17th Annual U.S. EPA
Emissions Inventory Conference

Development of High-Resolution Motor Vehicle Emission Inventories for City-wide Air Quality Impact Analysis in China

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June 3, 2008
Portland, Oregon

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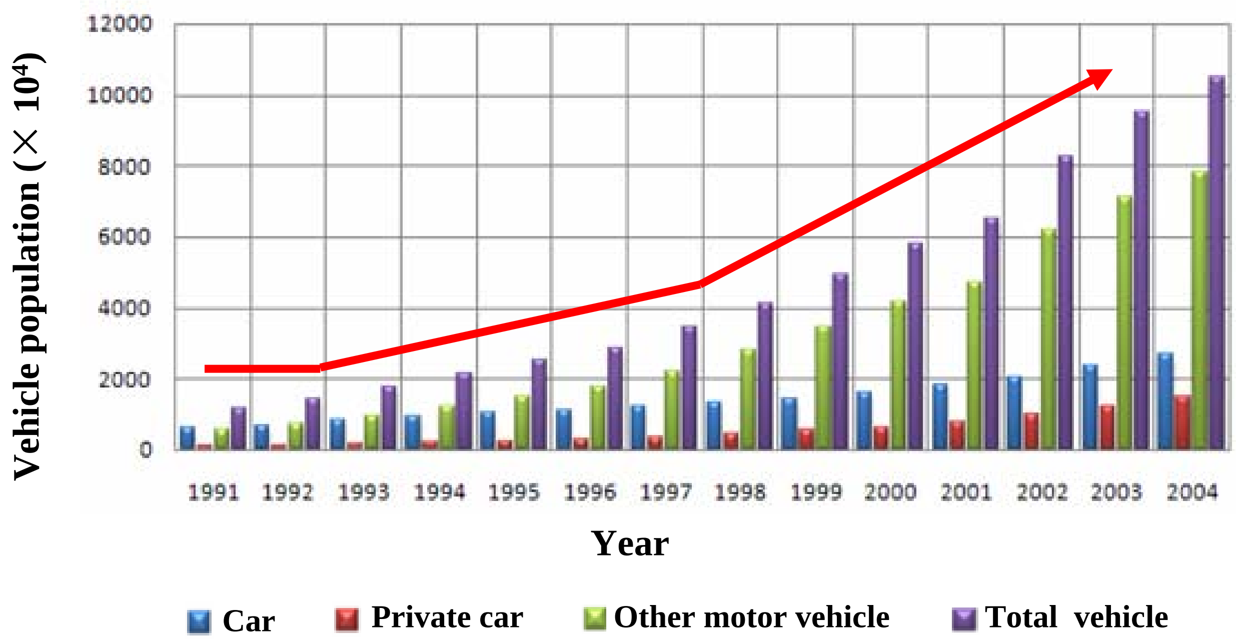
Background - Vehicle Fleet Growth in China



- **Status:**
  - Vehicle fleet growth rate > 20%
  - Traffic pollution becomes severe in large cites
- **Gaps in Vehicle Emission Estimation:**
  - Insufficient vehicle activity database
  - No comprehensive emission model based on China fleet characteristics

Objective of Study

- Develop a city-wide mobile source inventory system in support of policies to achieve emissions control targets
  - Identify an appropriate motor vehicle emission model to improve the estimation of motor vehicle emission factors
  - Improve the accuracy in estimating the motor vehicle activity levels with limited data sources
  - Develop high-resolution spatial and temporal emission inventories for on-road motor vehicles, which could be used directly as the inputs to urban air quality models

Adaptation Analysis of Existing Emission Models for China

Emission model	Developer	Applications in China	Characteristics, advantages and limitations
MOBILE	USEPA	Widely used	BEFs are identified by emission model year; Choosing the model year which is matched to the emission control level in China is a rough BEFs estimation; average-speed based; vehicle type classification is detailed and quite different from that in China
EMFAC	California Air Resources Board	Hong Kong, not widely used in the continental China	Especially designed for the California State; technology categories and input data requirements are more complicated than MOBILE; average-speed based
COPERT	European Union	Several applications	Similar testing procedures and similar vehicular pollution control standards; average-speed based; testing cycles are much simpler than the American ones
IVE	CE-CERT	Newly introduced; some applications	BEFs are determined by vehicle technology, BEFs are easily adjustable; driving cycle (VSP) based; simple vehicle classification

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IVE Model Data Requirement

- Base Emission Factor (BEFs)
  - Running BEFs of gasoline vehicles – adjusted by on-road remote sensing measurement in Hangzhou
  - Running BEFs of diesel vehicles and other fuel-type vehicles – default BEFs in IVE
  - Starting BEFs – default BEFs in IVE
- Vehicle activity level data
  - Based on existing database, surveys and measurements

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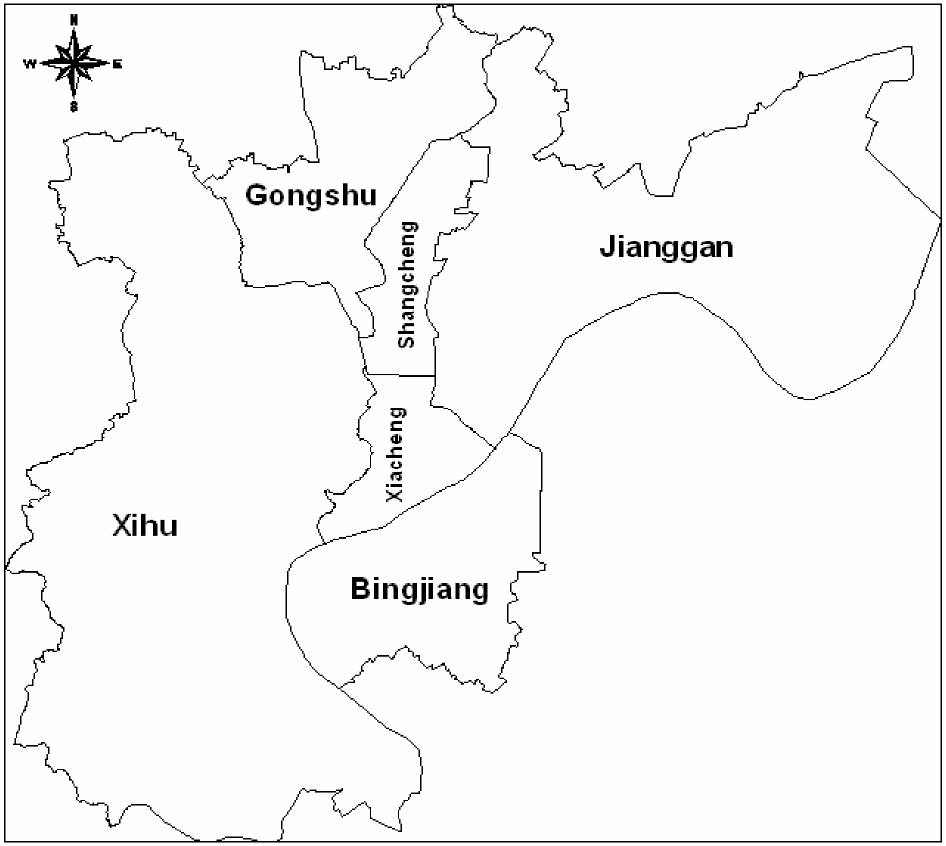
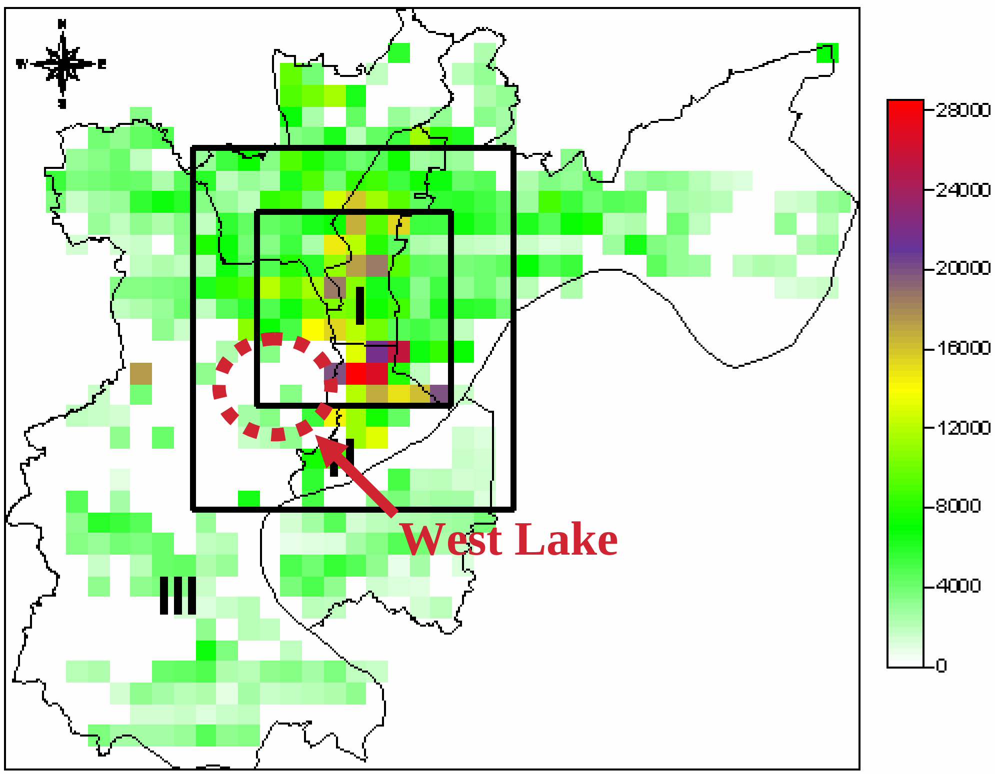
Study Area: Hangzhou Urban Area

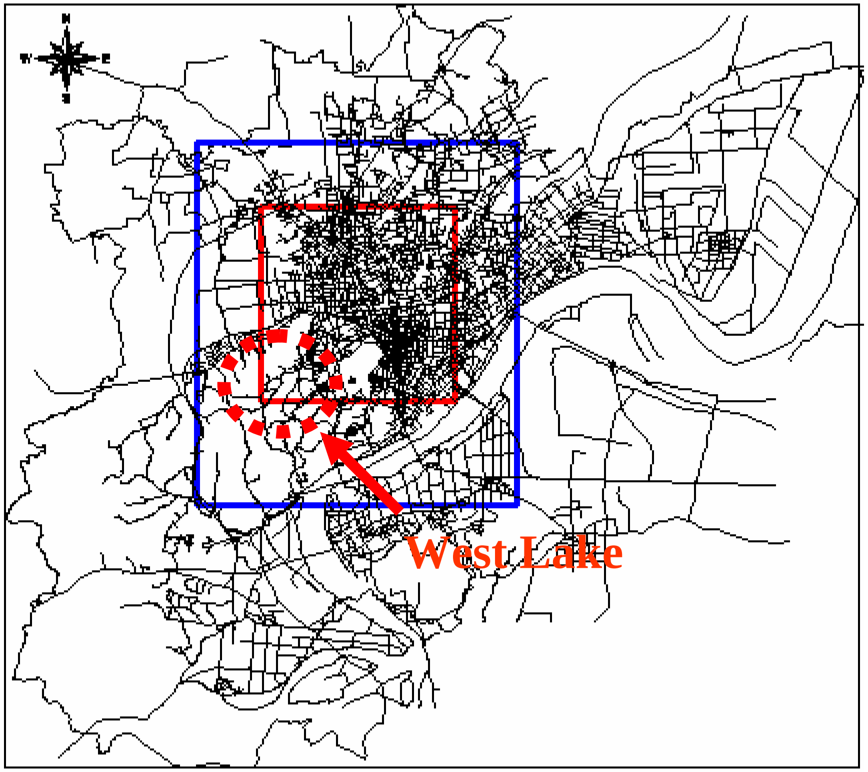


- 730 km^2 (6 districts)
- Over 2 million people
- 230,000 Vehicles (2004)
- Average annual vehicle growth rate was 27.8% from 2001 to 2004

Activity Study: Identification of Homogeneous Zones



Population distribution (people/km^2)



Road Network

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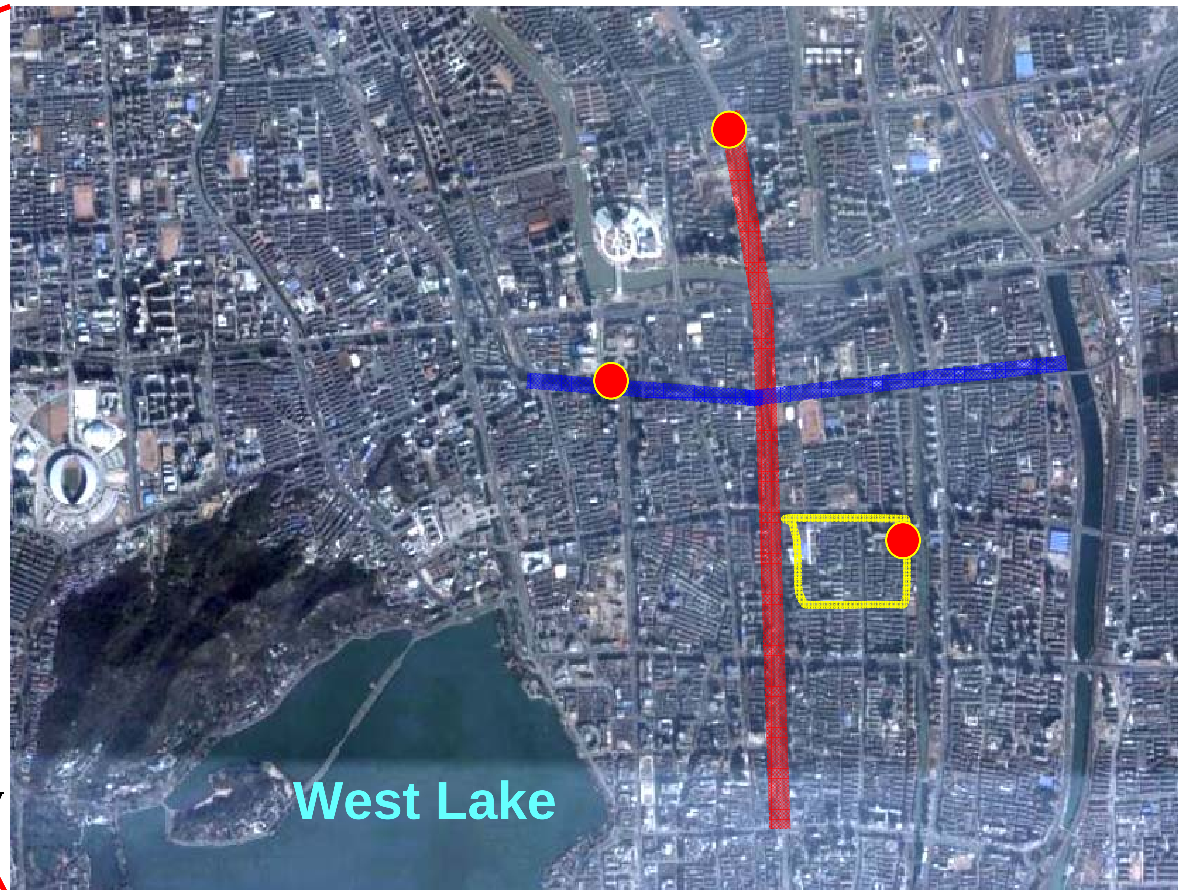
Activity Study: Street Types in Zone I



Highway

Arterial Way

Residential Way

Video-tape survey site

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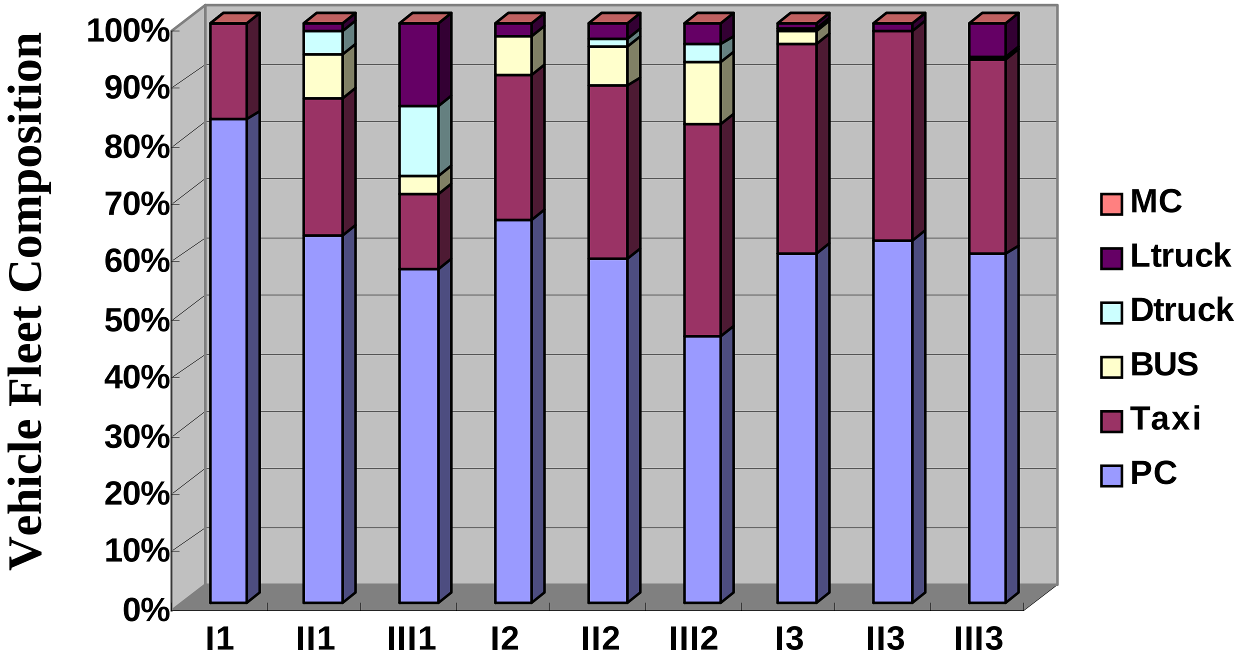
Activity Study: Traffic Flow and Vehicle Fleet Composition

- Video-tape survey on 9 roads in 3 Zones (I, II, III)
- Jan. 17-23, 2005 (7 days), from 6:00-22:00



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Activity Study: Vehicle Technology Distribution

- I/M station survey: 4,849 vehicles
- Bus information, by Hangzhou Public Transport Group Co. Ltd.

Vehicle Type	Fuel Type	Air/fuel system	Emission control	Fraction	Total
Passenger Car (PC)	Gasoline	Carburetor	No Catalyst	20.8%	100%
			2-way Catalyst	6.5%	
		SPFI	2-way Catalyst	4.4%	
			3-way Catalyst	11.9%	
		MPFI	3-way Catalyst	53.7%	
	Diesel	Direct injection	EGR	2.7%	
Taxi	Gasoline	MPFI	3-way Catalyst	91.7%	100%
	Diesel	FI	EGR	8.3%	
Bus	Gasoline	Carburetor	No Catalyst	17.7%	100%
		FI	Euro I	8%	
	Diesel	Direct injection	Improved	13.3%	
		FI	Euro I	51.0%	
		FI	Euro II	9.8%	
Ltruck	Gasoline	Carburetor	No Catalyst	11.7%	100%
		FI	Euro I	9.6%	
		FI	Euro II	4.4%	
	Diesel	Pre-Chamber	None	23.6%	
		FI	Euro I	44.4%	
		FI	Euro II	6.36%	
Dtruck	Gasoline	Carburetor	No Catalyst	14.6%	100%
	Diesel	Direct injection	Improved	68.7%	
		FI	Euro I	26.5%	

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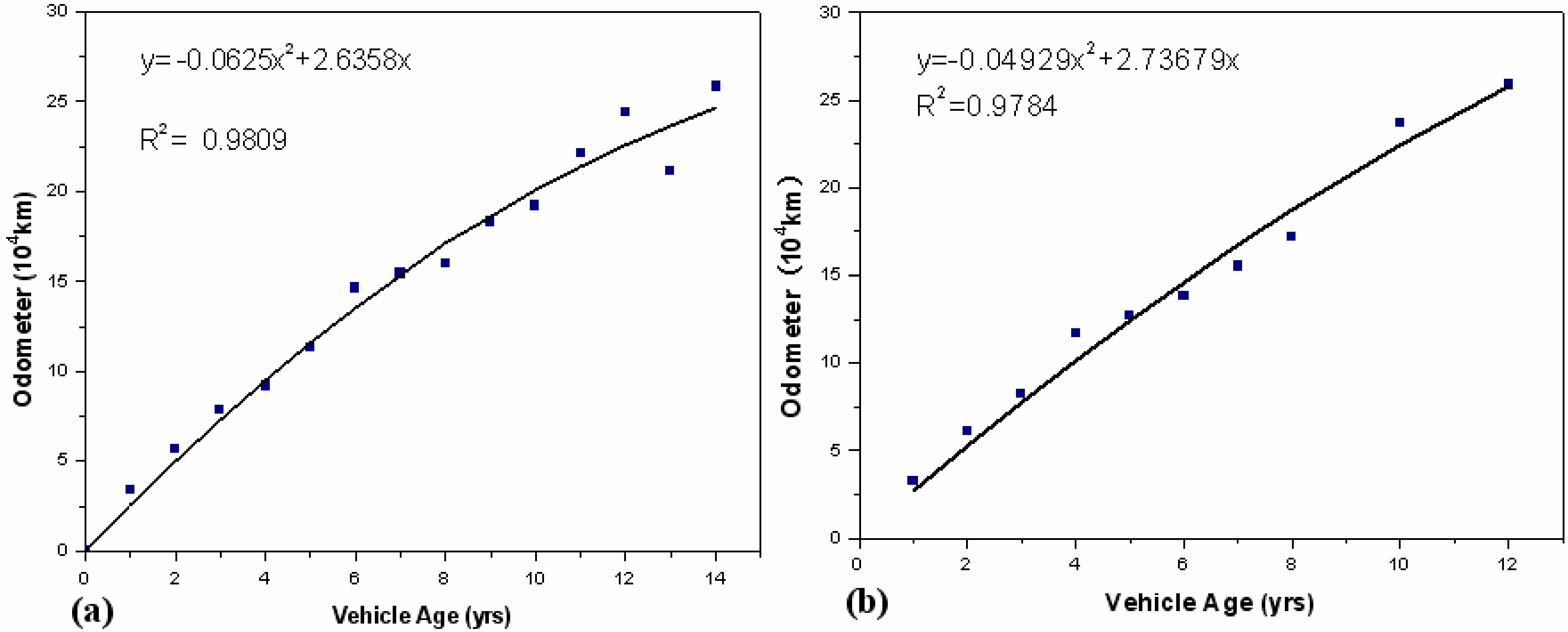
Activity Study: Vehicle Technology Distribution

- Size and Use Characteristics of Hangzhou Fleet

Vehicle type	Exhaust volume/ Vehicle weight	Vehicle use			Total
		<80,000 km	80,000-160,000 km	>160,000 km	
Passenger Car (PC)	Light（<1500cc）	8.4%	3.6%	2.4%	14.4%
	Medium（1500-3000cc）	48.6%	20.6%	14.3%	83.5%
	Heavy（>3000cc）	1.2%	0.5%	0.4%	2.1%
	Total	58.2%	24.7%	17.1%	100%
Taxi	Medium（1500-3000cc）	20.1%	12.37%	67.53%	100%
Bus	Light（4.1-6.4t）	3.7%	2.6%	4.5%	10.8%
	Medium（6.4-15t）	31.9%	19.7%	37.6%	89.2%
	Total	35.8%	22.1%	42.1%	100%
Ltruck	Light（<2.3t）	15.8%	18.7%	8.22%	42.8%
	Medium（2.3-3t）	20.9%	6.9%	3.2%	31%
	Heavy（3-4.1t）	11.58%	7.72%	6.93%	26.2%
	Total	48.3%	33.4%	18.3%	100%
Dtruck	Light（4.1-6.4t）	17.1%	12%	8.8%	38%
	Medium（6.4-15t）	25.3%	20.6%	16.2%	62%
	Total	42.4%	32.6%	25%	100%

The Annual Mileage Accumulation Rates

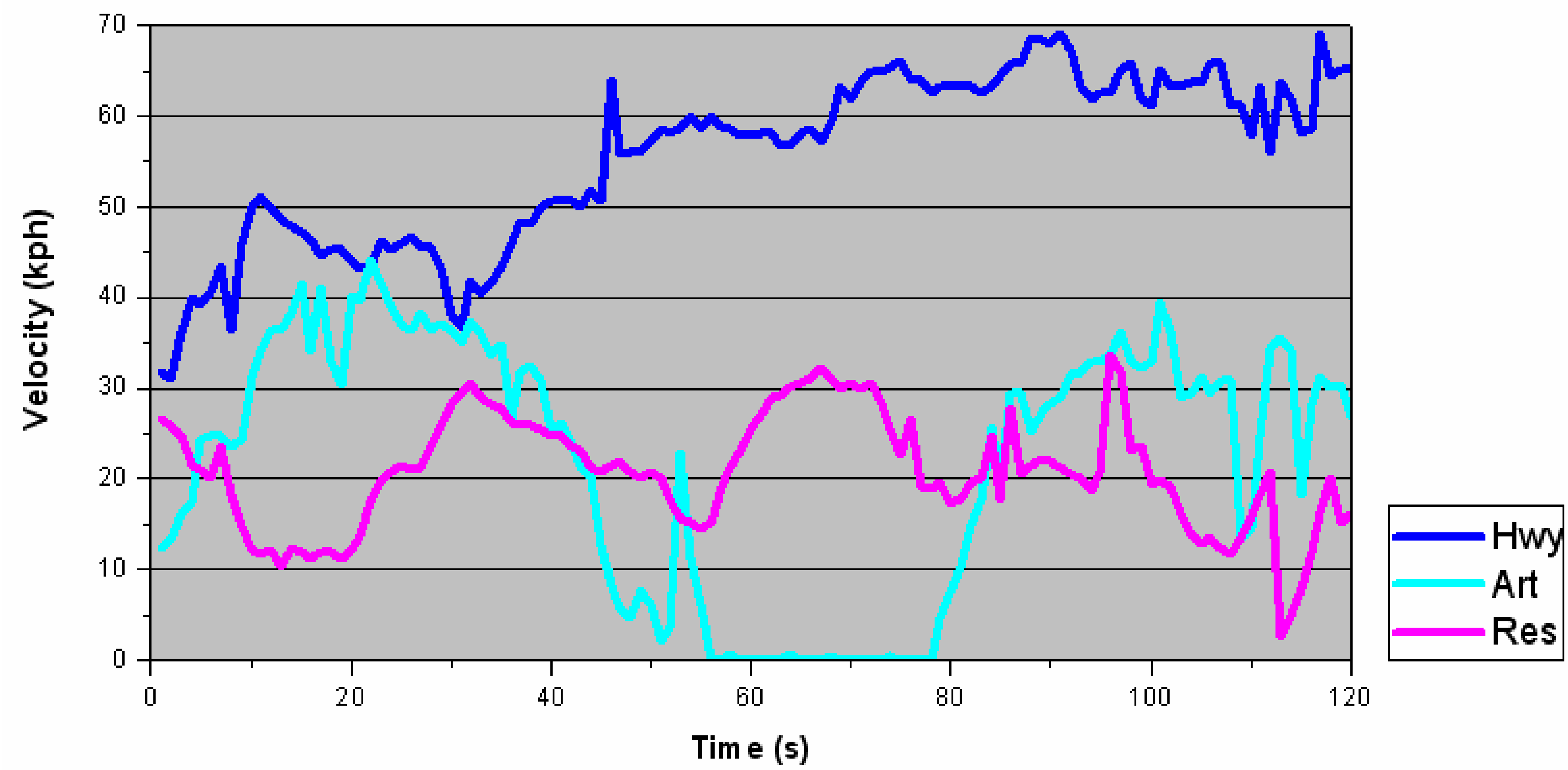
Vehicle use during the first fourteen years of age: (a) PC (b) LTruck



- For estimating the total annual mileage traveled in the model year, combing with vehicle age distribution

Activity Study: Vehicle Driving Patterns

- GPS technology: second by second measurements of vehicle speeds



Example of Residential, Arterial, and Highway Driving around 12:00 am in Hangzhou

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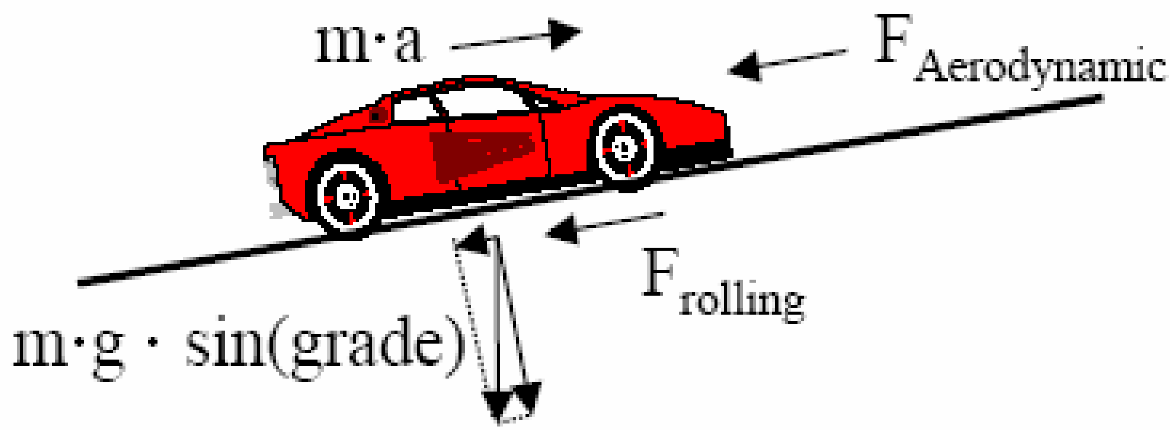
Activity Study: Vehicle Driving Patterns

- Driving patterns characterized with two parameters:
  - Vehicle Specific Power (VSP)
  - Engine Stress

Figure. Definition of Specific Power



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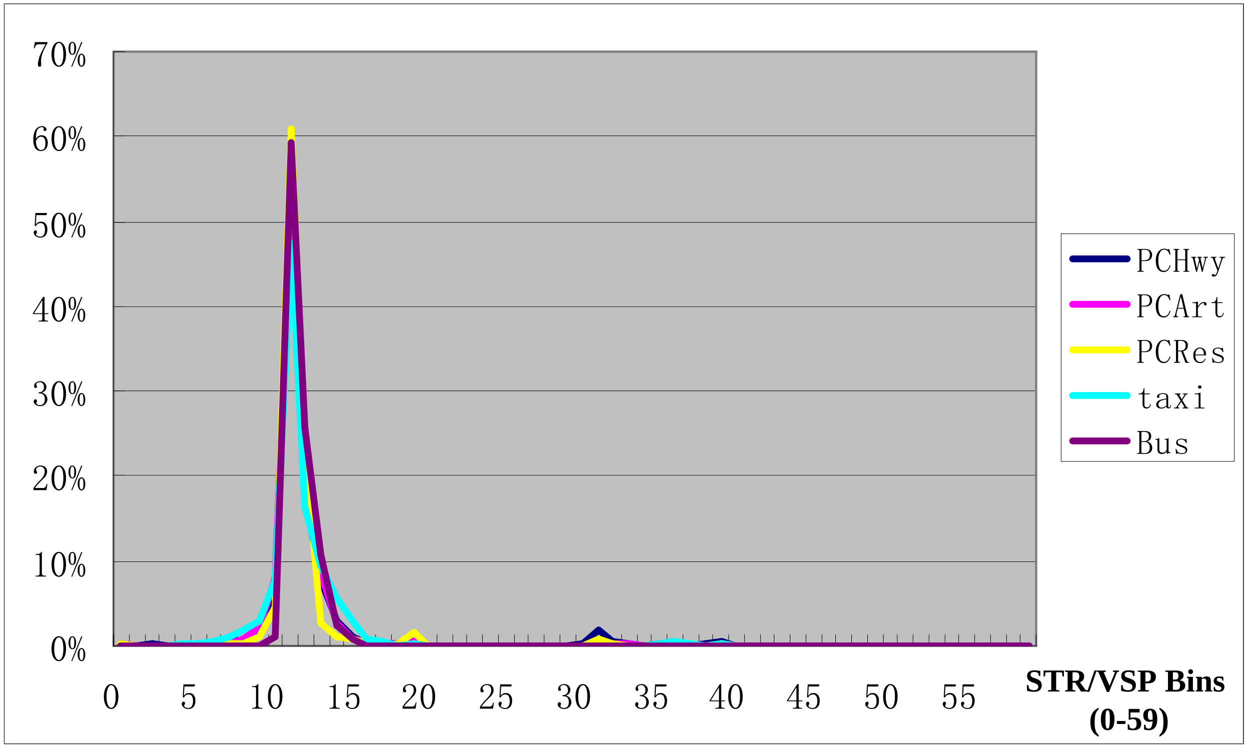
Activity Study: Vehicle Driving Patterns

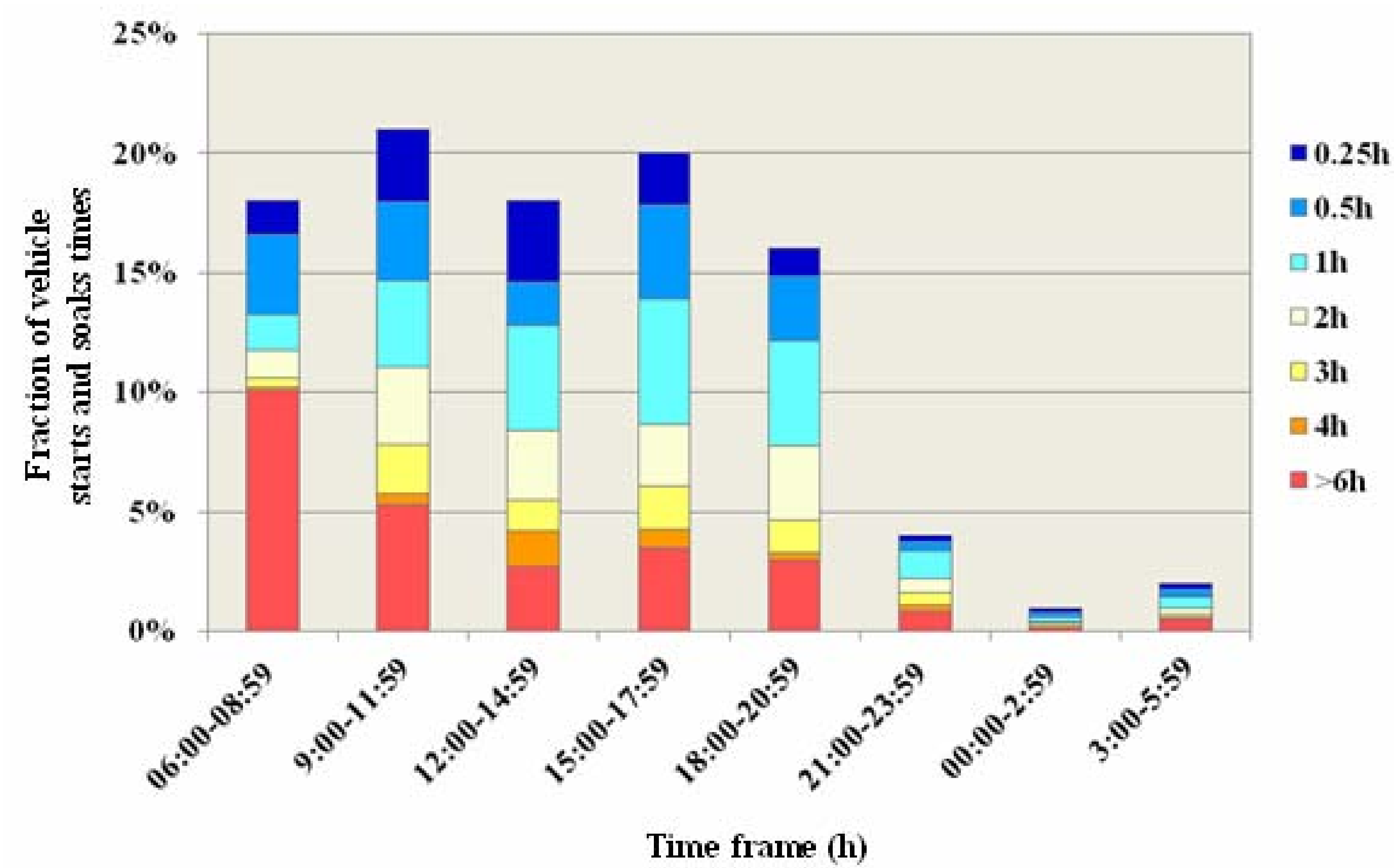


Comparison of Driving Patterns for Three Major Vehicle Classes at 5:30pm

Activity Study: Vehicle Start Patterns

- Questionnaire for vehicle drivers in I/M stations:
  - How many times did you start your vehicle the day before the survey day?
  - When the starts happened?
  - How long was the engine-off time (soak time) between two starts?
- Valid questionnaires: 522 (292 for PC, 176 for truck and 54 for taxi)
- Average daily start times: 7.1, 5.5 and 3.2 times for PC, truck and taxi, respectively.

Activity Study: Vehicle Start Patterns



Methodology: VKT Spatial Allocation

- Line sources for highway and arterial way:
  - Monitored traffic volume
  - Length of roadway links
- Area sources for residential way:
  - Area source mileage =
    Total mileage traveled– Line source mileage
  - Population density
  - Roadway density

Methodology: Start times and Patterns Allocation

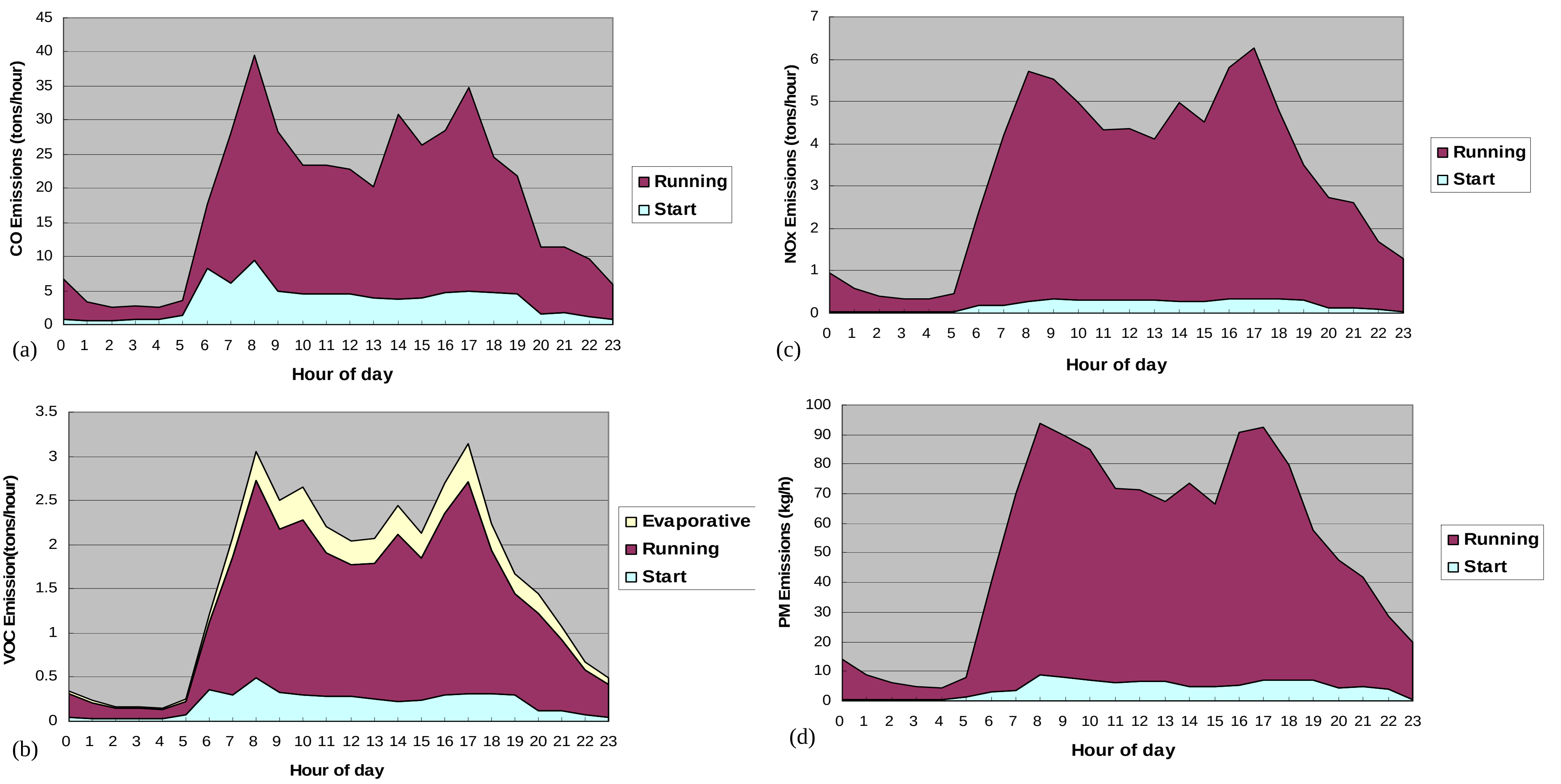
- It is assumed that the soak time distribution of each vehicle category was the same in all street types
- The start times can be allocated following:

Equation (5) $$S_{ij} = \frac{M_{ij}}{M} \times S$$

where,

S_{ij} – start times in grid j (or in link j) at i hour, times;
M_{ij} – mileage traveled in grid j (or in link j) at i hour, km;
M – daily total mileage traveled in the whole study area, km;
S – daily total start times in the whole study area, times;

Results: Temporal Emission Distribution



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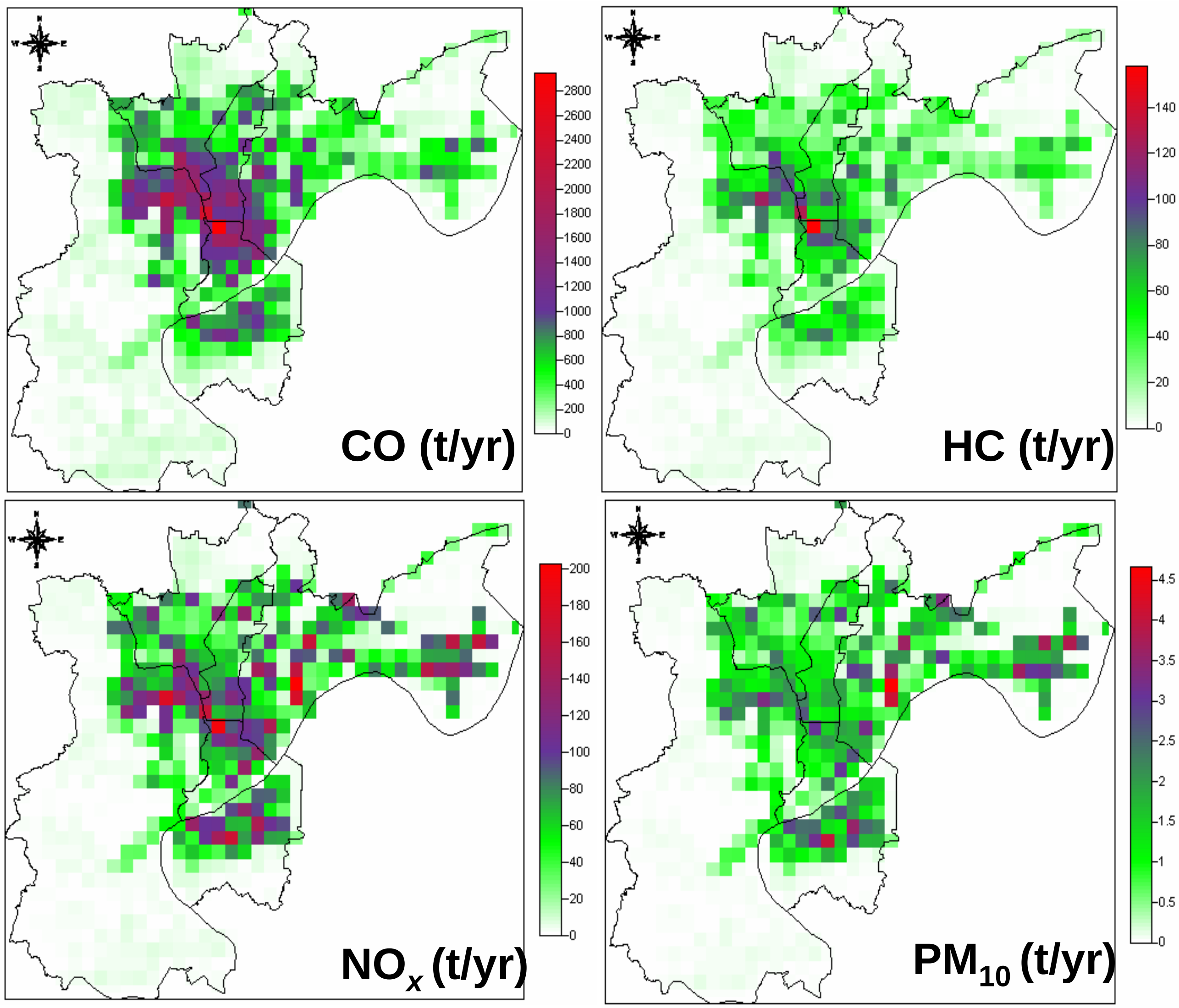
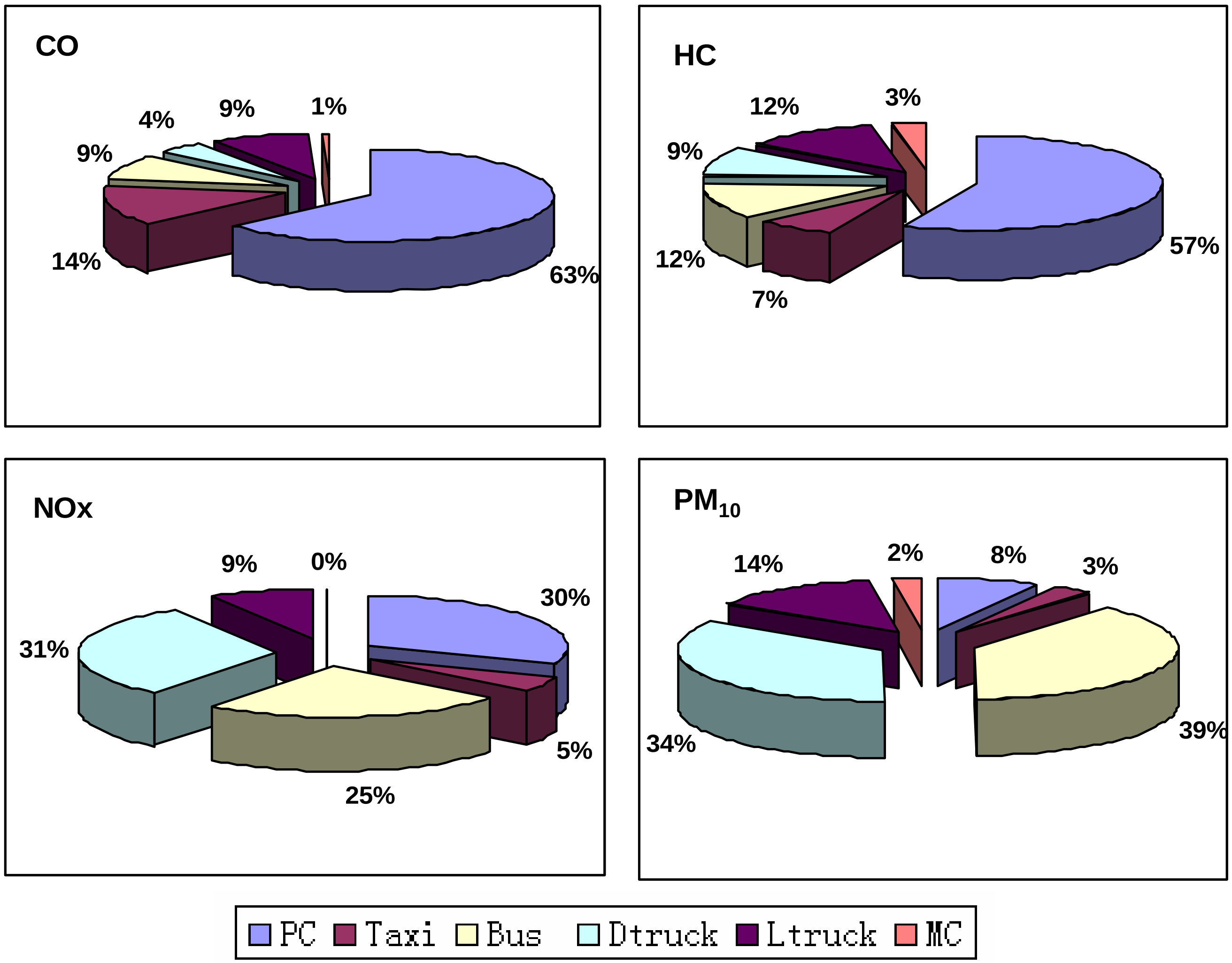
Results: Spatial Emission Distribution



Results: Emission Contribution from Different Vehicle Types



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Simulation of Pollutant Dispersion

- Assess the impact from mobile sources on air quality
- USEPA AERMOD model (version 07026)
- Inputs:
  - Hourly emission inventory of 161 line sources
  - Hourly emission inventory of 756 area sources
  - Hourly 2004 meteorological data from NCDC
  - 1° DEM data (90 meters resolution)

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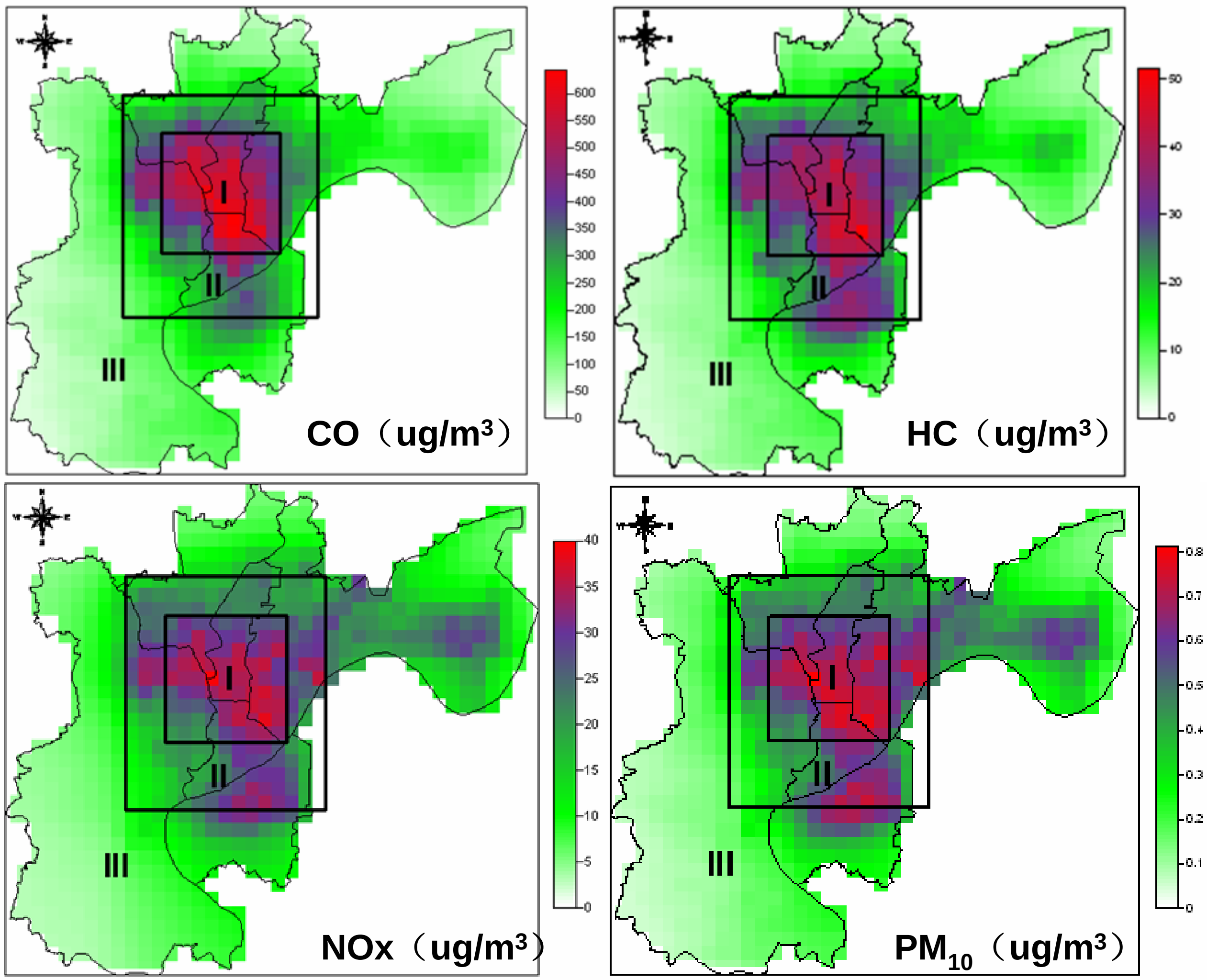
Results: Modeled Annual Average Concentration Distribution



Conclusions

- IVE model has the following advantages and are more suitable for China
  - BEFs can be defined by vehicle technology
  - BEFs are easily adjustable
  - Improvement of vehicle driving patterns modeling
- The methods of vehicle activity data collection are suitable in China
- Reasonable high-resolution temporal and spatial vehicle emission inventories can be developed using this methodology for urban air quality assessment

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Recommendations

- Develop informative and detailed vehicle registration systems in Chinese cities
- More on-road emission measurements are needed to adjust original BEFs in IVE model
- Refined methodology and additional survey to enhance the spatial distributions of start emissions

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