Master‘s Thesis of Eirini Triantafyllidi

“Assessing the Potential of Bidirectional Roundabouts for Efficient Traffic Management”

Mentoring: M.Eng. Athanasia Karalakou, Dr.-Ing. Majid Rostami Shahrbabaki

Urban traffic growth increases congestion, delays, and environmental impacts, with intersections acting as critical network bottlenecks. Roundabouts improve safety and efficiency, but under high demand and complex geometries, conventional unidirectional designs may become suboptimal. This highlights the **need for innovative roundabout concepts**.

GOAL: Examine the efficiency of bidirectional roundabouts

RQ.1 - How can SUMO be used for modeling and simulating two-directional roundabouts effectively?

RQ.2 - How does a two-directional roundabout impact traffic, compared to conventional one-directional infrastructures?

RQ.3 - Is there a potential breaking point of the system, and how does this affect safety and efficiency?

Gap in Literature and Motivation:

- All existing roundabouts (conventional and unconventional) are running unidirectional circulation. [1]
- Vehicles in large roundabouts often follow unnecessarily long detours.
- Lane-free and cooperative traffic shows that flexible, non-lane-based control is feasible.[2]
- The bidirectional concept is challenging but promising in non-motorized cases. [3]

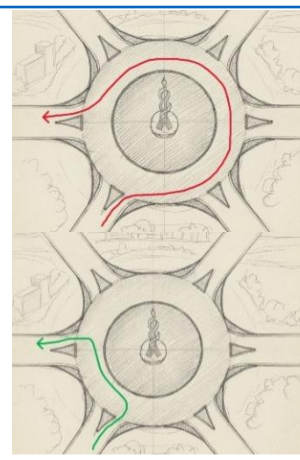


Fig. 1: The bidirectional roundabout concept

Methodology:

Network Design – Arc de Triomphe, Paris

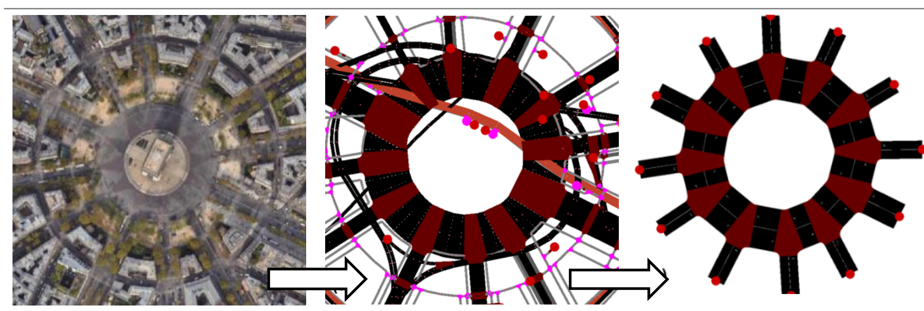


Fig. 2: Study area and network simplification

Simulation Design and Control Logic

- Shortest-path routing implemented manually (6 CW + 6 CCW routes per entry, 144 total)
- Custom vehicle model overriding SUMO defaults (IDM longitudinal, SL2015 lane-free lateral control)
- Vehicle behavior calibrated for realistic acceleration, gaps, and lateral motion
- TraCI-based dynamic control to manage wide, lane-free circulation
- Phase-based logic adapts lateral position by route direction, location, and route length

Scenario Comparison and Data Analysis

Scenario 1 – High Demand

→ High-demand traffic conditions

→ Bidirectional vs unidirectional roundabout

→ No control strategy, identical demand

Scenario 2 – Low Demand

→ Low-demand traffic conditions

→ Focus on operational quality

→ Bidirectional **with controller** vs unidirectional without control

Scenario 3 – Medium Demand

→ Increasing demand with active control

→ Same control logic as Scenario 2

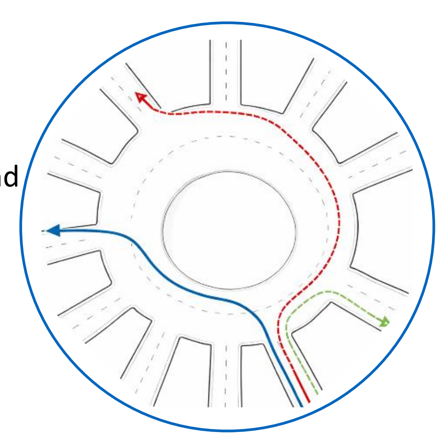
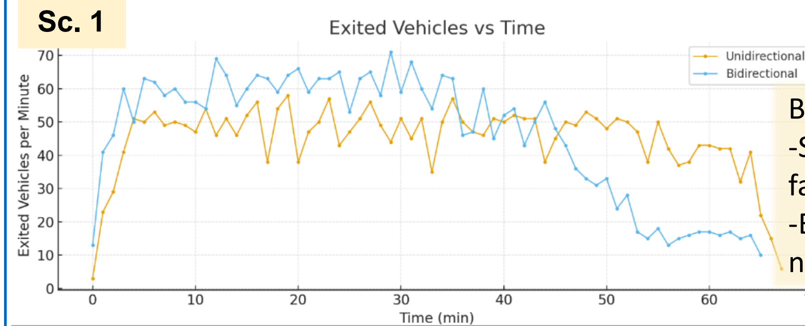


Fig. 3: Illustration of the controller’s concept (generated by ChatGPT)

Results:

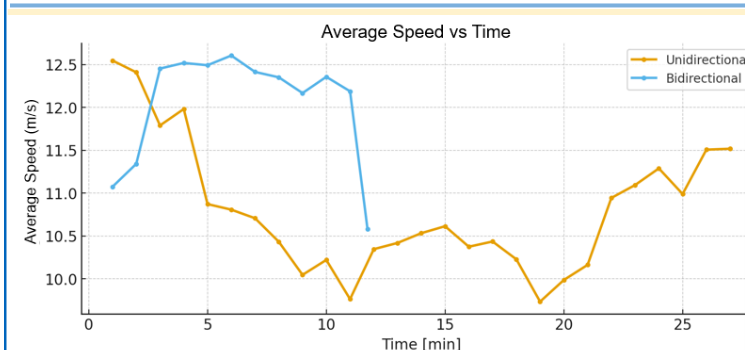
Sc. 1



Bidirectional
-Serves vehicles faster
-Empties the network earlier

Scenario 1	Trips completed	Avg route length [m]	Avg waiting time [s]	Total CO_2 [kg]
Unidirectional	3042	389.85	60.183	882.97
Bidirectional	3042	198.69	18.621	403.2

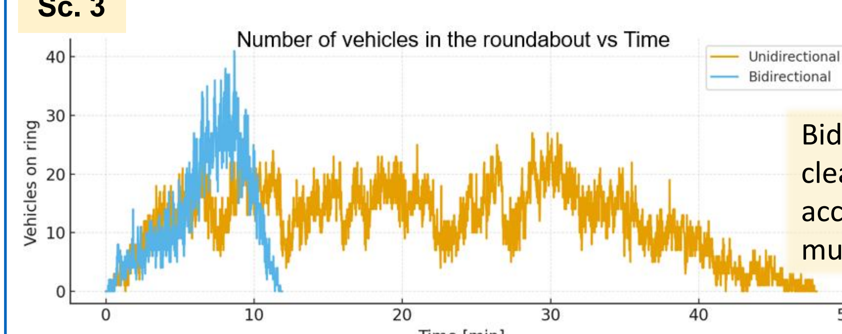
Sc. 2



Bidirectional:
-Maintains higher
-More stable speeds
-Completes traffic faster

Scenario 2	Trips completed	Avg route length [m]	Avg waiting time [s]	Total CO_2 [kg]
Unidirectional	1160	389.45	57.37	326.42
Bidirectional	1160	198.87	0.05	54.63

Sc. 3



Bidirectional clears vehicle accumulation much faster

- ✓ SUMO successfully modeled a bidirectional roundabout with realistic geometry and performance (RQ1)
- ✓ Bidirectional circulation improves efficiency: shorter routes, lower travel/waiting times, and reduced emissions (RQ2)
- ✓ Operational limit identified at ~70% of high demand, beyond which congestion and instability occur (RQ3)

List of References

[1] National Academies of Sciences, E. and M. (2010). Roundabouts: An Informational Guide – Second Edition.

[2] Karalakou, A., Rostami-Shahrbabaki, M., Rempe, F., & Bogenberger, K. (2025). A Deep Reinforcement Learning Approach for Controlling Autonomous Vehicles in Lane-Free Roundabouts. IEEE Intelligent Vehicles Symposium, Proceedings, 2348–2354. https://doi.org/10.1109/IV64158.2025.11097805

[3] Poudel, N., & Singleton, P. A. (2021). Bicycle safety at roundabouts: a systematic literature review