# A Development of an estimation method of air pollutant emissions from transportation sector in Asia


Soichi Morimoto, Gakuji Kurata, Yuzuru Matsuoka

Department of Environmental Engineering, Kyoto University, JAPAN



*2012 ACCENT-IGAC-GEIA Conference; June 11-13, 2012; Toulouse, France*



## 【Abstract】

Air pollutants such as $NO_x$ and PM are mainly emitted by transportation sector. Therefore, it is important to estimate the amount of air pollutants emitted from transportation sector in order to evaluate the health impact of these pollutants and to apply effective countermeasures on them.

In this research, emissions for $CO_2$, $NO_x$ and $PM_{10}$ by transportation sector in Asia were estimated.

Generally, to estimate the emissions from transportation sector, transportation demand derived from statistics is multiplied by emission factors. However, there are a lot of absences and errors in transportation statistics. Therefore we applied the adjustment method to interpolate and correct data in transportation statistics on Asia and estimated national transportation demand in 2005.

In addition, future transportation demands were also estimated by using future scenario such as modal shift under low carbon society

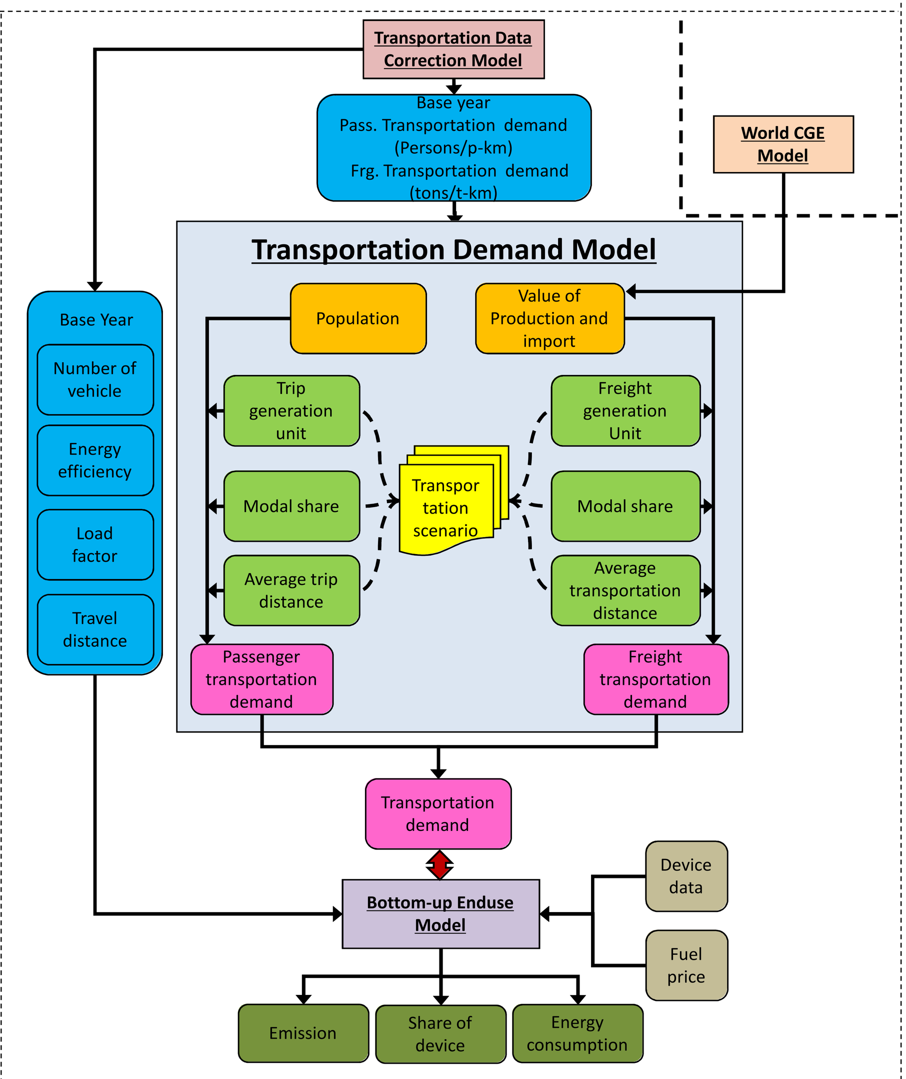
Finally, air pollutant emissions in Asia were estimated by using bottom-up enduse model, and it was discussed change in transportation demands and emissions in Asia.


## 【Approach】

The diagram showing right hand side is the framework of this research. We used three models in this research such as transportation data correction model, transportation demand model, and enduse model.

Main outcomes of these models are passenger and freight transportation demand, energy consumptions and $CO_2$, $NO_x$, $PM_{10}$ emissions in transportation sector in 2005 to 2030.

Details about these three models are explained next.




Framework of this research

## Transportation Data Correction Model

- A lot of errors and losses are included in Traffic statistics.
- Minimizing the errors from reference values, such as stock amount, mileage, freight amount, energy consumption and ratios between these values ( mileage/vehicle, load factor, energy consumption per mileage etc.)
- Reference values are derived from domestc and international statistics.
- Constrain the trend from large swing to avoid the discontinuous of time series.

Relation between parameters

$$VK_{j,t} = DS_j \cdot ST_{j,t},\ TV_{j,t} = LF_j \cdot VK_{j,t},\ ENT_{j,t} = FEV_{j,t} \cdot VK_{j,t}\ \cdots$$

Definition of error from reference values

$$ERST_{j,h,t} = ST_{j,t} - STR_{j,h,t},\ \cdots$$

Definition of change of time trend

$$CHST_{j,t} = (ST_{j,t} - ST_{j,t-1}) - (ST_{j,t-1} - ST_{j,t-2}),\ \cdots$$

Definition of error function

$$ER = \sum_t \sum_j \left\{ wch_{ST',j} \cdot CHST_{j,t}{}^2 + wer_{ST',j} \cdot \sum_h ERST_{j,h,t}{}^2 + wch_{TV',j} \cdot CHTV_{j,t}{}^2 + wer_{TV',j} \cdot \sum_h ERTV_{j,h,t}{}^2 + \cdots \right\} \rightarrow \min$$

Symbol used in transportation data correction model

| | symbol | definition |
|---|---|---|
| suffix | $j$ | mode |
| | $t$ | year |
| | $h$ | number of reference value |
| | $v$ | parameter (stock (ST), transpotation volume (TV), ・・・) |
| parameter | $TV_{j,t}$ | Transportation volume (p.km or t.km) |
| | $VK_{j,t}$ | mileage |
| | $ST_{j,t}$ | stock amount |
| | $DS_j$ | mileage/vehicle/year |
| | $FEV_{j,t}$ | energy consumption/mileage |
| | $LF_j$ | load factor |
| | $ERST_{j,h,t}$ | error of stock amount from reference values |
| | $ERTV_{j,h,t}$ | error oftransportation volume from reference values |
| | $STR_{j,h,t}$ | reference value for stock amount |
| | $ENT_{j,t}$ | energy consumption |
| | $CHST_{j,t}$ | change of stock amount from time trend |
| | $CHTV_{j,t}$ | change of transportation volume from time trend |
| | $wch_{v,j}$ | weight for change about time trend |
| | $wer_{v,j}$ | weight for error about reference values |
| | $ER$ | error function |

## Transportation Demand Model

Domestic passenger transport

$$PTV_{j,pa,ptp,t} = POP_{pa,t} \cdot PTG_{pa,ptp,t} \cdot PMS_{j,t} \cdot ATD_{j,t}$$

International passenger transport

$$PTV\_inter_t = TPOP_t \cdot PTG\_inter_t$$

*j*: mode (walk & bicycle, passenger car, bus, railway, domestic aviation)
*pa*: personal attribute
*ptp*: purpose of trip
*t*: year
$PTV_{j,pa,ptp,t}$ & $PTV\_inter_t$: passenger transportation demand [p.km]
$POP_{pa,t}$ & $TPOP_t$: population
$PTG_{pa,ptp,t}$ & $PTG\_inter_t$: trip generation unit
$PMS_{j,t}$: modal share
$ATD_{j,t}$: average trip distance

Domestic freight transport

$$FTV_{j,com,t} = PI_{com,t} \cdot FTG_{com,t} \cdot FMS_{j,t} \cdot AFD_{j,t}$$

International freight transport

$$FTV\_inter_t = PRD_t \cdot FTG\_inter_t$$

*j*: mode (truck, railway, domestic ship)
*com*: commodity
*t*: year
$FTV_{j,com,t}$ & $FTV\_inter_t$: freight transportation demand [t.km]
$PI_{com,t}$: value of production and import
$PRD_t$: value of production
$FTG_{com,t}$ & $FTG\_inter_t$: freight transportation demand generation unit
$FMS_{j,t}$: modal share
$AFD_{j,t}$: average freight transportation distance

Passenger Transportation Scenario in 2030

| parameter | change from 2005 |
|---|---|
| Population ($POP_{pa,t}$ & $TPOP_t$) | UN (2011) |
| Trip generation unit ($PTG_{pa,ptp,t}$ & $PTG\_inter_t$) | Domestic<br>・ Change woman's trip gene. unit same as man's one<br>・ 10% Decrease of trip for work, and decrease of trip for return related it<br>International<br>・ 20% increase of gene. Unit |
| Modal share ($PMS_{j,t}$) | Shift 30% of walk & bicycle trip to car, bus, and railway in the region that the share of walk & bicycle is over 50%. |
| Average trip distance ($ATD_{j,t}$) | 10% decrease of average trip distance of car, bus and railway |

*UN (2011): World Population Prospects The 2010 revision.

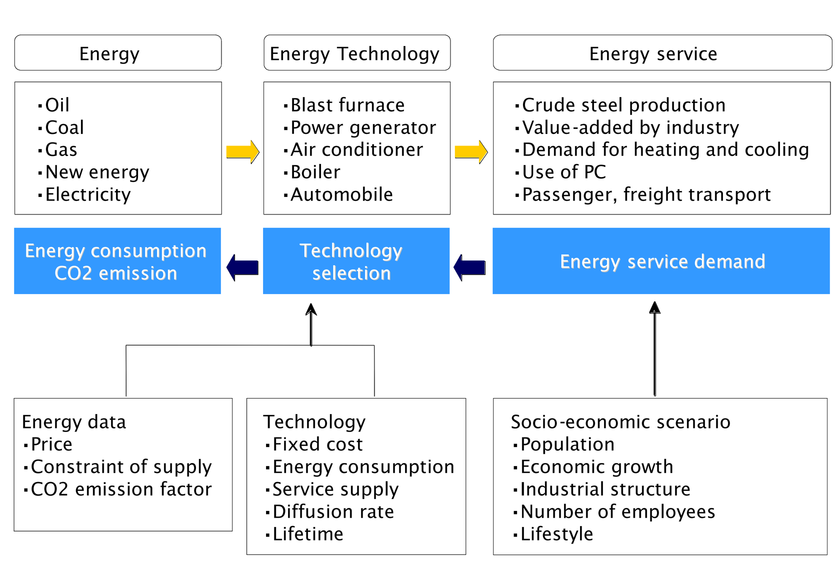
Freight Transportation Scenario in 2030

| parameter | change from 2005 |
|---|---|
| Value of Production & import ($PI_{com,t}$)<br>Value of production ($PRD_t$) | Output of CGE model in BaU case* |
| Freight transportation demand generation unit ($FTG_{com,t}$ & $FTG\_inter_t$) | Domestic<br>・ Same as 2005<br>International<br>・ 20% increase of gene. unit |
| Modal share ($FMS_{j,t}$) | Shift 10% of truck transport to railway and domestic ship |
| Ave. freight transportation distance ($AFD_{j,t}$) | 20% decrease of average freight transportation distance of truck |

*This is tentative results.

## Enduse Model

- Bottom-up type technology selection model developed by AIM project team (AIM/Enduse model)
- Technology selection is based on a linear optimization framework in which total costs are minimized by several constraints such as service demands and energy supply.
- Analysis tool for policies related to global warming and local air pollution like emission tax, subsidy, regulation and so on.




Structure of AIM/Enduse model

## 【Result】

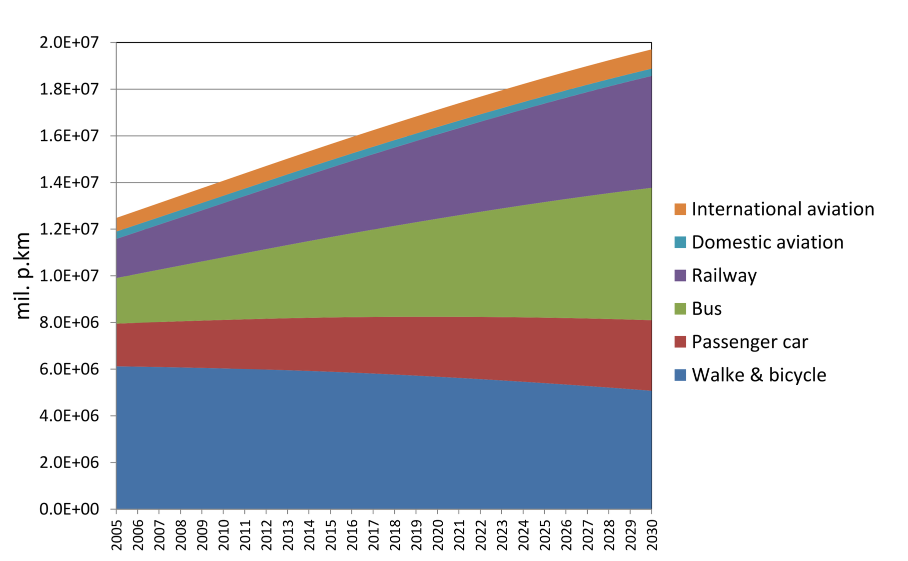
Two graphs showing below are the results of passenger and freight transportation demand in Asia (including east, south, south east, oceania Asia) from Transportation Demand Model under the scenario.

Total demand increased rapidly both in passenger and freight transportation because of driving force such as population and value of production/import.

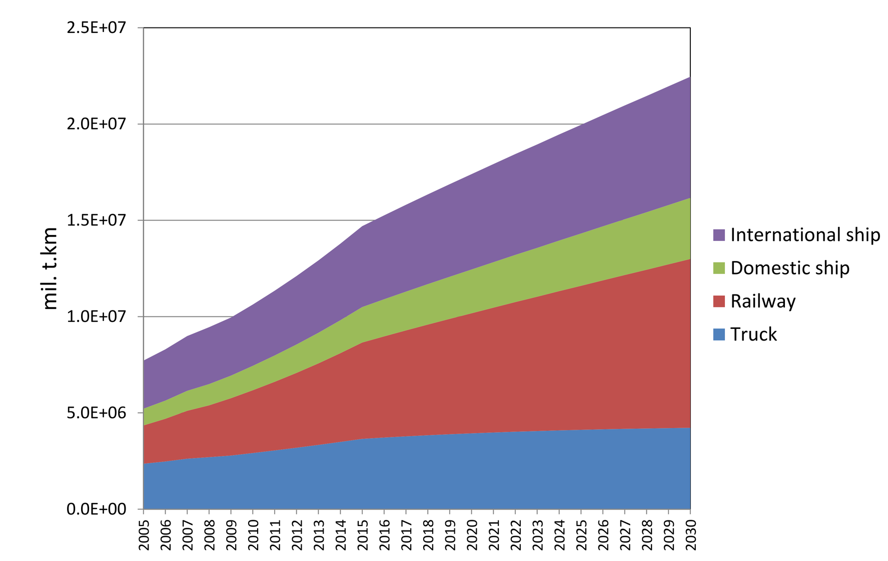
In terms of passenger transportation, transportation by walk & bicycle decreased because the trip share of walk & bicycle was over 50% in a lot of Asian countries in 2005, and 30% of them shifted to car, bus, and railway.

We used these results as an input of subsequent Enduse model analysis.

Passenger transportation demand in Asia



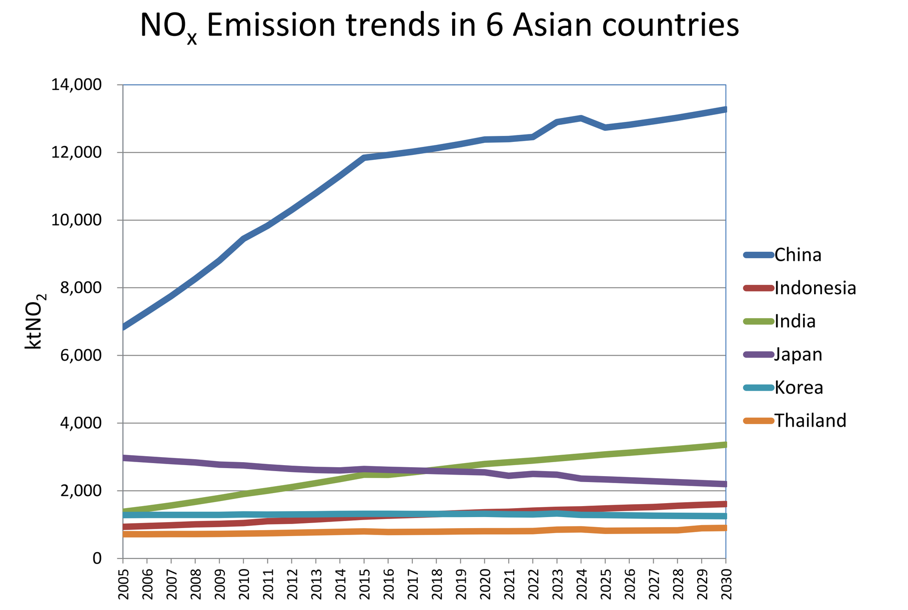

Freight transportation demand in Asia



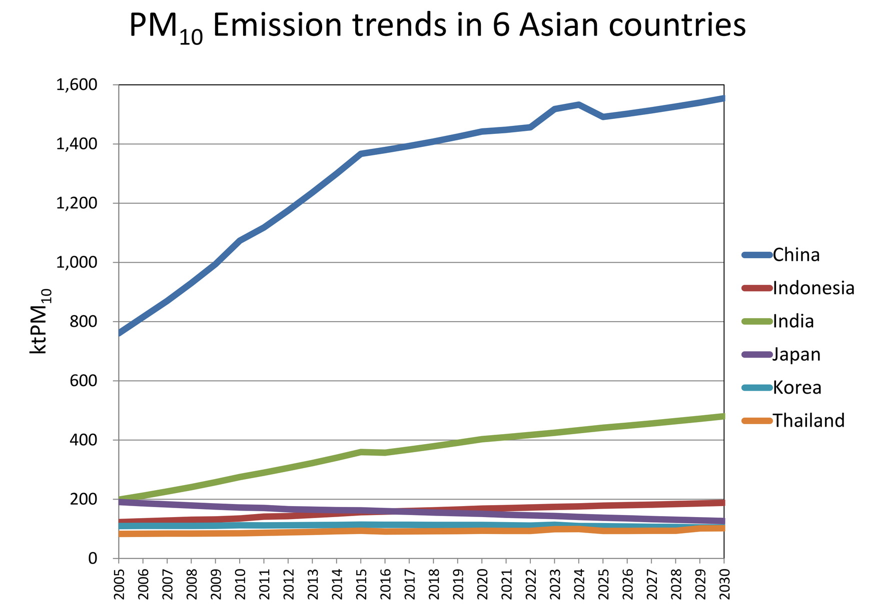

Two graphs showing below are the results of $NO_x$ and $PM_{10}$ emission trends in China, Indonesia, India, Japan, Korea and Thailand from Enduse model.

Both $NO_x$ and $PM_{10}$ emissions in China and India increased about double in 2030 comparing with 2005. On the other hand they decreased in Japan, and $NO_x$ emission in Japan became smaller than India in 2018.

$NO_x$ Emission trends in 6 Asian countries




$PM_{10}$ Emission trends in 6 Asian countries

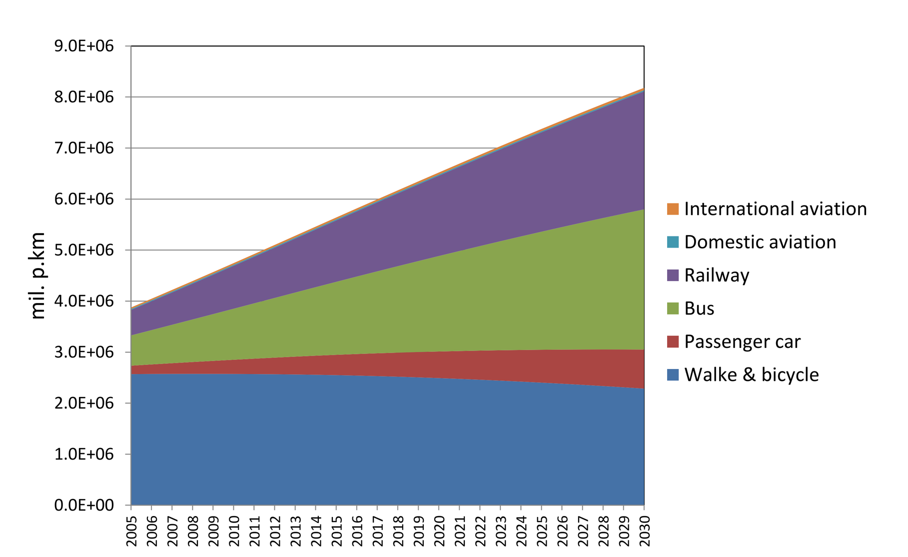



Four graphs showing below are the results focused on India. Upper two graphs are passenger and freight transportation demand, bottom left graph is the detail passenger car transportation demand estimated by enduse model, and bottom right graph is the detail energy consumption and $CO_2$ emission.

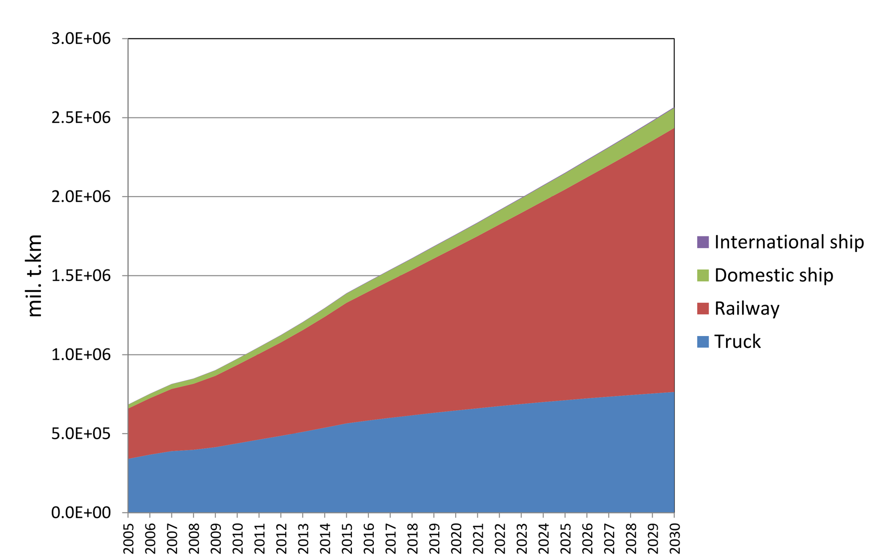
Various high efficiency passenger cars were selected in future instead of conventional gasoline and diesel car because new efficiency technologies costs lower than conventional technologies in future because of high fuel prices.

$CO_2$ emission increased 261% in 2030 comparing with 2005 and total energy consumption increased 237% as well. $CO_2$ emission increased dramatically because of the explosion of transportation demand nevertheless the share of high efficiency technologies became much larger such as truck transportation.

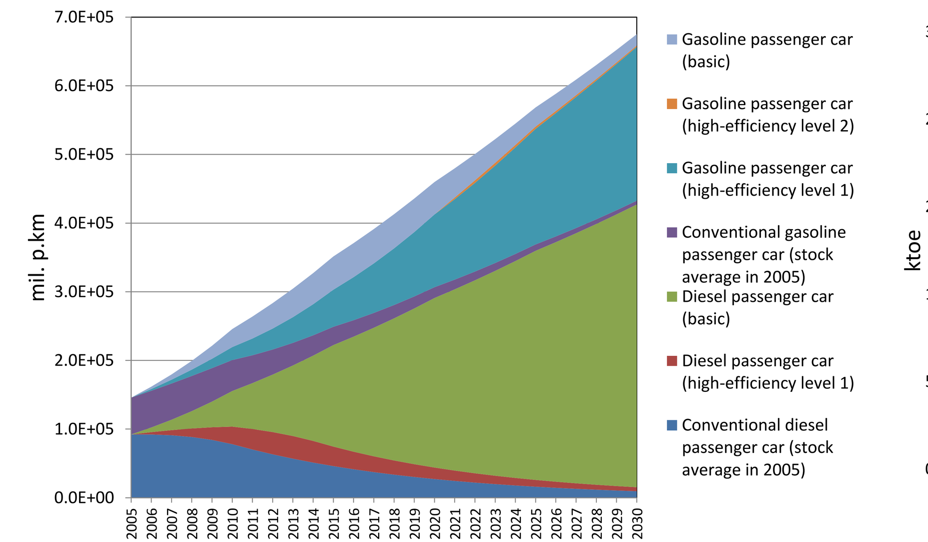
Passenger transportation demand in India



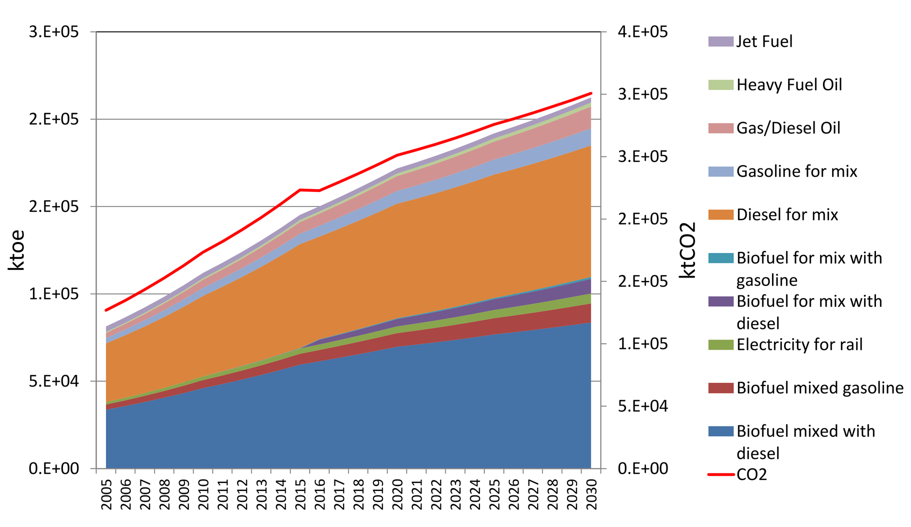

Freight transportation demand in India




Passenger car transportation demand in India




Energy consumption and $CO_2$ emission in India




## 【Conclusion】

In this research, we developed an estimation method of transportation demands, its energy consumptions, and air pollutant emissions by connecting some models effectively.

We used three models in this research such as;

- Transportation Data Correction Model: Interpolate and correct data in transportation statistics and estimate national transportation dataset in 2005.
- Transportation Demand Model: Estimating future transportation demand with reflecting transportation scenarios by changing some parameters.
- Enduse model: Estimate energy consumptions and emissions with detail technology selection framework

The method developed in this research is useful to evaluate emission reduction efficiency in transportation sector at the country level by reflecting various scenarios.

In this research, we tried only what-if analysis for estimating future transportation demands, and emission factors in Enduse model was tentative one. We need to set detail scenarios and reliable emission factors for each country.