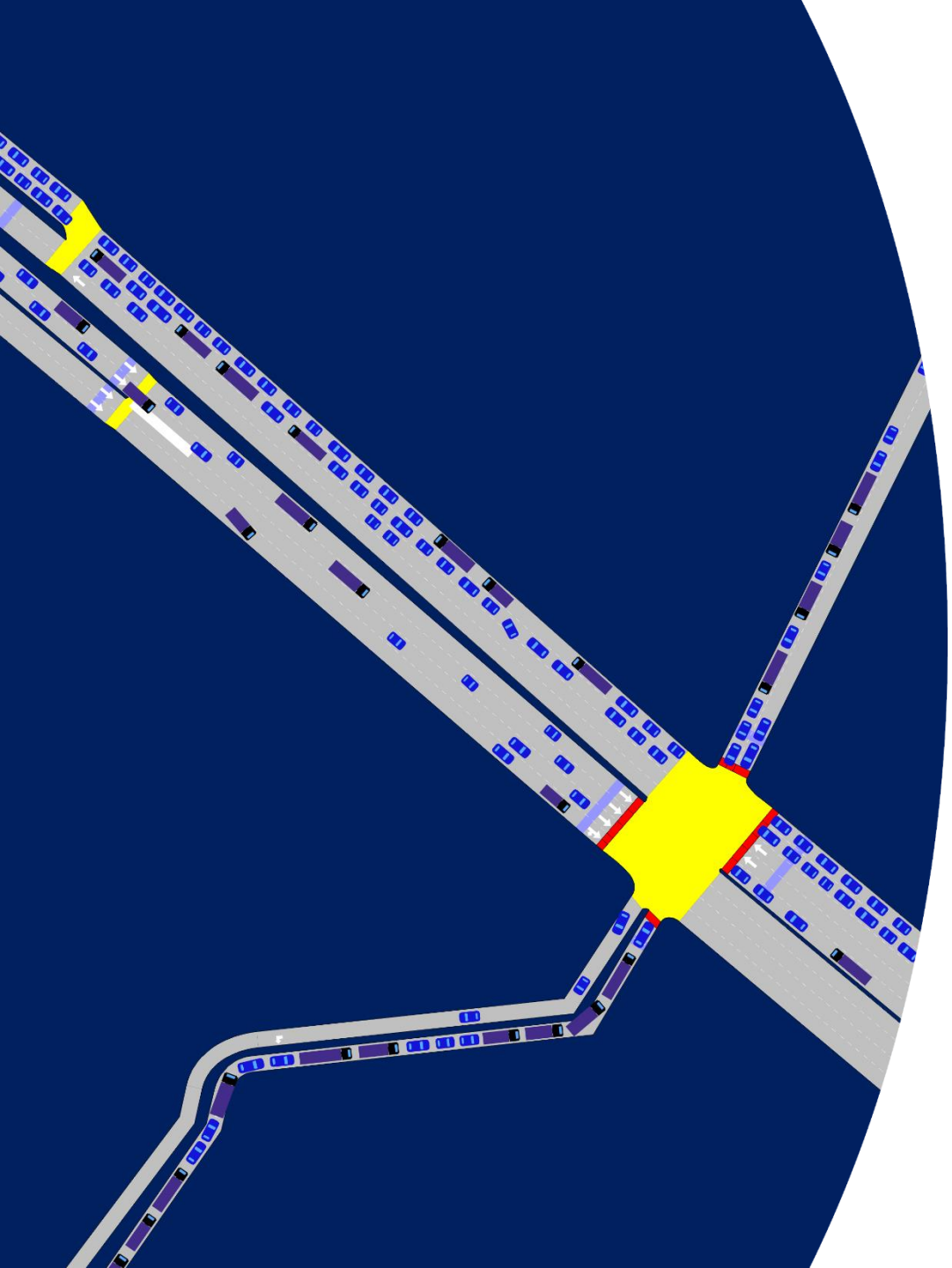

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Impacts of Autonomous Shuttle Services on Traffic, Safety and Environment for Future Mobility Scenarios

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Introduction

- Automation in road sector will impact private passenger cars and public transportation.
- Electric autonomous shuttles are expected to reduce operational costs while increasing ridership, as well as costs related to fuel consumption and driver employment.
- Shuttle bus use leads to a reduction in travel times for the pedestrians
- The 33% of the passengers feel safer in the shuttle than in conventional busses
- User enjoyment, benefits from autonomous shuttle use, resources available, perceived usefulness and first experience with autonomous shuttle influence their acceptability.

Objective

Impact assessment of an autonomous shuttle bus service on traffic, safety and environment in urban network.

Development of a microsimulation model to test future mobility scenarios and conditions:

- Peak and off peak hours
- Shuttle bus dedicated lane operation
- Accident occurrence

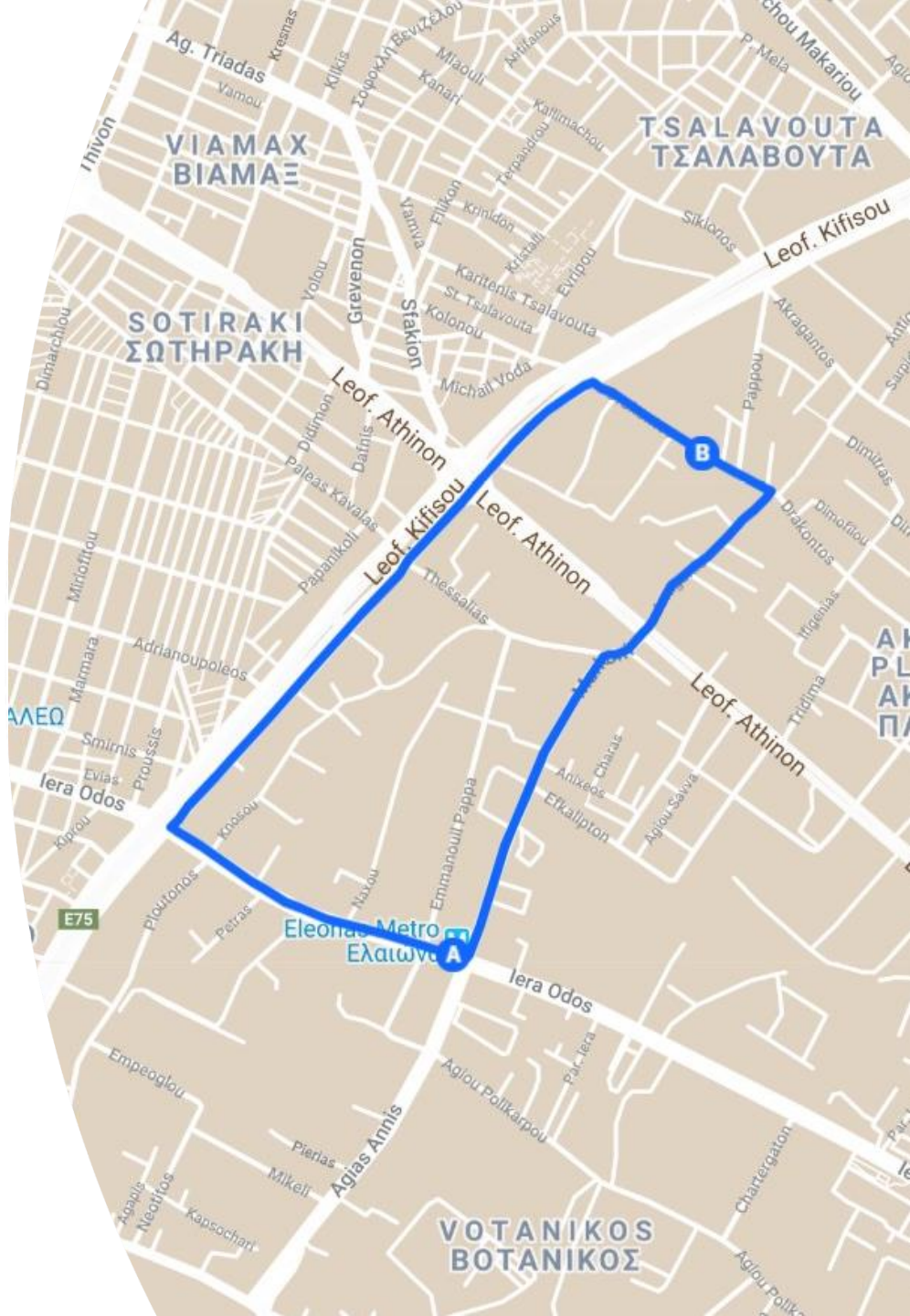
Use Case

Point to point automated shuttle service in Athens network in AIMSUN connecting:

A. the metro station “Eleonas” with
B. the Athens intercity bus hub.

Automated Shuttle service characteristics:

- 5.00 m length and 2.50 m width
- 10 passengers total capacity
- 40.0 km/h max operating speed
- 25.0 km/h mean speed
- 15 min service frequency
- 3.4 km route length
- No intermediate stations
- Signalized arterial and Secondary streets



Behavioral Model Parameterization

Automated Shuttle Bus:

- Cautious AV - connected

Surrounding Vehicles:

- The main AV profile is the "Cautious" AV profile:

  long clearance in car-following, long anticipation distance for lane selection, long clearance in gap acceptance in lane changing, limited overtaking, long gaps

- Two intermediate cautious profiles are created to normalize the appearance of automation in traffic:

  1st profile:
  more similar to a Human driven vehicle

  2nd profile:
  more similar to a Cautious AV

Models	Factors		Human Driven Vehicle	Cautious AV				
				Profile 1	Profile 2	Profile 2 conne-cted	Cautious AV	Cautious AV-conne-cted
	Safety Margin		1.0	1.25	1.75	1.75	2.0	2.0
Car Following Model	Sensitivity	Mean	1.0	1.3	1.4	1.4	1.5	1.5
		Min	1.0	1.0	1.1	1.1	1.1	1.1
		Max	1.0	1.5	1.8	1.8	1.9	1.9
	Vehicles Equipped with CACC:		0%	0%	0%	100%	0%	100%
Lane Changing Model	Overtake Speed Threshold:		90%	90%	85%	85%	85%	85%
	Cooperate in Creating a Gap:		YES	YES	NO	NO	NO	NO
	Distance Zone	Min	0.8	0.9	1.15	1.15	1.25	1.25
		Max	1.2	1.3	1.4	1.4	1.5	1.5

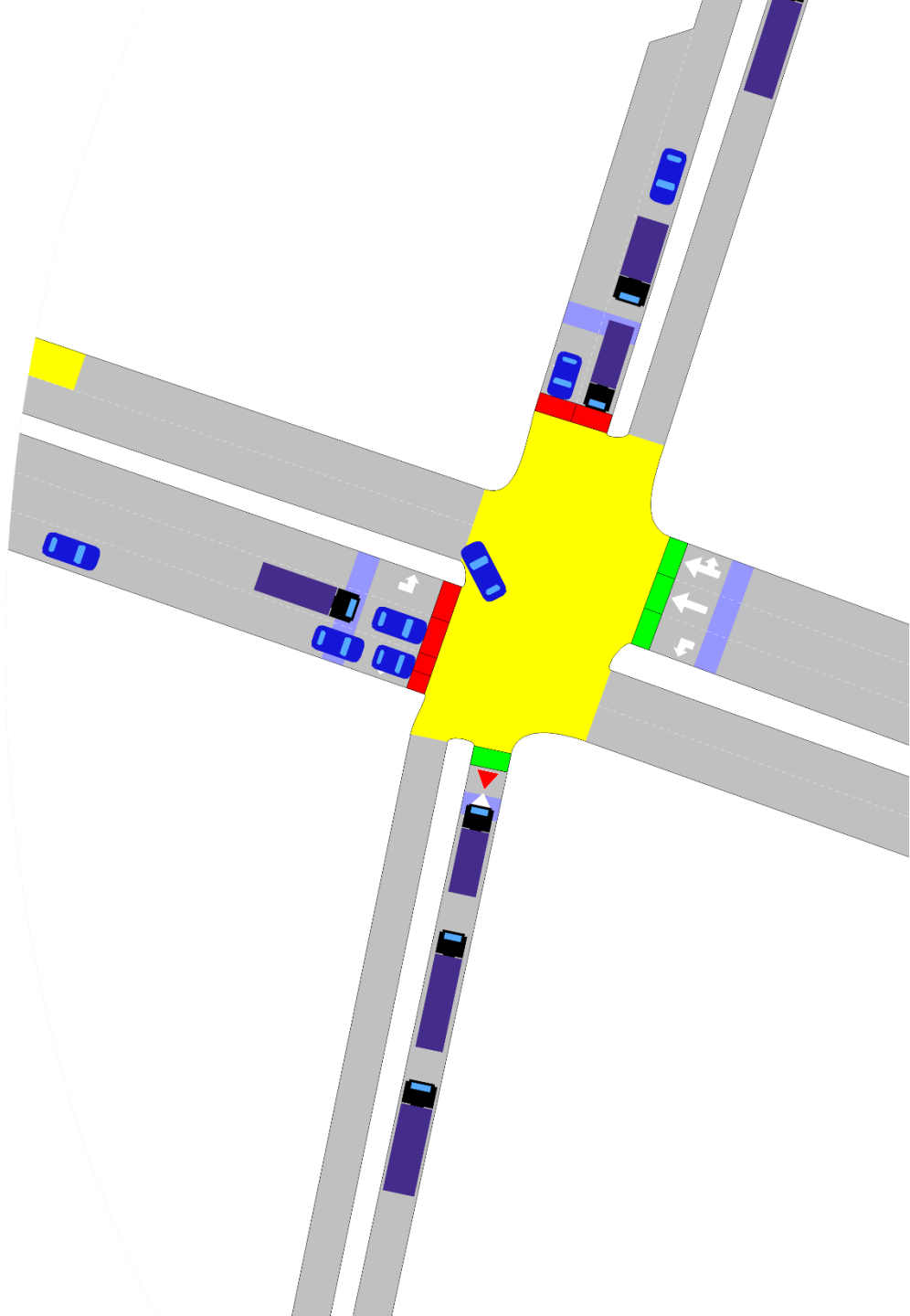
Scenarios

A. Scenarios on the shuttle bus route level:

- Horizon 2021
- With and without the shuttle bus service
- Peak and off peak hour

B. Scenarios on network level:

- Horizons 2021, 2040
- Peak and off peak hour
- Different future mobility scenarios
- Incident occurrence on the shuttle route
- With and without a dedicated lane for the shuttle service



Future Mobility Scenarios

- **No automation**:
  no automated vehicles are considered
- **Pessimistic**:
  low percentages of autonomous and connected vehicles are considered
- **Neutral**:
  high percentages of autonomous vehicles and low of connected vehicles are considered
- **Optimistic**:
  high percentages of autonomous and connected vehicles are considered

Vehicle profiles	No Automation		Pessimistic Scenario		Neutral Scenario		Optimistic Scenario	
	2021	2040	2021	2040	2021	2040	2021	2040
Car Levels 0-2 fossil fuel engine	94%	68%	93%	48%	92%	31%	91%	14%
Car Levels 0-2 electric	6%	32%	6%	22%	7%	19%	7%	11%
Cautious AV Profile 1	0%	0%	1%	9%	1%	15%	2%	23%
Cautious AV Profile 2	0%	0%	0%	8%	0%	10%	0%	15%
Cautious AV Profile 2 - connected	0%	0%	0%	4%	0%	10%	0%	15%
Cautious AV	0%	0%	0%	6%	0%	8%	0%	11%
Cautious AV - connected	0%	0%	0%	3%	0%	8%	0%	11%

Impacts on the Shuttle Bus Route

- The speed variance of the Shuttle bus gets higher values during off peak hour than peak hour.
- The shuttle bus leads to increased delay times on its route, especially on the signalized arterials.
- Shuttle bus service affects traffic only during off peak hour, when the traffic is much lower and stochastic.

Traffic condition	Street type	Speed variance (km/h)	Delay Time (sec/km)			CO2 Emission (kg)		
			No Shuttle service	Shuttle service	Change	No Shuttle service	Shuttle service	Change
Peak hour	Signalized Arterial	34	130	130	0%	476.6	487.9	2%
	Secondary Street	13	246	252	2%	672.7	729.8	8%
Off Peak hour	Signalized Arterial	45	8	14	63%	256.1	318.4	24%
	Secondary Street	26	8	10	24%	135.5	132.8	-2%

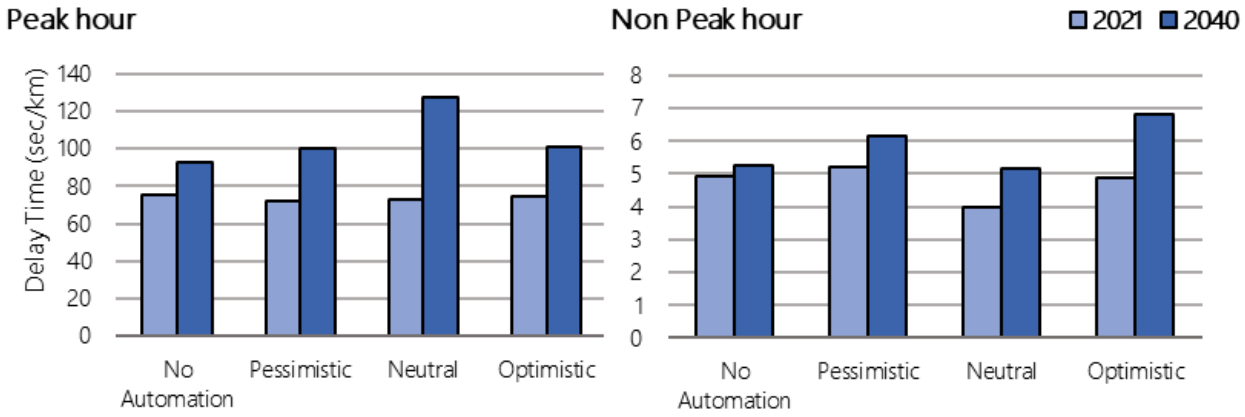
Network Level Safety Impacts

- Automation improves road safety, as the number of conflicts is reduced.
- Automation seems to lead to decreased numbers of rear end conflicts for both peak and off-peak hour scenarios.
- If the shuttle bus uses a dedicated lane, the number of lane change conflicts is higher.
- The number of rear end conflicts is increased if an incident occurs on the shuttle bus route.

Scenarios		Pessimistic		Neutral		Optimistic	
		2021	2040	2021	2040	2021	2040
Peak hour	Mixed traffic	-9%	-22%	-3%	-17%	1%	-6%
	Dedicated lane	17%	-17%	11%	-14%	46%	-8%
	Incident	-9%	-32%	0%	-21%	-5%	-13%
Off Peak hour	Mixed traffic	30%	98%	-68%	-43%	-33%	152%
	Dedicated lane	-5%	-7%	-17%	-2%	5%	8%

Network Level Traffic Impacts

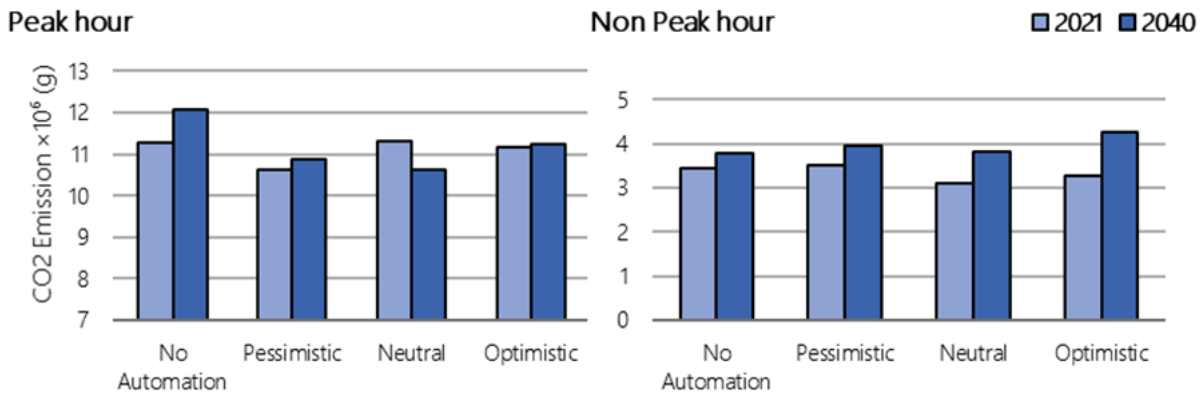
- Delay time gets higher values when more automated vehicles exist in the network.
- If the shuttle bus uses a dedicated lane, delay time is decreased during peak hour.
- An incident occurrence on the shuttle service route was not observed to affect traffic delays.



Scenarios		No Automation		Pessimistic		Neutral		Optimistic	
		2021	2040	2021	2040	2021	2040	2021	2040
Peak hour	Mixed traffic	75	92	72	100	73	127	74	101
	Dedicated lane	68	89	70	93	68	93	75	93
	Incident	75	95	71	95	73	91	71	99
Off Peak hour	Mixed traffic	5	5	5	6	4	5	5	7
	Dedicated lane	6	7	6	7	6	8	6	8

Network Level Environmental Impacts

- Automation decreases CO2 emissions during peak hour conditions, while no change in CO2 levels is observed during off peak hour.
- If the shuttle bus uses a dedicated lane, CO2 emissions are decreased during peak hour.



Scenarios		No Automation		Pessimistic		Neutral		Optimistic	
		2021	2040	2021	2040	2021	2040	2021	2040
Peak hour	Mixed traffic	11,287.5	12,075.2	10,625.8	10,889.0	11,303.0	10,613.3	11,157.4	11,237.6
	Dedicated lane	10,613.4	11,683.8	10,444.1	10,771.9	10,810.2	11,517.2	11,204.1	10,904.7
	Incident	11,746.3	12,557.4	10,816.5	10,662.5	11,284.7	11,614.8	11,035.3	11,261.2
Off Peak hour	Mixed traffic	3,429.3	3,798.2	3,497.7	3,956.3	3,100.2	3,815.8	3,286.9	4,262.3
	Dedicated lane	3,244.9	3,754.0	3,239.2	3,809.9	3,213.2	3,947.9	3,341.5	3,998.0

Conclusions

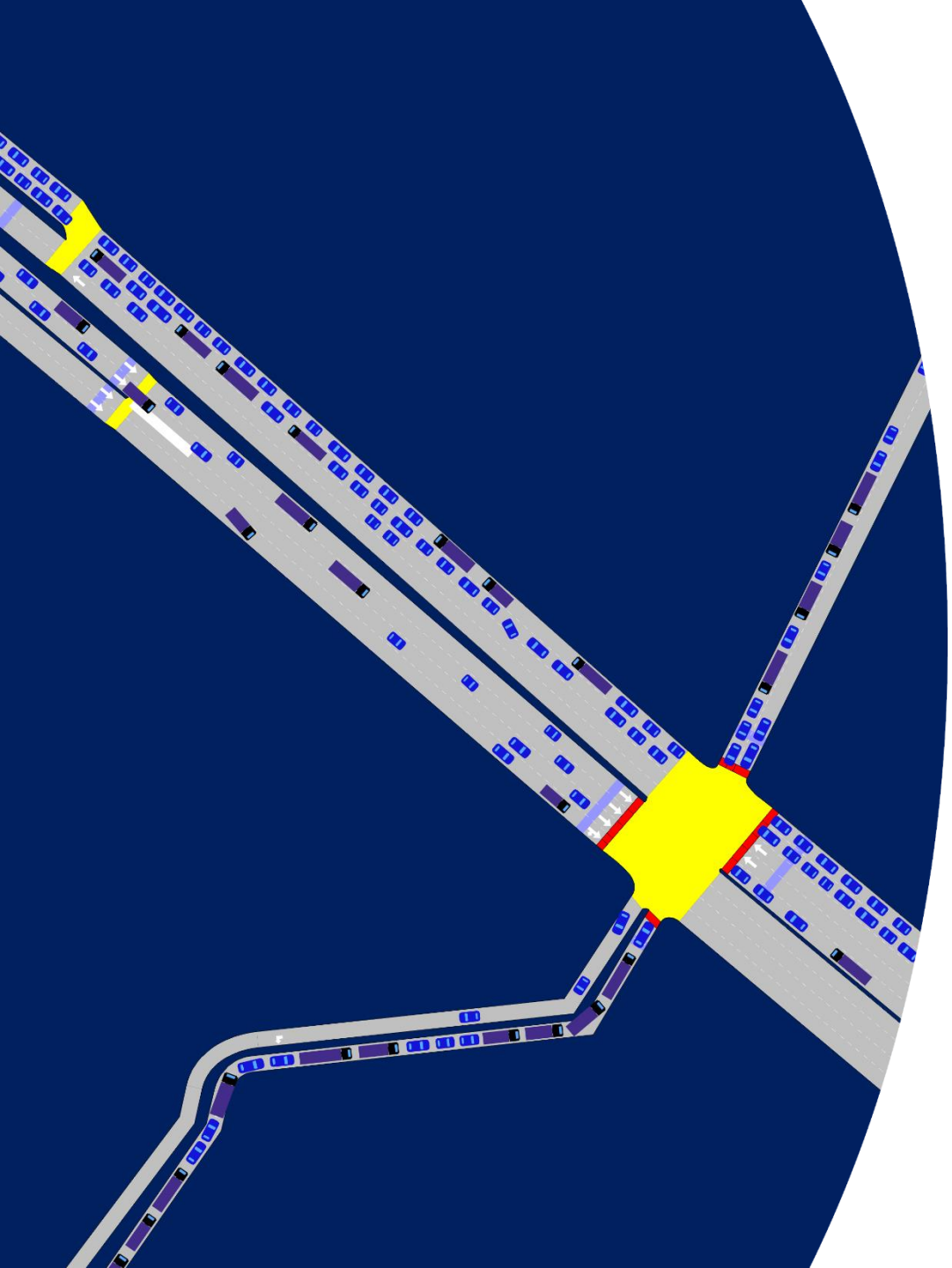
- The autonomous shuttle bus leads to increased delay times on its route, especially on the signalized arterials because of the higher speed limits.
- In case of dedicated lane, speed variance of shuttle bus and the prevailing traffic vehicles is up to 25 km/h during off peak hour.
- The analysis of the dedicated lane scenario revealed that both the delay time and CO2 emissions are decreased during peak hour.
- An incident occurrence on the shuttle service route was not observed to affect traffic delays.
- Automation decreases CO2 emissions during peak hour conditions while in contrary increases delay time. Nevertheless, improves road safety, as the number of conflicts is reduced.

Further Research

- More than one shuttle bus lines could be added in the city of Athens and investigate the impacts of a large-scale shuttle bus service in Athens in order to generalize the results to a city level.

- The impacts of drivers' behavior in the presence of automation and connectivity on the road network, in various urban contexts, should be investigated, since traffic conditions are expected to be mixed in the future.

- The integration of autonomous shuttle services to the future transport system where multiple different mobility on demand services in a city network will operate may deserve further research.



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