TES_03 'To improve transit services through dynamic multimodal management of PT corridor'

Description of the measure and main outcomes expected

The measure TES_03 aims to develop and evaluate alternative plans with respect to the reallocation of public space along a major signalized urban arterial corridor (i.e. Egnatia Street) in the city of Thessaloniki. To this end, **a microscopic traffic simulation model is developed to examine the impacts of the alternative plans on vehicular and pedestrian traffic**. This measure is expected to increase the level of service (LoS) for public transport (PT) and pedestrians, to improve accessibility to/from metro stations, facilitate multimodal trip making, shift travel demand towards sustainable transport modes, and enhance the commercial character of the city center. Additionally, this measure will be combined with measure "TES_06: Social optimum-based traffic management to reduce PT travel times and increase user satisfaction" to assess the introduction of transit signal priority (TSP) in each public space reallocation plan.

Preparation of the measure

Egnatia St. is the only two-way major signalized urban arterial corridor that spans across the city of Thessaloniki and can serve eastbound/westbound through traffic apart from inter-city trips. During the past two decades, traffic flow performance had been significantly deteriorated along Egnatia St. due to the presence of the construction sites of the new metro line. Recently, most of the construction sites have been removed in line with the expected completion of the metro line, and normal traffic operations along Egnatia St. have been restored. Moreover, the city of Thessaloniki recently conducted a Sustainable Urban Mobility Plan (SUMP) that proposes specific interventions pertaining to the operation of PT and the allocation of public space on Egnatia St. Based on the recommendations of the SUMP, the measure TES_03 proposes and evaluates three alternative scenarios that encompass infrastructure changes and redesign of PT lines along Egnatia St., taking into consideration the expected opening of the metro line. Table 2 below depicts the current status (baseline scenario) and the proposed changes per alternative scenario on Egnatia St.. The proposed space reallocation plans, the introduction of the metro line, and the redesign of the PT bus lines are expected to convert this street into a modern multimodal signalized corridor capable of adequately accommodating increased travel demand levels in the future.

Scenario No.	Scenario Name	General Purpose Lanes	Exclusive Bus Lanes	Sidewalks	Metro Line	Cycling Lanes	Bus Trips (AM Peak)
0	Baseline	2 lanes per direction	1 lane per direction	Yes	No	No	127
1	Scenario 1	2 lanes per direction	1 lane per direction	Yes	Yes	No	89
2	Scenario 2	1 lane per direction	1 lane per direction	Yes	Yes	1 middle lane per direction	89
3	Scenario 3	1 lane per direction	1 lane per direction	Yes	Yes	1 side lane per direction	89

Table 1 Infrastructure status and PT operation plan per examined scenario

The proposed alternative scenarios refer to future traffic conditions that do not currently prevail on Egnatia St.. For example, the introduction of the new metro line in Thessaloniki's transport system by the end of 2024 is expected to have profound implications on travel demand per transport mode. In the context of this simulation analysis, the mode choices per alternative scenario are inherited from the projections of SUMP and a General Transport Study that has been recently conducted for the future expansion of Thessaloniki's metro system. Findings from both studies have been rigorously assessed to select legitimate modal splits per alternative scenario (Table 3). Bicycle traffic has not been simulated for the first two scenarios, since very few bicycles run on Egnatia St. in real world conditions due to the absence of dedicated infrastructure. However, the existence of an exclusive bike lane per direction in future Scenarios 2 and 3 is expected to attract more bike trips. Additionally, the latter transport studies did not include information about the shares of light goods vehicles (LGV) and heavy goods vehicles in future scenarios. Thus, the numbers of the baseline scenario have been also adopted for the future scenarios. Finally, it can be observed that the introduction of the metro line, the redesign of the PT bus lines, and the allocation of existing space on the road to exclusive bike lanes is expected to shift travel demand from private means to public transport, walking and cycling.

Transport Mode	Mode Abbreviation	Baseline Scenario	Scenario 1	Scenario 2	Scenario 3
Private Car	**LV**	55.6%	46.22%	41.68%	41.68%
Taxi	**TAXI**	1.7%	1.51%	1.51%	1.51%
Light Goods Vehicle	**LGV**	2.4%	2.40%	2.40%	2.40%
Heavy Goods Vehicle	**HGV**	0.7%	0.71%	0.71%	0.71%
Public Transport	**PT**	18.5%	22.42%	24.09%	24.09%
Walking	**PED**	21.1%	24.10%	24.10%	24.10%
Bicycle	**BIC**	-	-	1.61%	1.61%

Table 2 Mode choice per examined scenario

Each scenario has been simulated with the use of the microscopic traffic simulator SUMO (Alvarez Lopez et al., 2018). A description of the development process of each simulation model is presented in dedicated sections below. A comparative analysis of the simulation results has been conducted to evaluate the impacts of the new public space reallocation and PT operation plans. In specific, several KPIs pertaining to network-wide and vehicle performance have been estimated, such as average network speed, average delay per vehicle type, number of stops per vehicle, and others.

Baseline Scenario: Existing transport infrastructure and traffic conditions

The baseline simulation model encompasses the existing topology of Egnatia St. as well as the currently available transport modes that operate along the latter signalized arterial corridor. In its existing configuration Egnatia St. has two general purpose (GP) lanes and one exclusive bus lane per direction. The network topology was imported in SUMO via OpenStreetMap and was modified to reflect the actual road layout with high precision. There are 12 bus stops on the eastbound direction, and 11 on the westbound one. The locations of the bus stops were imported in SUMO via a GIS file that is publicly available from the Organisation of Urban Transportation of Thessaloniki (OASTH), and configured (dimensions and person capacity) via SUMO's network editor (netedit). Traffic control elements (traffic signs and signals) and traffic monitoring devices (magnetometers) were also input and configured in netedit. Specifically, traffic signal plans were provided by Yunex Greece (technology provider that has installed and maintains the traffic controllers on Egnatia St.) in OCIT-C format. A script was developed to automatically translate the traffic signal plans in SUMO compatible file format. A manual cross-validation approach was adopted to ensure that the translation had produced correct SUMO input files for traffic signal control in the simulation model. The locations of the 66 traffic detectors that are installed along Egnatia St. and operated by the Region of Central Macedonia (RCM) were provided by RCM in GIS format. They were inserted and configured as induction loop detectors (E1) in SUMO.

Figure 19 depicts the network topology of the baseline simulation model with snapshots of the two major signalized intersections of the corridor.

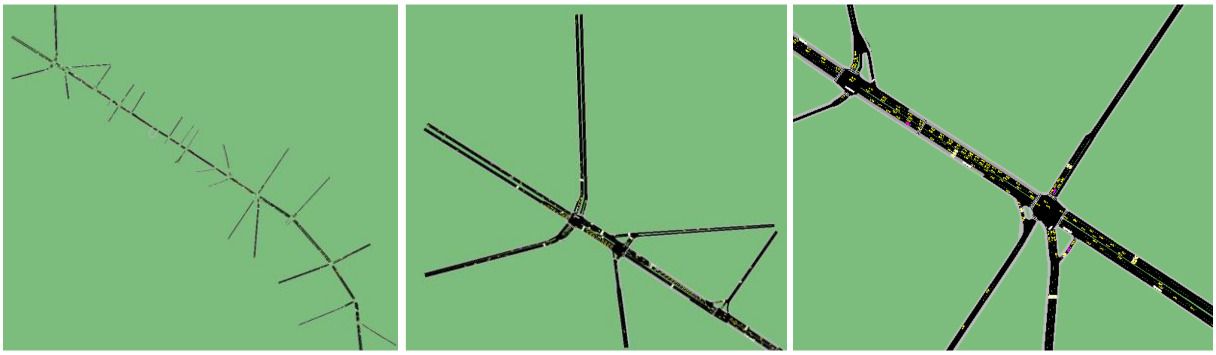

Figure 1 Network topology in the baseline traffic simulation model

Demand loading has been based on two different datasets containing traffic flow counts observed on Egnatia St.. On the one hand, traffic flow counts have been collected via the detection equipment of the Traffic Management Center (TMC) of RCM that is installed on 8 out of 12 signalized junctions along Egnatia St., while on the other hand traffic flow counts, splits rates, and traffic composition (percentage of private cars, light goods vehicles, heavy goods vehicles, and taxi) were collected via an on-site traffic count study conducted by CERTH that encompassed all junctions on Egnatia St.. Both datasets were used to estimate incoming traffic flows and corresponding split rates for all junctions on Egnatia St. during the morning rush hour (08:00-09:00AM). Figure 20 depicts the latter information for two major signalized junctions on Egnatia St.. Incoming traffic flows and split rates per junction were input to SUMO's "routeSampler.py" script to generate a realistic traffic pattern that fulfills the counting data.

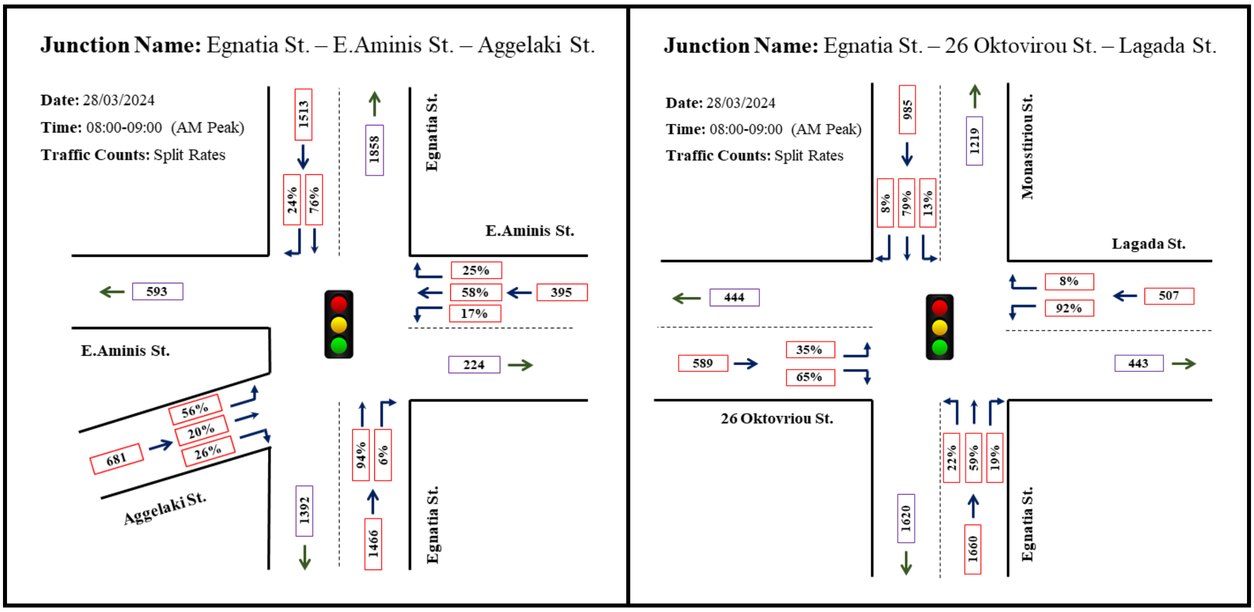

Figure 2 Traffic flow counts and split rates at two major signalized junctions on Egnatia St.

Pedestrian counts were also collected via a dedicated onsite study conducted by CERTH. These counts were used to estimate pedestrian movements (in the form of Origin-Destination Matrices) at six junctions along Egnatia St. where metro stops have been constructed. The ""routeSampler.py" script was used to generate a realistic pedestrian traffic patterns across the whole corridor that fulfilled the counting data. Figure 21 depicts the counting areas at two major signalized junctions on Egnatia St., while Table 4 shows the number of walking trips per feasible pedestrian movement at Egnatia St. – E.Aminis St. – Aggelaki St. junction.

Figure 3 Locations of pedestrian flow measurements at two major signalized junctions on Egnatia St.

Junction Name: Egnatia St. – E.Aminis St. – Aggelaki St.										
O / D	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Total**
1	0	60	44	4	12	4	0	8	4	136
2	40	0	12	4	0	4	8	12	20	100
3	32	0	0	4	4	32	32	16	4	124
4	12	0	0	0	0	4	60	0	4	80
5	28	4	4	4	0	4	8	0	0	52
6	0	4	12	4	0	0	20	4	76	120
7	16	8	36	12	0	44	0	0	72	188
8	64	16	20	0	0	16	4	0	56	176
9	44	8	24	16	4	60	176	28	0	360

Table 3 OD Matrix of walking trips at Egnatia St. – E.Aminis St. – Aggelaki St. junction

Information about existing bus lines, schedules, and ridership per line during the morning rush hour along Egnatia St. was provided by the Transport Authority of Thessaloniki (TheTA) and integrated into the simulation model. Table 5 shows the number of bus trips executed along each bus line during the morning rush hour and the average number of passengers per bus trip.

	Baseline Scenario		
No.	**Bus Line**	**Trips / Hour**	**Average Number of Passengers**
1	01X	6	27
2	02K	7	57
3	7	5	13
4	10	9	49
5	11-11B	7	37
6	14	9	53
7	17	9	14
8	20	4	11
9	21	3	11
10	22	1	27
11	25	4	7
12	26	4	9
13	27	8	17
14	28	3	52
15	29	5	3
16	31	4	39
17	32-32A	3	20
18	34	4	12
19	35	3	9
20	37	4	28
21	38	2	27
22	39	3	42
23	45A-45B	3	12
24	57	6	69
25	83-83B-83M	11	26

Table 4 Number of trips and average ridership per bus line operating along Egnatia St. during morning rush hour

Error checking was made to verify the accuracy of the coded input data. Specifically reviews of the coded network, coded demand, and default parameters were conducted to ensure that the calibration process did not result in parameters that were distorted to compensate for overlooked coding errors. Subsequently, a trail-and-error approach was adopted to calibrate model parameters for the development of a valid base model. Emphasis was placed on the calibration of model parameters related to car following, lane changing and vehicle insertion. Table 6 depicts the values of calibrated model parameters that achieved a substantial reconciliation of simulated traffic flows and travel times. Values within the parenthesis indicate the mean and standard deviation of the normal distribution that was used to generate values for vehicle parameters, while values within brackets indicated the minimum and maximum values that vehicle parameters could obtain from the distribution. Simulated and real-world traffic flows were compared on 34 intersection legs, while the respective travel times (estimated from floating car data) were compared along 6 routes on Egnatia St. (Figure 22). The comparative results shown on Figure 23 indicate that simulated traffic replicates with high accuracy the actual traffic conditions and that the baseline simulation model is valid.

Parameter Name	Private Car	Taxi	Light Goods Vehicle	Heavy Goods Vehicle	Bus
carFollowModel	Krauss	Krauss	Krauss	Krauss	Krauss
sigma	(0.5,0.1); [0.0,1.0]	(0.5,0.1); [0.0,1.0]	(0.5,0.1); [0.0,1.0]	(0.5,0.1); [0.0,1.0]	(0.5,0.1); [0.0,1.0]
tau	(1.0,0.1); [0.8,1.5]	(1.0,0.1); [0.8,1.5]	(1.1,0.1); [0.8,1.5]	(1.3,0.1); [1.1,1.8]	(1.3,0.1); [1.1,1.8]
decel	(4.5,0.3); [3.5,5.0]	(4.5,0.3); [4.0,5.0]	(4.5,0.2); [3.5,5.0]	(4.0,0.1); [3.8,4.2]	4
accel	(2.6,0.2); [2.0,3.0]	(2.7,0.2); [2.3,3.2]	(2.5,0.2); [2.0,3.5]	(1.5,0.2); [1.1,1.7]	1.2
speedFactor	(1.1,0.1); [0.8,1.2]	(1.1,0.1); [0.9,1.2]	(1.1,0.1); [0.9,1.1]	(1.0,0.1); [0.9,1.1]	(1.0,0.1); [0.9,1.1]
emergencyDecel	9	9	9	9	7
color	yellow	blue	magenta	gray	white
vClass	passenger	passenger	delivery	truck	bus
departLane	best	best	best	best	best
departPos	base	base	base	base	base
departSpeed	max	max	max	max	max
arrivalLane	random	random	random	random	random
arrivalPos	max	max	max	max	max

arrivalSpeed	current	current	current	current	current
length	(5.0,0.2); [4.0,5.6]	(5.0,0.2); [4.0,5.6]	(6.5,0.2); [6.0,7.0]	(8.0,0.2); [7.0,9.0]	12
width	1.8	1.8	(2.0,0.1); [1.9,2.2]	(2.4,0.1); [2.3,2.5]	2.5
lcAssertive	(1.1,0.1); [1.0,1.2]	(1.1,0.2); [1.0,1.2]	(1.0,0.2); [0.9,1.1]	(1.0,0.2); [0.9,1.1]	(1.0,0.2); [0.9,1.1]

Table 5 Parametrization of core SUMO models per simulated vehicle type

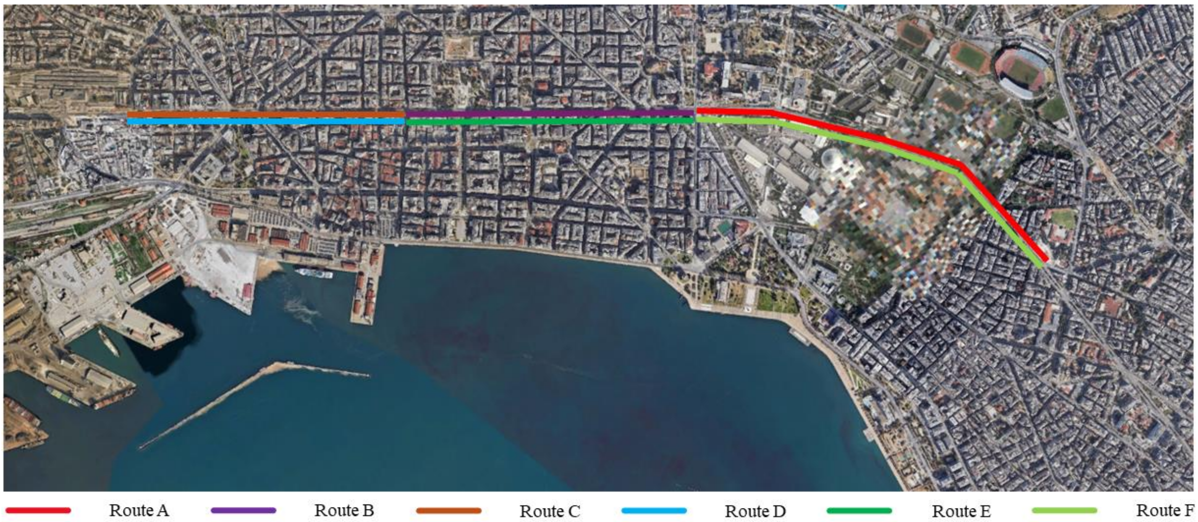

Figure 4 Definition of routes per direction along Egnatia St. for calibration purposes

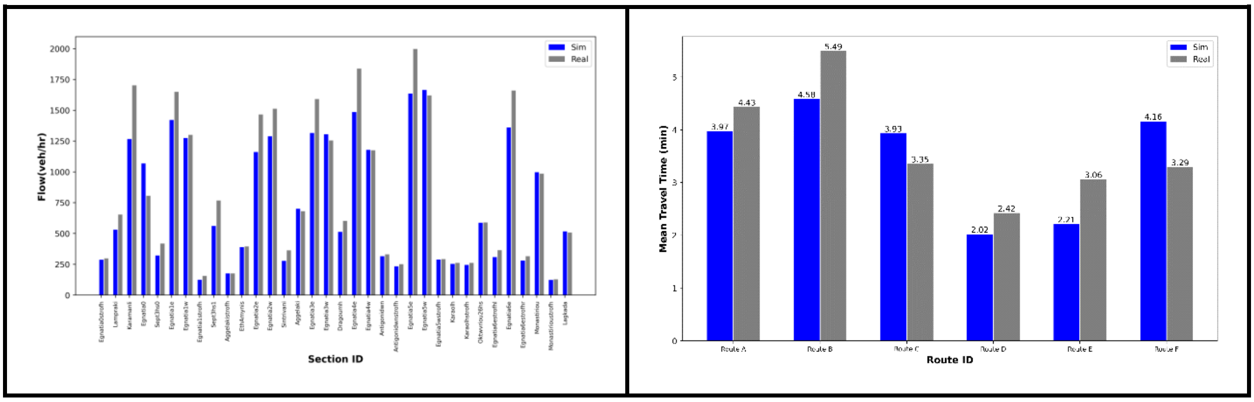

Figure 5 Comparison of simulated and real-world traffic flow performance measurements (traffic flow and travel time) pertaining to the baseline simulation model

Scenario 1: Metro line and redesign of PT bus lines

The newly constructed metro line below Egnatia St. that will become operational by the end of 2024 has been integrated into the baseline simulation model. Additionally, changes were made to the schedules of the bus lines that were input to the baseline model, according to one of the redesign plans of public transport that TheTA is considering implementing in the city of Thessaloniki concurrently with the beginning of the metro line operation. Specifically, the redesign plan integrated in the simulation model of Scenario 1 foresees the reduction of bus trips on the existing bus lines along Egnatia St. by 30%. Average ridership per bus line has been assumed to remain constant. Table 3 depicts the model split simulated in Scenario 1. Vehicular and pedestrian traffic patterns have been updated considering the new number of trips conducted with each transport mode. All other elements of this simulation model have remained the same as in the baseline model. Impact assessment will be based on the same simulation results and key performance indicators (KPIs) as the baseline model.

Scenario 2: Metro Line, redesign of PT bus lines, and exclusive right-side bike lane

The simulation model of Scenario 2 is based on that of Scenario 1 but also encompasses the reallocation of road space to different transport modes. In Scenario 2, the road layout is comprised of 1 GP lane, 1 exclusive bus lane, 1 exclusive bike lane next to the sidewalks, and wider pavements for pedestrians per direction. Table 3 depicts the modal split simulated in Scenario 1. Vehicular and pedestrian traffic patterns will be updated considering the new number of trips conducted with each transport mode. Traffic signal plans will be adapted to accommodate bicycle traffic. All other elements of this simulation model will remain the same as in the simulation model of Scenario 1. Additional KPIs related to bicycle traffic will be defined and estimated for impact assessment purposes.

Scenario 3: Metro Line, redesign of PT bus lines, and exclusive bike lane in the middle

The simulation model of Scenario 3 is similar to that of Scenario 2 but for the location of the exclusive bikes lanes which are placed in the middle of the street instead of the right-most part of it (next to the sidewalks). All other elements of this simulation model will remain the same as in the model of Scenario 2.

Preliminary Analysis of Simulation Results

A preliminary analysis of the Baseline and Scenario 1 simulation results has been conducted to determine the impacts of the introduction of the new metro line and the redesign of the public transport operation plans. Impact assessment has been based on traffic related KPIs estimated per vehicle type. Figure 24 depicts the boxplots of average vehicle speed per vehicle type for the two simulation scenarios. It can be observed that demand shift towards public transport and reduction of bus trips across Egnatia St. substantially increases average vehicle speed for all simulated vehicle types (approximately 25%). Moreover, a significant reduction of the number of stops per vehicle is observed for all vehicle types in Scenario 1 (Figure 25). Overall, the provision of enhanced public transport service along Egnatia St. is expected to generate significant travel time savings.

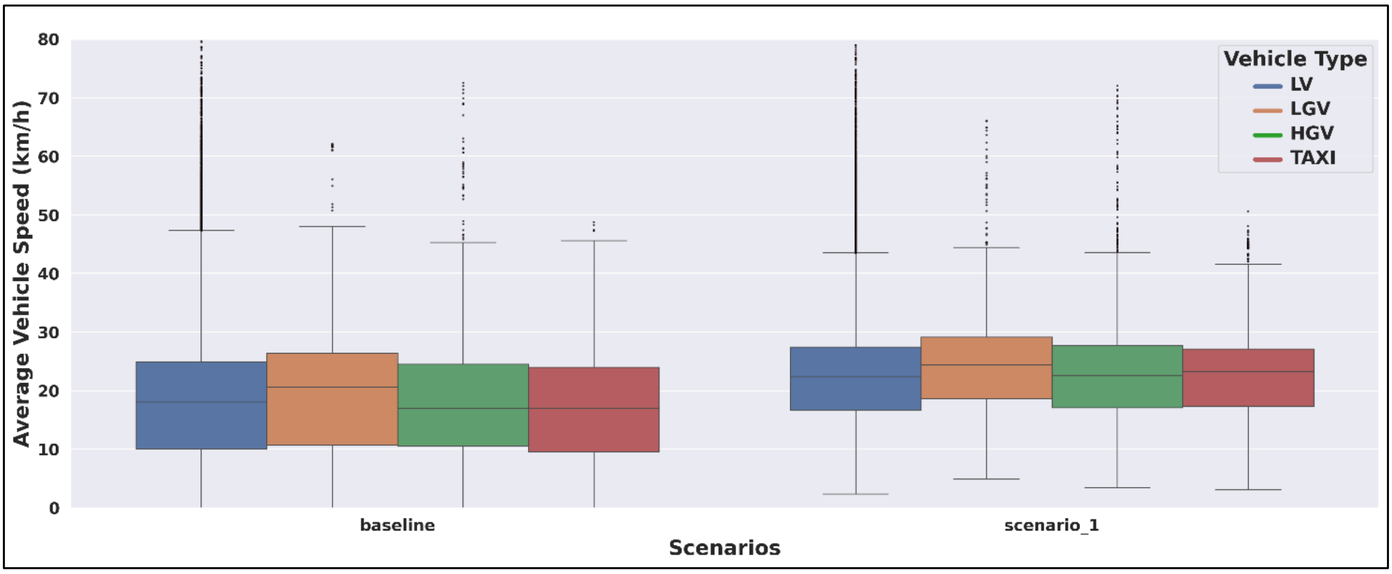

Figure 6 Distribution of average vehicle speeds per vehicle type for the Baseline Scenario and Scenario 1

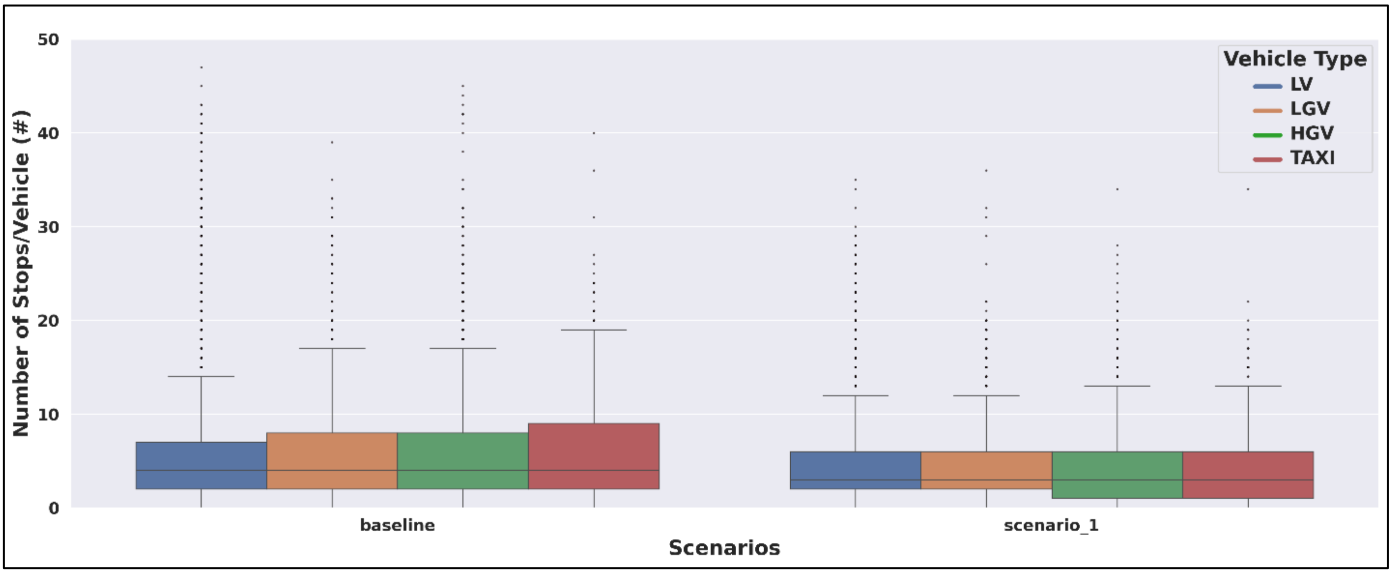

Figure 7 Distribution of average vehicle speeds per vehicle type for the Baseline Scenario and Scenario 1

Challenges & Mitigations

The error-checking and calibration tasks related to simulation model development are time-consuming and tedious. Thus, significant resources were allocated to review coding errors and calibrate model parameters to build a baseline simulation model that reflects real-world traffic conditions with high accuracy. Additionally, it is expected that significant resources will be required for the adaptation of traffic signal plans to cater for bicycle traffic in Scenarios 2 and 3. This process cannot be automated and will have to be manually conducted based on expert’s knowledge about traffic signal timing.

Next steps towards implementation

Within the next period simulation models pertaining to Scenarios 2 and 3 will be developed. Moreover, a more in-depth and comprehensive assessment of simulation results obtained from the Baseline and Scenario 1 simulation models will be conducted that will also account for KPIs related to vehicular emissions and pedestrian traffic.