Scaling Down Air Pollution Modeling Tools for Urban Stakeholders

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NILU
Oslo, Norway; June 5th 2008

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Why Bother?

- While air quality is important for health, it is also important for the economy
- High proportion of cities in developing countries, especially Asian cities, have significant urban air quality problems

Why Bother?

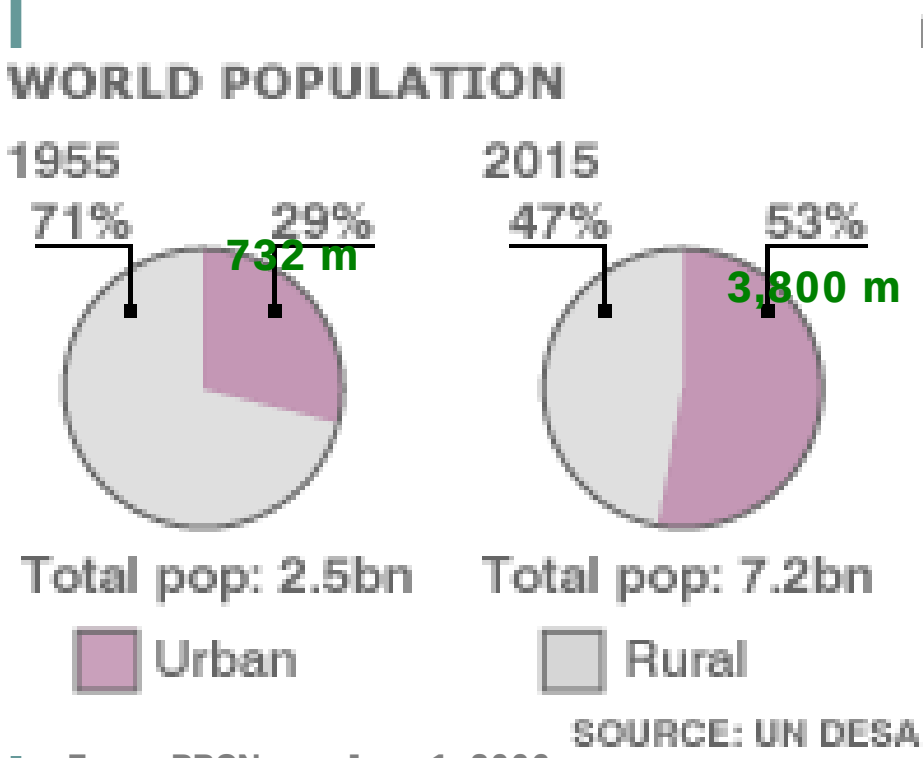
- Yet, the information base is often poor, fragmented, unorganized, and inaccessible

- Managers of these cities often face a bewildering array of management options to analyze

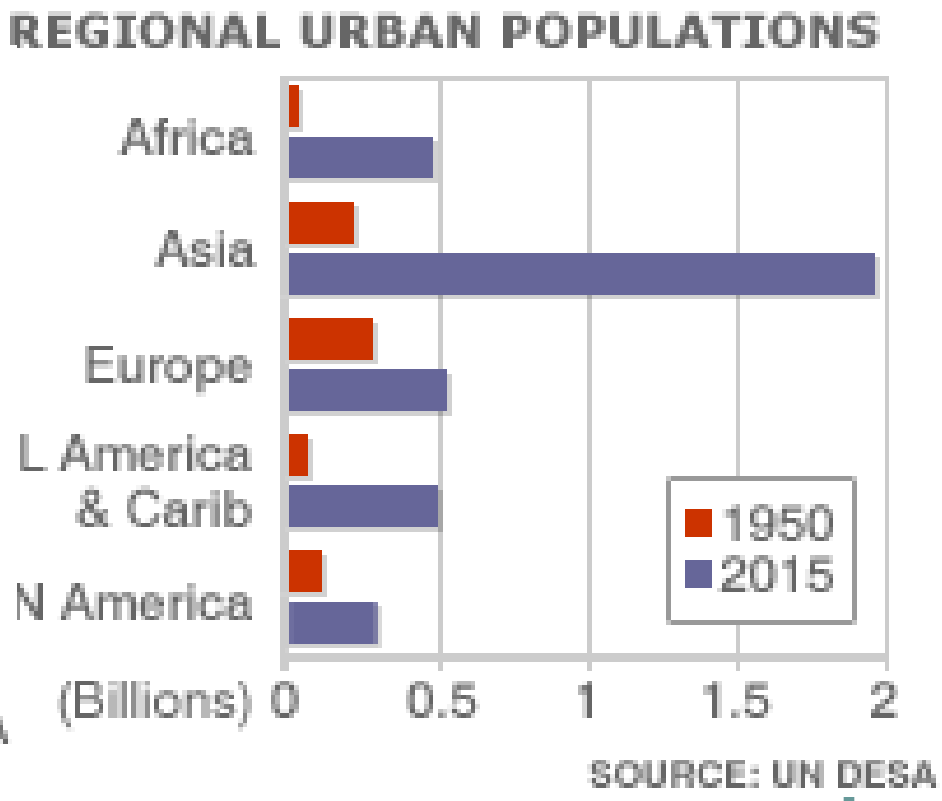
- Everyone has a better modeling mousetrap!

Places & People

Urbanization is on the rise…



From: BBCNews, June 1, 2006

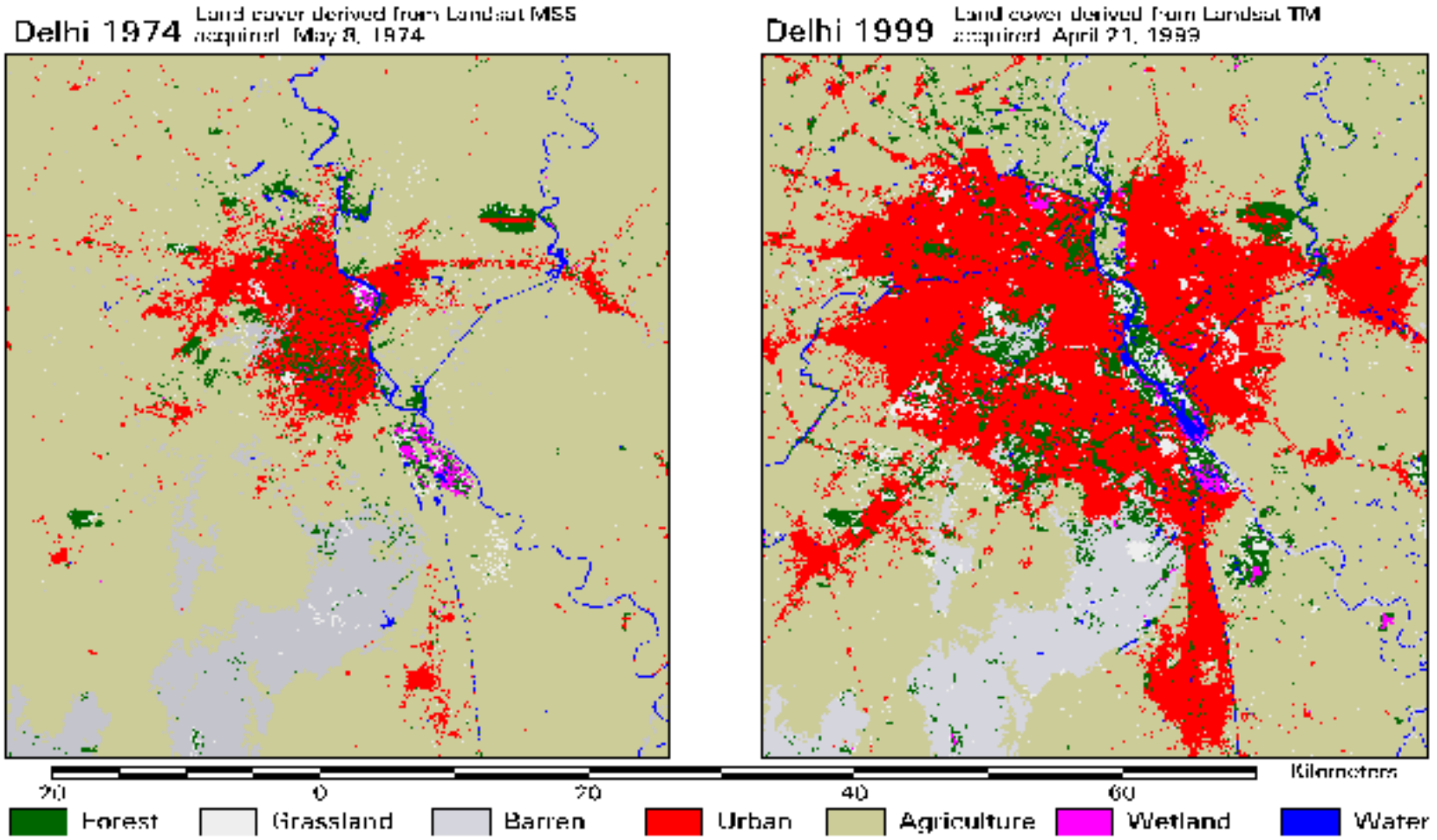


- **Cities are growing at the rate of 1 million people / week**
- **Megacities (>10 m pop)**
  - **-Currently, 23 Megacities (on 2% of land)**
  - **-36 Megacities expected by 2015**
  - **(300 cities >1 m pop by 2025 + thousands of Secondary Cities)**

Global Urban “Pin Cushion”

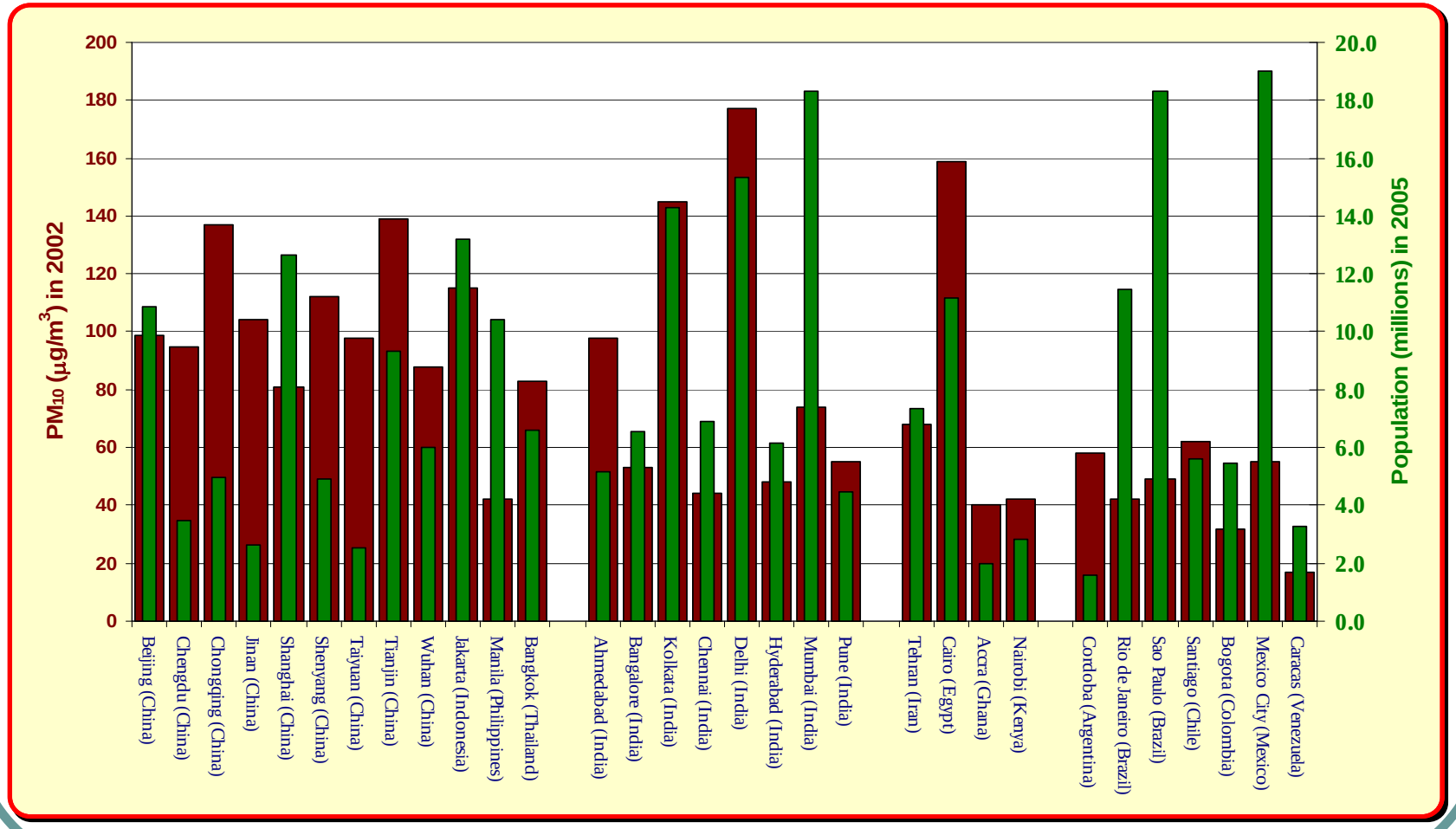
Visualization of Global GIS cities on Google Earth (Download Google Earth at http://earth.google.com and city information from http://geographynetwork.com)

Cities are growing…(e.g. Delhi)



Source: Harvard University

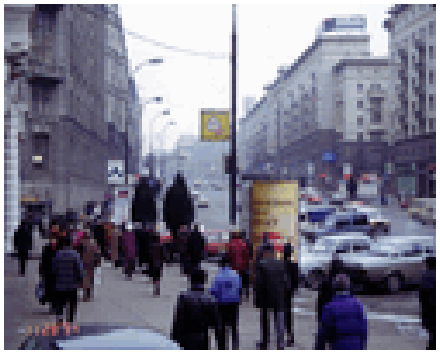
Urban PM_{10} vs. Population



Source: PMSA Handbook, Guttikunda et al., 2008; data from World Development Indicators, 2006

Cities: A part of the problem

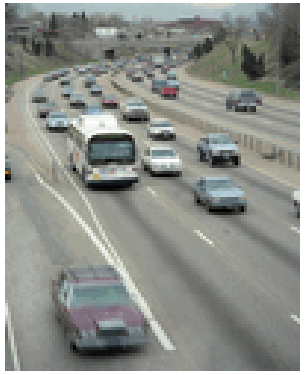
Energy Demand and Pollution



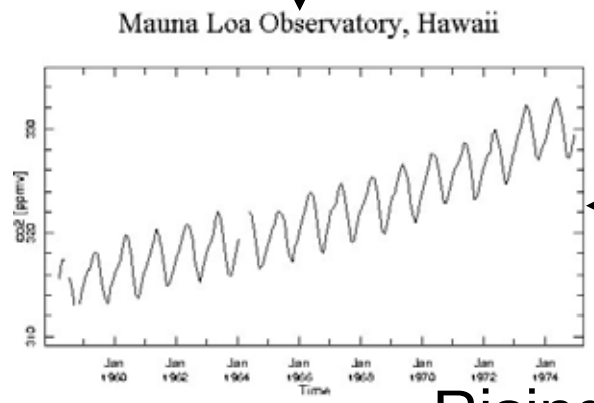
Urban Energy Demand

Energy Production

Waste Management



Urban transportation

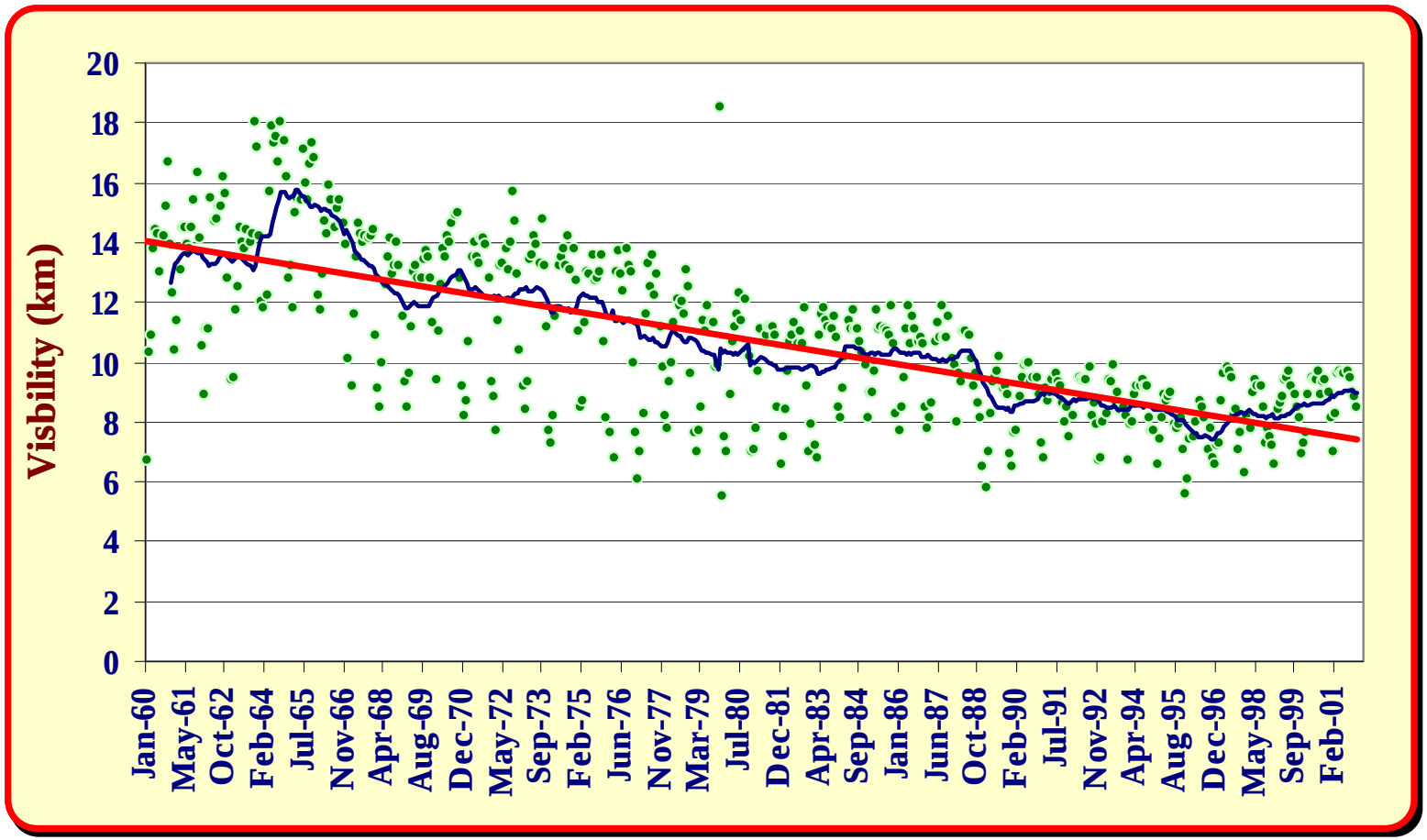


Rising GHG levels

Motorization is increasing…
e.g. Bangkok

Source: Road Transport Statistics, Department of Land Transport

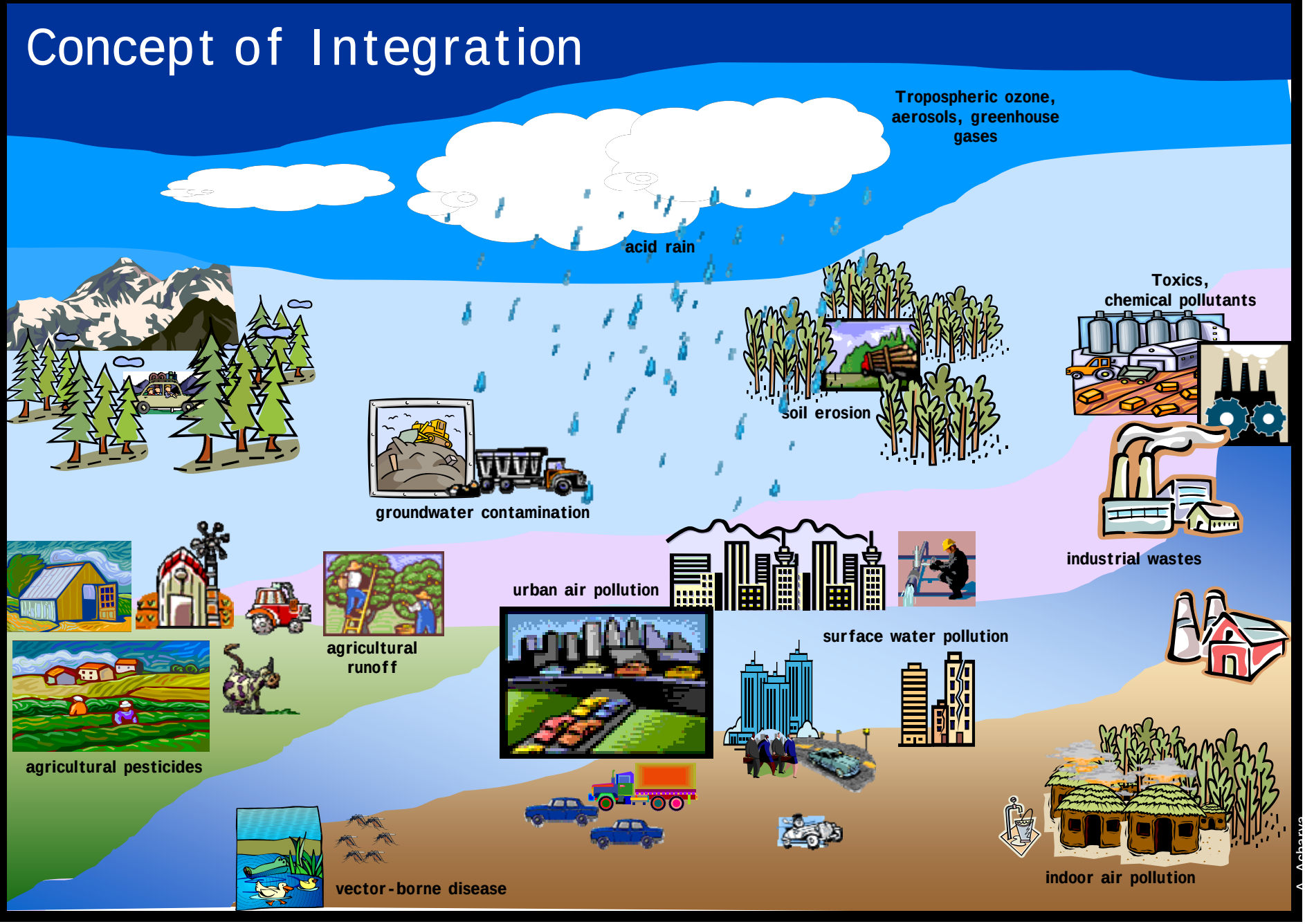
Bangkok Visibility Index



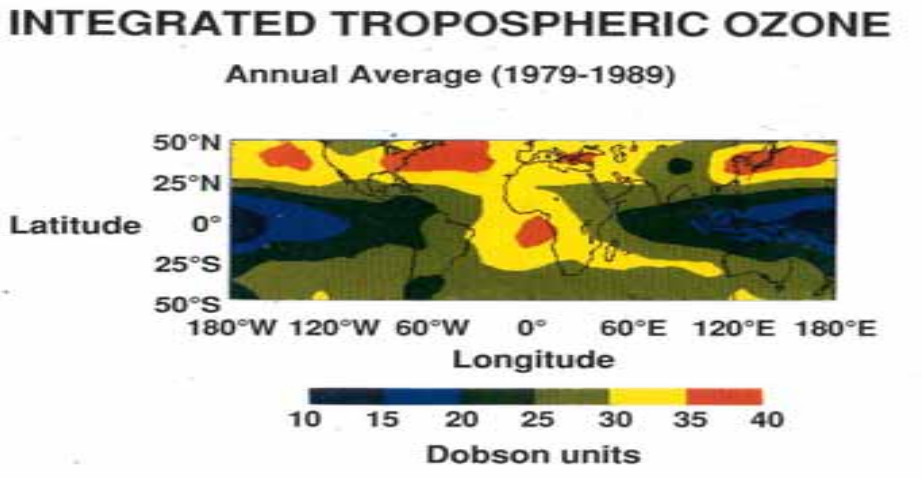
Source: Climatology Division, meteorology department, Thailand

Cities: A part of the solution

Concept of Integration



Impacts are Felt on Scales from Local to Global



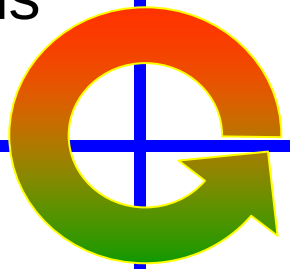
Integrated Assessment of Air

Air we breathe

Pollutants, Clean air, Limits, Regulations

Integration among

People, Places, Programs, Problems, & Pollution



Polluted Air

Cleaner Air

Quality

Ambient levels, Health, Visibility

Management of

Options - Policy, Technical, Economic, & Institutional

Integrated Air Quality Management

Array of Management Options

Policy	Technical	Economic	Institutional
Monitoring	Cleaner Technologies	Taxes	Emission Standards
Industrial Zoning	Fuel Improvements	Subsidies	Fuel Standards
Residential Zoning	End of Pipe Control Devices	Pricing	Energy Efficiency
Compliance	Cleaner Production	Charges	Maintenance
Traffic Management		Fines	Capacity Building
Public Transport		Tradable Permits	Compliance
NMT			Awareness
Landuse			

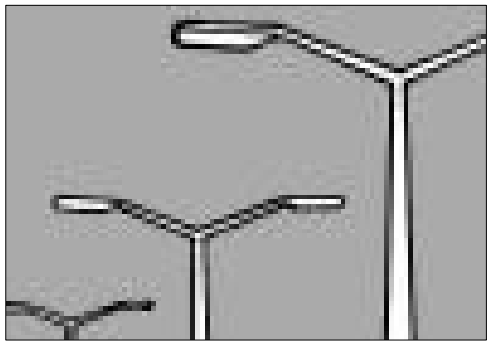
Examples of Management Options

Renewable Energy

Waste Management

Buildings & Operations

Transportation



Infrastructure

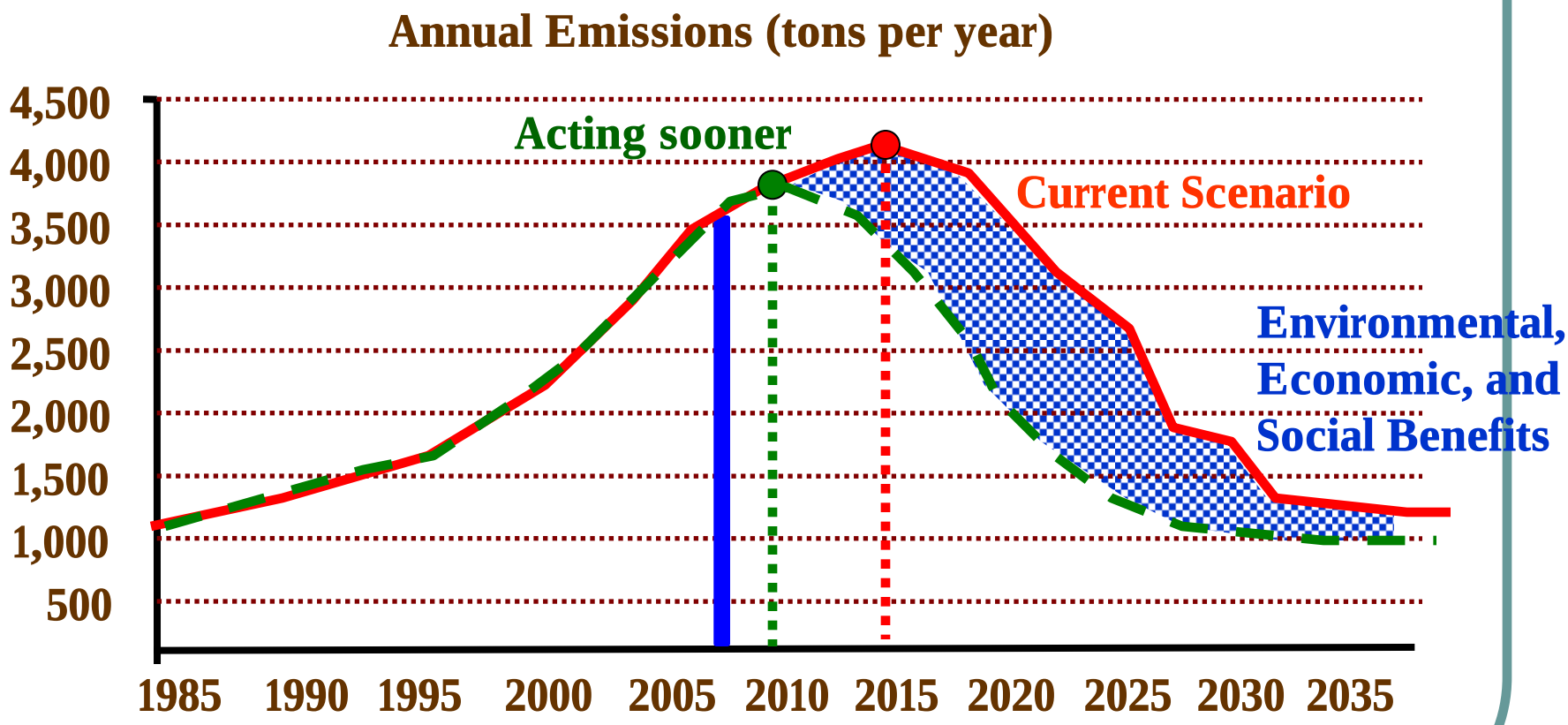
Decision Making

Let the “Blame Games” begin..

Sources are Many

Why not making a decision is a decision...

Timing is important !!



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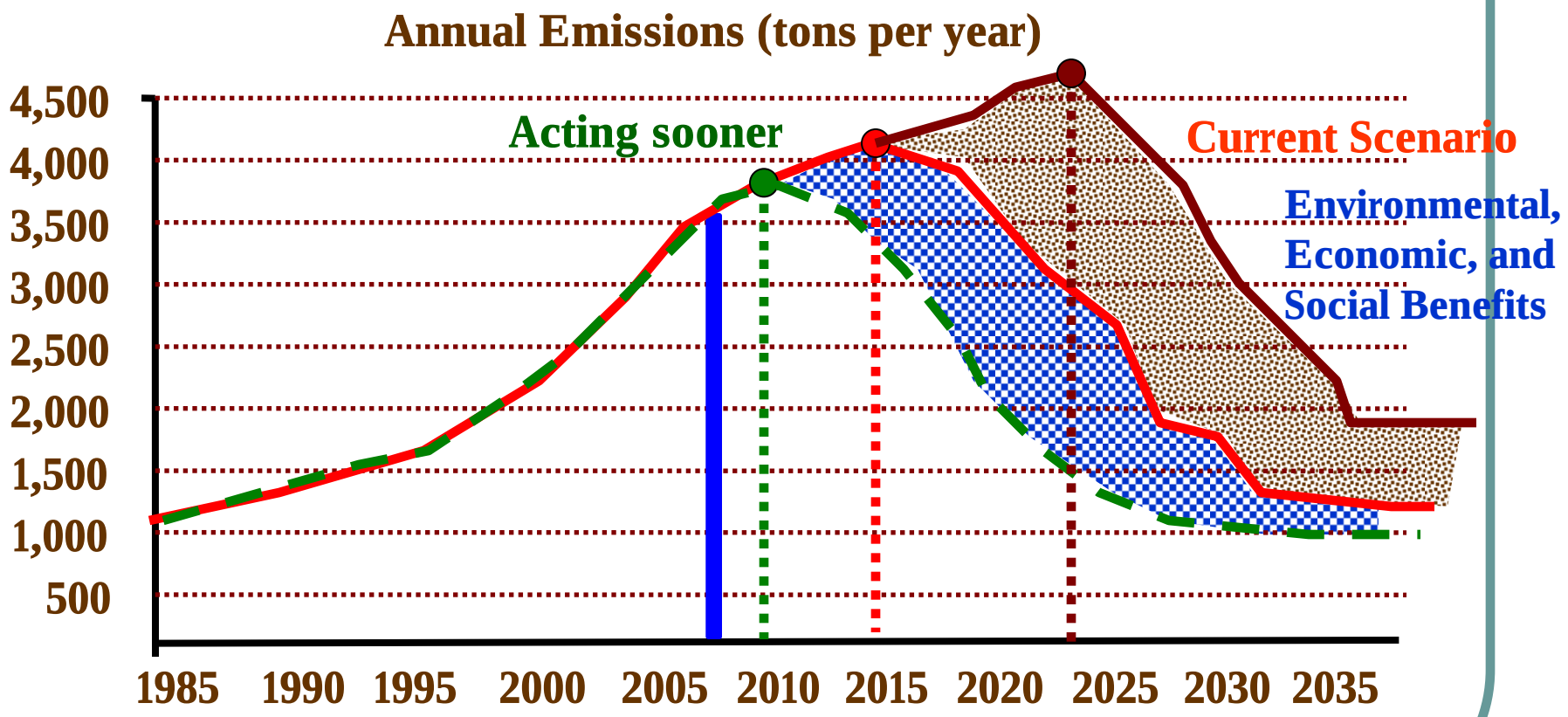

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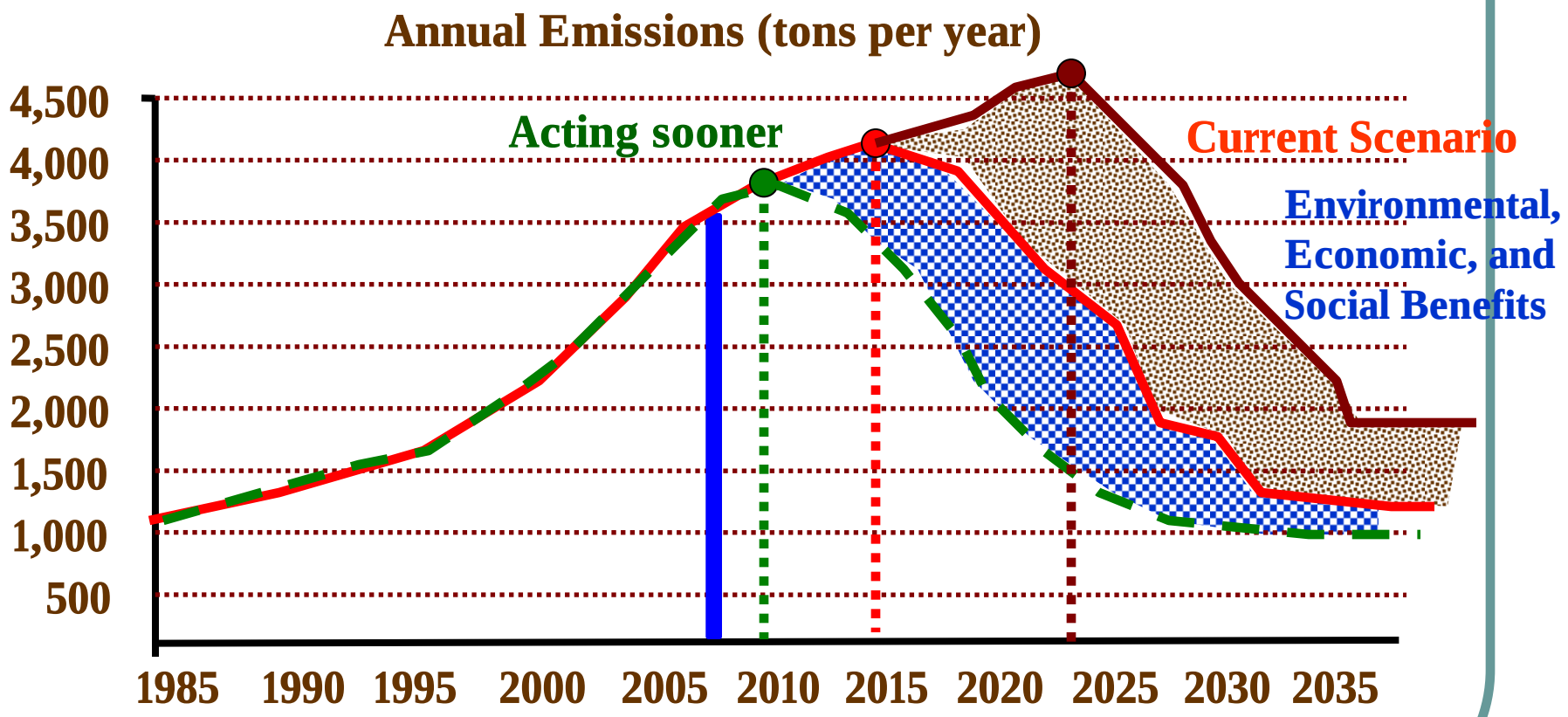


Why not making a decision is a decision...

Air Pollution Modeling

Limitations

Results are only as good as the databases – coverage, quality, consistency and access problems

Consensus on types of options to be considered

Evolving methodologies and tools for assessment

Involvement of multiple stakeholders and disciplines

Adequate reflection of political economy

Actual **USE** and constant updating of the systems developed

Knowledge Base

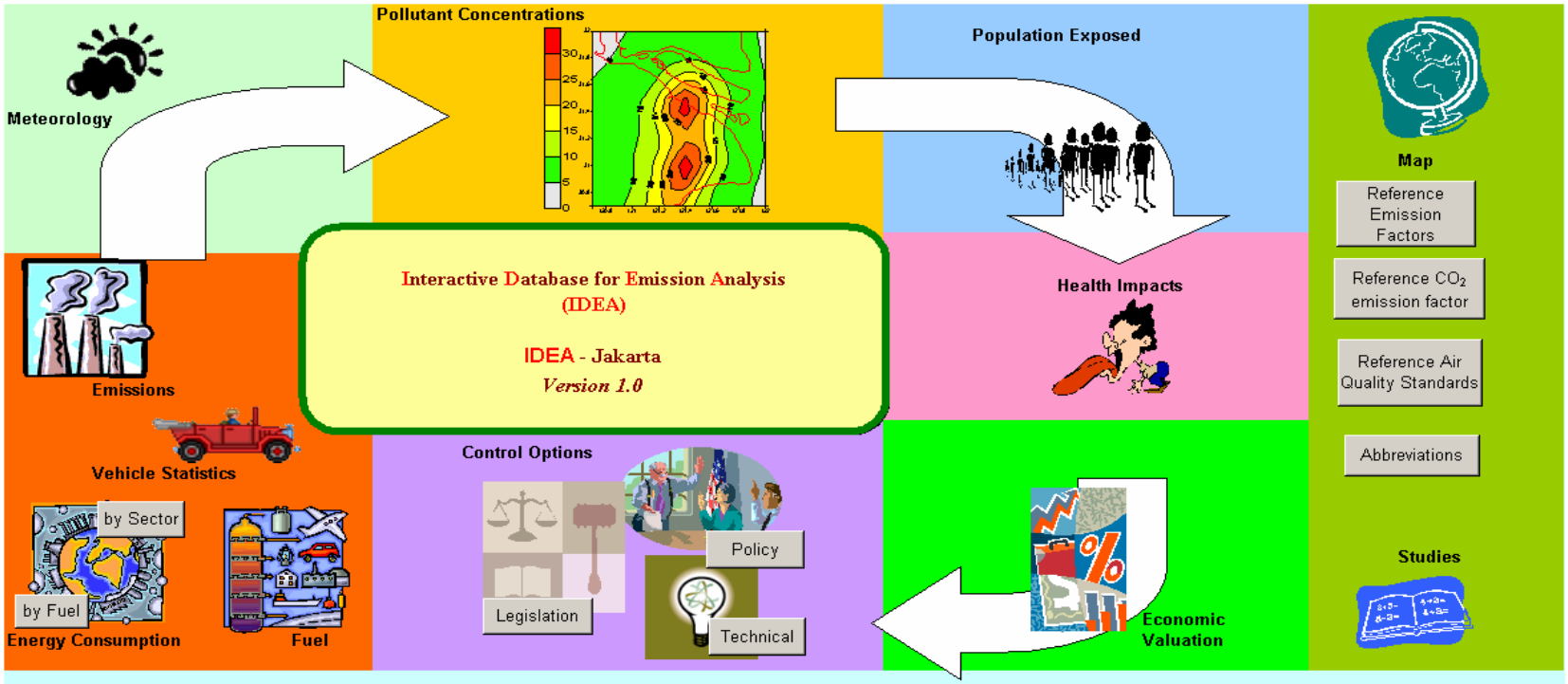
Knowledge Base

Types of Models

Target Audience

What can we do with what's available?

What you have – Collate Data



For more Information Contact:
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or
Eri Saikawa, EASTR (esaikawa@indiana.edu)

Note: *This database represents work-in-progress and contains secondary data. These are provided here to solicit feedback from partners. Information about better or more reliable data or sources is appreciated.*

Modeling Tools

- Software and Modeling tools available
  - Spreadsheets
  - GIS
  - Fortran or Visual basic based programs

Modeling Tools
for Emissions and Dispersion

- Energy and Emissions Analysis Tools
  - RAINS, GAINS, MOBILE 6, IPIECA Toolkit, HEAT, IVE, MARKAL, COPERT
- Dispersion Models
  - ADMS, ATMOS, ISC3, UAM-V, CMAQ, WRF-Chem
- Health Impacts Analysis
  - Ben Map, APHEBA
- Integrated Models
  - SIM-air, IDEAS, GAINS, DSS/IPC, Air-QUIS

Road Ahead..

- Simple equations or complicated models – plenty available to use

Example Applications

Hyderabad, India

Top-Down Vs. Bottom-Up

Qualitative Comparison

Location	Vehicles		Veh + Road Dust		Industries		OWB+Dom	
	SA	M	SA	M	SA	M	SA	M
Punjagutta	54 ± 10	40 - 45	81 ± 10	66 - 70	13 ± 10	15 - 20	5 ± 10	4-6
Chikkadpally	45 ± 10	40 - 45	80 ± 10	60 - 66	15 ± 10	20 - 30	4 ± 10	4-6
HCU	43 ± 10	30 - 35	80 ± 10	50 - 60	16 ± 10	10 - 15	5 ± 10	8-10

Note: Top-Down is source apportionment (SA) and Bottom-Up is modeled (M)

Limitations to interpretations

- No distinction is made between diesel and fuel oil utilized by vehicles and industries.
- Coal combustion between industries and domestic sector are not distinguished.
- All types of dust – road and soil – are clubbed together.
- Two of the sampling points for the source apportionment study are urban with most vehicular activity.
- Modeling results are annual average values and the source apportionment results are averaged over the three sampling months.

Estimated Health Impacts in 2006

Health Endpoint	Number of Incurred Cases
Mortality	2,143
Adult Chronic Bronchitis	5,621
Child Acute Bronchitis	33,308
Respiratory Hospital .Admission	1,837
Cardiac Hospital Admission	765
Emergency Room Visit	36,032
Asthma Attacks	4,990,049
Restricted Activity Days	8,724,933
Respiratory Symptom Days	28,011,627

Estimated total cost of health impacts is US $241 million or Rs. 917 crores

Proposed Action Plan

- Improve road maintenance, dust control, and traffic management
- Conversion of buses and auto rickshaws from diesel to alternate fuels (natural gas, biodiesel, LPG)
- Increase public transport use from 40% to 60% (including adding new buses)
- Introduction of new emissions standards for cars
- Phasing out old vehicles
- Improve dust collection facilities at industries and energy efficiency
- Enforce laws against waste burning.

Co-Benefits for 2010

- Largest benefits for Air Quality
  - Sweeping of paved roads
  - Increasing moisture content on paved roads
  - 3-Wheelers to LPG
  - Improving industrial efficiency at PM capture
- Largest reductions of GHG emissions
  - Gross polluters – goods vehicles and buses
  - Inspection and maintenance
  - Domestic cooking to LPG

Co-Benefits for 2010

Estimated Reductions

Intervention	PM_{10} (tons)	CO_2 (tons)
Conversion of 50% of in-use diesel public transport bus fleet to CNG	236	109,494
Conversion of all Petrol based 3-Wheelers to LPG	847	105,847
Promoting public transport with an expected VKT reductions of 10% in cars, 20% in 2Ws, and 20% in 3 Ws	888	800,293
Promoting wet sweeping resulting in 20% reduction in silt loading on paved roads and increasing moisture content on unpaved roads by 5%	2,119	

Co-Benefits for 2010

Estimated Reductions

Intervention	PM_{10} (tons)	CO_2 (tons)
Replacement of 50% of in-use diesel public transport bus fleet with newer diesel buses	70	55,851
Inspection and maintenance of in-use vehicles –5% improvement in the deterioration rates	125	92,897
Doubling the emission regulations of in-use diesel goods vehicles – light and heavy duty	1,457	883,001
Improving dust collection efficiency at industrial sites by 10%	3,283	

Co-Benefits for 2010

Estimated Overall Percent Reductions

Intervention	PM_{10} (%)	CO_2 (%)
50% buses old diesel to CNG	0.6	1.2
3Ws Petrol to LPG	2.3	1.1
Public transport	2.4	8.5
Wet & vacuum sweeping	5.8	
50% buses old diesel to new diesel	0.2	0.6
I & M	0.4	1.0
Emission regulations for GVs	4.0	9.4
Dust collection efficiency at industries	8.9	

Co-Benefits for 2010

Estimated Reductions

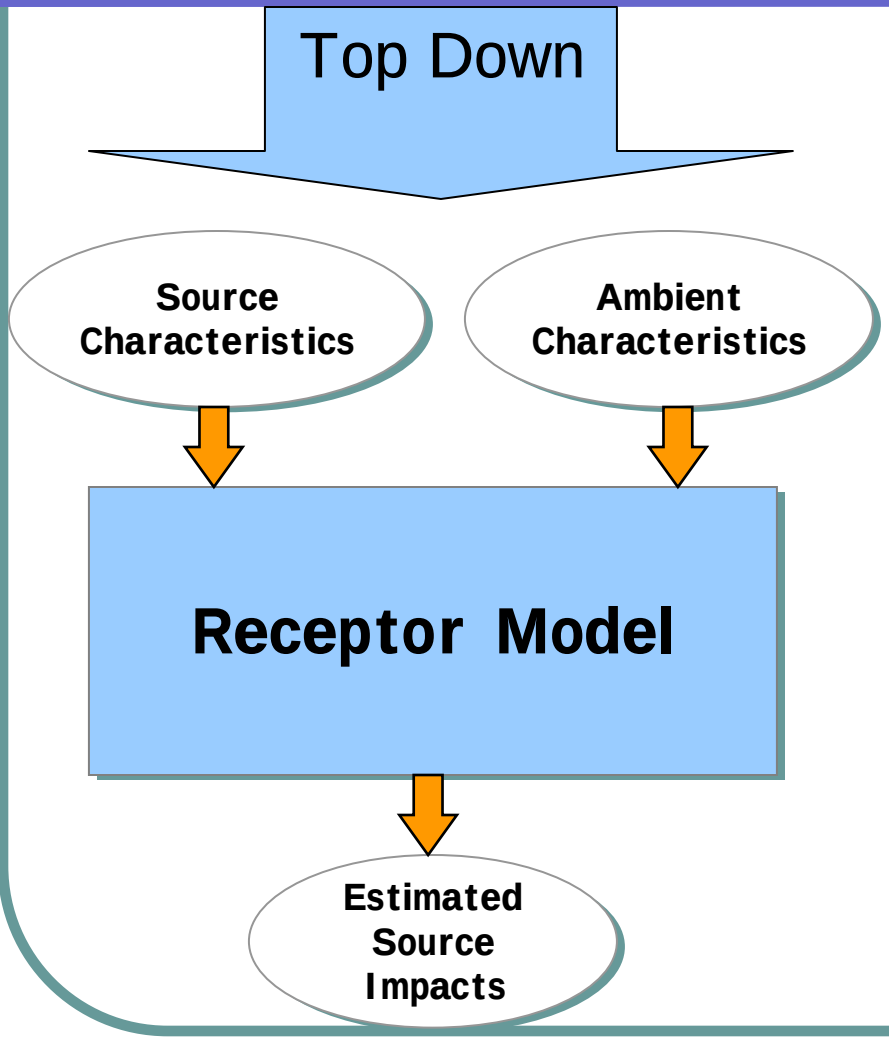
- Combined Reductions of all interventions
  - PM_{10} = 9,025 tons (25%)
  - CO_2 = 2,047,348 tons (22%)
- Combined reductions from vehicles (direct)
  - PM_{10} = 3,622 tons (33%)
  - CO_2 = 2,047,348 tons (25%)
- Combined reductions in industrial sector
  - PM_{10} = 3,283 tons (23%)

Handbook on Particulate Pollution Source Apportionment

Source Apportionment of Urban Air Pollution

Guttikunda and Johnson, The World Bank, 2008

Receptor Modeling Framework



- ✓ Locates monitoring sites with critical pollutant levels
- ✓ Identifies chemical composition of the PM
- ✓ Describes source impact estimates
- ✓ Documents primary and secondary PM
- ✓ Identifies sources would be most effective to control

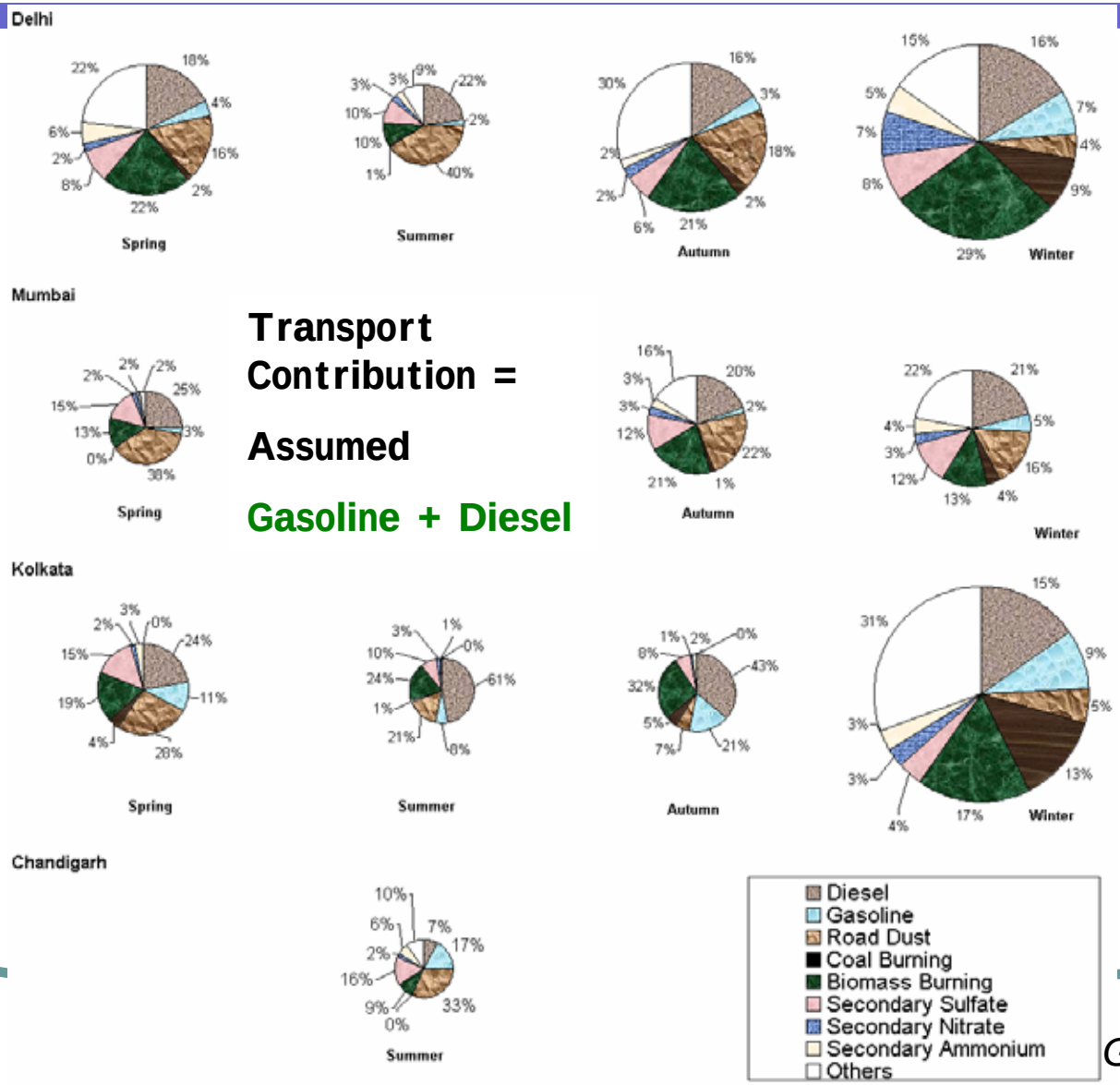
India Case Studies (2001 $PM_{2.5}$)

New Delhi

Mumbai

Kolkata

Chandigarh



Transport Contribution =

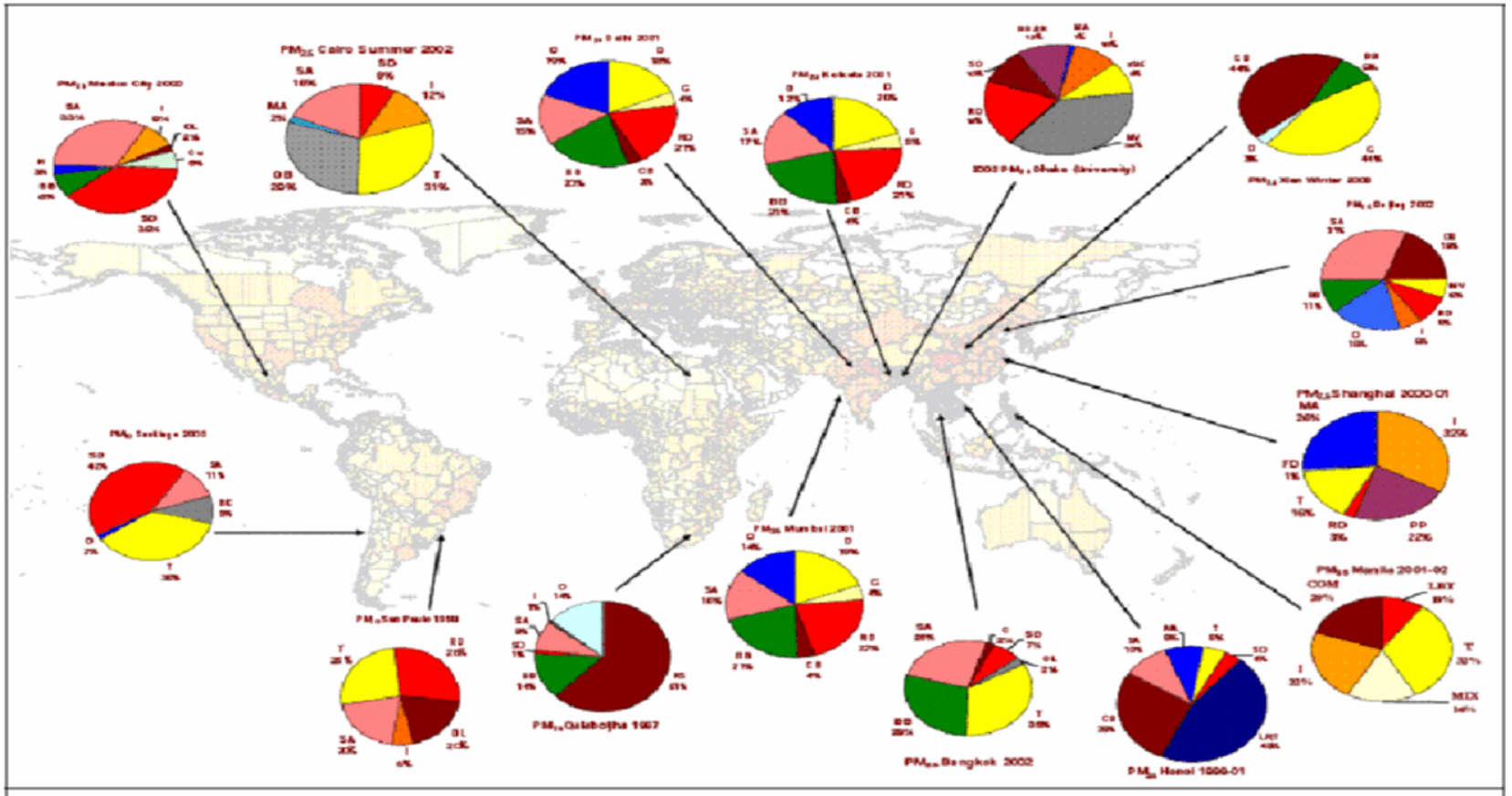
Assumed

Gasoline + Diesel

Spr-Sum-Aut-Win
22-24-19-23
28-*-22-26
35-69-64-24
-24--*

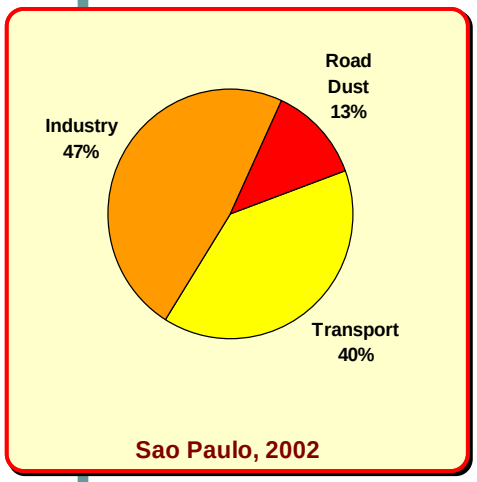
Geogia Tech (USA), 2004

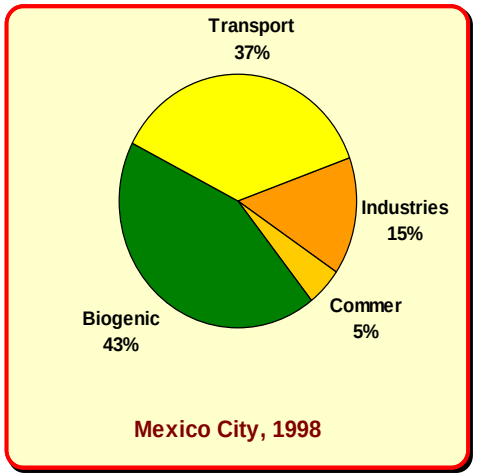
Summary of PMSA Studies

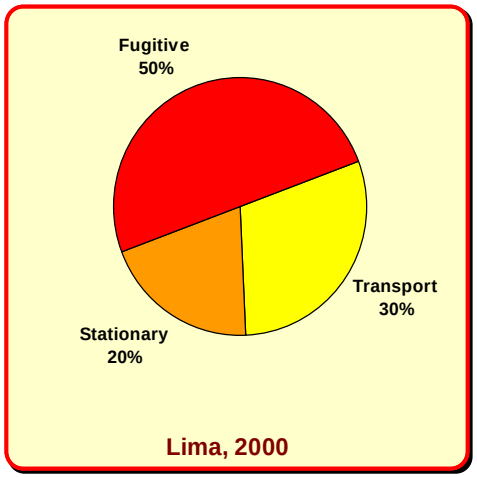


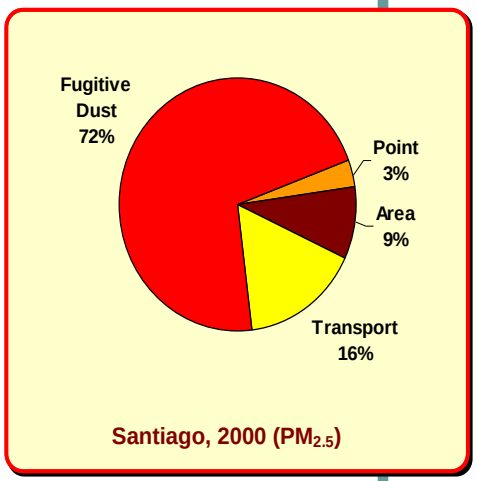
Guttikunda and Johnson, The World Bank, 2008

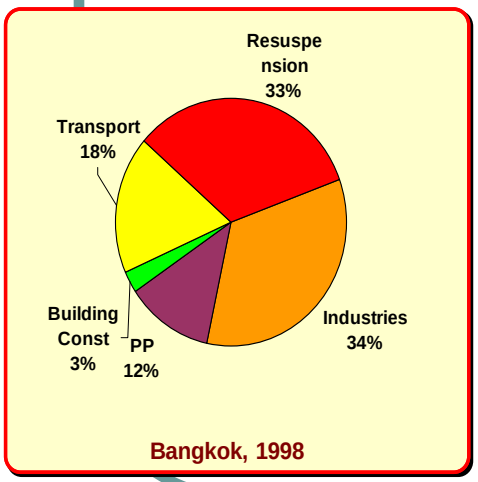
Urban Emissions Inventories

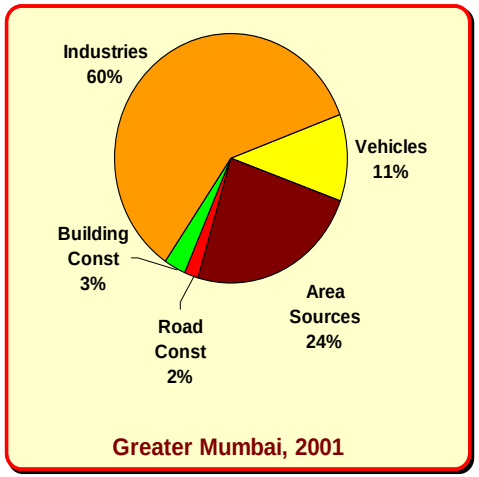


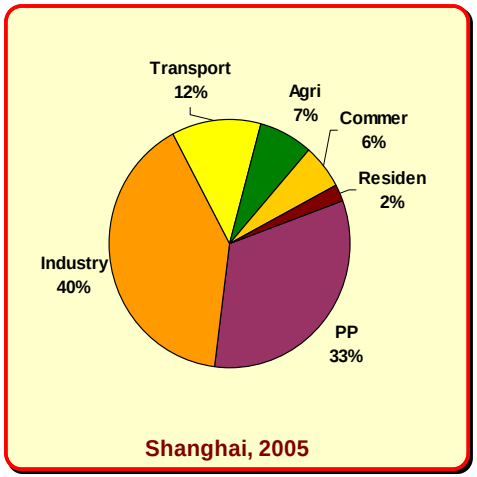


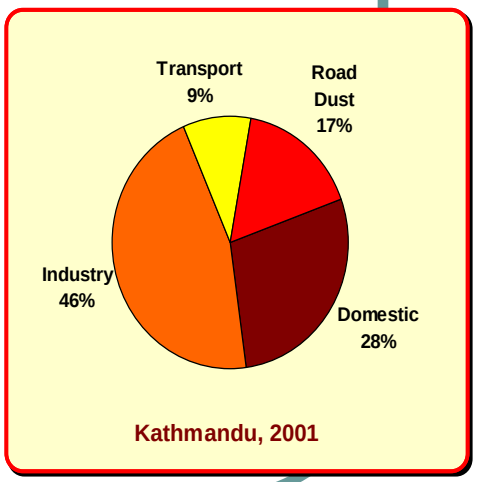












Guttikunda and Johnson, The World Bank, 2008

Ulaanbaatar, Mongolia

Challenges

- Harmonization of scattered and conflicting data
- Evolution of tools and methodologies
- Problems in adequately reflecting political economy of decision-making

Dispersion in Winter…

Traffic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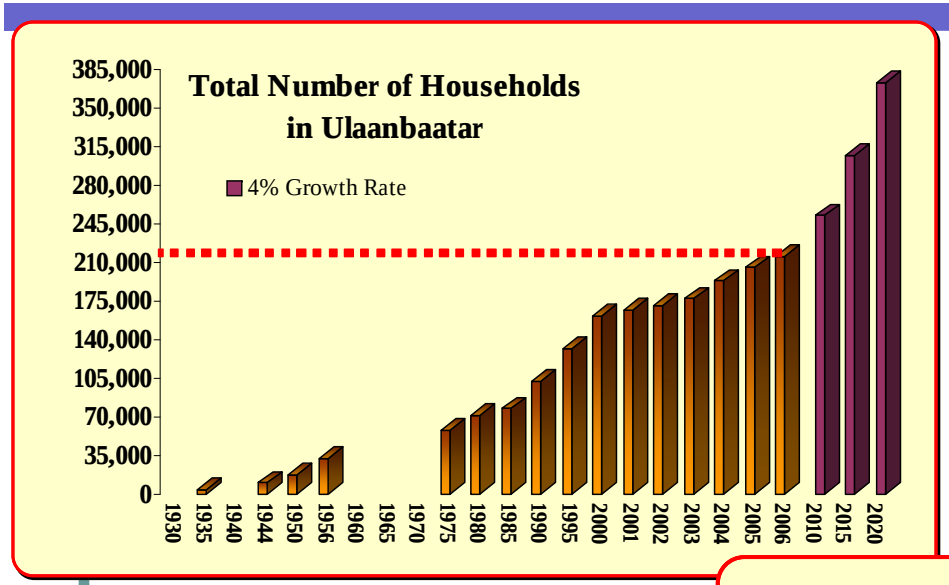
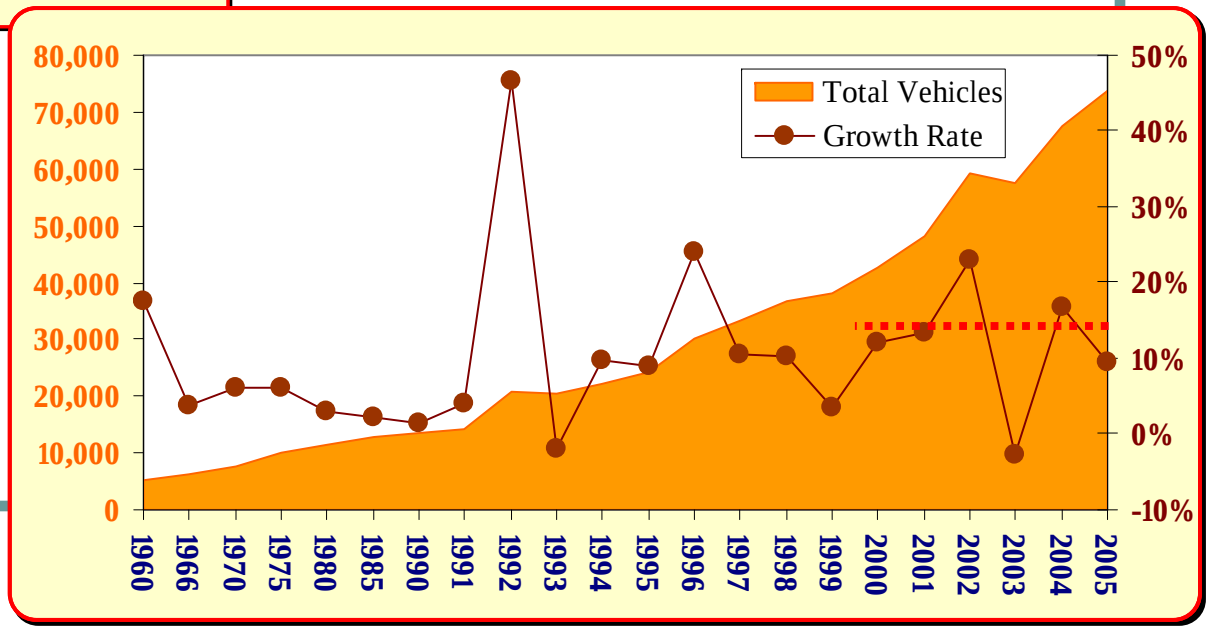
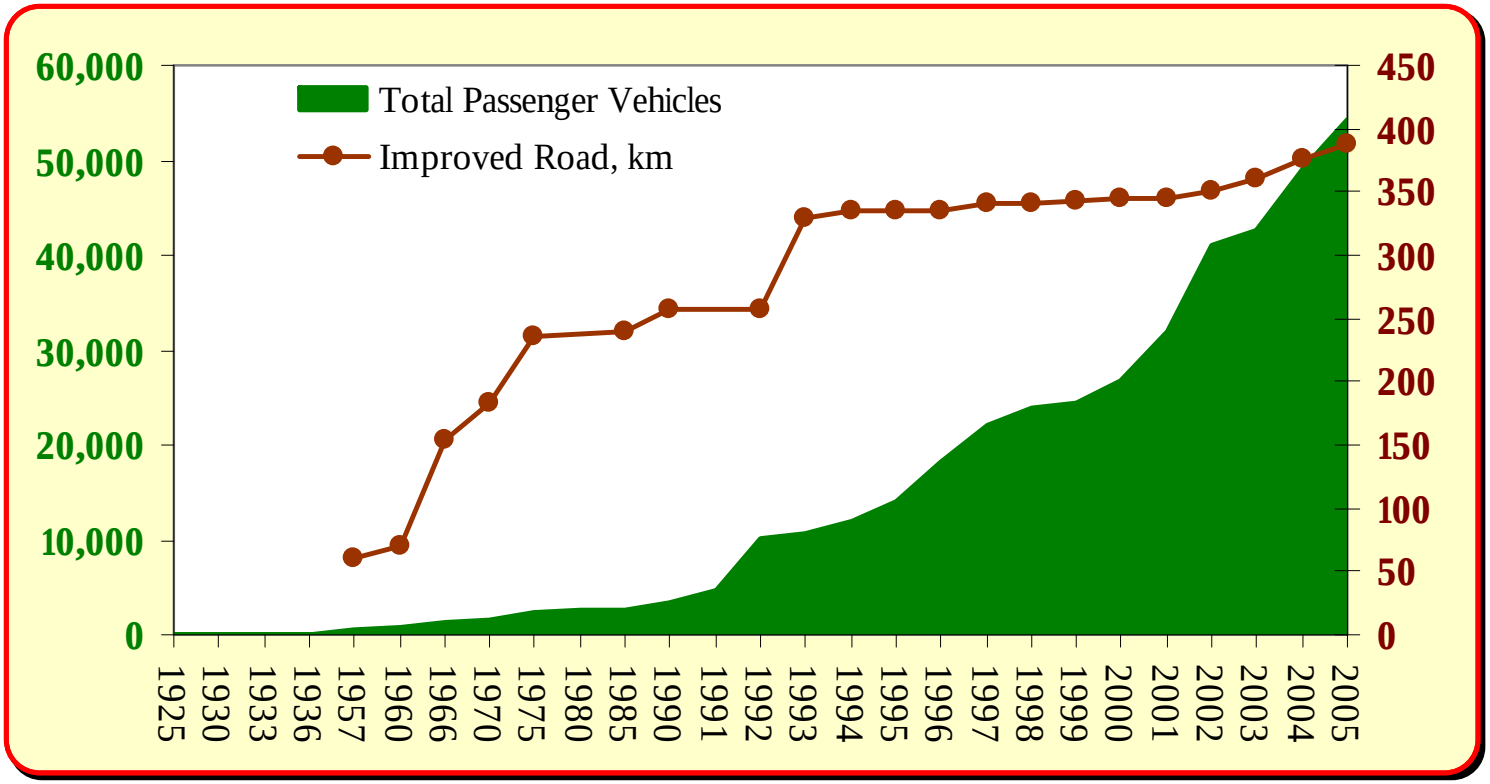
Local Statistics

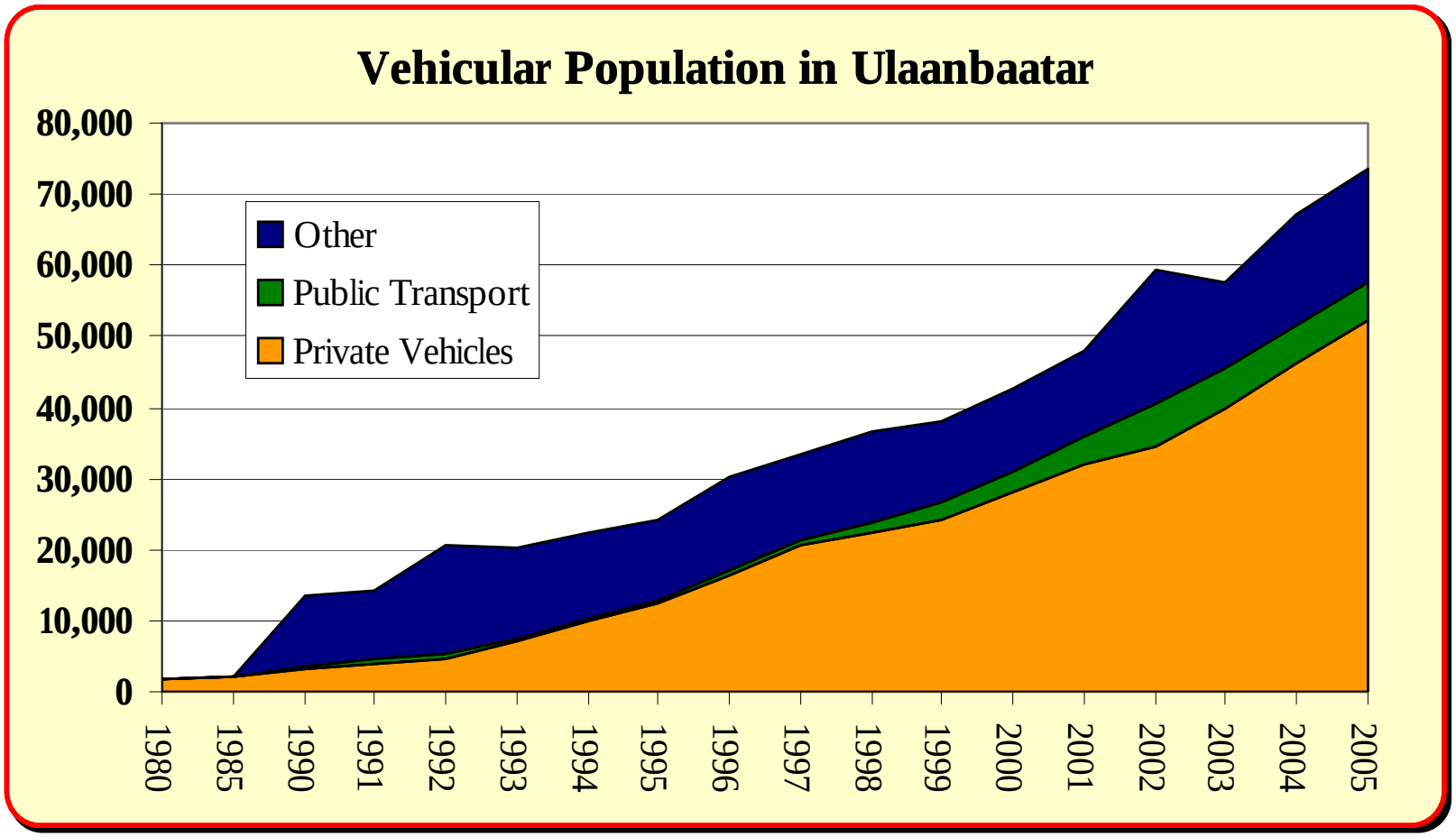


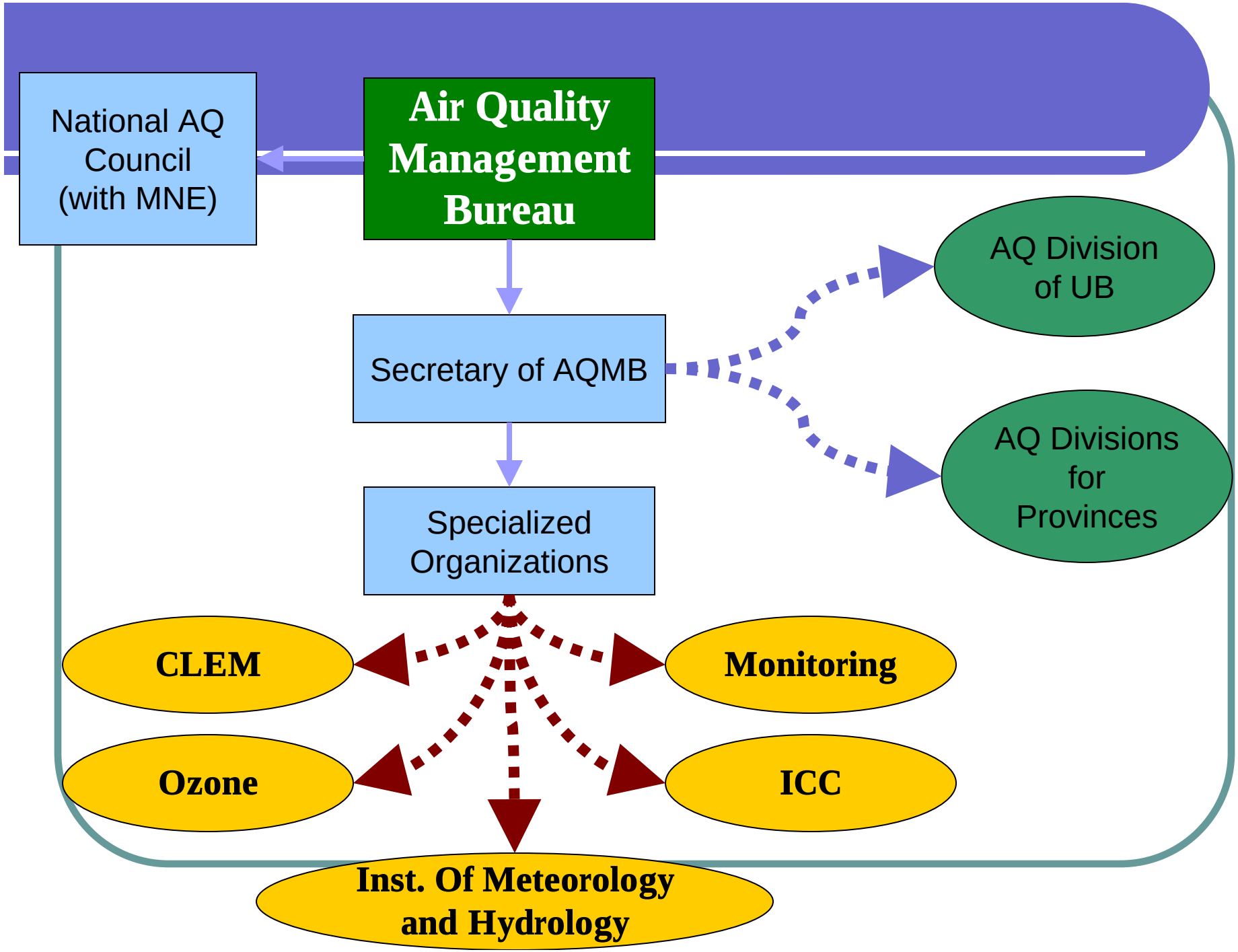


Traffic Congestion



Introduction of Public Transport




National AQ Council (with MNE)
Air Quality Management Bureau
AQ Division of UB
Secretary of AQMB
AQ Divisions for Provinces
Specialized Organizations
CLEM
Monitoring
Ozone
ICC
Inst. Of Meteorology and Hydrology

Bangkok, Thailand

DIESEL

DEVELOPING INTEGRATED EMISSION STRATEGIES FOR EXISTING LAND TRANSPORT

- Used by heavy duty traffic → Significant emitter of fine particulates, SOx, NOx (secondary PM) → associated health impacts
- Diesel vehicles have a long life time → delays introduction of latest technology
- Black smoke → major visible nuisance

Guttikunda, IDEAS Coordinator, The World Bank, Thailand, 2006

Summary of BKK DIESEL Results

		Average Speed		
		10	20	30
		Light Duty Vehicles		
HC	Pre-1994	0.52	0.32	0.25
CO		1.88	1.32	1.07
NOx		2.97	2.34	2.03
CO2		414.74	317.95	272.17
PM		216.18	187.54	172.59
HC	1994-96	0.36	0.24	0.20
CO		1.51	1.09	0.90
NOx		3.37	2.60	2.24
CO2		409.56	322.43	280.32
PM		153.14	155.50	156.90
HC	1997-99	0.34	0.21	0.16
CO		1.83	1.08	0.79
NOx		2.87	2.23	1.93
CO2		437.58	342.34	296.56
PM		169.94	166.20	164.05
HC	after 2000	0.27	0.19	0.16
CO		1.70	1.37	1.21
NOx		1.45	1.14	0.98
CO2		420.66	342.25	303.35
PM		138.24	145.44	149.83

		Average Speed		
		10	20	30
		Heavy Duty Buses		
HC	Pre-1995	2.35	1.31	0.93
CO		10.17	6.59	5.11
NOx		19.68	12.00	8.98
CO2		1299.06	843.09	654.71
PM		1319.11	962.30	800.18
HC	1996-97	1.81	1.10	0.82
CO		17.40	16.02	15.26
NOx		22.45	13.30	9.80
CO2		1317.69	999.87	850.79
PM		1928.59	1759.84	1668.06
HC	1997-2000	0.85	0.46	0.32
CO		18.21	15.42	13.99
NOx		19.68	12.00	8.98
CO2		1789.18	1154.76	893.83
PM		835.09	620.84	522.00
HC	after 2001	1.83	1.05	0.76
CO		6.36	3.72	2.72
NOx		13.50	9.47	7.70
CO2		1474.90	1038.44	845.75
PM		1116.67	982.14	911.09

		Average Speed		
		10	20	30
		Heavy Duty Trucks		
HC	Pre-1995	1.46	0.93	0.71
CO		13.12	10.35	9.02
NOx		15.02	10.44	8.44
CO2		1163.51	921.26	803.67
PM		2445.90	1859.44	1583.94
HC	1996-97	1.65	1.18	0.96
CO		4.24	3.46	3.08
NOx		14.24	10.88	9.30
CO2		1185.70	980.67	877.59
PM		933.68	880.38	850.62
HC	1997-2000	1.83	1.22	0.97
CO		4.24	3.46	3.08
NOx		15.02	10.44	8.44
CO2		1401.33	1127.40	992.71
PM		1283.03	925.60	764.66
HC	after 2001	0.83	0.55	0.43
CO		5.40	3.61	2.85
NOx		15.07	10.03	7.91
CO2		1438.36	1009.98	821.27
PM		447.67	410.40	390.06

Program details

@ ***http://www.pcd.go.th/info_serv/en_air_diesel.html***

Program final report (April'08)

@ *http://www.cleanairnet.org/caiasia/1412/article-72628.html*