Politecnico di Torino

PROGRAM IN CIVIL ENGINEERING

MASTER OF SCIENCE THESIS

Extended Use of the Intelligent Speed Adaptation System Based on Sight Limitations to Steady and Transitional Driving Conditions

Supervisors:

Prof. Marco Bassani

Ing. Abrar Hazoor

Candidate:

Juan Daniel Perdomo C.

Academic Year 2020/21

INDEX

ABSTRACT

Introduction. One of the most complex aspects of road safety management is speed control. Adherence to posted speed limits alone does not exclude the risk of traffic collision. In fact, the presence of temporary and/or permanent sight obstructions could negatively affect the visible distance in front of the driver to perform safe manoeuvres. In such cases, the driver could not be able to stop the vehicle before an unexpected obstacle. To address this problem, the V-ISA (Intelligent Speed Adaptation for visibility) system has been introduced. This is an in-vehicle speed control system, capable of suggesting a safe speed to the driver based on the sight conditions. Previous studies have investigated the efficiency, functionality, and the behaviour of drivers interacting with V-ISA in simple road environments.

Objective and methodology. The scope of this study is to test the *V-ISA* system in complex driving conditions involving several traffic flows, integrating curves with reduced visibility and transitional sections (i.e. diverging and merging ramp terminals). For this aim, the (i) informative (V-ISA-I) and the (ii) intervening (V-ISA-III) variants of the system are applied, where V-ISA-I informs the driver through coloured bars while V-ISA-III intervenes on the acceleration and breaking pedal, inhibiting speeding when safety speed is reached. A within-subject study was conducted in a driving simulator involving 32 drivers, who drove in the same road scenarios under the three randomly assigned driving modality, i.e. no V-ISA (baseline), V-ISA-I, and V-ISA-III. Their longitudinal and transversal behaviour were measured in steady and transitional driving conditions under two different traffic flow levels.

Results and conclusions. Drivers showed a positive response in the use of the V-ISA system over steady driving conditions, adopting consistent operating speeds without manifesting any compensating effects. At sections with reduced visibility, the V-ISA system effectively assists drivers to reduce their speed in correspondence to road location with sight limitations. On the other hand, at transitional sections, results demonstrate that the use of the V-ISA system does not affect drivers speed behaviour at sections where drivers diverge onto the adjoining lane, whereas traffic level remains a conditional factor over it. Along the ramp merging terminals with the use of the intervening (V-ISA-III) variant, drivers manifested early merging manoeuvres and lower merging speed. Further analysis is also required for acceptance and complete adaptation of the system to multiple road scenarios, as well as its integration among other Advanced Driver Assistance Systems such as the Adaptive Cruise Control, that could lead to complete driving assistance and reduced level of risk while driving.

1. INTRODUCTION

In road safety, one of the most challenging tasks is the speed control. Driving speed is a contributing factor not only in the severity of a vehicle crash but also in the potential risk to be involved in. When speed increases, the crash rate also increases (Aarts and Van Schangen, 2006).

There have been several solutions to mitigate the impact of speeding and ensure safer driving conditions. Within these countermeasures, police and automated enforcement (e.g., speed cameras), and engineering solutions (e.g. road signs and markings, rumble strips, speed humps, road narrowing, etc.) can be mentioned (Comte and Jamson, 2000; Li et al., 2020). Such safety countermeasures have demonstrated to be reliable and successful, although they have shown some limitations in time and space (Comte et al., 1997). For example, Pau & Angius (2001) observed that speed humps are effective within a certain range, since drivers tend to increase their speed quickly to initial levels right after it.

Similarly, in-vehicle systems may be more helpful because of their continuous and controlled operation while driving. In-vehicle systems collect information from environment to provide information, feedback, and/or vehicle control to support the driver in the optimal vehicle operation (van Driel, 2007).

Since the introduction of the first Driving Assistance System (DAS) in 1980, constant progress has been made to lead, eventually, to automated and safer driving. For speed control, positive results and effects have been obtained with the use of Advanced Driving Assistance Systems (ADAS). In particular, Intelligent Speed Adaptation (ISA) systems have found to encourage the driver to adopt a safer speed in correspondence to the speed limits (Young et al., 2010). ISA technologies have proven to significantly improve road safety with the decrease in vehicle speed (van der Pas et al., 2012) and also improve the driver speed behaviour (Starkey et al., 2020).

1.1 Related works

The Intelligent Speed Adaptation (ISA) system is an in-vehicle system that supports the driver in adopting a proper speed in relation to the speed limits by using environmental information depending on the vehicle positioning (Mobility and Transport, 2021). The introduction of the system dates from 1982 by Saad and Malaterre with the inclusion of an in-car speed limiter. From that moment onwards, investigations have been virtually continuous. A study (Almqvist and Towliat,

1993) carried out in Sweden in which a mode with informative feature and a mode where speed limit was set automatically were implemented, regards the first with a truly automated speed limit system. Following these studies, during the years, several others have developed the current well-known ISA nowadays, testing different variants of the system itself (van Loon and Duynstee, 2001), the acceptance of it (Adell, 2009; Young et al., 2010) and their incidence on driver behaviour (Jamson, 2006).

ISA systems are in three main variants: open, closed and half-open (van Loon and Duynstee, 2001). The distinction of this variants depends on the level of intervention of the system and, therefore, in the voluntary or mandatory use of the system. In the open variant, ISA system transmits visual or auditory information to the driver when she or he exceeds the speed limits. The closed variant corresponds to the intervening one, in which the vehicle speed is controlled to prevent the vehicle from surpassing the threshold speed limit; once this is reached, there will be no effect on the increasing vehicle speed if driver try to push the throttle pedal. Ultimately, with the half-closed variant, once the speed limit is reached, the driver must perform a greater force over the gas pedal to be able to increase the speed.

There are well documented information on the implication of the use of ISA system in drivers speed behaviour (Lai and Carsten, 2012; Regan et al., 2006; Chorlton and Conner, 2012; Ghadiri et al., 2013). The activation of ISA system while driving significantly reduces the road extension where speed limits are overpassed. In addition, in zones where speed is over the speed limit, the incidence of activating the system relies on shifting the distribution to below or around speed limits. This led also to a reduction in the risk of collision (in the UK, injury and fatal accidents are reduced by 20% and 37% accordingly) (Carsten and Tate, 2001). Ghadiri et.al, 2013, reinforces this, concluding that injuries related to road crashes will be crucially reduced with the implementation of Intervening ISA variant.

Literature has demonstrated that the inclusion of Intelligent Speed Adaptation System has a positive impact on drivers' behaviour and on road safety. The system entirely works with the adequate safe speed which should/must be adopted by drivers. This safe speed is not fixed since it depends on many factors and it is not entirely related to the posted speed limits indicated in prescriptions or vertical signals along the road. Some European countries have implemented dynamic speed limits on their motorways, to consider factors such as traffic flow, weather, and visibility conditions (Mobility and Transport, 2021). Consequently, dynamic limits reflect the safe speed depending upon current circumstances in terms of general conditions of the environment and road.

Adapting the ISA system to accurately provide these dynamic limits becomes a crucial task in order to improve the overall level of road safety and enhance the adopting speed behaviour of drivers.

1.2 Sight assessment

Within the aspects that affect the speed adoption, sight limitation is a major concern. In road infrastructure, the Available Sight Distance (ASD) is the visible length in the vehicle path from drivers' perspective. Some studies have found a direct relationship between an insufficient ASD and the crash rate (Sparks, 1968; Urbanik et al., 1989; Steinauer et al., 2002; Silyanov, 1973). In a study conducted by Castro and De Santos-Berbel, 2015, insufficient ASD was found to be responsible of 19 crash cases out of 585 in a 112 km road section, proving that insufficient ASD reduces the road safety level.

The insufficient ASD is associated with the condition in which the driver's sight distance is not enough to perform a stopping manoeuvre in case of an obstacle ahead, and this occurs because of sight obstructions in driver's range of view (i.e., safety barriers, vegetation, fences, buildings, etc.). This unsafe condition is evaluated by comparing the Available Sight Distance with the Stopping Distance (SD), implicating that the driver is safe when ASD > SD. According to current regulations, a driver needs to stop the vehicle, change lane or overtake in completely safe conditions, meaning that for each manoeuvre there must be enough available sight distance (Ministero delle Infrastrutture e dei Trasporti, 2001).

Since ASD is strongly affected by sight obstructions, the most critical condition may occur along horizontal curves. Figure 1 provides the representation of ASD for a rightward and leftward curve of radius R, in correspondence with the line of sight. For a proper interpretation, the parameter exhibited in Figure 1 follows:

- R is the radius of the curve;
- r_1 and r_2 are the radius of the vehicle trajectory for left and right vehicle respectively;
- d is the distance from obstruction to road edge;
- S_w is the shoulder width;
- D_1 and D_2 are distances from the obstruction position to the trajectory line of left and right vehicle respectively;
- ASD_1 and ASD_2 are the available sight distances for left and right trajectories respectively.

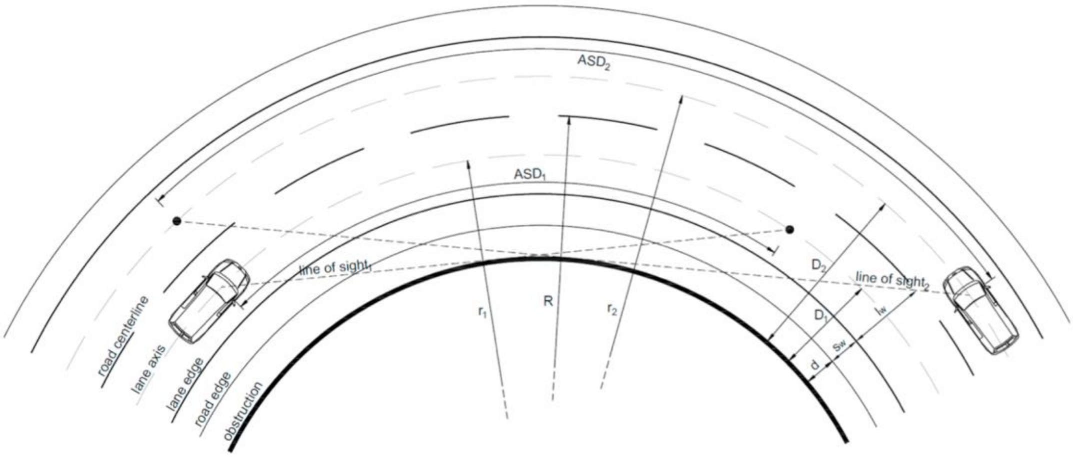


Figure 1: Representation of ASD for a rightward and leftward curve of radius R (Bassani et al., 2019a)

The Available Sight Distance of both vehicles is determined as follows:

$$ASD_{1,2} = r_{1,2} \cdot arcos\left[1 - \frac{D_{1,2}}{r_{1,2}}\right] \quad [1]$$

Note that subscripts 1 and 2 denote the distinction between the left and right vehicle respectively.

Roughly, three different driving conditions are expected when driving along a curve with sight limitations:

1. safe
2. partial safe, and

3. unsafe conditions.

The safe condition occurs when along a curve ASD > SD, whereas in a partial safe condition this is partially met along a stretch of that curve, and in the worst unsafe condition, the driver never counts with sufficient visibility to perform the stopping manoeuvre safely, thus ASD < SD along the entire curve.

In this scenario, Stopping Distance takes importance since it depends on vehicle speed, and variations lead to large differences in this parameter. Hence, design guidelines encourage the use of the SD for the definition of geometrical elements such vertical curves and horizontal curves enlargement, therefore, in a perfect scenario, the minimum SD required is always available. However, in many cases, due to assumptions made at the design stage, project constraints, and life-cycle operations, may produce changes resulting in non-compliance of SD minimum requirements at some locations (Gargoum et al., 2018).

These factors may have an incidence in drivers' behaviour when negotiating curves. Bassani et al., (2019), studied the longitudinal and transversal behavioural response of drivers travelling along curves with limited and unlimited ASD in rural highways. They concluded that there are specific strategies (Table 1) taken by drivers to adjust their trajectory under different ASD conditions. Results from this study showed that drivers' predominant behaviour when in unsafe condition (ASD < SD) is reduced their speed. However, a high percentage of drivers decided also to shift laterally to increase their sight range (ASD increases when offset distance from obstruction position is higher). While in safe condition, half of drivers tended to do not adopt any compensation strategy.

Table 1: Driver choice of compensation strategy combinations considering visibility conditions (Bassani et al., 2019).

Visibility conditions	**Adopted strategy**			
	Lateral shift	**Speed reduction**	**Both**	**No strategy adopted**
Safe condition (ASD > SD)	11.5%	36.8%	3.5%	48.1%
Partially safe condition	18.9%	40.3%	6.7%	34.1%
Unsafe condition (ASD < SD)	5.8%	49.3%	26.1%	18.8%
Total	14.0%	38.8%	5.9%	41.3%

1.3 V-ISA background

An ISA system based on road geometrics and real-time sight conditions has been tested, as posed by Hazoor et al., (2021). A Novel system which captures the essence of ISA systems in terms of speed management combined with visibility factors that can influence drivers' decision and behaviour on road. This new functionality is based on an algorithm created following the main visibility principle in roads $(ASD \geq SD)$ that distinguish between safe and unsafe conditions.

The development of the ISA system is presented in three variants:

1. Informative V-ISA
2. Warning V-ISA
3. Intervening V-ISA

Informative and warning V-ISA enable drivers to maintain a safe speed via the activation of visual or acoustic signals whenever the vehicle exceeds the speed limit; and intervening V-ISA, controlled the vehicle speed by disengagement of the gas pedal (accelerator pedal) and if required activation of the brake pedal.

The experiment was carried out at the driving simulator using the software *SCANeR Studio®*, in which a virtual environment with road scenarios were created. The visibility problem was addressed by the use of road markers placed along the lane centreline, which were captured by a virtual sensor, hence, the distance between the farthest marker visible from the virtual sensor and the vehicle provides the ASD, as shown in Figure 2.

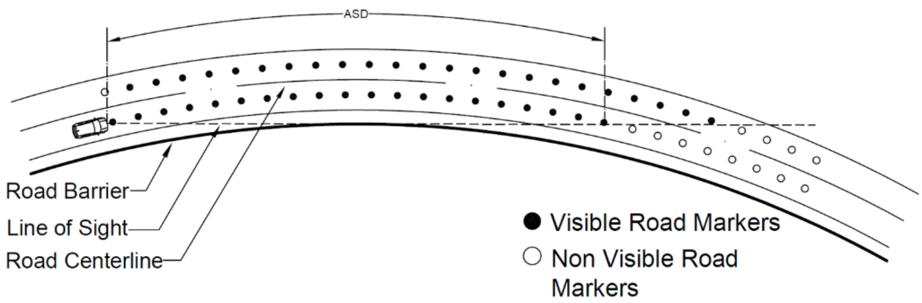


Figure 2: Road sensor points on the alignment visible from vehicle (Hazoor et al.,2021).

On the flip side, the SD is calculated, in real time, by means of the following equation:

$$SD = v \cdot \tau + \frac{v^2}{2g \cdot (f \pm i)} \qquad [2]$$

Which considers two factors, the lag distance, used to perceive and react to commands, and the braking distance to a complete vehicle stop.

In SD equation, v is the real-time vehicle speed in m/s, τ is the perception and reaction time in seconds (estimated with 2.8 - 0.01 · V, with V the speed in km/h), f is the tire-road friction coefficient (real-time values based on vehicle speed were used), g is the gravitational acceleration, and i is the longitudinal grade of the road.

As represented in Figure 3, both ASD and SD operations and estimations were carried out using the assistance of *MATLAB Simulink®,* that worked simultaneously and in collaboration with *SCANeR Studio®* to provide accurate real-time calculations and feedback, given the need to constantly input and output information from and to, between them.

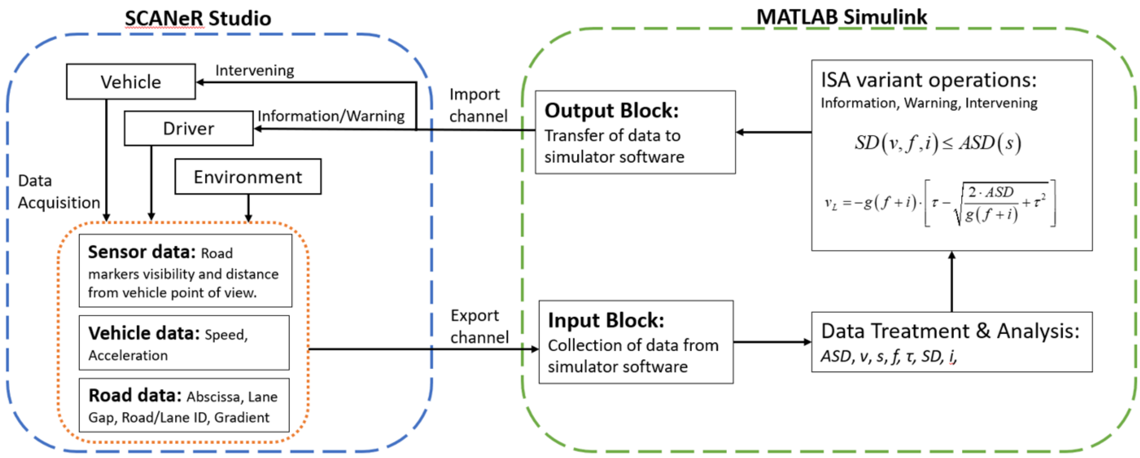


Figure 3: Interaction between SCANeR Studio® and MATLAB Simulink® co-simulation framework (Hazoor et al.,2021).

As reported in Figure 3, Informative and Warning V-ISA reception channel is the driver, while for Intervening, it is both vehicle and driver. In the case of Informative V-ISA variant, a colour bar recommending a reduction in speed is displayed in front of the driver (i.e., on the windscreen). With the Warning V-ISA variant, a sound is emitted to indicate that the ASD value had fallen below the estimated SD; and in the case of the Intervening V-ISA variant, it operates preventing the vehicle from exceeding a threshold speed limit (v_L), that is calculated in real-time along the road, by replacing the SD with the ASD in equation [2], as follows:

$$v_L = -g(f+i)\cdot\left[\tau - \sqrt{\frac{2\cdot ASD}{g(f+i)} + \tau^2}\right] \quad [3]$$

Hazoor et al., 2021, tested the system in a road environment composed by a two-lane rural highway with rightward and leftward curves endowed with safety barriers in their inner side, designed according to Italian design guidelines (Ministero delle Infrastrutture e dei Trasporti, 2001). Figure 4 exhibit curves cross section.

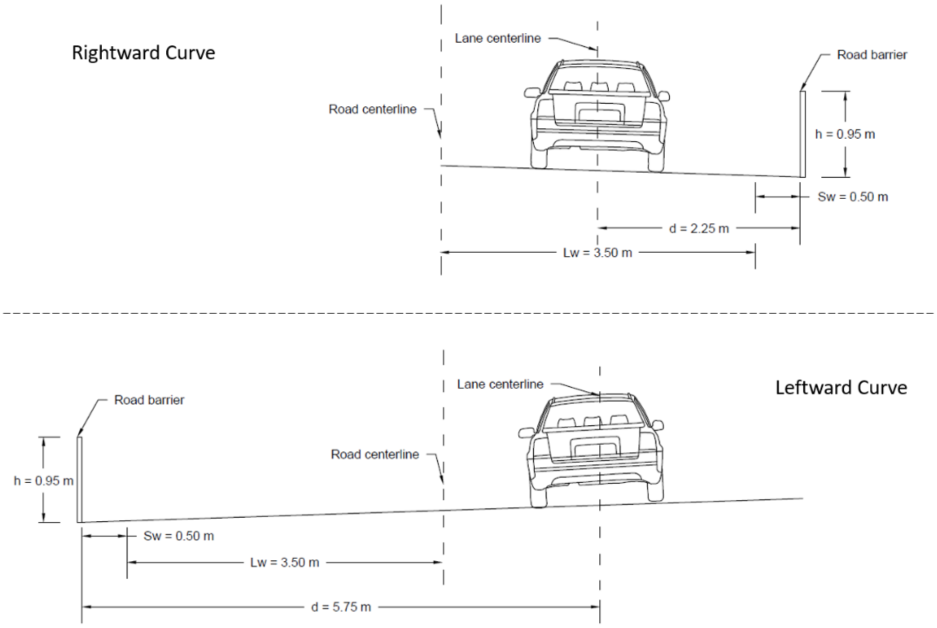


Figure 4: Cross-section of the roadway for RW and LW curves (Hazoor et al.,2021).

The validation and testing of the system were performed satisfactorily. In Figure 5, comparison between ASD values obtained from virtual sensors in *SCANeR Studio®* and those coming from manually calculation in AutoCAD software shows almost no differences, in fact, in most cases, the absolute difference between actual ASD and estimated ASD is less than 1 m along circular arcs. Subsequently, in Figure 6, SD profiles based on ISA variants and base condition, alongside ASD profile is reported.

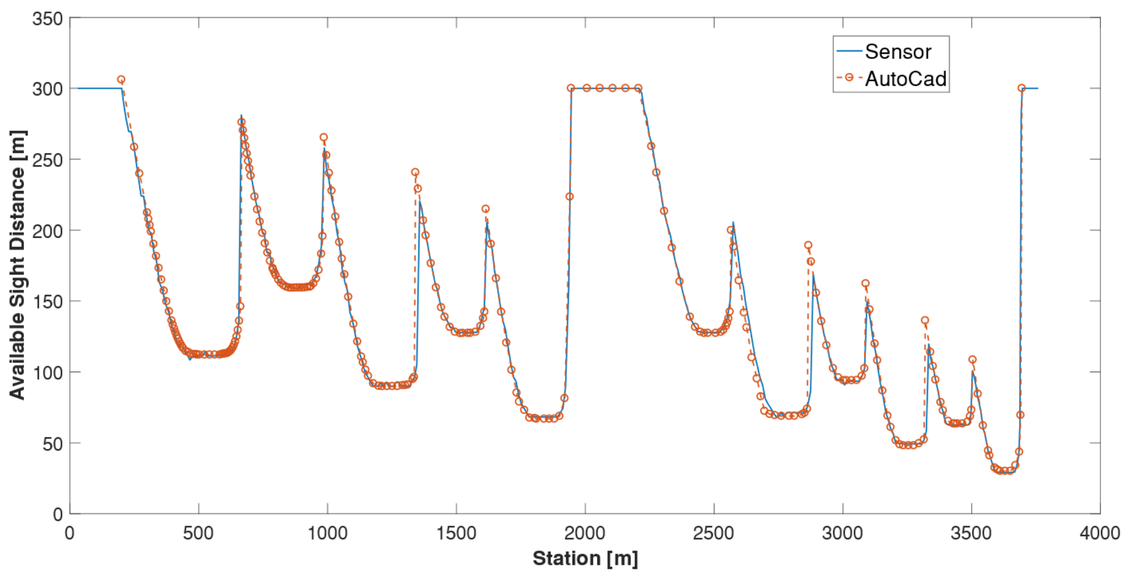


Figure 5: Comparison between ASD values for ISA validation provided by virtual sensors in SCANeR Studio® and actual ASD values from AutoCAD®.

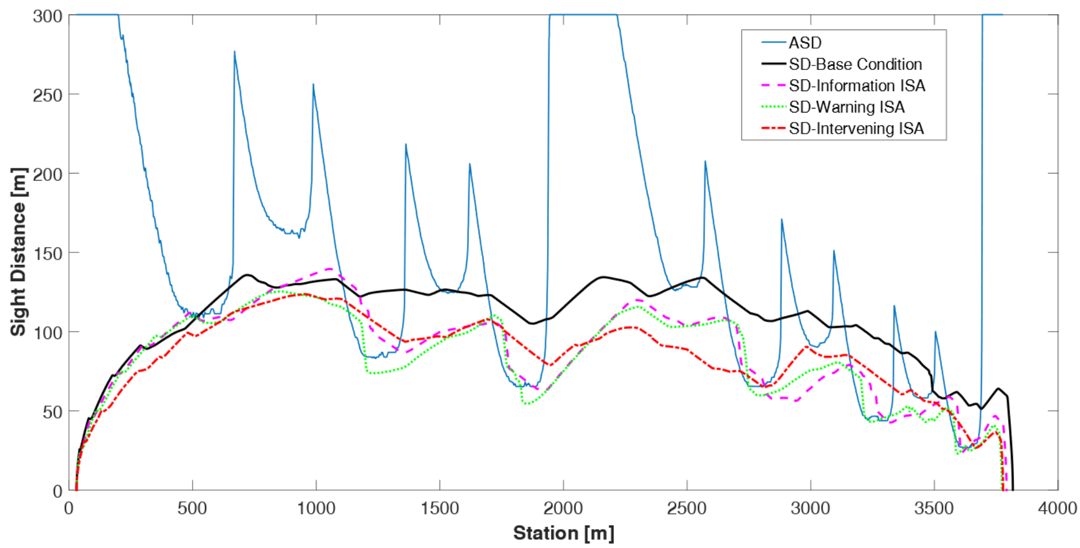


Figure 6: Comparison between ASD and SD profiles obtained in four different drives with and 3 without the ISA system (Hazoor et al.,2021).

It is clear that along curves, ASD values are reduced given the visibility constraints (i.e. safety barrier) as well as the SD values due to the reduced speed when negotiating curves. Furthermore, comparing SD values between base condition and V-ISA variants, the implication of the V-ISA system is evident, lowering the Stopping Sight Distance in all cases.

1.4 Problem statement and study objectives

The novel ISA system (*V-ISA*) proposed by Hazoor et al., 2021, was validated and tested under certain limitations such as the absence of traffic in a driving lane and its use over steady and transitional driving conditions. Therefore, the need of further evaluations to ensure the complete acceptance and implementation of the system is necessary.

The aim of this driving simulation study is to observe, study and analyse the effect of the novel V-ISA technology in drivers' behaviour along transitional and steady sections under different traffic conditions. The effect of the system on drivers' behaviour will be examined considering objective measures.

The incidence of the system is mainly evident in the longitudinal behaviour (i.e., speed, braking and gas pedal activation, acceleration, and deceleration rates), however, secondary effects on transversal behaviour of driver may be affected by the use of the system. Therefore, longitudinal and transversal driver behaviours are both in the research domain of this study.

For the purpose of this study, the V-ISA is proposed in two variants in accordance with the classification made for ADAS (Carsten, 2002): (1) **informative V-ISA operation (V-ISA-I)** that enables drivers to maintain a safe speed by providing visual information, and (2) **intervening V-ISA operation (V-ISA-III)**, in which vehicle speed is controlled by disengagement of the gas pedal (accelerator pedal) and if required activation of the brake pedal to prevent the vehicle from exceeding the threshold speed limit.

2. METHOD

2.1 EXPERIMENTAL DESIGN

The experimental track and scenario were designed using the already described software called *SCANeR Studio®*. Similarly, *MATLAB Simulink* code was updated in order to adapt V-ISA system to the different conditions of the road alignment, making it suitable for this study purposes.

Different scenarios were created within the scope of this study:

- Baseline scenario with high- and low-level traffic: free drive without any system;
- V-ISA-I with high- and low-level traffic: drive with V-ISA informative variant active
- V-ISA-III with high- and low-level traffic: drive with V-ISA intervening variant active;

The experimental study group was design following Italian population distribution by gender and age. Hence, 32 drivers were involved in the experiment, where each of them was in charge of driving all the scenarios in two driving sessions. As a result, this is a within-subject experimental design.

Data from drivers were collected by *SCANeR Studio®* software and grouped in .csv format for analysis. The observed variables were:

Longitudinal behaviour:

(i) Longitudinal speed.

Transversal behaviour:

(i) Lateral position of drivers: drivers' transversal distance from lane centreline to vehicle centre of gravity;
(ii) Standard deviation of lateral position (SDLP): illustrates the transversal weaving of the car (Figure 7);
(iii) Diverging and merging distances: distance at which drivers pass from road driving lane to terminal and from terminal to driving lane, respectively, measured from a reference point.

Results were analysed through statistical test and models to evaluate the statistical significance and degree of influence of the different variables involved during the experiment. For this purpose, t-test and Linear mixed effect model (LMM) were used.

With statistical t-test it was possible to evaluate the statistical significance of possible changes in drivers' behaviour by comparing the mean values of the baseline scenarios with the V-ISA ones. Whereas the LMM served to evaluate the influence and significance that factors, covariates and cluster variables involved, with factors and covariates as fixed effects, while cluster variables as random effects. LMM factors, covariates and cluster variable considered are grouped in Table 2 and further explained in the next section.

Table 2. Factors, Covariates and Cluster Variable considered in the Linear Mixed Model analysis with their description and level.

	Description	**Levels**
Factors		
V-ISA variant	Baseline, V-ISA-I, V-ISA-III	3
Age class	Class I, Class II, Class III	3
Traffic flow	High flow, Low flow	2
Gender	Male, Female	2
Covariates		
Age	Participant age in years	-
Experience	Driving experience in years	-
Kilometers/year	Participant kilometers per year	-
Accidents	Number of total accidents	-
Cluster Variable		
Test driver	ID of participants	32

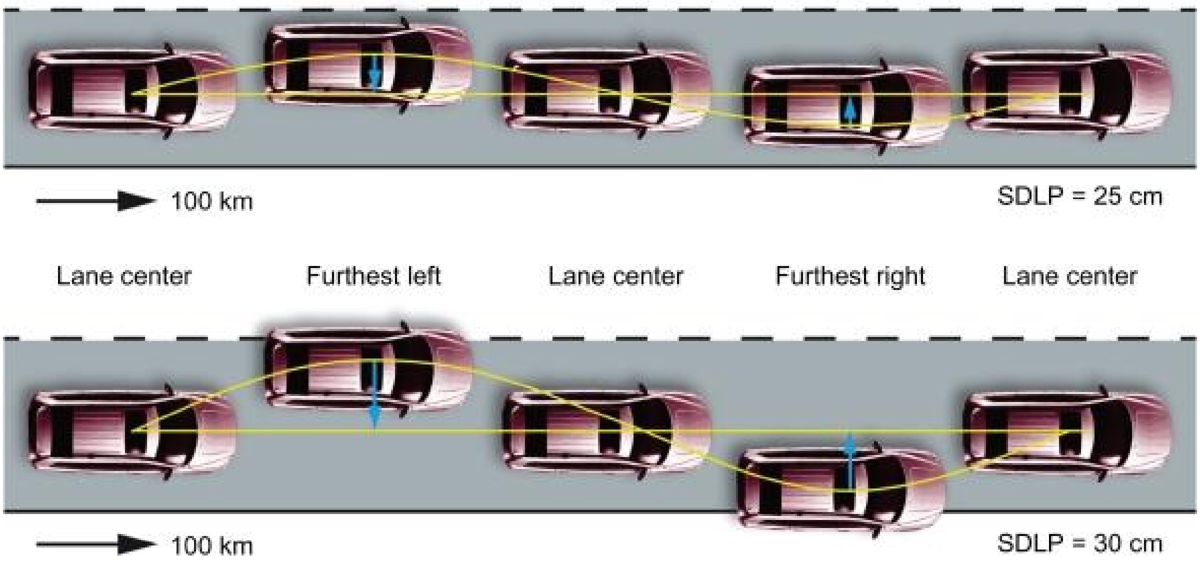


Figure 7. Comparison of different transversal behaviour in terms of standard deviation of lateral position. (Vester and Roth, 2011).

2.2 EQUIPMENT

2.2.1 Driving simulator

The driving simulator was located at the Road Safety and Driving Simulator Laboratory at the Department of Environment, Land and Infrastructure Engineering (DIATI, Politecnico Di Torino). It is a validated driving simulator from *Oktal* (now *AV Simulation*, France) which has become an international reference for producing state-of-the-art multi-sensor simulation software. The main purpose of the simulator is to provide a three-dimensional synthetic environment for drivers, which provides a realistic-driving experience.

The driving simulator (Figure 8) is equipped with:

- three, one central and two laterals, 32” Samsung Full HD screens which cover a 130° horizontal field of view. The two side screens are inclined by 25° with respect to the central one in order to guarantee a vision consistent with the virtual environment;
- adjustable seat with safety belt;
- force feedback steering wheel that simulates the passage of the wheels on the road pavement and any bumps, to which the controls for operating the direction indicators and wipers are connected;
- 12” screen that allows you to view the speedometer, the rev counter and the gear engaged;
- six-speed gearbox and reverse;
- pedals (clutch, brake and accelerator);
- control panel with ignition button, horn and parking brake;
- 5.1 surrounding audio system.

Figure 8: Driving simulator at DIATI, Politecnico di Torino.

Within the hardware component, there are three main elements (three different computers): main, visual and virtual reality.

The ***main computer***, is in charge of the simulation process and data collection, the ***visual computer***, allows the visual component to be reproduced in the main screens, and the ***virtual reality computer***, in charge of reproducing the scenario in a virtual reality environment supported by the VR Headset.

Additionally, 3D stereo speakers, 150 W, Dolby Surround 5.1, are available to reproduce engine and environmental road sounds.

Likewise, the software component, called *SCANeR Studio®,* in its *version 1.8,* is responsible for the definition of the road environment, simulation process and experimental management, with its diverse modes:

- ***Terrain***: for creating a road network including logical information (i.e. signs, traffic lights, speed limits) and including a 3D graphical environment.
- ***Vehicle***: For creating any mathematical model of vehicle (i.e. car, truck, tank).
- ***Scenario***: For creating experiments based on vehicles and terrain for testing (i.e. Drivers, road infrastructure, cockpit). And for controlling the surrounding parameters.
- ***Simulation***: For launching an experiment and managing all the simulator modules.
- ***Analysis***: For analysing results of the experiments (i.e. graphs, 3D animations, recordings, data-sheets).

2.2.2 MATLAB Simulink

For a successful application of the experiment, the driver simulator software, *SCANeR,* was co-simulated with MATLAB Simulink® in a 'Driver In the Loop' model (Khastgir et al., 2015). MATLAB and *SCANeR Studio®* worked simultaneously between them to accurately provide in-time feedback and results. The vehicle dynamic, road environment, and sensor data are transferred in real-time from SCANeR Studio® to Simulink® while information processed and results are transferred back to *SCANeR Studio®*.

A mandatory upgrade of the system (model), already proposed and developed by Hazoor et al., 2021, was ensured and tested before the driving experiments to provide the correct in-time feedback.

2.3 SCENARIO

2.3.1 Road geometrics

The road environment was design is such a way that the driver was obliged to transit along interchanges, performing merging and diverging manoeuvres. The road alignment is composed by two major motorway sections (A-Road class) and two major two-lane highway sections (C-Road class), joined by interchanges sections each, as shown in Figure 9, its design was supported in Italian Policies (Ministero delle Infrastrutture e dei Trasporti, 2001), and performed in *SCANeR Studio®* software. The cross section of both roads are represented in Figure 10 and Figure 11, further geometrical parameters are grouped in **Appendix A.**

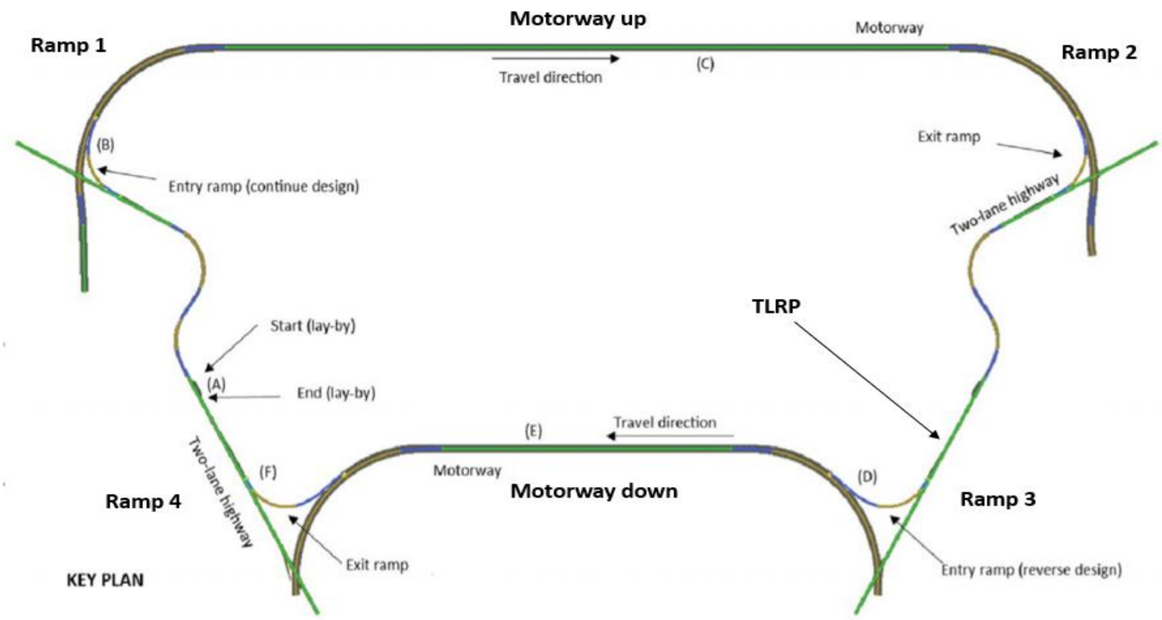


Figure 9. Key-plan of road alignment with indication of the main sections and ramps.

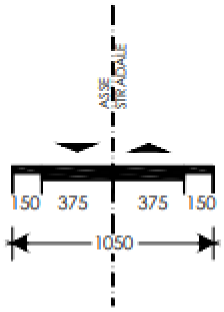


Figure 10: C1 - road class cross section (MIT, Norme Funzionali e Geometriche per la Costruzione delle Strade 2001)(Note: unit of measurement is cm).

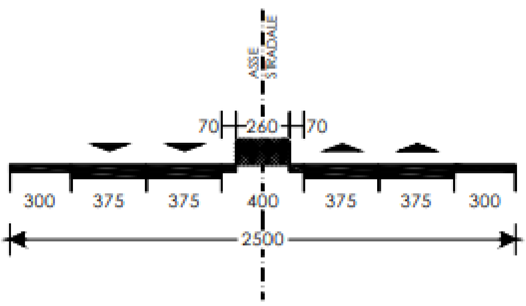


Figure 11: A - road class cross section (MIT, Norme Funzionali e Geometriche per la Costruzione delle Strade 2001) (Note: unit of measurement is cm).

The geometrical elements used for the design of the interchange were circular arcs and Cornu-spirals connections. As seen in Figure 9, four different interchange configurations were used: (i) linear exit-continuous entry, (ii) continuous exit-linear entry, (iii) linear exit-reverse entry and (iv) reverse exit-linear entry. When merging or diverging from and to the motorway, four different ramp-terminals configurations were used (Figure 12):

1. Continue on-ramp-terminal
2. Reverse on-ramp-terminal
3. Continue off-ramp-terminal
4. Reverse off-ramp-terminal

While a linear terminal configuration (Figure 13) was followed when merging or diverging from and to the C1-road.

The ramps were design in adherence to the Italian guidelines (MIT, Norme funzionali e geometriche per la costruzione delle intersezioni stradali, 2006). The fundamental parameters for their geometric design are indicated in Table 8 of the same standard. Specifically, when dealing with entry terminals, its design must be complying with Italian standards and their integration with HCM (2010).

Depending on weather acceleration or deceleration lanes are required, lengths differ from each other. Additionally, for this study purpose, a shorter length in the diverging terminal from A-Category road was adopted. The motivation in this was the implementation of a similar road scenario of previous studies (Bassani and Portera, 2021; Bassani and Portera, 2020) in order to facilitate analysis and potential comparisons with those in the literature.

Detailed calculations and information over terminals are collected in **Appendix B.**

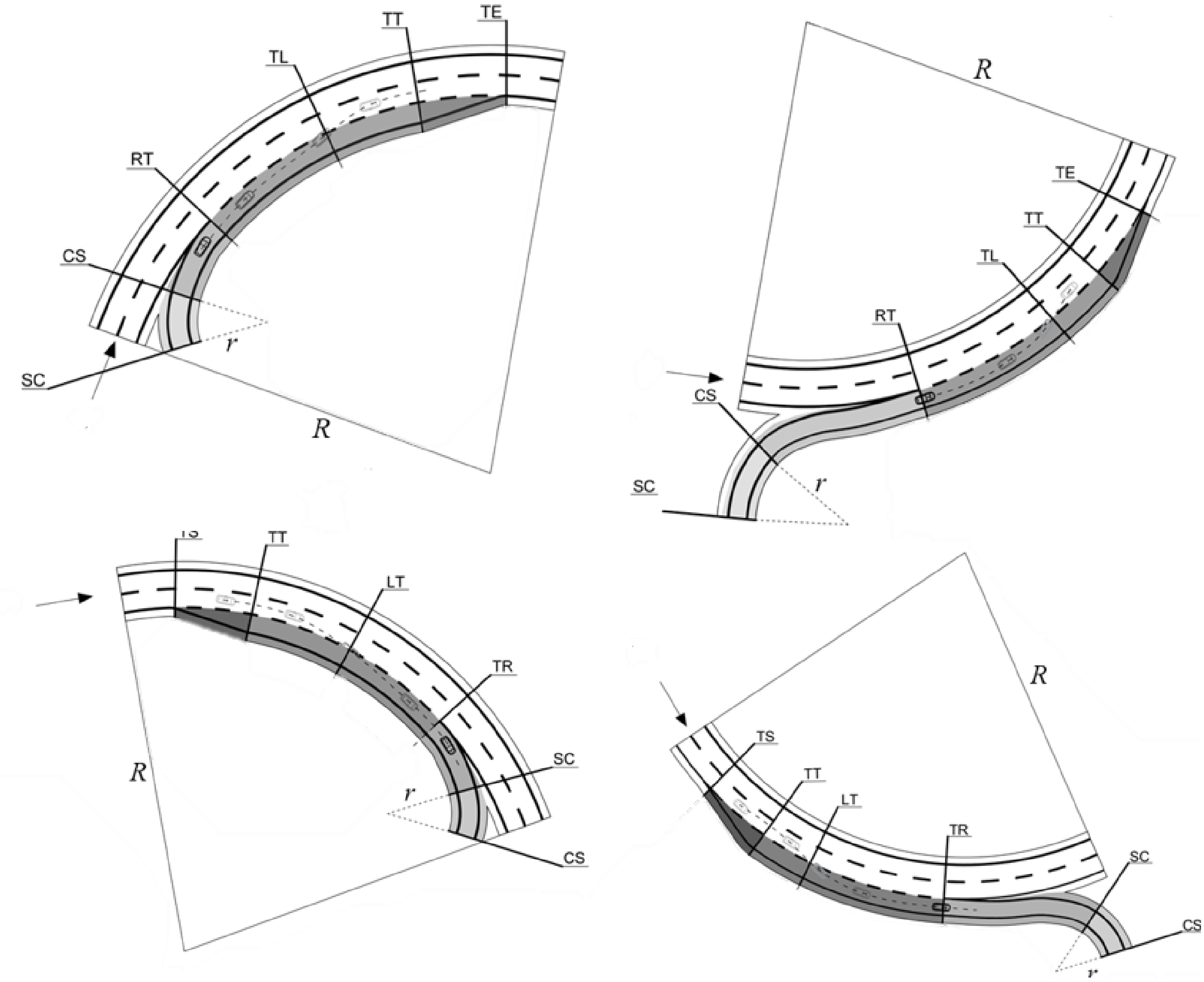


Figure 12: Continue and reverse ramp-terminal for merging and diverging manoeuvres.

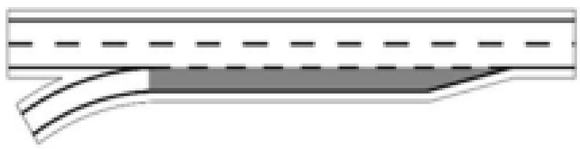


Figure 13: Linear terminal configuration.

Ramps cross sectional characteristics adopted are those recommended by the standards and are listed in Table 3.

Table 3: Ramps geometrical characteristics.

Element	Main road class	Cross section width (m)	Right shoulder width (m)	Left shoulder width (m)
One-way ramp	A	4.00	1.00	1.00

2.3.2 Sight conditions

Several factors affect visibility while driving. Both environmental and road geometrics influence the reduction in drivers' available range of view. In this experiment, safety barriers were imposed along the experimental track, in both type of roads, to restrict drivers' visibility.

According to UNI EN 1317 guideline, safety barriers are selected according to the road class and traffic level, considering the presence of heavy vehicles (Table 4).

Table 4: Barrier type according to traffic and road type.

Road class	Traffic	Description		
		Traffic divider	Lateral barrier	Bridge barrier
Motorway (A) and multilane highways (B)	I	H2	H1	H2
	II	H3	H2	H3
	III	H3-H4	H2-H3	H3-H4
Two-lane rural highways (C) and urban arterials (D)	I	H1	N2	H2
	II	H2	H1	H2
	III	H2	H2	H3
Collector urban roads (E), urban local streets and highways (F)	I	N2	N1	H2
	II	H1	N2	H2
	III	H1	H1	H2
Traffic: I – AADT ≤ 1000 or AADT > 1000, and trucks ≤ 5% Traffic II – AADT > 1000, and 5% ≤ trucks ≤ 15% Traffic III – AADT > 1000, trucks > 15%				

Hence, barrier type H1 with 2 waves and H2 with three waves were used in experimental track for C1 road class and motorway, respectively, as shown in Figure 14 and Figure 15.

Figure 14: C1-road class barrier in experimental scenario.

Figure 15: A-road class barrier in experimental scenario.

Along interchanges, barriers were maintained on both sides. At those positions, where exiting manoeuvres were required from motorway, H2 class barrier was used (Figure 16) while H1 type was maintained for exiting manoeuvres from C1 class road (Figure 17).

Figure 16: Interchange safety barrier. Merging manoeuvre from motorway to C1 class road.

Figure 17: Interchange safety barrier. Merging manoeuvre from C1 class road to motorway.

In road geometrics, visibility is associated with available sight distance (ASD), which is computed by means of equation [4].

$$ASD = 2 \cdot R \cdot arcos\left[1 - \frac{\Delta}{R}\right] \qquad [4]$$

Therefore, for each curve element, ASD was computed (Table 5).

Table 5: Available sight distance computed manually for road alignment curves.

Road category	Element [-]	R [m]	Δ [m]		ASD [m]	
C1	Curve 1	150.00	3.38		64.16	
	Curve 2	-150.00	7.13		92.26	
Ramp	Curve 3	150.00	3.50		64.93	
A	Curve 4	437.00	8.63	4.88	174.71	131.83
	Curve 5	437.00	8.63	4.88	174.71	131.83
Ramp	Curve 6	150.00	3.50		64.93	
C1	Curve 7	-150.00	7.13		92.26	
	Curve 8	150.00	3.38		64.16	
Ramp	Curve 9	150.00	3.50		64.93	
A	Curve 10	-437.00	6.33	2.58	147.60	94.51
	Curve 11	-437.00	6.33	2.58	147.60	94.51
Ramp	Curve 12	150.00	3.50		64.93	

*Separate values for A class road belong to outer and inner lane respectively.
*Negative radius represents leftward curves while positive, rightward curves.

2.3.3 Traffic

The influence of traffic towards the execution of merging and diverging manoeuvres and its implication in the speed adoption carries to behavioural changes in drivers. Hence, when implementing V-ISA variants, and their well-described effect on speed behaviour could lead to potential differences in it. Thus, round trip traffic was added to the scenario. The goal was to adopt two different traffic flows, to simulate two different traffic environments.

Two flow conditions were considered:

- Low flow condition: 1000 veh/h in motorway + 500 veh/h in two-lane highway
- High flow condition: 4000 veh/h in motorway + 1800 veh/h in two-lane highway

2.3.4 Operational conditions

In this experimental study, three different operational conditions were used: baseline and two V-ISA variants. The V-ISA system will be providing visual information or perform intervening operations to support the driver to keep the safe speed when exceeding the speed limits considering Available Sight Distance (ASD). Moreover, it will recognize the presence of vehicles ahead to deactivate the system, contemplating that speed is controlled by in-front vehicle, and sight limitations are no longer an issue.

- ***Baseline***

In baseline condition, no information is provided to the driver and none of the V-ISA operations are active, therefore, the driver feel free to perform at their usual desire speed.

- ***V-ISA-I (Information V-ISA system)***

Informative V-ISA system transmits visual information to the driver considering the safe and unsafe visibility conditions. These conditions are evaluated based on the comparison between the Available Sight Distance (ASD) and the Stopping Sight Distance (SD).

Thus,

- Safe condition: $ASD \geq SD$
- Unsafe condition: $ASD < SD$

The computation of the ASD is made by the virtual on-board sensors which detect, in real-time, the visible road markers to indicate the visible distance. While the SD is computed, simultaneously and in cooperation, in MATLAB software and *SCANeR Studio®* , trough the following equation [2].

The information is given to the driver by a virtual message that is displayed with LED light at the bottom of screen during the drive with (i) Green colour for safe condition ($ASD - SD > 20\ m$), (ii) Yellow colour for pre-information condition ($ASD - SD \leq 20\ m$) and (iii) Red colour for unsafe condition ($ASD < SD$) (Figure 18).

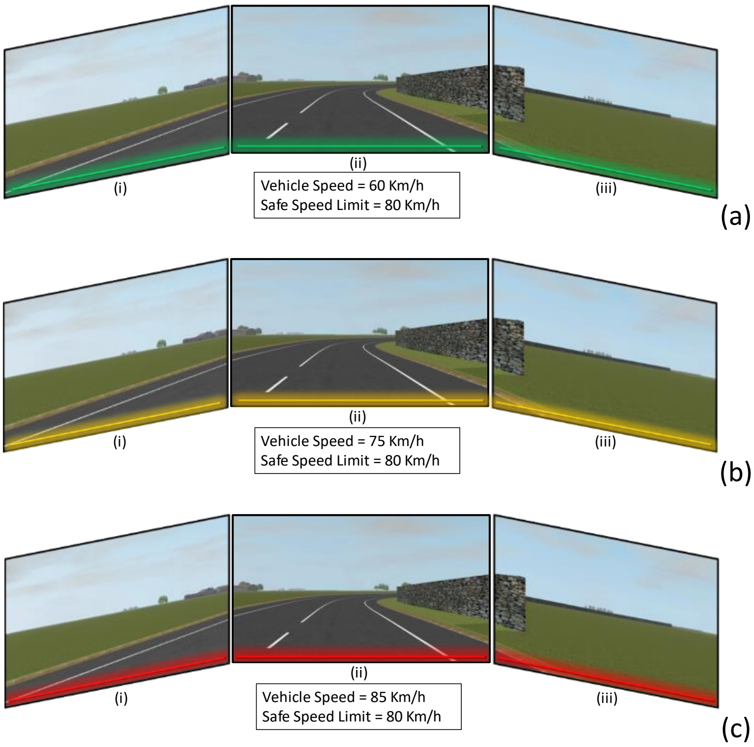


Figure 18: Example of LED on (i) Left screen display, (ii) Centre screen display, and (iii) Right screen display in the driving simulator. (a) ISA-Information with safe condition, (b) ISA-Information with Pre-Information/warning, (c) ISA-Information with unsafe condition.

- ***V-ISA-III (Intervening V-ISA System)***

Intervening V-ISA operation deals with enforcing speed control to prevent the vehicle from surpassing the threshold speed limit or automatically decreases the vehicle speed smoothly from unsafe to threshold speed limit. In this situation, the accelerator pedal will be disconnected and there will be no effect on the vehicle speed if driver try to push it.

The threshold speed limit corresponds to the speed at which the car must perform considering visibility conditions, and it is called '*Safe speed*'. The intervening variant relies on the safe speed to control the speed of the vehicle. Consequently, the system acts on the vehicle pedals considering two conditions:

1. Accelerator pedal is deactivated when:
   $Vehicle\ speed\ [km/h] - Safe\ speed\ [km/h] < 5\ km/h.$
2. Accelerator pedal is deactivated and breaking pedal is activated with a deceleration rate equal to 2.5 m/s^2 when:
   $5\ km/h < Vehicle\ speed\ [km/h] - Safe\ speed\ [km/h] < 15\ km/h.$

Throughout this operation, Blue LED strip will be displayed at the bottom of the screen to inform driver that intervening operation is activated by the system while in case of safe condition green LED will be displayed (Figure 19).

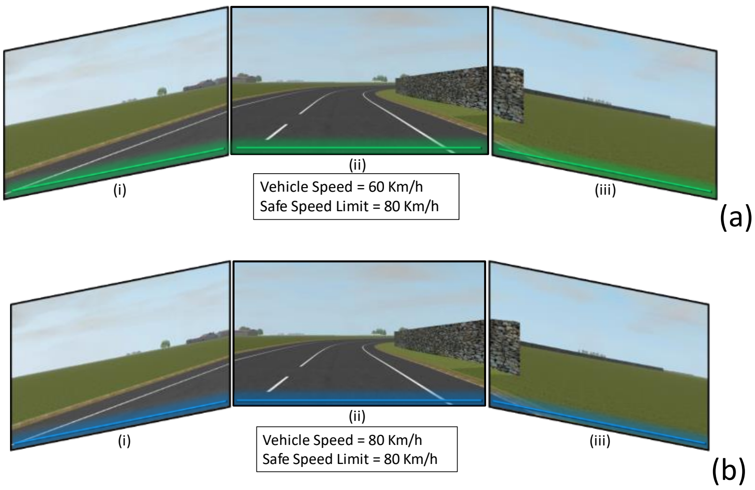


Figure 19: Example of LED on (i) Left screen display, (ii) Centre screen display, and (iii) Right screen display in the driving simulator. (a) ISA-Intervening with safe condition, (b) ISA-Intervening during intervening operation.

2.3.5 Speed enforcement

Prior to the experiment, validation of the V-ISA system within this scenario was conducted in order to secure a coherent speed enforcement considering posted speed limits, design speed and sight distances (safe speed). Thus, design speed through the experimental track was found using Italian prescriptions formulas and recommendations (*Ministero delle Infrastrutture e dei Trasporti*, 2001). Likewise, safe speed was computed with equation [3]. However, for comparison purposes, tire-road friction coefficient (f) and perception and reaction time (τ), were calculated using the design speed. Additionally, ASD obtained by the virtual sensors in a trial drive using the *informative V-ISA system* helped to obtain the correspondent safe speed.

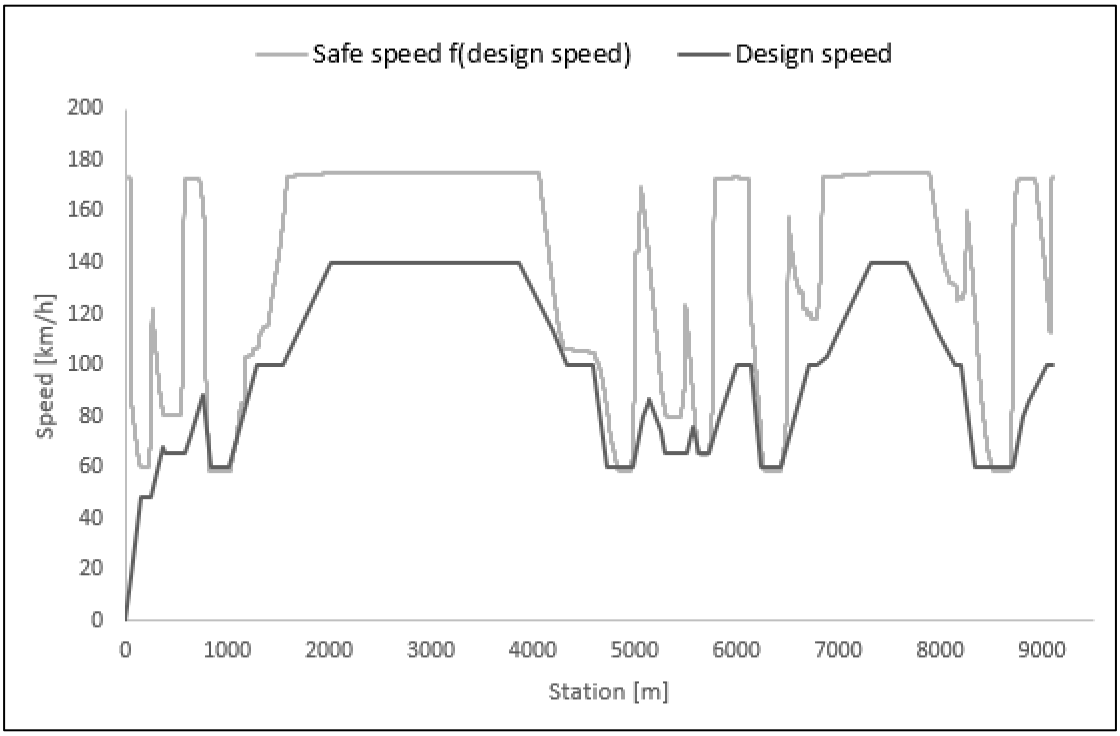


Figure 20: Safe speed vs design speed trough experimental track using informative V-ISA.

Subsequently, as seen in Figure 20, at locations of interest, such ramps and curves, safe speed values tend to be lower than design ones. Strengthening the idea that the system allows drivers to move at a safer speed even when design speeds and posted speed limits are correctly selected and calculated. In Italy, the design speed is defined as the highest speed that drivers can select within the contraints of road geometry and posted speed limits, and it should be consistent with the speed that drivers will adopt. Meaning that, in the particular case of ramps, driver may adopt higher speeds than limiting ones in terms of visbility.

2.4 PARTICIPANTS

Test drivers were selected from a database shortlist provided by the Road Safety and Driving Simulator Laboratory. The different V-ISA variants and traffic conditions lead to six different configurations (adding baseline scenario). Accordingly, the six combinations are:

- Baseline + Low flow condition
- Baseline + High flow condition
- V-ISA-I + Low flow condition
- V-ISA-I + High flow condition
- V-ISA-III + Low flow condition
- V-ISA-III + High flow condition

A group of 32 drivers were selected to carried out the experiment, each of those drivers must experience all configurations to have a stronger basis to relate the results. However, the drives composition for each driver was randomized to avoid familiarities with the systems that may affect them. Detailed information of drivers’ characteristics and driving configurations are in **Appendix C.**

The selection and construction of the driver's sample was performed following the dataset from the Italian Infrastructure and Transport Ministry (Ministero delle Infrastrutture e dei Trasporti, 2017), which contains information over the population characteristics of drivers in Italy. Consequently, the division of the sample was done by gender and age, distinguishing between three main classes:

- Age class I, drivers below 25 years old:
- Age class II, drivers between 25 and 44 years old;
- Age class III, drivers between 45 and 65 years old.

Table 6 and Table 7 reveal the proportionality of Italian drivers by gender and age, and the specific distribution in driver's sample.

Table 6: Italian drivers distribution by gender and age.

Class	Age	Male [55.56%]	Female [44.44%]	Total [%]
I	<25	5.48	4.39	9.87
II	25-45	23.29	18.62	41.91
III	45-64	26.79	21.43	48.22

Table 7: Driver's sample distribution.

Class	Age	Male	Female	Total
I	<25	3	2	5
II	25-45	7	6	13
III	45-64	8	6	14
Total		18	14	32

2.5 EXPERIMENTAL PROTOCOL

Participants were contacted by email, presenting the opportunity to be involved in the experimental part, providing general information about the experiment, as well as information on privacy and COVID containment actions. Those who replied positively, were contacted by phone to fix the appointment according to their availability.

The experiment was divided in two sessions per participant to lowering the workload and duration time, given the high number of drives (i.e., 6 in total). The experimental protocol can be summed up into the following steps:

Session 1:

- Complete a pre-drive questionnaire.
- Drive on a trial track to increase driver confidence at the driving simulator.
- Drive on a pre-selected 1st scenario.
- Complete post-drive questionnaire.
- Rest for a couple of minutes if required.
- Drive on a pre-selected 2nd scenario.
- Complete post-drive questionnaire.
- Rest for a couple of minutes if required.
- Drive on a pre-selected 3rd scenario.
- Complete post-drive questionnaires.

Session 2:

- Complete a pre-drive questionnaire.
- Drive on a pre-selected 1st scenario.
- Complete post-drive questionnaire.
- Rest for a couple of minutes if required.
- Drive on a pre-selected 2nd scenario.
- Complete post-drive questionnaire.
- Rest for a couple of minutes if required.
- Drive on a pre-selected 3rd scenario.
- Complete post-drive questionnaires.

Previous to the experiment, participants filled a questionnaire about their name, age, gender, year of driver's license expedition, driving experience, crash involvements, use of any visual correction device and healthy issues. In addition, consent to the use of their personal information through the signature of the General Data Protection Regulation was given, questionnaires and documentation for experiment activity can be found in **Appendix D.**

2.5.1 Pre-drive questionnaire

The aim of this questionnaire is to collect information from participants: general health state, general wellness, consumption of alcohol or drugs, time of last meal and the use of any vision correction device.

2.5.2 Covid measurements

On account of the current health situation concerning Covid-19, certain additional measurements have been adopted for external test drivers, therefore, previous to starting the experiment, a commitment and declaration form were filled.

2.5.3 Post-drive questionnaires

Within the post-drive questionnaires, we had two parts, one focused on the just driven scenario and another one with a general post-questionnaire concerning the entire session.

In the first part, those enclosing the acceptability and usability of the tested system were asked alongside the workload test, to evaluate fatigue during drives. While in the second part, a questionnaire which involves questions regarding the experience in the driving task and scenario, during the simulation, and sickness produced by the simulator, was provided. Four fields were covered by this questionnaire: (i) sense, (ii) experiment consequences, (iii) immersion, (iv) virtual presence; and it is useful to understand deficiencies that must be improved in future works.

2.6 PILOT TEST

Prior to the collection of the data and the initiation of the experiment, a pilot test was conducted to estimate the total duration of each session and prove all the scenarios were working correctly and accordingly to the scope of the experiment.

For the pilot test, three internal drivers (Politecnico students) were selected to test three different scenarios in a single session, following the experimental protocol described in 2.5. Estimated times, for all drivers combined, are shown in Table 8.

Table 8: Estimated times per phase of the experimental task.

PHASE	TIME
Pre-drive questionnaire	2’
Trial track drive	2’-3’
Pre-selected first scenario drive	8’-10’
Post-drive questionnaires	3’-4’
Rest	1’
Pre-selected second scenario drive	8’-10’
Post-drive questionnaires	3-4’
Rest	1’
Third scenario drive	8’-10’
Post-drive questionnaires	5’-6’

2.7 DATA PROCESSING

Data was collected by means of the *Analysis* section within *SCANeR Studio®* software. It has the capacity of measuring parameters with a frequency of 10 Hz and gives the possibility to extract data over the longitudinal and transversal behaviour of drivers. Raw data was extracted in .cvs format, function of the time and by referring to the specific road section. For this reason, it was necessary to convert the file into .xlsx and consequently apply a *MATLAB* code to obtain a *continuous abscissa*, controlling three important integrated-software parameters such *Road ID* (identifier parameter), *Road length* (length of the particular road section) and *Road abscissa* (abscissa in meters of the particular road section per time step).

This procedure was conducted to obtain longitudinal speed and lateral position of drivers in each of their drives, distinguishing between systems variants (V-ISA-I and V-ISA-III) and baseline, and traffic flows. Therefore, the procedure was conducted 192 times and data was collected and grouped in Excel files for analysis.

2.8 OBSERVED VARIABLES AND SECTIONS

For a new ADAS used to control speed, the main parameter to study is the longitudinal speed over constant (stationary) speed conditions, i.e. sections where theoretically speed changes may not occur or are very limited as over curves arcs and tangents, but also in transitional sections, i.e. sections where drivers accelerate or decelerate, like ramp terminals. Similarly, transversal behaviour of drivers was analysed, consequently, lateral position along with merging and diverging distances.

2.8.1 Analysed sections

Seven sections for stationary speed conditions were selected, two in the motorways mid-position, one in the two-lane rural highway and along the four ramps arc centre (Figure 9). On the other hand, for transitional sections, investigated section were on terminals. In this case, entry and exit terminals for both motorways and two-lane rural highway. For diverging terminals (Figure 21 and Figure 23), longitudinal speed was extracted from diverging point (LT) and at the end of the terminal section/start of the connection (TR). While for merging sections (Figure 22 and Figure 23), the end of connection/start of the terminal (RT) and merging point (TL).
Moreover, for the computation of the diverging and merging distances (L_{LT}), a common reference point was established. In diverging terminals, it was the start of the taper (TS), whereas for merging ones, the end of the connection (RT) section.

All in all, observed variables were:

- Longitudinal speed (S) and lateral position (LP) at motorway mid-position, both up (S_{M_up}; LP_{M_up}) and down (S_{M_down}; LP_{M_down}) ;
- Longitudinal speed (S) and lateral position (LP) at two-lane rural highway position (S_{TLRP}; LP_{TLRP});
- Longitudinal speed (S) and lateral position (LP) at the ramps arc centre, considering ramp 1 (S_{R_1}; LP_{R_1}), ramp 2 (S_{R_2}; LP_{R_2}), ramp 3 (S_{R_3}; LP_{R_3}), and ramp 4 (S_{R_4}; LP_{R_4});
- Standard deviation of lateral position along ramps arcs ($SDLP_{R\_i}$), where i represents the ramp number;
- Longitudinal speed (S) at LT (S_{LTi}) and TR (S_{TRi}) at the four diverging terminals, where i represents the ramp number;
- Longitudinal speed (S) at TL (S_{TLi}) and RT (S_{RTi}) at the four merging terminals, where i represents the ramp number;
- Merging and diverging distances ($L_{LT_{Mi}}$; $L_{LT_{Di}}$), where i represents the ramp number.

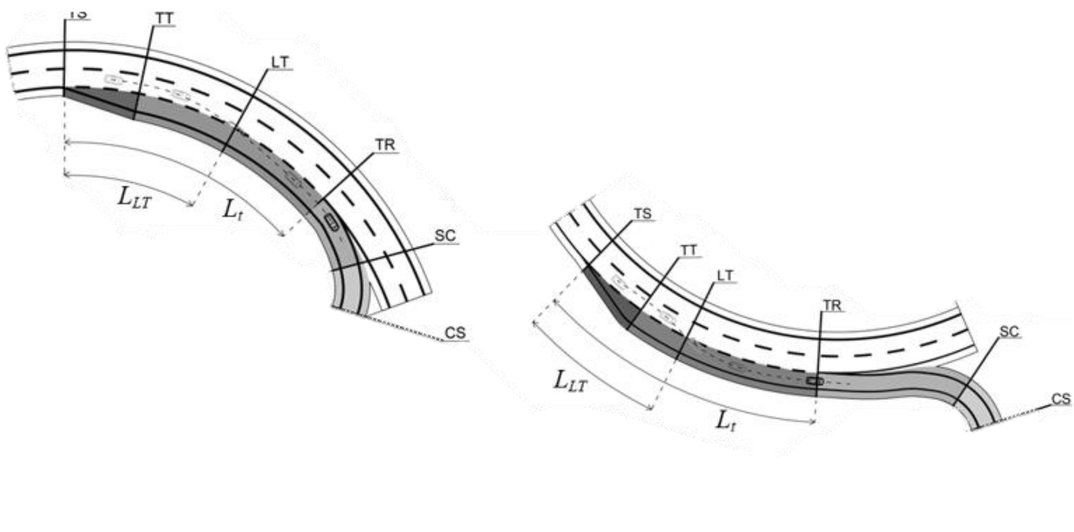


Figure 21. Diverging terminals. Ramp-terminal connection (between sections TR and SC) with continue (egg-shaped) curvature (left-hand side), and reverse (S-shaped, inflected) curvature (right-hand side). (Notes: TS = terminal start; TT = taper-to-terminal; LT = lane-to-terminal; TR = terminal-to-ramp; SC = spiral to curve; CS = curve to spiral.).

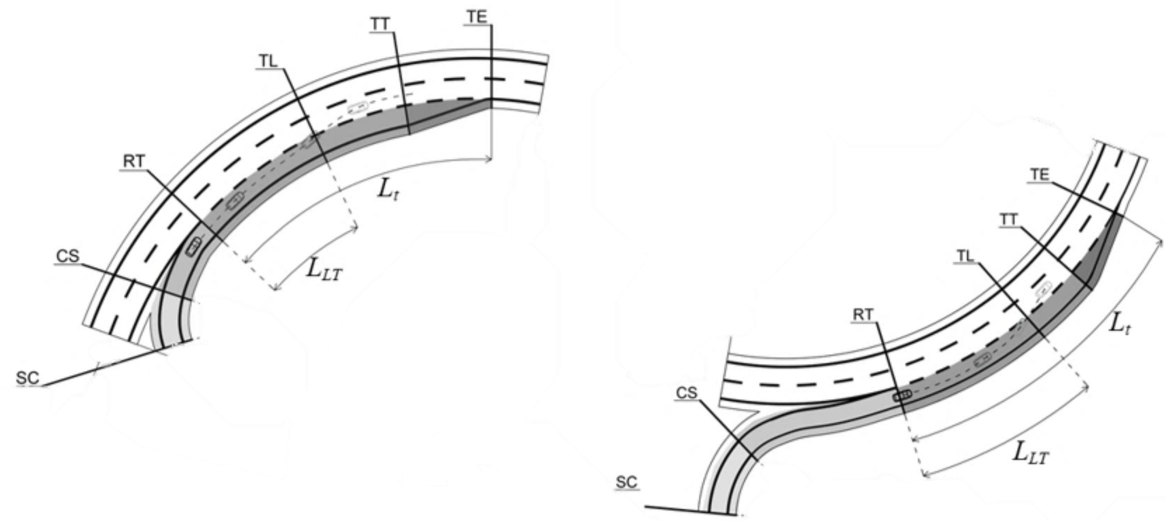


Figure 22. Merging terminals. Ramp-terminal connection (between sections CS and RT) with continue (egg-shaped) curvature (left-hand side), and reverse (S-shaped, inflected) curvature (right-hand side). (Notes: SC = spiral to curve; CS = curve to spiral; RT = ramp-to-terminal; TL = terminal-to-lane; TT = terminal-to-taper; TE = terminal end.).

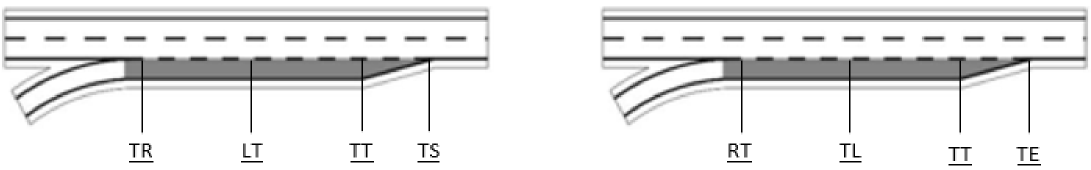


Figure 23. Diverging (left-hand side) and merging (right-hand side) linear terminals with particular reference on sections.

Observed variables were subjected to t-tests to evaluate the statistical significance of the differences between the data collected belonging to baseline conditions, V-ISA-I, and V-ISA-III, for high and low traffic flows, of every driver.

The output of this statistical test is represented by the *p-value,* which is the probability of obtaining test results at least as extreme as the results actually observed, under the assumption that the null hypothesis is correct. This significance value is compared with the selected level of confidence of 95%, indicating that *p-values* larger than 0.05 indicate insignificant differences between the means of the two compared data samples.

On the other hand, linear mixed models (LMM) were calibrated, a statistical technique that evaluates the influence and significance of the experimental factors, divided into fixed and random, have on the interested dependent variable measured during the study.

3. MOTORWAY AND TWO-LANE RURAL HIGHWAY

This chapter introduces the results and analysis of the data at the motorway and two-lane rural highway sections, investigating the longitudinal and transversal behaviour of drivers. As reported in the previous chapter, two sections were investigated along the motorway and one section is examined along the two-lane rural highway. The chapter provides the statistical results to highlight significant differences among the scenarios and fulfilled the initial objective of the study to find the effect of the V-ISA system on driver behaviour in straight sections.

3.1 MOTORWAY SECTIONS

3.1.1 Longitudinal behaviour outcomes

The driver longitudinal behaviour was examined based on the operating speed. The analysis performed contemplating: (i) the difference of driver's speed when V-ISA was active (by comparing the baseline condition with each of the two V-ISA variants under same traffic flow), (ii) the potential influence of traffic (comparing the scenarios between low and high traffic flow).

Statistical tests were carried out on samples paired as: ***baseline-V-ISA-I***, ***baseline-V-ISA-III***, ***V-ISA-I-V-ISA-III*** within same traffic flow, and within same system considering different traffic flows: ***baseline (high flow)-baseline (low flow)***, ***V-ISA-I (high flow)-V-ISA-I (low flow), V-ISA-III (high flow)-V-ISA-III (low flow)***.

Figure 24 and Figure 25 report values of mean speed by scenario and traffic flow for motorway up and down sections respectively; p-value is represented on top of the bars, indicating significance between samples, and error bars represent positive and negative value of standard deviation. For those cases in which significance is not strong (*p-value* higher than the significance value of 0,05), relation is not represented. In Table 9, mean and standard deviation (SD) of speed at motorway sections is grouped by scenario and traffic flow. The complete t-test analysis with p-values results is grouped in **Appendix E.**

Table 9. Mean and Standard deviation values for speed at motorway sections. (Note: P.S.L = Posted speed limit)

	P.S.L [km/h]	Baseline				V-ISA-I				V-ISA-III			
		High flow (HF)		Low flow (LF)		High flow (HF)		Low flow (LF)		High flow (HF)		Low flow (LF)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
S_{M_up}	130	121.52	11.36	124.25	13.36	118.41	11.88	126.24	17.28	120.21	12.14	124.83	12.62
S_{M_down}	130	115.87	12.60	116.57	12.21	113.82	14.90	116.77	13.82	116.75	13.90	116.86	14.34

At motorway sections, there is not an indication of speed variation with the use of V-ISA as evidenced in Figure 24 and Figure 25. Drivers operating speed do not follow any trend in reduction nor increase at those sections. Whereas looking at speeds among traffic levels, some differences might be found, and this could be attributed to the normal change in number of vehicles found traveling around motorway when two different levels of traffic are added. *T-test* support this indicating statistical significance between groups when comparing the V-ISA-I and V-ISA-III among the two traffic levels.

At motorway down section, t-test does not evidence significant differences between groups, as seen in Figure 25, reinforcing the results found over motorway up sections, where the V-ISA system did not have any influence in drivers' longitudinal speed.

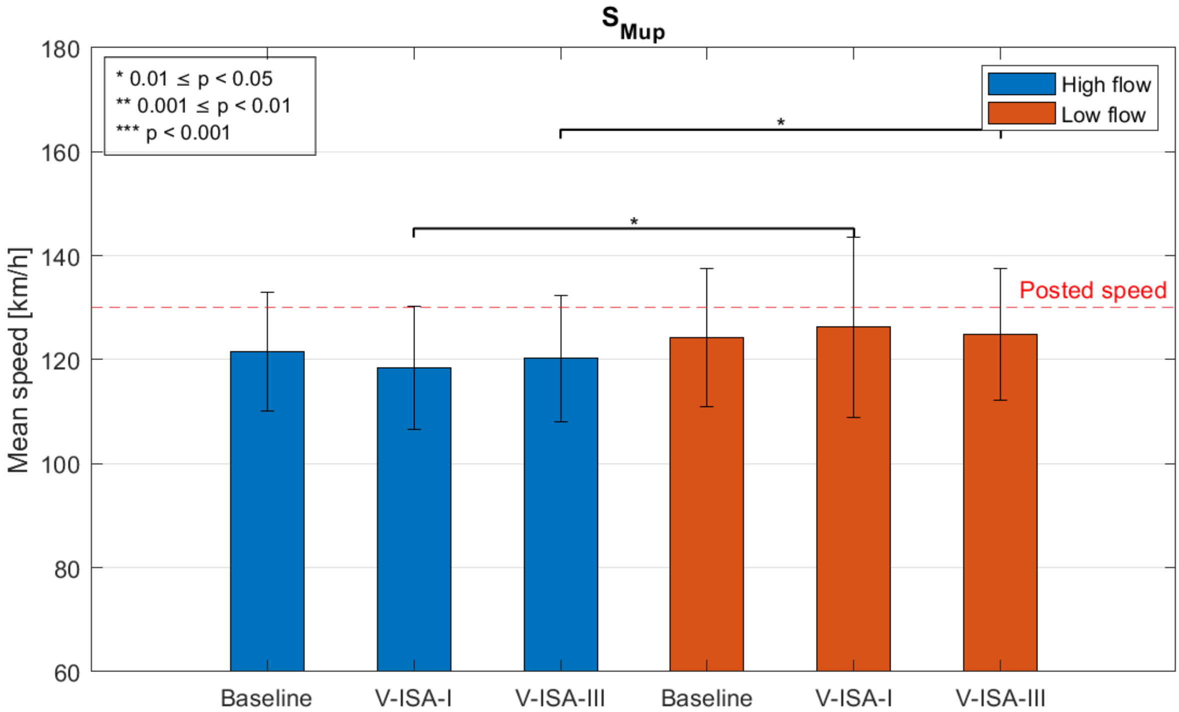


Figure 24. Representation of mean speed values at motorway up section with indication of the positive and negative standard deviation (error bars), posted speed limit and p-values.

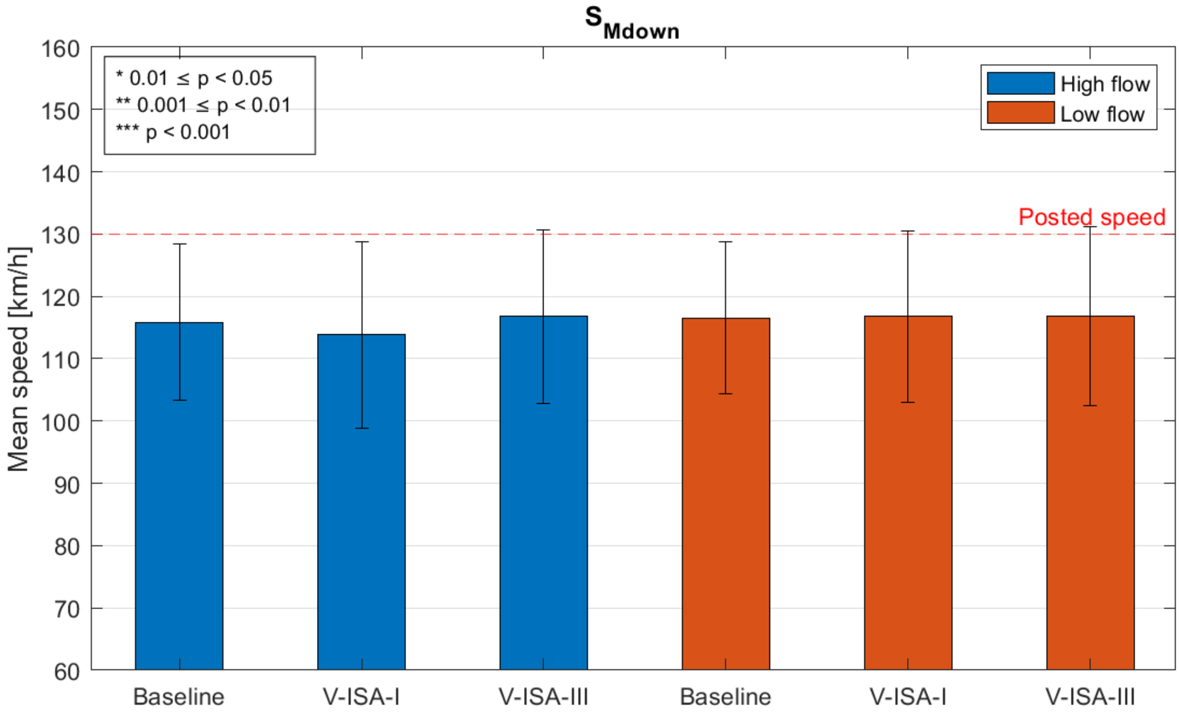


Figure 25. Representation of mean speed values at motorway down section with indication of the positive and negative standard deviation (error bars), posted speed limit and p-values.

Similarly, LMM outcomes (Table 10) indicate that traffic flow remains the only factor that affects the speed at the motorway up section. Figure 26 shows higher operating speeds on the low traffic level, which is in line with the results from t-test. Besides, LMM results (**Appendix H**, Table 57) manifested strong significance in the interaction between traffic flow and gender ($Low - High * F - M = -6.90, p = 0.011$) and between traffic flow and age class ($Low - High * II - III = -7.30, p = 0.012$). Bonferroni adjusted post-hoc test comparison between males and traffic level shows statistically significant differences ($M * High - Low = -8.24, p =< .001$), as well as between age class III drivers and traffic flow ($III * High - Low = -7.915, p = 0.002$). This indicates that males and older drivers tend to increase their speed when a lower number of cars are in the driving lane.

*Table 10. Fixed effect Omnibus tests table with factors influencing speed for motorway up section. (Note: some effects are not inserted because were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F(df, den df)(p-value)***
	S_{Mup}
Traffic flow	10.534 (1, 156)**
Gender	2.317 (1, 28)
Age class	.641 (2, 28)
Traffic flow ⁜ Gender	6.694 (1, 156)**
Traffic Flow ⁜ Age class	3.321 (2, 156)**

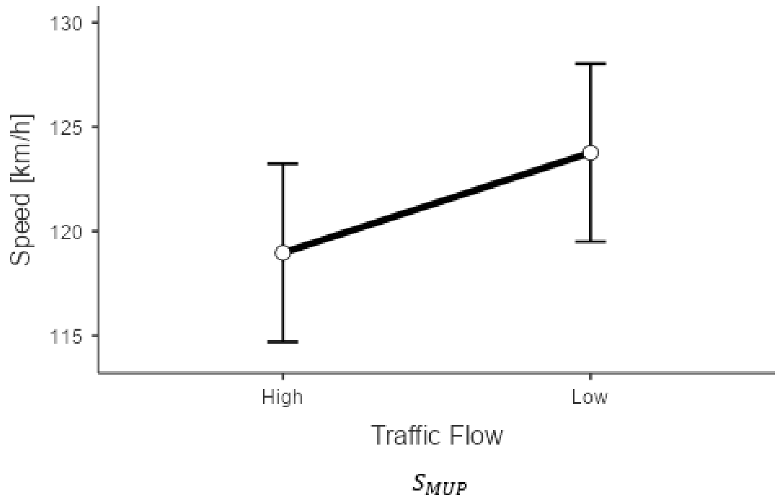


Figure 26. Plot of speed at motorway up section for high and low flow traffic levels with 95% confidence level bars.

Moreover, at motorway down section, LMM outputs (Table 11) reinforces what was obtained from t-test, showing no incidence of the V-ISA system in the drivers' longitudinal behaviour. These results reinforce the hypothesis (speed increment at straight sections) of no speed compensation from drivers over steady straight sections when the V-ISA system is active.

*Table 11. Fixed effect Omnibus tests table with factors influencing speed for motorway down section. (Note: some effects are not inserted because were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F(df, den df)(p-value)***
	S_{Mdown}
System Type	.510 (2, 142)
Traffic Flow	.988 (1, 142)
Gender	1.662 (1, 26)
Age Class	.079 (2, 26)
V-ISA ✻ Traffic Flow	.436 (2, 142)
V-ISA ✻ Gender	.689 (2, 142)
Traffic Flow ✻ Gender	.483 (1, 142)
V-ISA ✻ Age Class	1.663 (4, 142)
Gender ✻ Age Class	.562 (2, 26)
V-ISA ✻ Traffic Flow ✻ Gender	4.645 (2, 142)**
V-ISA ✻ Gender ✻ Age Class	1.838 (4, 142)

3.1.2 Transversal behaviour outcomes

The transversal behaviour over the motorway sections were analysed by comparing the lateral position of drivers (i) between baseline scenario and V-ISA variants scenarios, and (ii) between same scenarios within traffic levels.

The same type of analysis described in the longitudinal behaviour was performed. Mean and standard deviation values for lateral position of drivers at motorway sections are synthetized in Table 12. Further details regarding *p-values* are provided in **Appendix E.**

Table 12. Mean and Standard deviation values for lateral position at motorway sections.

	Baseline				**V-ISA-I**				**V-ISA-III**			
	High flow (HF)		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LP_{M_up}	-0.178	0.486	-0.035	0.448	-0.038	0.575	-0.053	0.381	-0.092	0.584	-0.008	0.357
LP_{M_down}	-0.224	0.546	0.020	0.570	-0.150	0.555	-0.109	0.362	-0.169	0.385	-0.195	0.263

Statistical analysis carried out on lateral positions of drivers at motorway sections does not evidence any statistical significance between groups as shown in Figure 27 and Figure 28.

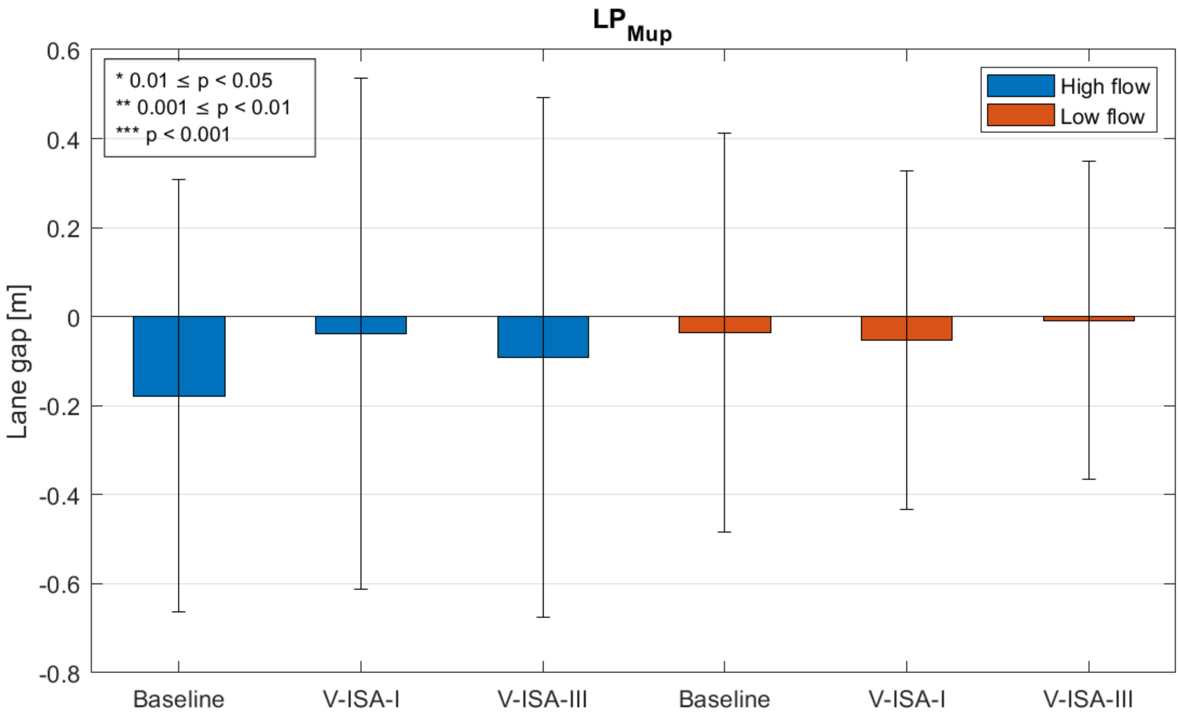


Figure 27. Representation of lane gap mean values for motorway up section with indication of the positive and negative standard deviation (error bars), and p-values.

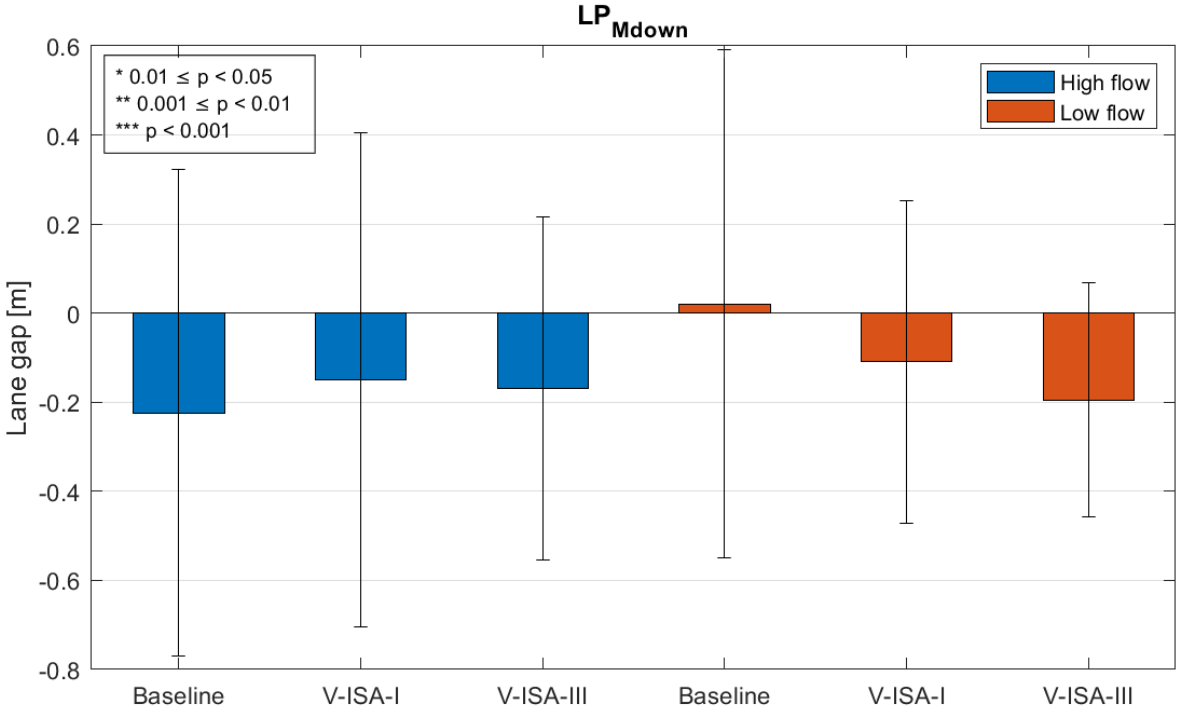


Figure 28. Representation of lane gap mean values for motorway down section with indication of the positive and negative standard deviation (error bars), and p-values.

Likewise, LMM results (Table 13 and Table 14) manifested no significance from the V-ISA system over the drivers' lateral position at motorway sections. Specific LMM analysis at motorway down section (**Appendix H**; Table 60) found strong significances between informative variant (V-ISA-I) and age classes ($LP_{V-ISA-I} - LP_{Baseline} * I - III = 0.498, p = 0.036; LP_{V-ISA-I} - LP_{Baseline} * II - III = 0.353, p = 0.044$). However, Bonferroni post-hoc test does not support it indicating no significance between groups. Overall, neither V-ISA-I nor V-ISA-III influenced drivers' transversal behaviour which results in a positive finding in the use of V-ISA over straight sections.

*Table 13. Fixed effect Omnibus tests table with factors influencing lateral position for motorway up section. (Note: some effects are not inserted because were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F(df, Den df)(p-value)***
	LP_{Mup}
Traffic flow	.067 (1, 157)
Age class	.570 (2, 29)
Traffic Flow ✻ Age class	1.786 (2, 157)

*Table 14. Fixed effect Omnibus tests table with factors influencing lateral position for motorway down section. (Note: some effects are not inserted because were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	*F(df, Den df)(p-value)*
	LP_{Mdown}
V-ISA	.769 (2, 151)
Traffic flow	1.756 (1, 151)
Gender	.713 (1, 26)
Age class	.692 (2, 26)
Traffic flow ✻ V-ISA	1.562 (2, 151)
V-ISA ✻ Age class	1.746 (4, 151)
Gender ✻ Age class	1.740 (2, 26)

3.2 TWO-LANE RURAL HIGHWAY SECTION

3.2.1 Longitudinal behaviour outcomes

Identical analysis was performed for drivers' longitudinal speed over the two-lane rural highway section. Table 15 provides the mean and standard deviation values for speed, with indication of the posted speed limit over the two-lane rural highway section listed for scenario and traffic flow.

Drivers mean speeds are similar comparing different driving scenarios. They did not evidence differences between baseline scenario and V-ISA ones, neither between traffic levels comparison (Table 15). t-test evaluation highlights significant difference just among the V-ISA-I and V-ISA-III variants, as illustrated in Figure 29. These results could be attributed to the speed controlled produced by the presence of an in front vehicle, for both low and high traffic level, where no possibility of overpassing was allowed.

Table 15. Mean and Standard deviation values for speed at two-lane rural highway section.

	P.S.L [km/h]	**Baseline**				**V-ISA-I**				**V-ISA-III**			
		High flow (HF)		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
S_{TLRP}	90	77.53	7.97	77.63	11.29	77.18	8.81	77.03	10.04	77.23	8.07	80.94	9.19

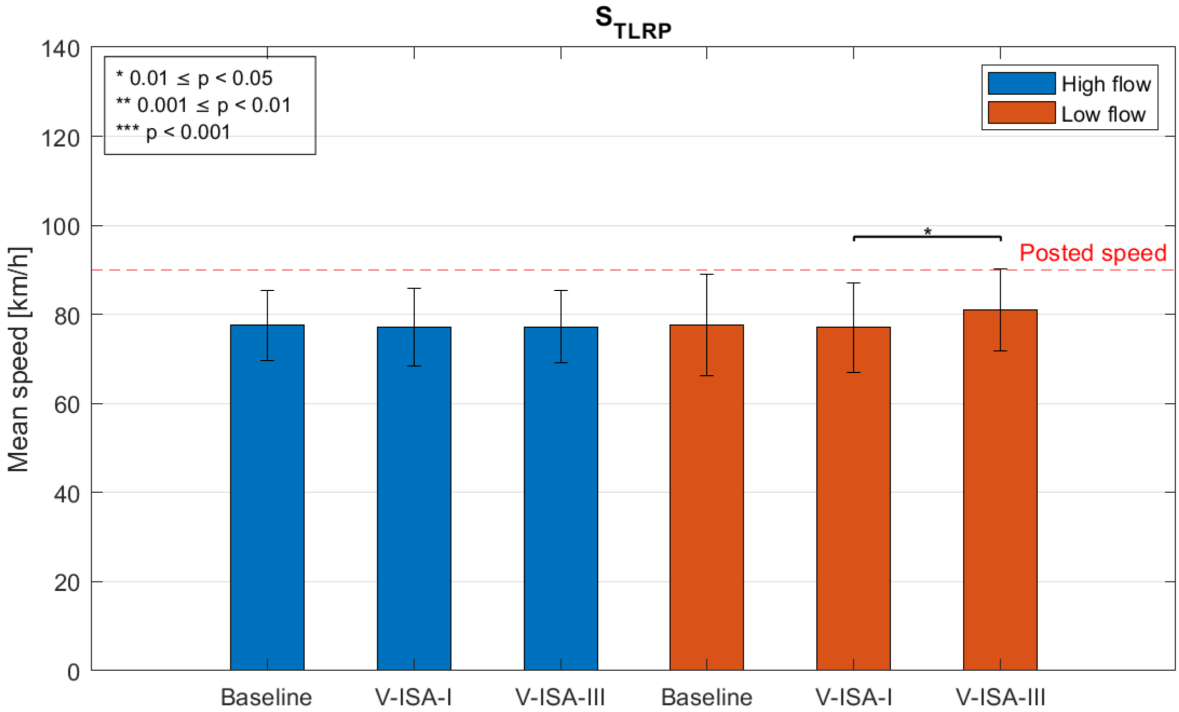


Figure 29. *Representation of mean speed values at two lane rural highway section with indication of the positive and negative standard deviation (error bars), posted speed limit and p-values.*

Consequently, LMM outputs support these results indicating that the V-ISA system has no incidence in drivers adopted speed (Table 16). Specific analysis (**Appendix H**;

Table 61) demonstrate a significance between groups in the comparison among traffic flow and age classes ($Low - High * II - III = -3.770, p = 0.048$). Nevertheless this result is not supported by the adjusted Bonferroni post-hoc test.

*Table 16. Fixed effect Omnibus tests table with factors influencing speed for two-lane rural highway section. (Note: some effects are not inserted because were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F(df, den df)(p-value)***
	STLRP
V-ISA	1.887 (2, 153)
Traffic Flow	.966 (1, 153)
Age Class	.189 (2, 29)
V-ISA ✻ Traffic Flow	2.052 (2, 153)
Age class ✻ Traffic Flow	2.122 (2, 153)

3.2.2 Transversal behaviour outcomes

Mean lateral position at two-lane rural highway section (Table 17) shows that drivers tend to maintain the vehicle to the right with respect of the lane centreline, and that behaviour does not vary with the V-ISA implementation. Moreover, standard deviations are similar in all scenarios which reinforce the idea of drivers maintaining a similar lateral position in all the cases.

Table 17. Mean and Standard deviation values for lateral position at two-lane rural highway section.

	Baseline				**V-ISA-I**				**V-ISA-III**			
	High flow (HF)		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LP_{TLRP}	-0.079	0.239	-0.035	0.290	-0.047	0.287	-0.075	0.275	-0.066	0.228	-0.066	0.322

In addition, t-test outcome does not evidence statistically significant differences comparing the baseline scenario with the V-ISA drives, neither among traffic levels (Figure 30).

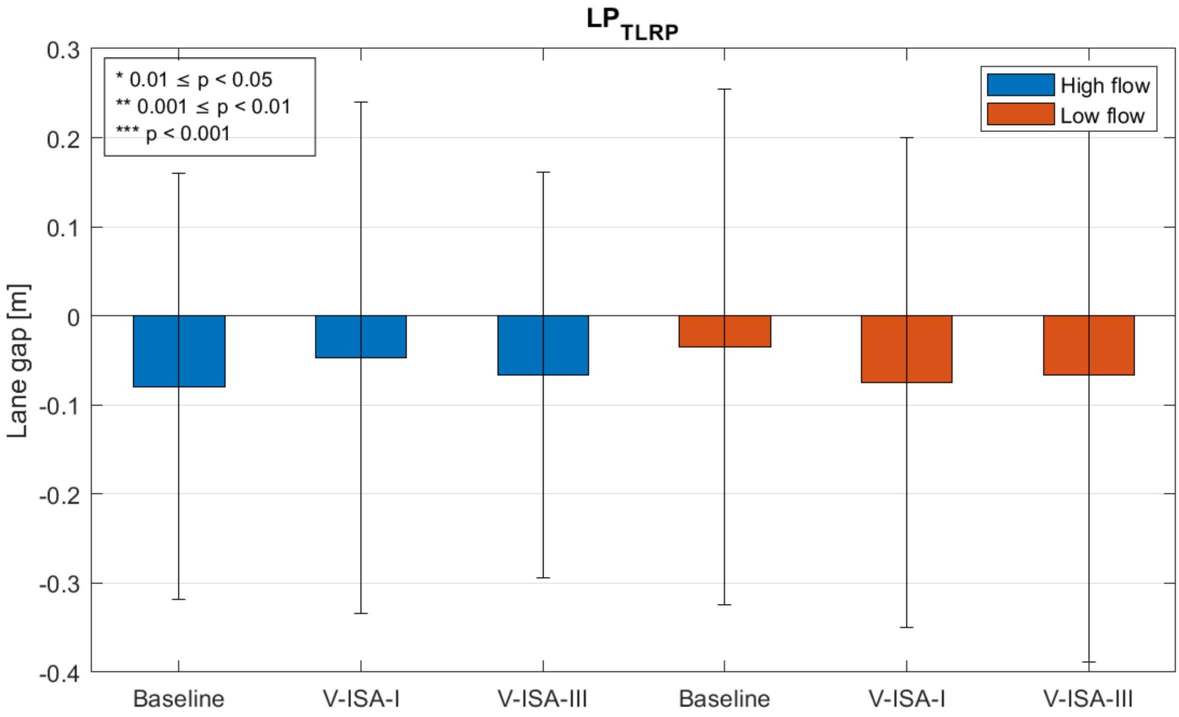


Figure 30. Representation of lane gap mean values for two-lane rural highway section with indication of the positive and negative standard deviation (error bars), and p-values.

LMM results (Table 18) are in line with what was found from t-test. No incidence is manifested among the V-ISA system and drivers' lateral position. Furthermore, significance is highlighted in the case of the V-ISA system and gender, specifically for the V-ISA-III variant ($LP_{V-ISA-II} - LP_{Baseline} * F - M = -0.210, p = 0.011$). Conversely, adjusted Bonferroni post-hoc tests carried out over these comparisons did not support these findings. These outputs reinforce what was observed over the motorway sections, indicating that drivers' lateral behaviour does not change when the V-ISA-I or V-ISA-III is active in straight sections.

*Table 18. Fixed effect Omnibus tests table with factors influencing lateral position for two-lane rural highway section. (Note: some effects are not inserted because were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F(df, den df)(p-value)***
	LP_{TLRP}
V-ISA	.658 (2, 130)
Traffic Flow	.252 (1, 130)
Gender	1.854 (1, 26)
Age Class	1.376 (2, 26)
V-ISA ✻ Traffic Flow	.546 (2, 130)
V-ISA ✻ Gender	3.447 (2, 130)**
Traffic Flow ✻ Gender	.185 (1, 130)
V-ISA ✻ Age Class	1.321 (4, 130)
Traffic Flow ✻ Age Class	1.368 (2, 130)
Gender ✻ Age Class	2.339 (2, 26)
V-ISA ✻ Traffic Flow ✻ Gender	1.590 (2, 130)
V-ISA ✻ Traffic Flow ✻ Age Class	.035 (4, 130)
V-ISA ✻ Gender ✻ Age Class	.891 (4, 130)
Traffic Flow ✻ Gender ✻ Age Class	.468 (2, 130)
V-ISA ✻ Traffic Flow ✻ Gender ✻ Age Class	1.799 (4, 130)

4. RAMPS

This chapter is divided into three main sections: (4.1) diverging terminals, (4.2) centre of ramps arc, and (4.3) merging terminals. Each section presents the results, analysis and discussion of the most relevant factors affecting drivers' longitudinal and transversal behaviour. The analysis was conducted by means of the t-test and series of linear mixed models (LMM). The chapter aims to investigate the influence of the V-ISA system in transitional and steady sections with poor visibility conditions.

4.1 DIVERGING TERMINALS

4.1.1 Longitudinal behaviour outcomes

Drivers mean speed, and standard deviation by scenarios and traffic flow level at diverging terminals sections LT and TR are shown in Table 19.

Table 19. Mean and Standard deviation values for speed at merging terminals sections.

	Baseline				**V-ISA-I**				**V-ISA-III**			
	High flow (HF)		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
S_{LT1}	66.86	8.86	69.83	10.23	67.72	8.56	69.29	11.09	66.41	10.14	69.97	12.31
S_{TR1}	61.67	9.71	64.80	11.53	63.66	10.41	63.04	11.51	62.43	10.67	65.14	11.31
S_{LT2}	87.62	10.01	92.30	11.80	88.78	13.40	86.76	11.66	88.00	9.10	88.25	9.72
S_{TR2}	75.04	13.77	78.28	12.68	76.00	12.83	72.83	14.03	75.74	12.67	70.80	6.90
S_{LT3}	75.90	10.07	74.59	13.34	74.39	11.50	74.31	11.80	74.65	10.21	76.98	10.49
S_{TR3}	63.97	14.41	64.86	12.68	60.55	10.09	60.41	10.21	58.49	10.42	60.06	9.84
S_{LT4}	87.10	10.56	89.57	10.78	86.88	8.19	88.13	15.29	86.55	10.12	90.52	11.45
S_{TR4}	80.08	11.03	80.61	11.39	77.96	10.69	77.67	13.01	78.02	14.69	82.38	14.87

Figure 31 shows the representation of the mean speed differences by scenario for the diverging terminal of ramp-1 at LT1 and TR1 sections, with particular reference to the *p-value*. Depreciable speed changes occurred over the ramp-1 diverging terminal. As seen in Table 19, comparing the baseline drive with the ones using V-ISA for both traffic flows, drivers did not manifest significant differences in the speed adopted. This behaviour is supported by t-test, where no statistically significant differences were found, except on the V-ISA-III high flow – V-ISA-III low flow comparison, indicating drivers' tendency of speeding in a reduced traffic level.

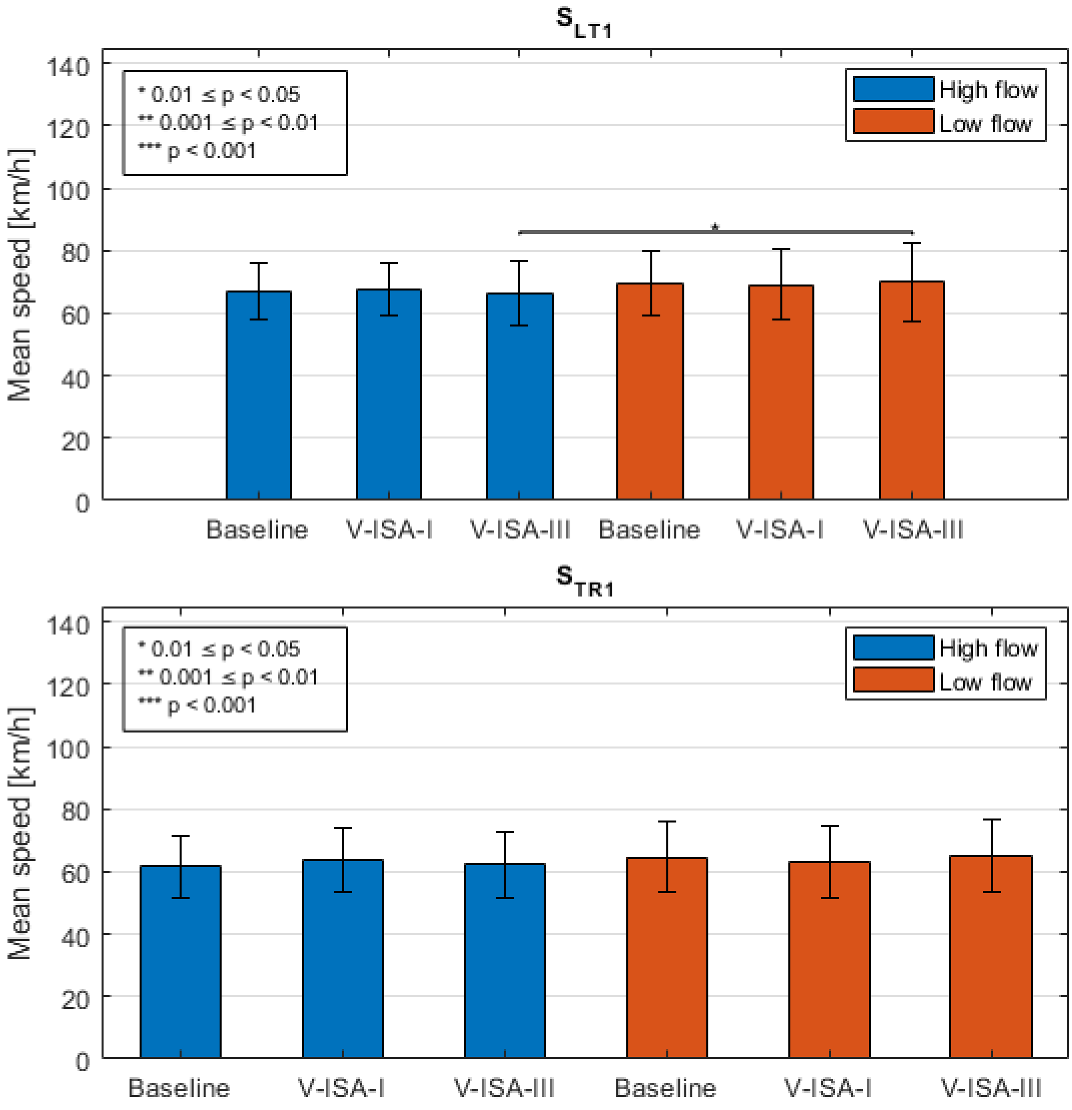


Figure 31. Representation of mean speed values for diverging terminal, ramp 1, with indication of positive and negative standard deviation (error bars) and p-values.

Along ramp-2 diverging terminal, specifically at diverging point, drivers mean speeds vary when comparing the baseline drive with V-ISA ones. For high flow level, drivers mean operating speed is higher compared to the baseline scenario, while similar speed were registered comparing baseline drives with V-ISA-III. Conversely, for low flow level, both V-ISA-I and V-ISA-III mean speeds are lower than baseline scenario speed, however, drives with V-ISA-III active manifested higher mean speed than V-ISA-I. Statistical analysis found significance between the baseline-V-ISA-I groups for low flow. Moreover, significance is evidenced between baseline groups among traffic flows. At the ramp-2 connection start (TR2), for high flow level drivers exhibited higher mean speeds for V-ISA drives compared with baseline driver, while for low flow, both variants are showing lower speeds in comparison to baseline scenario, reinforced by t-test results, that indicate strong significance between groups as seen in Figure 32.

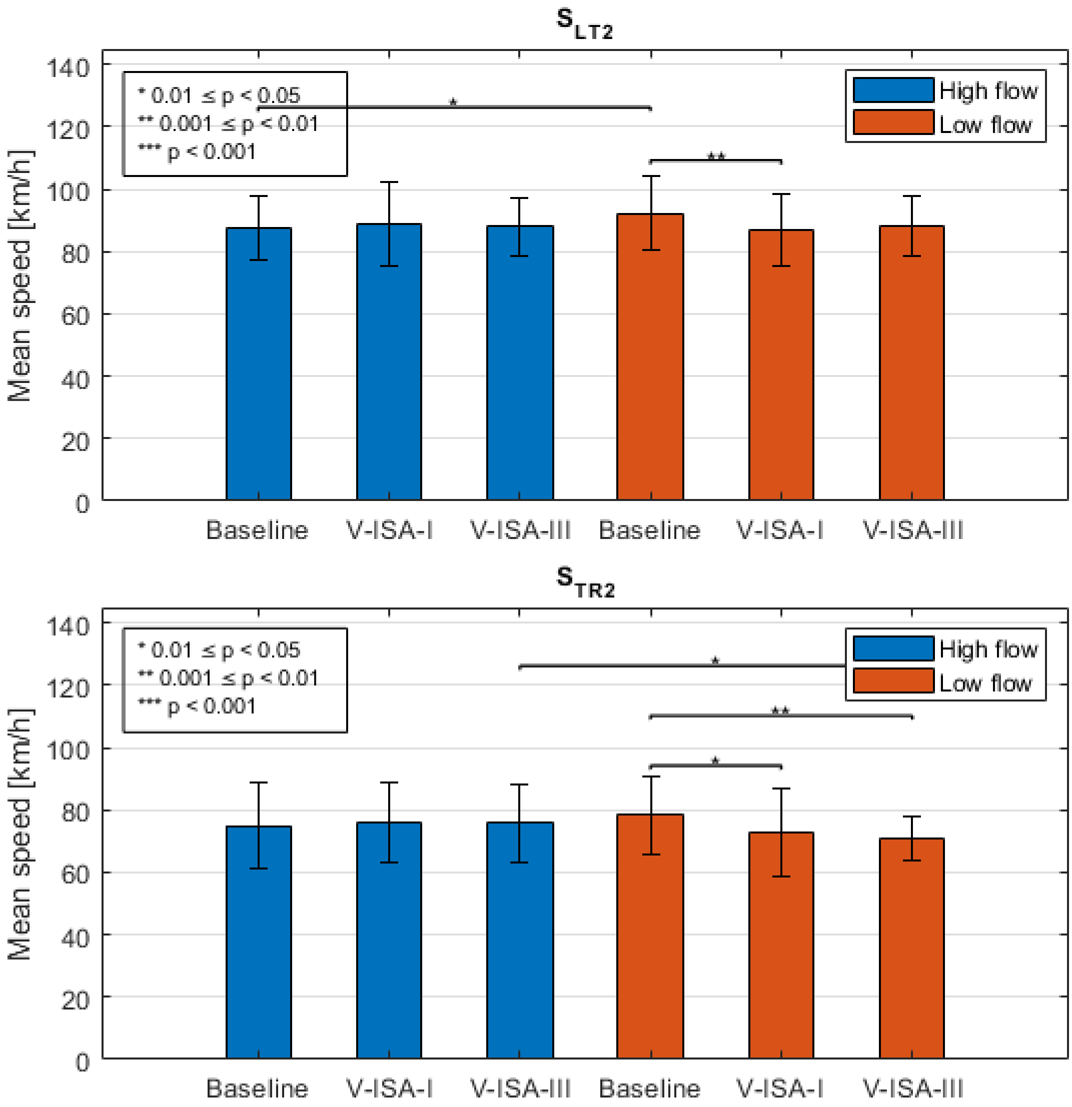


Figure 32. Representation of mean speed values for diverging terminal, ramp 2, with indication of the positive and negative standard deviation (error bars) and p-values.

In Figure 33, the ramp-3 diverging terminal sections are shown. At the point where drivers diverge from the two-lane rural highway, the use of the V-ISA system does not represent a considerable change in the mean speeds themselves. It can be seen that, for both the high flow and the low flow, there are no clear differences between one scenario and another.

However, in section TR3, is evident a predisposition of reducing the speed from drivers when using the V-ISA system. Results obtained from the t-test support the previous affirmation showing strong significance between baseline and V-ISA-I for high flow, and between baseline and both V-ISA-I and V-ISA-III for low flow.

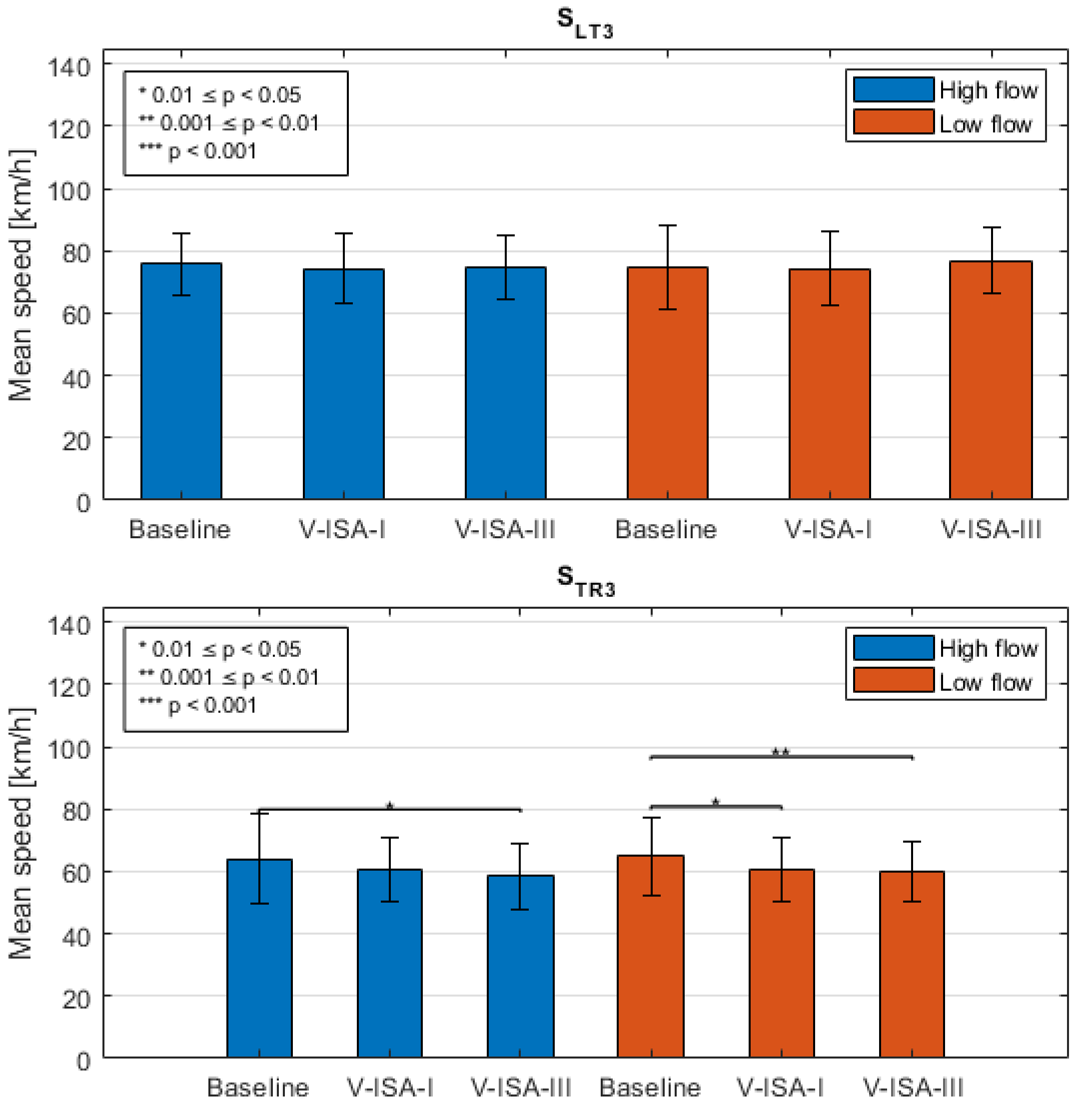


Figure 33. Representation of mean speed values for diverging terminal, ramp 3, with indication of the positive and negative standard deviation (error bars) and p-values.

Figure 34 shows the sections of the ramp-4 exit terminal. For this particular ramp, drivers do not show a change in longitudinal behaviour in terms of the adopted speed at the point where they diverge, which might indicate a positive finding in the use of the V-ISA system. However, there is also no statistical significance to corroborate the mentioned above. The same occurs in section TR4, where there is evidence of a slight reduction in the mean speed of the drivers in the V-ISA-I and V-ISA-III drives, however, for the case of low flow, the variant that intervenes in the system, shows a mean speed higher than any other managed at this point with an important statistical significance with respect to the informative low flow scenario.

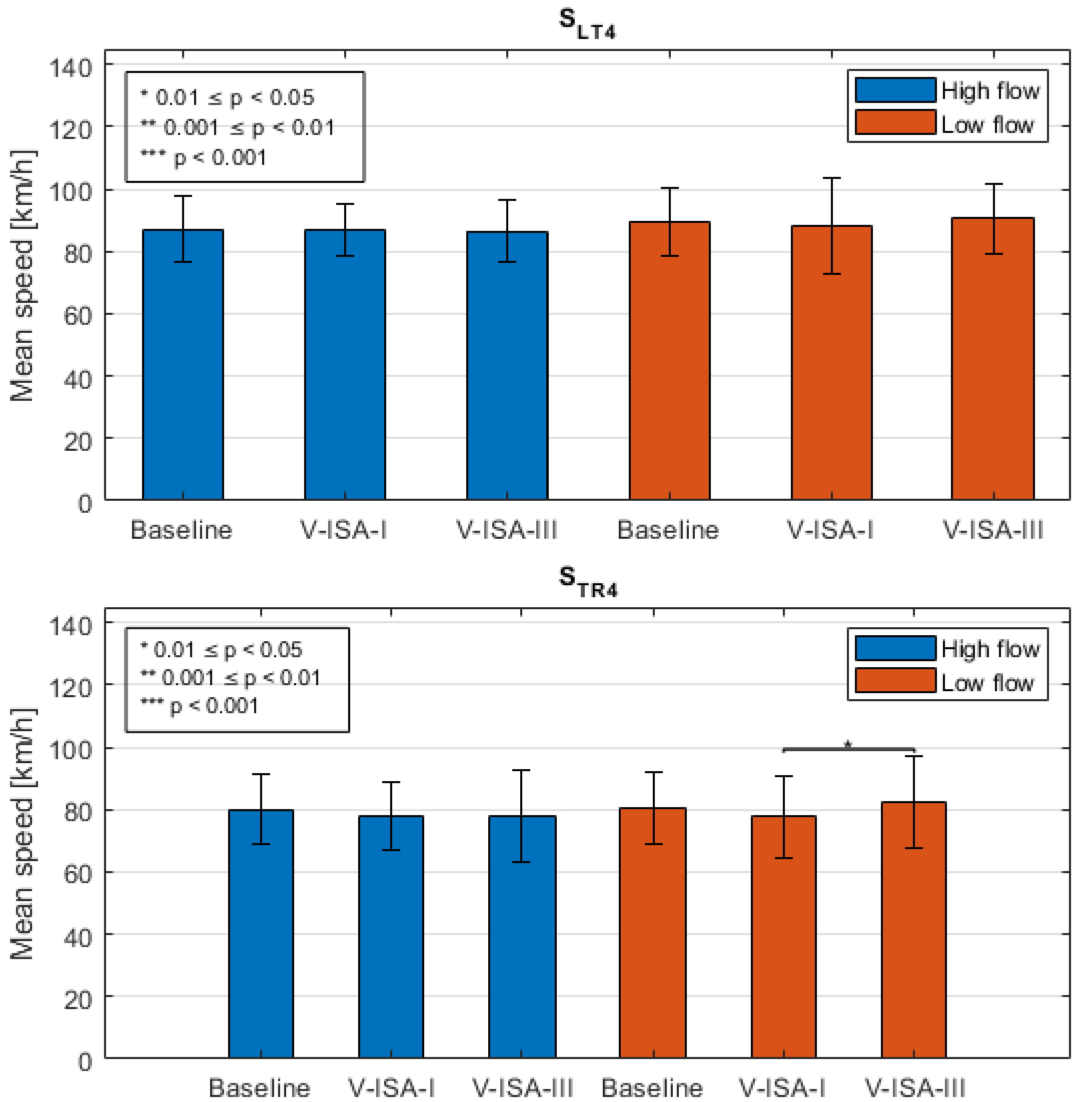


Figure 34. Representation of mean speed values for diverging terminal, ramp 4, with indication of the positive and negative standard deviation (error bars) and p-values.

According to Liner Mixed model (LMM) results (**Appendix H,** Table 63 and Table 69) drivers did not manifest speed behaviour changes influenced by the use of the V-ISA system in diverging manoeuvres for ramp-1 and ramp-4 (Table 20 and Table 21). Instead, traffic has an impact in the ramp-1 diverging point (LT1), exhibiting higher merging speed at low traffic levels (Figure 35 and Figure 36). This behaviour was already observed by Calvi and De Blasiis, 2011, where mean speed of drivers decreases by the increment of traffic flow.

*Table 20. Fixed effect Omnibus tests table with factors influencing speed for diverging terminals sections LT1, LT2, LT3, and LT4. (Notes: TF: traffic flow; AC: age class; some effects are not included given that were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F (df, den df) (p-value)***			
	S_{LT1}	S_{LT2}	S_{LT3}	S_{LT4}
System Type	.156 (2, 130)	1.472 (2, 150)	1.088 (2, 150)	-
TF	4.958 (1, 130)**	1.149 (1, 150)	.029 (1, 150)	8.430 (1, 157)**
Gender	.885 (1, 25)	.075 (1, 30)	.149 (2, 26)	-
AC	.667 (2, 25)	-	.013 (1, 26)	3.720 (2, 28)**
Kilometers per year	2.534 (1, 25)	-	-	-
Accidents	-	-	-	3.160 (1, 28)*
System Type ✻ TF	.207 (2, 130)	3.408 (2, 150)**	-	-
System Type ✻ Gender	2.464 (2, 130)*	1.120 (2, 150)	2.984 (2, 150)*	-
TF ✻ Gender	.275 (1, 130)	3.944 (1, 150)**	2.939 (2, 150)	-
System Type ✻ AC	.498 (4, 130)	-	-	-
Traffic Flow ✻ AC	6.489 (2, 130)**	-	.000 (1, 150)*	2.140 (2, 157)
Gender ✻ AC	.434 (2, 25)	-	.453 (2, 26)	-
System Type ✻ TF ✻ Gender	1.487 (2, 130)	2.678 (2, 150)*	-	-
System Type ✻ TF ✻ AC	.430 (4, 130)	-	-	-
System Type ✻ Gender ✻ AC	.674 (4, 130)	-	-	-
TF ✻ Gender ✻ AC	.783 (2,130)	-	3.769 (2, 150)**	-
System Type ✻ TF ✻ Gender ✻ AC	1.784 (4, 130)	-	-	-

*Table 21. Fixed effect Omnibus tests table with factors influencing speed for diverging terminals sections TR1, TR2, TR3, and TR4. (Notes: TF: traffic flow; AC: age class; some effects are not included given that were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F (df, den df) (p-value)***			
	S_{TR1}	S_{TR2}	S_{TR3}	S_{TR4}
System Type	.231 (2, 130)	2.398 (2, 146)*	8.716 (2, 147)***	-
TF	1.642 (1, 130)	1.657 (1, 146)	.569 (1, 147)	2.833 (1, 157)*
Gender	1.167 (1, 26)	.594 (1, 27)	.274 (2, 26)	-
AC	.355 (2, 26)	.610 (2, 27)	.543 (1, 26)	.830 (2, 28)
Accidents	-	4.218 (1, 27)*	-	4.667 (1, 28)**
System Type ✻ TF	.954 (2, 130)	5.037 (2, 146)**	-	-
System Type ✻ Gender	3.363 (2, 130)**	.545 (2, 146)	3.430 (2, 147)**	-
TF ✻ Gender	2.468 (1, 130)	.063 (1, 146)	-	-
System Type ✻ AC	.768 (4,130)	2.524 (4, 146)**	.419 (4, 147)	-
Traffic Flow ✻ AC	4.127 (2, 130)**	-	-	4.021 (2, 157)**
Gender ✻ AC	.606 (2, 26)	-	.671 (2, 26)	-
System Type ✻ TF ✻ Gender	1.998 (2, 130)	3.383 (2, 146)**	-	-
System Type ✻ TF ✻ AC	1.104 (4, 130)	-	-	-
System Type ✻ Gender ✻ AC	1.111 (4, 130)	-	2.089 (4, 147)*	-
TF ✻ Gender ✻ AC	2.177 (2, 130)	-	-	-

System Type ✻ TF ✻ Gender ✻ AC	1.431 (4, 130)	-	-	-

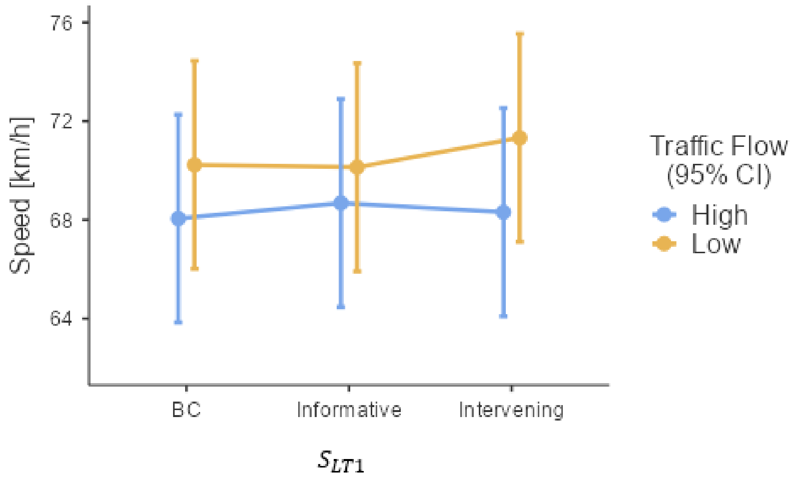


Figure 35. Plot of speed at ramp 1 diverging abscissa for different drives under the effect of V-ISA for high and low flow traffic levels with 95% confidence level bars.

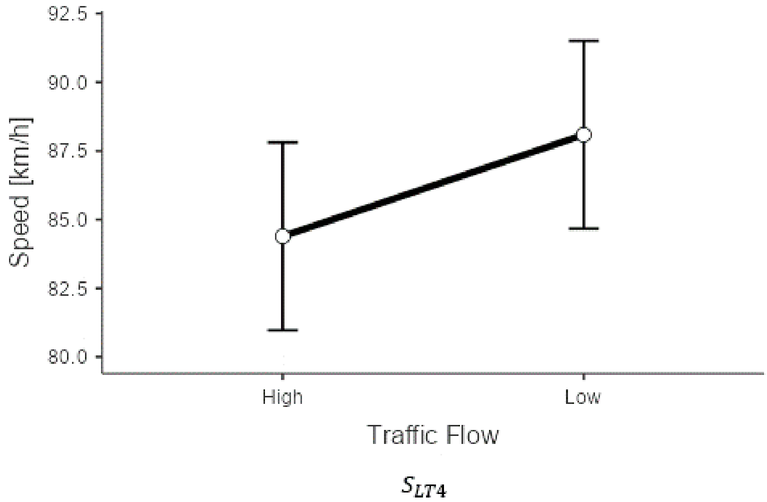


Figure 36. Plot of speed at ramp 4 diverging abscissa for high and low flow traffic levels with 95% confidence level bars.

Nevertheless, along diverging terminal of ramp-2, intervening variant has a significant influence in drivers speed at TR2, while at ramp two diverging point (LT2) no evidence of significance was found, as evidenced in Figure 37. This behaviour could be attributed to motorway curve radius combined with a continuous off-ramp terminal, where drivers tend to reduce the speed given the poor sight conditions and activation of the V-ISA-III system. Moreover, strong significance is found in the interaction between V-ISA and traffic over TR2 ($S_{TR2,V-ISA-I} - S_{TR2,Base} * Low - High = -7.049, p = 0.021$; $S_{TR2,V-ISA-III} - S_{TR2,Base} * Low - High = -9.148, p = 0.003$). Bonferroni adjusted post-hoc comparison between V-ISA-III variant and low traffic level shows statistically significant differences ($S_{TR2,Base} - S_{TR2,V-ISA-III} * Low = 8.201, p = 0.006$). Attributing that speed enforcement occurs mainly when drivers operating speed is higher due to the reduced presence of vehicles in the driving lane. Besides, for ramp-3 diverging terminal, LMM manifests strong significance between drivers speed at TR3 sections with both informative and intervening variant, indicating lower speeds (Figure 38).Demonstrating that drivers tend to increase their speed entering the ramp arc when the V-ISA is not active, similar behaviour were evidenced by Hazoor et al., 2021 at curve entrance section.

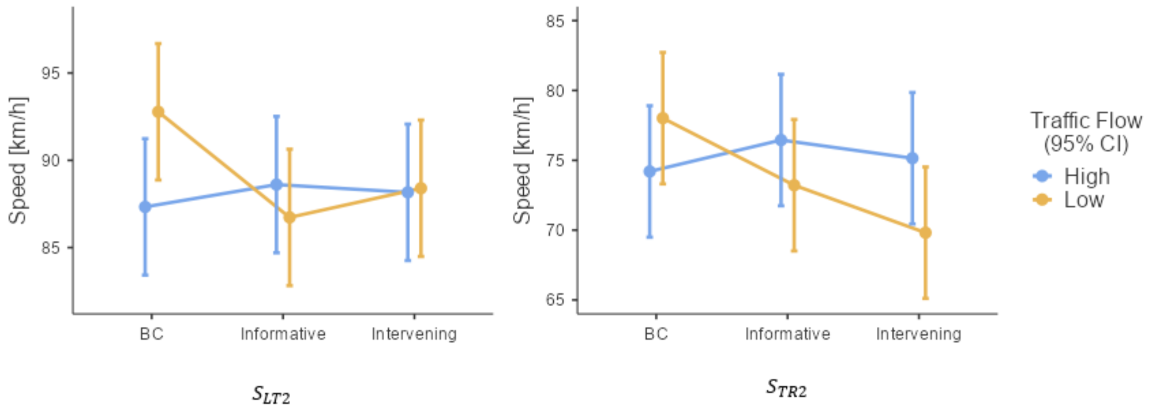


Figure 37. Plots of speed for ramp 2 diverging terminal sections (LT and TR) for different drives under the effect of V-ISA for high and low traffic levels with 95% confidence level bars.

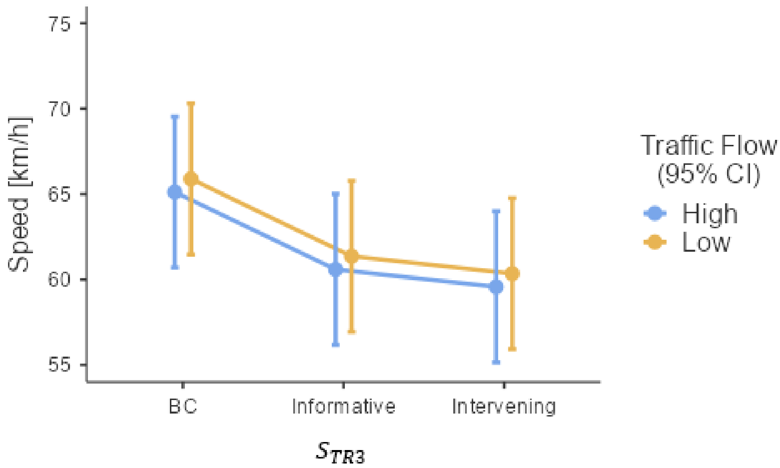


Figure 38. Plot of speed at TR3 section for different drives under the effect of V-ISA for high and low traffic levels with 95% confidence level bars.

4.1.2 Transversal behaviour outcomes

Transversal behaviour of drivers along diverging terminals were investigated from results on their diverging abscissa, which indicates the location at which drivers pass from the motorway or two-lane rural highway to the terminal.

Table 22. Mean and standard deviation values for diverging abscissa.

	Baseline				V-ISA-I				V-ISA-III			
	High flow (HF)		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
L_{LT_D1}	33.54	10.27	36.74	15.46	35.09	13.66	34.56	11.31	34.00	12.99	37.42	14.76
L_{LT_D2}	54.25	33.90	57.84	34.28	57.16	38.90	55.20	30.25	53.52	32.76	53.84	21.44
L_{LT_D3}	36.58	11.37	38.35	10.87	36.16	12.38	35.54	10.96	35.92	11.94	38.13	13.28
L_{LT_D4}	106.61	53.90	93.35	46.63	109.68	50.69	101.06	40.00	122.02	63.60	104.12	59.83

In Figure 39, boxplots synthesize diverging abscissa distribution in all scenarios and diverging terminals. Y-axis of figure represents the diverging abscissa, and the origin is placed at the TS section (taper start), including the representation of tapers ends (TT section), and terminals ends (TR section). Distribution of the data (distances) shows that drivers tend to merge at similar sections comparing baseline scenario with V-ISA ones over all diverging terminals. Results evidence that some drivers diverge after TR section, performing late diverging manoeuvres, mainly when diverging from the motorway (ramp-2 and ramp-4). While at linear terminals, drivers evidenced early diverging manoeuvres.

Larger distances were recorded at ramp-4 reverse diverging terminal, where drivers diverged mainly along the deceleration lane, contrary to what was observed over ramp-2 with continuous diverging terminal. These differences were already studied by Bassani and Portera, 2021, where continue terminals show a better performance than reverse ones.

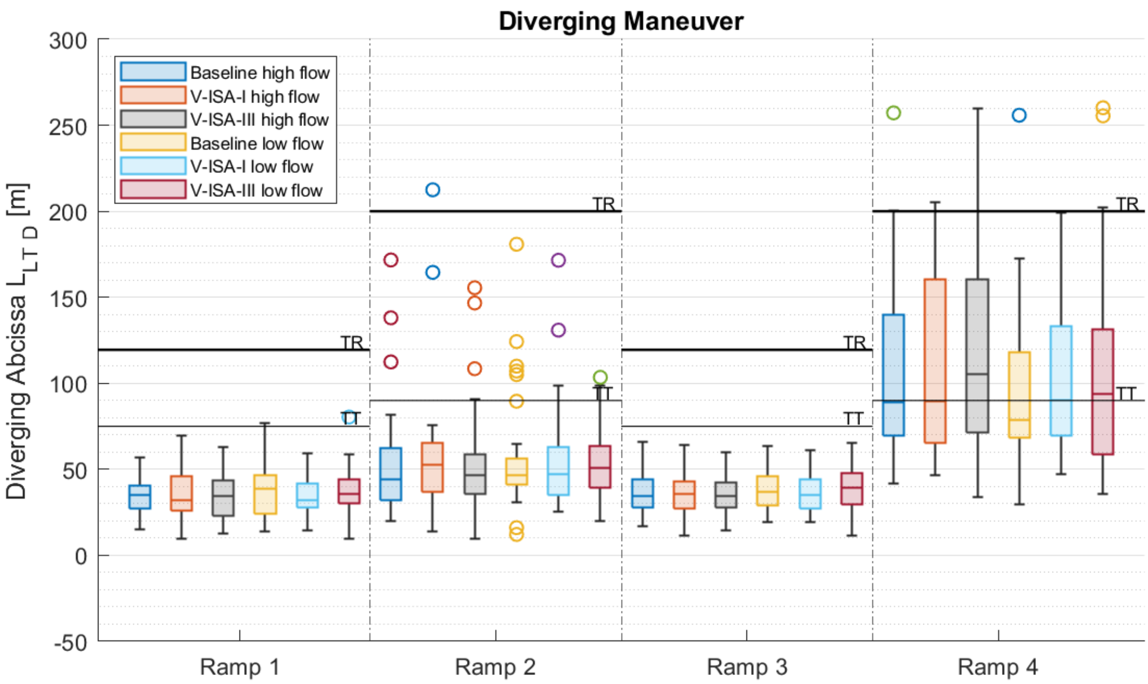


Figure 39. Box-plots for diverging abscissa across ramps and scenarios.

Breakdown of diverging distances can be found in **Appendix G**. Similarly, statistical evaluation with t-test was performed over the mean diverging distances to evaluate statistical significance of results, however, no statistical significance was found among groups. These are collected in **Appendix E**, and plots are represented in **Appendix F**.

Similarly, analysis conducted by LMM, show that the activation of the V-ISA system does not reflect any significant difference in drivers diverging abscissa (Table 23). Still, LMM outcomes specifies a significant difference due to the interaction between V-ISA-I and age class I – III, over ramp-1. However, Bonferroni adjusted post-hoc test did not support it, showing no statistical significance.

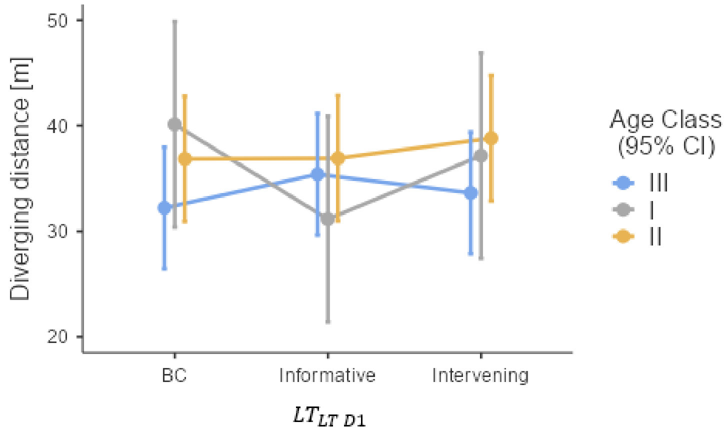


Figure 40. Plot for ramp 1 diverging abscissa for different drives under the effect of V-ISA for age classes with 95% confidence level bars.

*Table 23. Fixed effect Omnibus tests table with factors influencing diverging abscissa. (Note: some effects are not included given that effects were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F (df, den df) (p-value)***			
	$L_{LT\ D1}$	**$L_{LT\ D2}$**	**$L_{LT\ D3}$**	**$L_{LT\ D4}$**
V-ISA	.837 (2, 130)	.054 (2, 130)	-	1.400 (2, 157)
Traffic Flow	7.572 (1, 130)**	.004 (1, 130)	-	4.260 (1, 157)**
Gender	.564 (2, 26)*	5.693 (1, 26)**	1.469 (1, 16)	-
Age Class	2.960 (1, 26)	2.448 (2, 26)	.476 (2, 0.627)	-
V-ISA ⁜ Traffic Flow	1.669 (2, 130)	1.428 (2, 130)	-	-
V-ISA ⁜ Gender	1.492 (2, 130)	.439 (2, 130)	-	-
Traffic Flow ⁜ Gender	2.377 (1, 130)	.072 (1, 130)	-	-
V-ISA ⁜ Age Class	1.800 (4, 130)	.963 (4, 130)	-	-
Traffic Flow ⁜ Age Class	4.519 (2, 130)**	.681 (2, 130)	-	-
Gender ⁜ Age Class	4.112 (2, 26)**	3.279 (2, 26)*	5.464 (2, 26)**	-
V-ISA ⁜ Traffic Flow ⁜ Gender	2.606 (2, 130)*	.476 (2, 130)	-	-
V-ISA ⁜ Traffic Flow ⁜ Age Class	.411 (4, 130)	1.904 (4, 130)	-	-
V-ISA ⁜ Gender ⁜ Age Class	.664 (4, 130)	1.209 (4, 130)	-	-
Traffic Flow ⁜ Gender ⁜ Age Class	1.55 (2, 130)	.952 (2, 130)	-	-
V-ISA ⁜ Traffic Flow ⁜ Gender ⁜ Age Class	1.854 (4, 130)	2.425 (4, 130)*	-	-

LMM (Table 23) shows that traffic volume on the motorway and two-lane rural highway has implications on the drivers' diverging abscissa at ramp-1 and ramp-4. This contrast with results from Portera and Bassani, 2021, and Calvi et al., 2011, where traffic volume does not evidence significant differences in the drivers diverging abscissa. Additionally, LMM outputs for ramp-2 (**Appendix H**; Table 66) highlight differences between males and females, where females exhibited higher diverging distances than males, ascribing this to their prudent driving behaviour. In addition, older drivers manifested shorter merging distances compared to younger (<25) drivers over ramp-2. An implicit reason for this could be that older driver are more cautious in the lane change manoeuvre and are prone to an early merge compared to younger drivers.

4.2 RAMPS ARC CENTRE

4.2.1 Longitudinal behaviour outcomes

Ramps arc centre constitute sections where the V-ISA system might have big influence in drivers speed given the poor sight conditions due to the traffic barrier imposed over the ramps. In fact, results (Table 24) support the previous affirmation because drivers exhibited significant differences in their operating speed when comparing the baseline scenario with the V-ISA scenarios. In Table 24, drivers' mean speed values demonstrate that a reduction occurred over all ramps arc centre when comparing the drives with V-ISA-I with the baseline scenario. And this reduction is bigger when comparing the V-ISA-III drives.

Table 24. Mean, standard deviation and posted limit values for speed at ramps arc centre sections. (Note: P.S.L: Posted speed limit).

	P.S.L [km/h]	Baseline				V-ISA-I				V-ISA-III			
		High flow (HF)		Low flow (LF)		High flow (HF)		Low flow (LF)		High flow (HF)		Low flow (LF)	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
S_{R_1}	60	57.00	9.61	58.83	10.88	54.01	9.00	53.98	10.91	51.75	4.57	52.09	5.33
S_{R_2}	60	63.13	11.94	63.46	10.93	59.50	13.05	57.82	11.74	55.21	3.17	55.31	3.98
S_{R_3}	60	60.76	9.57	60.40	9.62	56.32	9.51	56.04	9.15	54.89	3.63	54.77	3.96
S_{R_4}	60	64.39	12.54	63.19	11.57	57.16	10.63	59.50	13.39	54.53	3.25	55.55	3.25

From Figure 41 to Figure 44, the representation of drivers mean speed with indication of the positive and negative standard deviation, safe speed, posted speed and illustration of p-values for each ramp arc centre sections are shown.

The first impression that shows up is that drivers tend to adopt a speed over the safe speed limit when the V-ISA system is not active (i.e. baseline scenario), this behaviour is evident at ramps arc centre 2, 3, and 4 with particular exception of ramp-1 arc centre. Once the system is active, drivers exhibited speeds below the safe speed limit and therefore, lower mean speeds comparing the V-ISA drives with the baseline drives. However, in none of the sections, speeds were below the posted speed limit.

Statistical analysis carried out over these sections reinforce the speed enforcement produced when the V-ISA system is active, showing strong statistical significance between groups in almost all the cases. Exception of this are the baseline – V-ISA-I comparison for ramp-1 arc centre and ramp-4 arc centre. It is important to point out that V-ISA-I variant is not a mandatory solution, meaning that driver still has the freedom of choose their operating speeds, and that could be the reason of drivers manifesting speeds over the safe speed limit with the V-ISA-I variant active, as seen in Figure 42 and Figure 44, for ramp-2 arc centre and ramp-4 arc centre, for high flow and low flow respectively. T-test results do not exhibit significance within traffic flow levels, this was expected since traffic was not added along ramps.

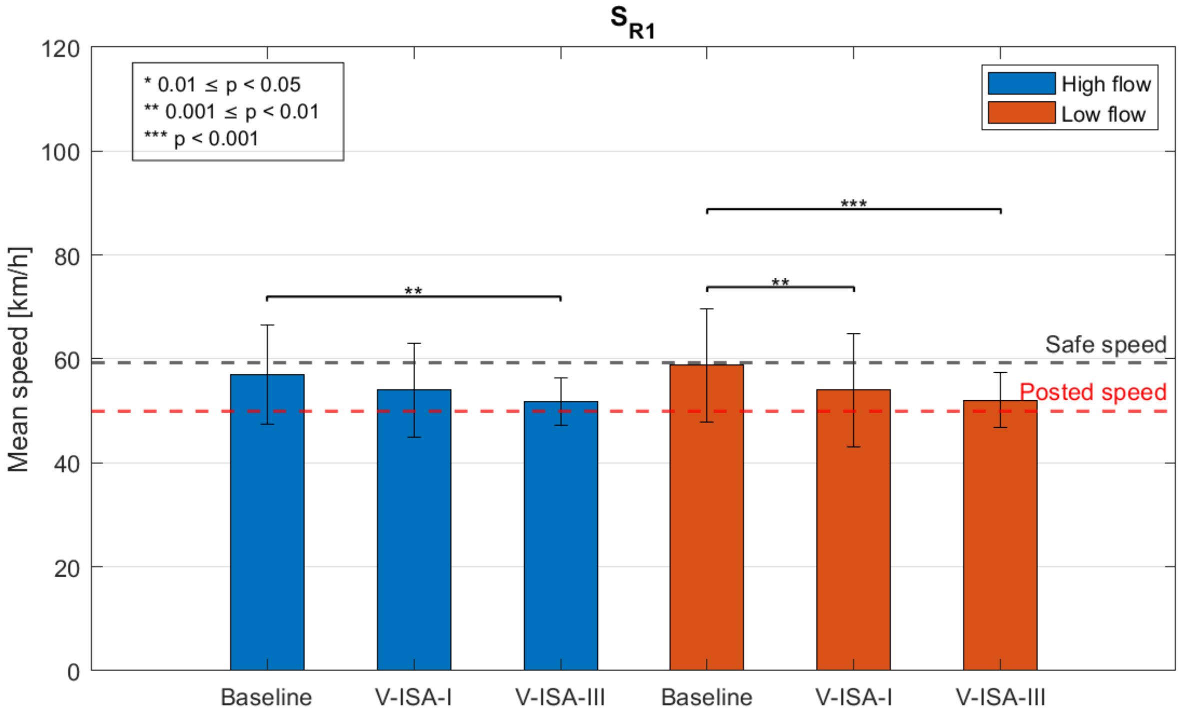


Figure 41. Representation of speed mean values for ramp 1 centre arc section with indication of the positive and negative standard deviation (error bars), posted speed limit, safe speed and p-values.

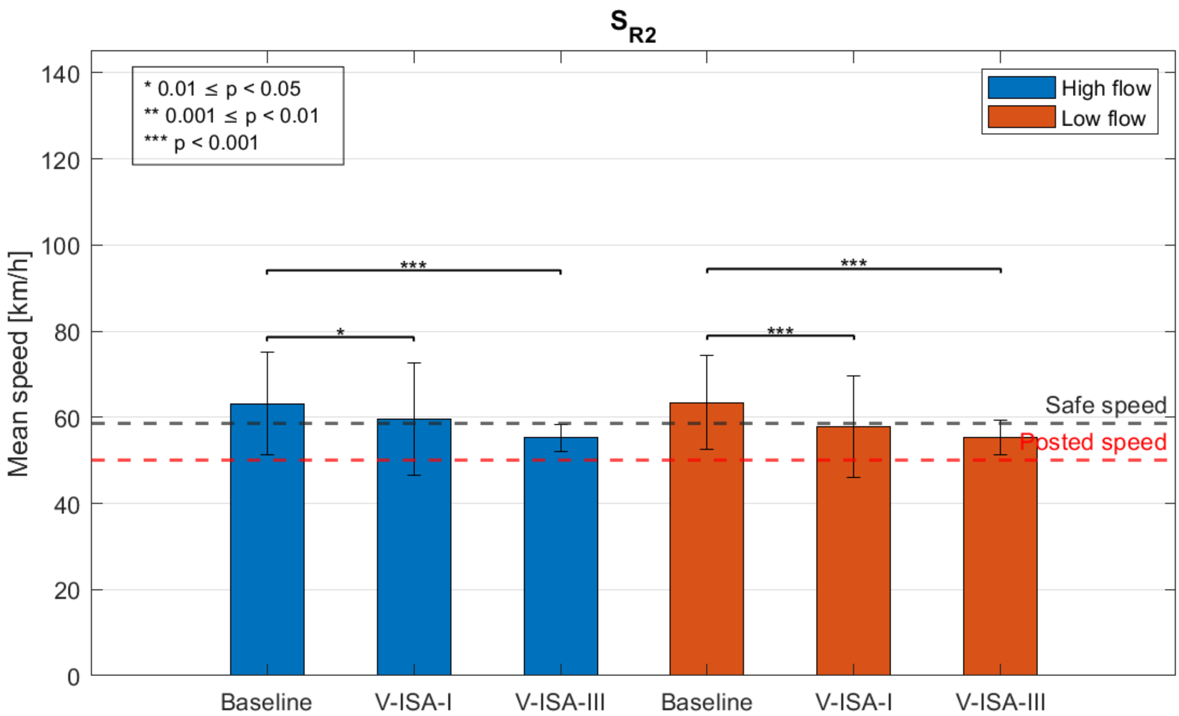


Figure 42. Representation of speed mean values for ramp 2 centre arc section with indication of the positive and negative standard deviation (error bars), posted speed limit, safe speed and p-values.

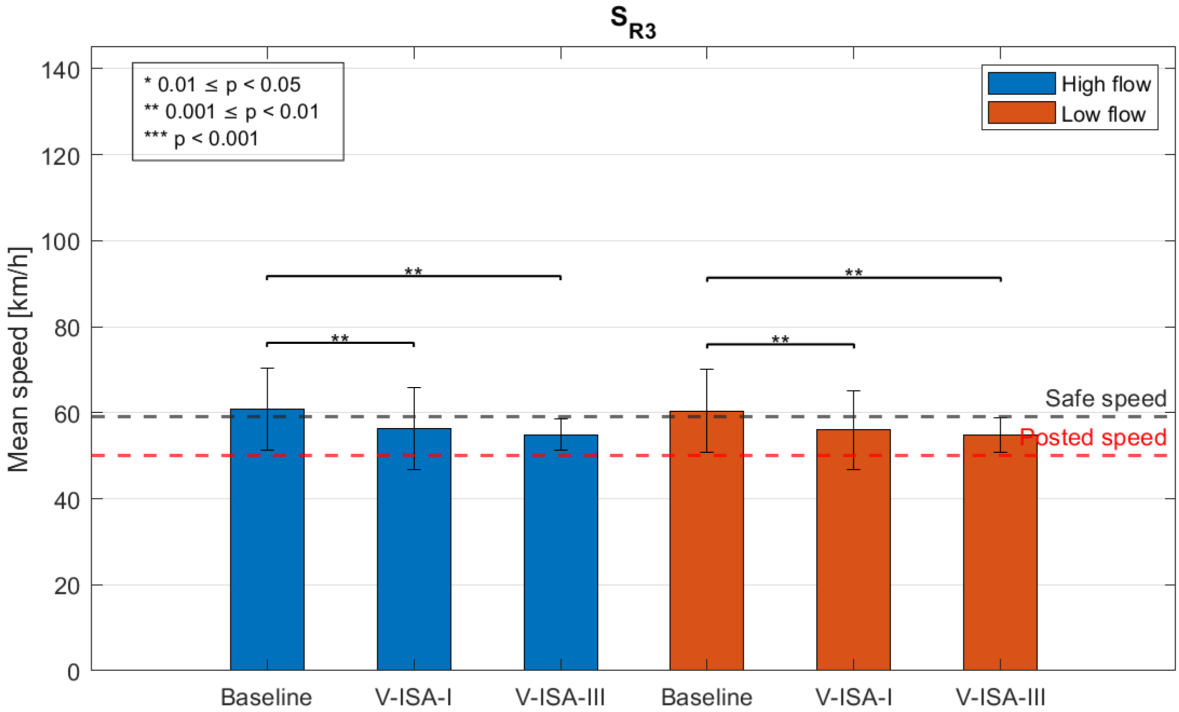


Figure 43. Representation of speed mean values for ramp 3 centre arc section with indication of the positive and negative standard deviation (error bars), posted speed limit, safe speed and p-values.

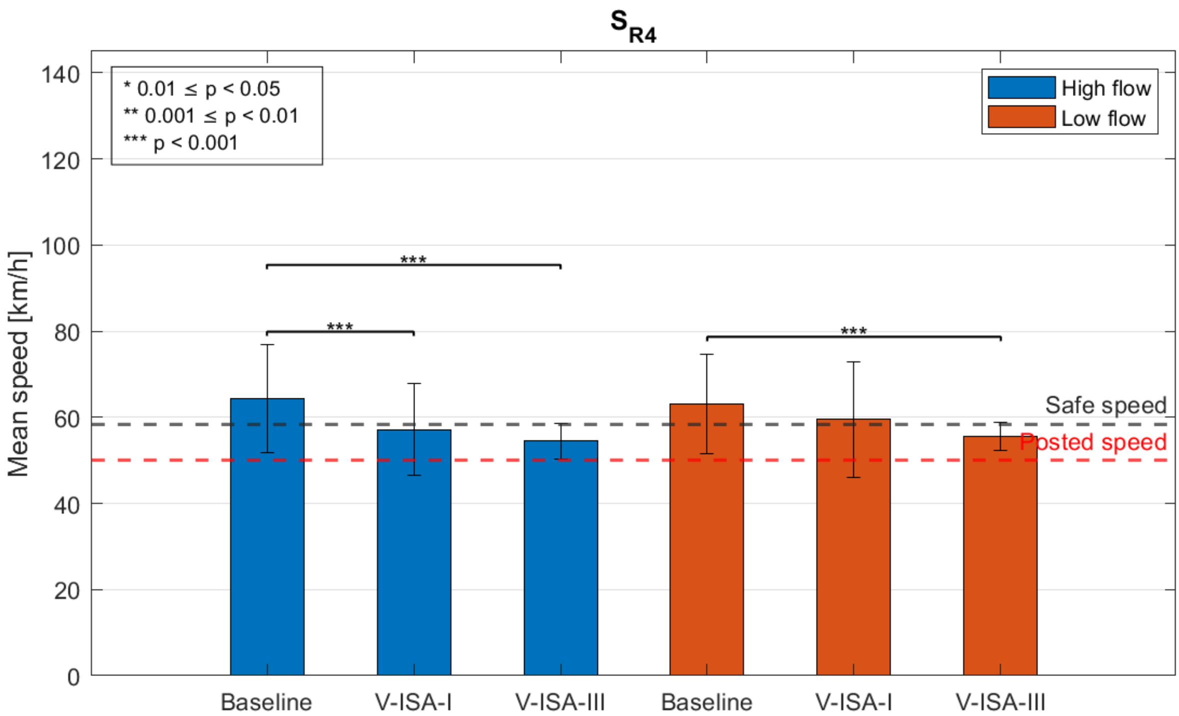


Figure 44. Representation of speed mean values for ramp 4 centre arc section with indication of the positive and negative standard deviation (error bars), posted speed limit, safe speed and p-values.

LMM outputs evince that activation of the system enforced drivers to maintain a safer and, consequently, lower, operating speed (Table 25). Moreover, as seen in Figure 45, V-ISA-III variant proves to be much more effective in forcing drivers to slow down to safer levels in accordance with sight limitations. However, it is evident that V-ISA-I also communicates in a robust way, the correct adoption of a safer speed, given that drivers also evidenced lower speed levels compared to the baseline scenario. At ramp-3 centre plot (Figure 45-S_{R3}), distinction between traffic flows is not represented given that groups are not significant and excluded from the LMM in the calibration process.

*Table 25. Fixed effect Omnibus tests table with factors influencing speed at ramps centre arc. (Note: some factors are not included given that effects were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F (df, den df) (p-value)***			
	S_{R1}	S_{R2}	S_{R3}	S_{R4}
V-ISA	18.278 (2, 130)***	27.574 (2, 142)***	17.000 (2, 158)***	17.137 (2, 136)***
Traffic Flow	.655 (1, 130)	.167 (1, 142)	-	.492 (1, 136)
Gender	.000 (1, 25)	.809 (1, 26)	-	.224 (1, 26)
Age Class	.552 (2, 25)	1.443 (2, 26)	-	.522 (2, 26)
Accidents	3.671 (1, 25)*	-	-	-
V-ISA ✻ Traffic Flow	.598 (2, 130)	0.679 (2, 142)	-	3.238 (2, 136)**
V-ISA ✻ Gender	2.065 (2,130)	1.519 (2, 142)	-	.657 (2, 136)
Traffic Flow ✻ Gender	2.562 (1, 130)	.061 (1, 142)	-	3.1968 (1, 136)*
V-ISA ✻ Age Class	2.222 (4, 130)*	3.345 (4, 142)**	-	2.230 (4, 136)*
Traffic Flow ✻ Age Class	1.060 (2, 130)	-	-	1.447 (2, 136)
Gender ✻ Age Class	.202 (2, 25)	0.422 (2, 26)	-	.085 (2, 26)
V-ISA ✻ Traffic Flow ✻ Gender	3.367 (2, 130)**	1.985 (2, 142)	-	1.444 (2, 136)
V-ISA ✻ Traffic Flow ✻ Age Class	.168 (4, 130)	.950 (4, 142)	-	2.786 (4, 136)**
V-ISA ✻ Gender ✻ Age Class	.702 (4, 130)	-	-	.807 (4, 136)
Traffic Flow ✻ Gender ✻ Age Class	1.325 (2, 130)	-	-	-
V-ISA ✻ Traffic Flow ✻ Gender ✻ Age Class	2.817 (4, 130)**	-	-	-

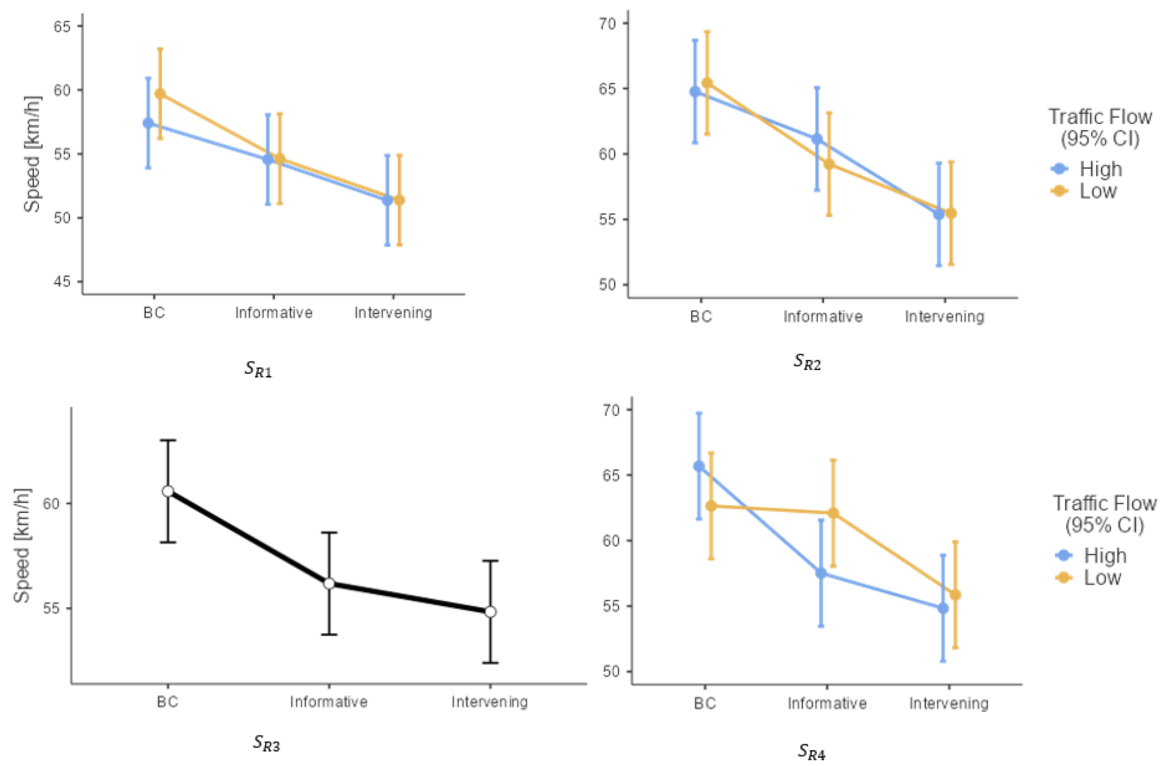


Figure 45. Plots of speed at centre ramps arc for different drives under the effect of V-ISA for high and low traffic levels (ramps one, two and four) with 95% confidence level bars.

4.2.2 Transversal behaviour outcomes

Drivers' transversal behaviour at ramps arc centre were evaluated by means of the lateral position and standard deviation of lateral position.

Over all sections, results showed (from Figure 46 to Figure 49) that drivers maintained the vehicle to the right side of lane centreline. Mean and standard deviation values for lateral position of drivers are synthetized in Table 26.

Table 26. Mean and standard deviation for lateral position at ramps arc centre sections.

	Baseline				**V-ISA-I**				**V-ISA-III**			
	High flow (HF)		Low flow (LF)		High flow (HF)		Low flow (LF)		High flow (HF)		Low flow (LF)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
LP_{R1}	-0.784	0.424	-0.708	0.437	-0.628	0.457	-0.846	0.356	-0.698	0.413	-0.739	0.333
LP_{R2}	-0.598	0.429	-0.534	0.417	-0.438	0.366	-0.593	0.405	-0.524	0.548	-0.546	0.394
LP_{R3}	-0.916	0.320	-0.827	0.419	-0.727	0.450	-0.846	0.417	-0.797	0.461	-0.777	0.314
LP_{R4}	-1.029	0.405	-1.018	0.413	-0.733	0.422	-0.923	0.365	-0.818	0.455	-0.761	0.396

T-test exhibit statistical significance between baseline and V-ISA-I drives for both high and low flow traffic levels at ramp-1 arc centre. Moreover, stronger significance is found between V-ISA-I groups among the traffic levels. Similar findings are exhibited in ramp-2 arc centre, nevertheless, no statistical significance was found for low traffic level.

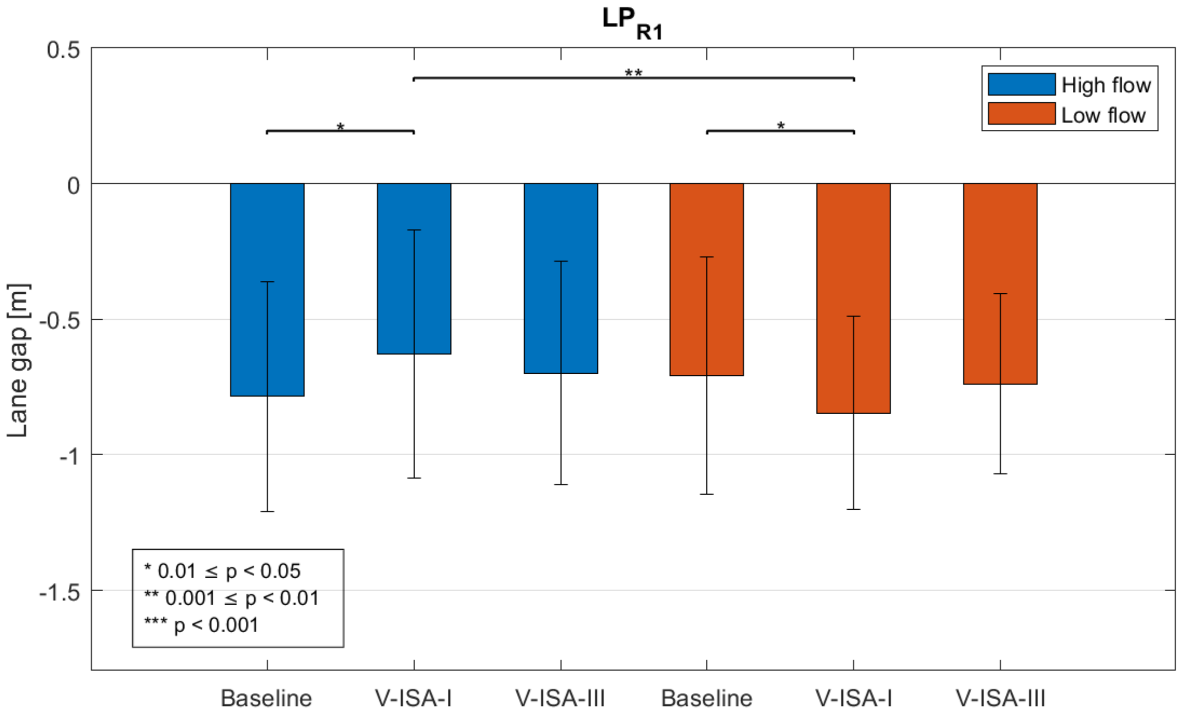


Figure 46. Representation of mean lateral positions values at centre of ramp 1-arc, with indication of the positive and negative standard deviation (error bars) and p-values.

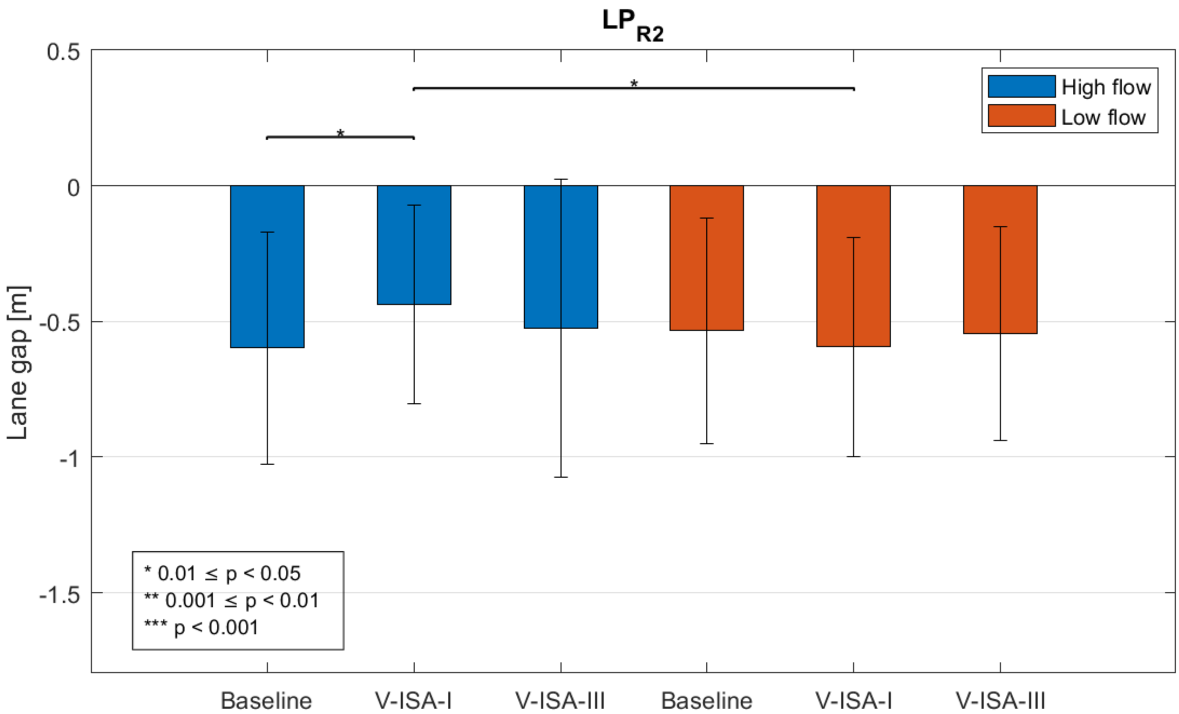


Figure 47. Representation of mean lateral positions values at centre of ramp 2-arc, with indication of the positive and negative standard deviation (error bars) and p-values.

While for ramp-3 arc centre, statistical significance is evident just over baseline – V-ISA-I for high flow traffic level. Ultimately, mean lateral positions of drivers at ramp-4 arc centre have more influence from the V-ISA drives. As seen in Figure 49, p-values suggest strong statistical significance when comparing baseline drives with V-ISA drives in both traffic levels. Whereas V-ISA-I between high and low flow also exhibit significant differences.

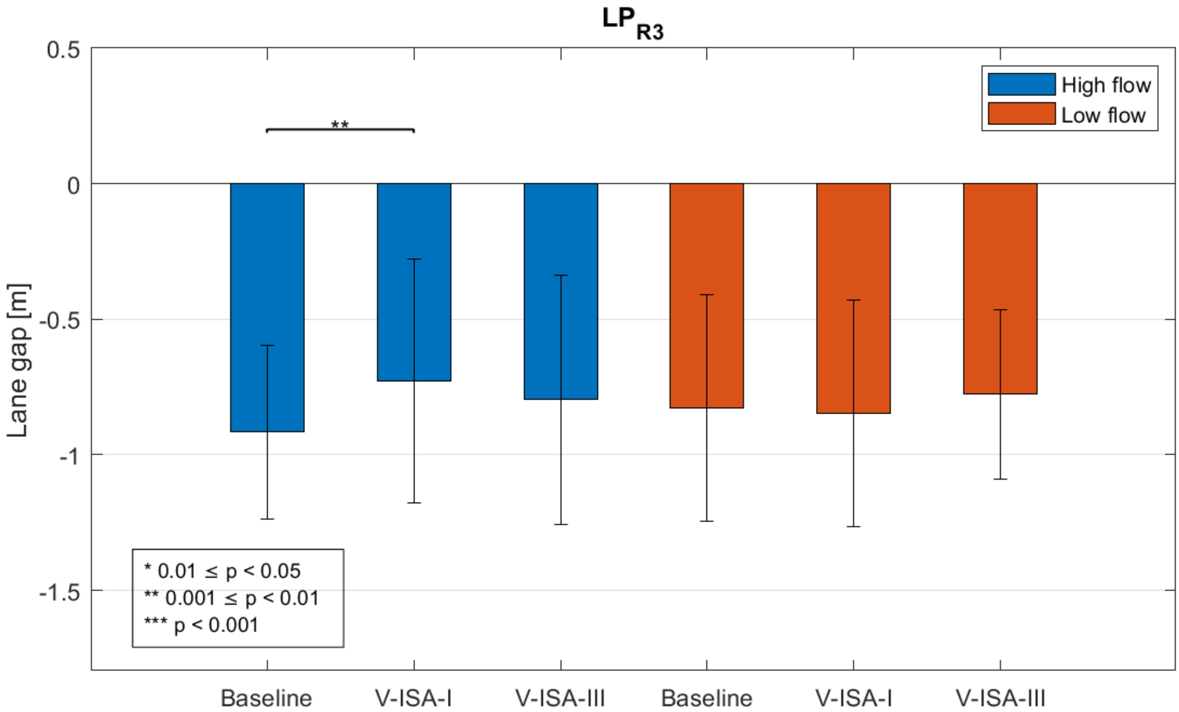


Figure 48. Representation of mean lateral positions values at centre of ramp 3-arc, with indication of the positive and negative standard deviation (error bars) and p-values.

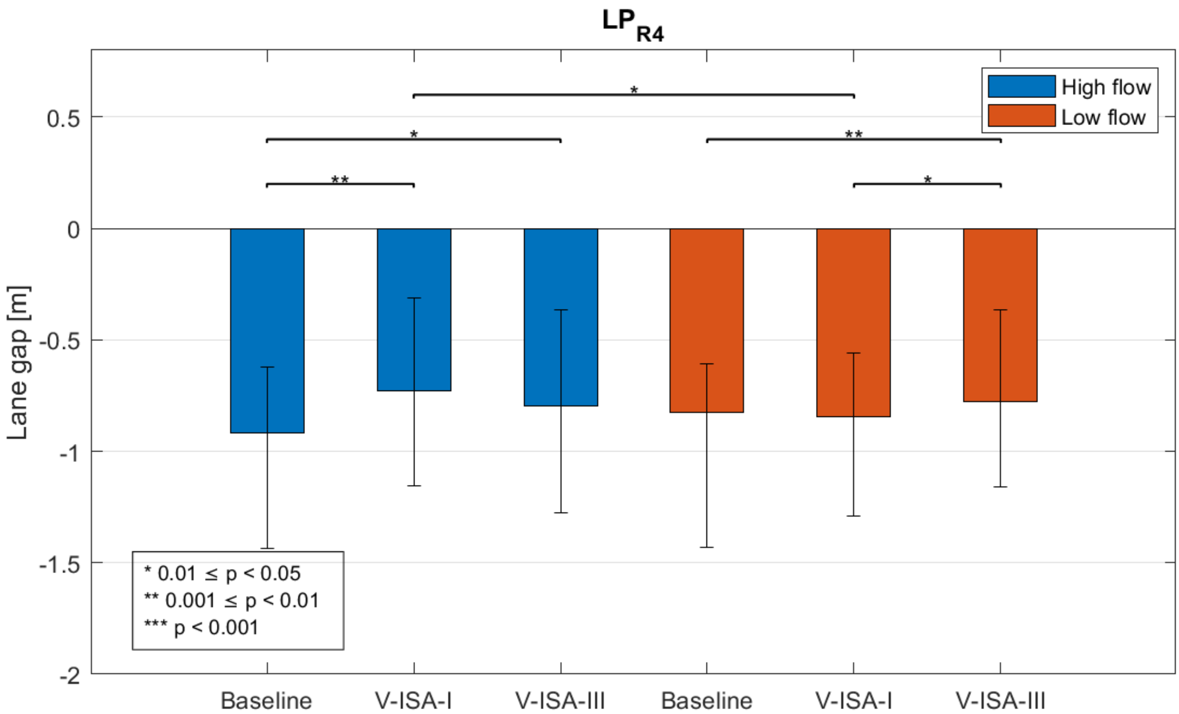


Figure 49. Representation of mean lateral positions values at centre of ramp 4-arc, with indication of the positive and negative standard deviation (error bars) and p-values.

Additionally, Linear Mixed Model (LMM) was conducted for lateral position of drivers at the ramps arc centre, Table 27 summarized fixed effect omnibus tests results, showing significant factors over the lateral position of drivers.

*Table 27. Fixed effect Omnibus tests table with factors influencing lateral position at ramps centre arc. (Note: some effects are not included given that were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F (df, den df) (p-value)***			
	LP_{R1}	**LP_{R2}**	**LP_{R3}**	**LP_{R4}**
V-ISA	.033 (2, 130)	.736 (2, 145)	1.643 (2, 139)	10.286 (2, 145)***
Traffic Flow	2.305 (1, 130)	.843 (1, 145)	.002 (1, 139)	.880 (1, 145)
Gender	1.299 (1, 26)	4.210 (1, 26)*	1.227 (1, 25)	.513 (1, 25)
Age Class	1.322 (2, 26)	1.920 (2, 26)	2.632 (2, 25)*	4.590 (2, 25)**
Age	-	-	4.100 (1, 25)*	-
Experience	-	-	-	5.401 (1, 25)**
V-ISA ✻ Traffic Flow	4.129 (2, 130)**	2.412 (2, 145)*	2.634 (2, 139)*	3.014 (2, 145)*
V-ISA ✻ Gender	.704 (2, 130)	.513 (2, 145)	.499 (2, 139)	1.346 (2, 145)
Traffic Flow ✻ Gender	.540 (1, 130)	-	-	-
V-ISA ✻ Age Class	1.350 (4, 130)	1.235 (4, 145)	1.608 (4, 139)	.648 (4, 145)
Traffic Flow ✻ Age Class	1.126 (2, 130)	-	.006 (2, 139)	-
Gender ✻ Age Class	2.567 (2, 26)*	4.170 (2, 26)**	3.617 (2, 25)**	2.944 (2, 25)*
V-ISA ✻ Traffic Flow ✻ Gender	.345 (2, 130)	-	1.192 (4, 139)	-
V-ISA ✻ Traffic Flow ✻ Age Class	.259 (4, 130)	-	-	-
V-ISA ✻ Gender ✻ Age Class	1.009 (4, 130)	1.776 (4, 145)	3.219 (4, 139)**	2.753 (4, 145)**
Traffic Flow ✻ Gender ✻ Age Class	1.007 (2, 130)	-		-
V-ISA ✻ Traffic Flow ✻ Gender ✻ Age Class	1.052 (4, 130)	-		-

LMM clearly manifests no significant influence of V-ISA system between groups regarding the lateral position in ramps arc centre 1, 2 and 3. Differences appear in ramp-4, where both V-ISA-I and V-ISA-III influence drivers lateral positions at the ramp arc centre, as shown in Figure 50. A higher lateral position indicates that drivers tend to drive close to the lane centreline, which implies a positive finding regarding the use of V-ISA along ramps, pondering that while the system was active, drivers were more aware of the vehicle control.

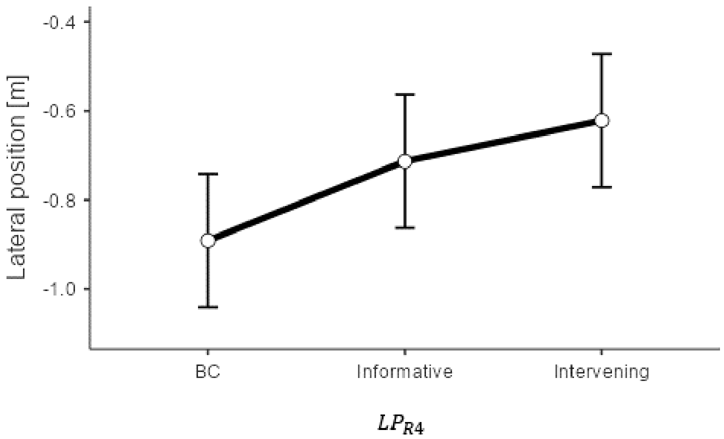


Figure 50. Plot of lateral position for ramp 4 centre arc for different drives under the effect of V-ISA with 95% confidence level bars. Positive LP means vehicle on the left side of the lane centreline, negative LP means vehicle on the right side of the lane centreline.

Rarely, significant difference was found in the interaction among V-ISA-I and traffic flow at ramp arcs 1, 2 and 3 (Figure 51). Since traffic was not considered along ramp arcs, there is not a clear attributable factor for this difference. Conversely, age is an influencing factor over lateral positions at centre ramp arcs, LMM outputs (**Appendix H**; Table 68 and Table 66) show differences between groups in ramps arc 2 and 3 concerning the interaction between V-ISA-III and age classes, as shown in Figure 52. In addition, age classes were significant over ramp-3 arc ($LP_{R3,I} - LP_{R3,III} = 0.797, p = 0.031$; $LP_{R3,II} - LP_{R3,III} = 0.511, p = 0.047$) and ramp-4 arc ($LP_{R4,I} - LP_{R4,III} = 1.015, p = 0.006$; $LP_{R4,II} - LP_{R4,III} = 0.583, p = 0.020$), showing positive estimates all cases, meaning that younger drivers tend to drive at lane centrelines.

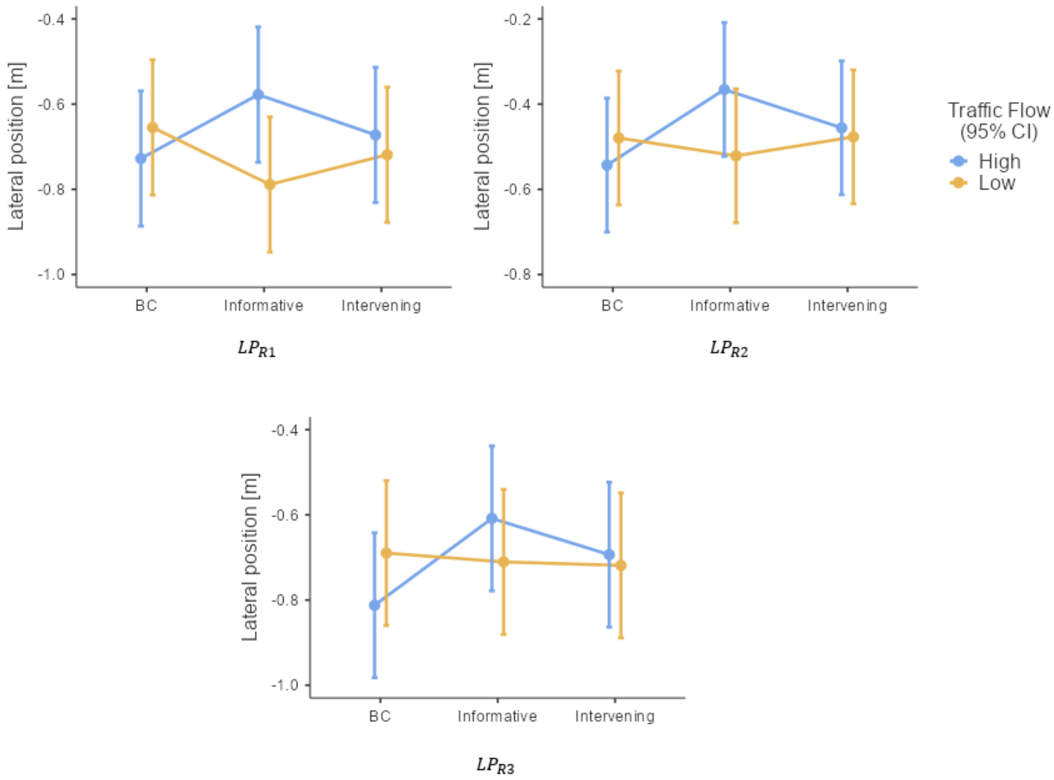


Figure 51. Plots of lateral position for ramps centre arc for different drives under the effect of V-ISA for high and low traffic levels with 95% confidence level bars. Positive LP means vehicle on the left side of the lane centreline, negative LP means vehicle on the right side of the lane centreline.

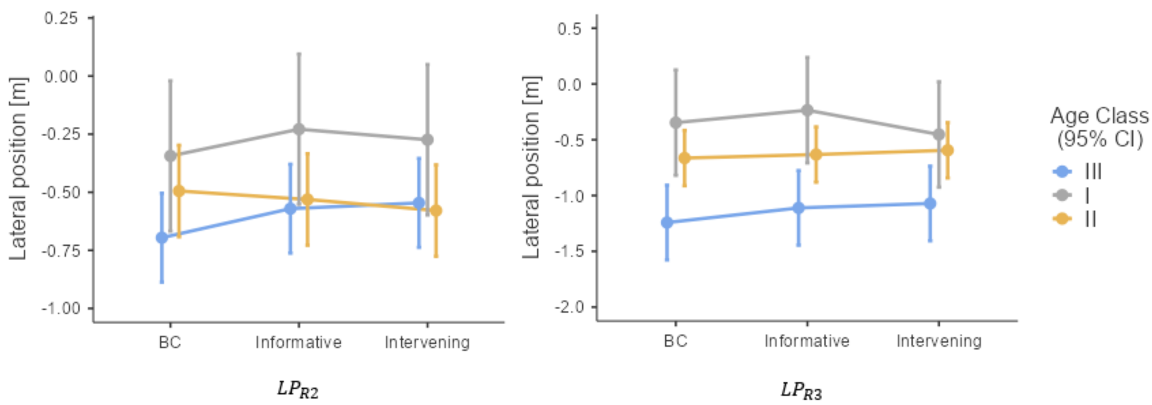


Figure 52. Plots of lateral position for ramps centre arc 2 and 3, for different drives under the effect of V-ISA for age classes with 95% confidence level bars. Positive LP means vehicle on the left side of the lane centreline, negative LP means vehicle on the right side of the lane centreline.

On the other hand, results (Table 28; Figure 53 to Figure 56) evidence that at ramps arc 1, 2 and 4, SDLP mean values are lower with the V-ISA system compared to the baseline scenario for high flow traffic level. This is not the case for ramp-3 arc, where V-ISA-I drive exhibited higher SDLP value than the baseline drive, for high flow traffic level. This behaviour does not replicate on the low flow, where at ramp arc one and two, the V-ISA-I drives manifested lower SDLP values compared to baseline, contrary to V-ISA-III drives. At ramp-3 arc, V-ISA-I variant scenario show higher SDLP mean value compared to baseline, while V-ISA-III and baseline groups evidenced same mean SDLP value. Ultimately, similar result was obtained comparing V-ISA-III drives with baseline, whereas V-ISA-I depicts higher SDLP mean value than baseline scenario.

Table 28. Mean and standard deviation for SDLP at ramps arc.

	Baseline		**V-ISA-I**		**V-ISA-III**	
	High flow (HF)	**Low flow (LF)**	**High flow (HF)**	**Low flow (LF)**	**High flow (HF)**	**Low flow (LF)**
	Mean	Mean	Mean	Mean	Mean	Mean
$SDLP_{R1}$	0.177	0.164	0.164	0.149	0.144	0.184
$SDLP_{R2}$	0.154	0.138	0.142	0.128	0.128	0.154
$SDLP_{R3}$	0.169	0.162	0.184	0.173	0.164	0.165
$SDLP_{R4}$	0.180	0.204	0.165	0.162	0.163	0.203

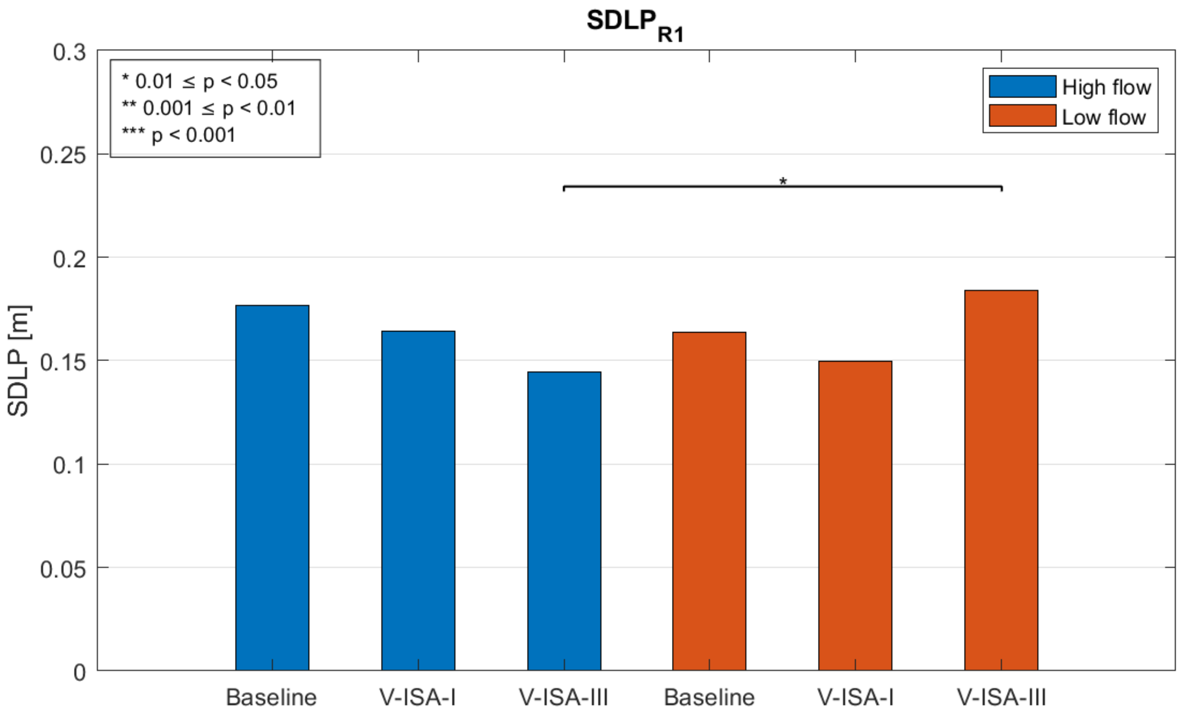


Figure 53. Representation of mean SDLP values along ramp arc 1, with indication of p-values.

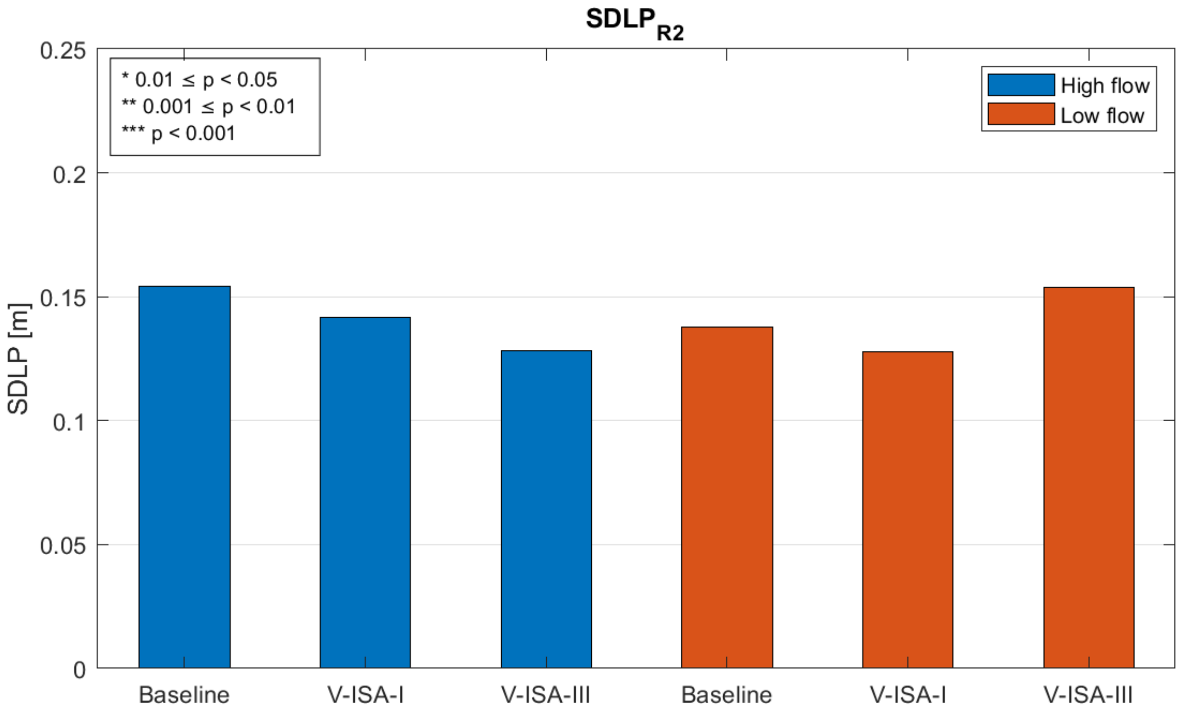


Figure 54. Representation of mean SDLP values along ramp arc 2, with indication of p-values.

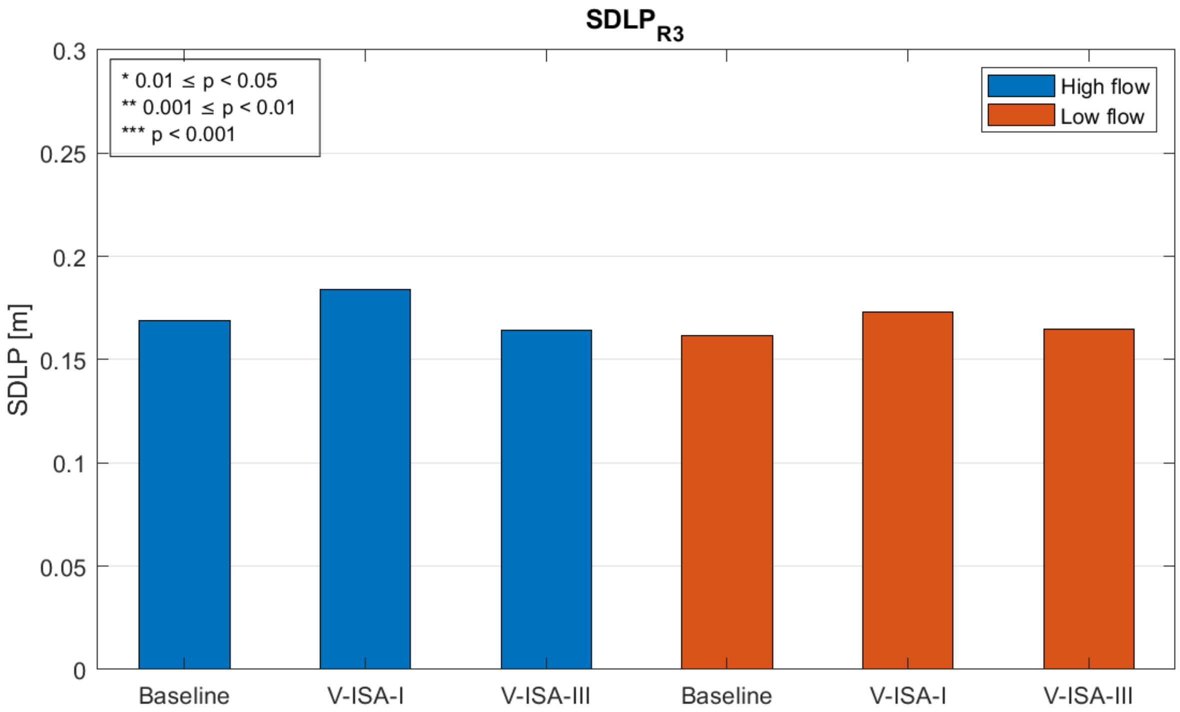


Figure 55. Representation of mean SDLP values along ramp arc 3, with indication of p-values.

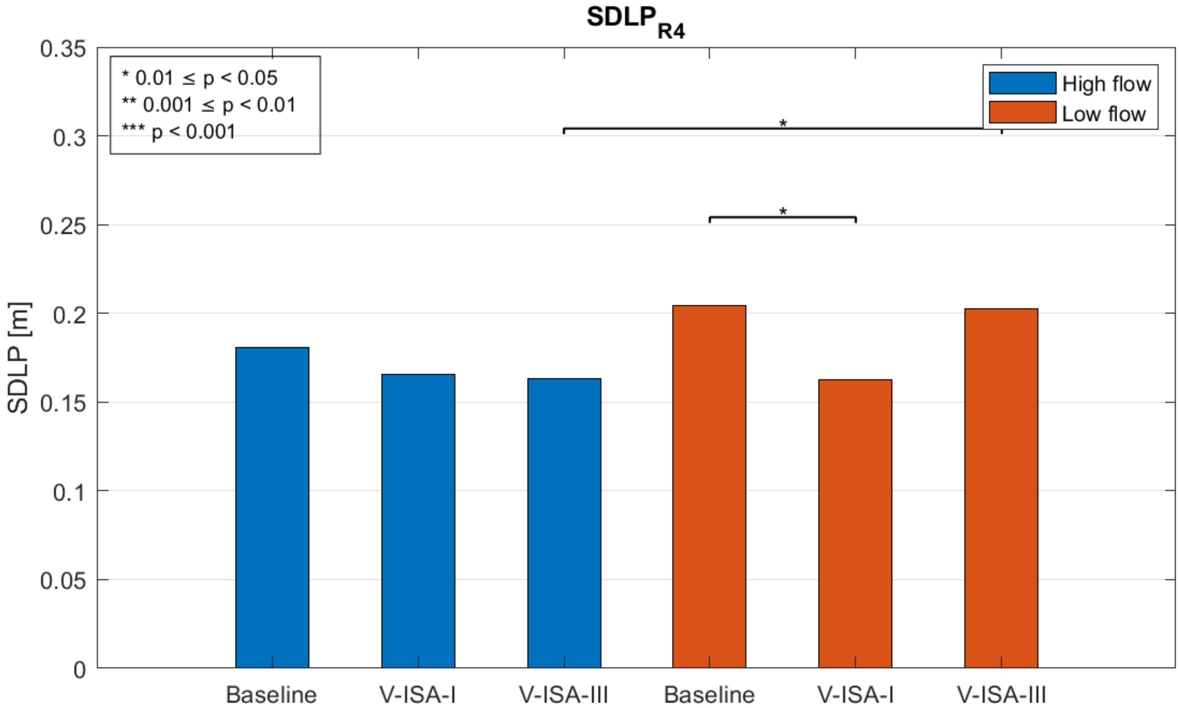


Figure 56. Representation of mean SDLP values along ramp arc 4, with indication of p-values.

V-ISA system drives showed low influence on the standard deviation of lateral position along ramp arcs. As is evident from Figure 53 to Figure 56, there is only statistical significance (*p* <0.05) in 11% of the cases, of which only one denotes influence of the V-ISA system within the drives. Details concerning t-test for lateral position and standard deviation of lateral position are provided in **Appendix E.**

Analysis performed by LMM, show that drivers did not manifest differences in lateral vehicle control while the system was active along ramps one, two and four (Table 29). Contrary to ramp-3, where the LMM output indicates that V-ISA-I variant shows an implication ($SDLP_{R3,V-ISA-I} - SDLP_{R3,Base} = 0.032, p = 0.017$) (Figure 57). Higher values of SDLP suggest that drivers have less vehicle lateral control. This can be attributed to a distraction generated in the way of communicating safe speed zones when V-ISA-I variant is active. This result differ from what was observed by Hazoor et al., 2021, along curves, where V-ISA-I depicted lower SDLP values compared to the baseline condition.

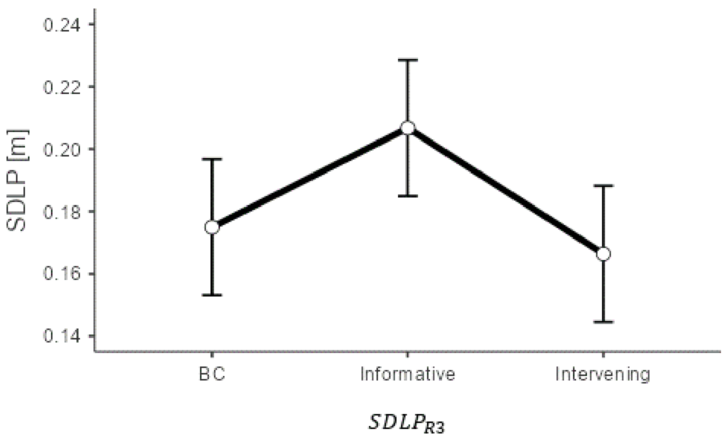


Figure 57. Plot of SDLP for ramp 3 for different drives under the effect of V-ISA with 95% confidence level bars.

*Table 29. Fixed effect Omnibus tests table with factors influencing SDLP along ramps arc. (Note: some effects are not included given that they were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	*F (df, den df) (p-value)*			
	$SDLP_{R1}$	$SDLP_{R2}$	$SDLP_{R3}$	$SDLP_{R4}$
V-ISA	1.184 (2, 140)	.446 (2, 181)	5.229 (2, 145)**	1.242 (2, 151)
Traffic Flow	.000 (1, 140)	.026 (1, 181)	.074 (1, 145)	6.557 (1, 151)**
Gender	1.608 (1, 26)	7.099 (1, 181)**	13.393 (1, 26)**	-
Age Class	1.475 (2, 26)	6.693 (2, 181)**	4.351 (2, 26)**	.837 (2, 29)
Experience	-	7.945 (1, 181)**	-	-
Kilometers per year	-	4.037 (1, 181)**	-	-
V-ISA ✻ Traffic Flow	2.249 (2, 140)	1.918 (2, 181)	.146 (2, 145)	-
V-ISA ✻ Gender	2.034 (2, 140)	-	-	-
Traffic Flow ✻ Gender	2.102 (1, 140)	-	-	-
V-ISA ✻ Age Class	1.162 (4, 140)	-	5.509 (4, 145)***	1.175 (4, 151)
Traffic Flow ✻ Age Class	.471 (2, 140)	-	2.858 (2, 145)*	2.491 (2, 151)*
Gender ✻ Age Class	3.165 (2, 26)*	-	3.228 (2, 26)*	-
V-ISA ✻ Traffic Flow ✻ Age Class	-	-	2.072 (4, 145)*	-
V-ISA ✻ Gender ✻ Age Class	1.575 (4, 140)	-	-	-
Traffic Flow ✻ Gender ✻ Age Class	1.940 (2, 140)	-	-	-

Bonferroni adjusted post-hoc test shows that over ramps arc 2 and 3, females manifested less lateral vehicle control ($SDLP_{R2,M} - SDLP_{R2,F} = -0.026, p = 0.013$; $SDLP_{R3,M} - SDLP_{R3,F} = -0.058, p = 0.001$); while comparison between age classes exhibited that, at ramp-2 arc, younger drivers tend to maintain vehicle close to the lane centreline ($SDLP_{R2,III} - SDLP_{R2,II} = 0.078, p = 0.021$). Whereas, along ramp arc three, opposite behaviour occurs ($SDLP_{R3,III} - SDLP_{R3,I} = -0.058, p = 0.033; SDLP_{R3,I} - SDLP_{R3,II} = 0.059, p = 0.031$).

Rarely, post-hoc test indicates that traffic level depicts significant differences between groups along ramp-4 arc, indicating a higher SDLP value when a lower traffic level is implemented. This behaviour is curious since traffic was not added along the ramps arc lanes, however, it could be attributed to driver perception of traffic over the lane they are going to merge onto that produces a higher weaving control of the vehicle when less cars are perceptible.

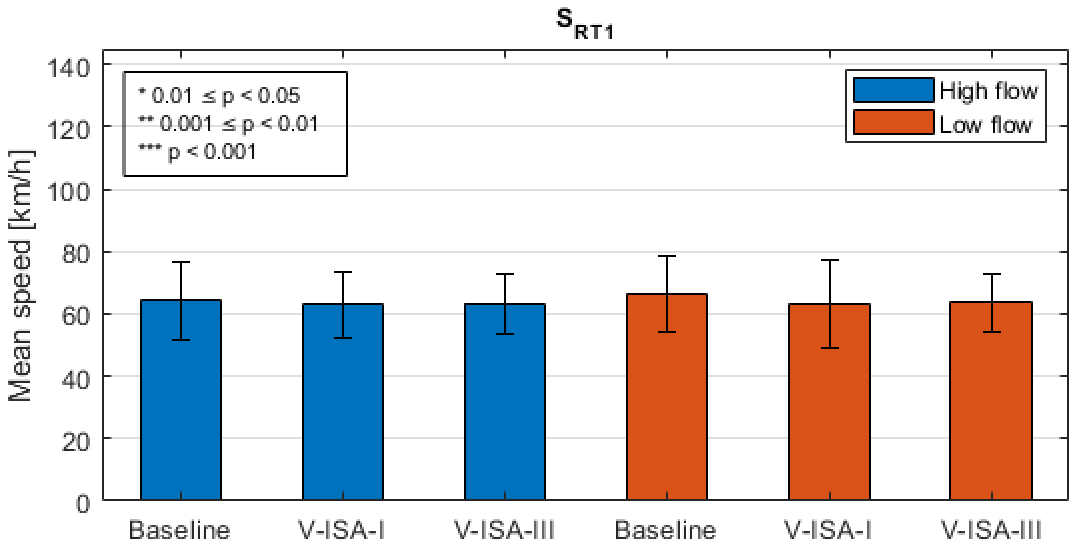
4.3 MERGING TERMINALS

4.3.1 Longitudinal behaviour outcomes

Drivers mean speed at RT and TL sections with their corresponding standard deviation are collected in Table 30. Results (Table 30) show that at ramp-1 merging terminal, mean speed of drivers do not vary significantly when comparing the baseline drives with the V-ISA drives, in fact, over RT1 and TL1, for high flow level, mean speed differences do not go over 2 km/h, while for low flow level, the most significantly variation is a reduction in the mean speed of drivers while using the V-ISA-III variant, exhibiting a lower mean speed of 4 km/h in comparison to baseline scenario. Actually, t-test support the above-mentioned outcome, showing statistical significance just between baseline and V-ISA-III group (Figure 58).

Table 30. Mean and standard deviation values for speed at merging terminals sections.

	Baseline				**V-ISA-I**				**V-ISA-III**			
	High flow (HF)		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
S_{RT1}	64.28	12.51	66.55	12.16	62.90	10.55	63.07	13.93	63.44	9.55	63.60	9.47
S_{TL1}	75.87	11.51	77.98	13.41	75.67	11.28	76.73	14.72	75.47	10.68	73.64	14.60
S_{RT2}	65.03	11.92	67.36	10.69	62.86	11.22	63.57	13.25	61.01	11.05	61.76	7.99
S_{TL2}	70.55	13.87	71.66	13.47	65.45	13.65	67.97	16.11	66.87	10.84	66.60	11.97
S_{RT3}	69.75	9.15	68.59	10.68	68.65	13.85	70.58	10.00	69.60	9.36	67.46	10.67
S_{TL3}	77.88	8.66	75.71	12.54	78.28	14.54	79.22	14.38	77.73	10.18	75.40	13.20
S_{RT4}	65.02	11.10	64.43	11.02	60.09	11.38	63.30	12.26	60.16	9.05	61.89	7.12
S_{TL4}	68.03	14.27	68.78	14.52	67.39	13.10	67.82	15.00	66.83	13.53	68.61	13.40



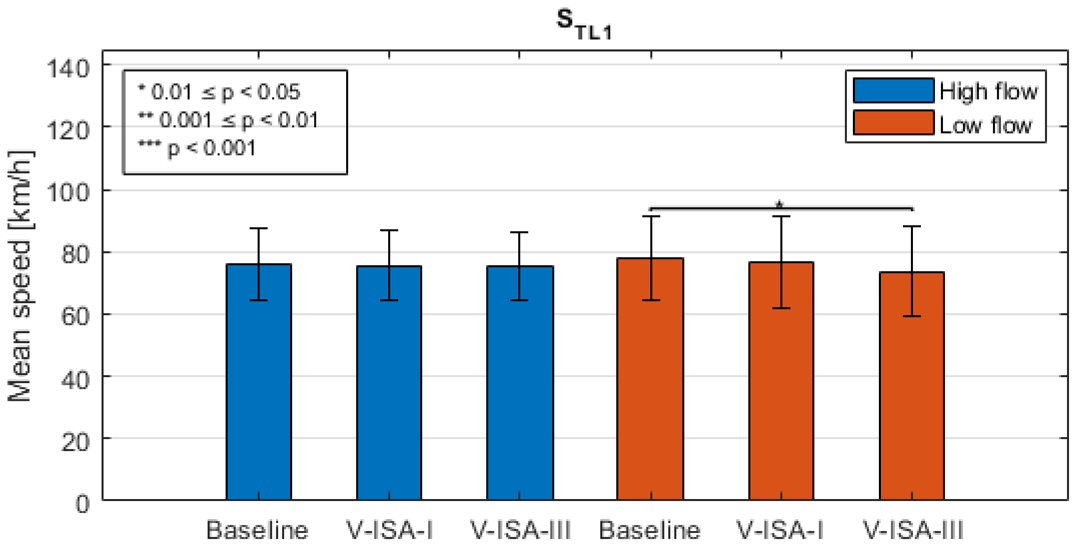


Figure 58. Representation of mean speed values for merging terminal, ramp 1, with indication of the positive and negative standard deviation (error bars) and p-values.

At RT2, results evidence that there are not notable changes in drivers mean speed for the high flow traffic level. Conversely, significant changes occur on the low flow traffic level, where both V-ISA-I and V-ISA-III. Additionally, t-test results evidence statistical significance between the differences among baseline drives and V-ISA drives for low flow level.

Similar results are evidenced at ramp-2 merging lane (Figure 59), where mean speed of drivers were lower when using the V-ISA system in comparison with the baseline drives. However, t-test found statistical significance between the baseline – V-ISA-I groups for high flow level, and baseline – V-ISA-III for the low flow level, which at the same time, represent the most significant variation in terms of speed with 5 km/h reduction in both cases.

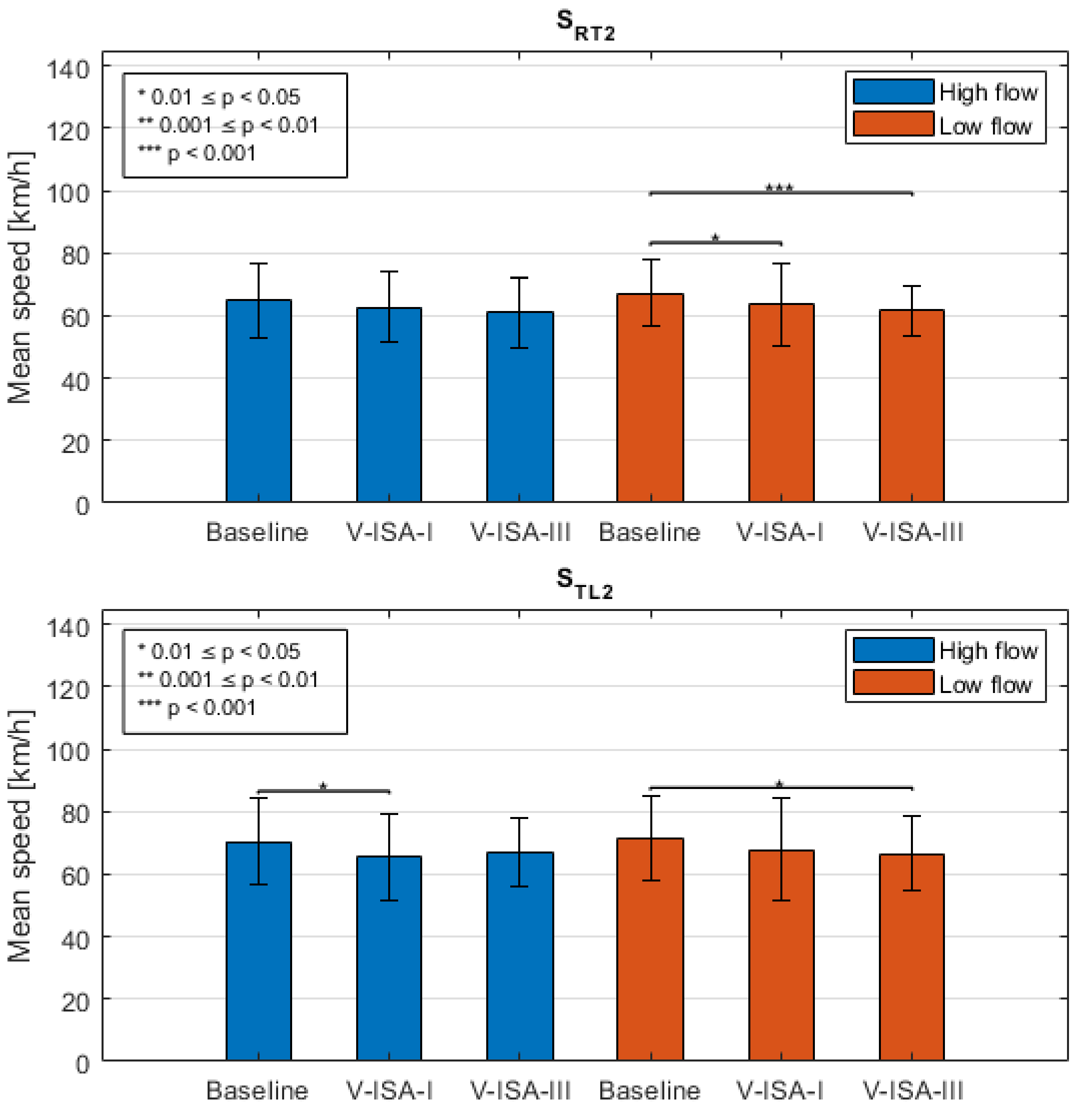


Figure 59. Representation of mean speed values for merging terminal, ramp 2, with indication of the positive and negative standard deviation (error bars) and p-values.

Looking at Figure 60, results manifested despicable speed variations among the scenarios. It is curious to perceive an increment in drivers mean speed for both RT3 and TL3 sections when driving with the V-ISA-I variant in comparison with the baseline drives, for the low flow traffic level. Nevertheless, t-test do not support any of these variations with none statistical significance.

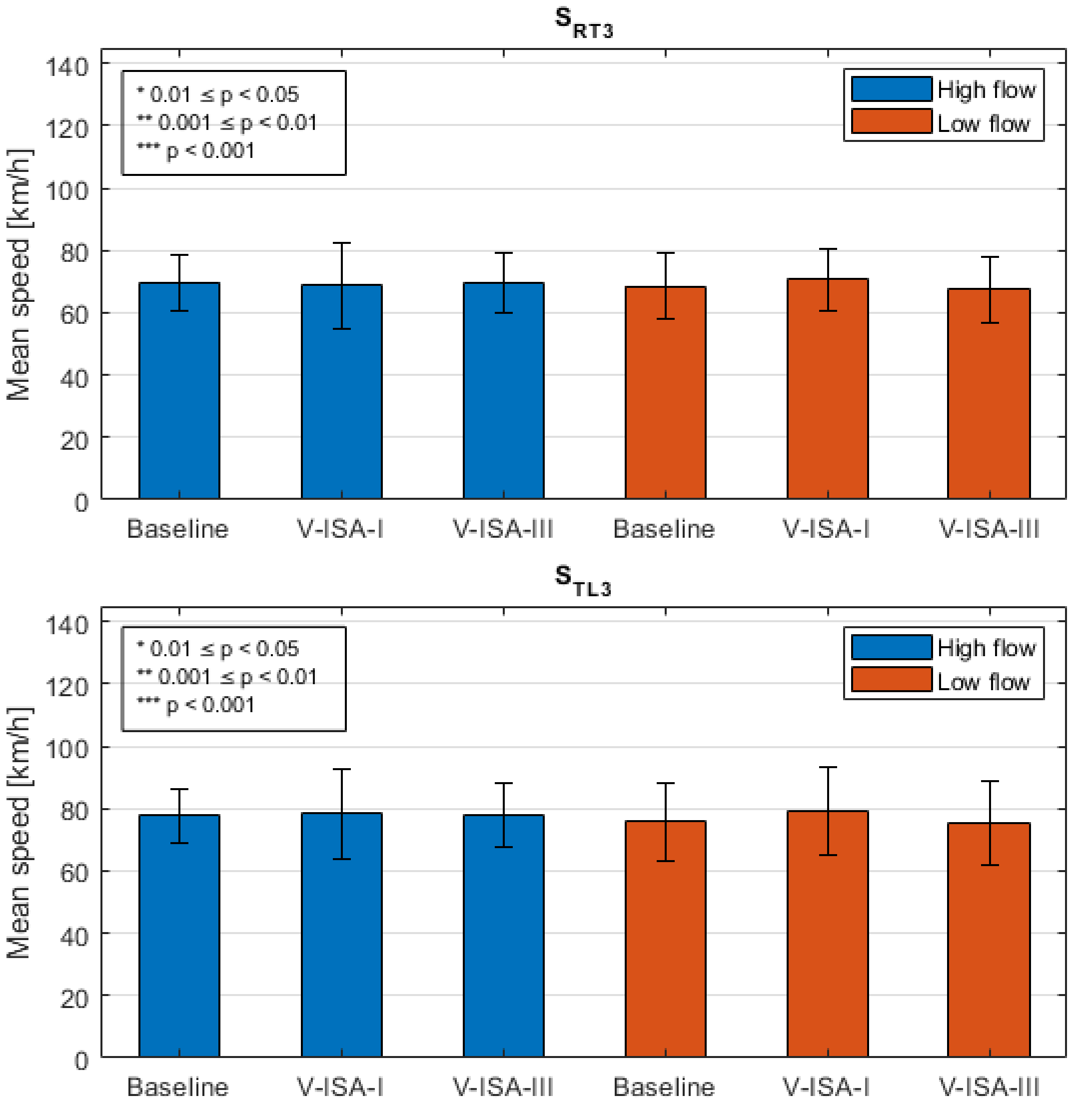


Figure 60. Representation of mean speed values for merging terminal, ramp 3, with indication of the positive and negative standard deviation (error bars) and p-values.

Eventually, indistinguishable mean speed variations were registered at the ramp-4 merging point without any statistical significance from t-test results. While reductions in the drivers mean speed at RT4 section occurred when comparing the V-ISA with the baseline drives, for both, high and low flow. Support from t-test results was found only over the high flow cases. Manifesting strong significances among groups (Baseline – V-ISA-I, p=0.001; baseline – V-ISA-III, p=0.003).

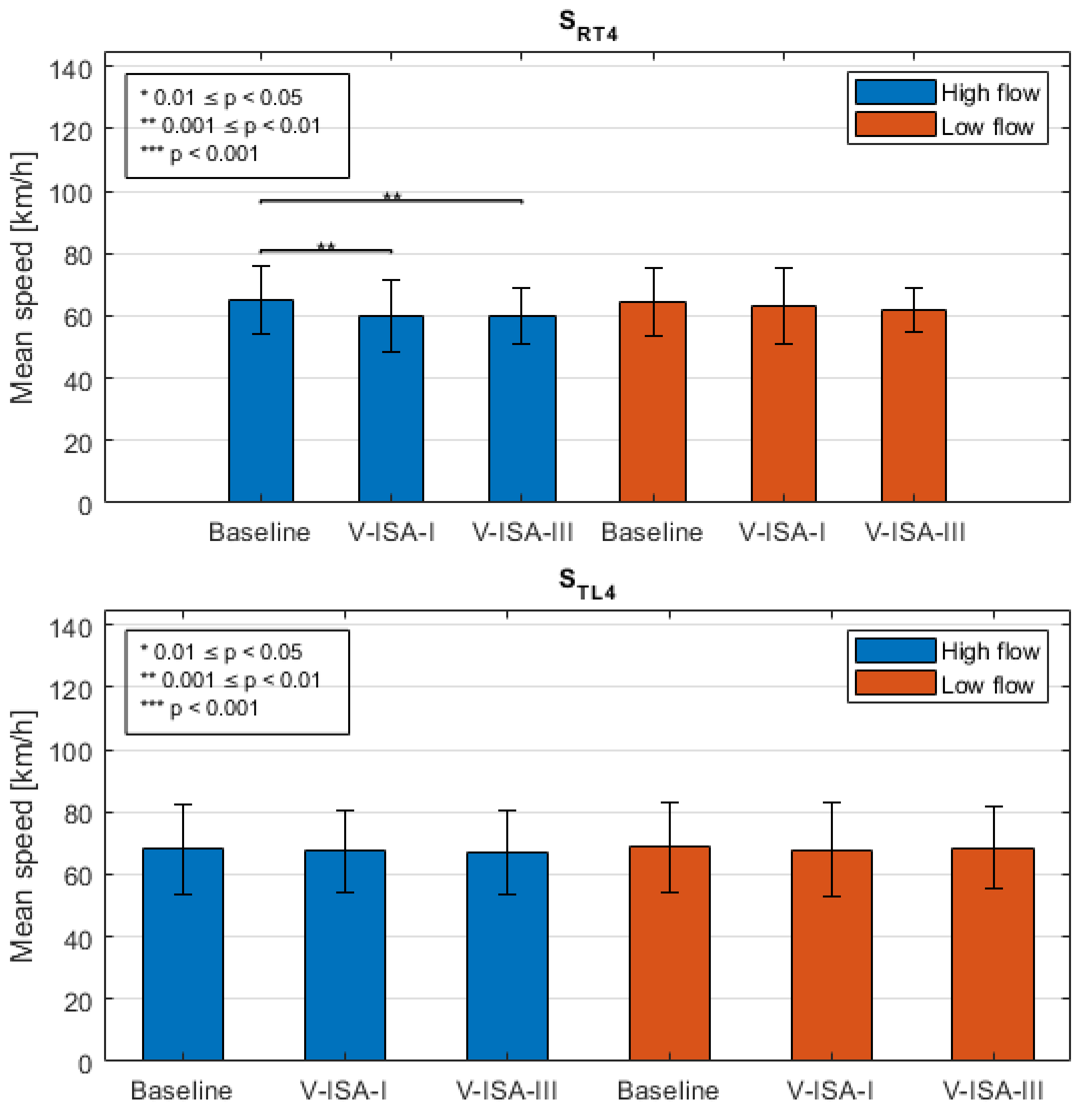


Figure 61. Representation of mean speed values for merging terminal, ramp 4, with indication of the positive and negative standard deviation (error bars) and p-values.

LMM outcome suggests no significant differences between groups when comparing V-ISA drives with baseline ones at RT sections for ramp-1 and ramp-3 (Table 31 and Table 32). However, strong significance was found between groups when using the V-ISA-III variant at RT2 and RT4 (Figure 62 and Figure 63, respectively). These differences emerge given the ramp-1 and ramp-3 geometric design. Continuous and reverse merging terminals lengths are longer compared to linear ones, consequently, at RT section for ramp 1 and 3, drivers did not exhibit any migration effect due to the speed reduction over the ramp arc, while in the case of ramp 2 and 4 linear on-terminals, mainly for the V-ISA-III variant, migration effect is manifested by drivers, showing lower operating speeds. In addition, Bonferroni adjusted post-hoc comparison evidenced significant differences among the interaction between V-ISA-III and age class III at RT2 ($S_{RT2,Base} - S_{RT2,V-ISA-III} * III = 8.010, p = < .001$), suggesting lower operating speeds for older drivers when the V-ISA-III is active compared to baseline drives; a possible reason could be the inability of older drivers to adjust the speed given the reduction in a previous location. In addition, significant differences between V-ISA-I and high traffic level at RT4 are evinced ($S_{RT4,Base} - S_{RT4,V-ISA-I} * High = 5.436, p = 0.047$), which could be attributed to the drivers perception of not being capable of merge within the terminal due to the combination of the linear length terminal and the large number of vehicles found in the adjoining line that makes it more difficult to find a gap to merge.

*Table 31. Fixed effect Omnibus tests table with factors influencing speed at merging terminal sections RT1, RT2, RT3, and RT4. (Notes: TF: traffic flow; AC: age class; some effects are not included given that were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F (df, den df) (p-value)***			
	S_{RT1}	**S_{RT2}**	**S_{RT3}**	**S_{RT4}**
V-ISA	1.377 (2, 130)	6.678 (2, 145)	.205 (1, 139)	3.733 (2, 142)**
TF	.487 (1, 130)	.403 (1, 145)	.231 (2, 139)	2.671 (1, 142)
Gender	1.408 (1, 25)	-	.062 (1, 26)	.267 (1, 25)
AC	.804 (2, 25)	.798 (2, 28)	.028 (2, 26)	.443 (2, 25)
Kilometers per year	-	-	-	-
Accidents	3.866 (1, 25)*	4.117 (1, 28)	-	3.455 (1, 25)*
V-ISA ✻ TF	1.276 (2, 130)	.019 (2, 145)	1.544 (2, 139)	3.209 (2, 142)**
System Type ✻ Gender	.659 (2, 130)	-	1.141 (2, 139)	-
TF ✻ Gender	5.004 (1, 130)**	-	-	10.905 (1, 142)**
V-ISA ✻ AC	1.612 (4, 130)	3.057 (4, 145)	.031 (2, 139)	1.011 (4, 142)
TF ✻ AC	.318 (2, 130)	1.208 (2, 145)	.351 (4, 139)	3.835 (2, 142)**
Gender ✻ AC	.003 (2, 25)	-	.942 (2, 26)	.214 (2, 25)
V-ISA ✻ TF ✻ Gender	3.213 (2, 130)**	-	-	-
V-ISA ✻ TF ✻ Age Class	.712 (4, 130)	1.987 (4, 145)	1.473 (4, 139)	2.116 (4, 142)*
V-ISA ✻ Gender ✻ AC	.247 (4, 130)	-	1.206 (4, 139)	-
TF ✻ Gender ✻ AC	.911 (2, 130)	-	-	3.781 (2, 142)**
V-ISA ✻ TF ✻ Gender ✻ AC	2.434 (4, 130)*	-	-	-

*Table 32. Fixed effect Omnibus tests table with factors influencing speed at merging terminal sections TL1, TL2, TL3, and TL4. (Notes: TF: traffic flow; AC: age class; some effects are not included given that were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	***F (df, den df) (p-value)***			
	S_{TL1}	**S_{TL2}**	**S_{TL3}**	**S_{TL4}**
V-ISA	3.144 (2, 145)**	4.495 (2, 130)**	3.070 (2, 139)*	.177 (2, 142)
TF	.023 (1, 145)	2.220 (1, 130)	.462 (1, 139)	.516 (1, 142)
Gender	4.252 (1, 28)**	.268 (1, 25)	.806 (1, 26)	2.653 (1, 25)
AC	.688 (2, 28)	.459 (2, 25)	.204 (2, 26)	1.312 (2, 25)
Kilometers per year	-	.002 (1, 25)	-	-
Accidents	-	-	-	3.979 (1, 25)*
V-ISA ✻ TF	1.000 (2, 145)	.504 (2, 130)	.753 (2, 139)	.044 (2, 142)
System Type ✻ Gender	-	.861 (2, 130)	.765 (2, 139)	2.787 (2, 142)*
TF ✻ Gender	-	.396 (1, 130)	-	.087 (1, 142)
V-ISA ✻ AC	1.708 (4, 145)	.622 (4, 130)	1.875 (4, 139)	.328 (4, 142)
TF ✻ AC	.191 (2, 145)	1.549 (2, 130)	.341 (2, 139)	-
Gender ✻ AC	-	.970 (2, 25)	.281 (2, 26)	.078 (2, 25)
V-ISA ✻ TF ✻ Gender	-	2.530 (2, 130)*	-	3.183 (2, 142)**

V-ISA ⁎ TF ⁎ Age Class	1.132 (4, 145)	1.846 (4, 130)	1.753 (4, 139)	-
V-ISA ⁎ Gender ⁎ AC	-	2.496 (4, 130)**	.808 (4, 139)	2.042 (4, 142)*
TF ⁎ Gender ⁎ AC	-	1.763 (2, 130)	-	-
V-ISA ⁎ TF ⁎ Gender ⁎ AC	-	1.646 (4, 130)	-	-

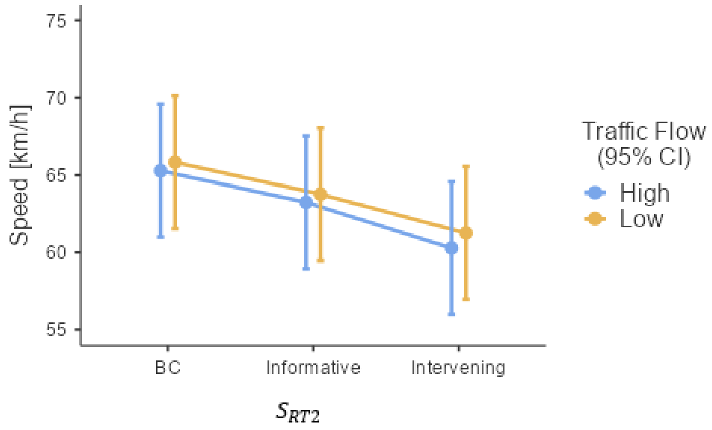


Figure 62. Plot of speed at RT2 section for different drives under the effect of V-ISA for high and low traffic levels with 95% confidence level bars.

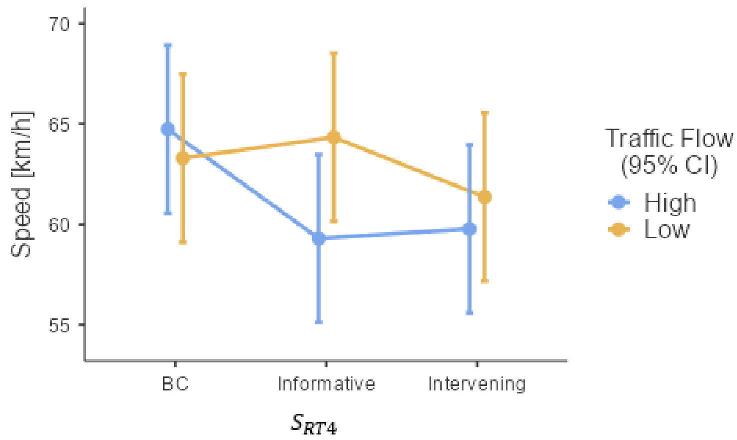


Figure 63. Plot of speed at RT4 section for different drives under the effect of V-ISA for high and low traffic levels with 95% confidence level bars.

At merging point, LMM evidence significantly differences between groups when using the V-ISA system in one of its two variants. Specifically, along ramp-1 merging section, lower operating speed were registered when using V-ISA-III (**Appendix H**; Table 63). Subsequently, as exhibited in Figure 64, gender was a determinant factor in speed variation, where males merged at higher speeds than females. This behaviour could be attributed to the different driving styles for male and female, with females being more prudent as posed by Degraeve et al., 2015.

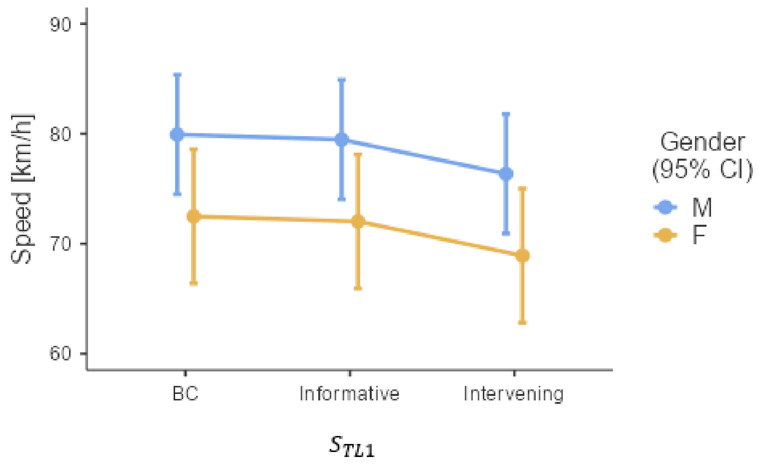


Figure 64. Plot of speed at RT4 section for different drives under the effect of V-ISA for high and low traffic levels with 95% confidence level bars.

At TL2, drivers manifested lower merging speeds when using the V-ISA system (Figure 65), conversely, at ramp-3 merging point, V-ISA-I variant depicts significance differences between groups with a higher merging speed for those drives with the V-ISA-I active. These results reinforce what was commented before, however, the particular speed increase at TL3 is because of its reverse design that lets drivers reach higher speeds given the longer connection and its inflection point where curvature is null. Oppositely, LMM output show significance among V-ISA-I and age class I-III (Figure 66), nonetheless, Bonferroni post-hoc test does not support this without evidencing significance among the combination.

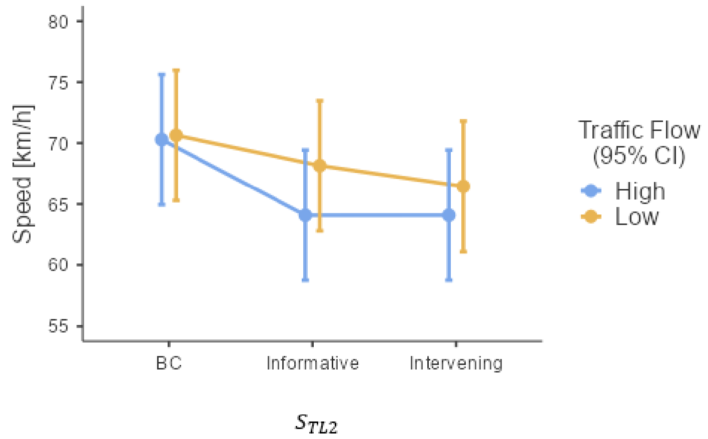


Figure 65. Plot of speed for ramp 2 merging abscissa for different drives under the effect of V-ISA for high and low traffic levels with 95% confidence level bars.

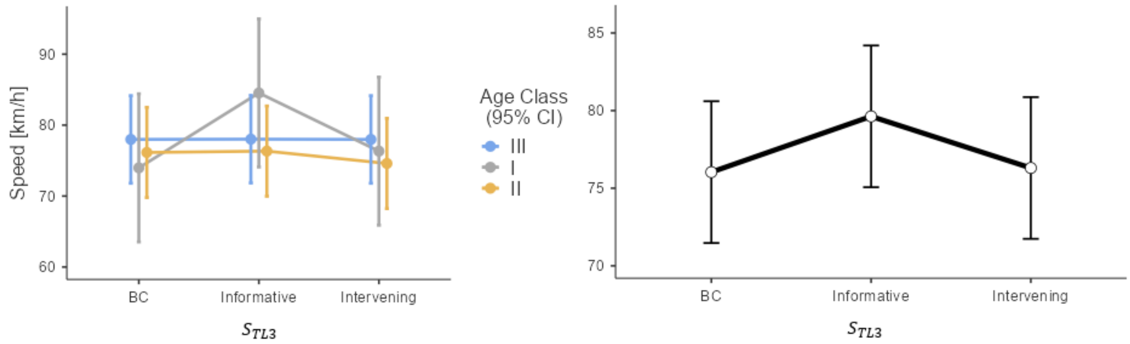


Figure 66. Plots of speed for ramp 3 merging abscissa for different drives under the effect of V-ISA and for age classes (left-hand side) with 95% confidence level bars.

Eventually, at ramp-4 merging section, interaction between V-ISA-I and gender exhibited significant differences (Figure 67) ($S_{TL4,Base} - S_{TL4,V-ISA-I} * F - M = -9.341, p = 0.020$). Manifesting those females operate at lower speed than males when merging with the V-ISA-I variant active, which reinforces the previously mentioned driving style differences among females and males.

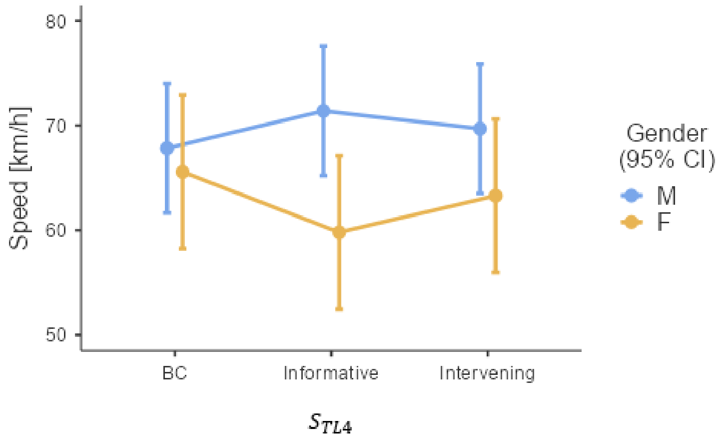


Figure 67. Plot of speed for ramp 4 merging abscissa for different drives under the effect of V-ISA for male and female with 95% confidence level bars.

4.3.2 Transversal behaviour outcomes

In the case of diverging terminals, transversal behaviour was studied by recording the drivers' merging abscissa for baseline and V-ISA scenarios. The diverging abscissa indicates where drivers passed from motorway or two-lane rural highway through lane to terminal. Results are presented in boxplot representation (Figure 68) with origin placed at RT section, moreover, start of the taper (TT section) and end of taper (TE) are also included. Additionally, mean diverging distances and standard deviation by scenario and traffic flow are collected in Table 33.

Table 33. Mean and standard deviation values for merging abscissa by scenario and level of traffic.

	Baseline				**V-ISA-I**				**V-ISA-III**			
	High flow (HF)		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**		**High flow (HF)**		**Low flow (LF)**	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
L_{LT_M1}	176.88	89.84	168.57	100.29	164.86	83.98	162.16	81.67	140.28	83.63	143.19	80.51
L_{LT_M2}	93.99	31.15	78.67	35.64	92.86	35.24	81.79	36.50	86.66	33.47	85.06	36.61
L_{LT_M3}	127.90	103.02	112.51	83.03	103.88	68.60	108.40	86.16	112.91	80.65	103.24	71.94
L_{LT_M4}	102.97	39.57	100.02	39.80	111.36	32.32	100.19	41.50	105.37	39.46	94.04	39.85

Results evidence there is not remarkable changes in the drivers' merging abscissa across ramps. In reality, ramp-2 and ramp-3, which are linear merging terminals to the two-lane rural highway, show similar distribution of data between scenarios, indicating that part of the drivers are merging within the taper length. Similarly, ramp 1 and 2 merging terminals distances are larger, which is in accordance with their longer terminals length (continuous and reverse design, respectively). According to the results, over those two merging terminals, most of the drivers merged before the taper, however, for continuous on-ramp (ramp one merging terminal) a higher number of drivers merged along the taper compared to the reverse on-ramp (ramp three merging terminal). Nevertheless, distribution of data remains alike when looking at different scenarios.

Statistical analysis was performed over drivers mean merging abscissa. T-test results do not evidence any statistical significance between groups. Complete t-test results and plots can be found in **Appendix E** and **Appendix F**, respectively. Whereas drivers merging distances are presented in **Appendix G**.

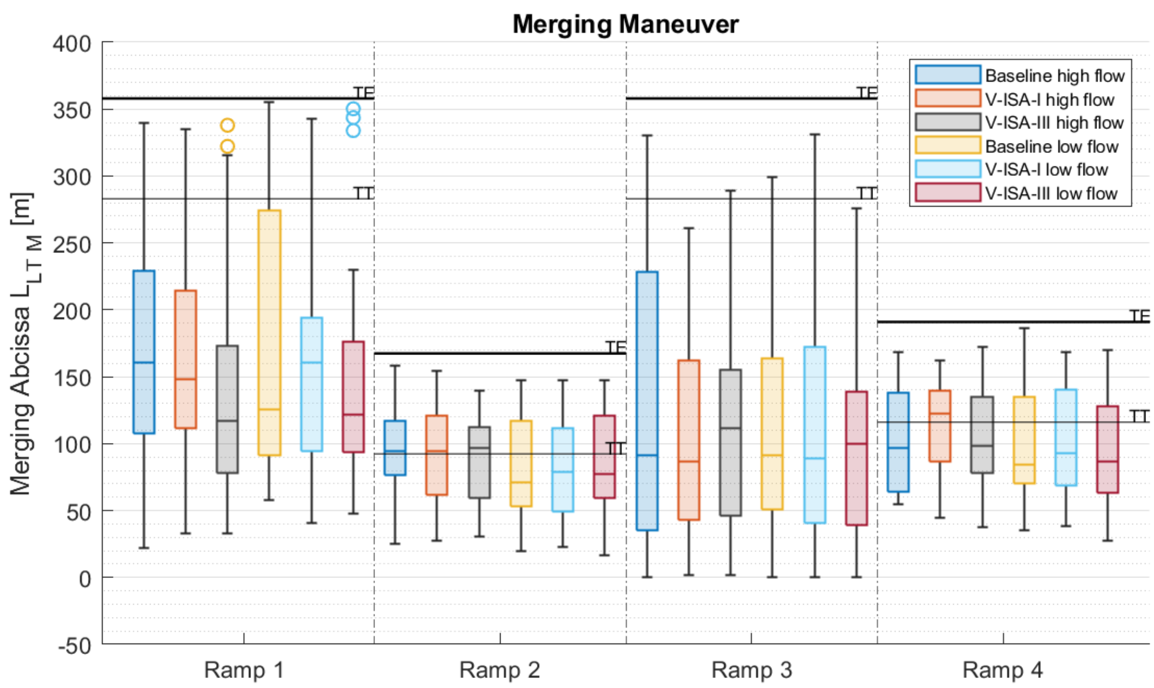


Figure 68. Box-plots for merging abscissa across ramps and scenarios.

According to LMM outcome (Table 34), the V-ISA system influences drivers merging abscissa over ramp-1 merging terminal, when its V-ISA-III variant is active (Figure 69). Surprisingly, drivers merged earlier when the V-ISA-III variant was active compared to the baseline scenario along ramp-1

(**Appendix H**; Table 64). A possible implication of this results is that driver did not have the need to compensate the reduction of speed over the ramp arc with longer merging distances. Moreover, LMM shows statistical difference among the interaction between V-ISA-I and age classes I – III at ramp-3 merging terminal ($LT_{LT\ M3,V-ISA-I} - LT_{LT\ M3,Base} * LT_{LT\ M3,I} - LT_{LT\ M3,III} = 71.316, p = 0.040$) (Figure 70). Nevertheless, Bonferroni adjusted post-hoc test does not support it, exhibiting no significantly differences between measures. Eventually, no significant differences from the V-ISA system use were exhibited in the remaining merging terminals.

*Table 34. Fixed effect Omnibus tests table with factors influencing merging abscissa. (Note: some effects are not included given that were excluded from the LMM in the calibration process due to their insignificant influence; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Fixed effect	F (df, den df) (p-value)			
	$L_{LT\ M1}$	$L_{LT\ M2}$	$L_{LT\ M3}$	$L_{LT\ M4}$
V-ISA	5.067 (2, 130)**	.193 (2, 130)	.936 (2, 145)	.979 (2, 130)
Traffic Flow	.322 (1, 130)	2.451 (1, 130)	.059 (1, 145)	1.170 (1, 130)
Gender	.711 (1, 26)	10.323 (1, 26)**	-	.071 (1, 24)
Age Class	.564 (2, 26)	3.256 (2, 26)*	2.654 (2, 26)*	.408 (2, 24)
Age	-	-	6.679 (1, 26)**	3.906 (1, 24)
Experience	-	-	-	3.765 (1, 24)
Kilometers per year	-	-	11.664 (1, 26)**	-
Accidents	-	-	4.971 (1, 26)**	-
V-ISA ✻ Traffic Flow	.481 (2, 130)	1.361 (2, 130)	.967 (2, 145)	.055 (2, 130)
V-ISA ✻ Gender	1.217 (2, 130)	.170 (2, 130)	-	.392 (2, 130)
Traffic Flow ✻ Gender	2.648 (1, 130)	.440 (1, 130)	-	.122 (1, 130)
V-ISA ✻ Age Class	1.653 (4, 130)	.767 (4, 130)	2.307 (4, 145)*	1.030 (4, 130)
Traffic Flow ✻ Age Class	.778 (2, 130)	.243 (2, 130)	1.029 (2, 145)	.907 (2, 130)
Gender ✻ Age Class	.203 (2, 26)	.203 (2, 26)	-	1.339 (2, 24)
V-ISA ✻ Traffic Flow ✻ Gender	1.263 (2, 130)	1.734 (2, 130)	-	1.361 (2, 130)
V-ISA ✻ Traffic Flow ✻ Age Class	.540 (4, 130)	2.056(4, 130)*	1.603 (41 145)	3.099 (4, 130)
V-ISA ✻ Gender ✻ Age Class	1.256 (4, 130)	2.260 (4, 130)*	-	1.234 (4, 130)
Traffic Flow ✻ Gender ✻ Age Class	.494 (2, 130)	2.44482, 130)*	-	1.061 (2, 130)
V-ISA ✻ Traffic Flow ✻ Gender ✻ Age Class	3.206 (4, 130)**	1.742 (4, 130)	-	2.419 (4, 130)

On the other hand, LMM outputs indicate that gender ($LT_{LT\ M2,M} - LT_{LT\ M2,F} = 18.8, p_{Bonferroni} = 0.003$) represents a significant difference in the merging distance along off-ramp-2, indicating that males merge later than female, which is curious, given females driving nature of being more conservative and prudent; moreover, comparison between age classes I - III ($LT_{LT\ M2,III} - LT_{LT\ M2,II} = 14.45, p_{Bonferroni} = 0.052$) represent a significant factors influencing merging abscissa along ramp-2, manifesting that older drivers tend to merge later compared to younger drivers. This result is in-line with those obtained by Titiloye et al., 2021, where older drivers take more time in the merging manoeuvre than younger ones due to their conservativeness and their decline in the cognitive ability.

Oddly, LMM does not show any significant difference in the merging abscissa due to traffic, which contrast with results from previous studies (Portera and Bassani, 2021; Calvi et al., 2011) where higher traffic levels increase the difficulty of merging into the adjoining lane. Complete LMM outcomes tables for ramps sections with significant factors for drivers longitudinal and transversal behaviour are grouped in **Appendix H.**

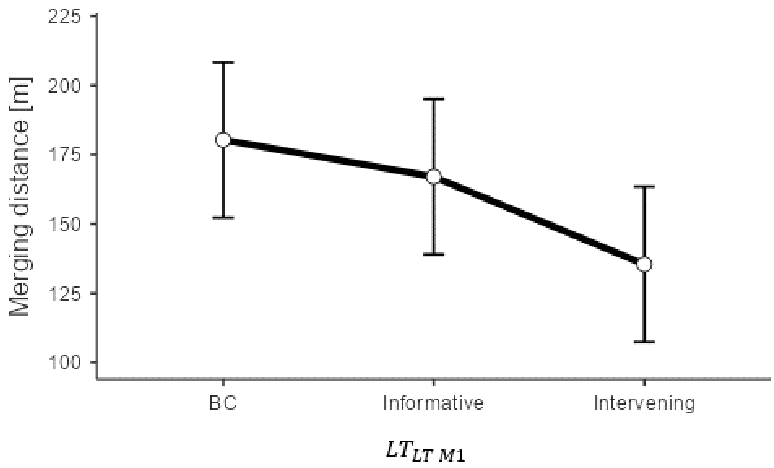


Figure 69. Plot for ramp 1 merging abscissa for different drives under the effect of V-ISA with 95% confidence level bars.

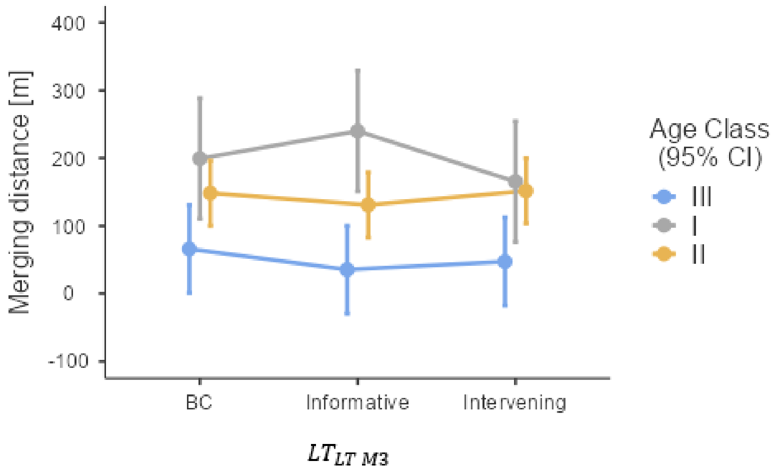


Figure 70. Plot for ramp 3 merging abscissa for different drives under the effect of V-ISA, for age classes with 95% confidence level bars.

5. CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

This study deals with one of the most recurrent problems in terms of road safety, speeding. Over the years, many systems have been implemented to compel driver in adopting the most appropriate speed. The implementation of vehicle on-board systems such as Intelligent speed adaptation systems (ISA) has shown significant results. However, traditional ISA systems are designed for speed adjustment depending on the posted speed limits assigned to each road section. Although showing positive effects, this system does not provide real-time information to ensure a better adjustment in the adoption of speed by drivers. Therefore, the idea of developing an ISA system that combines sight limitations with speed control, called V-ISA, emerges as a more convenient and safe solution. Accordingly, V-ISA was developed with three main variants: one that informs the driver of the most appropriate speed (V-ISA-I), a second one that warns the driver with sound (V-ISA-II), and a third one that actively intervenes on throttle and brake pedals (V-ISA-III). Such variants should not only influence the correct adaptation of a safe speed but should also not be a determining factor in drivers' negative behaviour.

Previous research activities carried out at the Road Safety and Driving Simulation Laboratory of the Politecnico di Torino have analysed the effectiveness of the V-ISA system in entry and exit curved sections with positive effects. This study intends to extend the case studies including complex driving conditions along motorways and two-lane rural sections, i.e. along transitional sections and under different traffic levels. Previous investigations found positive results in the use of two V-ISA variants: V-ISA-I and V-ISA-III.

This study used this two V-ISA variants. Results show that drivers did not compensate the speed reduction due to use of the system in previous and posterior sections. In the same way, in the case of sections with constant speed and sight limitation such as ramps arc, the system has significant effects on the drivers' speed, obtaining better speed profiles and a significant speed reduction. This implies that drivers adapt to V-ISA and allows them to maintain a safe speed behaviour in correspondence to road sections with poor sight conditions. It remains clear that the V-ISA-III variant is more effective in such task due to its ability to avoid speeding when the safe speed threshold is reached, while V-ISA-I variant allows driver to freely select traveling speed while informing through on-screen colours. Nevertheless, both variants exhibited effectiveness in speed control.

Similarly, the V-ISA system did not have repercussions in the transversal driver behaviour, since vehicle lateral control was not significantly affected in most of the ramp arcs, with the exception of three cases where higher SDLP values were observed when using the informative variant. This behaviour is attributed to the distraction of drivers who had to interpret the message provided by system, which in turn may have contributed to the slight loose of control.

Moreover, along acceleration and deceleration lanes, drivers showed different behaviours. Over the deceleration lanes, drivers maintained similar operating speeds and exit points from motorway and two-lane rural highway, in all scenarios, indicating that the V-ISA system has no influence on drivers' speed and diverging choice, except for one case, where drivers evidenced lower speeds in the merging manoeuvre with both V-ISA-I and V-ISA-III variants. Similarly, the same behaviour was observed along exit terminals, lower speeds were registered over the linear configurations, along with early merging manoeuvres observed at the continuous acceleration ramp, while the V-ISA-III variant was active. These findings indicate that the V-ISA-I variant showed better performance in this type of manoeuvres compared to the V-ISA-III variant.

It is worth highlighting that this study has certain limitations. The V-ISA system needs to be tested in several new road scenarios, that also need further assessment in terms of usability, acceptance, as well as mental workload. Finally, the integration among V-ISA and other Advanced Driver Assistance Systems (ADAS) such as the Adaptive Cruise Control (ACC) is a matter of study and future work.

6. REFERENCES

Aarts, L., & Van Schagen, I. (2006). Driving speed and the risk of road crashes: A review. *Accident Analysis & Prevention*, *38*(2), 215-224.

Adell, E. (2009). *Driver experience and acceptance of driver support systems-a case of speed adaptation*. Lund University.

Almqvist, S., & Towliat, M. (1993). Road side information linked to the vehicle for active safety Aspen Track. *7129*, *7129*.

Bassani, M., Catani, L., Salussolia, A., & Yang, C. Y. D. (2019). A driving simulation study to examine the impact of available sight distance on driver behavior along rural highways. *Accident Analysis & Prevention*, *131*, 200-212.

Bassani, M., Hazoor, A., & Catani, L. (2019). What's around the curve? A driving simulation experiment on compensatory strategies for safe driving along horizontal curves with sight limitations. *Transportation research part F: traffic psychology and behavior*, *66*, 273-291.

Carsten, O. (2002). European research on ISA: Where are we now and what remains to be done. *ICTCT, Nagoya. May*, *450*.

Carsten, O., & Tate, F. (2001). *Intelligent speed adaptation: The best collision avoidance system?* (No. 2001-06-0152). SAE Technical Paper.

Castro, M., & De Santos-Berbel, C. (2015). Spatial analysis of geometric design consistency and road sight distance. *International Journal of Geographical Information Science*, *29*(12), 2061-2074.

Chorlton, K., & Conner, M. (2012). Can enforced behavior change attitudes: exploring the influence of intelligent speed adaptation. *Accident Analysis & Prevention*, *48*, 49-56.

Comte, S., Várhelyi, A., & Santos, J. (1997). *The effects of ATT and non-ATT systems and treatments on driver speed behavior*. Espoo, Finland: VTT.

Gargoum, S. A., El-Basyouny, K., & Sabbagh, J. (2018). Assessing stopping and passing sight distance on highways using mobile LiDAR data. *Journal of Computing in Civil Engineering*, *32*(4), 04018025.

Ghadiri, S. M. R., Prasetijo, J., Sadullah, A. F., Hoseinpour, M., & Sahranavard, S. (2013). Intelligent speed adaptation: Preliminary results of on-road study in Penang, Malaysia. *IATSS research*, *36*(2), 106-114.

Ghadiri, S. M. R., Prasetijo, J., Sadullah, A. F., Hoseinpour, M., & Sahranavard, S. (2013). Intelligent speed adaptation: Preliminary results of on-road study in Penang, Malaysia. *IATSS research*, *36*(2), 106-114.

Hazoor, A., Bassani, M., Lioi, A. (2021). Development of a Novel Intelligent speed adaptation system based on Available Sight Distance. Transp. Res. Record.

Jamson, S. (2006). Would those who need ISA, use it? Investigating the relationship between drivers' speed choice and their use of a voluntary ISA system. *Transportation Research Part F: Traffic Psychology and Behaviour*, *9*(3), 195-206.

Khastgir, S., Birrell, S., Dhadyalla, G., & Jennings, P. (2015, May). Development of a drive-in driver-in-the-loop fully immersive driving simulator for virtual validation of automotive systems. In *2015 IEEE 81st Vehicular Technology Conference (VTC Spring)* (pp. 1-4). IEEE.

Lai, F., & Carsten, O. (2012). What benefit does Intelligent Speed Adaptation deliver: A close examination of its effect on vehicle speeds. *Accident Analysis & Prevention*, *48*, 4-9.

Ministero delle Infrastrutture e dei Trasporti, 2001. Norme Funzionali e Geometriche per la Costruzione delle Strade. Italia.

Ministero delle Infrastrutture e dei Trasporti, 2004. Direttiva sui criteri di progettazione, installazione, verifica e manutenzione dei dispositivi di ritenuta nelle costruzioni stradali. Italia.

Ministero delle Infrastrutture e dei Trasporti, 2006. Norme Funzionali e Geometriche per la Costruzione delle Strade. Italia.

Ministero delle Infrastrutture e dei Trasporti. (July 04, 2017). *Patenti di guida, sul sito del MIT i dati aperti.* https://www.mit.gov.it/comunicazione/news/patenti-dataset-online

Mobility and Transport. (April 27, 2021). *Intelligent Speed Adaptation.* European Commission.https://ec.europa.eu/transport/road_safety/specialist/knowledge/speed/new_technologies_new_opportunities/intelligent_speed_adaptation_isa_en

PAU, Massimiliano; ANGIUS, Silvano. Do speed bumps really decrease traffic speed? An Italian experience. *Accident Analysis & Prevention*, 2001, vol. 33, no 5, p. 585-597.

Portera, A., & Bassani, M. (2020). Factors influencing driver behaviour along curved merging interchange terminals. *Transportation research part F: traffic psychology and behaviour*, *75*, 187-202.

Portera, A., & Bassani, M. (2021). Experimental Investigation into Driver Behavior along Curved and Parallel Diverging Terminals of Exit Interchange Ramps. *Transportation Research Record*, 0361198121997420.

Portera, Alberto (2020). *A driving investigation on driver behaviour at curved ramp terminals of motorway interchanges* [Master Thesis, Politecnico Di Torino]. Webthesis library – Politecnico Di Torino.

Regan, M. A., Triggs, T. J., Young, K. L., Tomasevic, N., Mitsopoulos, E., Stephan, K., & Tingvall, C. (2006). On-road evaluation of intelligent speed adaptation, following distance warning and seatbelt reminder systems: Final results of the TAG SafeCar project. *Monash University Accident Research Centre Reports*, *253*, 270.

Silyanov, V. V. (1973). Comparison of the pattern of accident rates on roads of different countries. *Traffic Engineering & Control*, *14*(9).

Sparks, W. J. (1968). The influence of highway characteristics on accident rates. *Public Works*, *99*(3), 101-103.

Starkey, N. J., Charlton, S. G., Malhotra, N., & Lehtonen, E. (2020). Drivers’ response to speed warnings provided by a smart phone app. *Transportation research part C: emerging technologies*, *110*, 209-221.

Steinauer, B., Trapp, R., & Böker, E. (2002). Verkehrssicherheit in Kurven auf Autobahnen. *Straßenverkehrstechnik*, *46*(8).

Terrafino, Alberto (2021). *Behavioral effects induced by using a speed control system based on the available sight distance* [Master Thesis, Politecnico Di Torino]. Webthesis library – Politecnico Di Torino.

Transportation Research Board (2010). HCM 2010 – Highway capacity manual. National Research Council.

Urbanik, T., Hinshaw, W., & Fambro, D. (1989). Safety effects of limited sight distance on crest vertical curves. *Transportation Research Record*, *1208*, 23-35.

van der Pas, J. W. G., Marchau, V. A., Walker, W. E., Van Wee, G. P., & Vlassenroot, S. H. (2012). ISA implementation and uncertainty: A literature review and expert elicitation study. *Accident Analysis & Prevention*, *48*, 83-96.

van Driel, C. (2007). Driver support in congestion. *An assessment of user needs and impacts on driver and traffic flow*.

van Loon, A., & Duynstee, L. (2001, June). Intelligent Speed Adaptation (ISA): A successful test in the Netherlands. In *Proceedings of the Canadian Multidisciplinary Road Safety Conference XII, Ontario, Canada*.

Verster, J. C., & Roth, T. (2011). Standard operation procedures for conducting the on-the-road driving test, and measurement of the standard deviation of lateral position (SDLP). *International journal of general medicine*, *4*, 359.

Young, K. L., Regan, M. A., Triggs, T. J., Jontof-Hutter, K., & Newstead, S. (2010). Intelligent speed adaptation—Effects and acceptance by young inexperienced drivers. *Accident Analysis & Prevention*, *42*(3), 935-943.

LIST OF FIGURES

LIST OF TABLES

7. APPENDIX

A. GEOMETRICAL CHARACTERISTICS OF ELEMENTS COMPOSING THE EXPERIMENTAL ROAD ALIGNMENT

Table 35. Road alignment sections and geometrical characteristics.

Section	Category	Element	L/R Curve	Length [m]	Radius [m]	Scale factor A [m]	Initial abscissa [m]	Final abscissa [m]
1	-	Lay-by	-	70	-	-	0+000.00	0+035.00
2	C1	Tangent	-	18.50	-	-	0+035.00	0+053.50
		Clothoid	-	100.00	-	100.00	0+053.50	0+153.50
		Arc	R	100.00	150.00	-	0+153.50	0+253.50
		Inflection	-	130.00	-	100.00	0+253.50	0+383.50
		Arc	L	201.59	150.00	-	0+383.50	0+585.09
		Clothoid	-	50.00	-	100.00	0+585.09	0+635.09
		Tangent	-	604.90	-	-	0+635.09	0+842.09
3	On-Ramp	Ramp clothoid	-	66.10	-	100.00	0+842.09	0+908.19
		Ramp arc	R	115.93	150.00	-	0+908.19	1+024.12
		Ramp continuity	-	127.82	-	150.00	1+024.12	1+151.94
		Acceleration lane	-	360.00	437.00	-	1+151.94	1+551.94
4	A	Arc	R	612.95	437.00	-	1+551.94	1+551.94
		Clothoid	-	143.06	-	450.00	1+551.94	1+695.00
		Tangent	-	2495.88	-	-	1+695.00	4+190.88
		Clothoid	-	143.06	-	450.00	4+190.88	4+333.95
		Arc	R	612.95	437.00	-	4+333.95	4+733.95
5	Off-Ramp	Deceleration lane	-	200.00	437.00	-	4+733.95	4+733.95
		Ramp continuity	-	127.82	-	150.00	4+733.95	4+861.77
		Ramp arc	R	115.93	150.00	-	4+861.77	4+977.70
		Ramp clothoid	-	66.06	-	100.00	4+977.70	5+043.76
6	C1	Tangent	-	604.90	-	-	5+043.76	5+250.76

		Clothoid	-	50.00	-	100.00	5+250.76	5+300.76
		Arc	L	201.59	150.00	-	5+300.76	5+502.35
		Inflection	-	130.00	-	100.00	5+502.35	5+632.35
		Arc	R	100.00	150.00	-	5+632.35	5+732.35
		Clothoid	-	100.00	-	100.00	5+732.35	5+832.35
		Tangent	-	18.50	-	-	5+832.35	5+850.85
	-	Lay-by	-	70.00	-	-	5+850.85	5+920.85
	C1	Tangent	-	819.50	-	-	5+920.85	6+230.85
7	On-Ramp	Ramp clothoid	-	42.52	-	100.00	6+230.85	6+273.37
		Ramp arc	R	162.51	150.00	-	6+273.37	6+435.88
		Ramp inflection	-	199.31	-	150.00	6+435.88	6+635.18
		Acceleration lane	-	360.00	437.00	-	6+635.18	6+848.38
8	A	Arc	L	612.95	437.00	-	6+848.38	6+848.38
		Clothoid	-	143.06	-	450.00	6+848.38	6+991.45
		Tangent	-	1000.00	-	-	6+991.45	7+991.45
		Clothoid	-	143.06	-	450.00	7+991.45	8+134.51
		Arc	L	612.95	437.00	-	8+134.51	8+347.51
9	Off-Ramp	Deceleration lane	-	200.00	437.00	-	8+347.51	8+347.51
		Ramp inflection	-	199.50	-	150.00	8+347.51	8+547.02
		Ramp arc	R	162.51	150.00	-	8+547.02	8+709.52
		Ramp clothoid	-	42.52	-	100.00	8+709.52	8+752.04
10	C1	Tangent	-	819.50	-	-	8+752.04	9+062.04
11	-	Lay-by	-	70.00	-	-	9+062.04	9+097.04

B. DESIGN OF TERMINALS

According to Italian standards, terminals are divided into two categories: on-ramp and off-ramp terminals. Subsequently, on-ramp terminals are composed by three main elements:

(i) Acceleration lane ($L_{a,e}$);
(ii) Immersion lane ($L_{i,e}$);
(iii) Taper ($L_{v,e}$);

While off-tramp terminals are composed by:

(i) Taper ($L_{m,u}$);
(ii) Deceleration lane ($L_{d,u}$);

Both acceleration and decelerations lanes are design following kinematic criteria, whereas taper is design by geometric criteria. Ultimately, the immersion lane is design with the integration between HCM and Italian guidelines.

ACCELERATION AND DELECERATION LANES DESING

The following kinematic equation is used for acceleration and deceleration lanes design:

$$L_c = \frac{V_1^2 - V_2^2}{2a}$$

Where:

V_1: initial speed

V_2: final speed ($0.8 \cdot v$ for on-ramp terminals)

a: acceleration or deceleration rate (**deceleration terminals**: $3\ m/s^2$ for road type A and B, : $2\ m/s^2$ for other types; **acceleration terminals**: $1\ m/s^2$)

Hence,

Table 36. Deceleration lane length (left-hand side) and acceleration lane length (right-hand side) for CAT-C Road.

Deceleration lane	
v_1 [m/s]	27.77
v_2 [m/s]	16.66
a [m/s^2]	3
$L_{d,u}$ [m]	82

Acceleration lane	
v_1 [m/s]	16.66
v_2 [m/s]	22.22
a [m/s^2]	1
$L_{a,e}$ [m]	108

Table 37. Deceleration lane length (left-hand side) and acceleration lane length (right-hand side) for CAT-A Road.

Deceleration lane	
v_1 [m/s]	38.88
v_2 [m/s]	16.66
a [m/s^2]	3
$L_{d,u}$ [m]	206

Acceleration lane	
v_1 [m/s]	16.66
v_2 [m/s]	31.11
a [m/s^2]	1
$L_{a,e}$ [m]	345

TAPER DESIGN

Taper of on-ramp junctions, geometric criteria:

Table 38. Geometric criteria for on-ramp junctions.

Design speed of the road	Length [m]
$v_d > 80$ km/h	75
$v_d < 80$ km/h	50

Taper of off-ramp junctions, geometric criteria:

Table 39. Geometric criteria for off-ramp junctions.

Design speed of the road [km/h]	Length [m]
40	20
60	40
80	60
100	75
>120	90

Consequently,

Table 40. Taper length for on-ramp and off-ramp terminals, road CAT-C.

$L_{v,e}$ [m]	75
$L_{m,u}$ [m]	75

Table 41. Taper length for on-ramp and off-ramp terminals, road CAT-A.

$L_{v,e}$ [m]	75
$L_{m,u}$ [m]	90

IMMERSION LANE DESING

Integration among Italian standards and HCM is require to stablish the immersion lane length, by means of the following equation:

$$L_{i,e} = L_{A,HCM} - (L_{a,e} - L_{cl}) - L_{v,e}$$

Where undefined parameter such L_{cl} belongs to the length of the connecting clothoid.

Besides, the calculation of the HCM length ($L_{A,HCM}$) comes after several steps defined by HCM standard. Flow rate, demand flow, capacity and density are parameters calculated and defined to compute this length. Nevertheless, for low hierarchy roads, such cat-C roads, HCM defines a standard immersion lane length of 50 meters.

Therefore,

- Cat-A road $L_{A,HCM} = 360$ meters.
- Cat-C road $L_{A,HCM} = 50$ meters.

C. DRIVERS CHARACTERISTICS AND DRIVING SCENARIOS

Table 42. Drivers information.

TD	Gender	Age	Age class	Driving experience	Annual kilometres	# Accidents
1	M	58	III	28	10000	0
2	M	24	I	6	11000	1
3	M	50	III	32	25000	0
4	M	24	I	6	500	0
5	F	49	III	29	5000	1
6	M	47	III	29	10000	0
7	M	30	II	12	15000	0
8	M	34	II	15	20000	1
9	F	57	III	28	1200	1
10	M	47	III	28	9000	5
11	M	29	II	10	10000	2
12	M	30	II	12	2000	0
13	F	31	II	13	10000	0
14	M	52	III	28	8000	0
15	M	56	III	38	15000	3
16	F	24	I	5	10000	0
17	F	27	II	8	10000	0
18	M	20	I	1	3000	0
19	F	48	III	29	6000	3
20	M	53	III	34	12000	2
21	F	51	II	28	20000	1
22	F	26	II	8	500	0
23	F	49	III	30	6000	1
24	M	31	II	13	2000	0
25	M	29	II	10	10000	0
26	F	26	II	7	10000	0
27	F	35	II	16	15000	1
28	F	55	III	34	20000	0
29	M	31	II	13	10000	0
30	F	46	III	28	20000	2
31	M	47	III	29	20000	2
32	F	23	I	5	3000	0

Table 43. Driving scenarios per TD.

TD	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	Base: high	ISA-I: low	ISA-II: high	Base: low	ISA-II: low	ISA-I: high
2	ISA-II: high	ISA-I: low	Base: high	ISA-II: low	Base: low	ISA-I: high
3	Base: high	ISA-II: high	ISA-I: high	Base: low	ISA-II: low	ISA-I: low
4	ISA-I: low	ISA-I: high	Base: high	ISA-II: high	ISA-I: low	Base: low
5	ISA-II: low	ISA-I: low	Base: high	ISA-II: high	ISA-I: high	Base: low
6	ISA-II: low	Base: low	ISA-I: low	ISA-II: high	ISA-I: high	Base: high
7	ISA-I: high	Base: high	ISA-I: low	ISA-II: low	ISA-II: high	Base: low
8	Base: low	ISA-I: low	ISA-II: high	ISA-I: high	ISA-II: low	Base: high
9	Base: high	ISA-II: low	ISA-I: high	ISA-II: high	ISA-I: high	Base: low
10	ISA-II: high	ISA-II: low	Base: low	ISA-I: low	Base: high	ISA-I: high
11	ISA-I: high	ISA-II: low	Base: high	Base: low	ISA-II: high	ISA-I: low
12	Base: low	ISA-II: low	ISA-I: high	ISA-I: low	Base: high	ISA-II: high
13	ISA-II: low	Base: low	ISA-II: high	Base: high	ISA-I: high	ISA-I: low
14	Base: low	ISA-II: high	ISA-II: low	Base: high	ISA-I: low	ISA-I: high
15	Base: low	ISA-I: low	ISA-I: high	Base: high	ISA-II: low	ISA-II: high
16	Base: high	ISA-II: high	ISA-I: low	ISA-I: high	Base: low	ISA-II: low
17	Base: high	ISA-I: high	ISA-I: low	ISA-II: high	Base: low	ISA-II: low
18	Base: low	ISA-II: high	ISA-II: low	ISA-I: high	Base: high	ISA-I: low
19	ISA-I: high	ISA-II: high	Base: low	ISA-II: low	ISA-I: low	Base: high
20	Base: high	ISA-II: high	ISA-II: low	Base: low	ISA-I: low	ISA-I: high
21	Base: low	ISA-II: low	ISA-I: low	Base: high	ISA-I: high	ISA-II: high
22	ISA-I: low	ISA-II: low	Base: high	ISA-I: high	ISA-II: high	Base: low
23	ISA-I: high	Base: low	ISA-II: low	ISA-II: high	ISA-I: low	Base: high
24	Base: high	ISA-I: low	ISA-II: high	ISA-I: high	ISA-II: low	Base: low
25	ISA-II: high	Base: low	ISA-I: low	ISA-II: low	Base: high	ISA-I: high
26	Base: low	ISA-II: high	ISA-I: low	Base: high	ISA-I: high	ISA-II: low
27	ISA-II: high	Base: low	ISA-I: low	Base: high	ISA-I: high	ISA-I: high
28	ISA-I: low	ISA-II: high	Base: low	ISA-II: low	Base: high	ISA-I: high
29	ISA-II: high	Base: low	ISA-I: low	ISA-I: high	Base: high	ISA-II: low
30	ISA-I: high	Base: low	ISA-II: high	ISA-II: low	Base: high	ISA-I: low
31	ISA-I: low	Base: high	ISA-II: high	Base: low	ISA-I: high	ISA-II: low
32	ISA-I: low	Base: high	ISA-I: high	ISA-II: high	Base: low	ISA-II: low

D. QUESTIONNAIRES AND DOCUEMENTS FOR EXPERIMENTAL ACTIVITY

Presentation letter for experimental activity

Politecnico di Torino
Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture
prof. Marco BASSANI

PRESENTAZIONE DELL'ATTIVITA' DI RICERCA

Torino, Maggio 2021

Gentilissimo/a,

ti contatto in quanto componente del gruppo di *test driver* che supporta le attività del *Laboratorio di Sicurezza Stradale e Simulazione di Guida* del Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture (DIATI).

Nei prossimi mesi abbiamo in programma alcuni esperimenti che necessitano del tuo supporto. In giorni e orari a te più comodi ti chiediamo di venire in laboratorio per un tempo non superiore ai quaranta minuti in due distinti appuntamenti anche in giorni diversi.

Se tu fossi interessato/a a partecipare, ti chiederei cortesemente di restituirmi via email i due moduli di pagina 2 e 3 compilati (i campi si possono riempire direttamente con Adobe Acrobat Reader – Compila e firma).

Nel caso li avessi già compilati recentemente non è necessario che li rinvii nuovamente, abbiamo bisogno solo di un tuo messaggio di conferma di partecipazione.

Qualora disponibile, ti chiederei di seguire alcune utili raccomandazioni che troverai nel questionario stesso, così da non alterare l'esito dell'esperimento. Al ricevimento della documentazione o del messaggio di accettazione, sarai contattato telefonicamente da una delle persone qui sotto indicate per definire i dettagli dell'appuntamento:

- **Alberto Portera** (telefono: 328-8037889)
- **Alberto Terrafino** (telefono: 351-2034174)

I dati raccolti saranno diffusi in forma aggregata e del tutto anonima (v. "Informativa sulla privacy", pagina 4).

I risultati saranno divulgati per soli scopi scientifici senza fini di lucro, e potranno essere presentati in convegni, pubblicati su tesi di Laurea, o in articoli di riviste scientifiche sempre in forma aggregata e rigorosamente anonima.

L'accesso al Politecnico e ai locali del Laboratorio ti sarà consentito solamente se accompagnato/a da personale autorizzato. Ti trasmetto copia del documento rilasciato dal Politecnico per l'accesso ai laboratori dal titolo: "PROCEDURA PER IL CONTRASTO E IL CONTENIMENTO DELLA DIFFUSIONE DEL COVID 19".

Preciso, infine, che la partecipazione a questa attività è del tutto volontaria, e non è soggetta ad alcun compenso.

Ti ringrazio in anticipo per l'attenzione che presterai a questa iniziativa, e della gentile disponibilità che ci vorrai riservare,

Marco Bassani

General data protection regulation

POLITECNICO DI TORINO
Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture
Corso Duca degli Abruzzi, 24 – 10129, Torino
Tel. 011-5645635, 335-1300230, marco.bassani@polito.it

Informativa resa ai sensi degli articoli 13-14 del GDPR 2016/679 (*General Data Protection Regulation*)

Gentile Signore/a,

ai sensi dell'art. 13 del Regolamento UE 2016/679 ed in relazione alle informazioni di cui si entrerà in possesso, ai fini della tutela delle persone e altri soggetti in materia di trattamento di dati personali, si informa quanto segue:

1. FINALITÀ DEL TRATTAMENTO

I dati da Lei forniti saranno utilizzati per scopi di ricerca scientifica, consentendo ai soggetti autorizzati al trattamento di costruire un campione di guidatori con caratteristiche idonee all'attività in esame.

2. MODALITÀ DEL TRATTAMENTO

Il trattamento dei dati sarà effettuato sia manualmente, con supporti cartacei, sia con l'ausilio di mezzi informatizzati. I dati saranno conservati sia in archivi cartacei sia in archivi elettronici. In ogni caso il trattamento dei dati avverrà con logiche strettamente correlate alle finalità indicate e con modalità che garantiscano la sicurezza e la riservatezza dei dati medesimi, attraverso l'adozione di misure idonee ad impedire l'alterazione, la cancellazione, la distruzione, l'accesso non autorizzato o il trattamento non consentito o non conforme alle finalità della raccolta.

3. CONFERIMENTO DEI DATI

Il conferimento dei dati per le finalità di cui al punto 1 sono obbligatori e l'eventuale rifiuto dell'autorizzazione comporta l'esclusione dall'attività di ricerca.

4. COMUNICAZIONE E DIFFUSIONE DEI DATI

I dati forniti saranno comunicati ai soggetti autorizzati: ricercatori, responsabili e incaricati del trattamento. In ogni caso, i dati forniti non saranno soggetti a comunicazione né a diffusione. Come espresso all'art. 162 del Regolamento UE n. 2016/679, "*La finalità statistica implica che il risultato del trattamento per finalità statistiche non siano dati personali, ma dati aggregati, e che tale risultato o i dati personali non siano utilizzati a sostegno di misure o decisioni riguardanti persone fisiche specifiche*".

5. TITOLARE DEL TRATTAMENTO

Il titolare del trattamento dei dati personali è il prof. Marco Bassani, Politecnico di Torino, Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture, corso Duca degli Abruzzi, 24 – 10129 Torino.

6. DIRITTI DELL'INTERESSATO

In ogni momento, Lei potrà esercitare, ai sensi degli articoli dal 15 al 22 del Regolamento UE n. 2016/679, il diritto di:

a) chiedere la conferma dell'esistenza o meno di propri dati personali;
b) ottenere le indicazioni circa le finalità del trattamento, le categorie dei dati personali e, quando possibile, il periodo di conservazione;
c) ottenere la limitazione del trattamento;
d) ottenere la rettifica e la cancellazione dei dati.

Può esercitare i Suoi diritti con richiesta scritta inviata al titolare del trattamento, all'indirizzo mail marco.bassani@polito.it, oppure marco.bassani@pec.polito.it.

Io sottoscritto/a dichiaro di aver ricevuto l'informativa che precede.

Torino, lì ....   Firma ....

Io sottoscritto/a alla luce dell'informativa ricevuta

☐ esprimo il consenso ☐ NON esprimo il consenso al trattamento dei miei dati personali e, espressamente, al trattamento di eventuali dati sensibili, per il conseguimento delle su esposte finalità.

☐ esprimo il consenso ☐ NON esprimo il consenso al trattamento dei risultati delle esperienze di guida svolte e alla loro pubblicazione su tesi di Laurea Magistrale e/o pubblicazioni scientifiche in forma aggregata e rigorosamente anonima.

COVID declaration and prevention measurements

POLITECNICO DI TORINO

#OgnunoProteggeTutti

ATTO DI IMPEGNO E DICHIARAZIONE

Il sottoscritto ______________________________________

Nato a_____________________________il _____________

Residente a ______________________________________

Documento identità n.________________________________rilasciato da

________________________ il ____________

DICHIARA

- di aver preso visione, di aver compreso e di accettare le misure di sicurezza e tutela della salute adottate dal Politecnico;

SI IMPEGNA

- ad adottare, durante la permanenza nelle sedi dell'Ateneo, tutte le misure di contenimento necessarie alla prevenzione e contenimento del contagio da COVID-19.

Il Sottoscritto, consapevole delle conseguenze penali previste in caso di dichiarazioni mendaci ai sensi degli artt. 47 e 76 del DPR 445/2000,

dichiara sotto la propria responsabilità:

- di non essere sottoposto alla misura della quarantena in quanto contatto stretto di caso confermato COVID-19 o per ingresso / rientro recente dall'estero;
- di non essere sottoposto ad isolamento domiciliare fiduciario in quanto risultato positivo alla ricerca del virus SARS-COV-2;
- di non presentare febbre > 37.5 °C o sintomatologia simil-influenzale (ad es. tosse, alterata percezione dei sapori e degli odori, disturbi intestinali, ecc.);

La presente Dichiarazione viene rilasciata quale misura di prevenzione correlata con l'emergenza pandemica del SARS CoV 2.
Allega copia fotostatica del documento di identità.

FIRMA

------------------------------, il ---------------------------

Il Politecnico di Torino, in qualità di Titolare del trattamento, ti informa che tratterà i tuoi dati personali per la finalità istituzionale connessa all'evento nonché per la prevenzione dal contagio da COVID-19 in conformità i al Regolamento EU 2016/679 ("GDPR") e al D.Lgs. 196/2003 e s.m.i. ("Codice Privacy"). I dati rilasciati con il presente modulo verranno conservati per il tempo strettamente necessario alle attività di contact tracing.
L'informativa completa è disponibile alla pagina: www.polito.it/privacy

POLITECNICO
DI TORINO

#OgnunoProteggeTutti

MISURE DI PREVENZIONE

SI INFORMA CHE:

- in presenza di febbre > 37.5°C e/o altri sintomi influenzali (es. tosse, rinorrea, difficoltà respiratorie) è obbligatorio per chiunque rimanere al proprio domicilio e chiamare il proprio medico di famiglia e l'autorità sanitaria;
- è vietato l'accesso a chiunque sia entrato in contatto negli ultimi 14 giorni con persone risultate positive al virus SARS CoV-2;
- all'ingresso della sede è necessario presentarsi muniti di mascherina e sottoporsi alla misurazione della temperatura corporea. Nel caso in cui questa risulti >37.5°C e/o siano presenti sintomi influenzali, l'accesso alla sede sarà negato;
- nel caso in cui la febbre e/o i sintomi influenzali si manifestino successivamente all'ingresso nella sede, è necessario porsi in isolamento e chiamare il **numero di emergenza interno** per l'attivazione delle corrette procedure di intervento;
- per aiutare a combattere l'epidemia di COVID-19, è stata creata l'**APP Immuni**, che invitiamo a scaricare e mantenere attiva durante tutta la permanenza all'interno delle sedi dell'Ateneo.

ALL'INTERNO DELLA SEDE È FATTO OBBLIGO DI:

- **Indossare sempre la mascherina** negli spazi comuni e in tutte le situazioni di compresenza all'interno dei locali;
- rispettare la **distanza di sicurezza di 2 metri**, laddove possibile in funzione dell'attività svolta e comunque nelle aree comuni di passaggio e in caso di accodamenti;
- rispettare, ove presente, la **segnaletica orizzontale** a pavimento indicante il distanziamento minimo;
- rispettare le indicazioni riportate nei **cartelli informativi** e i messaggi trasmessi dai monitor e tramite diffusione sonora;
- osservare **comportamenti corretti sul piano dell'igiene**, in particolare:
  - segnalare al numero di emergenza interno della Portineria eventuali situazioni anomale riscontrate (es. situazioni di affollamento, presenza di persone con sintomi influenzali, mancato rispetto delle norme di igiene, etc.).
  - lavare frequentemente le mani con acqua e sapone o con i prodotti a base alcolica presenti nei dispenser dislocati nelle aree comuni;
  - evitare di toccarsi occhi, naso e bocca con le mani;
  - tossire e/o starnutire coprendo bocca e naso con un fazzoletto o con la piega del gomito;
- segnalare al **numero di emergenza interno della Portineria** eventuali situazioni anomale riscontrate (es. situazioni di affollamento, presenza di persone con sintomi influenzali, mancato rispetto delle norme di igiene, etc.).

Experimental activity questionnaire

POLITECNICO DI TORINO

Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture
Corso Duca degli Abruzzi, 24 – 10129, Torino
Tel. 011-5645635, 335-1300230, marco.bassani@polito.it

QUESTIONARIO PER ATTIVITA' DI RICERCA CON L'USO DEL SIMULATORE DI GUIDA

Nome e Cognome ....

Sesso ☐ M ☐ F

Anno di nascita ....

Telefono (cellulare) .... e-mail ....

Livello di istruzione ☐ licenza media inferiore ☐ qualifica professionale triennale
☐ diploma scuole superiori ☐ laurea 1° livello o diploma universitario
☐ laurea 2° livello o vecchio ordinamento
☐ specializzazioni/master post laurea 2° livello/dottorato

Anno di conseguimento della patente di guida ....

km percorsi in un anno (media) ....

n° di incidenti in cui si è stati coinvolti ....

Familiarità con l'uso di software di guida (es. videogiochi) ☐ SI ☐ NO

Utilizzi dispositivi per la correzione visiva? ☐ SI ☐ NO

Se si, quali? ☐ Occhiali ☐ Lenti a contatto

Precedenti episodi di crisi epilettiche? ☐ SI ☐ NO
(o epilessie in trattamento farmacologico)

Raccomandazioni da seguire prima di effettuare le guide al simulatore:

- **se utilizzi lenti a contatto, per cortesia indossale il giorno dell'esperimento,**
- **consuma pasti (colazione e/o pranzo) leggeri prima della guida,**
- **non assumere bevande alcoliche e/o eccitanti (caffè, *energy drink*, o simili) almeno 4 ore prima.**

Il sottoscritto si rende disponibile a effettuare l'addestramento e il test con il simulatore di guida presso il *Laboratorio di Sicurezza Stradale e Simulazione di Guida* – DIATI (ingresso 2, piano terreno):

il giorno lunedì – martedì – mercoledì – giovedì – venerdì alle ore 9 - 12 12 - 15 15 - 18 oppure
il giorno lunedì – martedì – mercoledì – giovedì – venerdì alle ore 9 - 12 12 - 15 15 - 18 oppure
il giorno lunedì – martedì – mercoledì – giovedì – venerdì alle ore 9 - 12 12 - 15 15 - 18
(cerchiare o spuntare il giorno e l'orario preferiti)

Luogo e data .... Firma ....

Pre-guide questionnaire

POLITECNICO
DI TORINO
Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture
Corso Duca degli Abruzzi, 24 – 10129, Torino
Tel. 011-5645635, 335-1300230, marco.bassani@polito.it

QUESTIONARIO PER ATTIVITA' DI RICERCA CON L'USO DEL SIMULATORE DI GUIDA

QUESTIONARIO PRE-GUIDA

Nome e Cognome
....#TD.....................

Giorno .... Ora...............................

È attualmente in buona salute? ☐SI ☐NO
Se no, di cosa soffre?
....

Ha assunto medicinali nelle precedenti 24h? ☐SI ☐NO
Se si, quali? (è sufficiente la categoria)
....

È affetto da malattie croniche (asma, diabete, ansia, allergia…)? ☐SI ☐NO
Se si, quali? (è sufficiente la categoria)
....

Quanto tempo fa ha consumato l'ultimo pasto? ....ore ....minuti

Come definirebbe il pasto consumato? ☐Leggero ☐Ordinario ☐ Abbondante

Ha assunto bevande alcoliche nelle due ore precedenti la guida? ☐SI ☐NO

Ha assunto bevande eccitanti (caffè, energy drink) nelle 2 ore precedenti la guida?
☐SI ☐NO

Utilizza dispositivi per la correzione visiva? ☐SI ☐NO

Attualmente li indossa? ☐SI ☐NO

Se si, quali? ☐ Occhiali ☐Lenti a contatto

Post-guide questionnaire

POLITECNICO
DI TORINO

Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture
Corso Duca degli Abruzzi, 24 – 10129, Torino
Tel. 011-5645635, 335-1300230, marco.bassani@polito.it

QUESTIONARIO PER ATTIVITA' DI RICERCA CON L'USO DEL SIMULATORE DI GUIDA
QUESTIONARIO DI POST-SIMULAZIONE

Nome e Cognome .... Numero identificativo del TD ....

Giorno ....   Ora ....

SENSAZIONI. Durante la guida nell' ambiente virtuale si è sentito:

- A suo agio	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- In grado di controllare la situazione e le proprie azioni	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Pieno di energia	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Nervoso	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Con la mente che vagava	☐ per nulla	☐ lieve	☐ moderato	☐ intenso

Sarebbe disposto a guidare ancora?

☐ SI   ☐ NO

Se SI per quanto tempo?

☐ <15min   ☐ < 30min   ☐ < 45min   ☐ >1h

CONSEGUENZE DELL' ESPERIMENTO. Indicare se attualmente percepisce uno o più dei seguenti sintomi:

- Generale disagio	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Fatica	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Mal di testa	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Stanchezza visiva	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Difficoltà nella messa a fuoco	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Incremento di salivazione	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Incremento di sudorazione	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Nausea	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Difficoltà di concentrazione	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Intontimento	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Visione offuscata	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Capogiro (a occhi aperti)	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Capogiro (a occhi chiusi)	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Vertigini	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Sensibilità di stomaco	☐ per nulla	☐ lieve	☐ moderato	☐ intenso
- Disturbi digestivi	☐ per nulla	☐ lieve	☐ moderato	☐ intenso

- Altro ....

POLITECNICO DI TORINO
Dipartimento di Ingegneria dell'Ambiente, del Territorio e delle Infrastrutture
Corso Duca degli Abruzzi, 24 – 10129, Torino
Tel. 011-5645635, 335-1300230, marco.bassani@polito.it

IMMERSIONE. Esprima un giudizio sulla veridicità dello scenario stradale:

- Qualità dell'immagine	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
- Corrispondenza alla realtà				
o Ambiente esterno alla strada (edifici, panorama, vegetazione)	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
o Margini stradali	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
o Sede stradale	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
o Segnaletica orizzontale	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
o Segnaletica verticale	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
o Presenza di altri veicoli	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo

Esprima un giudizio sull'interazione con i dispositivi audio-visivi e meccanici:

- Riproduzione del campo visivo	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
- Percezione degli specchietti	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
- Veridicità degli effetti sonori	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
- Veridicità della strumentazione di bordo	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
- Risposta del volante	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
- Risposta del cambio	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
- Percezione dell'acceleratore	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo
- Percezione del freno	☐ pessimo	☐ sufficiente	☐ buono	☐ ottimo

PRESENZA. È lo stato di coscienza legato al "senso di trovarsi lì", è il senso psicologico di trovarsi nell' ambiente virtuale. Risponda ai seguenti quesiti:

- Si è sentito fisicamente inserito nell'ambiente virtuale?
  ☐ per nulla ☐ poco ☐ abbastanza ☐ molto
- Si è sentito stimolato dall'ambiente virtuale?
  ☐ per nulla ☐ poco ☐ abbastanza ☐ molto
- Durante la guida, si è sentito coinvolto come se fosse dentro l'ambiente virtuale e non stesse guardando uno schermo o utilizzando le componenti del simulatore?
  ☐ per nulla ☐ poco ☐ abbastanza ☐ molto
- Durante la guida, si è sentito coinvolto al punto tale da non sapere cosa stesse accadendo attorno a se?
  ☐ per nulla ☐ poco ☐ abbastanza ☐ molto
- Durante la guida, si è sentito coinvolto dall'ambiente virtuale al punto da perdere la cognizione del tempo?
  ☐ per nulla ☐ poco ☐ abbastanza ☐ molto
- Quanto pensa sia durata la guida? ....

Di quali elementi/strumenti si è servito per valutare la velocità di marcia?

☐ Contachilometri
☐ Rumore del motore
☐ Altro: ....
☐ Vegetazione e oggetti a lato della strada
☐ Non ho prestato attenzione alla velocità

E. STATISTICAL ANALYSIS: T-TEST

Complete statistical analysis: *t-test* results (*p-value*) are grouped in tables [from Table 44 to Table 48].

Analysis was carried out on each section defined above and comparing the pair of samples represented in the first row of each table.

Results are divided by observed variables.

Table 44. T-test results for speed at transitional and steady sections.

Section	Baseline vs V-ISA-I (High flow)	Baseline vs V-ISA-III (High flow)	V-ISA-I vs V-ISA-III (High flow)	Baseline vs V-ISA-I (Low flow)	Baseline vs V-ISA-III (Low flow)	V-ISA-I vs V-ISA-III (Low flow)	Baseline (high flow) vs Baseline (Low flow)	V-ISA-I (high flow) vs V-ISA-I (Low flow)	V-ISA-III (high flow) vs V-ISA-III (Low flow)
S_{Mup}	0.079	0.551	0.452	0.375	0.788	0.575	0.264	0.015*	0.016*
S_{Mdown}	0.379	0.634	0.120	0.932	0.893	0.964	0.792	0.106	0.958
S_{TLRP}	0.814	0.816	0.967	0.658	0.082	0.015*	0.957	0.921	0.015*
S_{R1}	0.054	0.005*	0.137	0.003*	0.000*	0.251	0.334	0.982	0.736
S_{R2}	0.018*	0.001*	0.064	0.000*	0.000*	0.177	0.835	0.276	0.890
S_{R3}	0.005*	0.002*	0.364	0.003*	0.002*	0.422	0.811	0.825	0.870
S_{R4}	0.000*	0.000*	0.175	0.137	0.000*	0.089	0.592	0.206	0.192
S_{LT1}	0.482	0.752	0.265	0.737	0.939	0.719	0.122	0.237	0.027*
S_{TR1}	0.131	0.643	0.455	0.267	0.843	0.215	0.113	0.622	0.068
S_{RT1}	0.392	0.666	0.713	0.097	0.092	0.781	0.340	0.905	0.915
S_{TL1}	0.902	0.814	0.897	0.487	0.049*	0.219	0.238	0.594	0.439
S_{LT2}	0.544	0.845	0.736	0.007*	0.117	0.521	0.047*	0.316	0.904
S_{TR2}	0.662	0.777	0.906	0.010*	0.003*	0.424	0.136	0.170	0.027*
S_{RT2}	0.178	0.103	0.387	0.034*	0.000*	0.222	0.223	0.671	0.576
S_{TL2}	0.016*	0.136	0.573	0.227	0.019*	0.610	0.615	0.408	0.909
S_{LT3}	0.316	0.455	0.880	0.883	0.286	0.103	0.588	0.964	0.142
S_{TR3}	0.097	0.037*	0.230	0.014*	0.005*	0.822	0.725	0.912	0.236
S_{RT3}	0.544	0.928	0.565	0.282	0.533	0.082	0.558	0.341	0.273
S_{TL3}	0.848	0.931	0.727	0.173	0.878	0.097	0.343	0.659	0.245
S_{LT4}	0.909	0.767	0.846	0.509	0.652	0.225	0.191	0.599	0.061
S_{TR4}	0.309	0.445	0.979	0.172	0.451	0.023*	0.803	0.902	0.058
S_{RT4}	0.001*	0.003*	0.962	0.569	0.153	0.430	0.758	0.140	0.185
S_{TL4}	0.792	0.589	0.781	0.775	0.951	0.759	0.789	0.839	0.467

** p<0.05 high statistical significance*

Table 45. T-test results for lateral position at steady sections.

Section	Baseline vs V-ISA-I (High flow)	Baseline vs V-ISA-III (High flow)	V-ISA-I vs V-ISA-III (High flow)	Baseline vs V-ISA-I (Low flow)	Baseline vs V-ISA-III (Low flow)	V-ISA-I vs V-ISA-III (Low flow)	Baseline (high flow) vs Baseline (Low flow)	V-ISA-I (high flow) vs V-ISA-I (Low flow)	V-ISA-III (high flow) vs V-ISA-III (Low flow)
LP_{Mup}	0.311	0.426	0.725	0.880	0.791	0.655	0.213	0.902	0.488
LP_{Mdown}	0.640	0.646	0.871	0.254	0.082	0.182	0.115	0.704	0.759
LP_{TLRP}	0.436	0.795	0.696	0.362	0.564	0.879	0.347	0.594	0.994
LP_{R1}	0.036*	0.098	0.273	0.023*	0.627	0.069	0.236	0.004*	0.518
LP_{R2}	0.019*	0.412	0.286	0.381	0.873	0.400	0.436	0.026*	0.767
LP_{R3}	0.006*	0.130	0.319	0.740	0.494	0.286	0.137	0.114	0.741
LP_{R4}	0.005*	0.011*	0.389	0.073	0.002*	0.013*	0.879	0.030*	0.471

** p<0.05 high statistical significance*

Table 46. T-test results for SDLP at ramp arcs.

Section	Baseline vs V-ISA-I (High flow)	Baseline vs V-ISA-III (High flow)	V-ISA-I vs V-ISA-III (High flow)	Baseline vs V-ISA-I (Low flow)	Baseline vs V-ISA-III (Low flow)	V-ISA-I vs V-ISA-III (Low flow)	Baseline (high flow) vs Baseline (Low flow)	V-ISA-I (high flow) vs V-ISA-I (Low flow)	V-ISA-III (high flow) vs V-ISA-III (Low flow)
$SDLP_{R1}$	0.554	0.229	0.325	0.478	0.352	0.083	0.602	0.244	0.045*
$SDLP_{R2}$	0.499	0.195	0.346	0.463	0.263	0.128	0.407	0.346	0.134
$SDLP_{R3}$	0.473	0.761	0.202	0.456	0.843	0.709	0.625	0.575	0.979
$SDLP_{R4}$	0.372	0.463	0.919	0.033*	0.940	0.067	0.265	0.876	0.034*

** p<0.05 high statistical significance*

Table 47. T-test results for merging abscissa at transitional sections.

Section	Baseline vs V-ISA-I (High flow)	Baseline vs V-ISA-III (High flow)	V-ISA-I vs V-ISA-III (High flow)	Baseline vs V-ISA-I (Low flow)	Baseline vs V-ISA-III (Low flow)	V-ISA-I vs V-ISA-III (Low flow)	Baseline (high flow) vs Baseline (Low flow)	V-ISA-I (high flow) vs V-ISA-I (Low flow)	V-ISA-III (high flow) vs V-ISA-III (Low flow)
$L_{LT\ D1}$	0.516	0.834	0.538	0.380	0.758	0.269	0.238	0.784	0.206
$L_{LT\ D2}$	0.628	0.930	0.627	0.715	0.500	0.786	0.673	0.811	0.951
$L_{LT\ D3}$	0.853	0.783	0.890	0.215	0.922	0.116	0.423	0.676	0.323
$L_{LT\ D4}$	0.779	0.262	0.355	0.364	0.245	0.798	0.190	0.345	0.219

** p<0.05 high statistical significance*

Table 48. T-test results for merging abscissa at transitional sections.

Section	Baseline vs V-ISA-I (High flow)	Baseline vs V-ISA-III (High flow)	V-ISA-I vs V-ISA-III (High flow)	Baseline vs V-ISA-I (Low flow)	Baseline vs V-ISA-III (Low flow)	V-ISA-I vs V-ISA-III (Low flow)	Baseline (high flow) vs Baseline (Low flow)	V-ISA-I (high flow) vs V-ISA-I (Low flow)	V-ISA-III (high flow) vs V-ISA-III (Low flow)
$L_{LT\ M1}$	0.518	0.044*	0.142	0.759	0.200	0.326	0.693	0.881	0.884
$L_{LT\ M2}$	0.874	0.351	0.440	0.710	0.500	0.786	0.673	0.811	0.951
$L_{LT\ M3}$	0.203	0.421	0.586	0.773	0.563	0.775	0.449	0.743	0.602
$L_{LT\ M4}$	0.329	0.804	0.416	0.981	0.574	0.505	0.757	0.120	0.308

** p<0.05 high statistical significance*

F. REPRESENTATION OF DIVERGING AND MERGING DISTANCE ANALYSIS

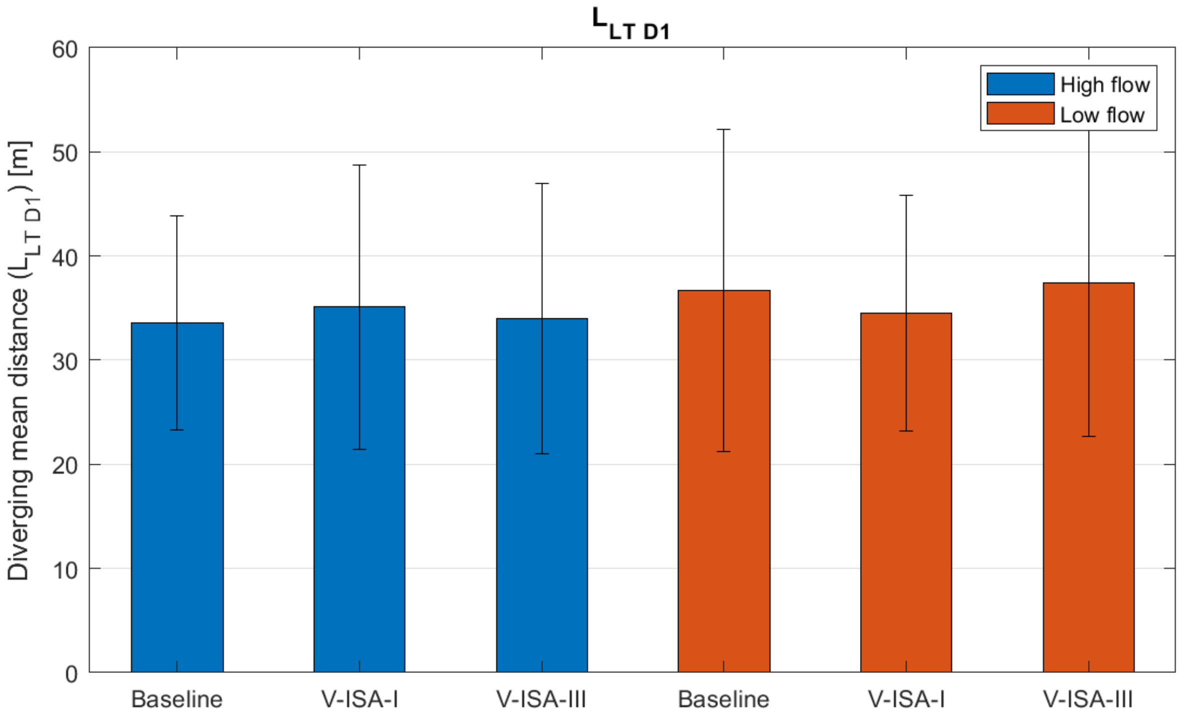


Figure 71. Representation of ramp 1 diverging distance mean values with indication of the positive and negative standard deviation (error bars).

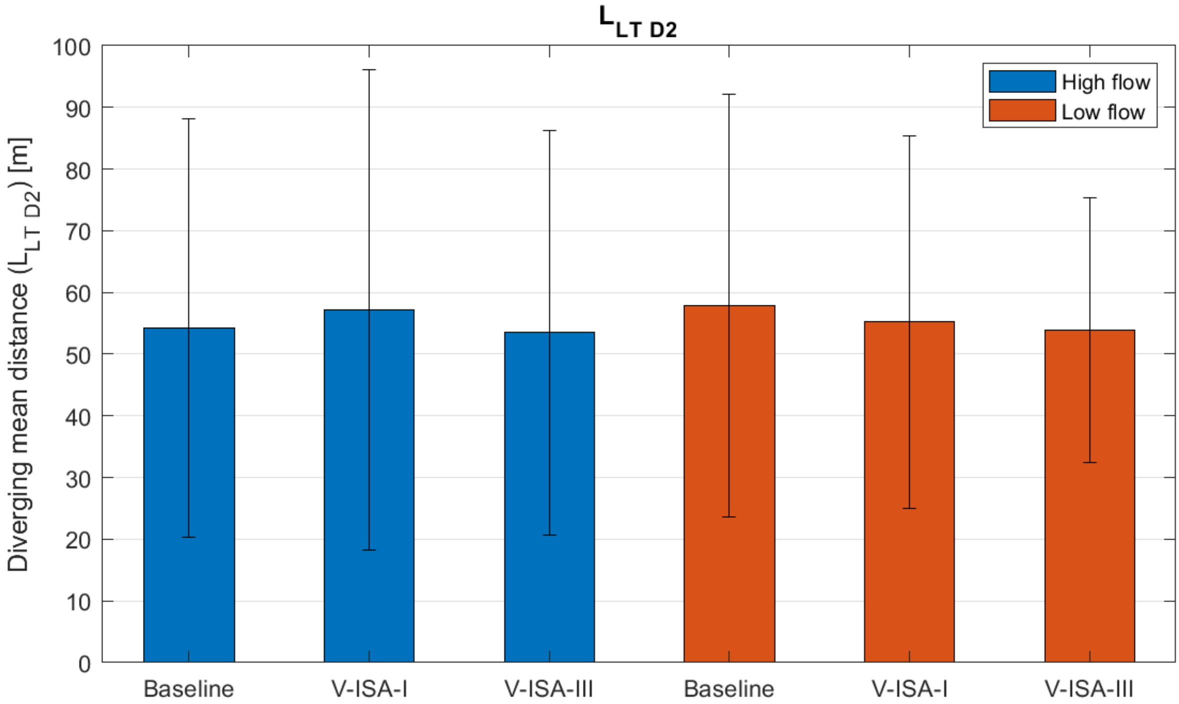


Figure 72. Representation of ramp 2 diverging distance mean values with indication of the positive and negative standard deviation (error bars).

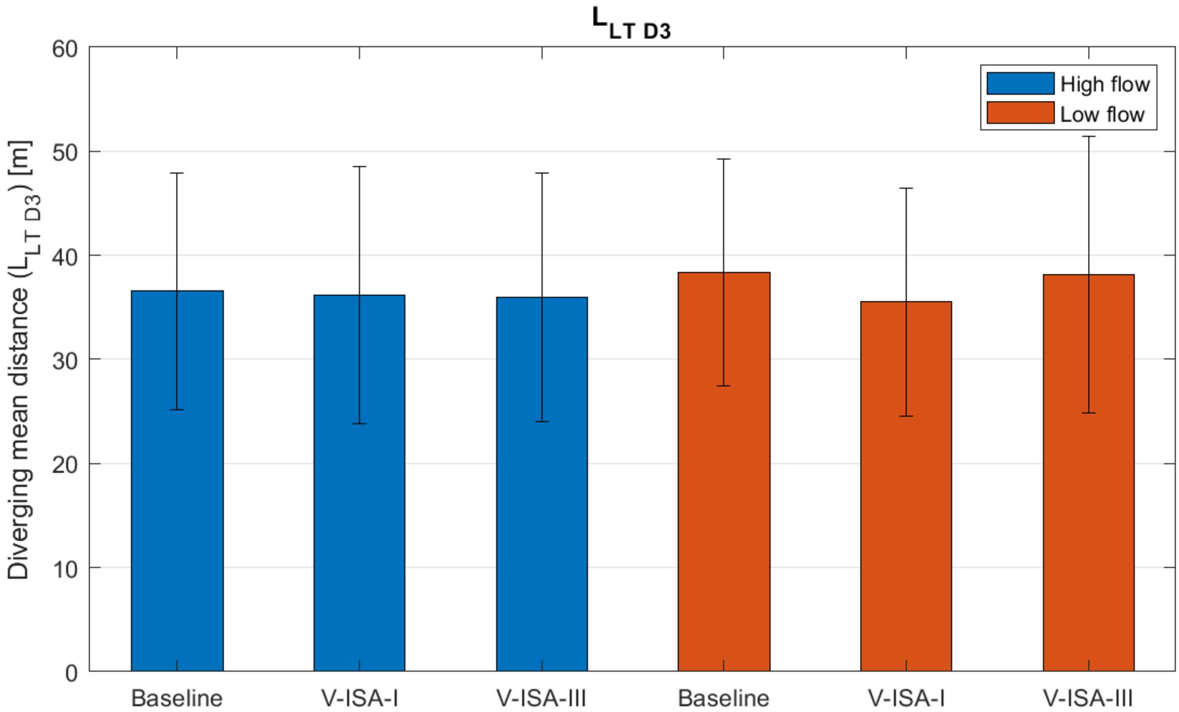


Figure 73. Representation of ramp 3 diverging distance mean values with indication of the positive and negative standard deviation (error bars).

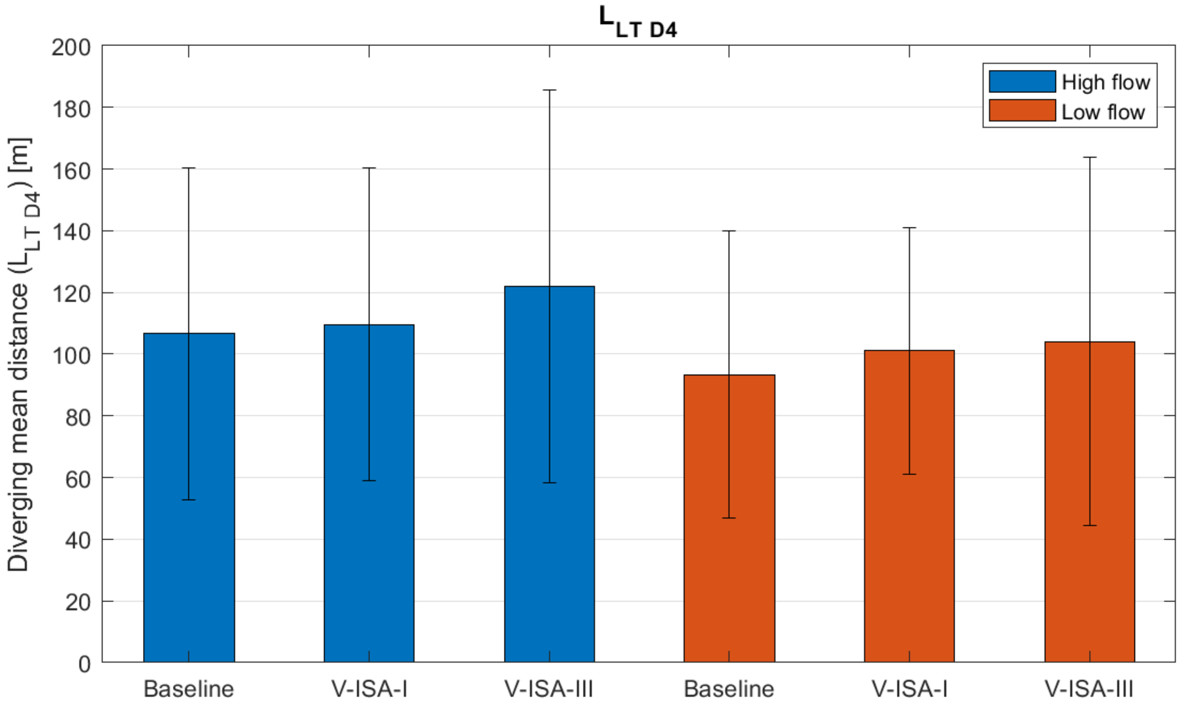


Figure 74. Representation of ramp 4 diverging distance mean values with indication of the positive and negative standard deviation (error bars).

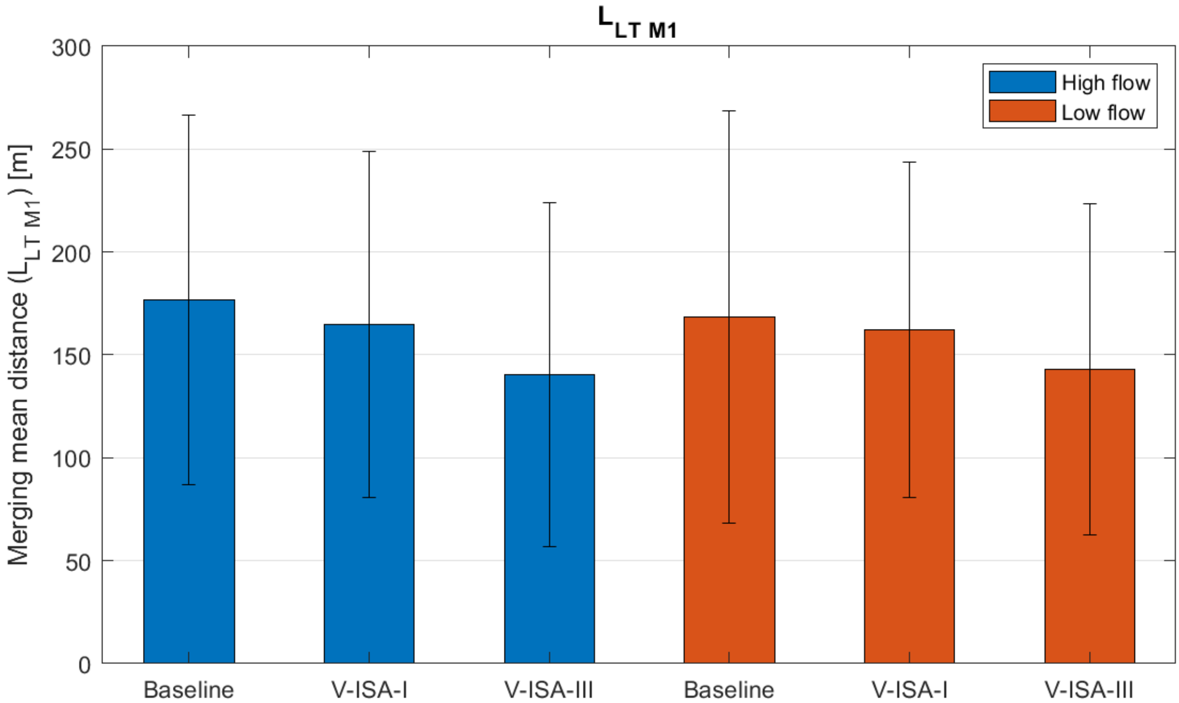


Figure 75. Representation of ramp 1 merging distance mean values with indication of the positive and negative standard deviation (error bars).

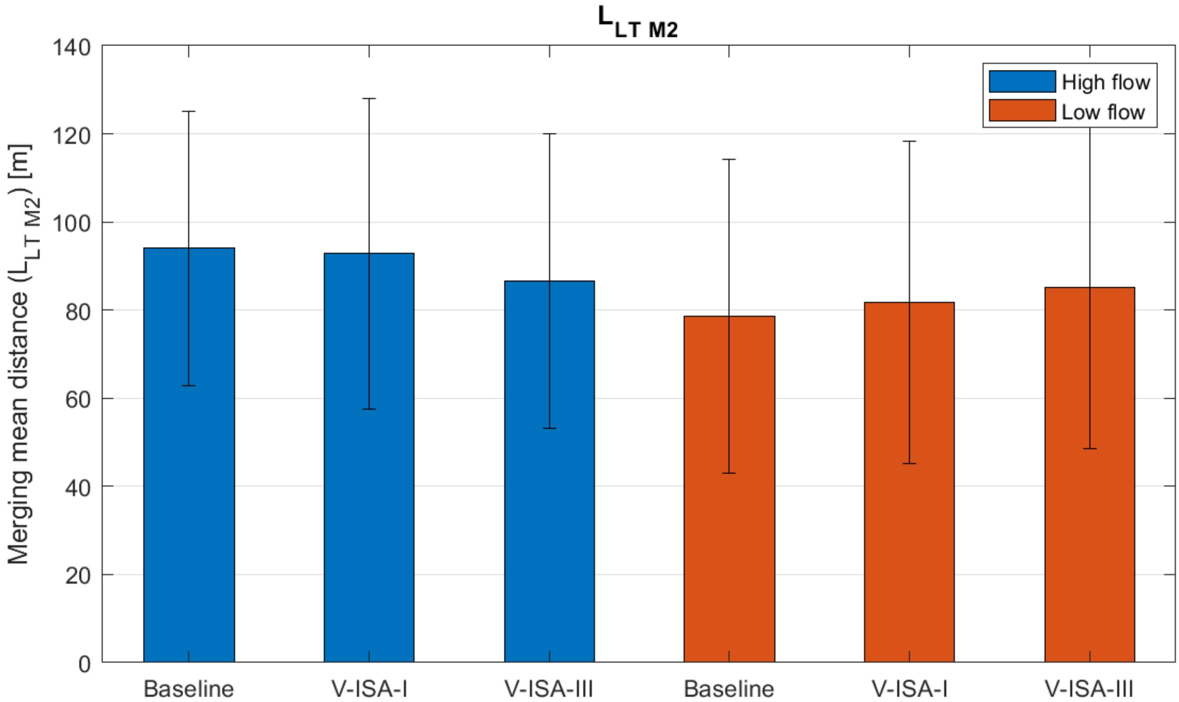


Figure 76. Representation of ramp 2 merging distance mean values with indication of the positive and negative standard deviation (error bars).

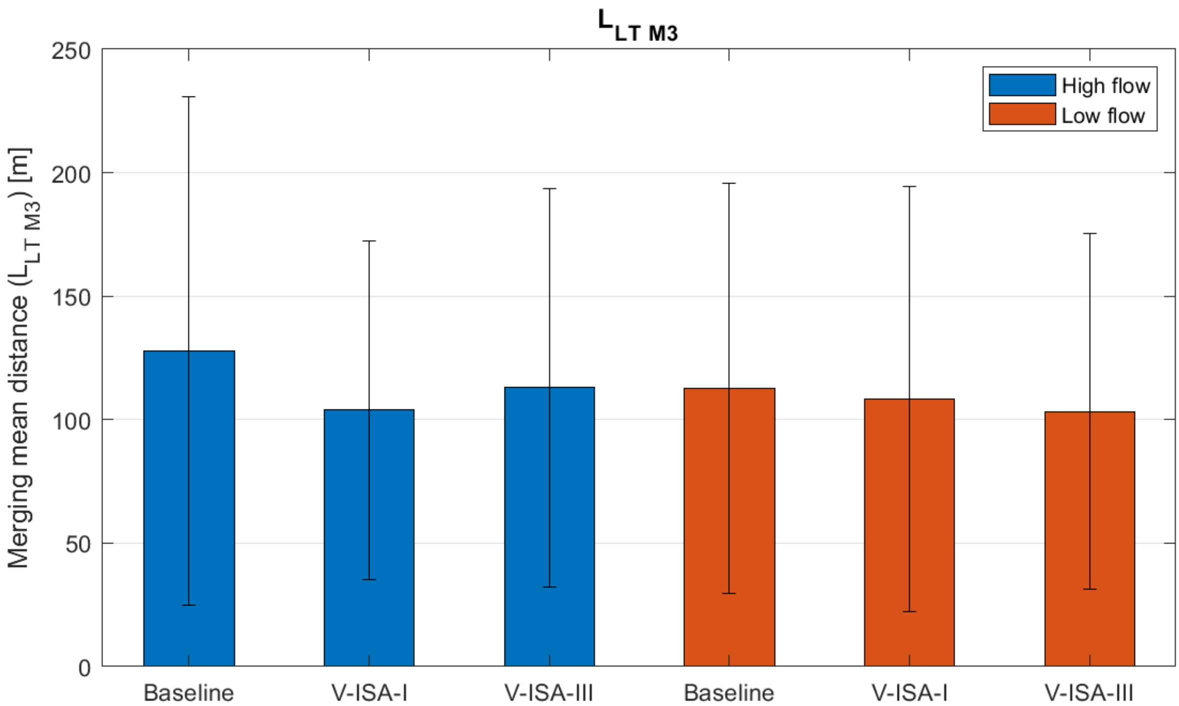


Figure 77. Representation of ramp 3 merging distance mean values with indication of the positive and negative standard deviation (error bars).

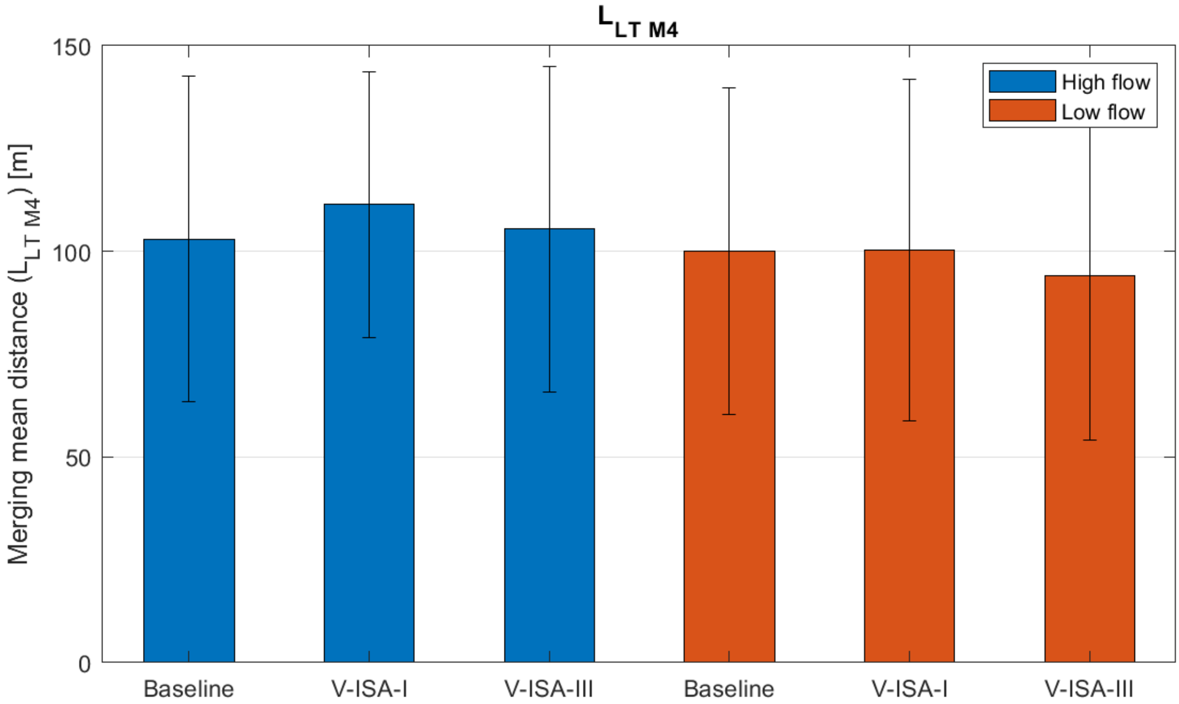


Figure 78. Representation of ramp 4 merging distance mean values with indication of the positive and negative standard deviation (error bars).

G. MERGING AND DIVERGING DISTANCES

Table 49. Diverging distance for ramp-1 by test driver under each driving scenario.

TD	Baseline (high flow)	Baseline (low flow)	V-ISA-I (high flow)	V-ISA-I (low flow)	V-ISA-III (high flow)	V-ISA-III (low flow)
TD1	24.90	15.35	9.35	14.28	12.73	18.08
TD2	27.71	24.69	15.35	30.48	20.27	33.95
TD3	29.53	14.03	55.16	27.89	24.77	29.04
TD4	41.12	23.52	23.28	24.87	22.89	33.26
TD5	15.61	22.65	25.36	19.75	22.51	9.35
TD6	23.47	15.65	20.55	24.64	16.33	16.77
TD7	40.03	35.80	49.01	38.10	36.86	40.59
TD8	57.16	49.34	55.98	55.00	47.23	56.67
TD9	36.13	17.54	26.79	31.71	26.79	38.24
TD10	33.76	29.53	33.77	30.73	23.41	30.69
TD11	39.21	45.87	31.08	53.20	48.59	31.08
TD12	39.48	42.33	29.73	29.53	42.24	30.07
TD13	36.04	15.24	25.16	19.44	15.24	54.79
TD14	36.66	42.24	30.24	27.93	38.57	40.43
TD15	37.69	39.03	26.07	27.97	36.15	37.85
TD16	27.43	77.06	33.69	32.82	28.40	57.69
TD17	44.06	41.60	30.80	46.78	38.35	30.24
TD18	26.94	42.42	18.06	32.59	19.14	29.43
TD19	45.63	31.69	69.67	59.28	59.68	40.41
TD20	29.31	27.36	19.79	29.28	18.83	29.99
TD21	29.77	60.76	32.86	37.82	37.08	80.38
TD22	17.69	38.29	42.27	51.83	47.89	42.09
TD23	33.29	49.15	51.43	49.36	41.24	45.71
TD24	45.00	47.89	39.26	21.83	28.35	40.07
TD25	38.16	47.78	39.22	37.06	44.41	39.29
TD26	22.88	27.68	26.15	34.47	30.06	21.75
TD27	15.07	21.24	28.93	28.54	32.48	14.74
TD28	42.92	66.76	51.68	47.30	63.20	55.96
TD29	29.86	41.99	46.47	35.54	49.44	32.66
TD30	15.40	28.39	46.76	22.53	26.86	30.92
TD31	45.42	46.57	43.51	42.74	41.18	46.81
TD32	46.11	46.17	45.49	40.76	46.77	58.45

Table 50. Diverging distance for ramp-2 by test driver under each driving scenario.

TD	Baseline (high flow)	Baseline (low flow)	V-ISA-I (high flow)	V-ISA-I (low flow)	V-ISA-III (high flow)	V-ISA-III (low flow)
TD1	65.54	37.09	26.12	33.84	22.15	30.06
TD2	33.66	30.80	37.09	28.39	56.59	43.65
TD3	58.23	46.14	53.92	52.58	9.68	26.18
TD4	45.47	41.06	56.28	40.86	46.77	51.14
TD5	22.15	16.08	13.93	25.19	13.32	26.12
TD6	30.27	124.25	27.96	35.37	45.06	47.36
TD7	42.35	41.28	75.58	33.66	37.34	51.12
TD8	40.81	52.67	69.12	64.40	155.52	82.02
TD9	138.06	40.98	38.55	31.89	38.55	19.76
TD10	23.54	57.24	32.18	46.15	34.51	38.55
TD11	59.55	33.94	36.59	48.17	57.69	36.59
TD12	38.74	52.16	37.29	34.27	44.49	33.97
TD13	77.93	46.45	73.26	61.87	46.45	103.47
TD14	54.80	44.49	58.79	60.25	46.63	58.43
TD15	49.45	109.96	46.77	68.99	29.65	48.74
TD16	81.25	89.57	64.14	74.95	64.34	96.86
TD17	171.68	36.90	212.48	44.18	26.93	51.56
TD18	38.96	47.27	73.09	63.47	21.54	85.76
TD19	47.75	12.15	38.77	36.58	37.88	55.16
TD20	40.84	52.54	46.88	59.39	51.12	39.92
TD21	28.20	105.03	65.99	34.81	49.17	68.50
TD22	22.44	48.44	49.91	171.51	48.84	51.02
TD23	42.41	44.83	52.36	50.96	58.69	50.25
TD24	81.82	55.82	57.07	67.79	71.48	60.37
TD25	24.63	45.26	52.94	41.25	52.78	44.12
TD26	24.68	44.98	28.11	44.95	42.61	48.27
TD27	20.13	45.33	23.77	38.71	58.41	28.10
TD28	112.41	107.11	71.69	130.91	90.57	98.83
TD29	55.78	64.97	65.09	51.45	108.48	59.48
TD30	40.16	44.15	20.14	33.55	28.55	51.89
TD31	67.17	51.01	58.85	98.82	70.14	66.80
TD32	55.23	180.83	164.48	57.39	146.68	68.99

Table 51. Diverging distance for ramp-3 by test driver under each driving scenario.

TD	Baseline (high flow)	Baseline (low flow)	V-ISA-I (high flow)	V-ISA-I (low flow)	V-ISA-III (high flow)	V-ISA-III (low flow)
TD1	16.85	35.40	11.60	19.74	14.19	20.92
TD2	25.72	25.32	35.40	25.36	26.30	30.61
TD3	48.99	19.33	25.57	26.35	19.47	17.30
TD4	31.90	27.03	35.58	24.00	25.32	40.73
TD5	21.03	24.99	22.54	19.63	29.74	11.60
TD6	22.16	25.22	20.71	20.02	16.13	20.37
TD7	35.83	35.91	35.64	39.37	26.90	52.70
TD8	48.09	49.90	64.44	61.34	48.92	61.79
TD9	33.36	25.26	32.11	45.31	32.11	43.65
TD10	32.68	30.50	27.40	38.75	37.22	47.80
TD11	39.71	55.89	34.40	45.55	59.84	34.40
TD12	35.63	37.81	41.96	39.20	33.81	46.51
TD13	40.88	37.48	26.98	21.54	37.48	30.85
TD14	41.09	33.81	36.76	46.07	30.70	42.47
TD15	38.91	37.56	52.11	36.80	42.30	30.67
TD16	28.60	44.62	38.45	33.58	34.16	40.22
TD17	43.26	27.72	40.64	27.89	40.20	28.94
TD18	52.50	63.28	17.30	22.13	17.35	24.84
TD19	65.92	42.67	43.98	45.07	34.59	51.94
TD20	23.23	35.86	23.68	29.65	24.99	32.08
TD21	32.77	59.99	41.22	33.08	34.95	65.46
TD22	24.15	28.84	28.72	32.92	47.52	32.40
TD23	32.85	43.76	49.49	30.01	37.59	38.41
TD24	50.03	47.55	33.00	32.75	42.89	40.96
TD25	44.90	43.99	34.23	37.71	47.83	38.90
TD26	29.89	40.23	28.75	36.23	33.33	26.93
TD27	27.34	29.50	22.40	27.98	28.54	19.74
TD28	44.85	48.56	53.50	58.52	56.19	48.65
TD29	42.31	50.95	40.81	39.47	41.56	47.84
TD30	33.14	47.14	52.63	43.42	35.34	40.41
TD31	24.51	34.86	45.97	49.46	55.35	58.30
TD32	57.51	36.46	59.29	48.47	56.61	51.69

Table 52. Diverging distance for ramp-4 by test driver under each driving scenario.

TD	Baseline (high flow)	Baseline (low flow)	V-ISA-I (high flow)	V-ISA-I (low flow)	V-ISA-III (high flow)	V-ISA-III (low flow)
TD1	189.55	67.03	93.44	88.24	132.32	54.15
TD2	62.77	80.95	67.03	199.39	142.38	60.69
TD3	200.29	255.83	160.33	170.51	208.29	260.15
TD4	42.47	38.27	64.41	67.75	67.71	73.24
TD5	105.76	68.44	59.30	108.65	64.19	93.44
TD6	64.49	29.43	49.16	47.03	108.02	61.05
TD7	101.52	69.08	199.97	133.16	47.67	54.20
TD8	257.19	138.71	132.02	140.93	118.40	98.49
TD9	192.66	43.47	90.91	63.28	90.91	198.29
TD10	84.87	117.78	134.19	150.49	78.08	81.66
TD11	41.97	89.26	166.21	119.25	70.88	166.21
TD12	153.44	93.45	46.75	51.19	33.57	96.81
TD13	169.43	87.33	194.45	92.90	87.33	202.41
TD14	78.90	33.57	88.56	105.52	157.19	106.34
TD15	68.68	70.91	62.18	79.93	37.40	46.83
TD16	75.30	141.03	87.30	98.42	127.36	121.22
TD17	78.54	63.24	65.44	85.17	259.92	56.40
TD18	179.95	172.38	205.26	168.96	254.45	160.32
TD19	136.56	124.23	124.90	161.50	159.68	94.18
TD20	43.48	68.37	59.84	55.91	53.26	55.90
TD21	81.18	149.29	64.95	71.93	88.31	255.45
TD22	123.88	68.17	83.18	141.74	63.15	97.23
TD23	70.23	92.85	131.94	83.37	160.69	68.53
TD24	86.15	44.94	70.70	91.74	190.20	75.47
TD25	91.51	112.86	66.15	69.19	96.94	103.08
TD26	142.64	76.29	163.96	88.41	96.70	40.21
TD27	51.13	118.21	160.73	48.92	102.08	96.07
TD28	109.04	75.08	175.61	96.91	163.72	156.36
TD29	81.00	69.17	61.78	63.24	257.68	76.88
TD30	48.58	74.01	116.92	133.23	72.01	43.32
TD31	96.16	108.78	76.24	69.69	123.99	35.84
TD32	102.28	144.75	185.95	87.24	190.23	141.50

Table 53. Merging distance for ramp-1 by test driver under each driving scenario.

TD	Baseline (high flow)	Baseline (low flow)	V-ISA-I (high flow)	V-ISA-I (low flow)	V-ISA-III (high flow)	V-ISA-III (low flow)
TD1	189.10	169.47	108.00	126.37	119.82	164.76
TD2	108.87	123.74	169.47	165.69	106.61	128.33
TD3	337.41	252.58	122.73	182.99	337.95	230.26
TD4	337.13	134.25	292.06	179.89	104.67	187.70
TD5	323.42	296.08	289.82	242.11	250.23	108.00
TD6	88.90	119.35	236.33	168.06	96.79	56.78
TD7	101.46	81.07	249.47	258.48	211.15	131.23
TD8	193.06	337.23	154.02	298.91	322.18	102.39
TD9	216.83	76.23	36.62	60.26	36.62	95.83
TD10	166.34	122.37	299.20	186.25	315.15	101.63
TD11	165.00	144.32	115.51	128.31	281.42	115.51
TD12	135.35	84.46	162.24	74.34	62.46	111.52
TD13	124.59	113.95	161.16	87.99	113.95	138.19
TD14	85.84	62.46	142.18	189.10	131.76	144.17
TD15	339.99	112.38	192.57	240.18	106.91	215.50
TD16	242.00	133.85	61.58	88.79	143.44	56.47
TD17	147.15	338.25	188.35	305.42	52.11	343.66
TD18	187.18	340.78	334.73	158.82	209.16	100.10
TD19	115.97	323.77	148.64	198.98	134.34	134.25
TD20	122.91	173.75	140.66	111.92	97.58	200.27
TD21	253.50	87.13	142.37	120.87	176.84	333.95
TD22	75.02	67.19	148.33	43.08	73.71	89.79
TD23	209.84	326.97	274.14	86.69	139.52	350.25
TD24	287.17	296.20	156.09	162.96	152.98	144.89
TD25	53.61	102.33	32.76	40.40	61.00	57.86
TD26	105.87	57.79	76.33	321.87	32.57	84.89
TD27	21.76	93.28	58.47	100.00	72.55	47.76
TD28	102.57	355.28	104.94	65.20	79.37	91.82
TD29	204.64	89.38	332.42	141.08	169.73	136.98
TD30	156.01	119.09	84.12	163.62	77.42	63.56
TD31	132.39	126.73	118.98	147.91	124.60	206.88
TD32	329.31	132.37	141.38	342.63	94.35	106.80

Table 54. Merging distance for ramp-2 by test driver under each driving scenario.

TD	Baseline (high flow)	Baseline (low flow)	V-ISA-I (high flow)	V-ISA-I (low flow)	V-ISA-III (high flow)	V-ISA-III (low flow)
TD1	158.17	117.75	65.01	35.93	98.39	124.74
TD2	85.91	122.09	117.75	103.03	33.95	126.18
TD3	111.67	119.11	154.24	83.12	134.11	102.72
TD4	106.58	55.74	138.47	35.79	94.52	71.28
TD5	114.31	117.26	103.47	133.15	30.93	65.01
TD6	125.76	90.73	83.52	75.10	131.51	61.45
TD7	129.55	71.58	130.96	68.30	66.09	123.88
TD8	40.83	37.27	58.53	139.02	59.95	98.46
TD9	24.97	70.68	100.80	36.91	100.80	120.18
TD10	112.42	144.78	142.88	103.34	65.45	118.07
TD11	36.66	123.59	88.55	67.85	101.43	88.55
TD12	86.76	59.63	120.18	42.37	102.91	25.49
TD13	130.86	124.55	111.71	23.11	124.55	21.35
TD14	116.42	102.91	122.16	146.98	71.26	73.09
TD15	116.96	147.06	96.53	125.38	125.83	147.63
TD16	52.92	28.59	45.03	56.61	46.84	116.43
TD17	57.59	69.50	40.98	97.06	86.20	72.90
TD18	77.56	75.83	125.46	91.80	112.59	142.10
TD19	119.32	53.03	79.67	89.37	47.18	121.07
TD20	77.69	83.66	123.94	62.83	139.44	56.51
TD21	104.64	20.05	56.94	34.34	101.64	40.84
TD22	97.44	50.03	50.67	74.79	135.95	53.10
TD23	133.53	62.33	116.07	104.52	61.16	58.56
TD24	82.56	117.28	103.56	98.64	59.13	60.16
TD25	71.80	86.36	38.00	121.11	48.17	127.35
TD26	76.07	38.74	51.91	118.41	112.32	52.94
TD27	113.77	55.51	27.75	70.15	43.29	16.75
TD28	120.62	25.82	148.05	118.97	90.35	80.42
TD29	84.99	52.82	92.74	130.70	99.51	130.74
TD30	62.36	53.13	92.28	30.13	32.19	60.16
TD31	91.26	54.59	64.36	31.89	98.64	74.63
TD32	85.83	85.30	79.48	66.57	117.00	89.21

Table 55. Merging distance for ramp-3 by test driver under each driving scenario.

TD	Baseline (high flow)	Baseline (low flow)	V-ISA-I (high flow)	V-ISA-I (low flow)	V-ISA-III (high flow)	V-ISA-III (low flow)
TD1	25.54	133.90	151.23	1.10	146.10	10.00
TD2	209.26	32.29	133.90	166.96	153.43	24.08
TD3	25.13	85.85	26.09	18.34	38.42	138.94
TD4	31.33	128.83	90.13	109.32	139.55	139.17
TD5	57.04	135.33	234.93	36.59	72.26	151.23
TD6	79.33	228.14	196.19	218.25	129.47	204.12
TD7	73.16	79.28	160.35	97.47	57.96	203.06
TD8	148.84	45.31	79.21	45.43	78.77	119.69
TD9	38.74	4.01	1.40	0.00	1.40	0.00
TD10	255.04	55.36	72.25	105.81	43.29	25.35
TD11	26.36	134.06	65.83	192.13	51.66	65.83
TD12	65.63	53.67	113.53	102.41	47.54	136.72
TD13	86.62	219.82	47.36	25.46	219.82	172.07
TD14	14.73	47.54	26.18	12.48	74.46	67.31
TD15	282.47	98.44	166.65	73.43	242.58	128.99
TD16	0.00	59.25	80.80	134.26	20.60	6.44
TD17	96.03	62.31	35.04	46.16	44.78	79.97
TD18	41.05	298.80	163.75	250.12	156.61	41.87
TD19	172.55	118.39	174.44	156.41	273.38	115.78
TD20	190.78	155.69	142.04	53.19	57.71	82.88
TD21	153.65	83.70	169.26	248.86	133.40	110.19
TD22	38.45	38.10	14.05	71.01	150.18	89.94
TD23	330.27	181.41	59.09	178.35	289.14	36.98
TD24	253.31	246.16	83.32	132.19	241.98	271.23
TD25	136.45	75.33	50.50	79.82	165.03	13.71
TD26	266.02	18.64	175.60	29.26	20.28	122.71
TD27	14.83	0.00	25.56	1.60	13.62	90.59
TD28	290.87	97.10	96.19	208.16	6.67	275.77
TD29	250.43	246.55	155.98	213.43	136.00	161.00
TD30	0.00	0.00	38.89	77.57	105.22	34.89
TD31	191.06	172.35	33.58	52.33	117.68	74.62
TD32	247.98	264.84	260.91	330.95	184.05	108.58

Table 56. Merging distance for ramp-4 by test driver under each driving scenario.

TD	Baseline (high flow)	Baseline (low flow)	V-ISA-I (high flow)	V-ISA-I (low flow)	V-ISA-III (high flow)	V-ISA-III (low flow)
TD1	55.57	121.58	47.53	81.94	86.23	101.62
TD2	125.06	77.98	121.58	68.64	126.01	61.84
TD3	94.06	138.05	130.88	158.06	172.27	114.57
TD4	66.51	34.94	141.01	38.35	75.22	101.87
TD5	163.53	144.37	126.82	164.34	160.15	47.53
TD6	168.30	110.88	144.43	73.03	154.88	61.93
TD7	99.14	132.28	89.21	92.59	93.08	80.18
TD8	89.63	149.93	144.94	129.91	134.66	68.47
TD9	59.05	114.13	149.20	95.10	149.20	34.15
TD10	151.14	87.03	137.94	154.12	124.27	81.92
TD11	67.94	67.68	135.43	78.98	87.76	135.43
TD12	167.62	45.17	100.04	87.99	51.40	66.01
TD13	153.86	80.32	74.36	75.55	80.32	154.70
TD14	84.09	51.40	123.08	111.33	121.41	98.46
TD15	165.99	154.08	130.61	147.16	39.86	120.43
TD16	116.71	71.91	75.38	125.02	102.01	163.24
TD17	62.32	76.08	64.19	92.72	94.58	66.06
TD18	55.18	186.08	64.21	112.22	68.03	53.04
TD19	115.01	77.67	109.77	123.40	104.13	89.55
TD20	68.38	128.69	162.07	152.50	159.69	98.28
TD21	58.46	69.19	79.73	55.83	87.10	143.11
TD22	57.57	65.57	141.23	68.42	76.09	151.18
TD23	152.39	162.22	143.68	149.82	160.13	169.86
TD24	104.36	137.30	122.84	153.59	91.34	135.54
TD25	58.68	82.34	93.43	40.92	134.86	45.43
TD26	141.69	42.05	96.29	43.48	134.27	101.86
TD27	126.14	97.26	44.39	45.11	48.63	84.42
TD28	55.09	76.79	110.45	49.54	105.74	55.87
TD29	133.77	114.06	126.72	133.39	83.19	149.90
TD30	100.53	157.86	95.37	72.28	168.31	27.63
TD31	82.51	76.52	84.69	62.65	59.64	64.43
TD32	94.66	69.26	152.00	168.25	37.43	80.77

H. LINEAR MIXED MODEL OUTPUTS

*Table 57. LMM outputs on significant factors influencing speed at motorway up section. (Notes: F: female, M: male; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	**Estimate (p-value)**	
		LMM
	Effect	**S_{Mup}**
Fixed effects:		
Intercept		121.360***
Traffic flow	Low - High	4.800***
Gender	F - M	-
Age class	I - III	-
	II - III	-
Traffic flow * Gender	Low - High * F - M	-6.880**
Traffic flow * Age class	Low - High * II - III	-7.310**
Random effects:		
Test driver ID		(<.001)
Summary statistics:		
AIC		1469
BIC		1470
R^2 marginal		.123
R^2 conditional		.565
ICC		.504
Observations		192
Drivers		32
Observations/driver		6
KS test for normality of residuals (p-value)		.065

*Table 58. LMM outputs on significant factors influencing speed at motorway down section. (Notes: F: female, M: males; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	Estimate (p-value)	
	Effect	LMM
		S_{Mdown}
Fixed effects:		
Intercept		115.956***
V-ISA	V-ISA-I - Baseline	-
	V-ISA-III - Baseline	-
Traffic flow	Low - High	-
Gender	F - M	-
Age class	I - III	-
	II - III	-
V-ISA * Age class	V-ISA-III - Baseline * II - III	-5.749*
V-ISA * Traffic flow * Gender	V-ISA-I - Baseline * Low - High * F - M	-16.328**
	V-ISA-III - Baseline * Low - High * F - M	-13.007**
V-ISA * Gender * Age class	V-ISA-III - Baseline * F - M * I - III	21.113**
Random effects:		
Test driver ID		(<.001)
Summary statistics:		
AIC		1449
BIC		1429
R^2 marginal		.121
R^2 conditional		.704
ICC		.664
Observations		192
Drivers		32
Observations/driver		6
KS test for normality of residuals (p-value)		.067

*Table 59. LMM outputs on significant factors influencing lateral position at motorway up section. (Notes: F: female, M: male; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	**Estimate (p-value)**	
	Effect	**LMM**
		LP_{Mup}
Fixed effects:		
Intercept		-
Traffic flow	Low - High	-
Age class	I - III	-
	II - III	-
Traffic flow * Age class	Low - High * I - III	-.360*
	Low - High * II - III	-
Random effects:		
Test driver ID		(<.001)
Summary statistics:		
AIC		269
BIC		314
R^2 marginal		.030
R^2 conditional		.047
ICC		.018
Observations		192
Drivers		32
Observations/driver		6
KS test for normality of residual (p-value)		.132*

*Table 60. LMM outputs on significant factors influencing lateral position at motorway down section. (Notes: F: female, M: male; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	Estimate (p-value)	
		LMM
	Effect	LP_{Mdown}
Fixed effects:		
Intercept		-.119**
V-ISA	V-ISA-I - Baseline	-
	V-ISA-III - Baseline	-
Traffic flow	Low - High	-
Gender	F - M	-
Age class	I - III	-
	II - III	-
V-ISA * Traffic flow	V-ISA-III - Baseline * Low - High	-.270*
V-ISA * Age class	V-ISA-I - Baseline * I - III	.498**
	V-ISA-I - Baseline * II - III	.353**
Gender * Age class	F - M * I - III	-.390*
Random effects:		
Test driver ID		(<.001)
Summary statistics:		
AIC		262
BIC		357
R^2 marginal		.092
R^2 conditional		.117
ICC		.028
Observations		192
Drivers		32
Observations/driver		6
KS test for normality of residual (p-value)		.106*

*Table 61. LMM outputs on significant factors influencing speed at two-lane rural highway section. (Notes: F: female, M: male; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	Estimate (p-value)	
	Effect	LMM
		S_{TLRP}
Fixed effects:		
Intercept		77.522***
V-ISA	V-ISA-I - Baseline	-
	V-ISA-III - Baseline	-
Traffic flow	Low - High	-
Gender	F - M	-
Age class	I - III	-
	II - III	-
V-ISA * Traffic flow	V-ISA-III - Baseline * Low - High	3.605*
Traffic flow * Age class	Low - High * II - III	-3.770**
Random effects:		
Test driver ID		(<.001)
Summary statistics:		
AIC		1321
BIC		1331
R^2 marginal		.037
R^2 conditional		.608
ICC		.593
Observations		192
Drivers		32
Observations/driver		6
KS test for normality of residual (p-value)		.047

*Table 62. LMM outputs on significant factors influencing lateral position at two-lane rural highway section. (Notes: F: female, M: male; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	Estimate (p-value)	
		LMM
	Effect	LP_{TLRP}
Fixed effects:		
Intercept		-
V-ISA	V-ISA-I - Baseline	-
	V-ISA-III - Baseline	-
Traffic flow	Low - High	-
Gender	F - M	-
Age class	I - III	-
	II - III	-
V-ISA * Gender	V-ISA-III - Baseline * F - M	-.210**
V-ISA * Age class	V-ISA-I - Baseline * I - III	.208*
Gender * Age class	F - M * II - III	-.300**
V-ISA * Gender * Age class	V-ISA-III - Baseline * F - M * I - III	-.030*
V-ISA * Traffic flow * Gender * Age class	V-ISA-III - Baseline * Low - High * F - M * II - III	-.609*
Random effects:		
Test driver ID		(<.001)
Summary statistics:		
AIC		22
BIC		245
R^2 marginal		.213
R^2 conditional		.515
ICC		.384
Observations		192
Drivers		32
Observations/driver		6
KS test for normality of residual (p-value)		.044

*Table 63. LMM outputs on significant factors influencing speed at ramp-1 sections (LT1, TR1, R1, RT1, and TL1). (Notes: F: female, M: male; TF: traffic flow; AC: age class; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	**Effect**	**Estimate (p-value)**				
		LMM				
		S_{LT1}	**S_{TR1}**	**S_{R1}**	**S_{RT1}**	**S_{TL1}**
Fixed effects:						
Intercept		69.5***	63.8***	54.8***	62.8***	74.9***
V-ISA	V-ISA-I - Baseline	-	-	-3.9***	-	-
	V-ISA-III - Baseline	-	-	-7.2***	-	-3.6**
TF	Low - High	2.2**	-	-	-	-
Gender	F - M	-	-	-	-	-7.4**
Accidents		-	-	-2.2*	-3.2*	-
V-ISA * Gender	V-ISA-I - Baseline * F - M	-	-	-4.8**	-	-
TF * Gender	Low - High * F - M	-	-	-	5.1**	-
V-ISA * AC	V-ISA-III - Baseline * I - III	-	-	-6.0*	-	-8.5**
TF * AC	Low - High * I - III	-5.8**	-5.6**	-	-	-
	Low - High * II - III	-6.7***	-4.8**	-	-	-
V-ISA * TF * Gender	V-ISA-I - Baseline * Low - High * F - M	-8.1*	-	-9.4*	-11.3**	-
	V-ISA-III - Baseline * Low - High * F - M	-	-9.3*	-11.6**	-13.0**	-
	V-ISA-I - Baseline * Low - High * II - III	-	8.8*	-	-	-
	V-ISA-III - Baseline * Low - High * II - III	-	-	-	-	-11.7*
TF * Gender * AC	Low - High * F - M * I - III	-	9.9*	-	-	-
V-ISA * TF * Gender * AC	V-ISA-I - Baseline * Low - High * F - M * I - III	-23.4*	-	-27.0**	-28.4*	-
	V-ISA-III - Baseline * Low - High * F - M * I - III	-	-23.7*	-40.7**	-42.6**	-
	V-ISA-III - Baseline * Low - High * F - M * II - III	-	-	-16.3*	-	-
Random effects:						
Test driver ID		(<.001)	(<.001)	(<.001)	(<.001)	(<.001)
Summary statistics:						
AIC		1357	1356	1334	1406	1433
BIC		1348	1328	1312	1370	1425
R^2 marginal		.148	.112	.210	.160	.134
R^2 conditional		.707	.744	.631	.688	.651
ICC		.656	.684	.533	.629	.597
Observations				192		
Drivers				32		
Observations/driver				6		
KS test for normality of residual (p-value)		.053	.038	.058	.035	.060

*Table 64. LMM outputs on significant factors influencing lateral position and SDLP at ramp-1, and merging and diverging abscissa for ramp-1. (Notes: F: female, M: male; TF: traffic flow; AC: age class; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	**Estimate (p-value)**				
		LMM			
	Effect	**LP_{R1}**	**$SDLP_{R1}$**	**$L_{LT\ D1}$**	**$L_{LT\ M1}$**
Fixed effects:					
Intercept		-.690***	.169***	35.8***	160.9***
V-ISA	V-ISA-III - Baseline	-	-	-	-13.3**
Traffic flow	Low - High	-	-	3.9**	-
Gender	F - M	-	-	6.4*	-
V-ISA * TF	V-ISA-I - Baseline * Low - High	-.284**	-	-	-
	V-ISA-III - Baseline * Low - High	-	.053*	-	-
V-ISA * Gender	V-ISA-III - Baseline * F - M	-	.056*	6.1*	-
V-ISA * AC	V-ISA-I - Baseline * I - III	-	-	-12.2**	-
	V-ISA-III - Baseline * II - III	-.177*	-	-	-
TF * AC	Low - High * I - III	-	-	11.5**	-
Gender * AC	F - M * I - III	.630*	-	-	-
	F - M * II - III	-	.087**	-15.7**	-
V-ISA * TF * Gender	V-ISA-I - Baseline * Low - High * F - M	-	-	-16.2**	-
V-ISA * Gender * AC	V-ISA-I - Baseline * F - M * I - III	-	-.203**	-	-
	V-ISA-III - Baseline * F - M * I - III	-.489*	-	-	-
	V-ISA-I - Baseline * F - M * II - III	-	-	-	99.3*
	V-ISA-III - Baseline * F - M * II - III	-	-	-	112.9**
TF * Gender * AC	Low - High * F - M * I - III	-	-.142*	-	-
V-ISA * TC * Gender * AC	V-ISA-I - Baseline * Low - High * F - M * I - III	-	-	-	474.5**
	V-ISA-III - Baseline * Low - High * F - M * I - III	-1.056**	-	-	-
	V-ISA-III - Baseline * Low - High * F - M * II - III	-	-	23.9*	226.4**
Random effects:					
Test driver ID		(<.001)	(<.001)	(<.001)	(<.001)
Summary statistics:					
AIC		121	-365	1480	2267
BIC		325	-136	1429	2069
R^2 marginal		.187	.171	.240	.153
R^2 conditional		.681	.264	.604	.411
ICC		.607	.113	.479	.304
Observations		192			
Drivers		32			
Observations/driver		6			
KS test for normality of residual (p-value)		.043	.096*	.045	.084

*Table 65. LMM outputs on significant factors influencing speed at ramp-2 sections (LT2, TR2, R2, RT2, and TL2). (Notes: F: female, M: male; TF: traffic flow; AC: age class; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	**Estimate (p-value)**					
		LMM				
	Effect	**S_{LT2}**	**S_{TR2}**	**S_{R2}**	**S_{RT2}**	**S_{TL2}**
Fixed effects:						
Intercept		88.7***	74.5***	60.2***	63.3***	67.3***
V-ISA	V-ISA-I - Baseline	-	-	-4.9***	-	-4.3**
	V-ISA-III - Baseline	-	-3.6**	-9.7***	-4.9***	-5.2**
Accidents		-	-3.2*	-	-3.1*	-
V-ISA * TF	V-ISA-I - Baseline * Low - High	-7.3**	-7.1**	-	-	-
	V-ISA-III - Baseline * Low - High	-5.2*	-9.2**	-	-	-
TF * Gender	Low - High * F - M	4.7**	-	-	-	-
V-ISA * AC	V-ISA-III - Baseline * I - III	-	-	-6.4*	-	-
	V-ISA-III - Baseline * II - III	-	7.8**	4.7 *	6.7**	-
V-ISA * TF * Gender	V-ISA-I - Baseline * Low - High * F - M	-10.1*	-10.1*	-9.2*	-	-13.9*
	V-ISA-III - Baseline * Low - High * F - M	-12.6**	-15.5**	-	-	-
V-ISA * TF * AC	V-ISA-I - Baseline * Low - High * I - III	-	-	-	-	18.6*
	V-ISA-III - Baseline * Low - High * I - III	-	-	-	-	17.6*
	V-ISA-III - Baseline * Low - High * II - III	-	-	-	-10.5**	-
V-ISA * Gender * AC	V-ISA-I - Baseline * F - M * I - III	-	-	-	-	21.1**
	V-ISA-III - Baseline * F - M * I - III	-	-	-13.0*	-	-
	V-ISA-I - Baseline * F - M * II - III	-	-	-	-	20.1**
TF * Gender * AC	Low - High * F - M * II - III	-	-	-	-	-10.9*
V-ISA * TF * Gender * AC	V-ISA-III - Baseline * Low - High * F - M * I - III	-	-	-	-	42.2**
Random effects:						
Test driver ID		(<.001)	(<.001)	(<.001)	(<.001)	(<.001)
Summary statistics:						
AIC		1422	1451	1362	1372	1501
BIC		1425	1447	1354	1371	1464
R^2 marginal		.056	.153	.188	.150	.183
R^2 conditional		.490	.585	.656	.677	.601
ICC		.460	.510	.576	.620	.513
Observations				192		
Drivers				32		
Observations/driver				6		
KS test for normality of residual (p-value)		.063	.035	.070	.063	.052

*Table 66. LMM outputs on significant factors influencing lateral position and SDLP at ramp-2, and merging and diverging abscissa for ramp-2. (Notes: F: female, M: male; TF: traffic flow; AC: age class; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1,**=p<.05, ***=p<.001).*

Factors, covariates, and cluster	**Effect**	**Estimate (p-value)**			
		LMM			
		LP_{R2}	**$SDLP_{R2}$**	**$L_{LT\ D2}$**	**$L_{LT\ M2}$**
Fixed effects:					
Intercept		-.474***	.137***	59.4***	84.8***
Gender	F - M	.254*	.026**	17.6**	-18.8**
Age class	I - III	.322*	-.062*	21.5**	-
	II - III	-	-.078**	-	-14.5**
Experience		-	-.004**	-	-
Kilometres/year		-	.000**	-	-
V-ISA * TF	V-ISA-I - Baseline * Low - High	-.219**	-	-18.2*	-
	V-ISA-III - Baseline * Low - High	-	.042*	-	-
V-ISA * AC	V-ISA-III - Baseline * II - III	-.234**	-	-	-
Gender * AC	F - M * I - III	.745**	-	48.8**	-
V-ISA * TF * Gender	V-ISA-I - Baseline * Low - High * F - M	-	-	-	43.9*
V-ISA * TF * AC	V-ISA-I - Baseline * Low - High * I - III	-	-	-79.1**	-
V-ISA * Gender * AC	V-ISA-I - Baseline * F - M * II - III	-.386*	-	-	-62.9**
	V-ISA-III - Baseline * F - M * II - III	-.568**	-	-	-
TF * Gender * AC	Low - High * F - M * II - III	-	-	-	-39.7*
V-ISA * TF * Gender * AC	V-ISA-I - Baseline * Low - High * F - M * I - III	-	-	-142.3**	-
	V-ISA-III - Baseline * Low - High * F - M * I - III	-	-	147.2**	-
	V-ISA-III - Baseline * Low - High * F - M * II - III	-	-	-	-98.2**
Random effects:					
Test driver ID		(<.001)	(<.001)	(<.001)	(<.001)
Summary statistics:					
AIC		149	-476	1881	1916
BIC		277	-332	1755	1783
R^2 marginal		.207	.121	.202	.252
R^2 conditional		.607	.121	.385	.287
ICC		.505	.000	.229	.046
Observations		192			
Drivers		32			
Observations/driver		6			
KS test for normality of residual (p-value)		.036	.066	.129	.052

*Table 67. LMM outputs on significant factors influencing speed at ramp-3 sections (LT3, TR3, R3, RT3, and TL3). (Notes: F: female, M: male; TF: traffic flow; AC: age class; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1,**=p<.05, ***=p<.001).*

Factors, covariates, and cluster	Effect	Estimate (p-value)				
		LMM				
		S_{LT3}	S_{TR3}	S_{R3}	S_{RT3}	S_{TL3}
Fixed effects:						
Intercept		74.7***	62.1***	57.2***	68.9***	77.3***
V-ISA	V-ISA-I - Baseline	-	-4.5**	-4.4***	-	3.6**
	V-ISA-III - Baseline	-	-5.5***	-5.8***	-	-
V-ISA * TF	V-ISA-I - Baseline * Low - High	-	-	-	4.9*	-
V-ISA * AC	V-ISA-I - Baseline * I - III	-	-	-	-	10.5**
Traffic flow * AC	Low - High * II - III	-5.4**	-	-	-	-
V-ISA * TF * AC	V-ISA-III - Baseline * Low - High * I - III	-	-	-	16.0**	-
	V-ISA-I - Baseline * Low - High * II - III	-	-	-	-	15.7**
V-ISA * Gender * AC	V-ISA-III - Baseline * F - M * I - III	-	18.6**	-	12.9*	14.8*
TF * Gender * AC	Low - High * F - M * II - III	-10.3**	-	-	-	-
Random effects:						
Test driver ID		(<.001)	(<.001)	(<.001)	(<.001)	(<.001)
Summary statistics:						
AIC		1391	1397	1287	1402	1449
BIC		1388	1387	1298	1384	1425
R^2 marginal		.067	.091	.086	.095	.104
R^2 conditional		.658	.671	.516	.609	.634
ICC		.633	.638	.470	.568	.591
Observations				192		
Drivers				32		
Observations/driver				6		
KS test for normality of residual (p-value)		.066	.055	.071	.044	.060

*Table 68. LMM outputs on significant factors influencing lateral position and SDLP at ramp-3, and merging and diverging abscissa for ramp-3. (Notes: F: female, M: male; TF: traffic flow; AC: age class; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1,**=p<.05, ***=p<.001).*

Factors, covariates, and cluster	Effect	Estimate (p-value)			
		LMM			
		LP_{R3}	$SDLP_{R3}$	$L_{LT\ D3}$	$L_{LT\ M3}$
Fixed effects:					
Intercept		-.705***	.183***	37.2***	131.5***
V-ISA	V-ISA-I - Baseline	.092*	.032**	-	-
Gender	F - M	-	.058**	-	-
Age class	I - III	.797**	.058**	-	152.1**
	II - III	.511**	-	-	94.2*
Age		.023*	-	-	-8.5**
Experience		-	-	-	15.1**
Kilometres/year		-	-	-	-.0**
V-ISA * TF	V-ISA-I - Baseline * Low - High	-.225**	-	-	-
V-ISA * AC	V-ISA-I - Baseline * I - III	-	.107**	-	71.3**
	V-ISA-III - Baseline * I - III	-.277**	-	-	-
Gender * AC	F - M * I - III	.674**	.105**	-	-
	F - M * II - III	-	-	-17.4**	-
V-ISA * TF * AC	V-ISA-III - Baseline * Low - High * I - III	-.501*	-.131*	-	-131.2*
V-ISA * Gender * AC	V-ISA-III - Baseline * F - M * I - III	-.809**	-	-	-
	V-ISA-III - Baseline * F - M * II - III	-.529**	-	-	-
Random effects:					
Test driver ID		(<.001)	(<.001)	(<.001)	(<.001)
Summary statistics:					
AIC		114	-430	1424	2216
BIC		289	-338	1424	2149
R^2 marginal		.234	.120	.176	.198
R^2 conditional		.656	.261	.532	.422
ICC		.551	.160	.432	.279
Observations		192			
Drivers		32			
Observations/driver		6			
KS test for normality of residual (p-value)		.034	.062	.089*	.073

*Table 69. LMM outputs on significant factors influencing speed at ramp-4 sections (LT4, TR4, R4, RT4, and TL4). (Notes: F: female, M: male; TF: traffic flow; AC: age class; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1,**=p<.05, ***=p<.001).*

Factors, covariates, and cluster	Estimate (p-value)					
		LMM				
	Effect	**S_{LT4}**	**S_{TR4}**	**S_{R4}**	**S_{RT4}**	**S_{TL4}**
Fixed effects:						
Intercept		86.2***	78.4***	59.7***	62.1***	66.3***
V-ISA	V-ISA-I - Baseline	-	-	-4.4**	-2.2*	-
	V-ISA-III - Baseline	-	-	-8.8***	-3.5**	-
TF	Low - High	3.7**	2.4*	-	-	-
AC	I - III	-11.9**	-	-	-	-
	II - III	-	-	-	-	-
Accidents		-2.4*	-3.4**	-	-2.7*	-3.5*
V-ISA * TF	V-ISA-I - Baseline * Low - High	-	-	7.6**	6.5**	-
V-ISA * Gender	V-ISA-I - Baseline * F - M	-	-	-	-	-9.3**
TF * Gender	Low - High * F - M	-	-	3.9*	6.9**	-
TF * AC	Low - High * I - III	6.1*	-	-	-	-
	Low - High * II - III	-	-6.7**	-4.0*	-5.7**	-
V-ISA * TF * Gender	V-ISA-III - Baseline * Low - High * F - M	-	-	-8.9*	-	-17.8**
V-ISA * TF * AC	V-ISA-I - Baseline * Low - High * I - III	-	-	23.2**	12.6*	-20.2*
	V-ISA-III - Baseline * Low - High * I - III	-	-	13.9*	-	-
V-ISA * Gender * AC	V-ISA-I - Baseline * F - M * II - III	-	-	-10.2*	-	-
TF * Gender * AC	Low - High * F - M * II - III	-	-	-	-8.9**	-
Random effects:						
Test driver ID		(<.001)	(<.001)	(<.001)	(<.001)	(<.001)
Summary statistics:						
AIC		1408	1453	1410	1366	1513
BIC		1414	1458	1388	1358	1488
R^2 marginal		.145	.107	.200	.164	.150
R^2 conditional		.532	.548	.562	.675	.557
ICC		.452	.494	.453	.611	.479
Observations				192		
Drivers				32		
Observations/driver				6		
KS test for normality of residual (p-value)		.040	.047	.064	.045	.081

*Table 70. LMM outputs on significant factors influencing lateral position and SDLP at ramp-4, and merging and diverging abscissa for ramp-4. (Notes: F: female, M: male; TF: traffic flow; AC: age class; V-ISA-I: informative V-ISA variant, V-ISA-III: intervening V-ISA variant; Significance level: *=p<.1, **=p<.05, ***=p<.001).*

Factors, covariates, and cluster	**Estimate (p-value)**				
		LMM			
	Effect	**LP_{R4}**	**$SDLP_{R4}$**	**$L_{LT\ D4}$**	**$L_{LT\ M4}$**
Fixed effects:					
Intercept		-.742***	.184***	106.1***	101.9***
V-ISA	V-ISA-I - Baseline	.177**	-	-	-
	V-ISA-III - Baseline	.269***	-	13.1*	-
TF	Low - High	-	.032**	-13.3**	-
AC	I - III	1.015**	-	-	-
	II - III	.583**	-	-	-
Age		-	-	-	-2.6*
Experience		.028**	-	-	3.1*
V-ISA * TF	V-ISA-I - Baseline * Low - High	-.200*	-	-	-
TF * AC	Low - High * I - III	-	.064*	-	-
Gender * AC	F - M * I - III	.645**	-	-	-
V-ISA * TF * AC	V-ISA-III - Baseline * Low - High * I - III	-	-	-	79.7**
	V-ISA-III - Baseline * Low - High * II - III	-	-	-	82.4**
V-ISA * Gender * AC	V-ISA-III - Baseline * F - M * II - III	-.619**	-	-	-
V-ISA * TF * Gender * AC	V-ISA-I - Baseline * Low - High * F - M * I - III	-	-	-	147.1**
	V-ISA-III - Baseline * Low - High * F - M * I - III	-	-	-	185.5**
	V-ISA-III - Baseline * Low - High * F - M * II - III	-	-	-	121.9**
Random effects:					
Test driver ID		(<.001)	(<.001)	(<.001)	(<.001)
Summary statistics:					
AIC		158	-395	2050	1964
BIC		296	-305	2047	1826
R^2 marginal		.274	.059	.026	.220
R^2 conditional		.542	.210	.308	.328
ICC		.369	.160	.290	.138
Observations		192			
Drivers		32			
Observations/driver		6			
KS test for normality of residual (p-value)		.062	.097*	.103	.056