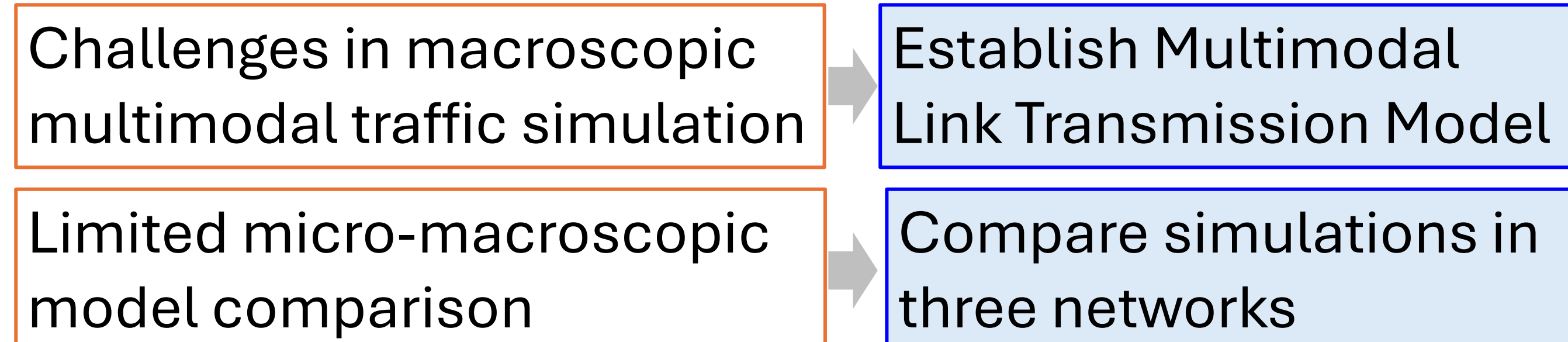


# Analysis and Comparison of Multimodal Link Transmission Model and SUMO in Urban Networks

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## Problem Statement



## Multimodal Link Transmission Model

Multimodal Link Transmission Model (M-LTM) macroscopically captures road and tramway traffic dynamics and their interactions through link and node models.

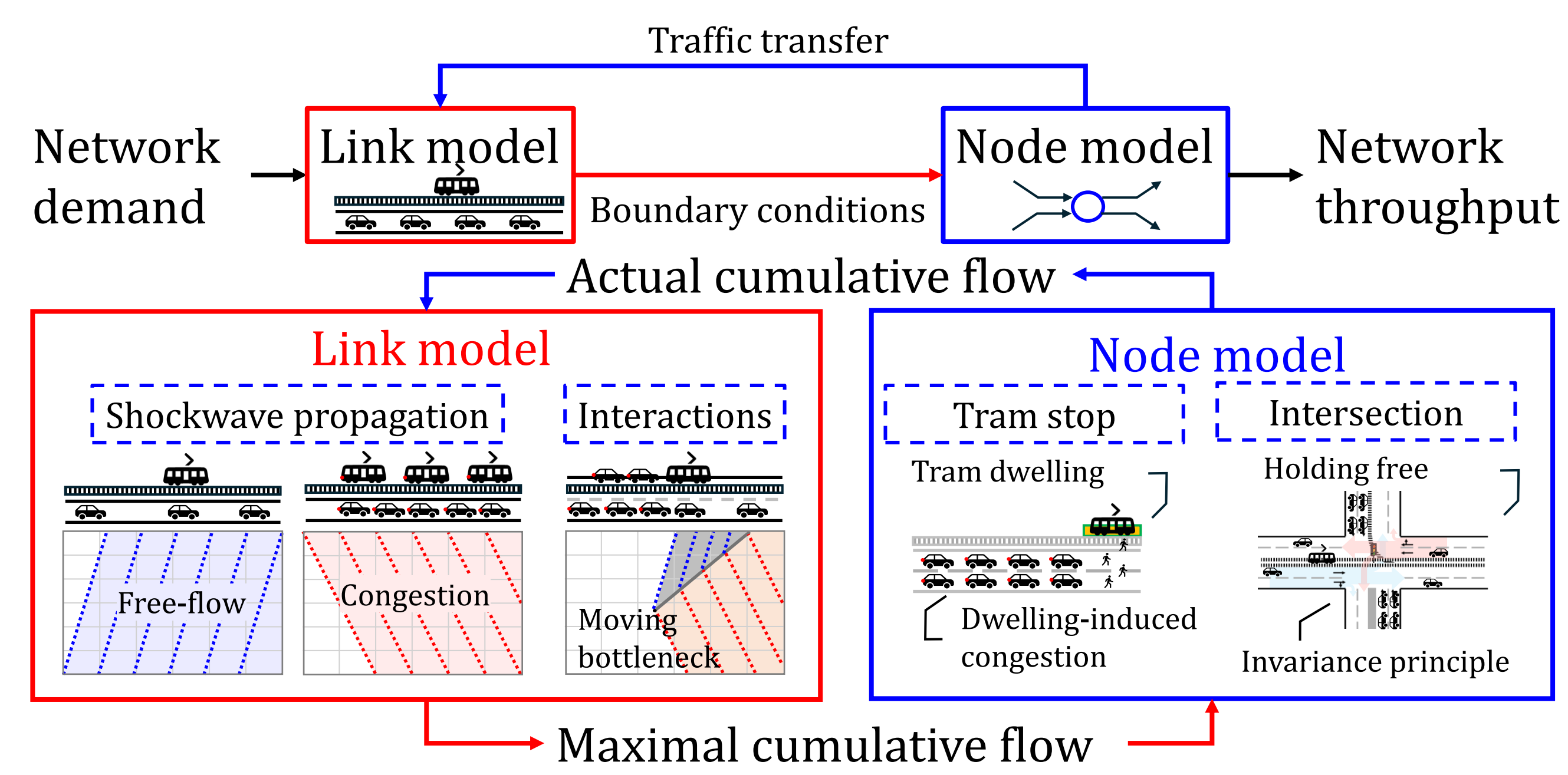


Figure 1 Framework of M-LTM.

## Deviations between M-LTM and SUMO

Simulation results in the three networks are quantitatively compared by cumulative flow normalized deviation:

$$D = \frac{\sqrt{\frac{1}{T} \int_0^T (N_{MLTM}(t) - N_{SUMO}(t))^2 dt}}{Q}$$

where  $D$  is normalized deviation,  $N_{MLTM}(t)$  and  $N_{SUMO}(t)$  is the cumulative flow at time  $t$  in M-LTM and SUMO,  $T$  is total simulation time, and  $Q$  is total traffic demand.

Table 1 Normalized deviations of road traffic cumulative flow between M-LTM and SUMO.

Network	Tram stop	Intersection	Artery
$D$	0.49%	2.56%	7.87%

## Case 1: Tram Stop Simulation

### Tram dwelling process and dwelling-induced congestion

Tram dwelling and dwelling-induced congestion on road traffic are simulated distinctly with similar performance.



Figure 2 (a) Layout of tram stop network.

Figure 2 (b) SUMO setup of the tram stop.

Table 2 Comparison of simulation approaches at the tram stop network in M-LTM and SUMO.

	M-LTM	SUMO
Tram dwelling	Defined at each stop by a function.	Defined for each tram in route files.
Dwelling-induced congestion	Transferred from function of tram dwelling time.	Controlled by TraCI when tram arriving.

## Case 2: Signalized Intersection Simulation

### Road traffic spillback and tram priority

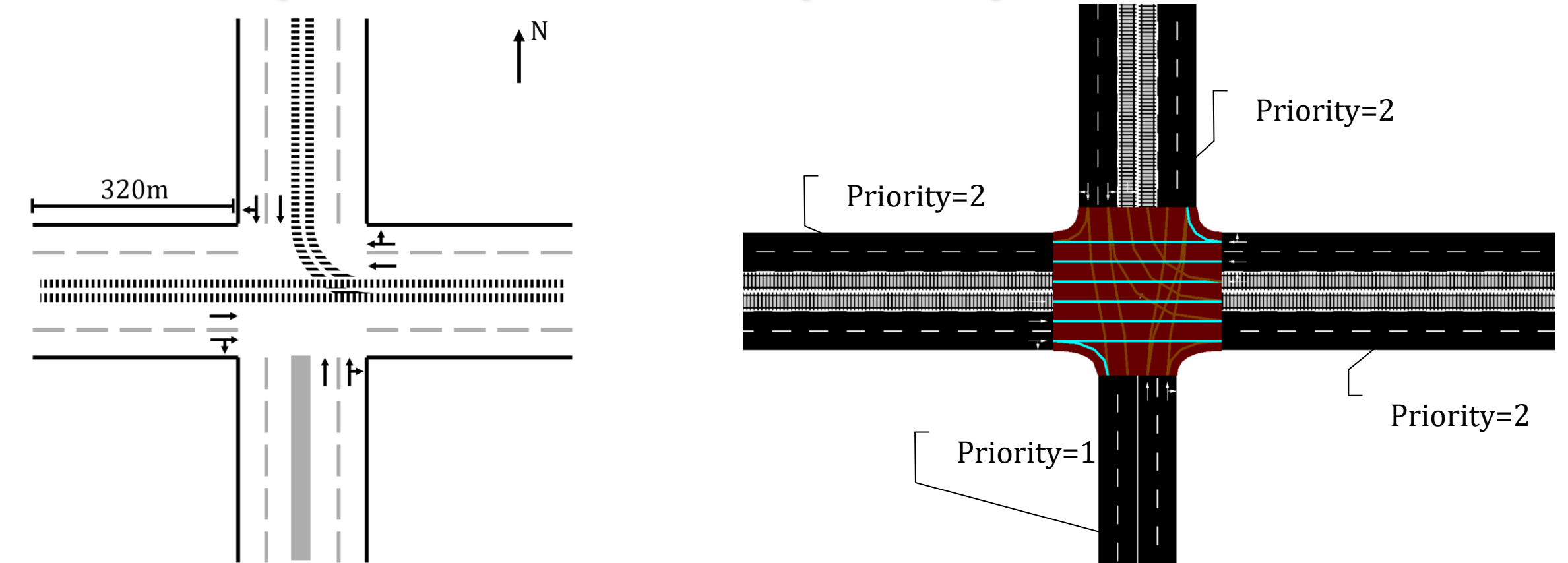


Figure 3 (a) Layout of intersection network. Figure 3 (b) Connection setup at the intersection in SUMO. Main deviations between road traffic cumulative flows at the intersection result from different signal representations.

M-LTM utilizes green ratios, but SUMO considers phase time.

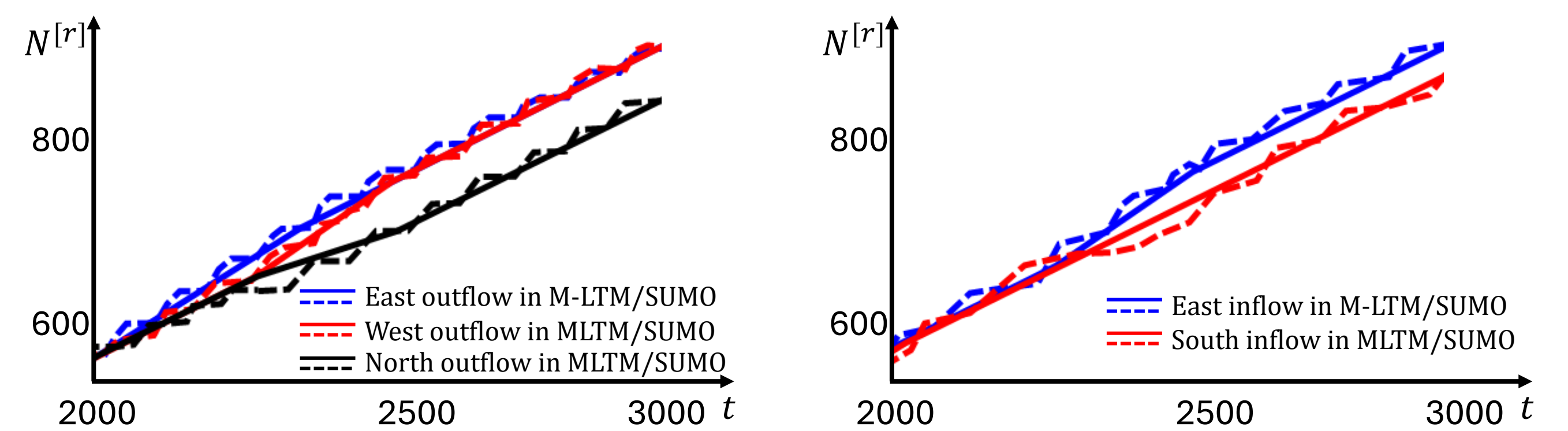


Figure 4 (a) Road traffic cumulative outflow of outgoing links at the intersection network.

Figure 4 (b) Road traffic cumulative inflow of incoming links at the intersection network.

## Case 3: Artery Simulation

### Tramway delay propagation and multimodal interactions

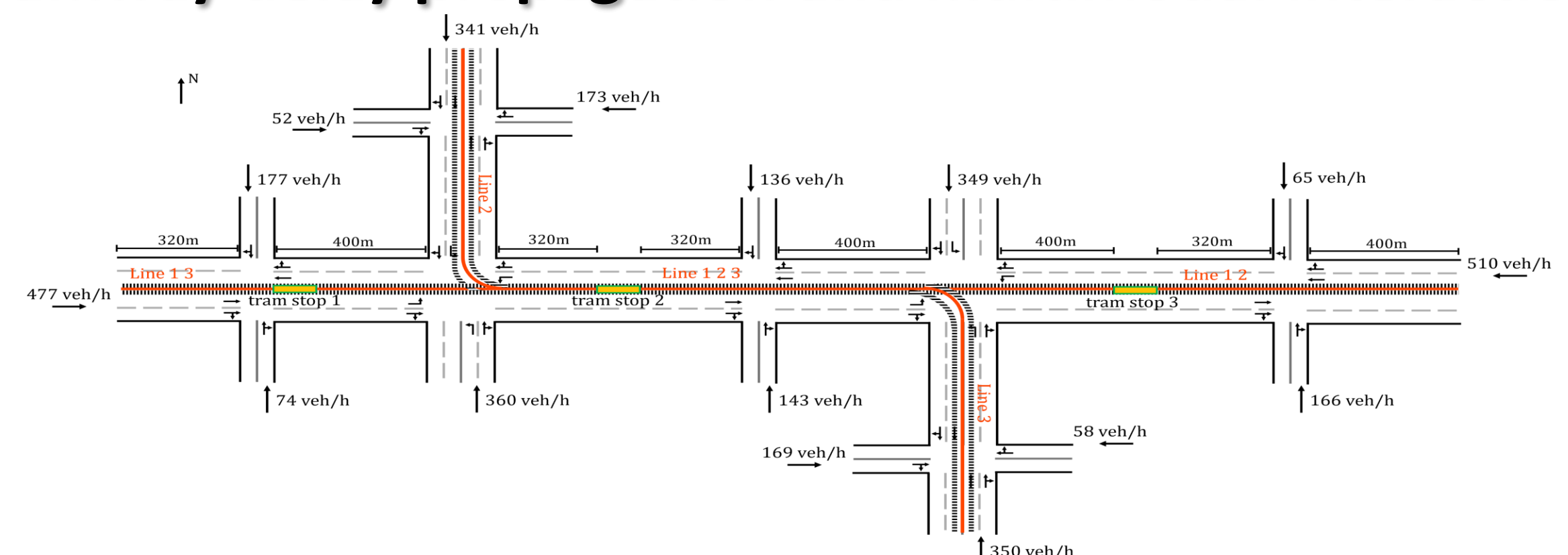


Figure 5 Layout of artery network.

- Trams suffer delays on shared-ROW (Right-Of-Way) links in the two simulations.
- M-LTM assumes that trams pass intersections without stoppages, which causes deviations in road traffic flow.
- Deviations between M-LTM and SUMO are compensated, and the normalized deviation converges.

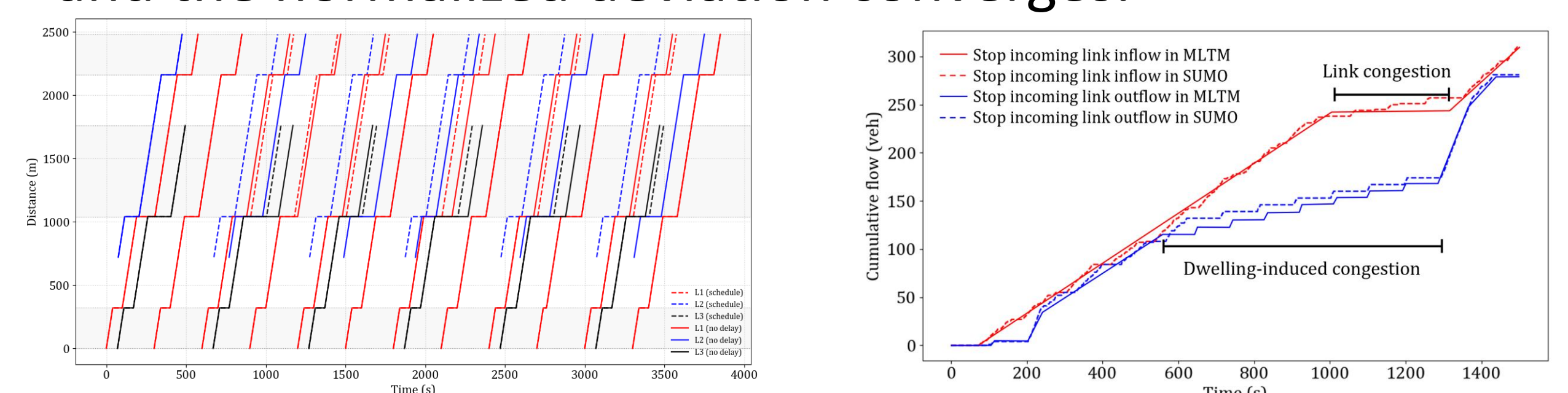


Figure 6 (a) Tram trajectories along the horizon artery.

Figure 6 (b) Road traffic cumulative flows on the artery.

## Conclusion and Future Work

- Simulation results of M-LTM and SUMO are highly consistent.
- Compared to SUMO, M-LTM simulates the multimodal traffic dynamics at link level without details of vehicle movements.
- Future work will focus on hierarchical multimodal traffic control with the combination of M-LTM and SUMO. The M-LTM serves for long-term strategies, while SUMO is applied to real-time adaptive control.

