ENSEMBLE

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ENSEMBLE

ENabling **S**af**E** **M**ulti-**B**rand p**L**atooning for **E**urope

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Written By	JALLAIS, C, TATTEGRAIN, H., MOREAU, F., NDIAYE, D., VIENNE, F., CARO, S.	04-06-2019
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Revision history

Version	Date	Author	Summary of changes	Status
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V1	31/05/2019	Jallais, C., Tattegrain, H., Moreau, F., Ndiaye, D., Vienne, F., Caro, S.	Protocol modifications following GA Ensemble	
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V5	25-05-2020	Hoedemaeker, M.	Updated after new comments EC	

FIGURES

TABLES

1. EXECUTIVE SUMMARY

1.1. Context and need of a multi brand platooning project

Context

Platooning technology has made significant advances in the last decade, but to achieve the next step towards deployment of truck platooning, an integral multi-brand approach is required. Aiming for Europe-wide deployment of platooning, 'multi-brand' solutions are paramount. It is the ambition of ENSEMBLE to realize pre-standards for interoperability between trucks, platoons and logistics solution providers, to speed up actual market pick-up of (sub)system development and implementation and to enable harmonization of legal frameworks in the member states.

Project scope

The main goal of the ENSEMBLE project is to pave the way for the adoption of multi-brand truck platooning in Europe to improve fuel economy, traffic safety and throughput. This will be demonstrated by driving up to seven differently branded trucks in one (or more) platoon(s) under real world traffic conditions across national borders. During the years, the project goals are:

- Year 1: setting the specifications and developing a reference design with acceptance criteria
- Year 2: implementing this reference design on the OEM own trucks as well as perform impact assessments with several criteria
- Year 3: focus on testing the multi-brand platoons on test tracks and international public roads

The technical results will be evaluated against the initial requirements. Also, the impact on fuel consumption, drivers and other road users will be established. In the end, all activities within the project aim to accelerate the deployment of multi-brand truck platooning in Europe.

Abstract of this Deliverable

This deliverable provides the different use cases that will be studied in the task 4.4.1 on a car simulator located at Ifsttar TS2-LESCOT facilities. The objectives are to 1) evaluate possible problems of other road users when encountering a platoon in different road situations and 2) test different simulated solutions to these problems to improve road safety and platoon acceptance by other drivers. To do so, we have planned to use different use cases. The use cases deal with the interaction between light car drivers and a platoon of several trucks. All the use cases have to be seen from the light car drivers' point of view.
This deliverable describes the different driving situations used to evaluate the light car drivers' behaviour while encountering a platoon. Therefore it presents the use cases defined in collaboration with all OEMs and the protocol defined to assess other road users' driving behaviour while encountering a platoon. Note that the results and conclusions of this driving simulator study will be presented in the deliverable D4.7 which corresponds to an update of this D4.4.

Two platooning levels are under consideration in the ENSEMBLE project: platooning as a support function and platooning as an autonomous function. These levels could be disentangled amongst some technical points such as the time gap between two trucks. The use cases assessed in this driving simulator study will be based on these ENSEMBLE platooning levels.

In order to be able to study these platooning levels, it has been proposed to study two time gaps (i.e., elapsed time to cover the inter vehicle distance by a truck indicated in seconds), being 1.5 seconds for the support function and 0.8 seconds for the autonomous function with a platoon speed limit fixed at 80 kph. The study will also focus on the number of trucks involved in the platoon (3 or 7). Moreover, we aim to study two traffic volumes on a highway (high and low) and three driving situations (overtaking the platoon, highway ingress and egress).

2. DEFINITION OF THE USE CASES

The use cases described in the sections below come from several discussions and meetings with the different partners of the ENSEMBLE project. These use cases should respond to several questions about the road users' behaviour while encountering a platoon. To define these use cases, some information coming from WP2 were needed. Indeed, the platoon rules are described in the deliverable D2.2. According to the possibilities that the platoon offers, several use cases were discussed to fit the research needs regarding road safety concerns.

The objectives of the task 4.4.1 are to 1) evaluate possible problems of other road users when encountering a platoon in different road situations and 2) test different simulated solutions to these problems to improve road safety and platoon acceptance by other drivers. To do so, we have planned to use different use cases. The use cases deal with the interaction between light car drivers and a platoon of several trucks. All the use cases have to be seen from the light car drivers' point of view.

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These use cases are composed of:

- 3 manoeuvres: entry, exit of highway and overtaking of the platoon,
- 2 platoon lengths (3 and 7 trucks),
- 2 levels of traffic volume (high and low)
- 2 levels of inter-vehicular distances in the platoon (1.5 second and 0.8 second)
- Different other road users' behaviours (aggressive behaviour and slowing down behaviour).

Driving Action	Traffic volume	Number of Trucks within platoon	Distance	Figure	Variant
Overtaking	Low	3	1.5s	1	
			0.8s	2	
	High	3	1.5s	3	
			0.8s	4	
	High	3	1.5s	13	Slow down
			0.8s	14	
	High	3	1.5s	15	Aggressive behaviour
			0.8s	16	
Egress	Low	3	1.5s	5	
			0.8s	7	
	High	3	1.5s	6	
			0.8s	8	
Ingress	Low	3	1.5s	9	
			0.8s	11	
	High	3	1.5s	10	
			0.8s	12	
Overtaking	Low	7	1.5s	1	
			0.8s	2	
	High	7	1.5s	3	
			0.8s	4	
	High	7	1.5s	13	Slow down
			0.8s	14	
	High	7	1.5s	15	Aggressive behaviour
			0.8s	16	
Egress	Low	7	1.5s	5	
			0.8s	7	
	High	7	1.5s	6	
			0.8s	8	
Ingress	Low	7	1.5s	9	
			0.8s	11	
	High	7	1.5s	10	
			0.8s	12	

Table 1: Presentation of different variables and modalities studied in ENSEMBLE WP4.4

Table 1 above describes the repartition of the different use cases along the modalities described in the previous section. All these use cases are described in the section hereafter.

These driving situations are in common with the Autopilot EU project which assessed the interaction of platoon with normal traffic (i.e, events and situations for interaction with nearby traffic are distinguished, such as merging, entry and exit, cut-in, lane changing, overtaking, breaking, crossing – Autopilot D4.1, Aittoniemi et al., 2018). In contrary, this study will focus on the interaction between other road users and the platoon according to the road users' point of view.

2.1.1. Overtaking – low traffic – 1.5 second

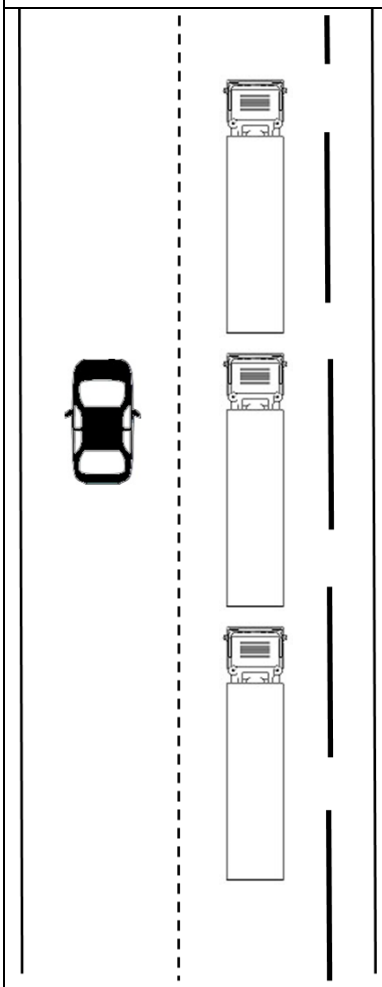
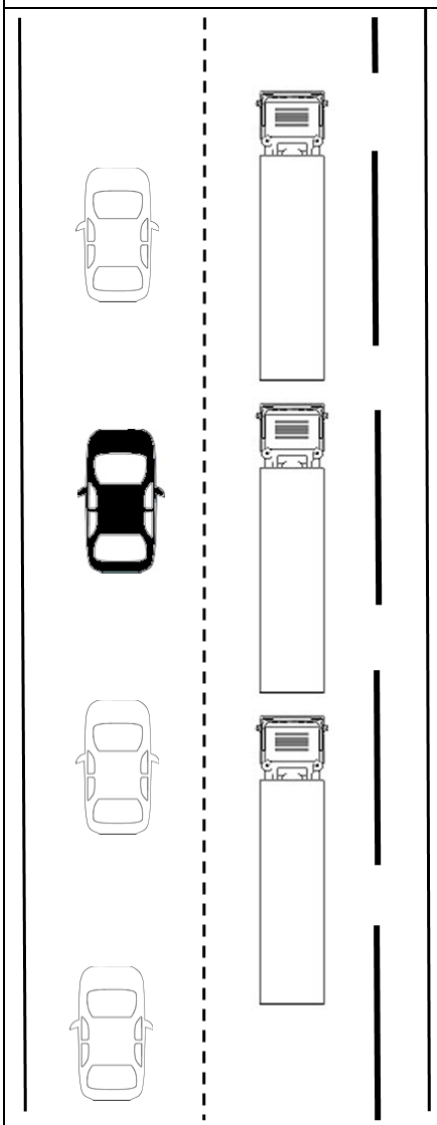
	Road: • Platoon speed range 80km/h, • Road structure =2 lanes • Participant limit speed <130 km/h Traffic description: • No vehicle ahead • No vehicle behind • 3 or 7 trucks in the platoon • 1.5 second as inter-vehicular distance in the platoon Weather: • Dry road

Figure 1: Use case 1 (overtaking - low traffic – 1.5 sec)

The aim of this use case is to observe road users' behavior under normal traffic conditions (no impairment). The indicators obtained here would give useful information to WP4.5 (traffic simulation) like time to overtake, distance of lane change (before and after overtaking) and mean speed.

2.1.2. Overtaking – High traffic – 1.5second



Road:
- Platoon speed range 80km/h,
- Road structure =2 lanes
- Participant limit speed <130 km/h

Traffic description:
- several vehicles ahead
- several vehicles behind
- 3 or 7 trucks in the platoon
- 1.5 second as inter-vehicular distance in the platoon

Weather:
- Dry road

Figure 2: Use case 2 (overtaking – high traffic – 1.5 sec)

The aim of this use case is to observe road users' behavior under high traffic conditions (several vehicles on both ways with an inter-vehicular distance around 1 sec; not a traffic jam situation). The indicators obtained here would give useful information to WP4.5 (traffic simulation) like inter-vehicular distance (between participant and car in front) and lane position.

2.1.3. Overtaking – Low traffic – 0.8 second

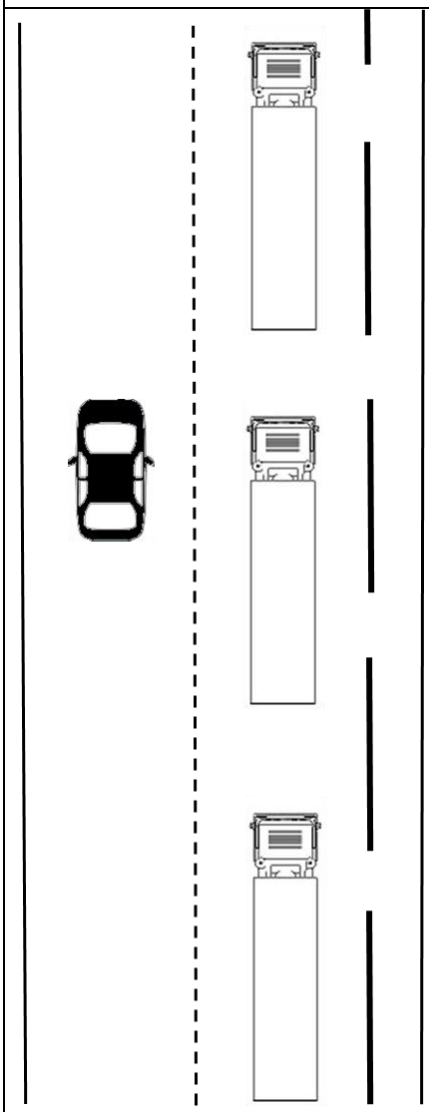
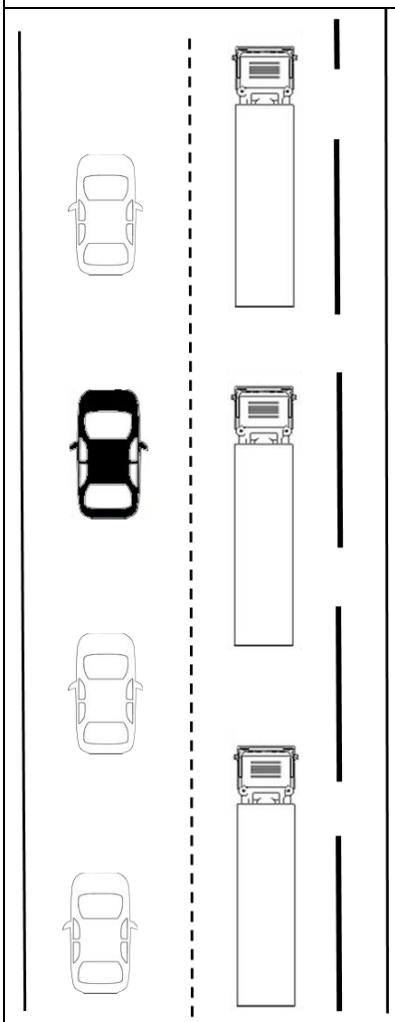
	Road: • Platoon speed range 80km/h, • Road structure =2 lanes • Participant limit speed <130 km/h Traffic description: • No vehicle ahead • No vehicle behind • 3 or 7 trucks in the platoon • 0.8 second as inter-vehicular distance in the platoon Weather: • Dry road

Figure 3: Use case 3 (overtaking – low traffic – 0.8 sec)

The aim of this use case is to observe road users' behaviorbehaviour under normal traffic conditions (no impairment). The indicators obtained here would give useful information to WP4.5 (traffic simulation) like time to overtake, distance of lane change (before and after overtaking) and mean speed. This driving situation will be compared to use case 1 in order to have an idea about the stress coming from the inter-vehicular distance between the trucks.

2.1.4. Overtaking – High traffic – 0.8 second



Road:
- Platoon speed range 80km/h,
- Road structure =2 lanes
- Participant limit speed <130 km/h

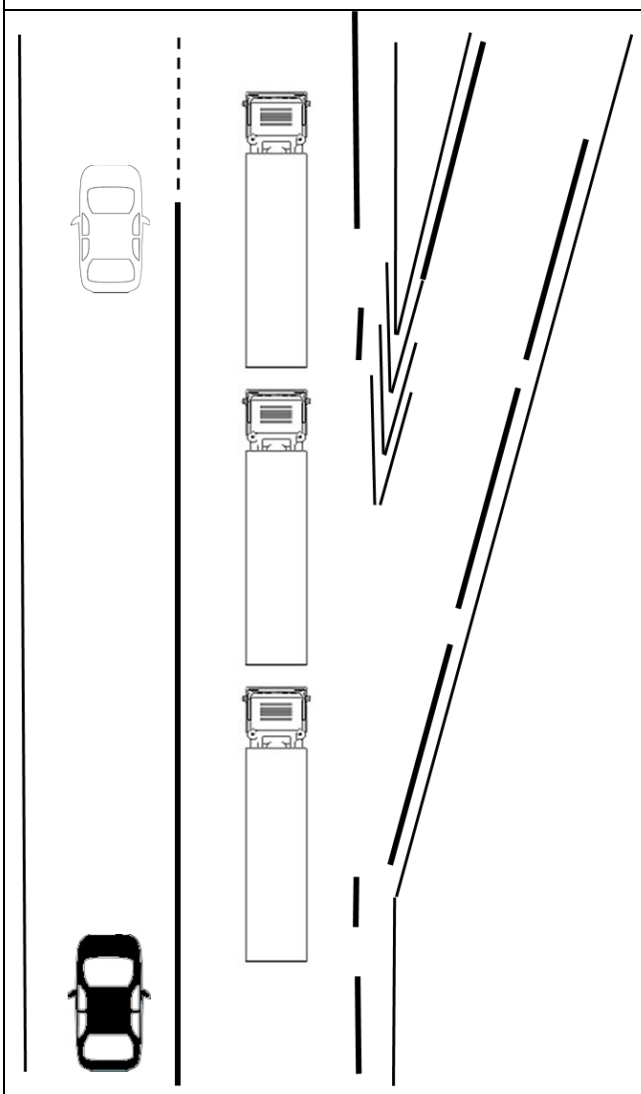
Traffic description:
- several vehicles ahead
- several vehicles behind
- 3 or 7 trucks in the platoon
- 0.8 second as inter-vehicular distance in the platoon

Weather:
- Dry road

Figure 4: Use case 4 (overtaking – high traffic – 0.8 sec)

The aim of this use case is to observe road users' behaviour under high traffic conditions. The indicators obtained here would give useful information to WP4.5 (traffic simulation) like inter-vehicular distance (between participant and car in front) and lane position. This driving situation will be compared to use case 2 in order to have an idea about the stress coming from the inter-vehicular distance between the trucks.

2.1.5. Egress – Low traffic – 1.5 second



Road:
- Platoon speed range 80km/h,
- Road structure =2 lanes
- Participant limit speed <130 km/h

Traffic description:
- one vehicles ahead with regular distance
- No vehicle behind
- 3 or 7 trucks in the platoon
- 1.5 second as inter-vehicular distance in the platoon

Weather:
- Dry road

Road event:

Participant is “forced” to overtake the platoon During the overtaking, information is given to the participant to take the next exit. Participant has to decide whether he/she wants to stop or continue the overtaking

Figure 5: Use case 5 (egress – low traffic – 1.5 sec)

The aim of this use case is to observe road users’ behaviour under normal traffic conditions (no impairment). This situation would give information about driver’s strategy (accelerate or slow down or cut-in) which could be useful to improve WP4.5 simulation.

2.1.6. Egress – high traffic – 1.5 second

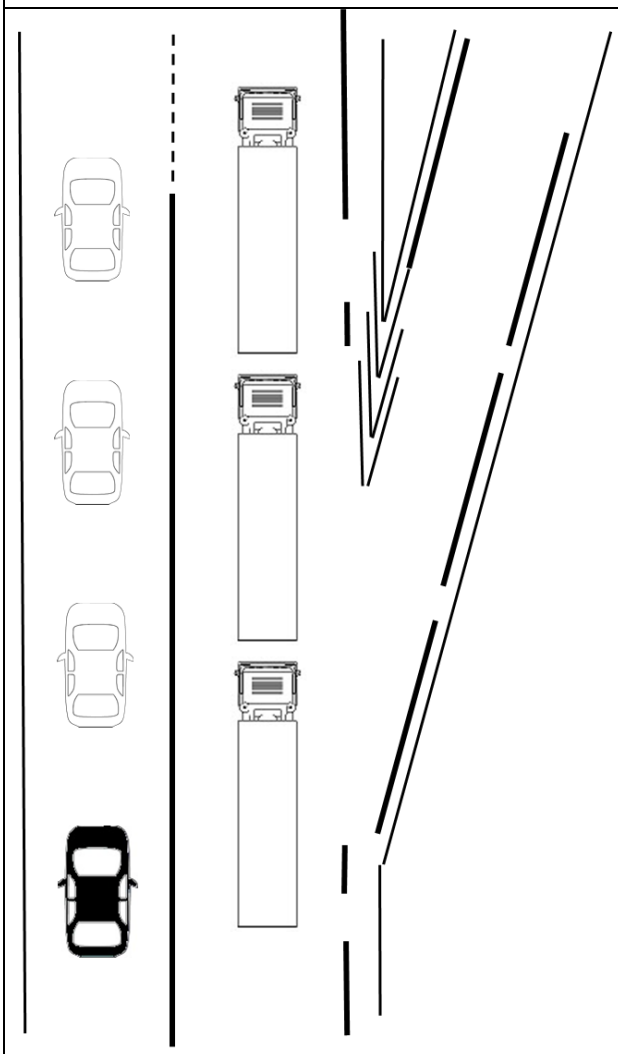
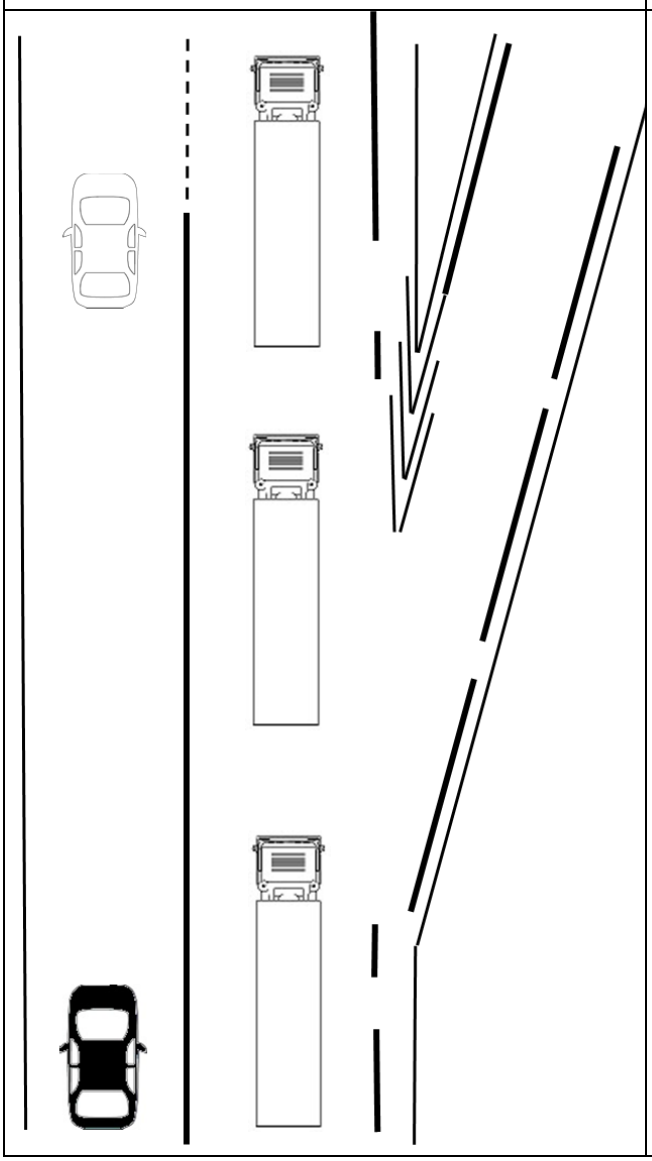
	Road: • Platoon speed range 80km/h, • Road structure =2 lanes • Participant limit speed <130 km/h Traffic description: • several vehicles ahead • several vehicles behind • 3 or 7 trucks in the platoon • 1.5 second as inter-vehicular distance in the platoon Weather: • Dry road Road event: Participant is “forced” to overtake the platoon During the overtaking, information is given to the participant to take the next exit. Participant has to decide whether he/she wants to stop or continue the overtaking Several other road users are behind and ahead the participants

Figure 6: Use case 6 (egress – high traffic – 1.5 sec)

This driving situation will be compared to use case 5 in order to have an idea about the different possible decision making and the stress coming from the inter-vehicular distance between the trucks.

2.1.7. Egress – Low traffic – 0.8 second



Road:
- Platoon speed range 80km/h,
- Road structure =2 lanes
- Participant limit speed <130 km/h

Traffic description:
- one vehicles ahead with regular distance
- No vehicle behind
- 3 or 7 trucks in the platoon
- 0.8 second as inter-vehicular distance in the platoon

Weather:
- Dry road

Road event:

Participant is “forced” to overtake the platoon During the overtaking, information is given to the participant to take the next exit. Participant has to decide whether he/she wants to stop or continue the overtaking

Figure 7: Use case 7 (egress – low traffic – 0.8 sec)

The aim of this use case is to observe road users’ behaviour under normal traffic conditions (no impairment). This situation would give information about driver’s strategy (accelerate or slow down or cut-in) which could be useful to improve the traffic flow simulation studies that will be conducted in WP4.5 of Ensemble project. This driving situation will be compared to use case 5 in order to have an idea about the stress coming from the inter-vehicular distance between the trucks.

2.1.8. Egress – high traffic – 0.8 second

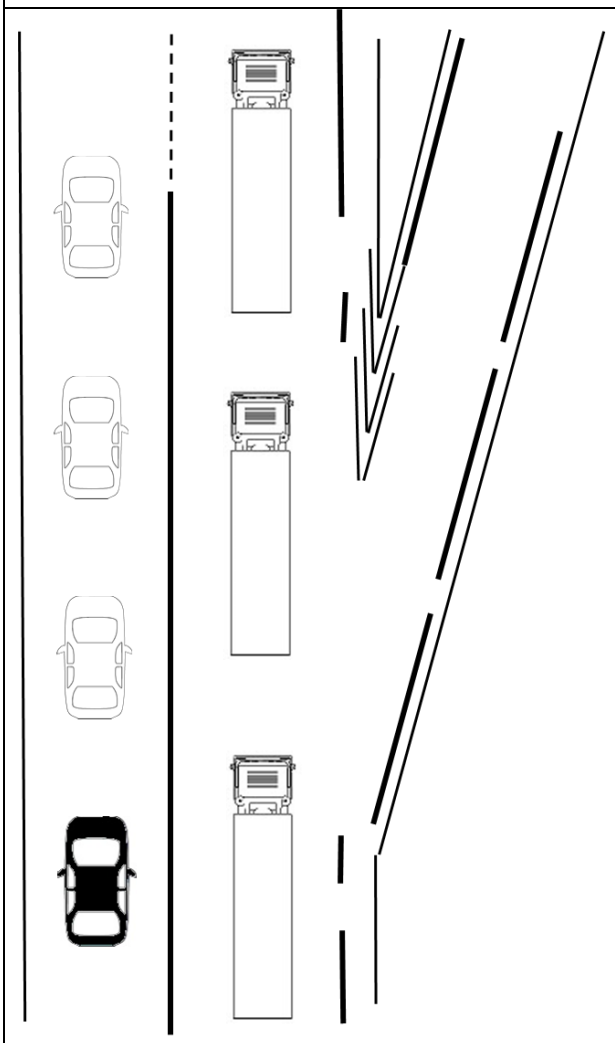
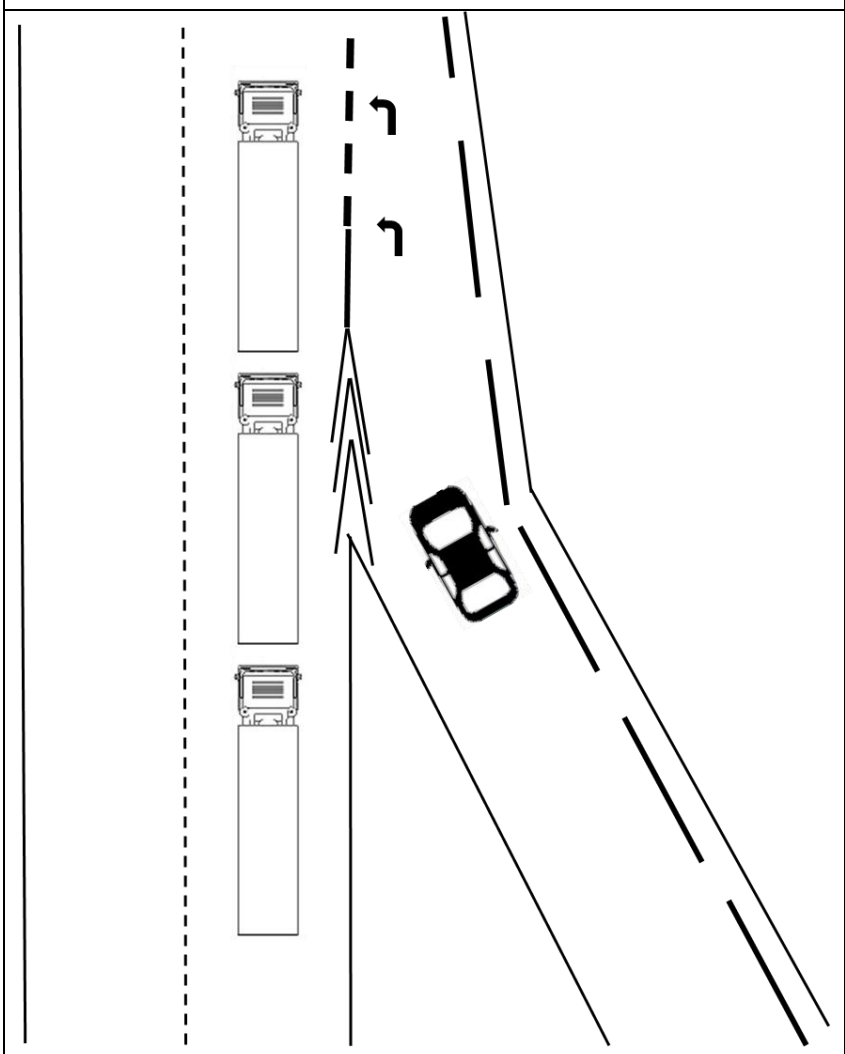
	Road: • Platoon speed range 80km/h, • Road structure =2 lanes • Participant limit speed <130 km/h Traffic description: • several vehicles ahead • several vehicles behind • 3 or 7 trucks in the platoon • 0.8 second as inter-vehicular distance in the platoon Weather: • Dry road Road event: Participant is “forced” to overtake the platoon During the overtaking, information is given to the participant to take the next exit. Participant has t decide whether he/she wants to stop or continue the overtaking Several other road users are behind and ahead the participants

Figure 8: Use case 8 (egress – high traffic – 0.8 sec)

This driving situation will be compared to use case 7 in order to have an idea about the different possible decision making and the stress coming from the inter-vehicular distance between the trucks.

2.1.9. Ingress – Low traffic – 1.5 second



Road:
- Platoon speed range 80km/h,
- Road structure =2 lanes
- Participant limit speed <130 km/h

Traffic description:
- No vehicle ahead
- No vehicle behind
- No traffic on the left lane
- 3 or 7 trucks in the platoon
- 1.5 second as inter-vehicular distance in the platoon

Weather:
- Dry road

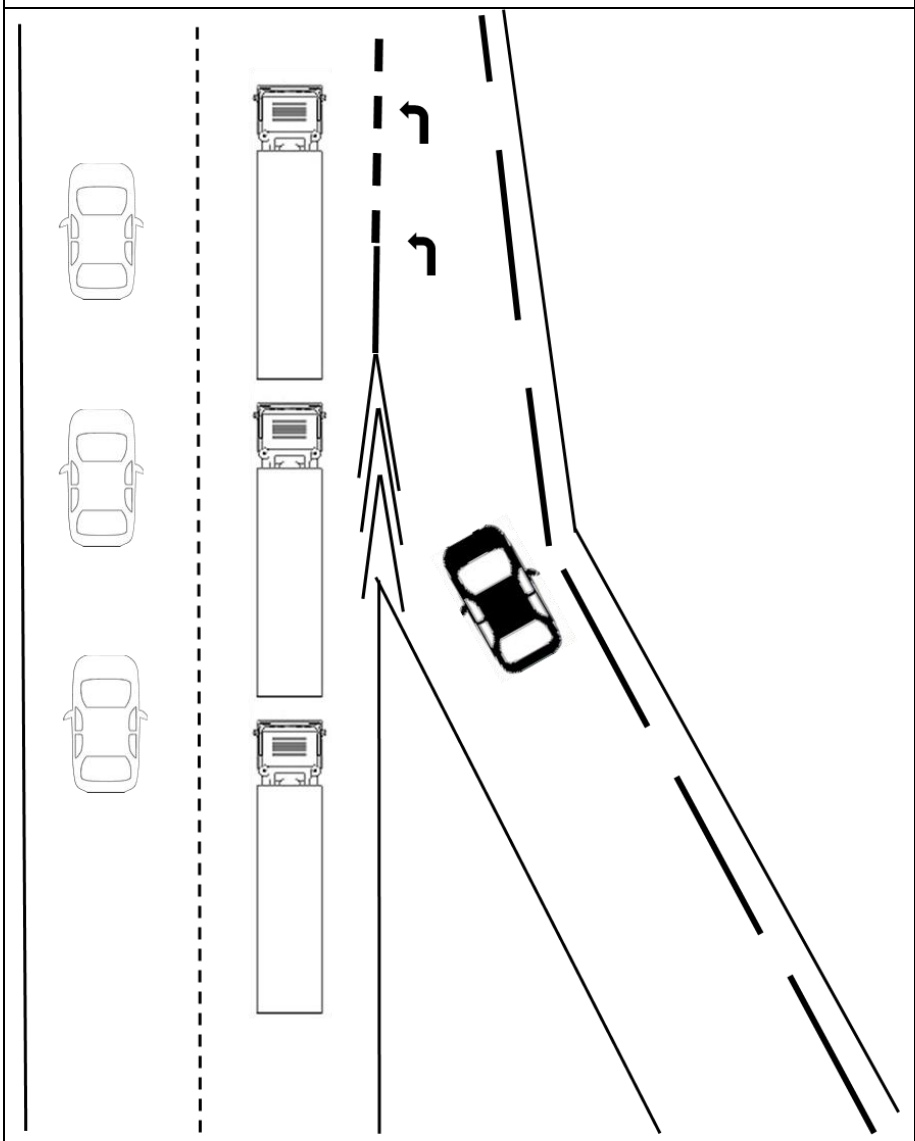
Road event:

Participant is on the road insertion path when the convoy is arriving

Figure 9: Use case 9 (ingress – low traffic – 1.5 sec)

The aim of this use case is to observe road users' behaviour under normal traffic conditions. This situation should give some ideas about the drivers' strategy to entry on the highway (entry in front of or behind or cut-in the platoon). This information will be useful to WP4.5 for the traffic simulation including also speed profile and lane positioning.

2.1.10. Ingress – High traffic – 1.5 second



Road:
- Platoon speed range 80km/h,
- Road structure =2 lanes
- Participant limit speed <130 km/h

Traffic description:
- No vehicle ahead
- No vehicle behind
- Several vehicles are located on the left lane
- 3 or 7 trucks in the platoon
- 1.5 second as inter-vehicular distance in the platoon

Weather:
- Dry road

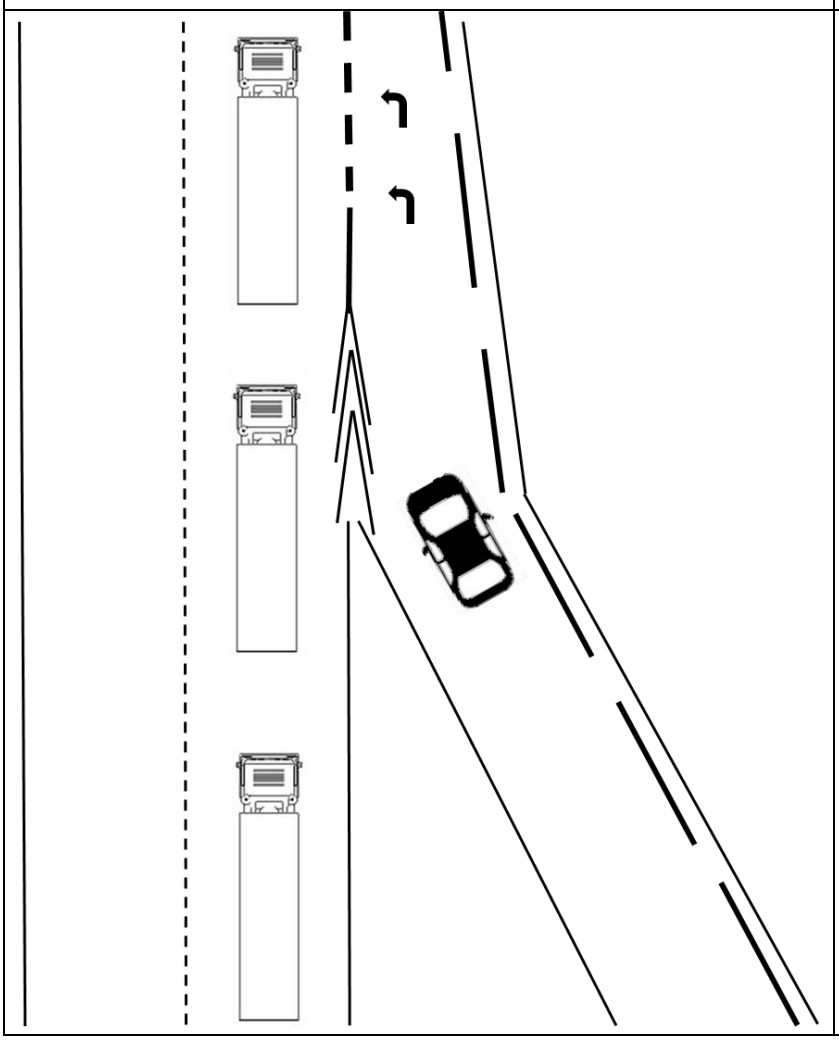
Road event:

Participant is on the road insertion path when the convoy is arriving

Figure 10: Use case 10 (ingress – high traffic – 1.5 sec)

The aim of this use case is to observe road users' behaviour under high traffic conditions and will give information about road users' behaviour during the highway ingress. The impact of traffic on drivers' strategy will be studied here.

2.1.11. Ingress – Low traffic – 0.8 second



Road:
- Platoon speed range 80km/h,
- Road structure =2 lanes
- Participant limit speed <130 km/h

Traffic description:
- No vehicle ahead
- No vehicle behind
- No traffic on the left lane
- 3 or 7 trucks in the platoon
- 0.8 second as inter-vehicular distance in the platoon

Weather:
- Dry road

Road event:

Participant is on the road insertion path when the convoy is arriving

Figure 11: Use case 11 (ingress – low traffic – 0.8 sec)

The aim of this use case is to observe road users' behaviour under normal traffic conditions (no impairment). This situation should give some ideas about the drivers' strategy to entry on the highway (entry in front of or behind or cut-in the platoon). This information will be useful to WP4.5 for the traffic simulation including also speed profile and lane positioning. This use case will be compared to use case 9.

2.1.12. Ingress – High traffic – 0.8 second

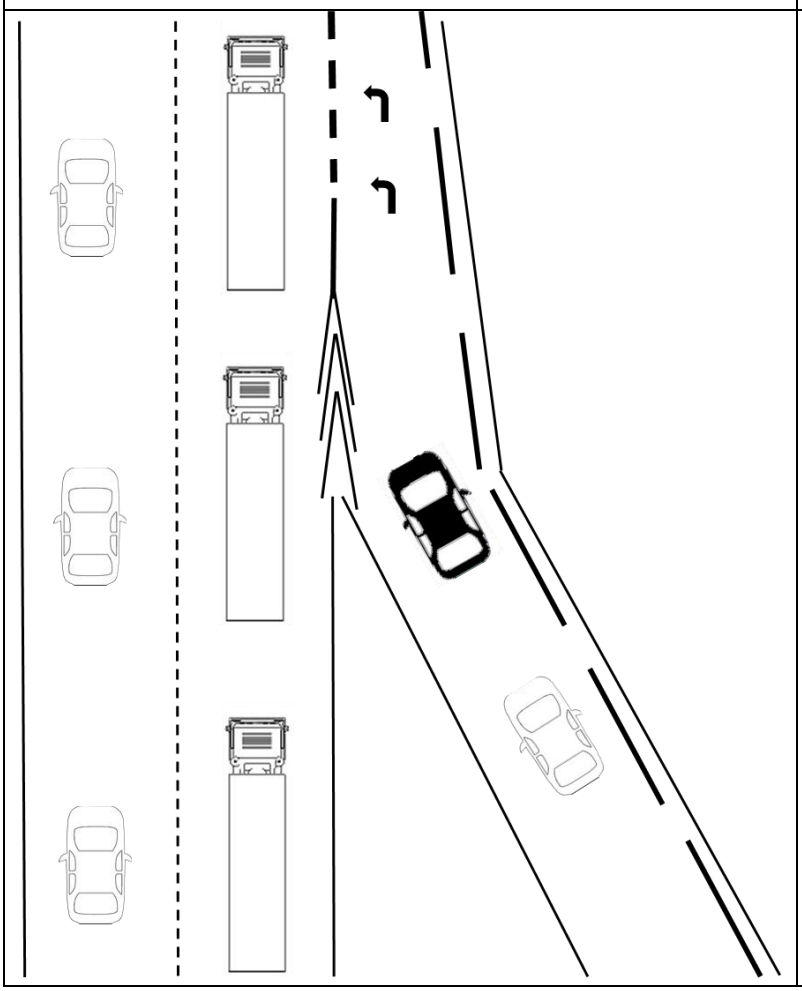
	Road: • Platoon speed range 80km/h, • Road structure =2 lanes • Participant limit speed <130 km/h Traffic description: • No vehicle ahead • One vehicle behind the participant • Several vehicles are located on the left lane • 3 or 7 trucks in the platoon • 0.8 second as inter-vehicular distance in the platoon Weather: • Dry road Road event: Participant is on the road insertion path when the convoy is arriving

Figure 12: Use case 12 (ingress – high traffic – 0.8 sec)

The effect of 0.8 sec as inter-vehicular distance between the trucks will be studied in terms of choice of strategy, speed profiles and emotions.

2.1.13. Overtaking – slow down behaviour - 1.5 second

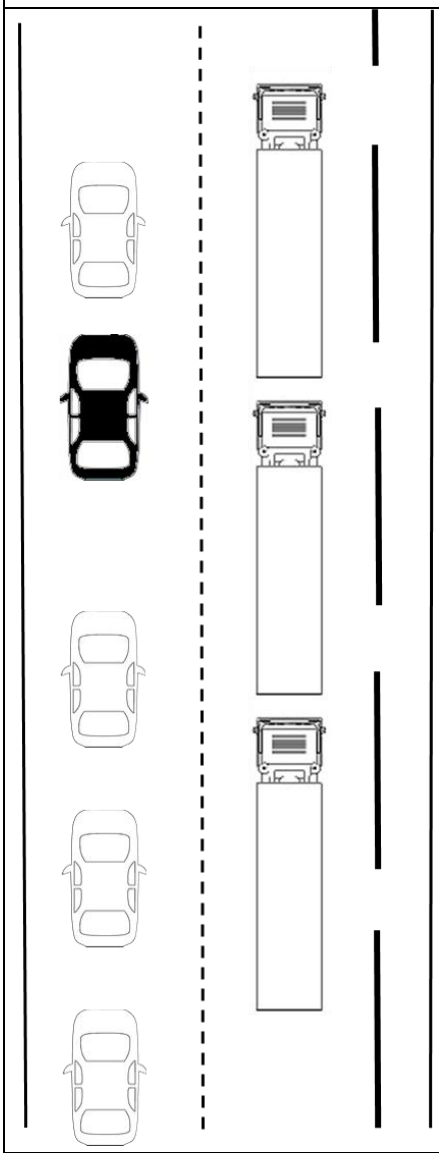
	Road: • Platoon speed range 80km/h, • Road structure =2 lanes • Participant limit speed <130 km/h Traffic description: • several vehicles ahead • several vehicles behind • 3 or 7 trucks in the platoon • 1.5 second as inter-vehicular distance in the platoon Weather: • Dry road Road event: One vehicle ahead is slowing down the participant

Figure 13: Use case 13 (overtaking – slow down – 1.5 sec)

This specific use case will give information about the inter-vehicular distance between the participant and the car in front. This information is needed by WP4.5 to simulate of traffic jam creation.

2.1.14. Overtaking – slow down behaviour 0.8 second

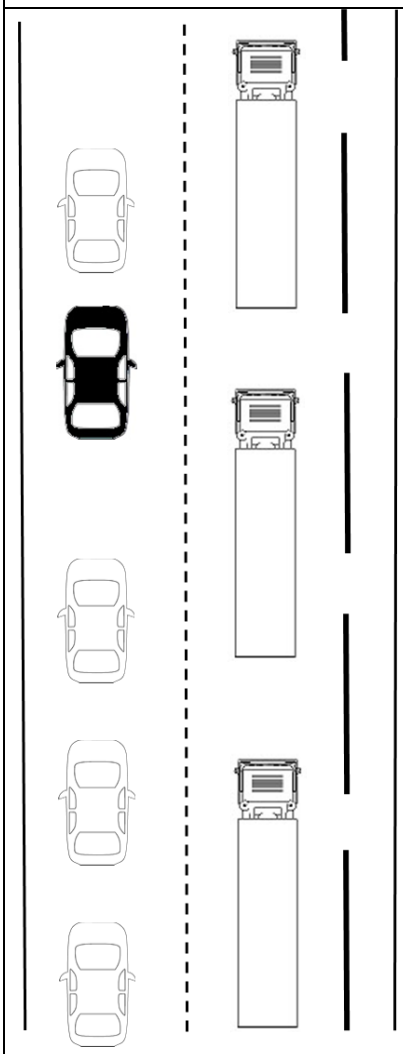
	Road: • Platoon speed range 80km/h, • Road structure =2 lanes • Participant limit speed <130 km/h Traffic description: • several vehicles ahead • several vehicles behind • 3 or 7 trucks in the platoon • 0.8 second as inter-vehicular distance in the platoon Weather: • Dry road Road event: One vehicle ahead is slowing down the participant

Figure 14: Use case 14 (overtaking – slow down – 0.8 sec)

This specific use case will give information about risky behaviour (e.g., respect of safety distance, inter-vehicular distance between the participant and the car in front). This information is needed by WP4.5 to simulate of traffic jam creation. This use case will be opposed to use case 13.

2.1.15. Overtaking – aggressive behaviour - 1.5 second

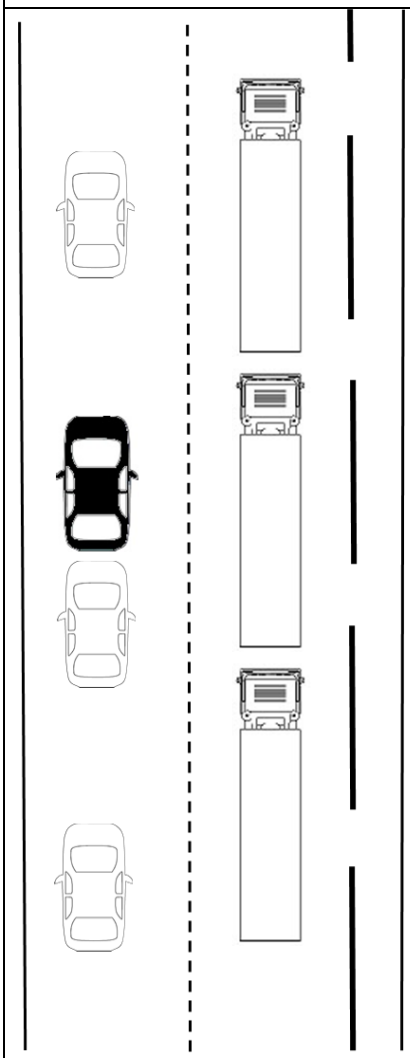
	Road: • Platoon speed range 80km/h, • Road structure =2 lanes • Participant limit speed <130 km/h Traffic description: • several vehicles ahead • several vehicles behind • 3 or 7 trucks in the platoon • 1.5 second as inter-vehicular distance in the platoon Weather: • Dry road Road event: One vehicle behind reduces the safety distance, flashes and honks

Figure 15: Use case 15 (overtaking – aggressive behaviour – 1.5 sec)

This specific use case will inform about the emergence of risky behaviours. A higher stress level should be induced that could change drivers' behaviour (e.g., cut-in, increase of speed…).

2.1.16. Overtaking – aggressive behaviour - 0.8 second

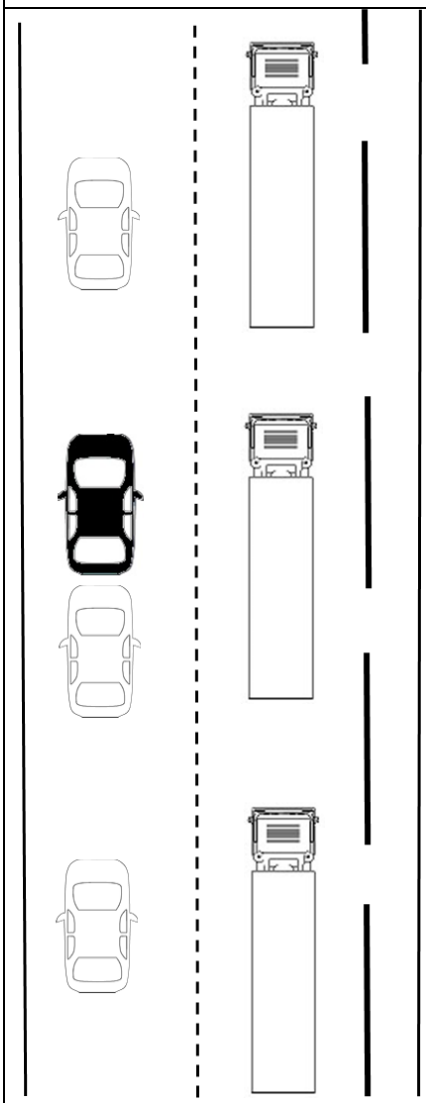
	Road: • Platoon speed range 80km/h, • Road structure =2 lanes • Participant limit speed <130 km/h Traffic description: • several vehicles ahead • several vehicles behind • 3 or 7 trucks in the platoon • 0.8 second as inter-vehicular distance in the platoon Weather: • Dry road Road event: One vehicle behind reduces the safety distance, flashes and honks

Figure 16: Use case 16 (overtaking – aggressive behaviour –0.8 sec)

This specific use case will inform about the emergence of risky behaviours. A stress level should be induced that could change drivers' behaviour (e.g., cut-in, increase of speed…). This situation will compared to use case 15.

3. SIMULATOR ENVIRONMENT

3.1. Car simulator

The car simulator used in this study is developed at IFSTTAR by LEPSiS laboratory. It consists of a Peugeot 308 cabin surrounded by 8 screens of 220 cm × 165 cm. This installation provides participants with a field of view of 280 ° horizontal and 40 ° vertical. An upgrade of the simulator is scheduled especially for the ENSEMBLE project in order to have a 360° of horizontal angle.

Figure 17: please insert figure text according to the template

3.2. Simulator virtual base

The driving environment in which the participants will have to drive on is based on a 2x2 lanes highway and several 1x1 secondary roads. All roads characteristics are representative of French roads policies. The highway is 32 kms long, the width is 3.5 meters. Several curves are implemented. The curves have a radius of curvature of 800m and a curvature angle of between 15° and 60°.

Seven Egresses and ingresses are built in respect of French roads policies. The ingresses are 250 meters long, the egress are 150 meters long. The base allows to let the participants drive continuously from one highway to a secondary road and to a highway again. There are 6 secondary roads with a length comprised between 2 kms and 6 kms with a 3.5 meters width.
The platoon will be implemented only on highway sections while other road users (especially light cars) will be implemented to all the types of roads.

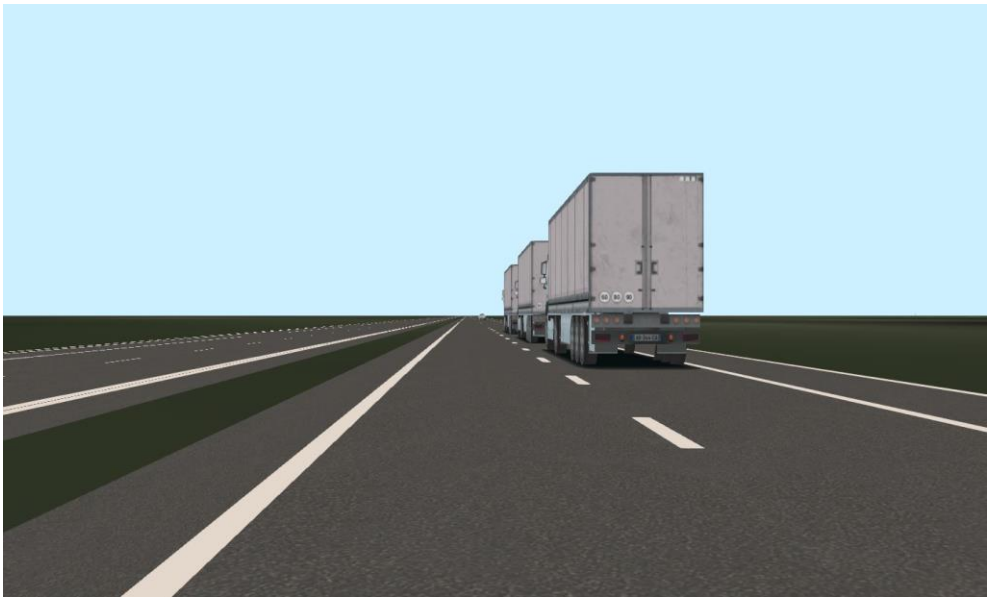


Figure 18: screenshot of an overtaking situation

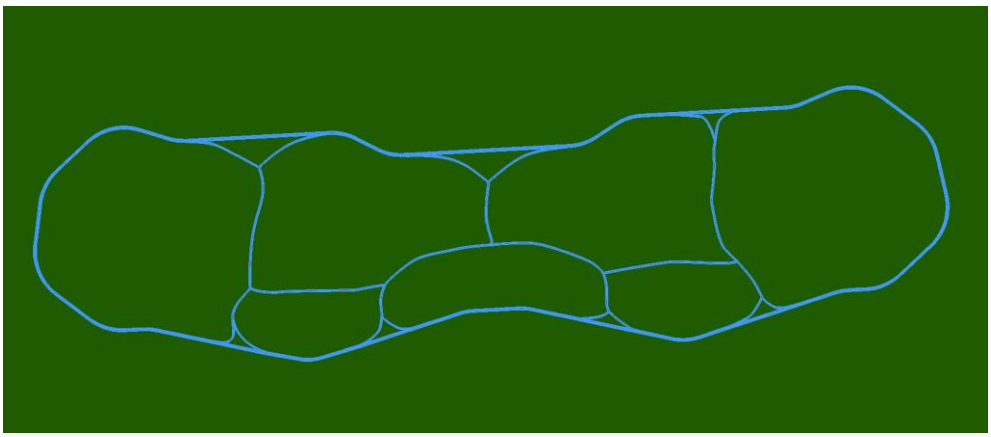


Figure 19: View from above the circuit (highway in the periphery and national roads in the centre)

4. MEASURES

By manipulating these variables, light car drivers will have the possibility to cut-in or cut-through the platoon. Cut-in situations represent a lane change manoeuvre performed by vehicles from the adjacent lane to platoon's lane, at a distance close enough (i.e., shorter than desired inter vehicle distance) relative to the truck involved in the platoon. A cut-through situation is defined by a lane change manoeuvre performed by vehicles from the adjacent lane (e.g. left lane) to the platoon's lane, followed by a lane change manoeuvre to the other adjacent lane (e.g. right lane or highway exit).
These variable manipulations will allow us to identify and understand the feelings and behaviours of the other road users while encountering the platoon: do light car drivers change their driving behaviours in terms of risky one, do they feel stress or fear during the interactions. Different measures will be assessed to this aim.

In order to assess the interaction between the platoon and road users behaviour, different measures will be recorded: questionnaires and behavioural measures. The questionnaires will help us to assess the feelings felt by the participants during the different driving situations. All participants will have to fill in the different questionnaires before and after the driving situations so as to have an idea of the magnitude of the emotional changes during the interaction with the platoon. We will also collect data from the driving simulator in order to evaluate the possible risks taken by the participants during the cut-in procedures.

List of the different measures that will be collected during the driving situations:

- Questionnaires evaluating emotional state including STAI (State-Trait Anxiety Inventory) T (Spielberger, 2010), Geneva Emotion Wheel (Scherer et al., 2013),
- NASA-TLX to evaluate mental workload (Hart & Staveland, 1988, frecnh version adapted by Cegarra & Morgado, 2009),
- Drivers' activity (video),
- Eye-tracking data. Note that the data collected will concern only the gaze coordinates inside the cockpit,
- Lateral position of the participant,
- Standard deviation of the steering wheel,
- Speed,
- Acceleration variation,
- Inter-vehicular distance,
- Position of each truck of the platoon.

List of indicators:

- Driving strategy: decision making in terms of interaction with the platoon (e.g., number cut-in/cut-through manoeuvres, positioning during ingress/egress (in front or behind the platoon).
- Emotions: level of stress, fear, serenity…

- Visual strategy: Number of fixations in areas of interests inside the cockpit of the car (number of fixations on the mirrors, speedometer…).

5. SUMMARY AND CONCLUSION

This deliverable presents the different use cases that will be assessed during the task 4.4.1 on a car simulator. These use cases will be counterbalanced across the participants. These use cases bring together different technical specifications of the platoon as described in the deliverable D2.2. The objectives of the task 4.4.1 are to test the different platoon specifications during the interaction between the light car road users and the trucks that compose the platoon. Different traffic conditions (high or low traffic) will give some ideas about the interactions and the impacts of road users' behaviour on both road safety and traffic flow. The results obtained here could be also useful to Task 4.5 to improve the traffic model.

6. BIBLIOGRAPHY

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