Implementation of Different Methods for User Equilibrium and System Optimum Routing in the Microscopic Simulation Platform SUMO

Master's Thesis of Arinze Ekwueme

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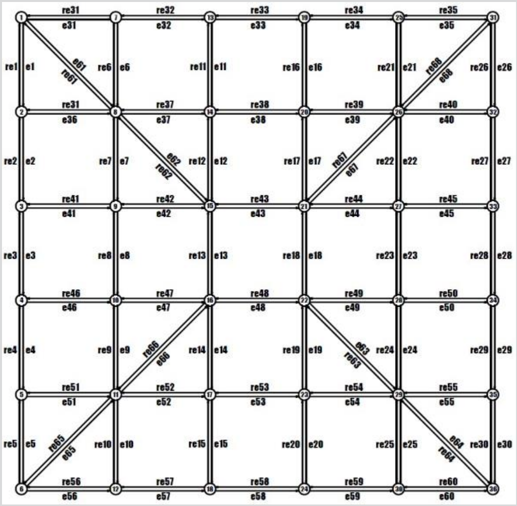

Fig 1.1: Network Topology: Nodes and Directed Links

Scenario	CAVs PR (SO)	HDVs PR (UE)
1	0 %	100
2	10 %	90 %
3	20 %	80 %
4	50 %	50 %
5	80 %	20 %
6	100 %	0 %

Tab. 1.2 Simulation Scenaros: CAVs & HDVs PR

Introduction and Background

- Urban congestion, exacerbated by population growth and limited infrastructure, cannot be solved by road expansion alone, as Braess et al., [2005] reveals it may worsen network performance.
- Current navigation systems use User Equilibrium (UE) routing, minimizing individual travel costs but leading to suboptimal network efficiency; System Optimum (SO) routing improves overall performance but imposes higher costs on some users [Angelelli et al., 2020].
- Connected and autonomous vehicles (CAVs) enable new possibilities for balancing individual and collective benefits, approaching SO traffic states through V2I and V2V communication.
- This research explores how varying CAV penetration rates (PR) affect traffic flow using a microscopic simulation platform, aiming to optimize urban traffic systems and inform future planning.

Methodology and Case Study

- The DualterateMix tool developed by [Behzad et al., 2023] was used to iteratively optimize routes for a multiclass trip assignment involving CAVs and HDVs.
- CAV routing and driving behavior followed the SO principle, while HDVs adhered to UE principle.
- Python scripts were developed to generate network files, operate SUMO via TraCI, log vehicle parameters during simulation. Calculate key performance metrics.
- The synthetic network (Fig. 1.1) consists of 36 nodes, 136 links, and 19,200 trips simulated over a 3-hour period.
- Six scenarios (Tab. 1.1) with CAV penetration rates of 0%, 10%, 20%, 50%, 80%, and 100% were simulated for CAV rerouting probabilities (CAVRePr) of 0.5 and 1.0.

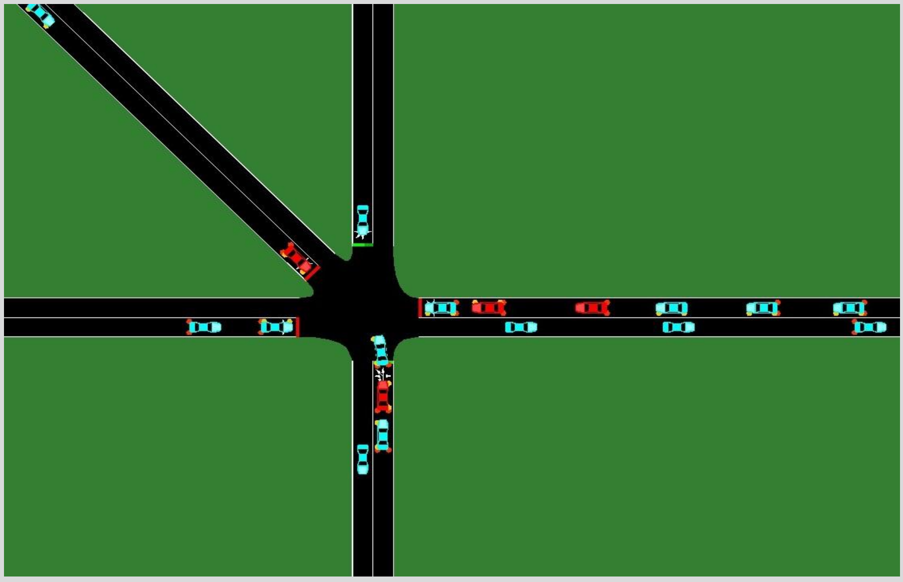

Fig 2: Simulation platform (SUMO) visualizing dynamic vehicle movements within the network

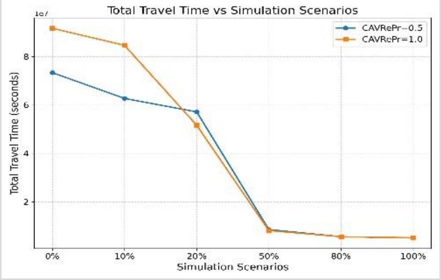

Fig 3.1: Total Travel Time vs Scenarios

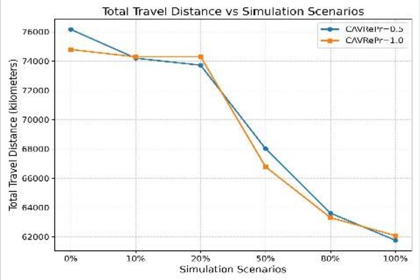

Fig 3.2: Total Travel Distance vs Scenarios

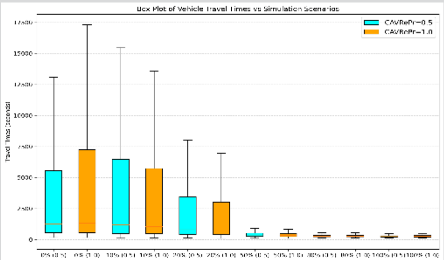

Fig 3.3: Boxplot Average TT vs Scenarios

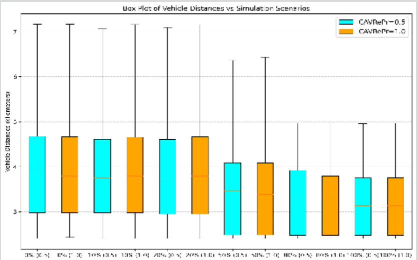

Fig 3.4: Boxplot Average TD vs Scenarios

Key Findings and Insight

- Total travel time (Fig. 3.1) improved by 88% and 91% at 50% CAV penetration rates for CAVRePr values of 0.5 and 1.0, respectively.
- Average travel time (Fig. 3.3) decreased from 3821 seconds and 4775 seconds (scenario 1) to 263 seconds and 269 seconds (scenario 6) for CAVRePr values of 0.5 and 1.0, respectively.
- Total traveled distance (Fig. 3.2) improved by 10.7% and 18.9% (Scenario 4) and 10.7% and 17.0% (Scenario 6) for CAVRePr values of 0.5 and 1.0, respectively.
- Average travel distance (Fig. 3.4) decreased from 3.9 km to 3.2 km in both CAVRePr cases.
- Implementing policies that increase CAV PR can significantly reduce congestion, shorten commute times, and lower emissions.