The 16th Workshop on GHG Inventory in Asia (WGIA16)
New Delhi, India
July 10 – 12, 2018

Emissions Projections of GHGs and Air Pollutants in the Transport Sector and Importance of Improving National GHG Inventories

Tatsuya HANAOKA

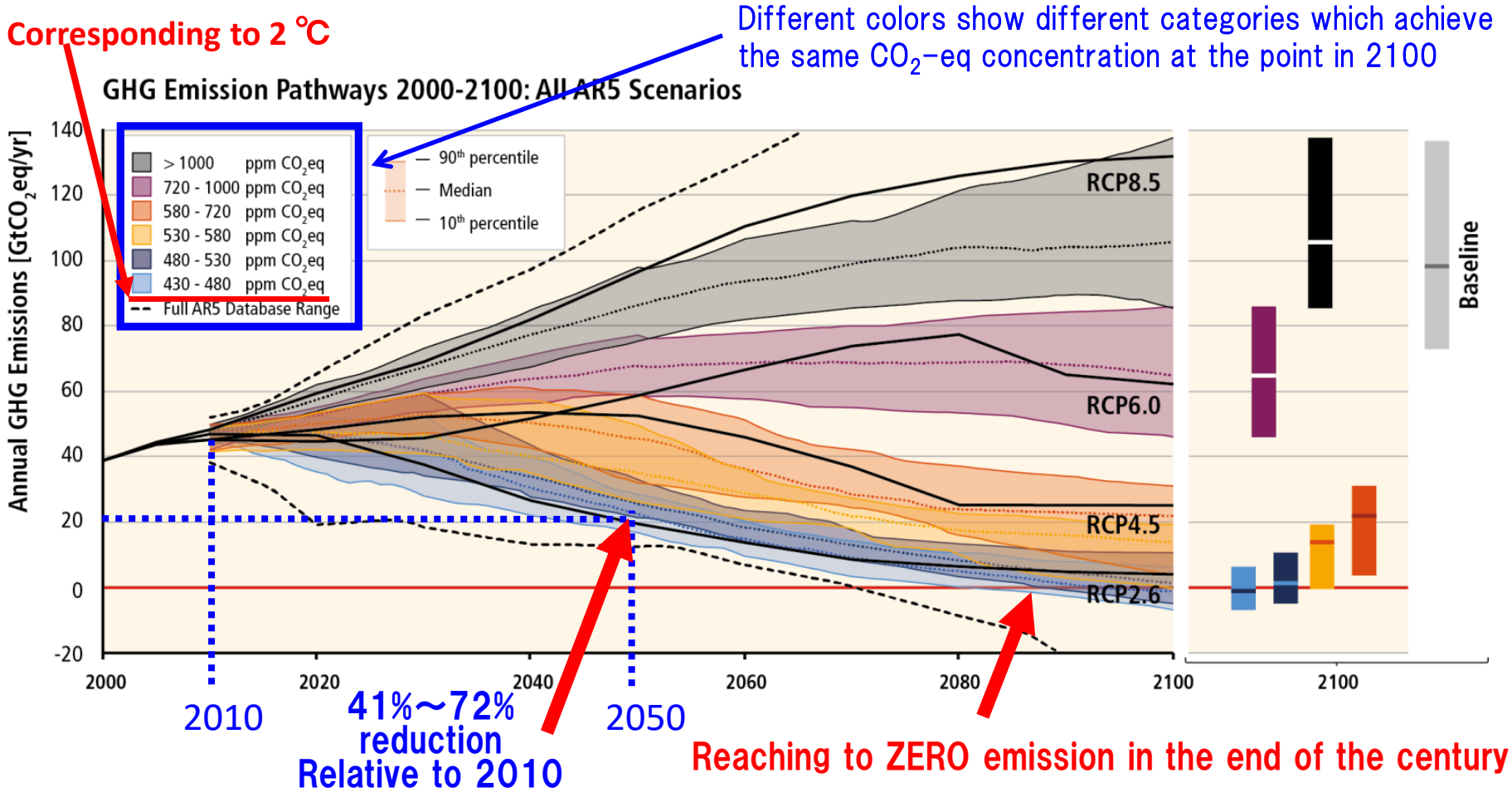
Integrated Environment and Economy Section
Center for Social and Environmental Systems Research
National Institute for Environmental Studies

AIM
ASIA-PACIFIC INTEGRATED MODEL

NIES JAPAN

IPCC AR5 WG3 (2014)
Chapter 6: Assessing Transformation Pathways

- Without more mitigation, **global mean surface temperature might increase by 3.7 – 4.8℃** by 2100.
- To stay below 2℃, **the range of GHG emissions are roughly between 30-50 Gt CO2eq in 2030.**
- To stay below 2℃, **41–72% reductions by 2050 compared to the 2010 level** are required.

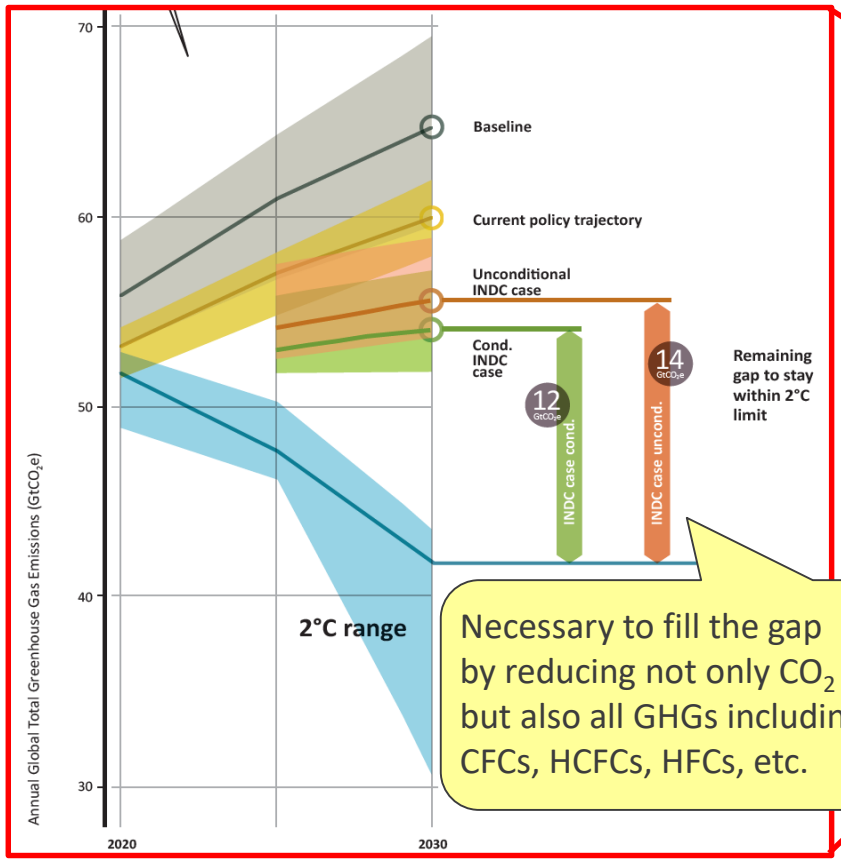


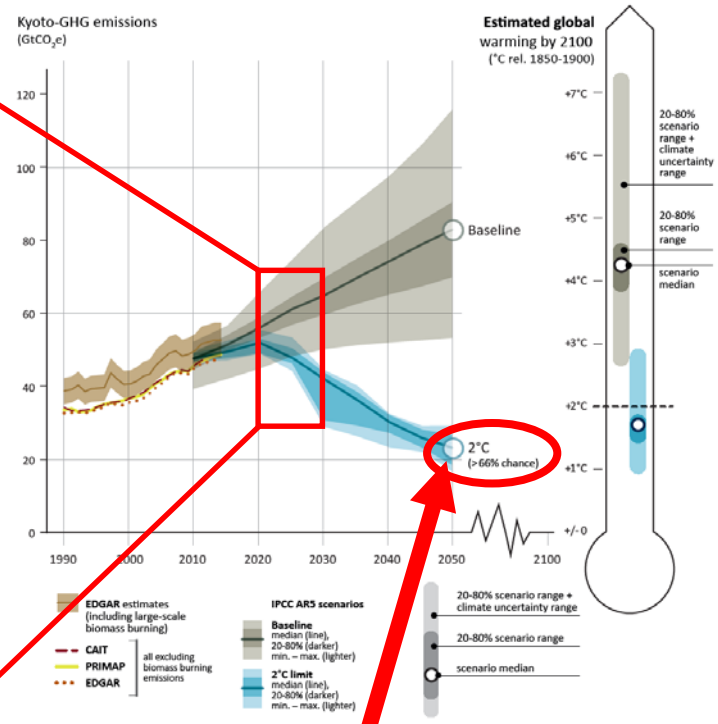
Source) IPCC AR5 WG3 (2014), Figure SPM.4

UNEP (2015) The Emission Gap Report

Emissions Pathways are in line with the 2℃ target under the Paris Agreement?

- Without enhanced ambition, the likely global average temperature increase will be in the range of **<3.0 - 3.5℃ by the end of the century**
- INDCs emission levels are **4 - 6 $GtCO_2eq$ lower than the current policy trajectory in 2030**
- However, emission gaps between INDCs and 2℃ pathways are **12 Gt — 14 Gt CO_2eq in 2030.**





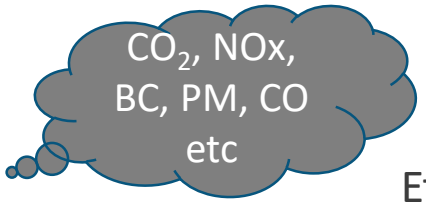
Around halving emissions by 2050 relative to 2010 (equivalent to achieving around 2 tCO_2eq per capita)

Source) UNEP (2015), FigureES1, Figure ES2
http://uneplive.unep.org/media/docs/theme/13/EGR_2015_ES_English_Embargoed.pdf

Synergies and Tradeoffs of Transport Measures for Reducing Multi-gas

— Considering effects and combinations of mitigation measures in transport —

Efficiency improvement effect



Conventional IC vehicles
(Gasoline, Deisel)

Efficiency
improvement

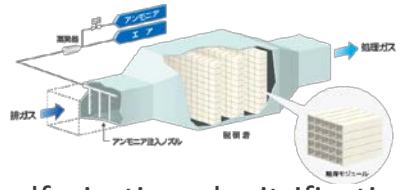
High efficient hybrid vehicles

Energy shifting effect

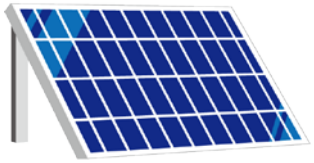
EV vehicle

No
emission

Coal power plant



Desulfurization, denitrification,
Dust-collecting, and CO_2 capture



Renewable energy (wind, solar, etc)

Transport Sector in the Integrated Assessment Model

- Emission Factors by energy, by mode, by region, need to be collected and set by reviewing several guidelines, various peer-reviewed journal papers, reports, etc.

Categories (IPCC guideline code)	CO2	CH4	N2O	NOx	SO2	CO	NM VOCs	BC	OC	PM2.5	PM10	NH3
Transport (1A3)												
Passenger transport												
Road (1A3b)												
Motorcycles												
Cars												
Buses												
Rail (1A3c)												
Navigation (1A3d)												
Domestic												
International												
Aviation (1A3a)												
Domestic												
International												
Freight transport												
Road (1A3b)												
Light duty truck												
Heavy duty truck												
Rail (1A3c)												
Navigation (1A3d)												
Domestic												
International												
Aviation (1A3a)												
Domestic												
International												
Pipeline (1A3e)												

- When modeling the transport sector in integrated assessment modeling, we usually divide the sector into two; passenger & freight.
- In passenger and freight separately, we need to collect & estimate activity data (i.e. transport volume)

IPCC Inventory Guideline 2006 in the Road Transport Sector

Tier1 $$Emission = \sum_a Fuel_a \times EF_a$$

Tier2 $$Emission = \sum_a \sum_b \sum_c Fuel_{a,b,c} \times EF_{a,b,c}$$

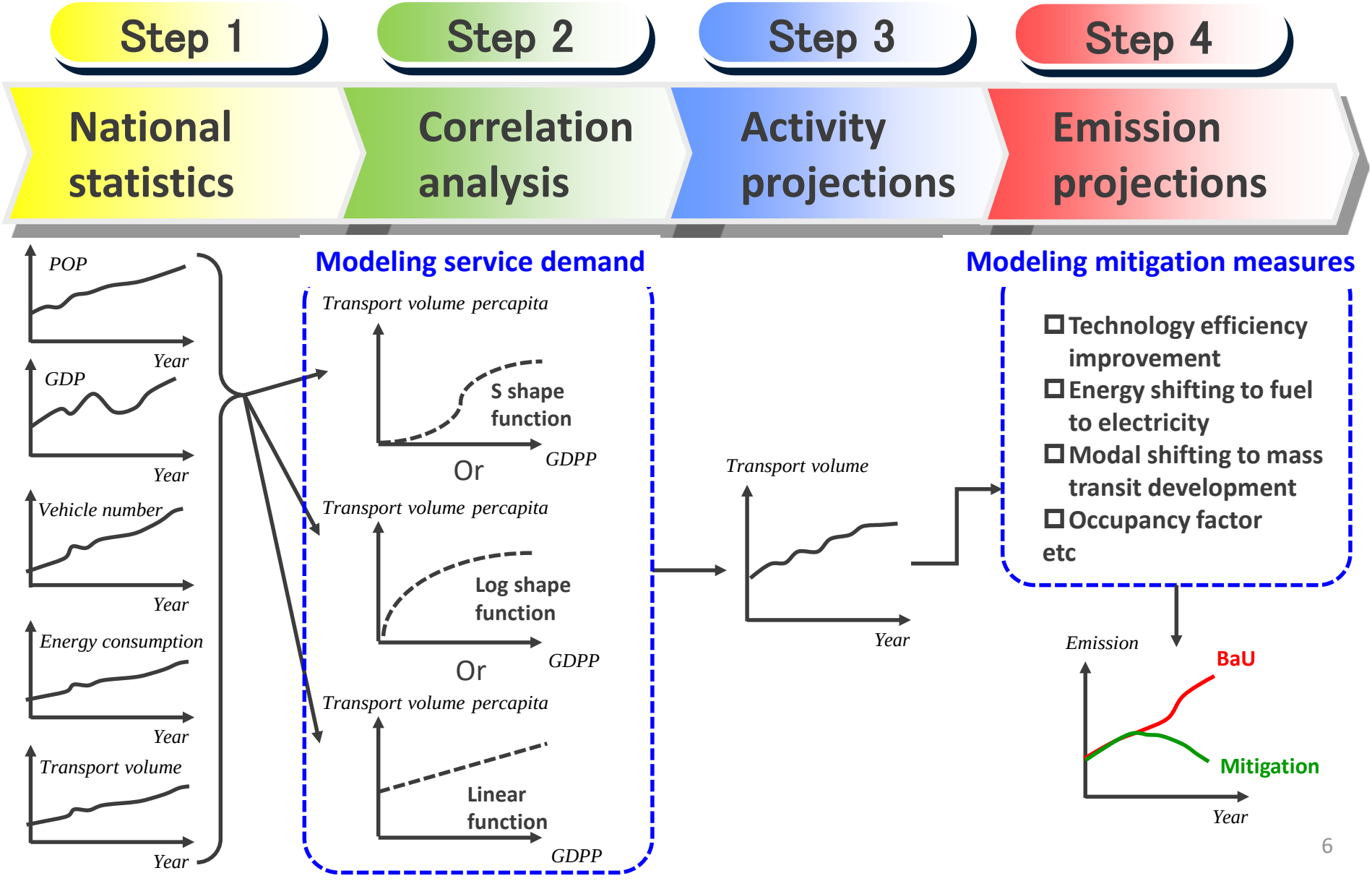
How to project future activity ?

Fuel = fuel consumed or sold [TJ]
EF = emission factor [kg-gas/TJ]
a = fuel type such as petrol, diesel, natural gas, LPG
b = vehicle type
c = emission control technology such as uncontrolled, catalytic converter

Tier3 $$Emission = \sum_a \sum_b \sum_c \sum_d Distance_{a,b,c,d} \times EF_{a,b,c,d} + \sum_a \sum_b \sum_c \sum_d C_{a,b,c,d}$$

Distance = distance traveled [vehicle km]
EF = emission factor [kg-gas/km]
C = emission during warm-up
d = operating conditions (urban or rural road type, climate factor etc)

How to Estimate Emissions Projections in the Road Transport - Overview of Analysis Flow -



How to Estimate Road Transport Volume
- Preparation for Historical Time-series Data -

- In order to project future GHG and air pollutants emissions, we firstly need to project future transport volumes.
- In order to get ready for projecting future transport volumes, we need to prepare historical time-series data and estimate transport volume in the following equation

$$TPV_{m,r,t} = VHN_{m,r,t} \times ADT_{m,r,t} \times OCC_{m,r,t} \quad \cdots \text{Eq(1)}$$

$$= OWN_{m,r,t} \times POP_{r,t} \times ADT_{m,r,t} \times OCC_{m,r,t} \quad \cdots \text{Eq(2)}$$

r: region
t: year
m: mode

This value is "distance" which is also required for the national inventory

$TPV_{m,r,t}$: transport passenger volume of each mode [person km]

$VHN_{m,r,t}$:number of vehicles in-use of each mode [vehicle]

$OWN_{m,r,t}$: ownership rate, i.e. number of vehicles per 1000 people in each mode [vehicle/1000 person]

$POP_{r,t}$: population [1000 person]

$ADT_{m,r,t}$: utilization factor, i.e. average annual distance travelled in each mode [km/vehicle]

$OCC_{m,r,t}$: occupancy rate in each mode [person/vehicle]

Note1) If there is lack of data availability of *ADT* and *OCC* by region and by year, *ADT* and *OCC* can be set at the constant value in each mode across all regions and years.

How to Project Road Transport Volume
- Concept of Methods -

- There are several methods to project future transport volumes (TPV).
  - Method 1: estimating TPV projections by projecting VHN
  - Method 2: estimating TPV projections by projecting OWN
  - Method 3: projecting TPV directly.
- Depending on data availability and research questions, we decide suitable methods.

$$TPV_{m,r,t} = VHN_{m,r,t} \times ADT_{m,r,t} \times OCC_{m,r,t} \quad \cdots \text{Eq(1)}$$

$$= OWN_{m,r,t} \times POP_{r,t} \times ADT_{m,r,t} \times OCC_{m,r,t} \quad \cdots \text{Eq(2)}$$

r: region
t: year
m: mode

This value is "distance" which is also required for the national inventory

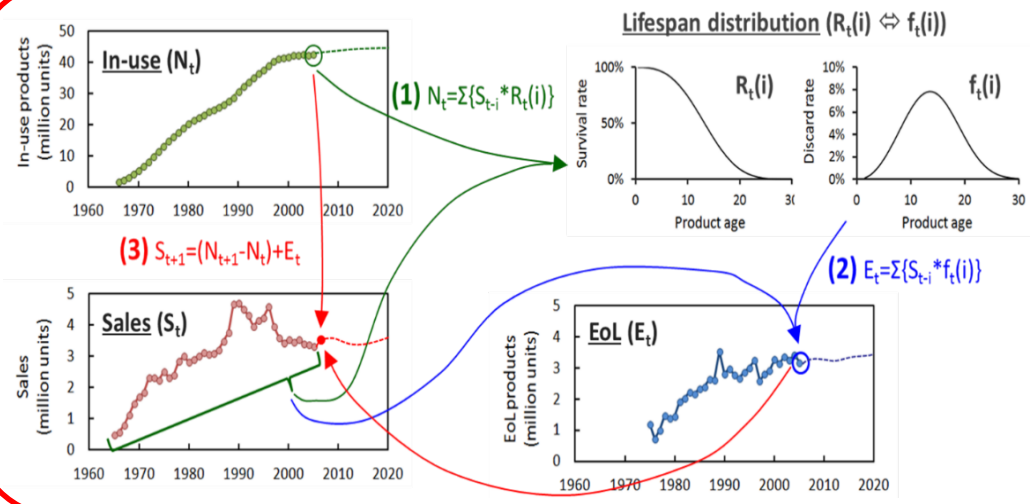
Method	Correlation function	Merit	Demerit
Method 1	correlation among number of vehicles and socio-economic indicators	☐ Intuitive from statistics ☐ Suitable for near-term/mid-term future	☐ Require detailed data sets of stock and flow of vehicles. ☐ Better to avoid simple regression analysis
Method 2	correlation among ownership rate and socio-economic indicators	☐ Applicable to variety of scenarios ☐ Suitable for mid-term/long-term future	☐ You may face with low value of coefficient determination depending on mode ☐ You also need to check other countries statistical data, to set scenario assumptions
Method 3	correlation among transport volume and socio-economic indicators.		

How to Project Road Transport Volume

- Method 1: correlation b/w no. of vehicles and socioeconomics -

- Regression model is suitable only for short- & mid-term analysis, because if POP & GDP keep increasing, number of vehicles will also keep increasing without any threshold.
- It is recommended to use population balance model rather than simple regression model.

Methodology	Overview	Required variable for future scenario
Multi regression model	Using historical correlation between objective variable and basic socio-economic variable.	GDP, POP, per capita GDP
Lifetime model	Using historical correlation between number of sales by device and lifetime duration by device.	Sales numbers by device. lifetime duration by device.
Population balance model	Using historical correlation between number of stocks by device and lifetime duration by device.	Stock (in-use) numbers by device. Lifetime duration by device.



Overview of how to estimate end-of-life products (=dispose of used products) by using Population Balance Model

Source)
Oguchi M., Terazono A., Hanaoka T. (2017) Estimating the potential amount of fluorocarbons in end-of-life products generated in Asian developing countries, 2017 Joint Conference ISIE and ISSST.

How to Project Road Transport Volume

- Method 2: correlation b/w ownership rate and socioeconomics -

- Depending on data availability and also data fittings to a specific function by checking determinate coefficient, we will change suitable functions, as follows.
- When using Gompertz function or Logistic function, we need to set a suitable saturation value, by reviewing/collecting/analyzing developed countries statistics too.

Gompertz function

$$OWN_{m,r,t} = a_r \times e^{b \cdot e^{c \cdot GDPP_{r,t}}}$$

or

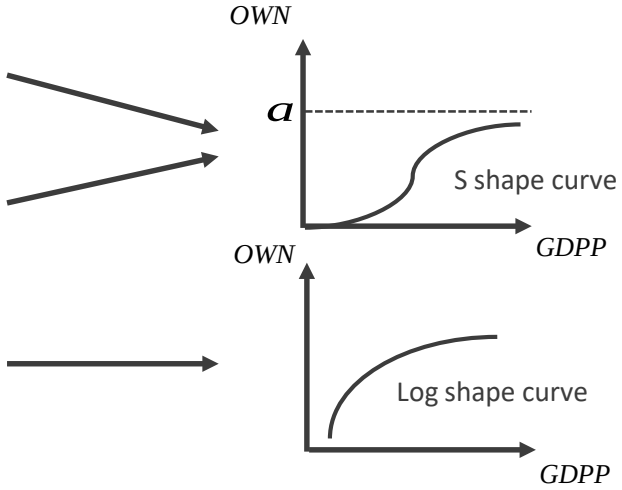
Logistic function

$$OWN_{m,r,t} = \frac{a_r}{1 + e^{\left\{-c \cdot \left(GDPP_{r,t} - b\right)\right\}}}$$

or

Log regression function

$$OWN_{m,r,t} = \alpha \log(GDPP_{r,t}) + \varepsilon$$



a_r : saturation value

b_r : regression coefficient that influence the displacement along the *X-axis* (i.e. graph to left/right)

c_r : regression coefficient that influence the shape of S-curve, the growth rate along the Y-*axis*

α : regression coefficient that influence the slope

ε : regression coefficient influence the intercept

Note1) explanatory variables can be not only GDP per capita but also GDP or POP etc.
Note2) regression can be either single or multiple, single-log or both-log, etc.

How to Project Road Transport Volume

- Method 3: correlation b/w transport volume and socioeconomics -

- We can discuss transport volume directly and apply to variety of future scenarios easily.
- When using Gompertz function or Logistic function, we need to set a suitable saturation value, by reviewing/collecting/analyzing developed countries statistics too.

Logistic function

$$PKTOTP_{r,t} = \frac{pka_r}{1 + e^{\left\{-pkc \cdot \left(GDPP_{r,t} - pkb_r\right)\right\}}}$$

or

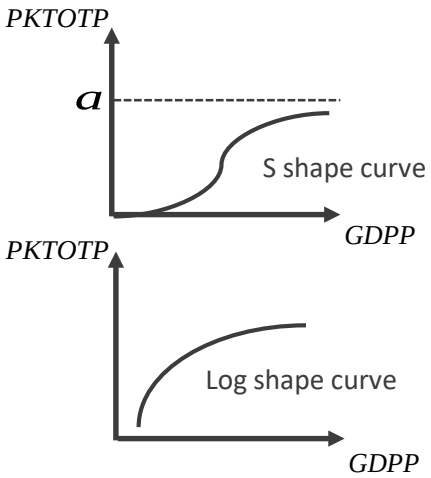
Gompertz function

$$PKTOTP_{r,t} = pka_r \times e^{pkb \bullet e^{pkc \bullet GDPP_{r,t}}}$$

or

Log regression function

$$PKTOTP_{r,t} = \alpha \log(GDPP) + \varepsilon$$



$PKTOTP_{r,t}$: total transportation volume per capita [person km / person]

pka_r : saturation value

pkb_r : regression coefficient that influence the displacement along the *X-axis*

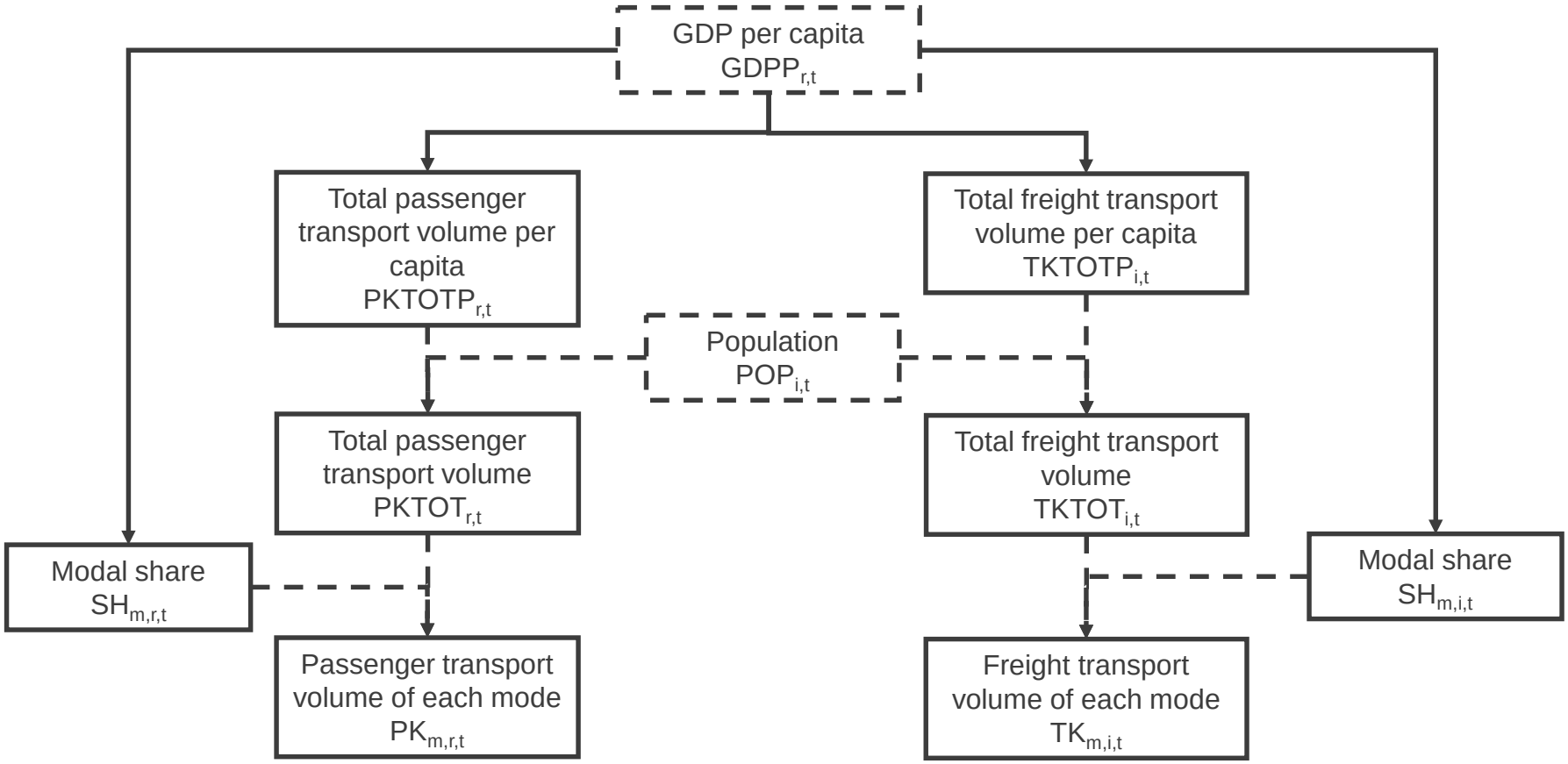
pkc_r : regression coefficient that influence the shape of S-curve, the growth rate along the Y-*axis*

α : regression coefficient that influence the slope

ε : regression coefficient influence the intercept

Note1) explanatory variables can be not only GDP per capita but also GDP or POP etc.
Note2) regression can be either single or multiple, single-log or both-log, etc.

How to Estimate Road Transport Volume - Overview: Method 3 -



Passenger volume [unit: person km]

Freight volume [unit: ton km]

Exogenous variable

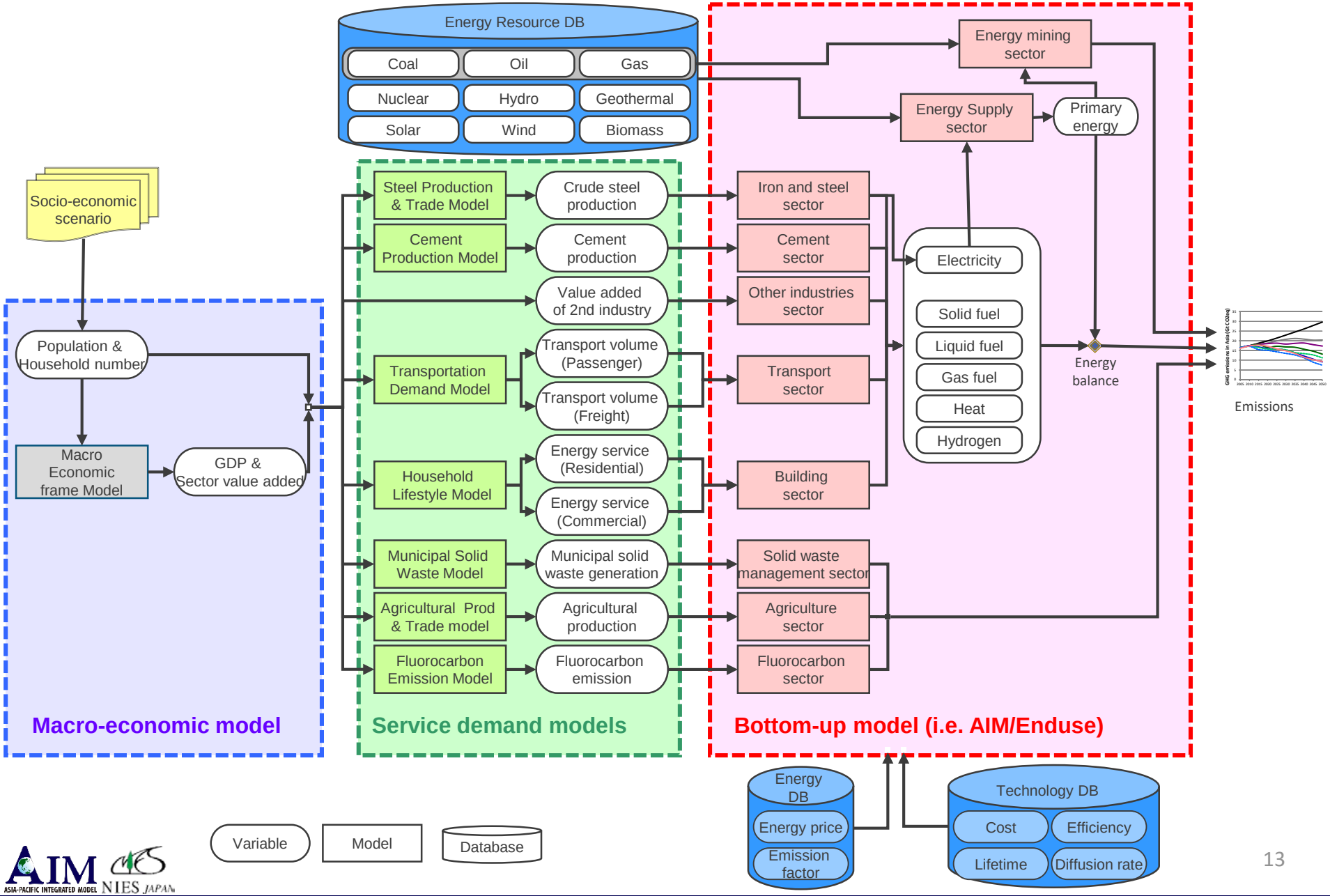
Endogenous variable

Definitional equation

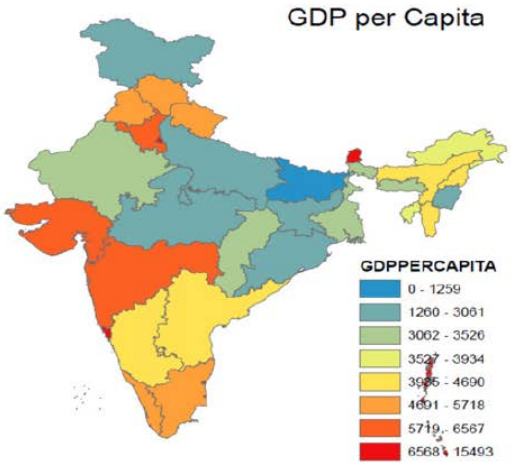
Estimation equation

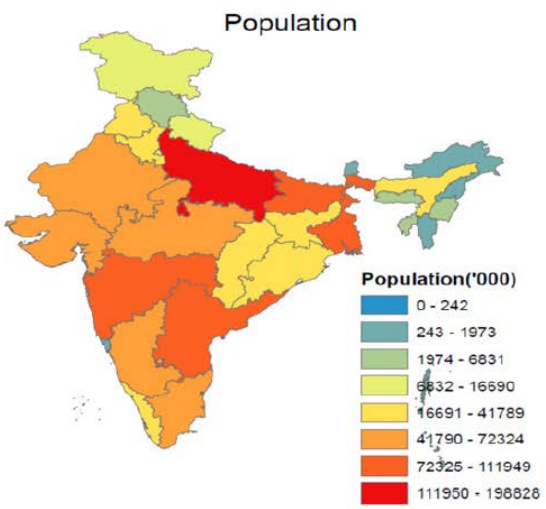
r: region
t: year
m: mode

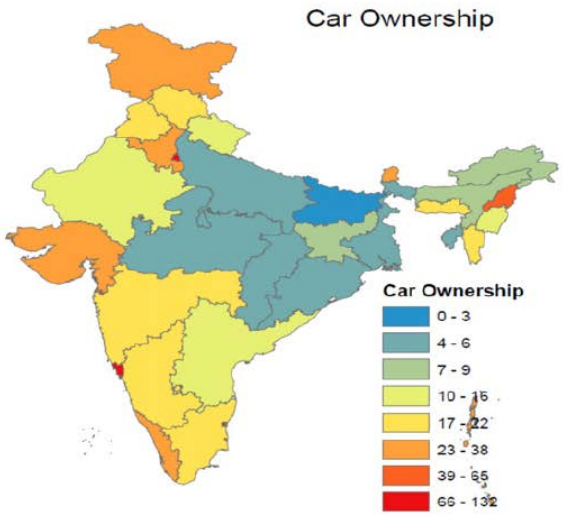
How to Estimate Mitigation Option: AIM/Enduse model

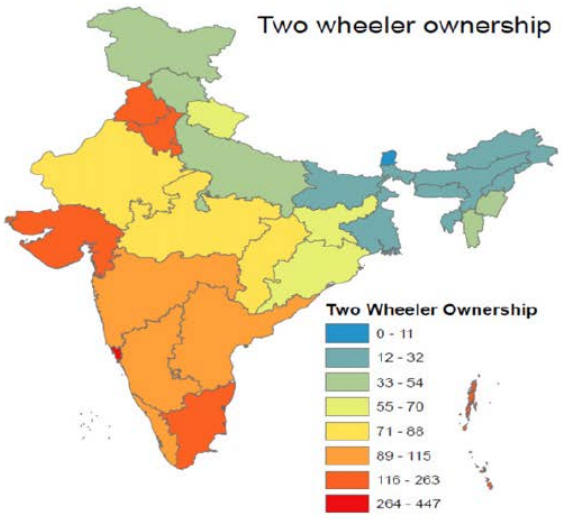


Preparation for Historical Data on Socio-economics and Road Transport - Example Data Characteristics in 2010 in India -





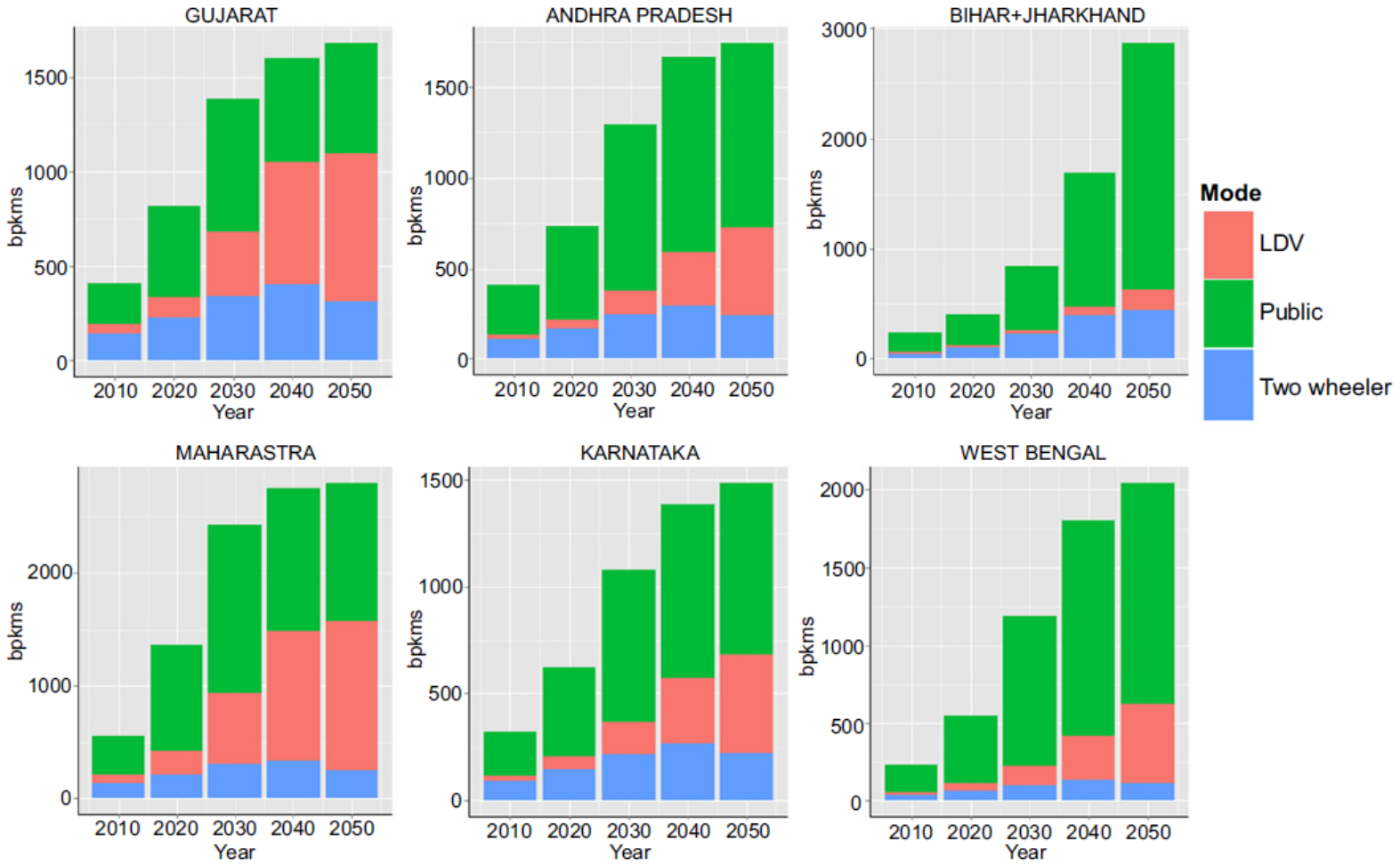




Source)
Mittal, S., Hanaoka, T., Shukula, P.R., Masui, T. (2015) Air Pollution co-benefit of low carbon policies in road transport: a sub-national assessment for India, Environ. Res. Lett. 10

Results of Passenger Road Transport Volume - Results of Future Projections in India -

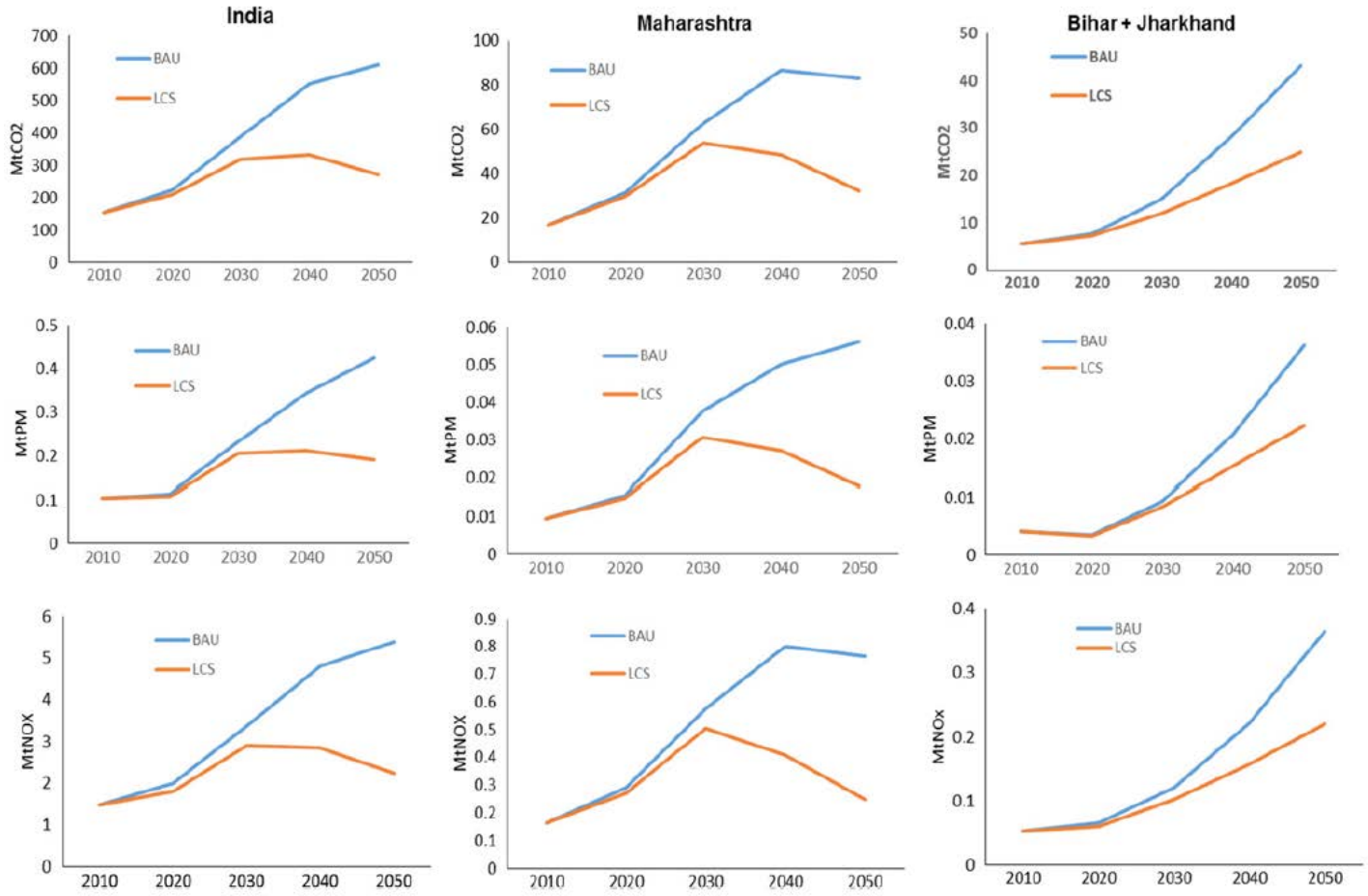
- Development speeds and shares are different depending on state-wise characteristics



Source)
Mittal, S., Hanaoka, T., Shukula, P.R., Masui, T. (2015) Air Pollution co-benefit of low carbon policies in road transport: a sub-national assessment for India, Environ. Res. Lett. 10

Emissions Projections: BaU vs Low Carbon Scenario - Cobeneifts of reducing $PM_{2.5}$ and NOx-

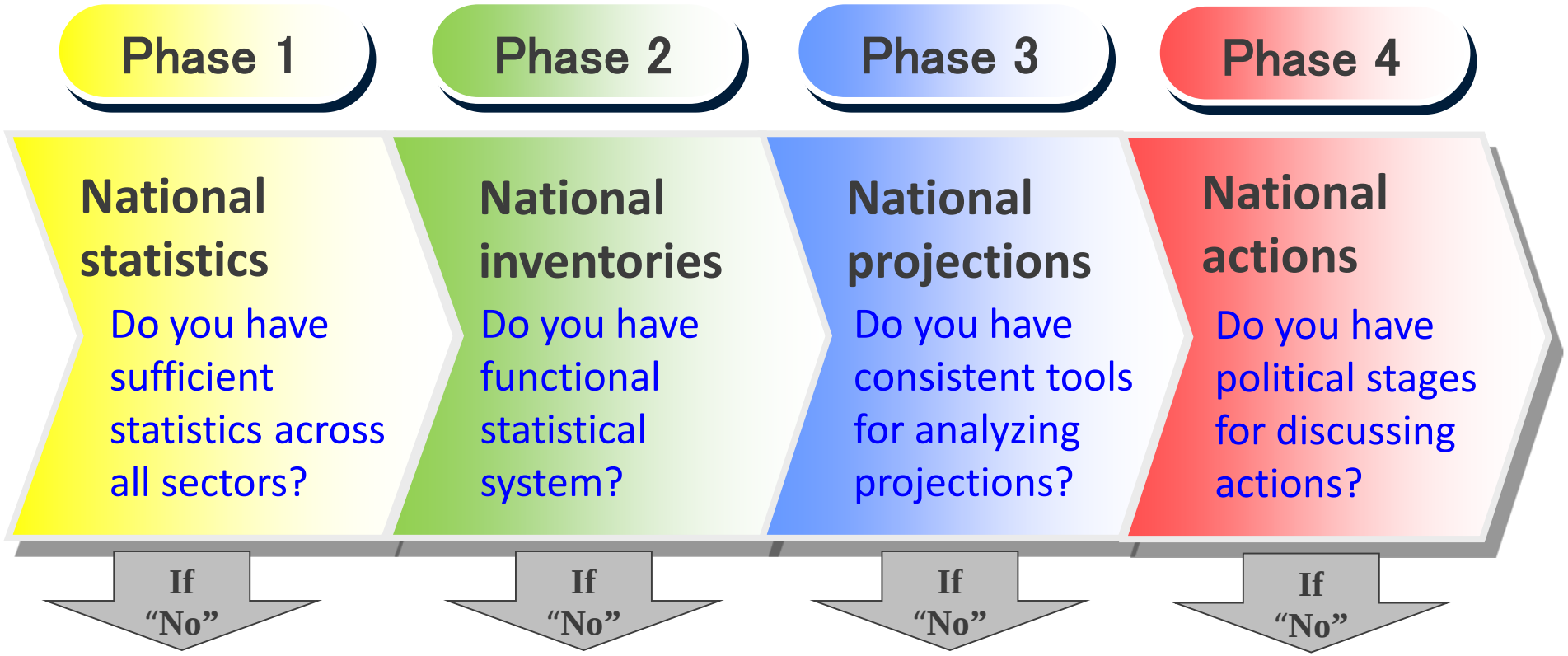
- Important to take into account cobenefits reducitons of air pollutants (NOx, $PM_{2.5}$ etc) Short-Lived Climate Pollutant (BC) due to low-carbon actions in the road transport.



Source)
Mittal, S., Hanaoka, T., Shukula, P.R., Masui, T. (2015) Air Pollution co-benefit of low carbon policies in road transport: a sub-national assessment for India, Environ. Res. Lett. 10

Bridging the GAP
- Statistics, Inventories, Projections, & Actions -

It is essential to enforce MRV(Measurable, Reportable, Verifiable) for analyzing national future GHG emissions and mitigation actions.



ご清聴ありがとうございました

Thank you for your attention