Model development for quantifying the multiple environmental-health-economic benefits from low-emission urban transport development strategies in Delhi, India

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（インドのデリーにおける低排出の都市交通開発戦略による複数の環境・健康・経済的利益を定量化するためのモデル開発）

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論　文　内　容　の　要　旨
Thesis Summary

Climate change mitigation and air pollution reduction actions provide several advantages, including increased energy efficiency, improved air quality, and public health. This study aimed to quantify the expected climate co-benefits from the implementation of both clean transport technology and active transport scenarios in the urban transportation system in Delhi, India. To this aim, an integrated co-benefits assessment modeling framework was developed in this study to assess the health, environmental, and economic co-benefits of two plausible scenarios of: 1) replacing the current CNG busses with the battery-electric bus (BEB) fleet as a part of the Delhi electric vehicles policy 2020 and 2) adopting nonmotorized transportation (Walking and cycling) in the Delhi public transportation system. The co-benefits modeling framework in this research includes four main parts:

1. Estimation of the avoided emissions from introducing the new scenario:

- ✓ **Model (A) Estimation of the avoided emissions from replacing the CNG bus fleet with the new BEBs in Delhi:** To determine the avoided emissions from replacing the CNG bus fleet with the new BEBs, the annual operating time of the BEB was estimated by developing a detailed simulation model of battery electricity management, taking into account time lost in charging as well as state-of-charge (SOC) and capacity loss of the BEB's lithium battery and emission factors.
- ✓ **Model (B): Replacement of private motorized transportation with NMT (Walking and cycling) based on the willingness in Delhi**: Avoided emissions were calculated based on the total per capita extra distance traveled and the total VKT (vehicle kilometers) replaced by

walking and cycling, through developing a detailed daily trip model, taking into account the willingness of people in Delhi to use walking and cycling travel modes. The willingness to use NMT in Delhi was estimated, using a logistic regression model based on the collected data from a cross-sectional interview with 250 inhabitants in Delhi.

2. Estimation of the near-roadway PM2.5 exposure:

In order to assess the impact of avoided emissions (particularly $PM_{2.5}$) on improving public health in Delhi, a near-roadway $PM_{2.5}$ dispersion model was developed and applied to the selected traffic zones in 11 major districts of Delhi. In the BEB scenario, a steady state gaussian dispersion model was developed to estimate the hourly concentration at 200 meters downwind distance from the center of the street. Additionally, to estimate the short-term area concentration of $PM_{2.5}$ over the area in the upwind and crosswind directions, a ground-level concentration model is developed, taking into account the relationship between the wind coordination. In the case of the NMT scenario, an air dispersion modeling tool called CALRoads View (Lakes Environmental Software) was used to predict pollutant concentrations for receptors located within 150 meters on either side of the roadways.

3. Health impact assessment:

To establish a link between the avoided concentration of $PM_{2.5}$ and health benefits, a health risk assessment model was developed in the third part, which estimates the relationship between changes in $PM_{2.5}$ concentrations and the occurrence of specific health outcomes in the selected traffic areas, using the concentration-response function (CRF) for several diseases. The CRF coefficient values used in this study are derived from the relative risk (RR) level, which measures the likelihood of an adverse health outcome among the population exposed to a higher level of ambient air pollution than a lower level of ambient air pollution. The values of the RR utilized in the study were extracted from a detailed meta-analysis of previous studies. To this aim, a systematic review of epidemiological studies, meta-analyses, and review articles was conducted to assess the relationship between changes in $PM_{2.5}$ concentrations and changes in the incidence of each health endpoint.

4. Economic impact assessment:

The Value of Statistical Life (VSL) approach was used in this study to calculate the mortality cost of $PM_{2.5}$ exposure cost of illness (COI), and the cost of an emergency room visit (ERV) approach was used to determine the cost of treatment.

The research findings indicated that, the utilization of the new BEB fleet leads to a 74.67%

reduction in the total pollutant emissions from the existing bus fleet in Delhi. The results of the integrated co-benefits assessment reveal a significant reduction in $PM_{2.5}$ emissions (44 t/y), leading to avoidance of mortality (1370 cases) and respiratory diseases related hospital admissions (2808 cases), respectively, and an annual savings of about USD 383 million from the avoided mortality and morbidity cases in Delhi. The results from the application of the NMT in Delhi show the annual reduction of CO_2 and $PM_{2.5}$ by 121.5 kilotons and 138.9 tons, respectively. The model estimates the expected co-benefits from increased physical activities and reduced $PM_{2.5}$ exposure at 17529 avoided cases of mortality with an associated savings of about USD 4870 million in Delhi.