Using an iterative Markov Chain process to develop driving cycles based on large-scale GPS data: a case study in Beijing

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Introduction

- **Typical Driving Cycles** are important in evaluation of vehicle fuel consumption, emission and environmental impacts.
- Researches have shown that previous regulatory driving cycles (e.g., NEDC) fail to represent real-world traffic effects on vehicle emissions.
- Second-by-second vehicle trajectory data collected from various road types, traffic conditions and individual vehicles (e.g., **459 vehicles in this study**) are fundamental to develop representative driving cycles under various circumstances of concerns.
- We have developed representative driving cycles of passenger cars in Beijing by using a **Markov Chain** stochastic method.

Theory and Method

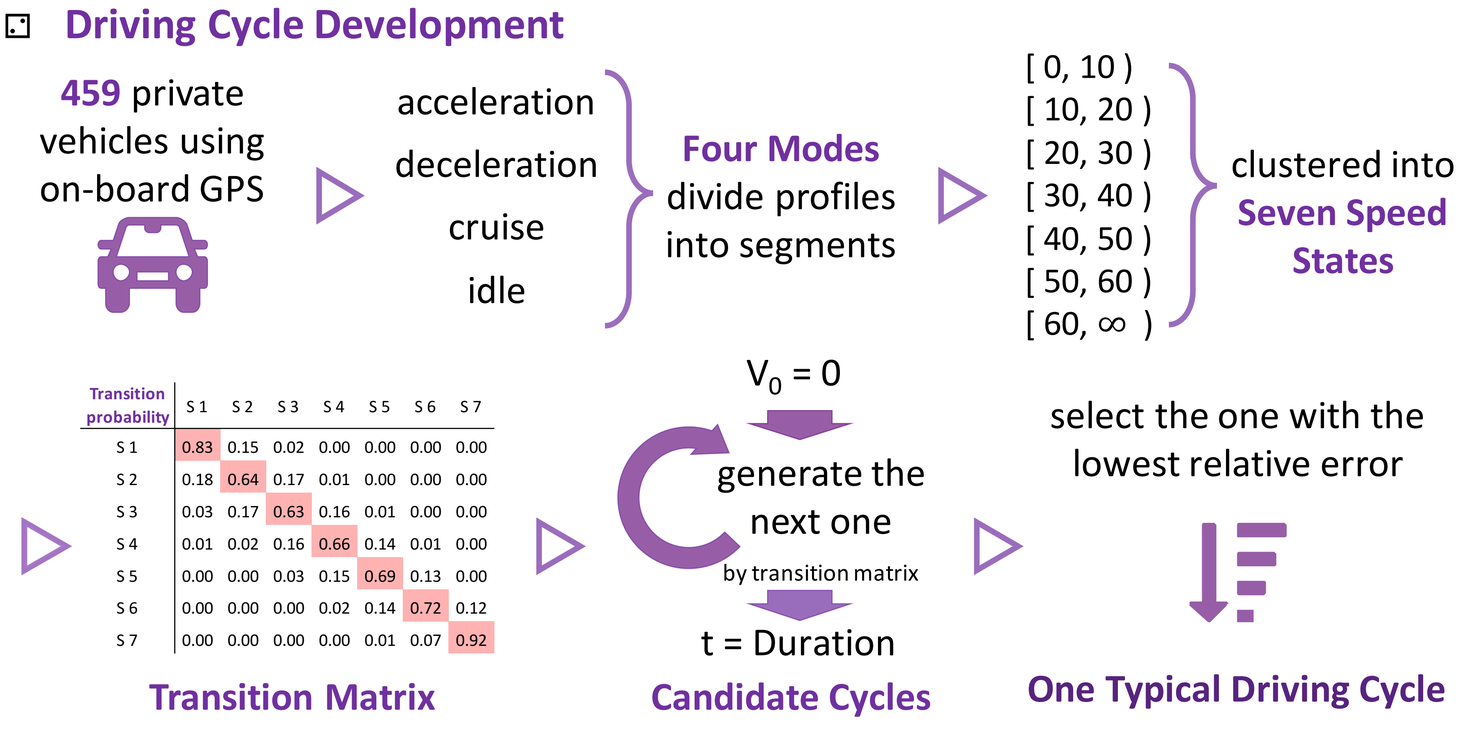
Markov Chain Process. The shift between two consecutive quasi-instantaneous (typically 2 – 3 seconds) driving status can be simulated by the Markov Chain method. The driving status of the next moment is in association with the present status by probability.

$$P\{X_{n+1} = j | X_0 = i_0, X_1 = i_1, \dots, X_n = i\} = P\{X_{n+1} = j | X_n = i\}$$

One-step transition probability matrix:

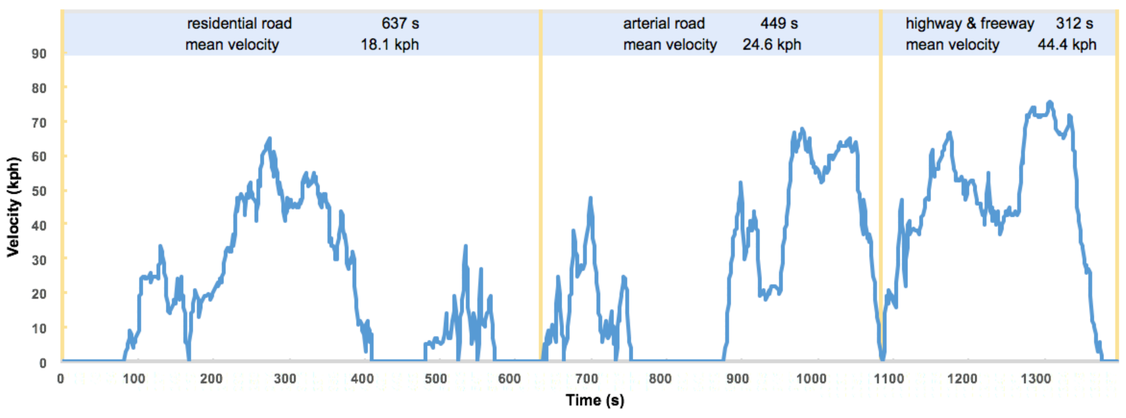
$$\mathrm{P} = (p_{ij}) = \begin{pmatrix} p_{00} & p_{01} & p_{02} & p_{03} & \cdots \\ p_{10} & p_{11} & p_{12} & p_{13} & \cdots \\ p_{20} & p_{21} & p_{22} & p_{23} & \cdots \\ p_{30} & p_{31} & p_{32} & p_{33} & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix}$$

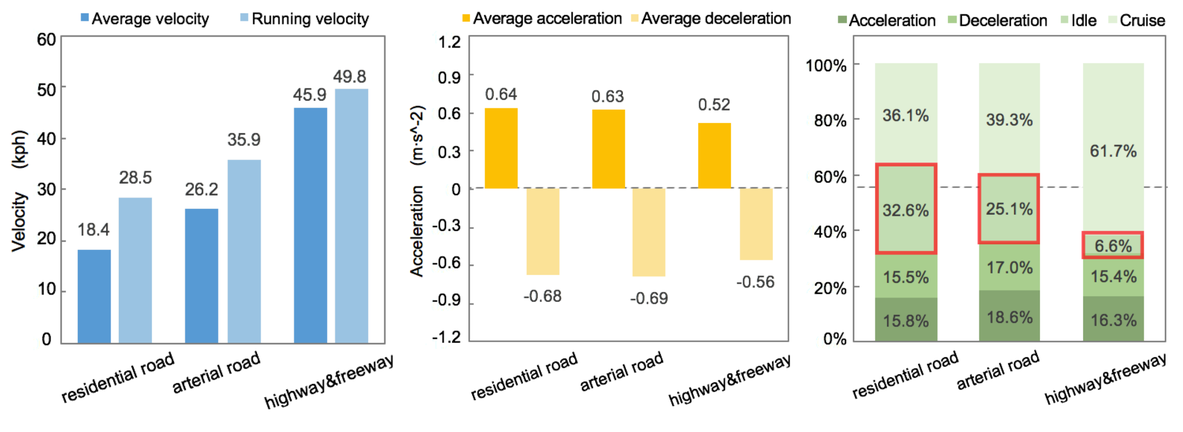
Driving Cycle Development



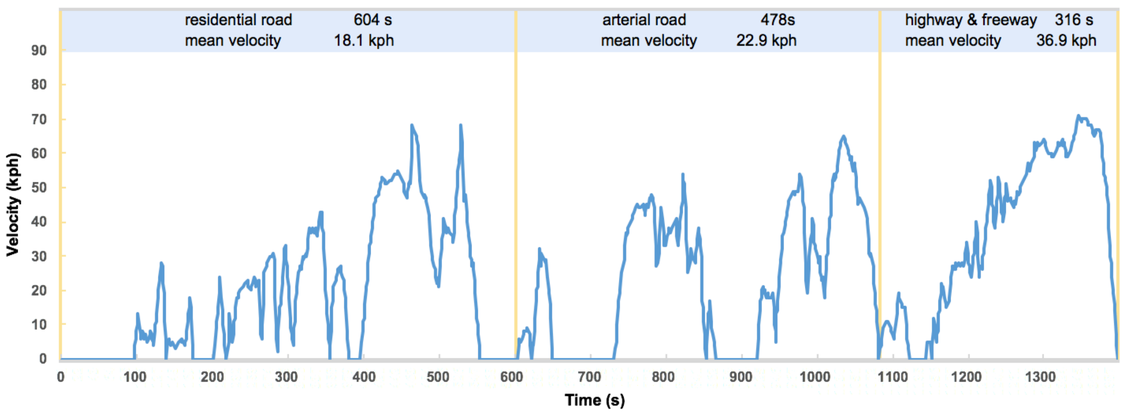
Results

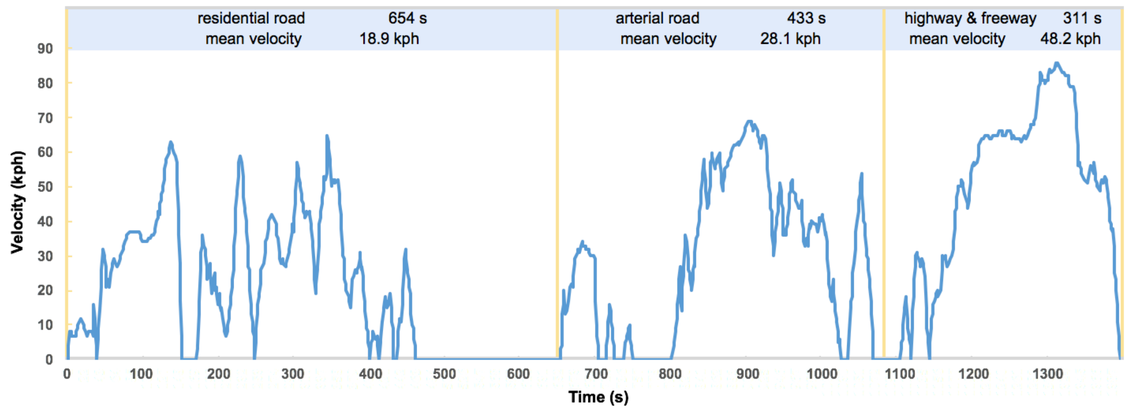
Spatial Analysis





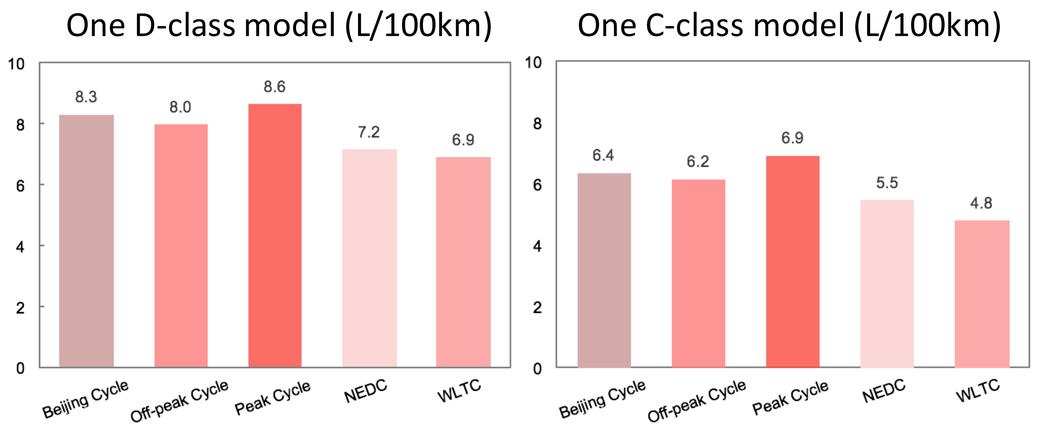
Temporal Analysis





Model Application on Fuel Consumption Estimation

- Fuel consumption under real-world driving could be higher than NEDC and WLTC by up to 30%.
- Fuel consumption during peak period is approximately 10% higher than off-peak period.
- Weighted average of Peak Cycle and Off-peak Cycle results are 8.15 and 6.37 L/100km for two models respectively, which shows **highly self-consistent** with results under Beijing Cycle (8.31 and 6.37 L/100km).



Based on normalized OBD fuel consumption data using a VSP-binning method

Conclusion

- This research used an **iterative Markov method** to develop driving cycles based on **large-scale GPS data**, providing a scientific approach for urban driving cycle development.
- The research developed driving cycles for various **spatial and temporal dimensions**, providing an improved basis for emission estimation and fuel consumption simulation.
- Fuel consumption simulation results confirmed that Beijing real-world driving has higher fuel consumption than NEDC and WLTC.