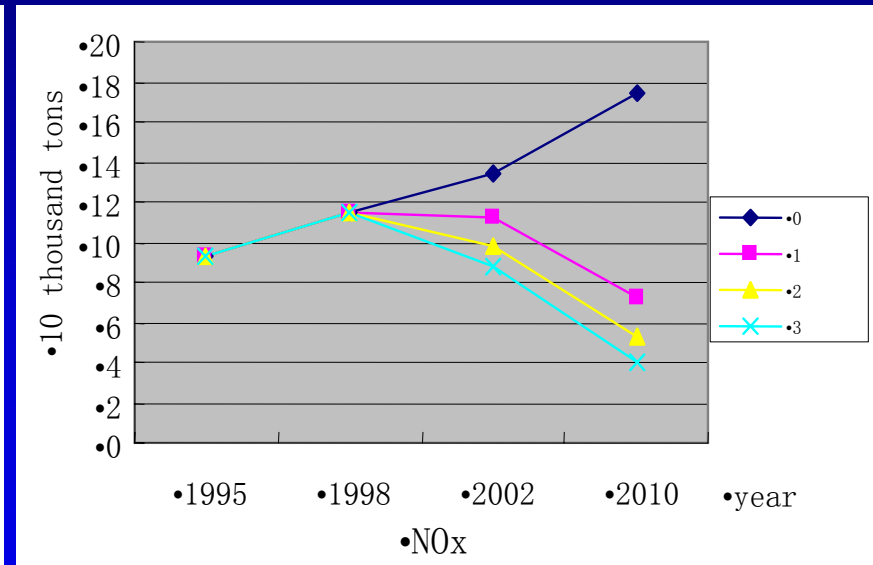
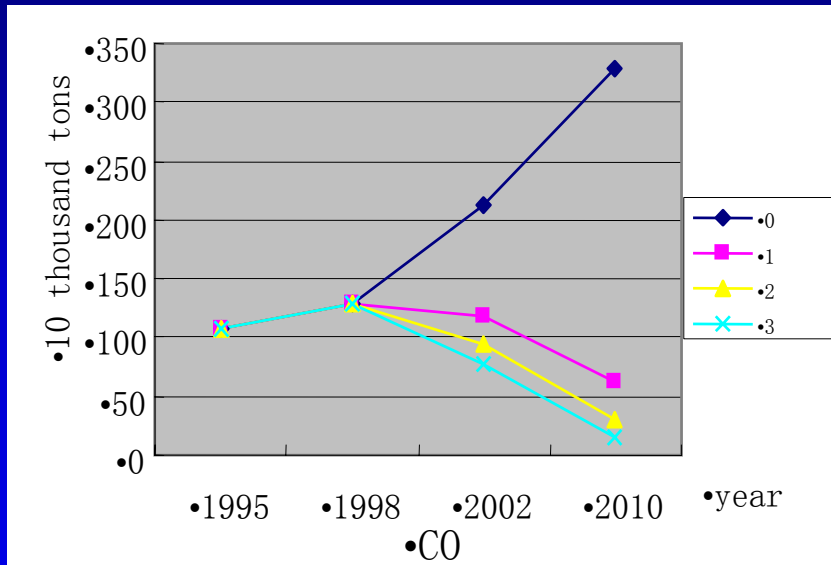
-- For new vehicles

	•EURO •1	•EURO •2	•EURO •3	•EURO 4
•Light-duty •vehicles •I	•1999.1.1	•2003.1.1	•2007.1	•2010.
•Light-duty •vehicles •II	•2000.1.1	•2003.1.1	•2007.1	•2010.
•High-duty •vehicles	•2000.1.1	•2003.1.1	•2008.1	•2014
•Motorcycles	•2001.1.1			

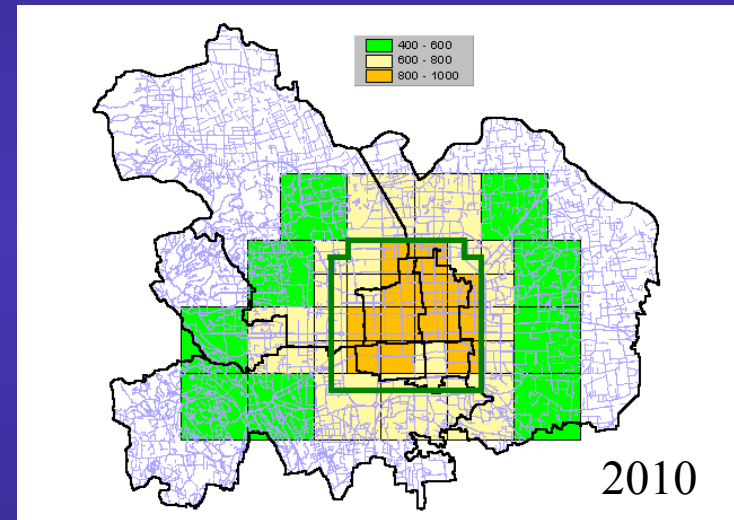
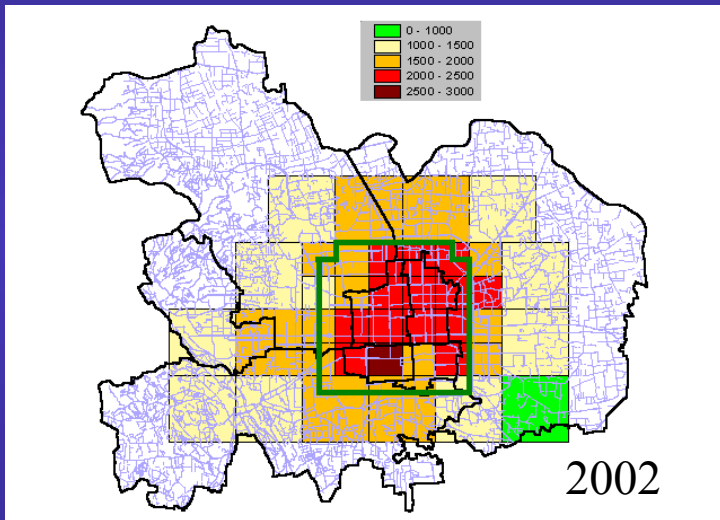


Case I: IMPACTS OF EMISSION CONTROL ON AIR QUALITY

The reduction potential of different control strategies



Case I: IMPACTS OF EMISSION CONTROL ON AIR QUALITY

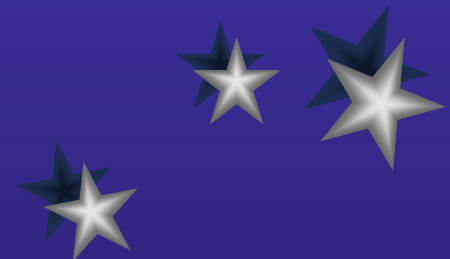


CO concentration with control (ug/m³)



Case I: Government Action

- ☆ **Beijing: emission standard for exhaust pollutants from light-duty vehicles**
- ☆ **Shanghai: emission standard for exhaust pollutants from light-duty vehicles**
- ☆ **Emission Standard for exhaust pollutants from light-duty vehicles (GWPB1-1999)**
- ☆ **Standard for hazardous contents in gasoline (GWPB001-1999)**



Case II:

Measures for mobile source in phase I

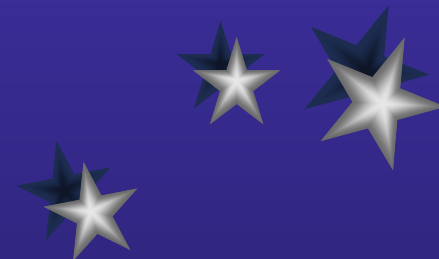
Vehicle type	vehicle no.	NOx red.	Ratio to popu.
Scrap m-bus	14000	8902	6.3%
Scrap other	24000	4648	3.3%
Temp. stop	3782	732	0.5%
return	544/day	211	0.1%
retrofit	56416	4696	3.3%



Case II:

Measures for mobile source in phase II

Vehicle type	vehicle no.	NOx red.	Ratio to popu.
Scrap m-bus	6762	4300	3.05%
Scrap other	13238	2564	1.82%
Temp. stop	17000	3292	2.33%
return	370	143	0.10%
retrofit	312500	15130	10.73%
PCV	62000	8405	5.96%

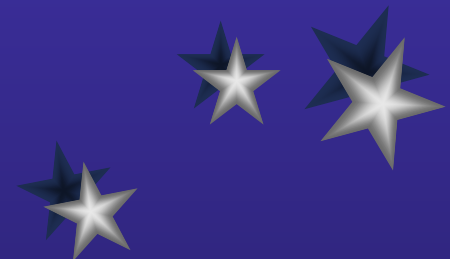




Case II:

Measures for mobile source in phase III

Vehicle type	vehicle no.	NOx red.	Ratio to popu.
Temp. stop	430 / week	1082.582	0.77%
return	94 / day	36.41	0.03%
retrofit	12000	998.78	0.71%

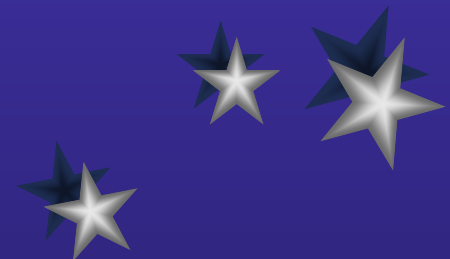




Case II:

Measures for mobile source in phase IV

- ☆ Attainment rate for vehicle emission control reached 90%, which results in 8922.4 ton NO_x reduction
- ☆ Measures for stationary sources is considered in the calculation





Effectiveness from four phases' control measures

- emission reduction
(baseline:1998)

	SO ₂	NO _x		PM10
		transport	coal	
Phase 1	1.31%	4.52%	0.27%	0.4%
Phase 2	11.02%	9.68%	2.86%	3.9%
Phase 3	23.39%	12.84%	4.77%	8.8%
Phase 4	27.63%	15.53%	6.84%	11.4%



Effectiveness from four phases' control measures

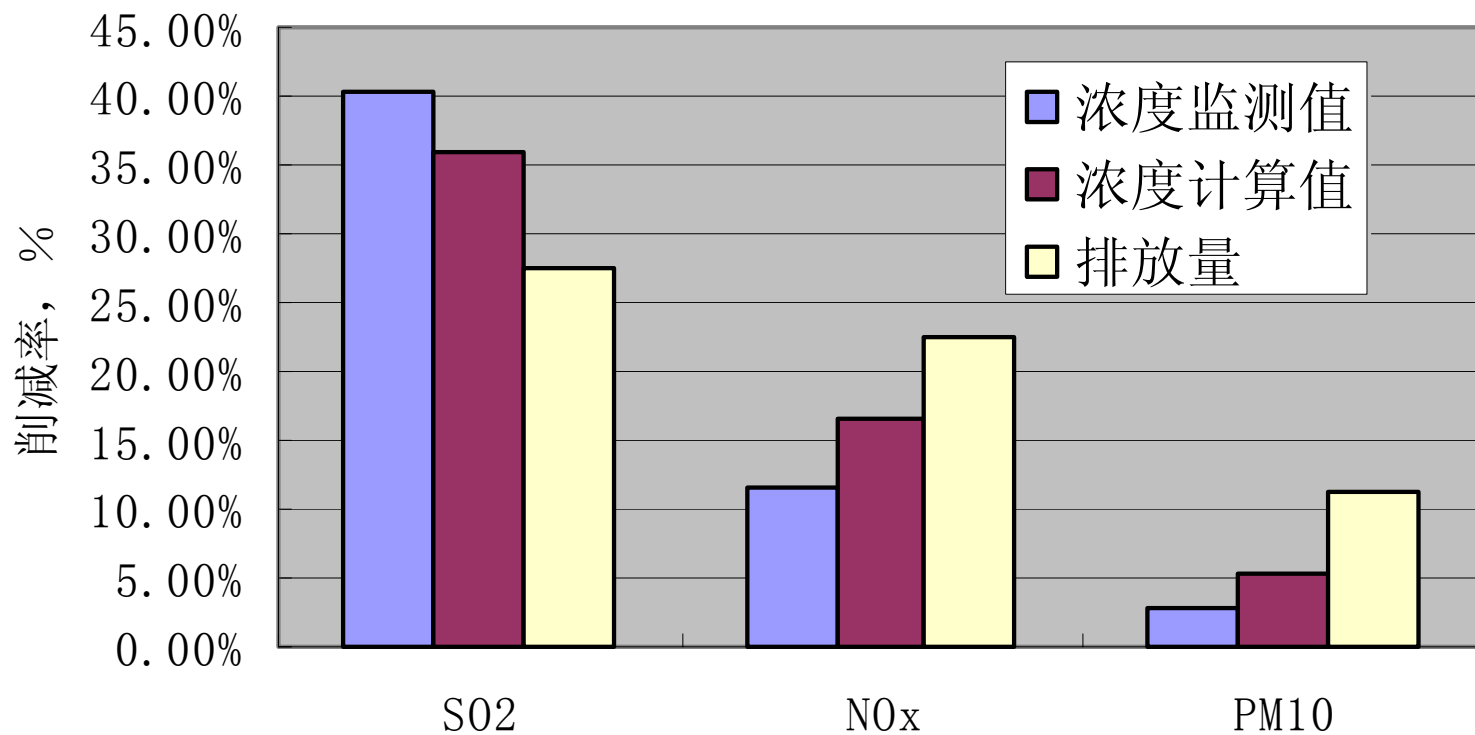
☆ Air concentration reduction (model calculation)

(baseline: 1998)

	SO ₂ ($\mu\text{g}/\text{m}^3$)	NO _x ($\mu\text{g}/\text{m}^3$)	PM10 ($\mu\text{g}/\text{m}^3$)
After control	76.4	123.6	174.2
Reduction rate	35.8%	16.5%	5.3%

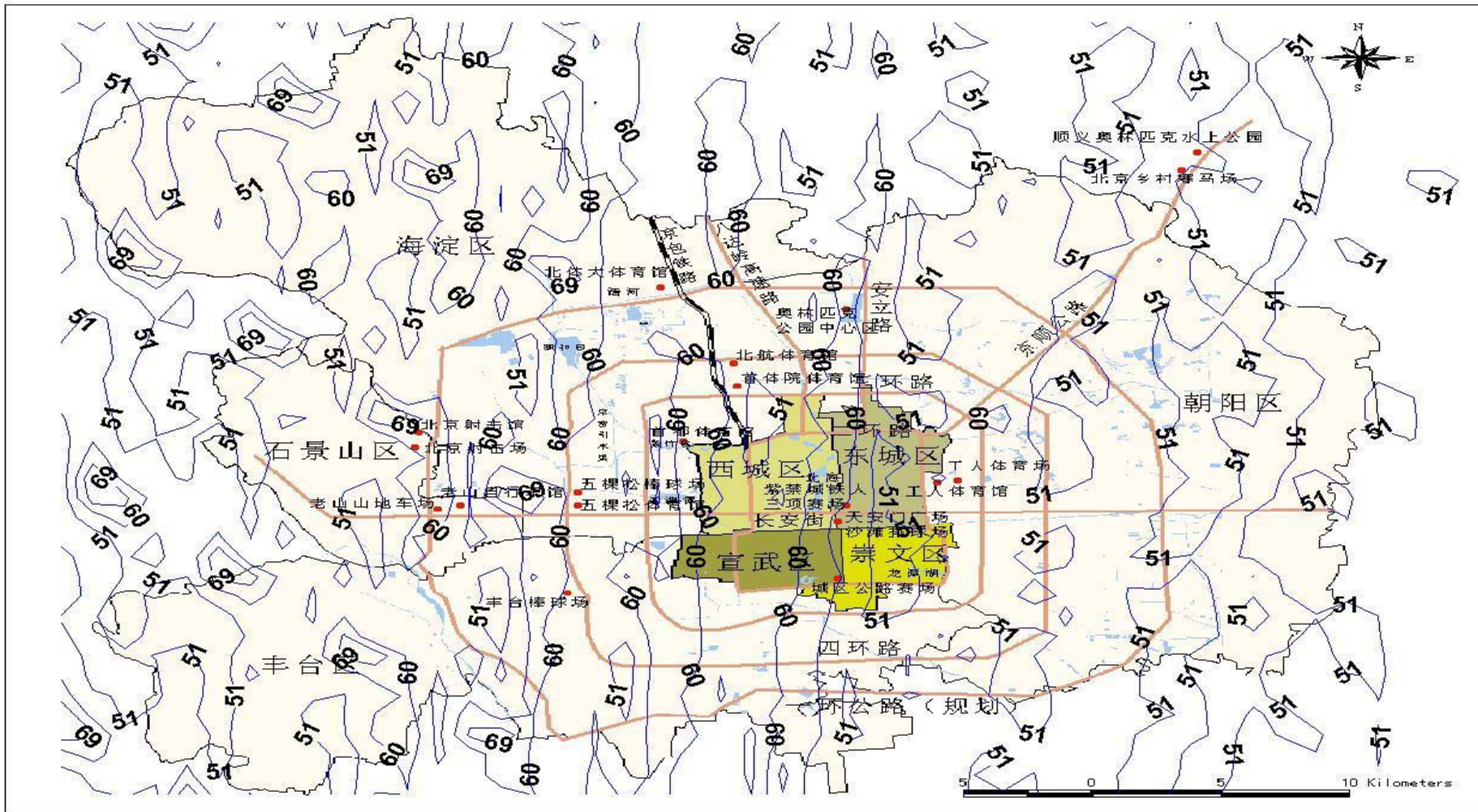
Effectiveness from four phases' control measures

四期措施后相对于1998年的削减率



Case III:

Prediction of PM10 Concentration in Beijing in 2008

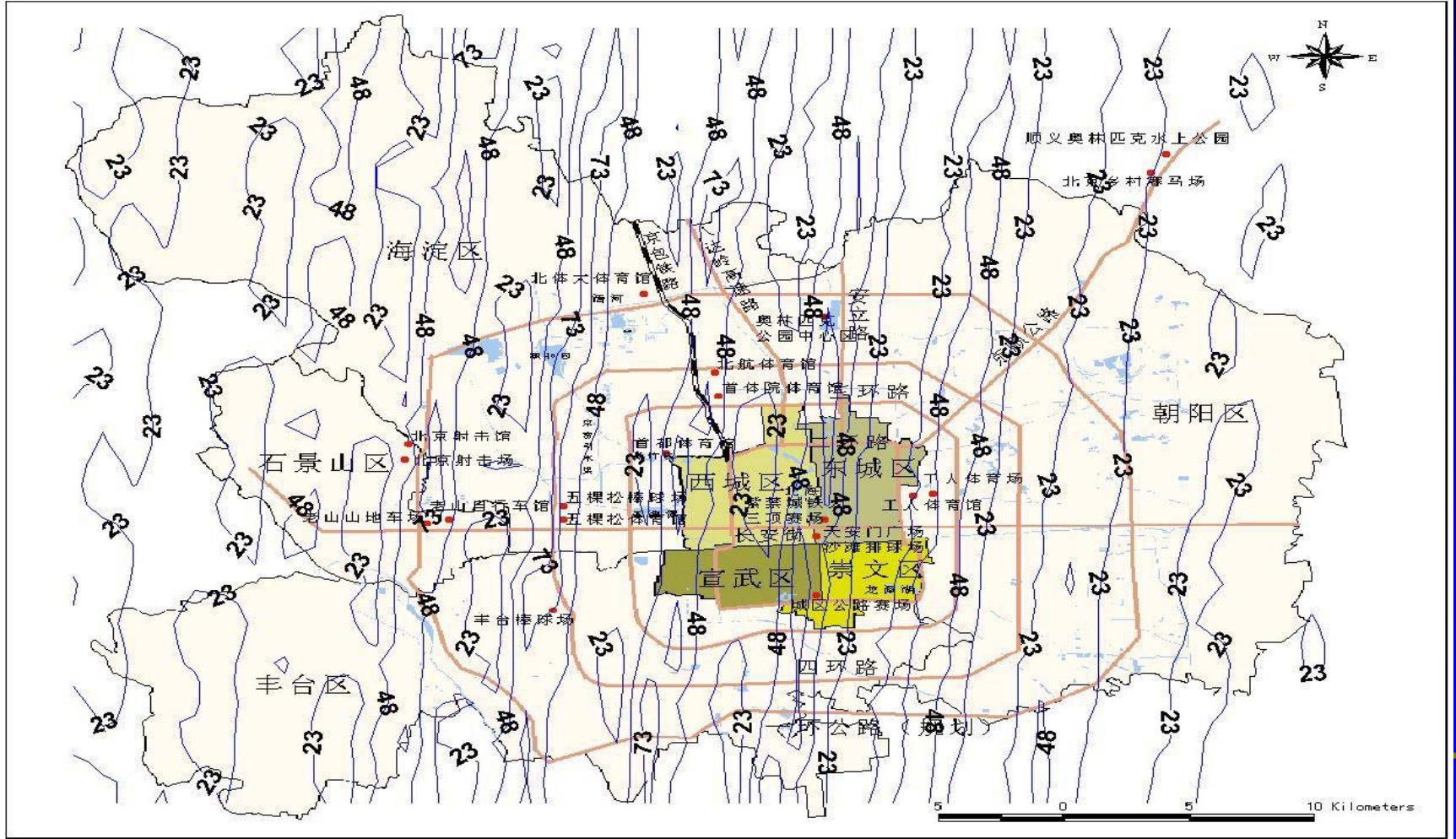


北京市2008年PM10年均浓度值分布图

(单位: $\mu\text{g}/\text{m}^3$)

Case III:

Prediction of NOx Concentration in Beijing in 2008



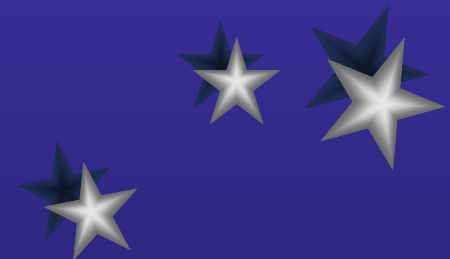
北京市2008年NOx年均浓度值分布图

(单位: ug/m3)



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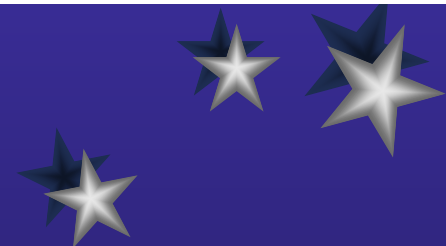


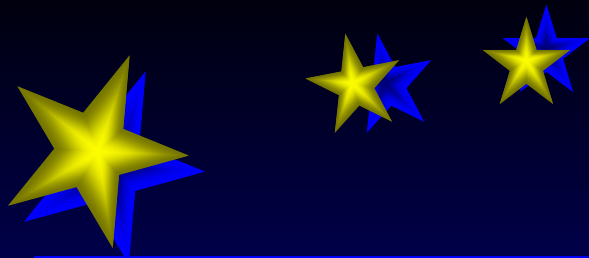
Clean transportation for Olympics

Subway: **1.3 million person-trip / day in 1999**
 2.5 million person-trip / day in 2007

Mass Transit: **9 million person-trip / day in 1999**
 18 million person-trip / day in 2007

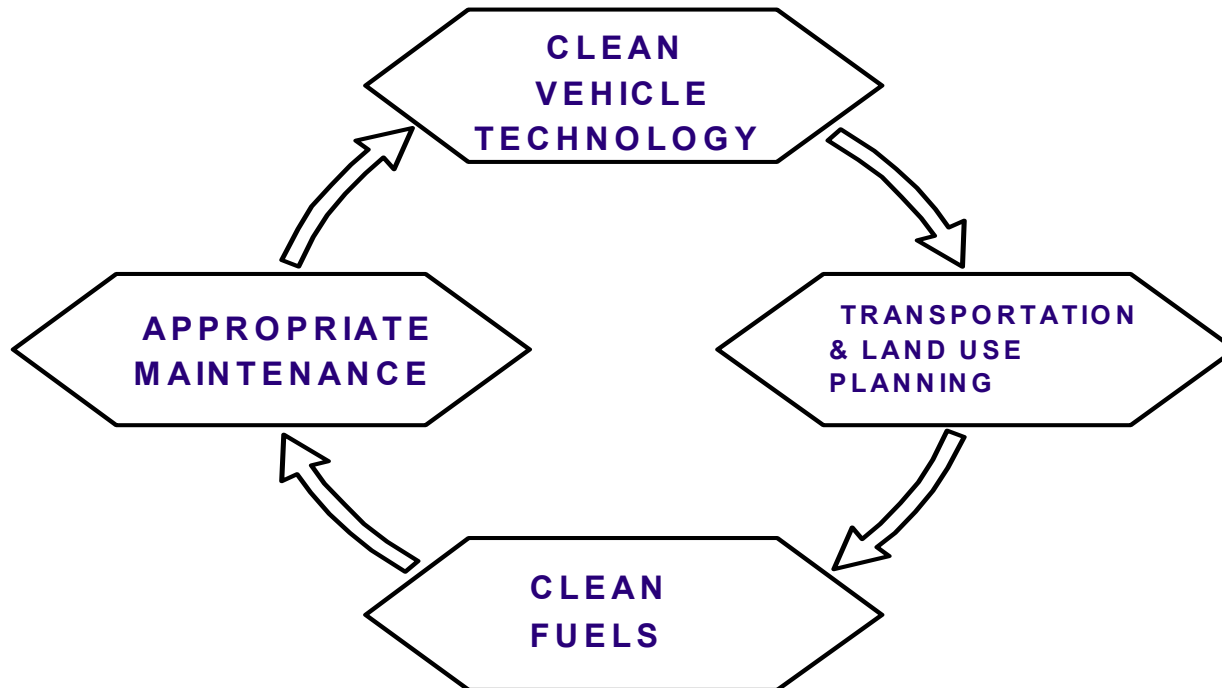
34,000 clean fuel vehicle, 1300 pure CNG
8 million bicycles





Future Consideration

ELEMENTS OF A COMPREHENSIVE VEHICLE POLLUTION CONTROL STRATEGY



***THANK
YOU!***

