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Calibrating driver's decision to cross or not during the yellow phase; a microsimulation study

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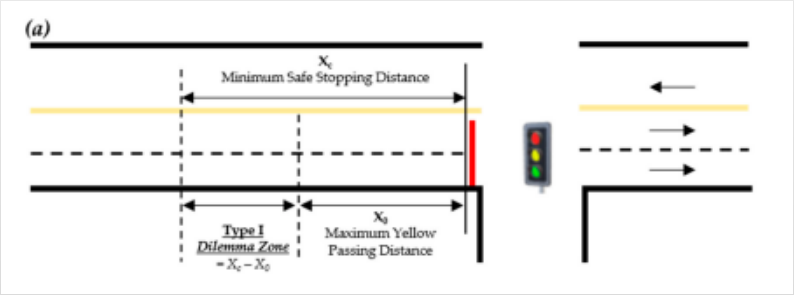
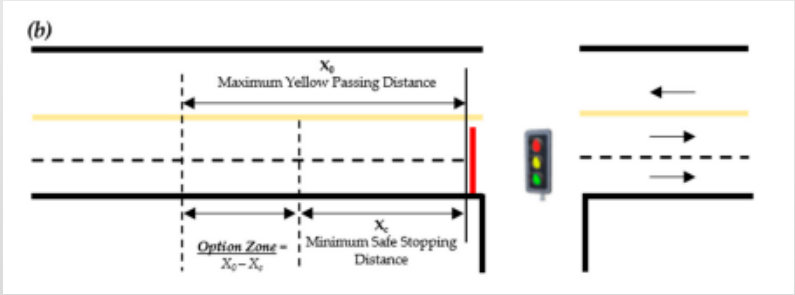
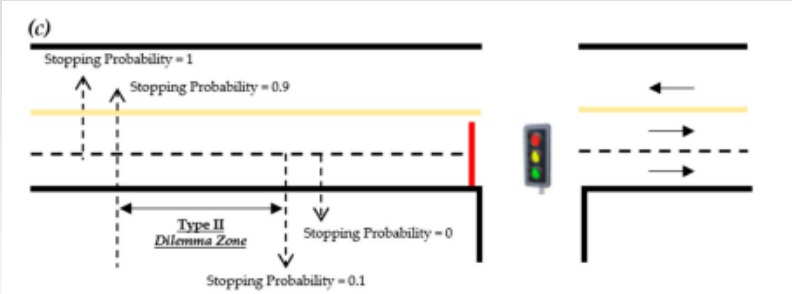
- accident statistics → most of traffic accidents occur at intersections, some of which are signalized (Hakkert & Mahalel, 1978)
- main issue at signalized intersections → driver's decision whether or not to cross the intersection during the yellow signal
- dilemma zone → area near the stop line, within which drivers traveling at the legal speed limit can neither stop nor clear the intersection sucesfully (Gazis et al., 1960); (Papaioannou, 2007)



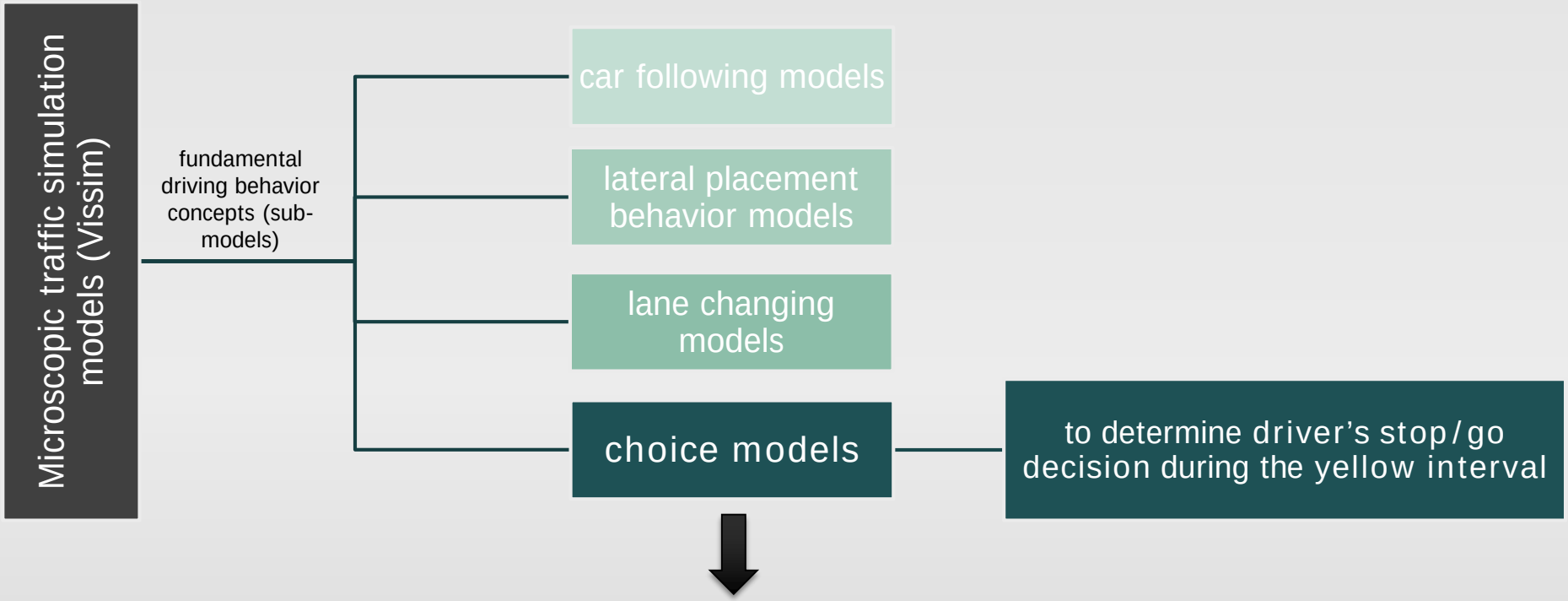
Type I dilemma zone



Option zone



Type II dilemma zone



Vissim uses decision factors (*distance to stop line* & *approaching speed* *at the onset of the yellow signal*) to determine driver's choice to either proceed or stop when facing a yellow signal

The coefficients of those factors are set to predefined values proposed by the software manufacturers, which in some cases may not be able to replicate the driving conditions of the area concerned

Vissim allows users to input a range of values for different factors, including those affecting driver's stop/go behavior in the yellow interval

purpose of current study

➡ examine whether Vissim default parameter values are capable of representing the actual field conditions in terms of driver's stop/go behavior during yellow phase at a typical signalized intersection in eastern Thessaloniki, Greece

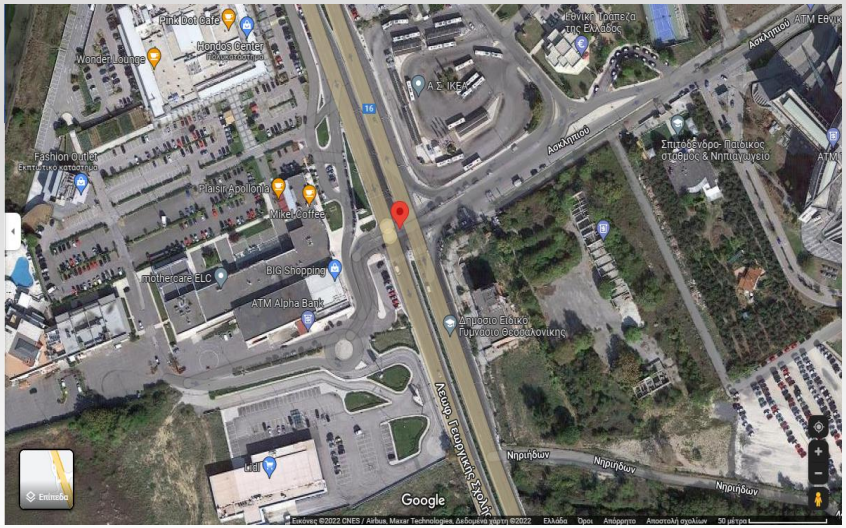
➡ if not, to calibrate those parameter values based on a binary choice model, developed using field data

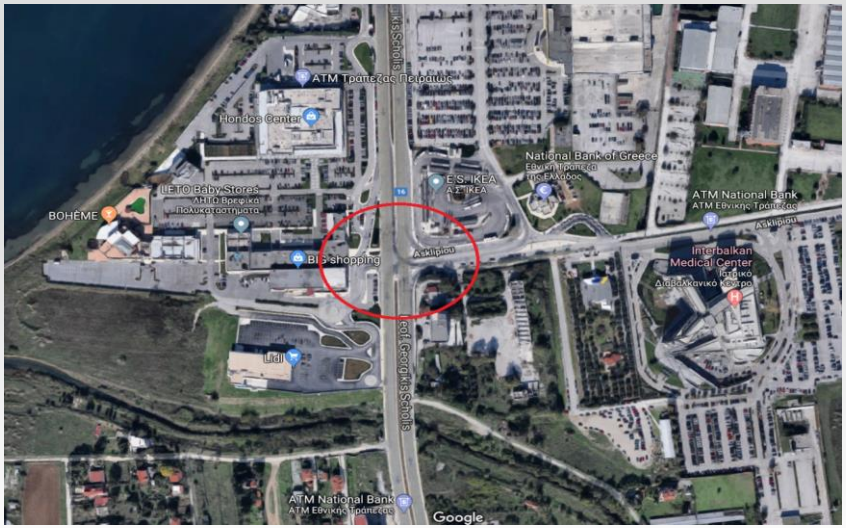
study area --> a signalized cross-shaped intersection, located in eastern Thessaloniki, Greece

traffic data --> collected only for one approach of the intersection (the one that connects the city of Thessaloniki with the “Makedonia” airport, one of the major trip generators in the wider area of Thessaloniki)

chosen road section --> smooth traffic conditions, with a traffic flow of 1,500 vehicles/hour and a capacity of 6,000 vehicles/hour (morning peak-hour)

- collection of adequate data
- absence of saturation conditions (no affect phenomenon under consideration)





collected data

data required for network building (Vissim)

⇩

basic field data

- road and intersection geometry
- traffic volume
- signal timing

collected through field observation

- road section under consideration --> 3 traffic lanes, 3,5 m wide each
- signalization of intersection --> priority to direction towards airport --> significantly higher traffic load than the crossing road
- cycle length of intersection (approach of concern) = 85 s (green signal duration = 50 s, red = 31 s, yellow = 4 s)
- traffic volume --> set so as on average, 60 veh/hour simulation to be captured within 140 m from traffic light, at the time of yellow indication (*based on field observations*)
- car speed = 70 km/h (posted speed limit)

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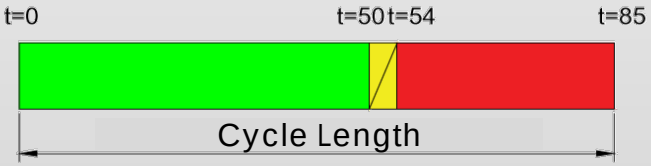
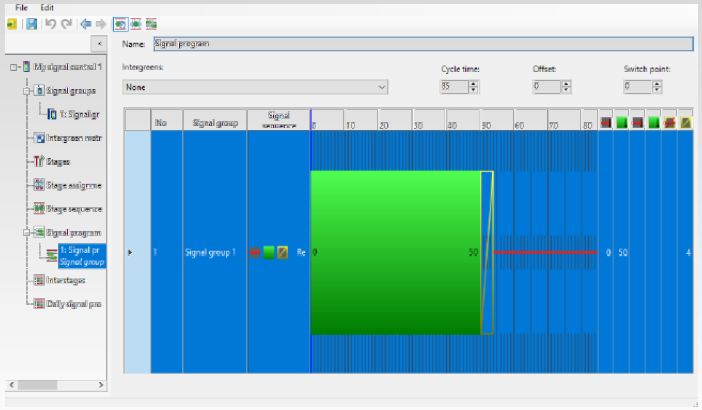




collected data

data required for modeling driver's behavior
(to calibrate default Vissim parameter values of those parameters affecting driver's stop/go decision during the yellow interval)

⇩

collected through video recordings captured by an UAV (built-in high-resolution camera)

⇩

500 vehicles captured to face yellow signal

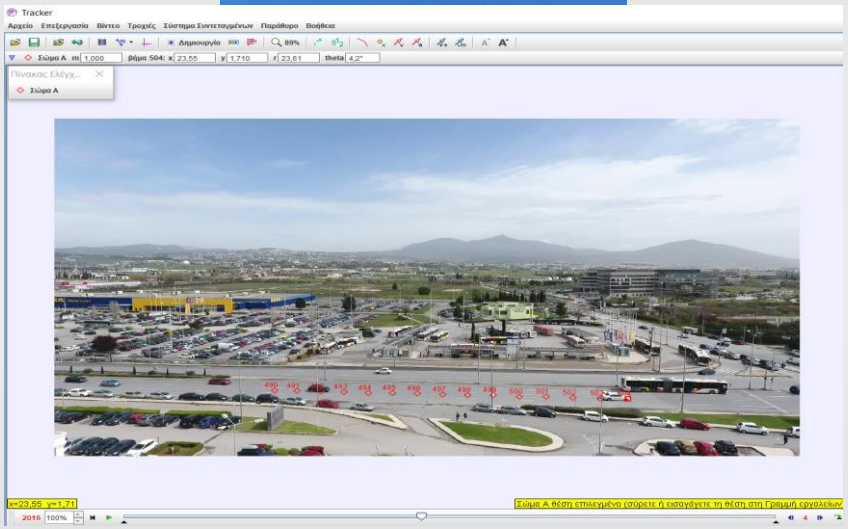
⇩

Tracker Video Analysis and Modeling Tool (special kinematic analysis software) for analyzing the motion of vehicles from the collected videos

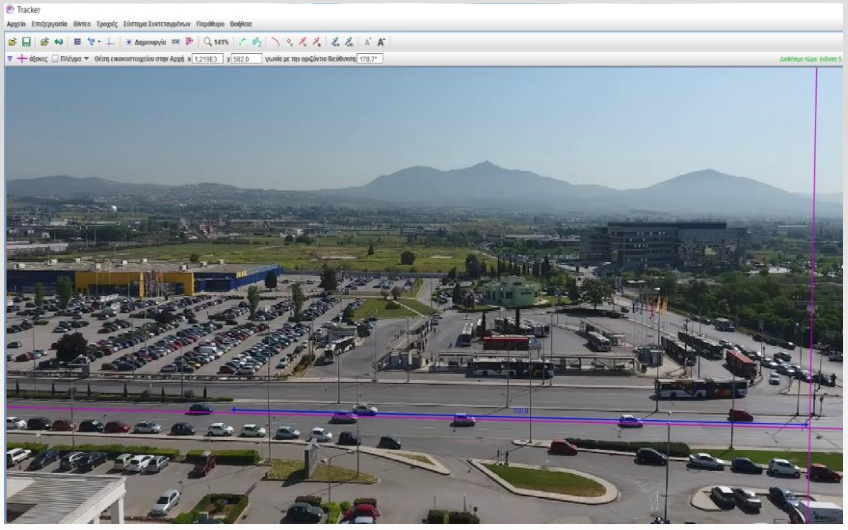
⇩

several data recorded (calculated variables) for vehicles facing yellow signal, including:

- *approaching speed*
- *distance to stop line*
- *acceleration/deceleration*
- *type of vehicle*
- *driver's stop/go decision*

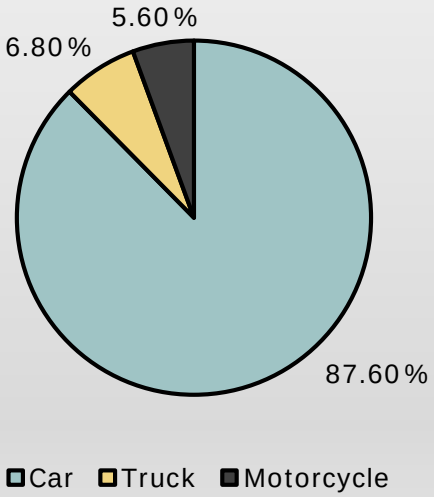


Kountouri E., Tracking of dilemma zone in signalized intersections of unmanned drone aircraft and development of a logistic regression model for decision making, 2019 (Undergraduate Diploma Thesis)



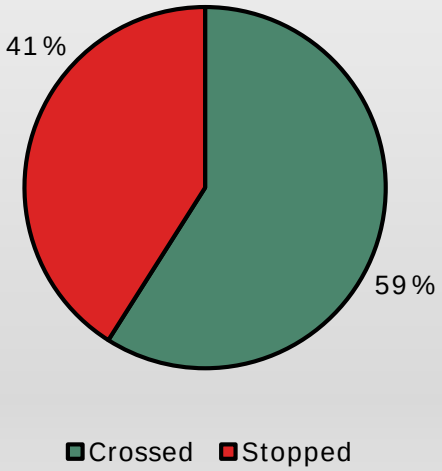
- sample size: N = 500 (number of vehicles observed to face the yellow signal)

type of vehicles:

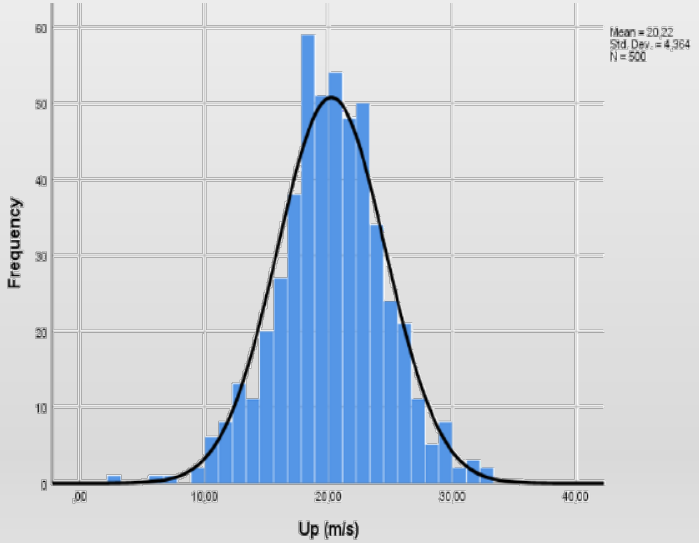


only this vehicle category was used for the simulation scenarios

driver's categorization based on stop/go decision:



approaching speeds at the initiation of yellow signal



average approaching speed at the initiation of yellow signal = 20,22 m/s (S.D. = 4.36) or 72,80 km/h, slightly higher than the posted speed limit (70 km/h)

Correlation of driver's decision with approaching speed and distance to stop line – field data

most drivers choose to clear intersection

vast majority of drivers decide to stop

for modeling driver's stop/go decision during yellow phase --> Vissim --> binary logistic regression model

dependent variable = binary stop/go outcome (0 = cross the intersection, 1 = stop)

calculation of the results…

$$P = \frac{1}{1+e^{-(a+b_1 \cdot v+b_2 \cdot dx)}}$$

(*PTV Vissim 10 User Manual*)

constant term (slope of graph)

coefficient of approaching speed

coefficient of distance to stop line

… *at the onset of yellow signal*

values of a, b_1 and b_2 --> *predefined* and *provided* by Vissim software *by default*, largely representing driver's stop/go behavior in Germany

- a = 1,59
- b_1 = -0,26
- b_2 = 0,27

⇨ using the default parameter values, the 1st simulation scenario was performed

⇩ results

- approaching speed & distance to stop line, of each vehicle at the time of the yellow signal (simulation paused at the exact moment of initiation of yellow indication and the relevant information was recorded)
- stop/go decision outcome (recorded by observing each vehicle's stop/go reaction, in a run simulation mode)

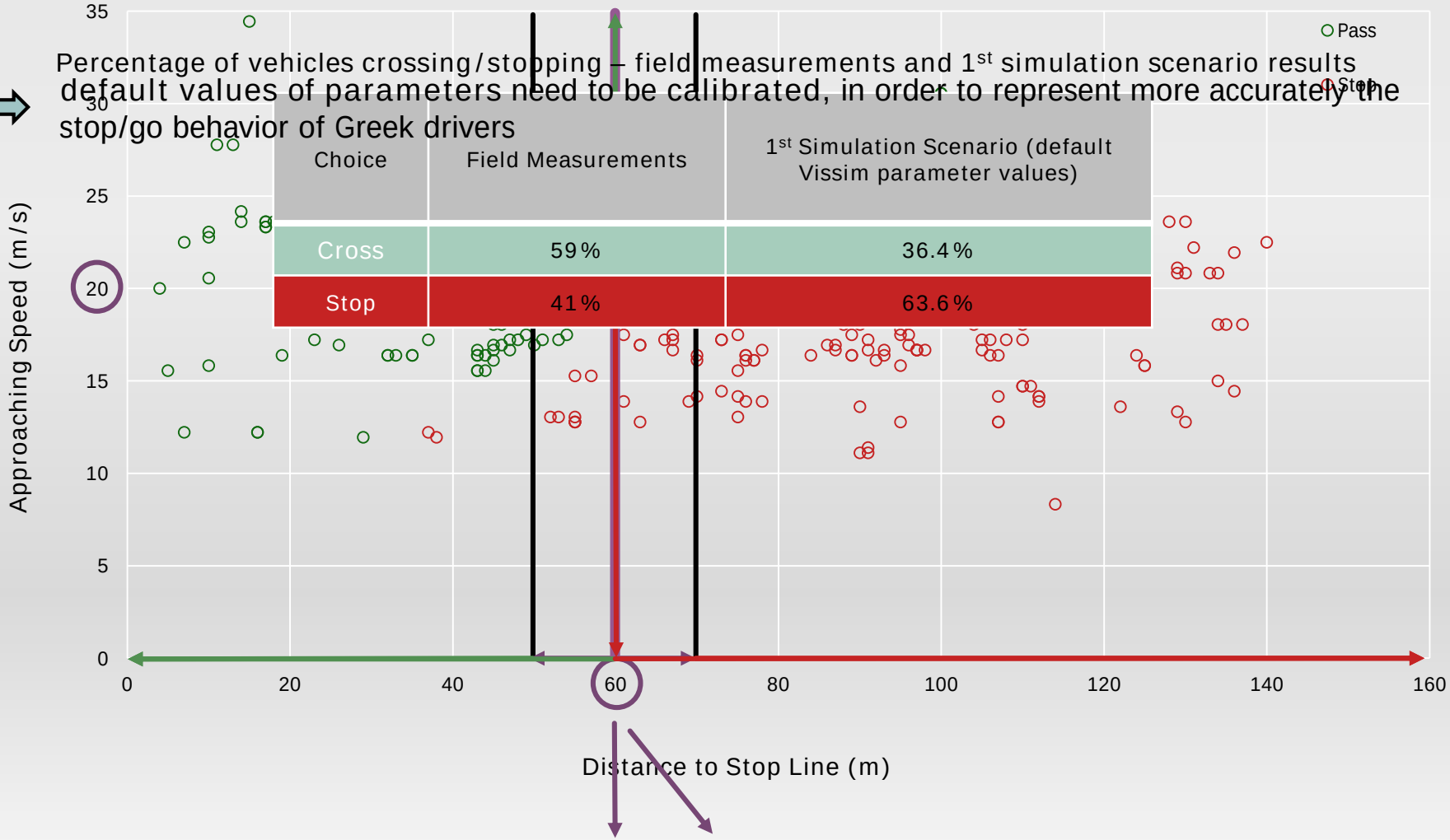
} for 500 vehicles (sample size from field observations)

1st simulation scenario --> when using the default Vissim parameters, the simulation may not adequately reflect the reality of the area concerned (in terms of driver's stop/go behavior during the yellow interval

⇨ Correlation of driver's decision with approaching speed and distance to stop line – 1st simulation scenario results: ~~inconsistent results --> barely~~ replicate the field conditions in terms of *total number of vehicles that crossed the intersection or stopped, during the yellow phase*)

⇨ default values of parameters need to be calibrated, in order to represent more accurately the stop/go behavior of Greek drivers

Percentage of vehicles crossing/stopping – field measurements and 1st simulation scenario results



most drivers decided to stop

distance to stop line for which there is not obvious stop/go decision, considerably decreases (60m - 100m based on field measurements)

significantly lower than the corresponding distance calculated using the field observations (80m)

most drivers decided to stop

most drivers decided to cross the intersection

- Calibrate default Vissim parameter values --> Binary Logit Choice model was developed --> relying on field data (collected using UAV technology and processed using Tracker Video Analysis and Modeling Tool)

- developed in an IBM-SPSS environment --> explaining driver's stop/go behavior as a function of observable factors

  - *distance to stop line*
  - approaching speed

  } factors considered by Vissim as contributing for driver's stop/go decision

at the initiation of yellow indication...

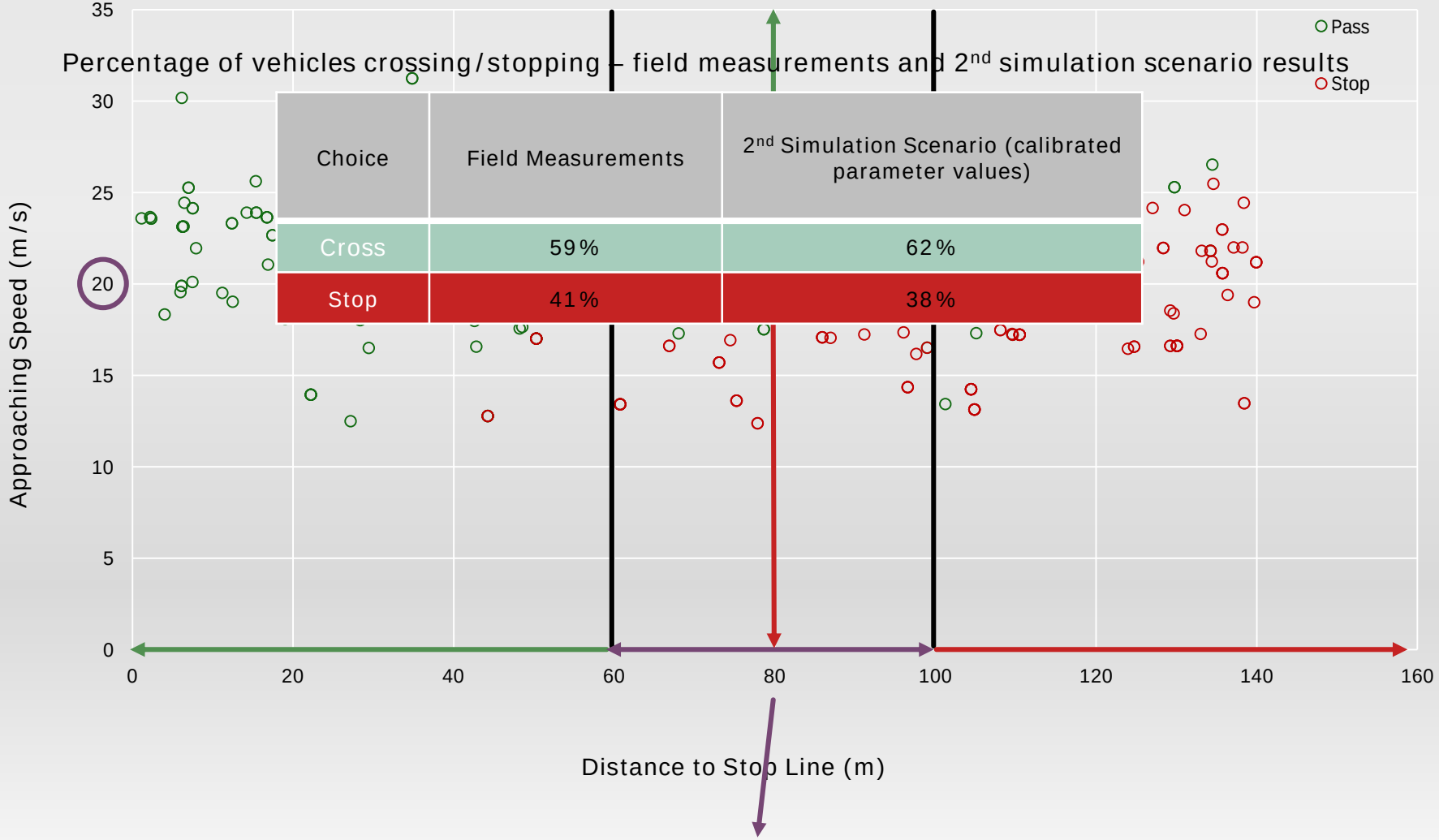
2nd simulation scenario was performed

Parameter estimates of the binary choice model

Variable	Parameter	Estimated value	Standard error	p-Value	OR
Approaching Speed	b_1	-0,158	0,076	<0,001	0,85
Distance to Stop Line	b_2	0,085	0,010	<0,001	1,09
Constant	α	4,021	1,271	0,002	55,76
Goodness of Fit Metrics					
Nagelkerke R Square					0,82
Hosmer and Lemeshow Test					0,97
Classification (overall percentage)					91,80%

2nd simulation scenario --> when using the calibrated parameter values, the simulation can reflect to a very large extent the real driving conditions of the area concerned (in terms of *total number of vehicles that crossed the intersection or stopped, during the yellow phase*)

Correlation of driver's decision with approaching speed and distance to stop line – 2nd simulation scenario results



most drivers choose to clear intersection

distance to stop line for which there is not an obvious stop/go decision --> 60 m – 100 m (same as ground truth)

most drivers choose to stop

Percentage of vehicles crossing/stopping – field measurements and simulation scenarios results

Choice	Field Measurements	1st Simulation Scenario (default Vissim parameter values)	2nd Simulation Scenario (calibrated parameter values)
Cross	59%	36.4%	62%
Stop	41%	63.6%	38%

Default & modeled parameter values

Variable	Parameter	Vissim default parameter value	Estimated value (modeled – calibrated using field data)
Approaching Speed	b_1	-0,26	-0,158
Distance to Stop Line	b_2	0,27	0,085
Constant	α	1,59	4,021

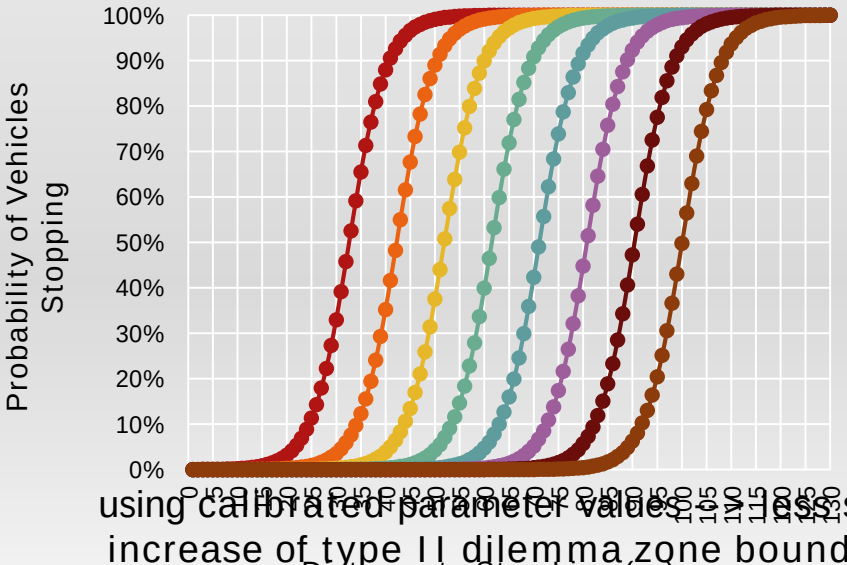
coefficients of approaching speed and distance --> almost identical in absolute values (nearly same degree of influence in stop/go decision)

approaching speed --> the most significant contributing factor for driver's stop/go behavior

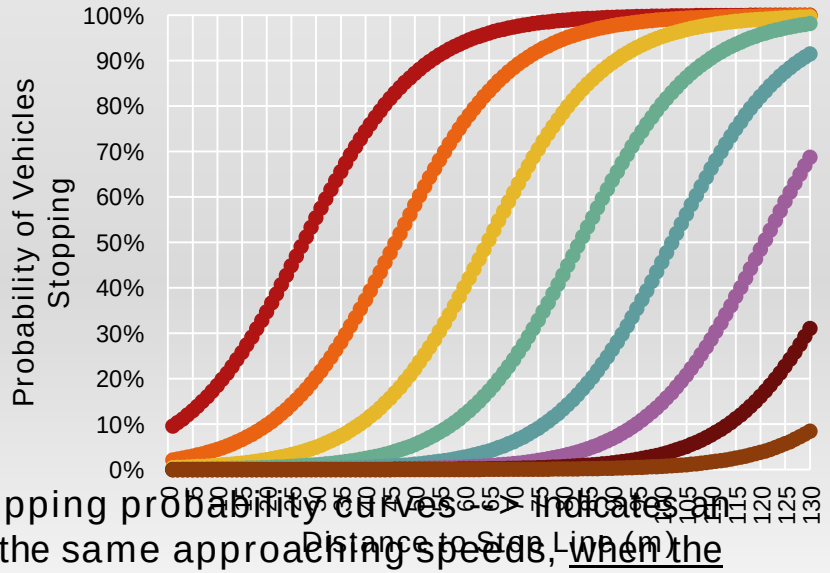
more than doubled --> significantly different slope of the stopping probability curves

- *default & calibrated parameter values* & *probability calculation formula* (binary choice model)...
- X axis --> used for determination of dilemma zone boundaries, based on the type II dilemma zone concept
- type II dilemma zone --> area on a signalized intersection approach, where more than 10% and less than 90% of drivers would choose to stop, in response to yellow light indication (*Zegeer & Deen, 1978; Gates et al., 2007; Parsonson, 1992*)

Probabilities of Vehicle Stopping based on its Position at the Onset of Yellow Signal for different Approaching Speeds



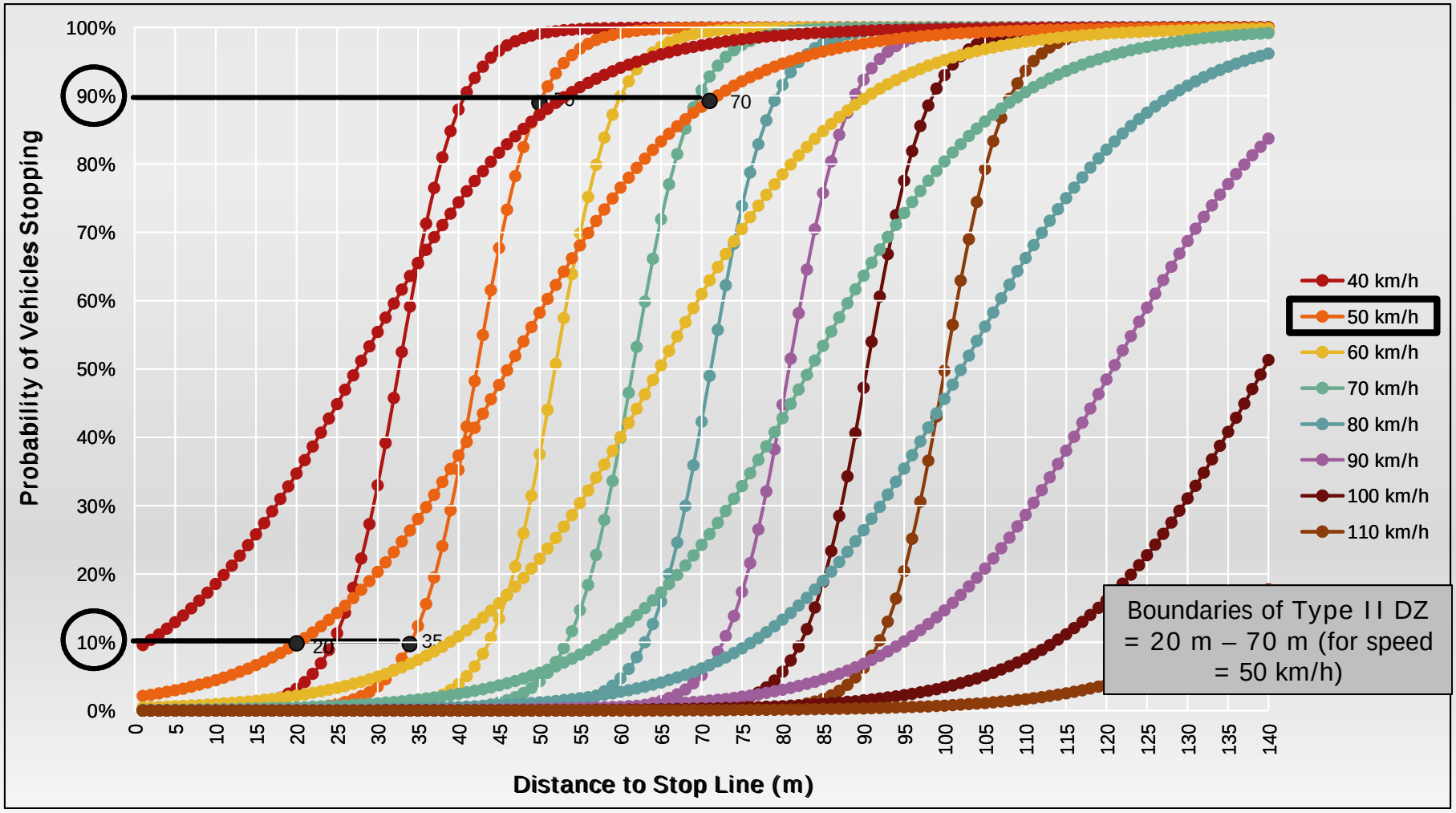
Vissim Default Parameter Values



Calibrated Parameter Values

using calibrated parameter values --> less sharp stopping probability curves --> indicates an increase of type II dilemma zone boundaries for the same approaching speeds, when the stopping probability is calculated using the calibrated parameter values

Probabilities of Vehicle Stopping based on its Position at the Onset of Yellow Signal for different Approaching Speeds, Using Default Parameter Values



- calculation of various traffic-related parameters for two simulation scenarios (1-hour simulation)...

Comparison of traffic-related parameters resulting from simulation scenarios

Traffic-related Parameter	1st Simulation Scenario (default Vissim parameter values)	2nd Simulation Scenario (calibrated parameter values)	% Difference
CO2 emissions (gm)	410,597	391,130	-4.74%
NOX emissions (gm)	1.094,924	1.043,012	
CO emissions (gm)	273,731	260,753	
Total number of vehicles	818	818	0
Average speed (km/h)	33,20	34,85	+4.90%
Total travel time (sec)	13.686,55	13.037,65	-4.74%
Total delay (sec)	7.673,48	7.025,41	-8.40%
Total number of stops	263	246	-6.40%
Total delay stopped (sec)	3.369,47	2.952,26	-12.38%
Average number of stops	0,32	0,30	-6.66%
Average delay of all vehicles (sec)	9,36	8,57	-8.44%
Average delay per vehicle (sec)	8,53	7,78	-8.79%
Average queue length (m)	4,09	3,69	-9.78%
Maximum queue length (m)	44,13	42,40	-3.92%
Number of queue stops	288	272	-5.56%

- smoother traffic situation --> reduction of calculated values of those factors contributing to heavy traffic flow conditions
- use of default, non-calibrated parameter values --> overestimation/underestimation of traffic-related parameters that actually describe traffic flow conditions of the area of concern...

- further investigation needed for adoption of calibrated parameter values in other contexts (e.g., different types of intersections within Greece and/or different countries)

- further investigation needed for adoption of default parameter values in other contexts (e.g., different driving conditions and/or different countries) and may need to be calibrated

- based on stopping probability curves --> range of distance values that defines the boundaries of type II dilemma zone, was *actually wider* than that resulted from simulation using default Vissim parameter values

- calibrated parameter values should be further tested for other signalized intersections located in Greece and other countries --> examine whether systematically produce more accurate results

- field observations may capture - among others - some unobserved, "latent" factors that affect driver's stop/go decision during yellow interval, such as acceleration/deceleration rate, driver's age, gender, aggressiveness level, etc.

- sensitivity analysis could be conducted --> examine the sensitivity of the stop/go simulation outcome in relation to variations of those parameter values

- utilization of default parameter values --> could lead to overestimation/underestimation of traffic-related parameters that largely determine traffic flow conditions of the area concerned

- calibration could be extended to the values of other driving behavior parameters rather than those affecting stop/go behavior during yellow phase (e.g., maximum look ahead distance, maximum deceleration, minimum headway, etc.)

- parameterization Vissim --> to include more factors for determination of binary stop/go outcome (e.g., driver's age, gender, familiarity with study area, etc.)

- stop/go behavior of autonomous vehicles during yellow interval

Thank you for your attention !

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