Designing Route Guidance Mechanisms to Internalize Various Negative Externalities

Urban and Transportation Planning Lab in Hiroshima university
B226288 Shiraki Keito
Supervisor：Prof. Chikaraishi Makoto
2026.01.13

HIROSHIMA UNIVERSITY

Background

- Navigation apps are widely used and allow drivers to easily choose the shortest-time or shortest-distance routes

- However, such routes often lead to
  - Through-traffic in residential areas
  - Increased noise, safety risks, and environmental burdens

- These social externalities are not fully considered in current navigation systems

Background

- The rapid spread of connected cars enables the use ofhigh-resolution GPS and CAN data

- Previous studies have shown that:
    - Drivers rely on both experiential and descriptive information
    - Route choice is influenced by bounded rationality and cognitive biases
    - Route choice is strongly influenced by actual travel time (descriptive information), but past experience (experiential information) also affects decision-making.

- Remaining gaps
    - Limited quantitative comparison between individual and social optima
    - Insufficient mechanism-design approaches for internalizing externalities
    - Lack of large-scale empirical analysis in Higashi-Hiroshima City

Research Objectives

1. Develop link-level indicators for multiple negative externalities

2. Examine the divergence between
    - ・Individual optimum routes (shortest travel time)
    - ・Socially desirable routes (minimum externalities)

3. Explore route guidance mechanisms to internalize externalities

Data Used

- GPS / CAN data (Sep 2023 – Dec 2023)
  - Vehicle trajectories, speeds, and timestamps
  - Acceleration and deceleration
  - Brake and accelerator signals
  - 2.77 billion observations

- Building point data (2020)
  - Approximately 63,945 building points

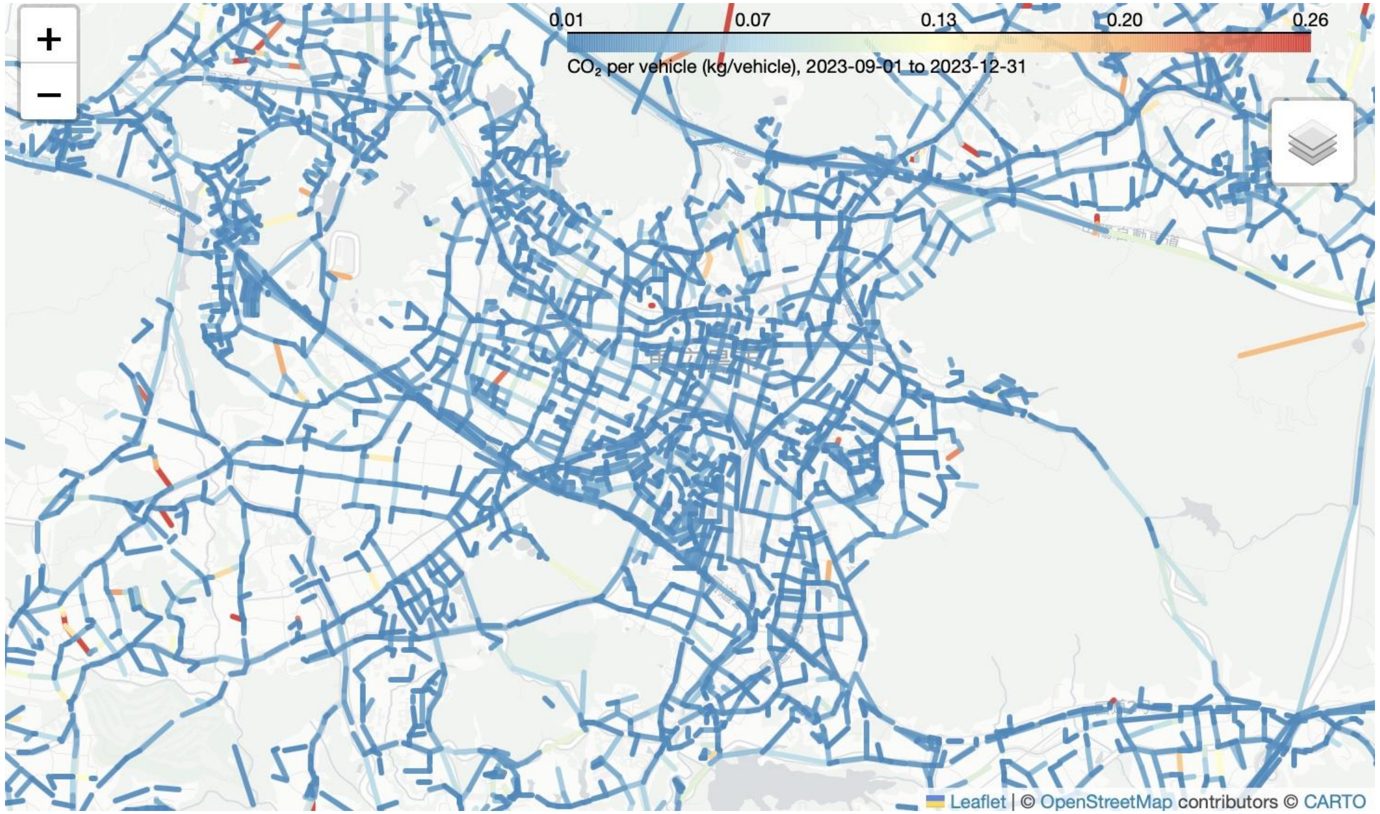
- Traffic accident data (2019 – 2024)
  - 2,192 recorded accidents

Methodology

1. Preprocess GPS and CAN data
2. Aggregate and visualize externalities at the link level
3. Construct externality indicators
4. Compare individual and social optima

CO_2 Emissions

CO_2 emissions were estimated at the link level.
Per-vehicle CO_2 emissions tend to be lower on arterial roads, while they are higher on local streets.

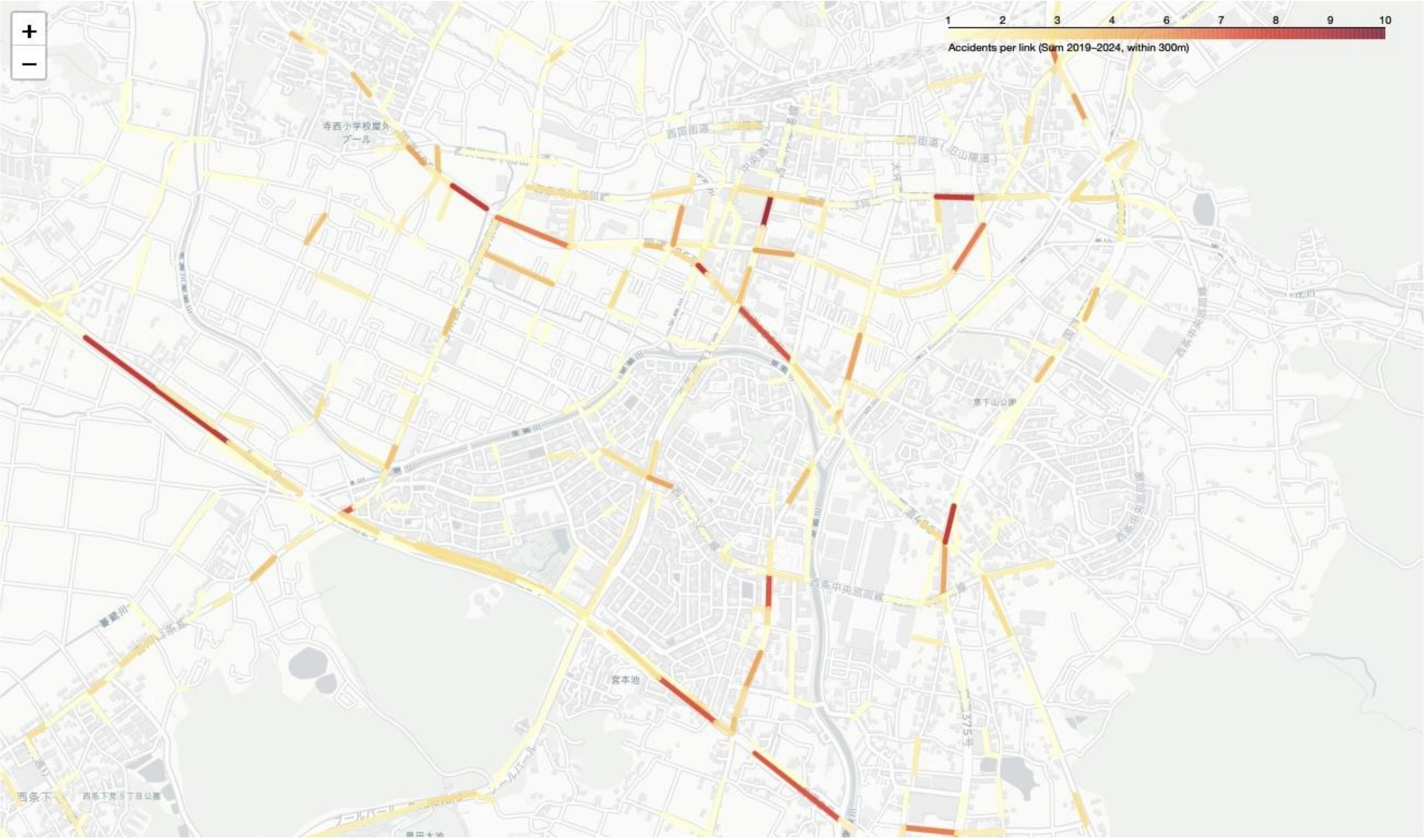


Gasoline vehicle assumption:
EF = 2310 gCO_2/L

$$CO_{2i} = \frac{fuelconsumption_i}{3600} \times EF \times \Delta t$$

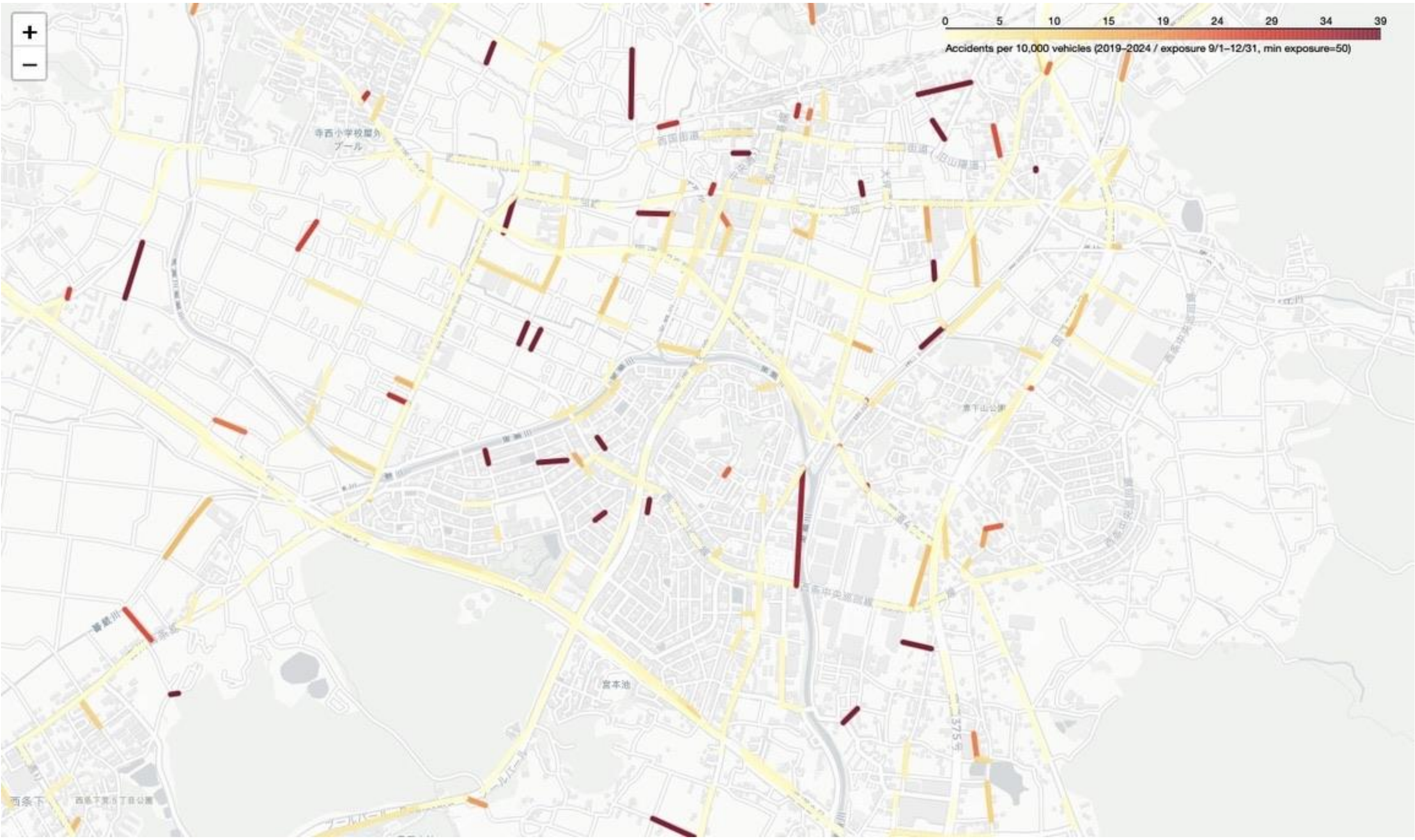
Traffic Accidents

Traffic accident counts were aggregated at the link level.
These counts are strongly dependent on traffic volume.



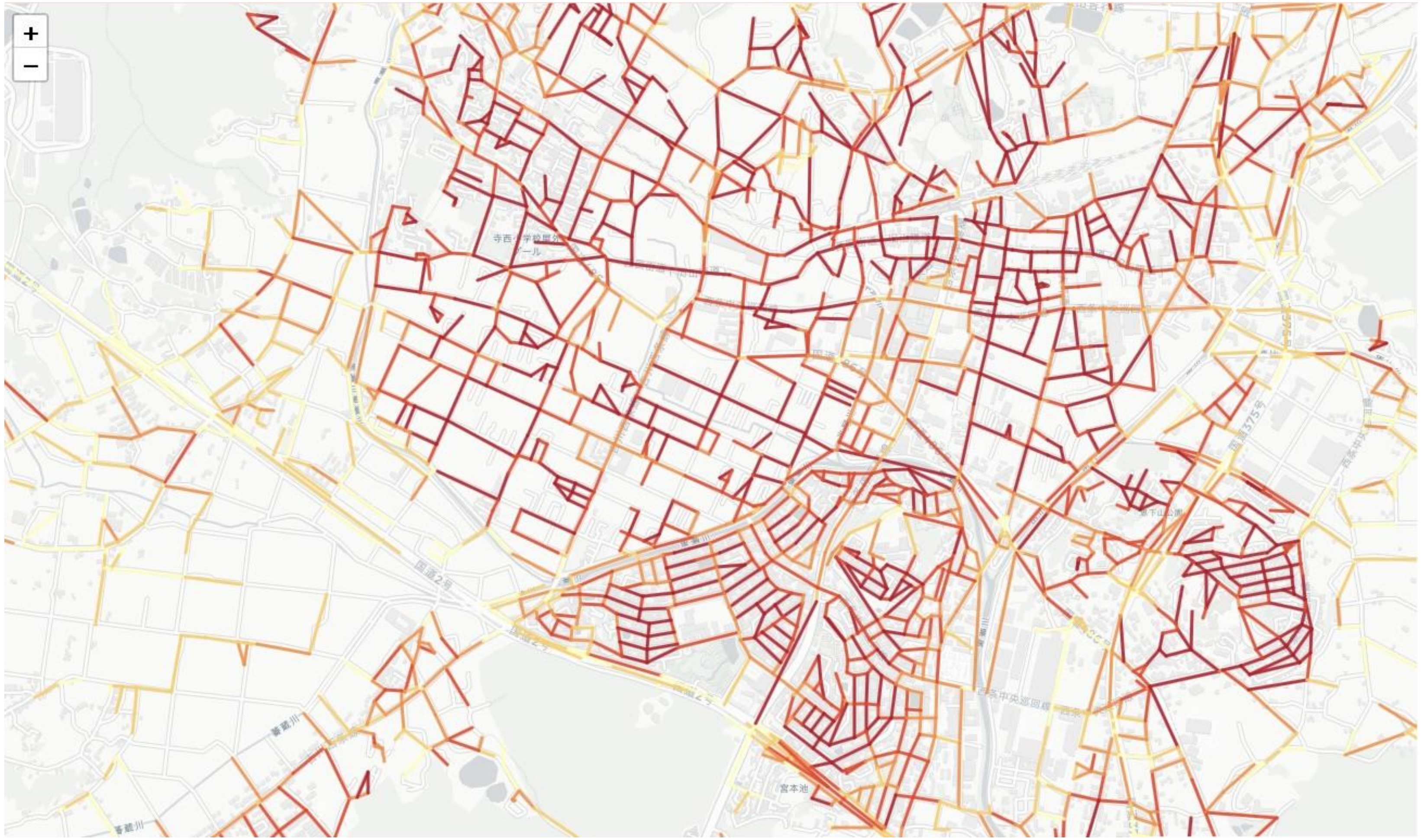
Traffic Accidents

Due to the lack of comprehensive traffic volume data,
link-level passage counts derived from CAN data were used as a proxy.
Although this approach does not provide an exact measure of accident risk,
it enables the identification of links with relatively high accident risk.



Methodology

Noise risk was visualized at the link level.



- Impact radius: 100 m
- Distance decay coefficient: 0.05
- Building weight: 1 (count-based)

$$NoiseRisk_a = \sum_{i:d_{ai} \le R} \exp(-\beta d_{ai}) \cdot N_i$$

- d_{ai} : Shortest distance between link a and building i
- R : Impact radius
- β : Distance decay coefficient
- N_i : Weight of building i

Discussion

**Across all externality indicators considered in this study,
larger externality values tend to be observed on arterial roads,
while smaller values are generally found on local streets.**

Future Work

- Further refinement of calculation methods for multiple externality indicators
- Comparison between individual optimum routes and socially optimal routes
- Design of incentive schemes for internalizing negative externalities, including information provision and behavioral interventions

Reference

・Varghese, V., Luo, L., Chikaraishi, M., & Watanabe, Y. (2025). Revisiting the rationality of route choice behavior and modeling information provision effects,トヨタ×広島大学 共同研究成果報告書.
・Ben-Elia, E., & Avineri, E. (2015). Response to travel information: A behavioral review. Transport Reviews, 35(3), 352–377.
・Ben-Elia, E., & Shiftan, Y. (2010). Which road do I take? A learning-based model of route-choice behavior. Transportation Research Part F, 13(4), 259–272.
・Gonzalez, C., Lerch, F. J., & Lebiere, C. (2003). Instance-based learning in dynamic decision making. Cognitive Science, 27(4), 591–635.

Thank you for your attention.