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ANNUAL MEETING

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From Links to Lanes: A Lane-Level Traffic Assignment Framework

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Motivation

- Traditional link-based traffic assignment treats each segment as homogeneous

- Cannot capture critical lane-level behaviors:
  - merging friction
  - turning-pocket spillback
  - cross-weave turbulence

- Modern maps (HD maps), connected vehicles, and AV systems require **lane-level fidelity**

Contributions

Our framework introduces:

- Maneuver-specific lane-level cost functions
  - straight
  - turning
  - lane changing

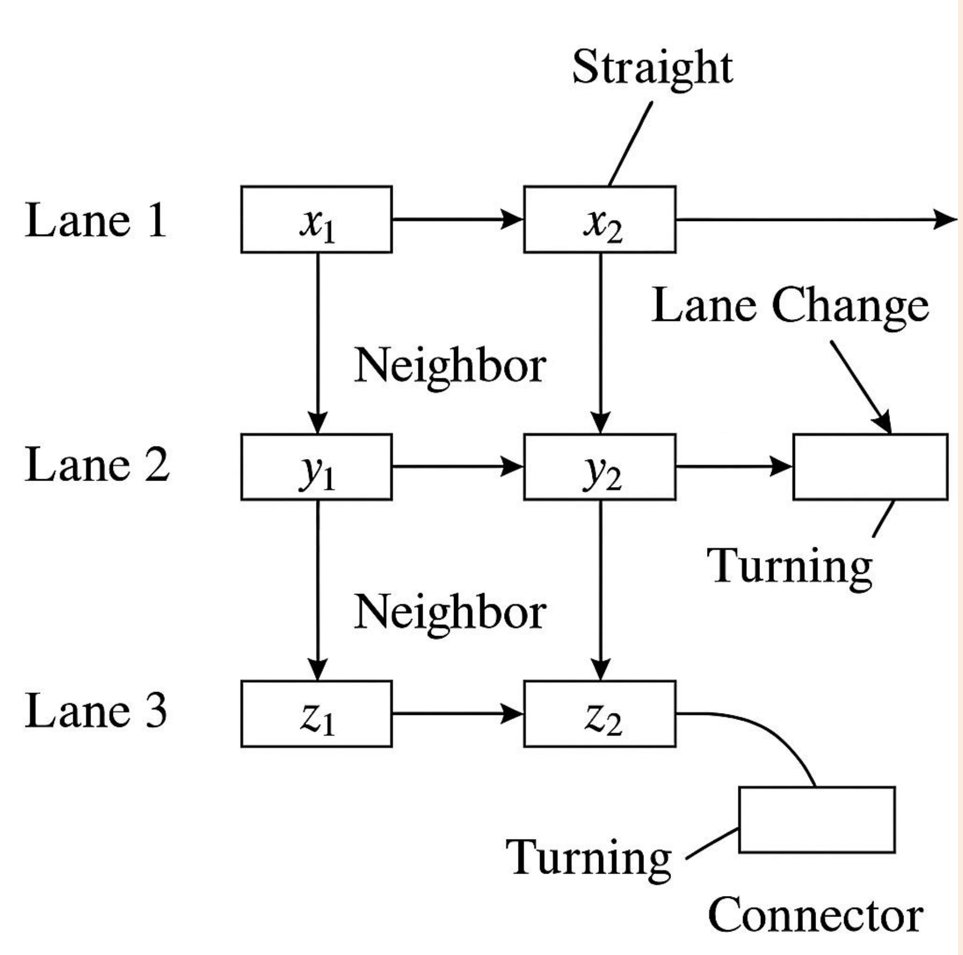
- Flow-dependent delays on both origin and receiving lanes

- Microscopic validation using SUMO

- Real-world evaluation on lane-expanded Sioux Falls network
  → Improves congestion-prediction accuracy by 22%

Lane-Level Network

- Lane graph: $G = (L, M)$
- Lanes as nodes, maneuvers as edges
- Three maneuver types:
  - $S(i)$ straight
  - $T(i \rightarrow j)$ turning
  - $LC(i \rightarrow j)$ lane changing



Maneuver-Specific Volume–Delay Functions

- **Straight movement:**

$$c_s = t_{0,s}\left(1 + \alpha\left(\frac{v_s}{C_s(1-\gamma_s)}\right)^{\beta}\right)$$

- **Turning:**

$$c_t = t_{0,t}\left[1 + a_1\left(\frac{v_i}{C_i}\right)^{\theta_1} + a_2\left(\frac{v_j}{C_j}\right)^{\theta_2}\right]$$

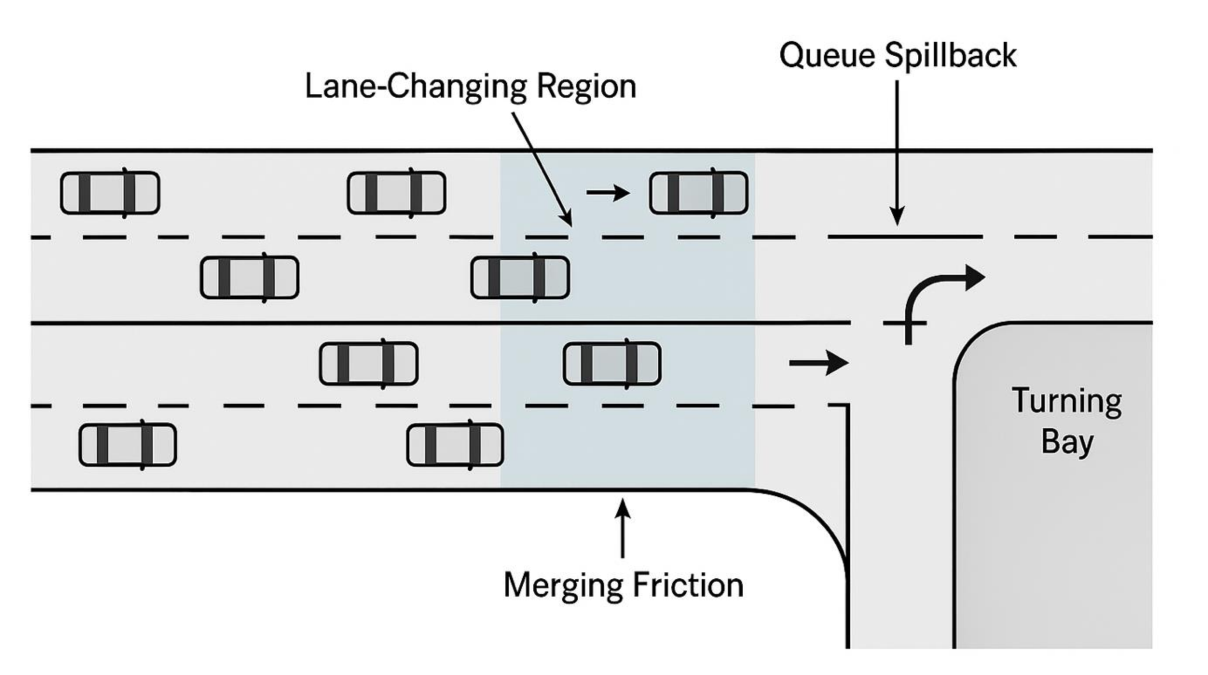
- **Lane change:**

$$c_{lc} = t_{0,lc}\left[1 + b_1\frac{v_i}{C_i} + b_2\frac{v_j}{C_j} + b_3\frac{v_i v_j}{C_i C_j}\right]$$

SUMO Microscopic Simulation

- Three-lane corridor
- 1200 vehicles
- Krauss + Lc2013
- Validation focuses on:
  - merging delays
  - lane-changing friction
  - spillback

  → Maneuver-specific functions match SUMO dynamics well



Sioux Falls Experiment

- Lane-expanded Sioux Falls network
  Accuracy metric:

$$\text{Accuracy} = 1 - \frac{\| T_{model} - T_{SUMO} \|}{\| T_{SUMO} \|}$$

- Result

Model	Accuracy
Link-based DTA	baseline
Lane-level DTA	+22%

- Practical insights:
  - ➢ adjust turn-bay lengths
  - ➢ revise lane-use regulations
  - ➢ improve intersection operations

Conclusion

- Lane-level DTA significantly improves congestion modeling fidelity
- Captures lane-changing turbulence and flow interaction
- Validated on both micro-simulation and real-world networks
- Next: AV lane-selection, IoV real-time data, RL-based control

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