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NIES, Tsukuba, JAPAN

Detail Model development of **Transportation** and **Air pollution**

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Contents

Transportation model

We developed a **reconciliation tool for domestic and international Transport statistics** to estimate the **reliable past traffic volume.**

We broke down **domestic passenger and freight transport** for each "**purpose**", "**type of Transportation**", "**personal attribute**" and "**trip distance**".

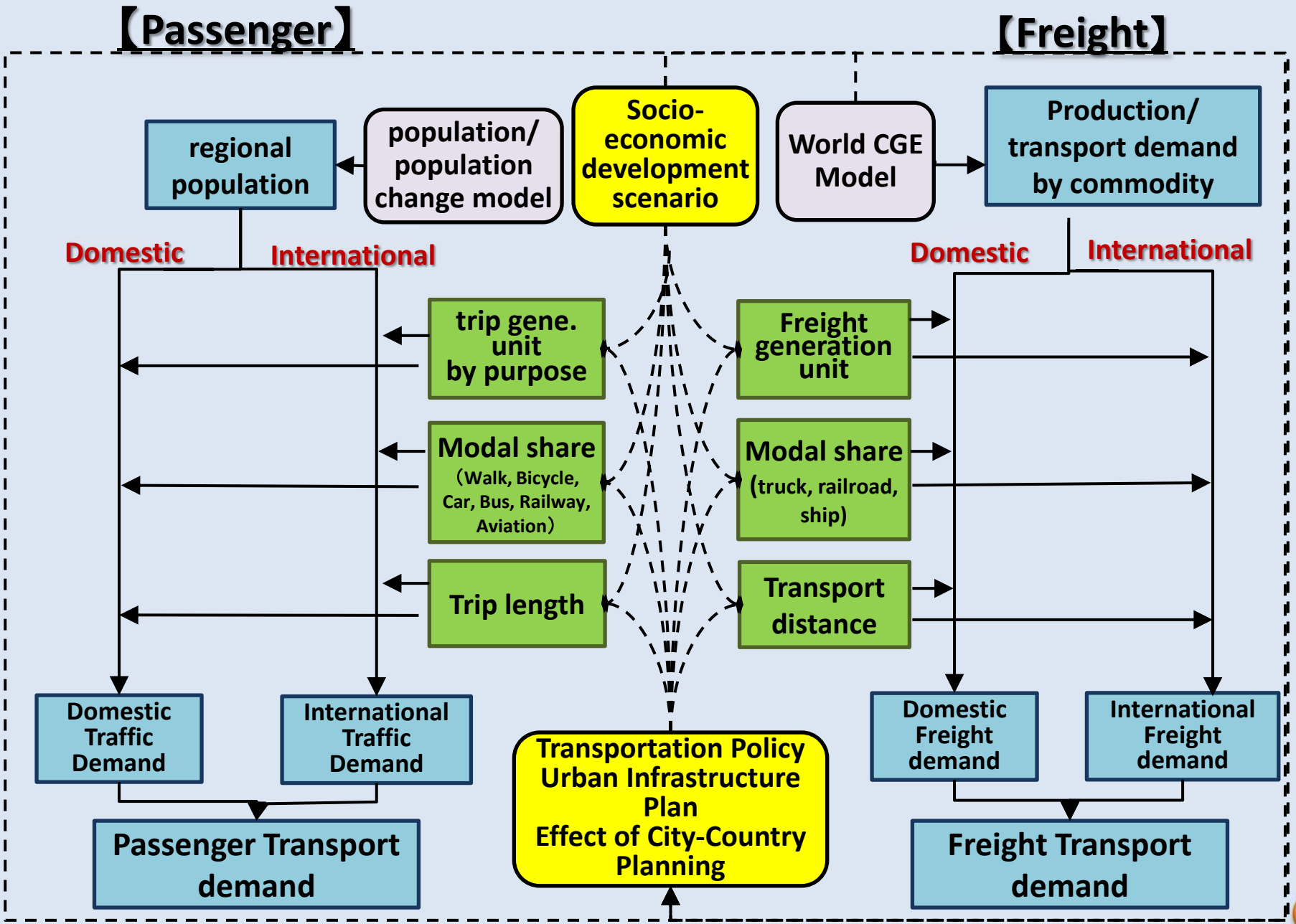
Air Pollution model

We developed **human exposure model** of $PM_{2.5}$ both **indoor** and **outdoor** for Chinese 31 province.

In the exposure model, we developed **roadside model** to consider the high concentration from road traffic.

By connecting these **two models**, detail estimation of **co-benefit** of LCS countermeasure to the reduction of air pollution impact, especially by transportation related LCS policy.

framerowk of traffic demand model



Estimation method of **Passenger transport demand**

$$PTV = \sum POP_{i,pa} \cdot PTG_{i,pa,pt} \cdot PTS_{i,m,pt,d} \cdot DIS_{i,d}$$

i: transportation type(domestic or international)
pa: personal attribute
pt: purpose of trip
d: representative distance
m: mode
PTV: passenger transportation volume[p-km]
POP: effective population[person]
PTG: trip generation rate[number/person]
PTS: modal share[-]
DIS: trip distance[km]

Estimation Method of **Freight Transportation demand**

$$FTV = \sum PI_{i,com} \cdot FTG_{i,com} \cdot FTS_{i,m,d} \cdot DIS_{i,d}$$

i: transportation type(domestic or international)

com: commodity

d: representative distance

m: mode

FTV: freight transportation volume[ton-km]

PI: production and import volume of commodity[US$]

FTG: freight transport generation rate[ton/US$]

FTS: modal share[-]

DIS: freight transport distance[km]

Parameter Estimation for Base Year

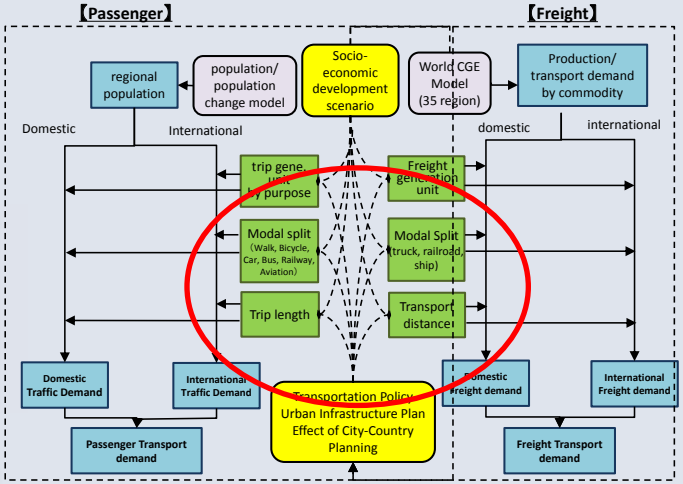
Task | Data

STEP1

Traffic Statistics
Energy Statistics

Reconciliation of traffic data
1971-2005,
Possession of vehicle, transport, Total transport, energy consumption using statistical data

Each type of transport
Possession | Total transportation | Energy consumption



Each type of Transport
Total Passenger Transport

Each type of Transport
Total Freight Transport

STEP2-P

STEP2-F

- Population
- Trip generation unit
- Trip distance share by type
- Trip distance share by Purpose

Decomposition of Passenger Transport
Estimation of the parameters of passenger transportation at 2005

Decomposition of Freight Transport
Estimation of the parameter of Freight transportation at 2005

- Production + import
- Freight generation unit
- Distance share by type

Trip generation unit
modal share
trip distance

Freight generation unit
modal share
transportation distance

STEP1: Reconciliation of Traffic statistics

- A lot of **errors** and **losses** are included in Traffic statistics.
- **Minimizing the errors from reference values**, such as possession, total mileage, freight amount, energy consumption and ratios between these values (mileage, load coefficient, fuel consumption per distance etc)
- Reference value is derived from statistics and literatures.
- Constrain the trend from large swing to avoid the discontinuous of time series.

Objective Function

$$
\begin{aligned}
ER = \sum_t \sum_j \Big\{ & wch_{ST',j} \cdot CHST_{j,t}^{\ 2} + wer_{ST',j} \cdot \sum_h ERST_{j,h,t}^{\ 2} \\
& + wch_{VK',j} \cdot CHVK_{j,t}^{\ 2} + wer_{VK',j} \cdot \sum_h ERVK_{j,h,t}^{\ 2} \\
& + wch_{TV',j} \cdot CHTV_{j,t}^{\ 2} + wer_{TV',j} \cdot \sum_h ERTV_{j,h,t}^{\ 2} \\
& + wch_{PS',j} \cdot CHPS_{j,t}^{\ 2} + wer_{PS',j} \cdot \sum_h ERPS_{j,h,t}^{\ 2} \\
& + wch_{TN',j} \cdot CHTN_{j,t}^{\ 2} + wer_{TN',j} \cdot \sum_h ERTN_{j,h,t}^{\ 2} \\
& + wch_{ENT',j} \cdot CHENT_{j,t}^{\ 2} + wer_{ENT',j} \cdot \sum_h ERENT_{j,h,t}^{\ 2} \\
& + wer_{DS',j} \cdot \sum_h ERDS_{j,h,t}^{\ 2} + wer_{LF',j} \cdot \sum_h ERLF_{j,h,t}^{\ 2} \\
& + wer_{FEV',j} \cdot \sum_h ERFEV_{j,h,t}^{\ 2} + wer_{FET',j} \cdot \sum_h ERFET_{j,h,t}^{\ 2} \\
& + wer_{ATD',j} \cdot \sum_h ERATD_{j,h,t}^{\ 2} + wer_{AFD',j} \cdot \sum_h ERAFD_{j,h,t}^{\ 2} \Big\} \quad \rightarrow \quad \min
\end{aligned}
$$

Numbers of Vehicle
Total transport (km)
Total transport (person·km, t·km)
Total transport (person)
Total transport (t)
Energy consumption
travel distance (km/year/vehicle)
Load coefficient (person/vehicle, t/vehicle)

Fuel consumption
(ktoe / vehicle, ktoe / km person , ktoe / km t)

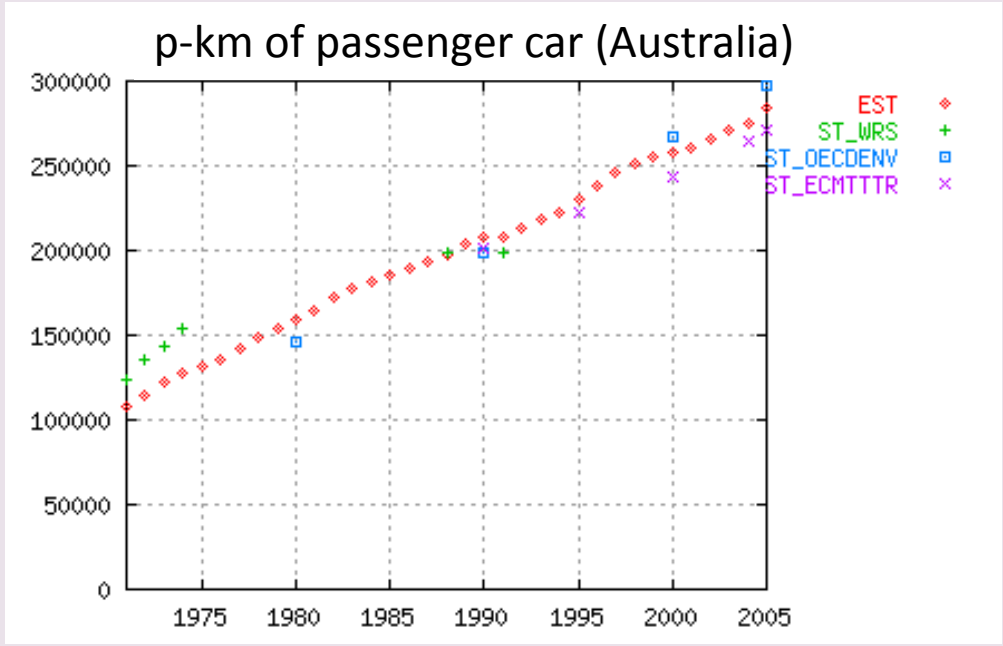
Average trip distance(Passenger),
Average transport distance(Freight)

Used International and domestic statics for transportation

Statistics Name	Source
World Road Statistics 63-89, 1995,2001,2002,2006	IRF, 2003,1995,2001,2002,2006
World Develoement Indicators 2005	World Bank, 2005
World Develoement Indicators 2007	World Bank, 2007
Statistical Year book 47	UN, 2003
EUROSTAT(web)	European Comission, webからDL(2008/4/11)
ODYSSEE	ADEME, 2002
OECD Environmental Data Compendium 2006/2007 Transport	OECD, 2007
Statistical Trends in Transport 1965-1994	ECMT, 1998
Trends in the Transport Sector 1970-2005	ECMT, 2007
World Bank's Railway Database	World Bank, 2001
Energy Balnces of OECD Countries, Energy Balnces of non-OECD Countries	IEA, 2007
Globalstat	enerdata, 2006
World Motor Vehicle Statistics	Japan Automobile Manufacturers Association, 2004, 2008
International Historical Statistics	Mitchell, 2003
China Statistical Yearbook	National Bureau of Statistics of China, 1993, 1994, 1995, 2000, 2001, 2006
Korea Statistical Yearbook	Korea National Statistical Office, 2002, 2006
TEDDY(TERI Energy Data Directory & Yearbook)	TERI, 2002, 2006
Land Transport Statistics Japan	MLIT Japan, 2001, 2006
Automobile Transportation statistics Japan	MLIT Japan 1987-2006
National Transportation Statistics 2008	Bureau of Transportation Statistics, U.S. Department of Transportaion, 2008
World Railways	Japan Railway Technical Service, 2005
ANNUAL BULLETIN OF TRANSPORT STATISTICS FOR EUROPE AND NORTH AMERICA	UN Economic Commission for Europe, 2004, 2005, 2008
Handbook of Transport Statistics in the UNECE region 2006	UN Economic Commission for Europe, 2006
Malaysia Transport Statistics 2006	, 2006
Statistical Handbook of Vietnam	General Statistics Office of Vietnam, 2005, 2006
Philippine Yearbook 2006	National Statistics Office, 2006
USSR Facts & Figures Annual	Academic International Press, 1977,1979,1987,1990,1991,1992
Statistical Yearbook Thailand	National Statistical Office, 1998,2000,2002,2004
Transport and Communications Yearbook 2003	SWEDISH INSTITUTE FOR TRANSPORT AND COMMUNICATIONS ANALYSIS, 2003
Transport Statistics Great Britain 2005	DEPARTMENT FOR TRANSPORT, 2005
China Energy Databook 2004	Lawrence Berkeley National Laboratory, 2004
Statistical Abstract of Transport in Asia and the Pacific 2007	UN Economic and Social Commission for Asia and the Pacific, 2007
Philippine Statistical Yearbook 1991	Republic of the Phillippine National Statistical Coordination Board, 1991
North American Transportation Statistics	North American Transportation Statistics Database, 2007
Taiwan Statistical Databook 2007	Council for Economic Planning and Development Exective Yuan, R.O.C., 2007
Statistical Yearbook of Bangladesh 2005	Bngladesh Bureau of Statistics, 2005

Sample image of Result output

Example of the Result



Parameter Estimation for Base Year

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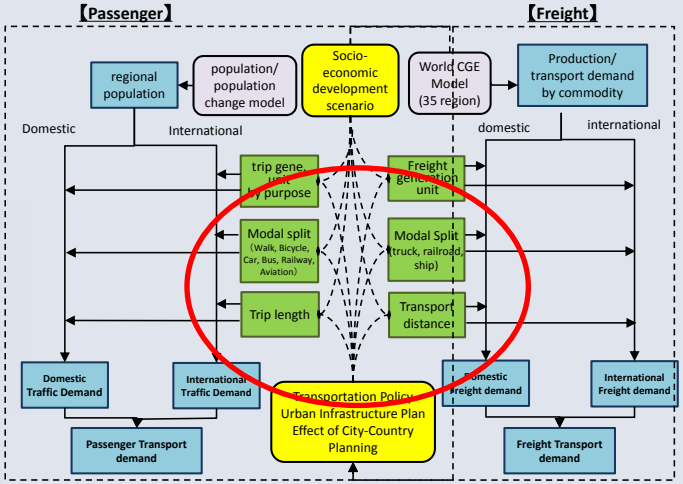
- Energy consumption



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Each type of Transport
Total Freight Transport

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STEP2-F

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Decomposition of Freight Transport
Estimation of the parameter of Freight transportation at 2005

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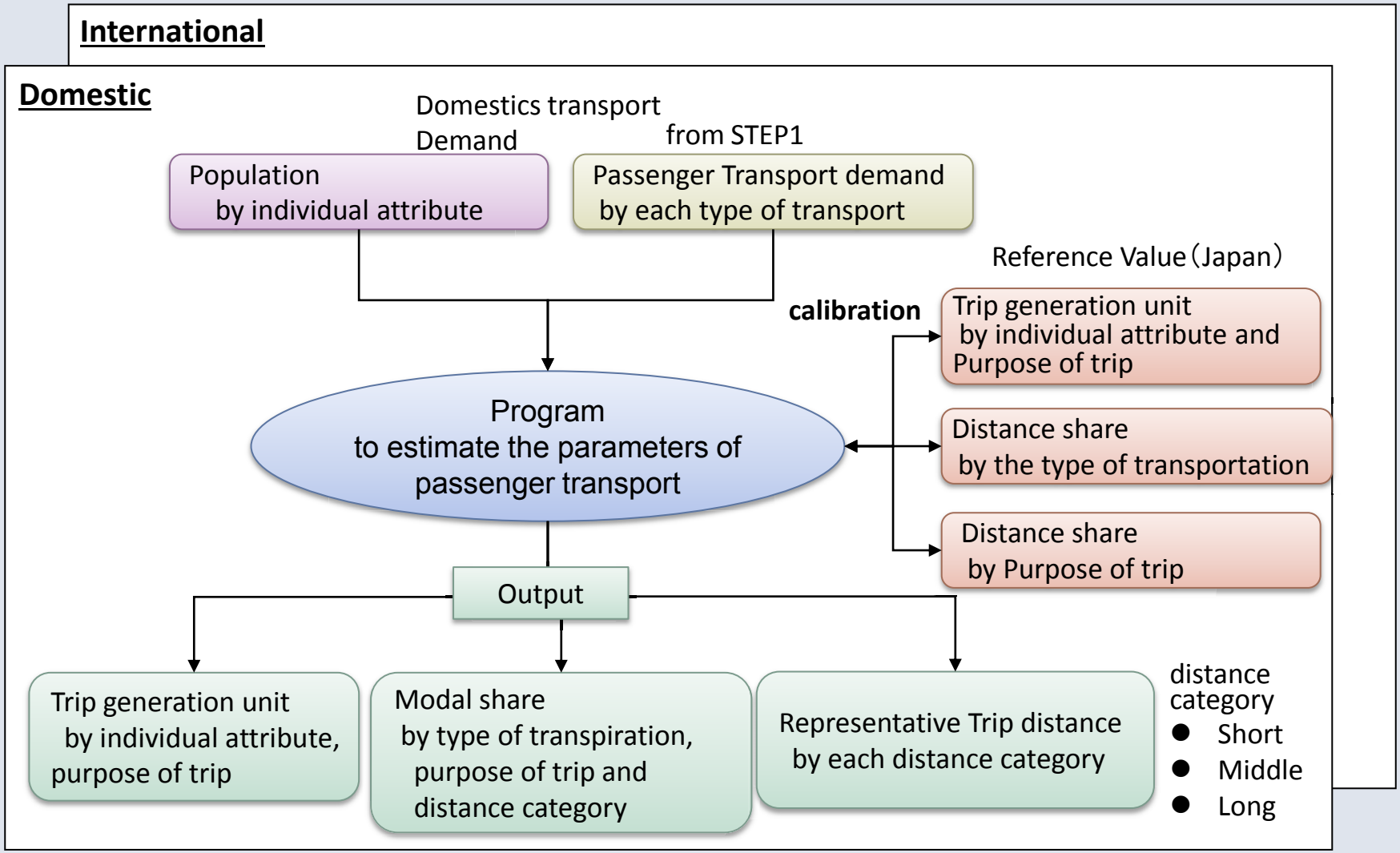
- Freight generation unit
- Distance share by type

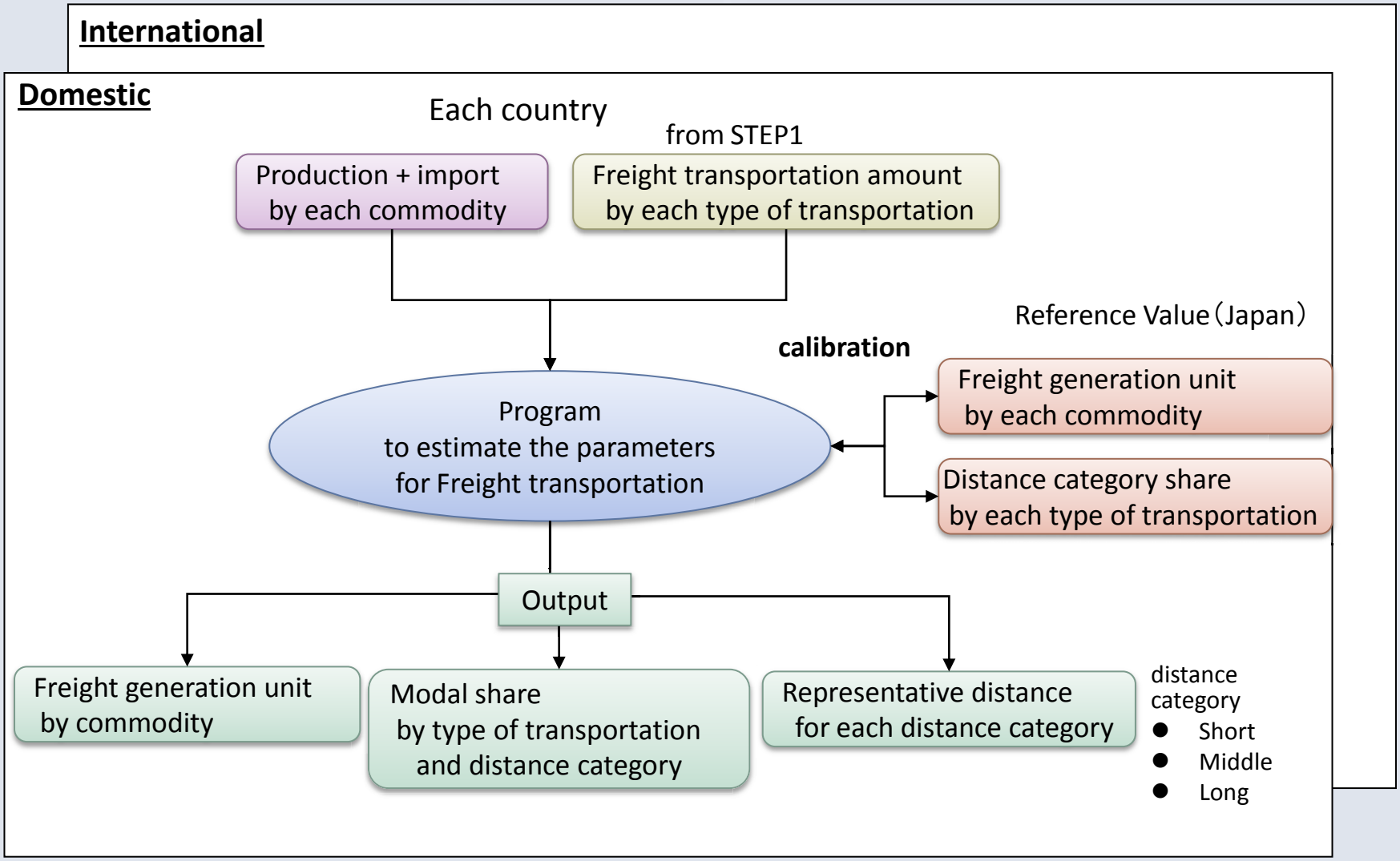
Trip generation unit
modal share
trip distance

Freight generation unit
modal share
transportation distance

STEP2-P: Decomposition of Passenger Transport Demand

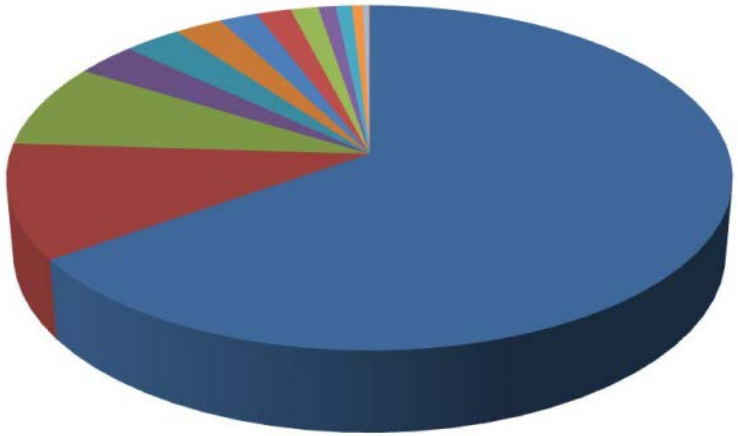


STEP2-F: Decomposition of Freight transportation



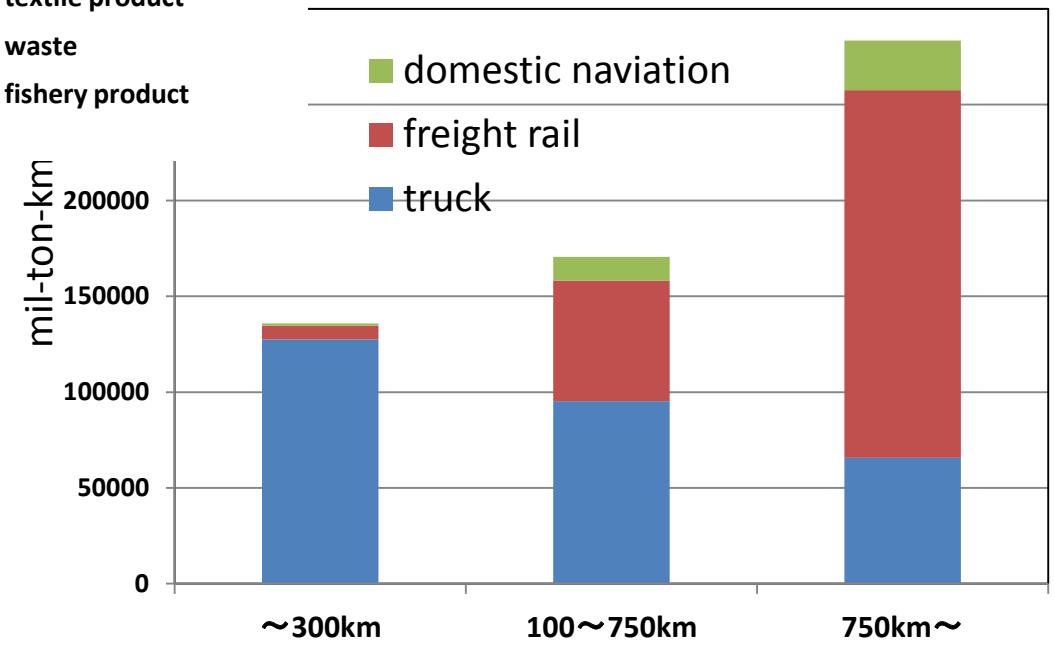
Tentative outputs（Canada）

ton-km by commodities

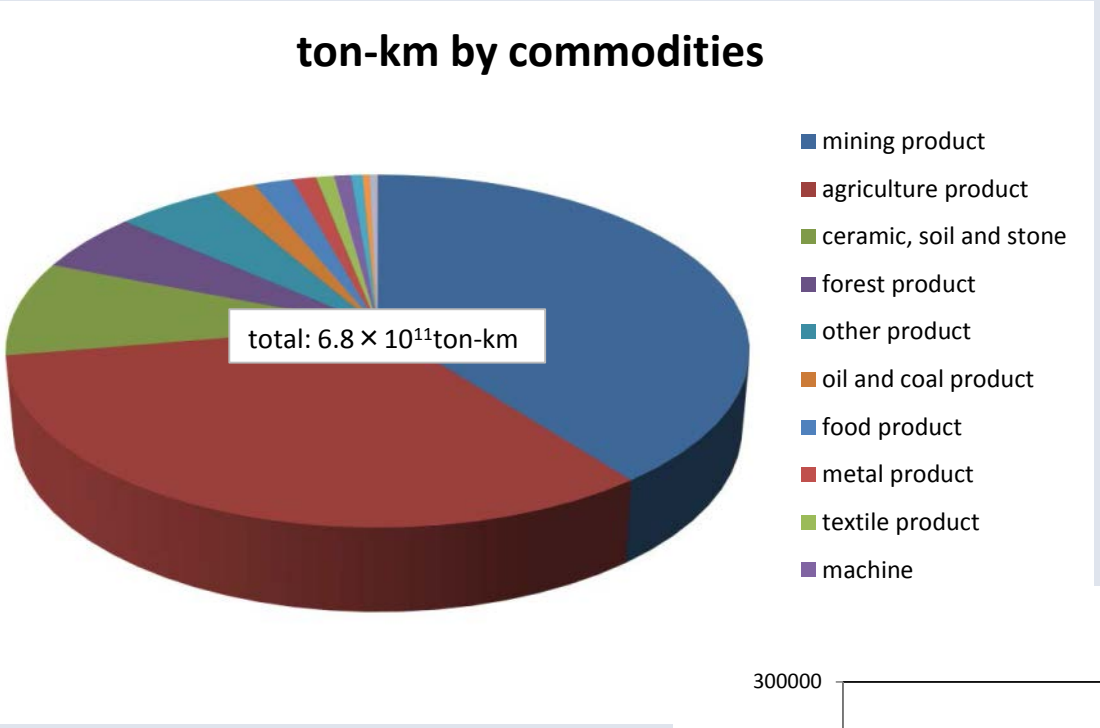


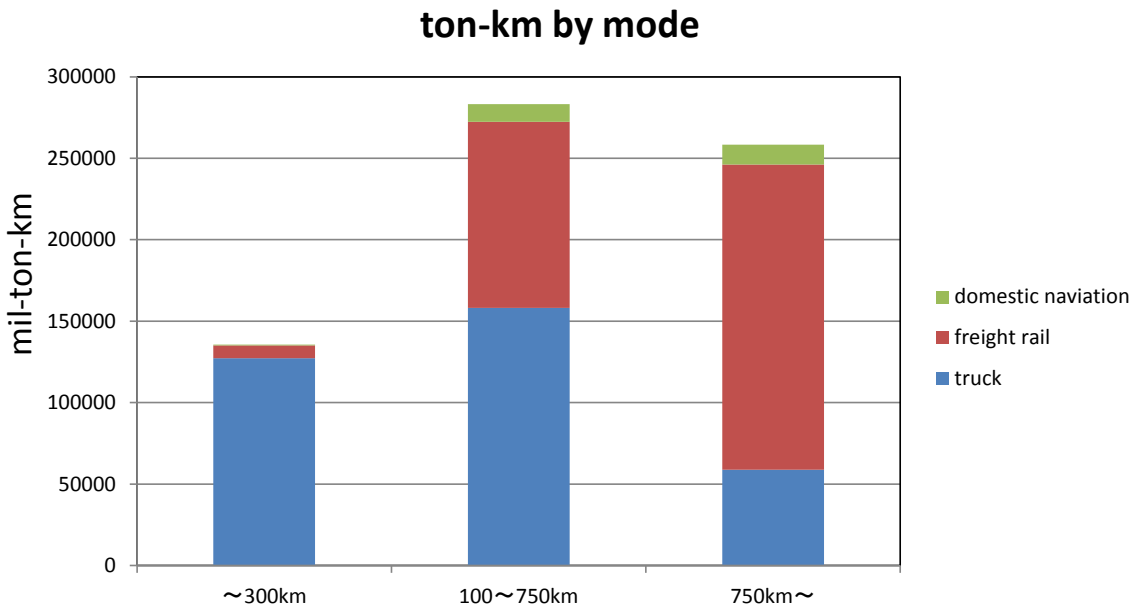
- mining product
- other product
- forest product
- machine
- food product
- agriculture product
- ceramic, soil and stone
- oil and coal product
- metal product
- paper and pulp
- chemical product
- textile product
- waste
- fishery product

ton-km by mode



Tentative outputs（India）





Contents

Transportation model

We developed **Country level Transportation model** to estimate the **traffic volume** which is consistent with available statistics.

We broke down **domestic passenger and freight transport** for each "**purpose**", "**transportation facility**", "**personal attribute**" and "**trip distance**".

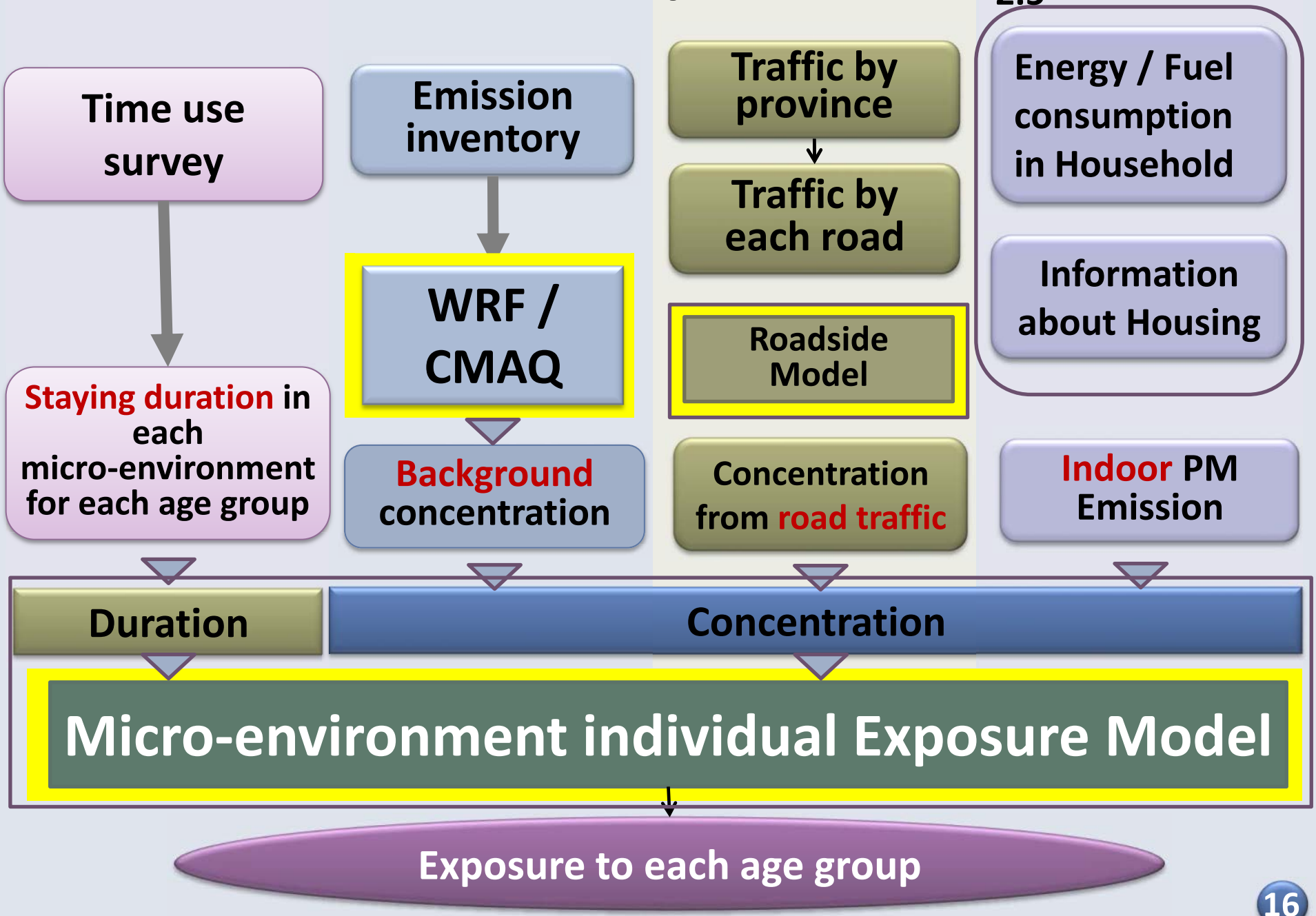
Air Pollution model

We developed **human exposure model** of $PM_{2.5}$ both **indoor** and **outdoor** for Chinese 31 province.

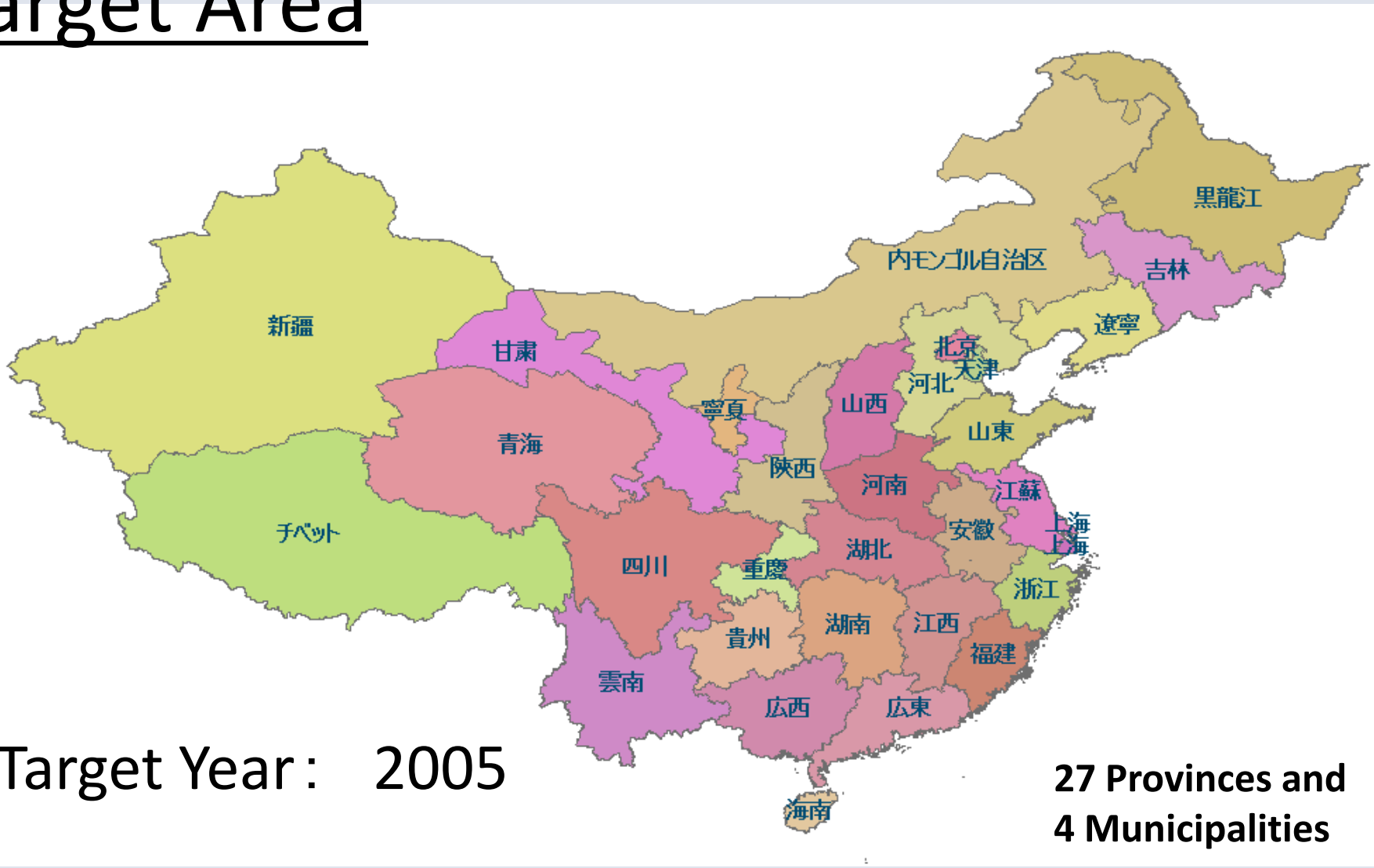
In the exposure model, **roadside model** to consider the high concentration from road traffic.

By connecting these **two models**, detail estimation of **co-benefit** of LCS countermeasure to reduction of air pollution impact, especially by transportation relate LCS policy.

Estimation of Individual Exposure to $PM_{2.5}$



Target Area



Target Year : 2005

27 Provinces and 4 Municipalities

Polutant : $PM_{2.5}$

Micro-environment individual Exposure Model

◆Daily average exposure concentration

$$\overline{E^a} = \sum_m C_m \cdot T_m^a$$

Concentration in micro-environ. × Stay duration

Classification of individual attribute

54 age 0-4,5-14, 15-19, ...70-74, 75+ 15group
Male / Female
Employed / Unemployed

$\overline{E^a}$: Daily average exposure concentration (μg/m^3)

C_m : Concentration in micro-environment (μg/m^3)

T_m^a : Duration of stay in micro-environment m (–)

a : Individual attribute group

Micro-environment individual Exposure Model

Considered micro-environment in this model

Micro Environ.	Place	Purpose	Indoor Emission source	Duration of stay
A	Indoor	Cooking Hot water	Oven, Cooking Stove	Cooking
B	Indoor	Heating	Heating Stove, Fireplace	Home (except sleeping time) (When average outdoor temperature < 10℃)
C	Indoor	Lighting	Kerosene lamp	Night time
D	Indoor	-	None	Inside Building (Home and Building)
E(H)	Outdoor	-	-	Outdoor activity (<100 m from road)
E(M)		-	-	Outdoor activity (100-500 m from road)
E(L)		-	-	Outdoor activity (>500 m from road)

Time use survey

Adult (age 15 and above) :
Time use survey (10 provinces)

Child : from literatures

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Micro-environment individual Exposure Model

Single-Compartment Mass Balance Model under steady-state assumption

$$C_m = \frac{1}{v + F_d}\left(F_p v C_o + \frac{Se}{V}\right)$$

◆Formulation to calculate concentration.

➢**with Indoor emission ME A、B、C**

$$C_m = \frac{1}{(v + F_d)}(F_p v C_0 + \frac{S_e}{V})$$

➢**w/o indoor emission ME D**

$$C_m = \frac{F_p v}{v + F_d} C_o$$

➢**Outdoor ME E**

$$C_m = C_o$$

C_m : Pollutant concentration at micro environment (m) (μg/m³)

C_o : Pollutant concentration at Outdoor (μg/m³)

F_p : Penetration Factor (-)

v : Air Exchange Rate (1/hr)

F_d : Deposition rate (1/hr)

S : Energy consumption (KJ/hr)

e : Emission Factor (μg/KJ)

V : Volume of Micro Environment(m³)

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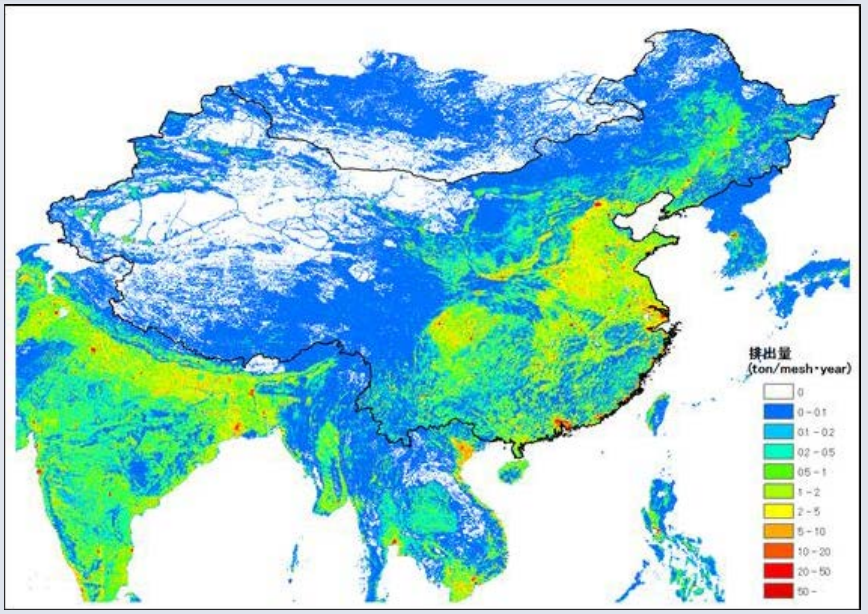
Emission inventory of Air pollutants

Used data:

- Large Point Source: from International database
  (Power plant, Iron & steel, Cement, Petrochemical)
- GDP, Road length, Rail length : China annual statistics
- Population, Population by industry :
  Histrical Population database fo China(2000)

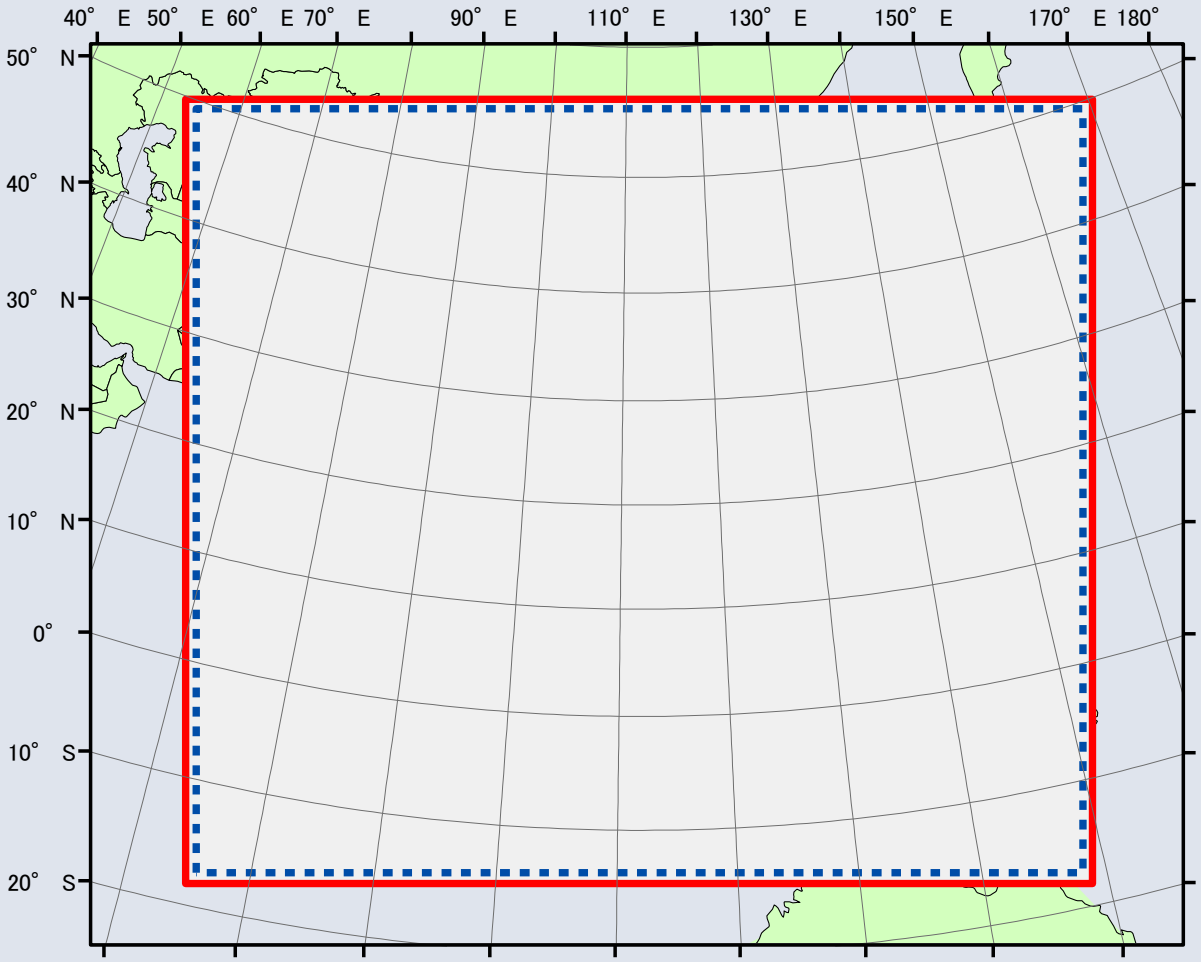
Mothodology:

Based on Yasuhuku(2011)
Output species: NOx, SOx, CO,
PM2.5, PM10, NMHC
Output resolution:
30sec x 30sec (≒ 1km)



PM2.5 emission (ton/mesh・year)

Chemical Transport Model



WRF

CMAQ

Target Area

Lambert Conformal
Center : 112° E 21° N
Standard latitude :10° , 30°

	WRF	CMAQ
Grid Size	80km	80km
Number of Grids (East-West)	120	117
Number of Grids (North-South)	105	102

Calculation Term

1 Jan 2001 – 31 Dec 2001

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WRF

(Weather and Forecasting Model)

- Meso-scale Meteorological Model developed by NCAR and Research community.
- WRF ARW(Advanced Research WRF) version 3.1.1
- Input Data
  - Terrain and Landuse data : USGS(U.S. Geological Survey)
  - Initial and Boundary Meteorological Data: JRA-25 (Re-Analysis by JMA)

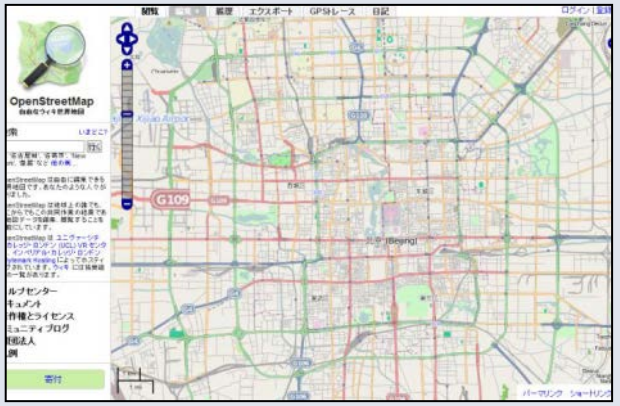
CMAQ

(Community Multi-scale Air Quality Modeling System)

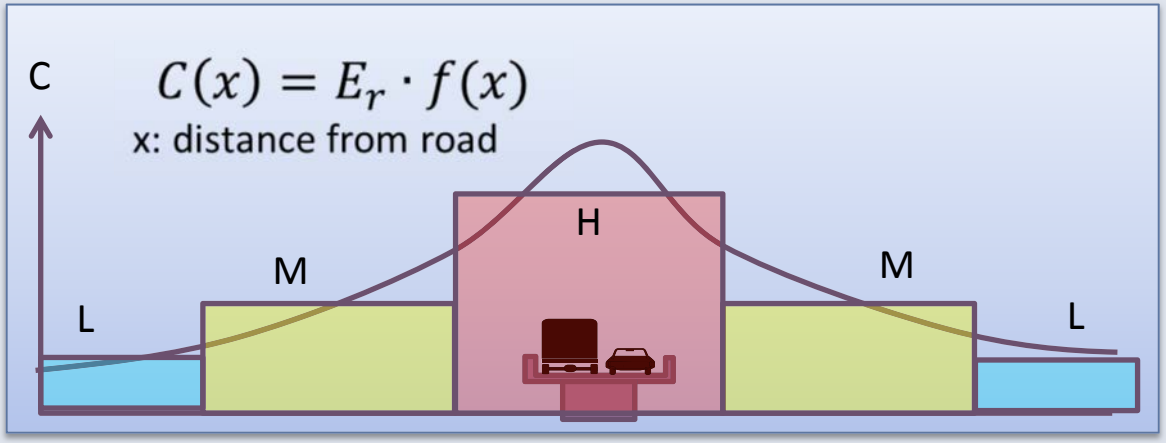
- Multi scale Chemical Transport Model developed by US EPA
- CMAQ version 4.7
- Input Data
  - Emission Mesh Data
- Chemical Reaction Mechanism
  - Gas Phase: CB05 (51 chemical Species, 156 Reactions)
  - Aerosol : AERO5

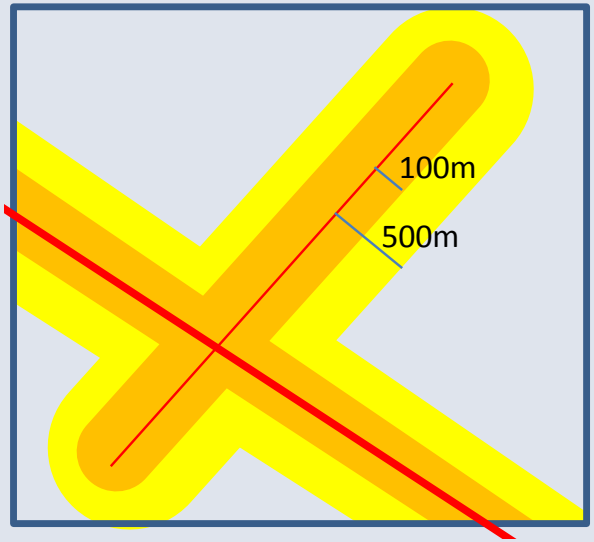
Roadside Model

Road Network Data:
OpenStreetMap



- Calculation case and mesh size：
  ①Whole China Case： 10km
  ②Beijing Fine Case： 1km
- Divided a mesh to 3 classes by the distance from road.



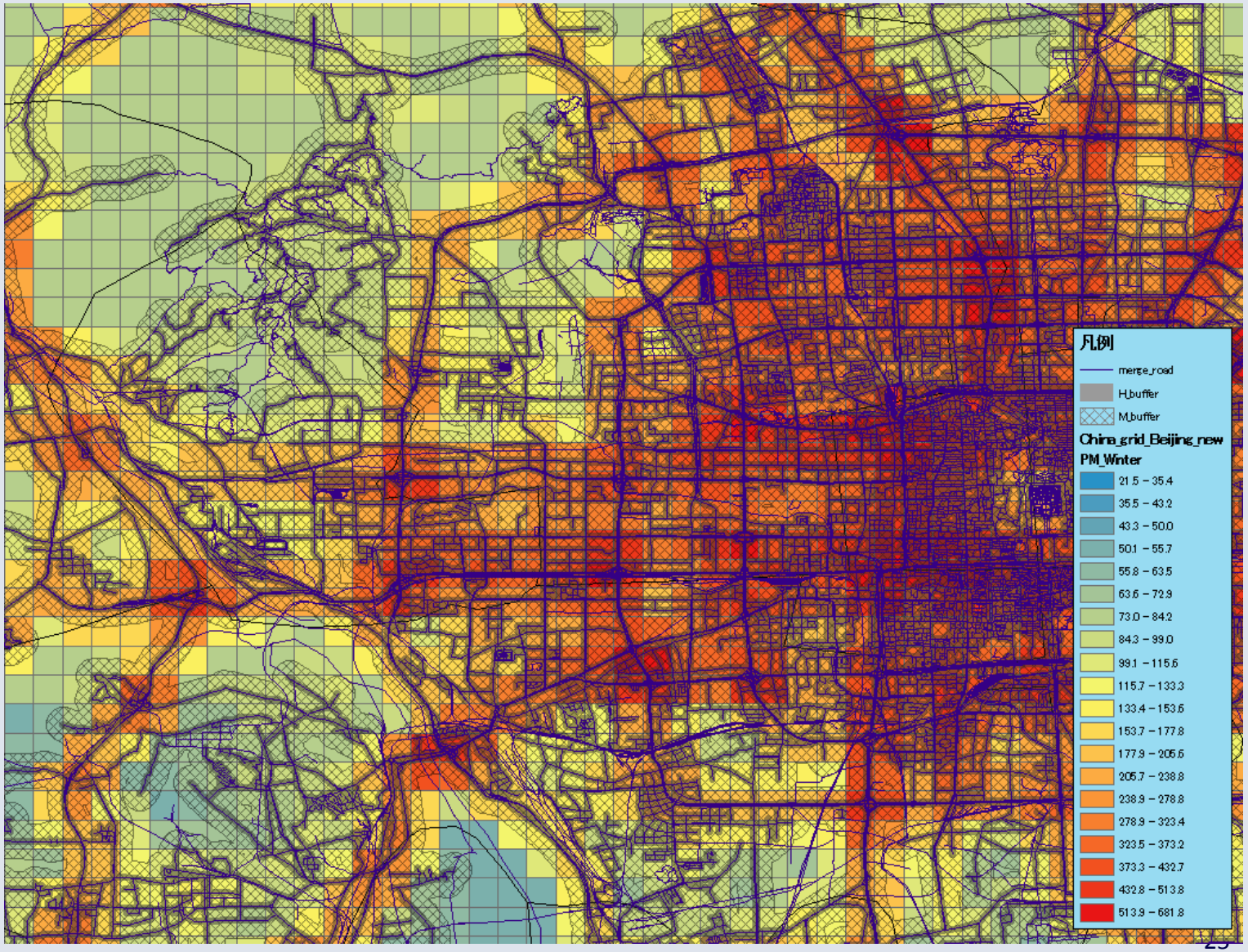


「High」: <100m
「Middle」: 100m～500m
「Low」: >500m

Definition of the buffer area of Roadside Model

Road : OpenStreetMap

In the case of Beijing 1 km mesh case.



Indoor Fuel Consumption

Considered Fuel:

Biomass, Coal, petroleum, kerosene, LPG, natural Gas

Energy consumption per capita in Household

- Household energy consumption both Urban/Rural:

  「Labor and population statistics」、「Chinese Energy statistics」

- Household Biomass consumption in Rural area:

  「Chinese Rural energy statistics 」

Fuel Share by Fuel type and purpose [%]

	Purpose	Biomass		Coal	Kerosene	LPG	Natural Gas	Heat
		Wood	Agr. Residue					
Urban	Cooking	0	0	46	100	100	100	0
	Heating	0	0	54	0	0	0	100
	Lighting	0	0	0	0	0	0	0
Rural	Cooking	67	66	68	0	100	100	0
	Heating	33	34	32	0	0	0	0
	Lighting	0	0	0	100	0	0	0

Preliminary RESULT from Exposure Model

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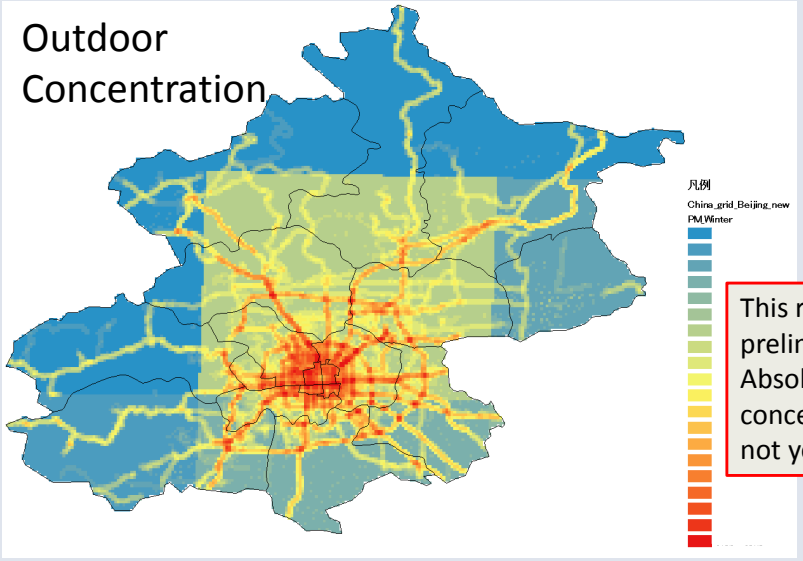
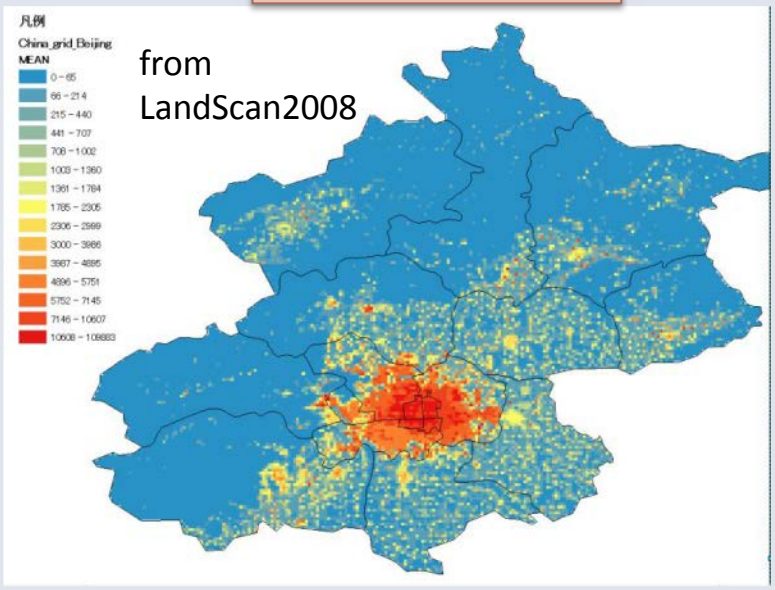
Individual Exposure Concentration



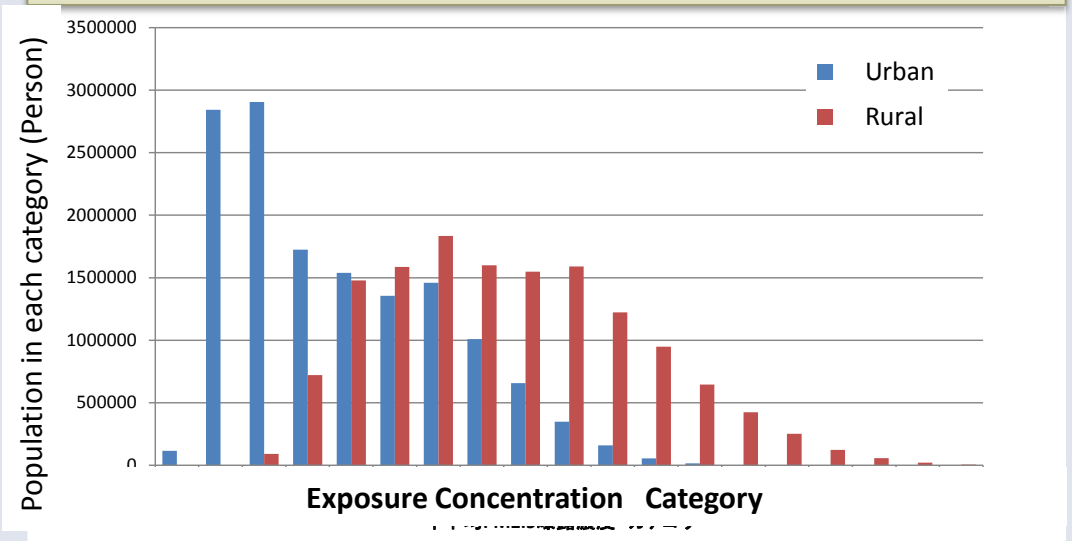
This result is still preliminary. Absolute value of concentration is not yet validated.

Population Density



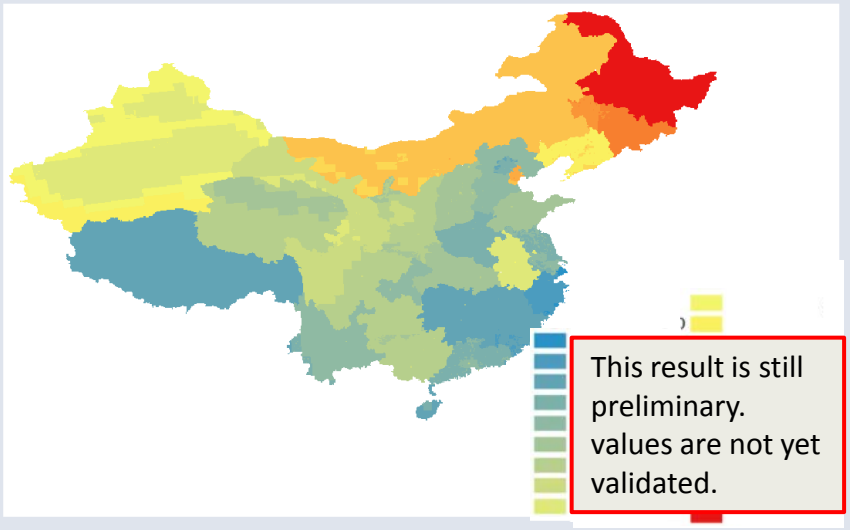
+ Contribution from Indoor emission

Population Histogram in Exposure concentration.

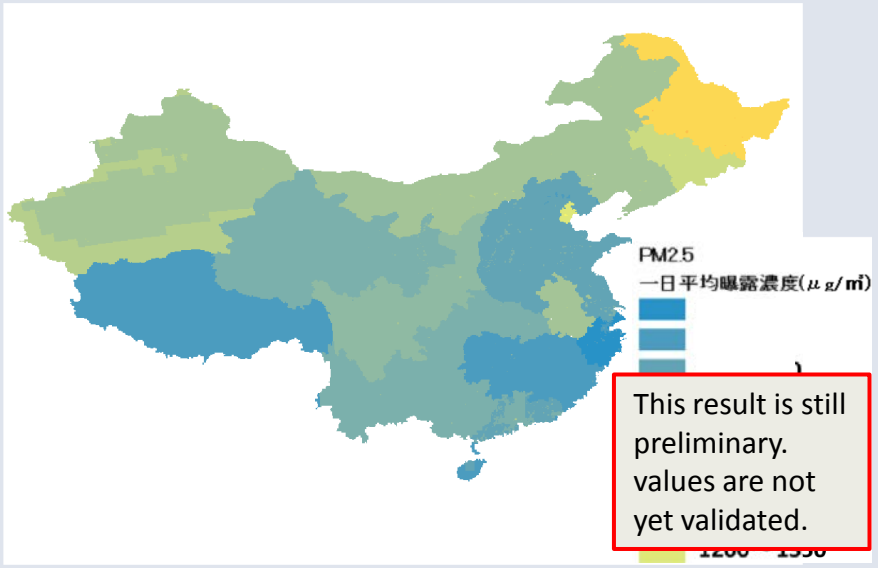


- **In the Urban area, Major contributor is "indoor w/o emission", this mean source of pollutants is outdoor, and stay duration to indoor is much longer than duration at outdoor.**
- **Still exposure in rural area is higher than urban area due to the high usage of biomass fuel in Kitchen and Heating.**

Result from Exposure Model



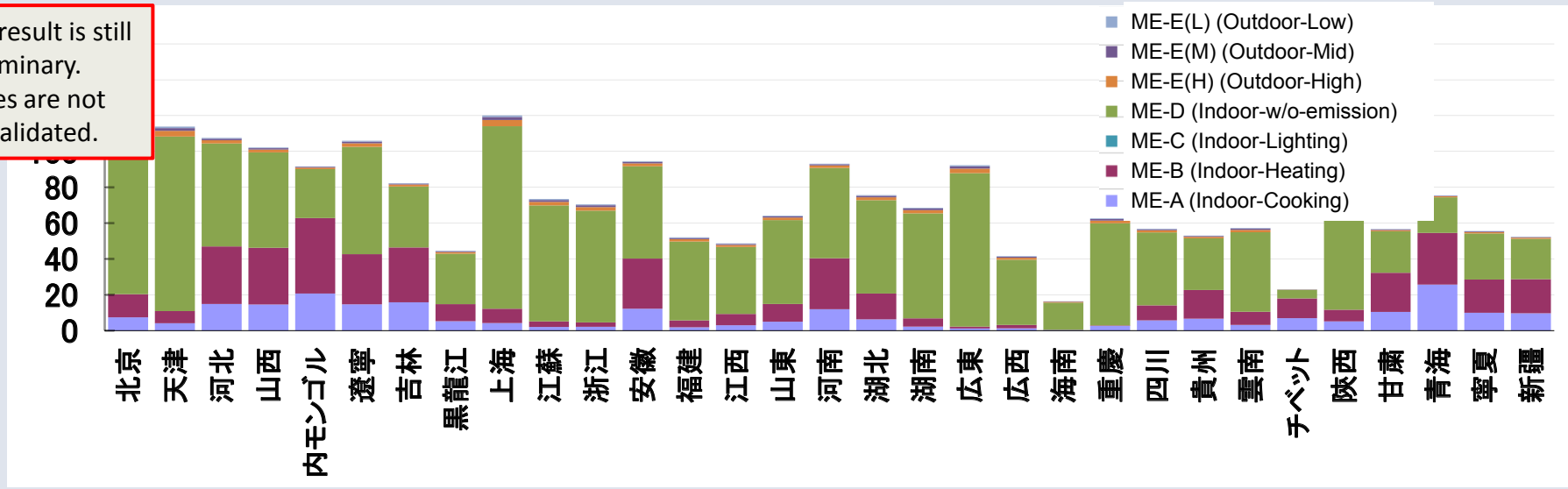
Average PM2.5 exposure concentration for Female, age 60-64 unemplyed ($\mu g/m^3$)



Average PM2.5 exposure concentration for Male, age 65-69, unemployed ($\mu g/m3$)

Comparison between all province (Urban / Rural)

This result is still preliminary. values are not yet validated.



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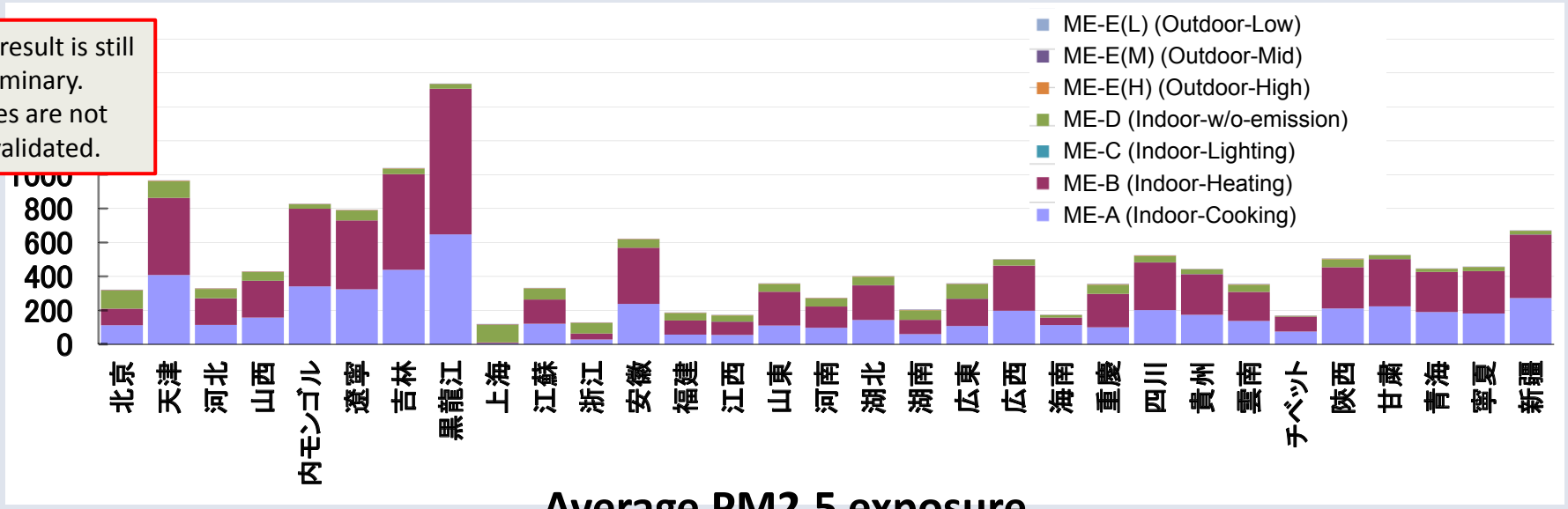

Average PM2.5 exposure
(Upper: Urban Lower: Rural)

Comparison between all Individual attribute group

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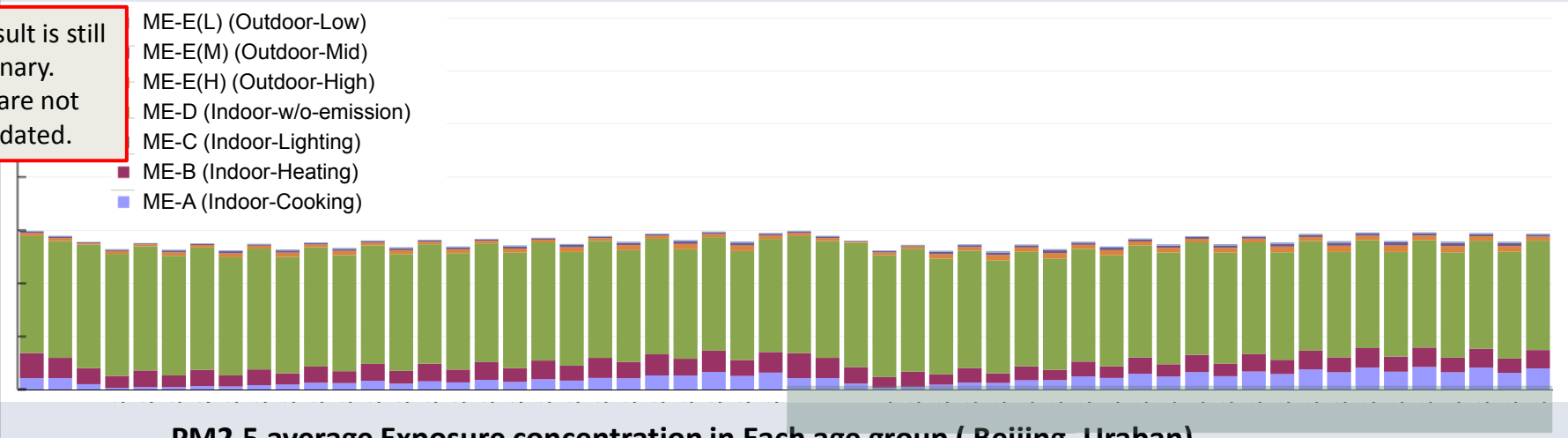

PM2.5 average Exposure concentration in Each age group (Beijing, Uraban)

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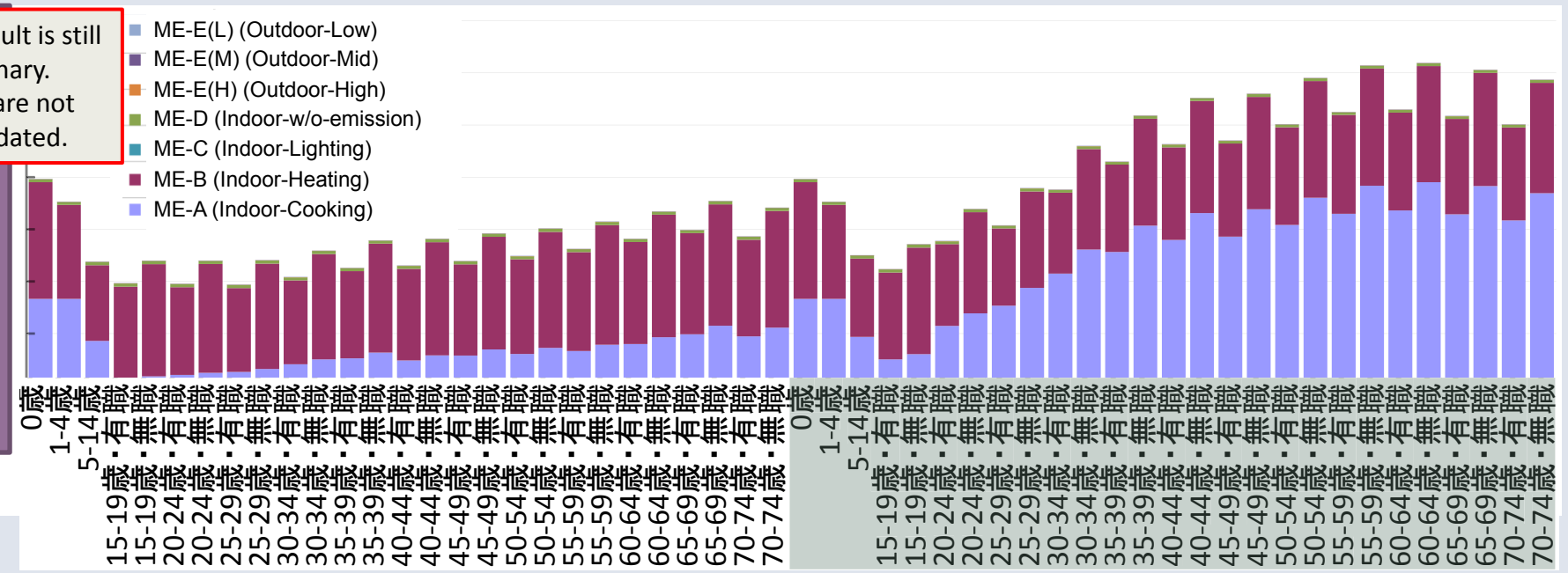

黒龍江省・農村におけるコホート別PM2.5曝露濃度

Summary

Transportation Model

- We developed the **reconciliation method** to estimate more reliable **international and domestic traffic data**.
- We are developing the method to **decompose the passenger and freight transportation demand** by individual attribute, trip purpose, type of transportation and trip distance.
- This analysis may improve the future prediction of transportation demand and its structure.

Air Pollution Model

- We developed the individual exposure model to estimate the human exposure from both **indoor** and **outdoor** air pollution, using WRF, CMAQ, roadside model and Exposure model.
- We calculated individual exposure at the 1km or 10km mesh, so that we can estimate the population histogram of exposure concentration.
- We developed the emission data from each road segment and the **roadside model**. More detail co-benefit analysis will be possible.

Thank you for your attention