EUROPEAN COMMISSION

HORIZON 2020
H2020-ART-2016-2017/H2020-ART-2017-Two-Stages
GA No. 769115

ENSEMBLE

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

Deliverable No.	D4.5	
Deliverable Title	Understanding the grouping of trucks phenomenon to forecast the adoption of platooning by truck drivers	
Dissemination level	Public	
Written By	Christophe Mundutéguy, Emmanuel Cohen, Özgür Aycik, Jean-François Bercher Univ Eiffel	21-02-2022
Checked by	Franziska Schmidt, Univ Eiffel	22-02-2022

Approved by	Marika Hoedemaeker, TNO	10-03-2022
Status	APPROVED BY EC	06-08-2022

Please refer to this document as:

Christophe Mundutéguy, Emmanuel Cohen, Özgür Aycik, Jean-François Bercher, Franziska Schmidt (2022). Understanding the grouping of trucks phenomenon to forecast the adoption of platooning by truck drivers. D4.5 of H2020 project ENSEMBLE, (www.platooningensemble.eu)

Disclaimer:

ENSEMBLE is co-funded by the European Commission, DG Research and Innovation, in the HORIZON 2020 Programme. The contents of this publication is the sole responsibility of the project partners involved in the present activity and do not necessarily represent the view of the European Commission and its services nor of any of the other consortium partners.

TABLE OF CONTENTS

Revision history

Version	Date	Author	Summary of changes	Status
1.0	21/02/2022	Christophe Mundutéguy, Emmanuel Cohen, Özgür Aycik, Jean-François Bercher, Franziska Schmidt, Univ Eiffel, FR	Initial version	Prepared
1.1	21/02/2022	Comments by WP Leader (Franziska Schmidt, Univ Eiffel)	Revised version	Prepared
2.0	10/03/2022	Marika Hoedemaeker	Final quality review	Approved

FIGURES

TABLES

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 realise 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 harmonisation 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 has been 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 and 3: implementing this reference design on the OEM own trucks as well as perform impact assessments with several criteria
- Year 4: 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

The phenomenon of spontaneous platoon formation is crucial to study the dynamics of the use and sharing of the road capacities by users in general and the transport of goods in particular. Such information could be useful to transport companies and to public decision-makers for the development of platooning, before the introduction of autonomous vehicles.

Therefore, the objective of this deliverable is to analyse this phenomenon. To do so, an original dataset of inter-vehicle distances between trucks was gathered on French highways, produced by Weigh-In-Motion stations. The distribution of this inter-vehicle distance is measured, correlations with possible explanatory variables are explored. The quantitative analysis is supplemented with a study of the answers to a questionnaire by the test drivers of the ENSEMBLE project.

The main conclusion is that the formation of spontaneous, informal platoons, or convoys, could appear, when truck traffic is high enough. In those situations, distances of less than 2 seconds at current speed are often observed.

INTRODUCTION

Initially, this work package proposed to understand the “convoy” practice to forecast the adoption of platooning by truck drivers. The aim was to identify the variables preceding the formation of the convoy, to specify the strategies developed by the drivers to integrate a convoy, to maintain the distances or to leave it, to give insight in the management of the interaction between the trucks involved in the future platoons. Based on observations on-board the trucks, the driving activity should have been recorded by videos, with the driving situation in front of the driver and the situation behind the vehicle. The video recording would have been combined with the distance and speed recording.

But many difficulties encountered in making observations of the activity of drivers in real situations led us to modify our method. The revised project focuses on the grouping of truck phenomenon rather than the convoy practice, and to identify the conditions based on traffic databases. The definition of a convoy is a group of vehicles, typically motor vehicles (or ships), travelling together for mutual support and protection. Therefore, we consider the grouping of trucks phenomenon, which can be intended or not.

Whereas numerous works focus on the preconditions for the formation of platooning with connected vehicles (Bhoopalam, Agatz, Zuidwijk 2018), there is no literature on the grouping of manually driven Heavy Goods Vehicles (HGV). Nevertheless, this phenomenon is crucial to study the dynamics of the use and the sharing of road capacities by users in general and the transport of goods in particular. Such information could be useful to transport companies and to public decision-makers for the development of platooning, before the introduction of autonomous vehicles. Confronted with vehicle coordination problems before the formation of platoons, the former could benefit from identifying road configurations likely to facilitate these formations (Boysen, Briskorn, Schwerdfeger, 2018), whereas the latter will have to combine land use planning and traffic management.

The grouping of HGVs at a distance smaller than the regulatory 50 meters (corresponding to 2s at 90 km/h) presents certain platooning properties with connected vehicles. As defined by ACEA (2017): “Truck platoons (…) automatically maintain a set, close distance between each other when they are connected for certain parts of a journey, for instance on motorways (…). In the first instance, drivers will remain in control at all times, so they can also decide to leave the platoon and drive independently.” ACEA (2017) notes that “drivers still play a crucial role”. This is why it seemed important to us to identify the road configurations in which they will be more likely to integrate a platoon willingly. Indeed, putting them in similar situations could facilitate their acceptance of the system.

MATERIAL AND METHODS

The material of this research corresponds mainly to quantitative data with a database built from different pre-existing databases. On top of that we collected complementary qualitative data through the consultation of professional forums and exchanges with some drivers via social networks.

3.1. The original databases

The data comes from Weigh-in-Motion systems (WIM) located on several French high-speed roads (freeways and national highways). These systems make it possible to measure and record the weight of each vehicle.

Each time a vehicle passes over the sensors composing the WIM station, the system increments a database. For each heavy goods vehicle (HGV), the system records 95 variables. Among those, the ones of interest for us are: the date of passage, the time on which the first axle passed over the station, the instantaneous speed, the total weight, and the various axle weights, the number of axles, the length between the front bumper and the last axle, the width between the outside of the right wheel and the inside of the left wheel, the lateral deviation from the centre of the lane, the type of vehicle according to the classification of the French Ministry of Ecological Transition. For each HGV, an ID number was created in the form of a month-day-hour-minute-second-passage number.

We obtained from Cerema[1], the databases from 3 weighing stations in operation: Fabrègues (A9), Massay (A20) and Maulan (RN4). Only the first database had a sufficient number of situations where trucks presented an inter-vehicle time of less than 2 seconds.

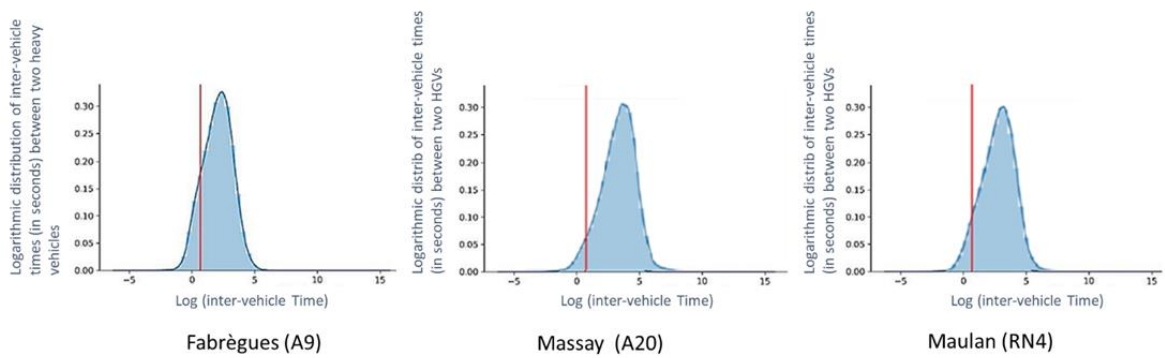


Figure 1: Logarithmic distributions of inter-vehicle time (in seconds) between 2 heavy vehicles for Massay, Maulan and Fabrègues

[1] Centre for Studies on Risks, the Environment, Mobility and Urban Planning is a French public institution under the dual supervision of the ministry for ecological transition and the ministry for regional cohesion and local authority relations,

Thus, the data were all taken from the WIM system located near Fabrègues, in the South of France, on the A9 freeway, in the direction of Montpellier (seventh largest city in France by population, located 13,5 km away), at kilometre point 112.9 (PK), at GPS coordinates 43°32'21.6 "N 3°47'06.0 "E.

The length of the WIM database is one calendar year.

3.2. A new database

New variables were built from the data produced by the WIM system.

3.2.1. Distance between HGV

Not having the distance between the rear bumper of vehicle N and the front bumper of vehicle N+1, an estimation based on the dates of passage, the length and the speed of the vehicles was made:

$$\hat{distance}_{N/N+1} = \Delta date_{N/N+1} * speed_N - lenght_N \qquad (1)$$

The first term corresponds to the distance covered by vehicle N when the first axle of vehicle N+1 is located on the WIM system. At this distance, the length of vehicle N is subtracted to obtain the distance between the last axle of vehicle N and the first axle of vehicle N+1.

3.2.2. Following situations or preparation of overtaking

A short distance at time t does not necessarily correspond to a stabilized following situation. In the absence of dynamic data, drivers' intentions had to be inferred from their speed and their vehicle position in the lane.

A short distance between trucks means the follower attempts to overtake the previous or just stay behind it.

If the driver of the following vehicle is in the centre of the lane or is lined up behind the vehicle in front of him or her, and is traveling at the same speed, it is assumed that the driver does not intend to pass it. On the other hand, if the driver is driving on the left side of the lane or of the vehicle in front of him/her and/or if the driver adopts a higher speed than it, it is assumed that he intends to overtake it quickly.

3.2.3. Hourly traffic

The hourly traffic flow is estimated from the ID number allocated to each HGV. Every six minutes, the number of vehicles is determined based on the difference between the ID numbers of the first registration and the last registration,

$$\hat{traffic} = \frac{nb_{vehicles} * 360}{\Delta date_{first/last}} \quad (2)$$

3.3. Complementary databases

New variables were obtained from additional sources to specify the environmental conditions that may or may not favour the phenomenon of grouping of trucks.

3.3.1. Weather condition

Meteorological data were obtained by web scraping from the website www.infoclimat.fr. Unfortunately, we did not have the data corresponding precisely to the position of the weighing-in-motion station. The meteorological station chosen is located 6.4 km from the weighing station. 5 variables were selected: temperature, wind speed, gusts, wind direction and precipitation.

Data collected had to be combined with the data from the weighing stations. Thus, to each vehicle is associated the meteorological data of the time when it passed over the weighing station.

Given the distance between the collection area and the position of the weighing station, we must be very cautious about the results concerning this environmental dimension and the conclusions that could be drawn from them: To observe the impact of temperature and precipitation, a station located within a 6 km periphery may be sufficient. On the other hand, wind (speed, gusts, direction) is a very local phenomenon. Its direction can change very quickly, and gusts are only present occasionally and locally.

3.3.2. Traffic flow

Later after the estimation of the hourly traffic, data were provided by the road manager, responsible for the portion of the highway where the weighing-in-motion station is located. They allowed us to verify the accuracy of our estimates (see Figure 2).

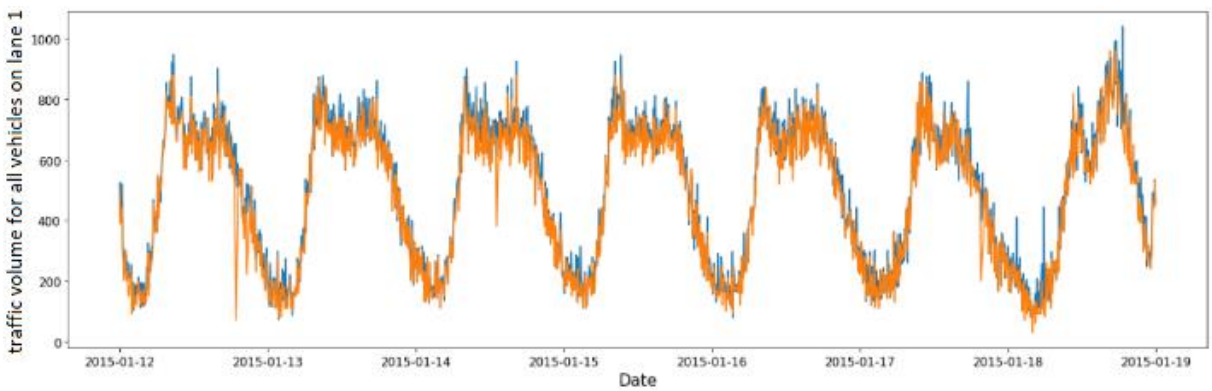


Figure 2: Logarithmic distributions of inter-vehicle time (in seconds) between 2 heavy vehicles for Massay, Maulan and Fabrègues

These variables concerned the traffic flow and were measured every 6 minutes. By aggregating this data, we wanted to measure the impact of the traffic on the groupings of trucks. Data were multiplied by 10, to obtain the flow for one hour (for every 60 minutes).

3.3.3. Qualitative data

The absence of references to the phenomenon of trucks grouping in literature led us to consult professional discussion forums[2] and to enlist the participants in order to gather their experience of the phenomenon. Exchanges were conducted with French, American and Australian drivers in order to clarify the practice of grouping trucks and its possible dependence on the traffic context (type of roads, distances travelled, traffic densities, etc.).

We made the hypothesis that the phenomenon of grouping of trucks can be related to the level of isolation of the driver. This one notably depends on the road context that presents a continuum of urban or peri-urban roads with a high density of traffic and many entry and exit zones to the roads of large spaces with few or no vehicles, and no entry or exit roads.

[2] https://www.quora.com/What-makes-trucks-travel-in-convoys
https://www.planet-truck.fr/forum/topic-1959-1+la-conduite-en-convoi-non-exceptionnel.php

RESULTS

4.1. An infrequent phenomenon in France on regional highways

On the road section where is located the Fabrègues WIM station, 14.39% of HGVs do not respect the safety inter-vehicle time gap (2 sec.) with the previous HGV (Figure 3). They are even less numerous in the other two sites for which we had data.

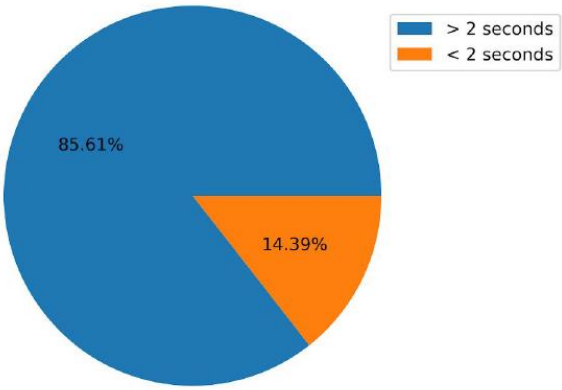


Figure 3: Distribution of HGV compliance with inter-vehicle time.

Nearly three-quarters of the HGV recorded in the database are driving alone (73,75%).

If we distinguish each grouping situation according to the number of involved vehicles, we observe that a large part of these groupings concern only two vehicles (19,62% of all the trucks and 74,77% of grouping situation, Figure 4).

This proportion must be precised because among these situations, there are situations of overtaking. If we restrict ourselves to situations with at least three HGV following each other within less than 2 seconds, and for which we can assume that at least two are in a grouping situation, only 6.62% of all trucks are concerned (25,23% of HGV present in a situation where they have an inter-vehicle time of less than 2 seconds).

Number of trucks in grouping		Number	Proportions		
[redacted]	(1)	1 174 112	**73,75 %**		
[redacted]	(2)	156 200	19,62 %		74,77 %
[redacted]	(3)	26 317	4,96 %		18,90 %
[redacted]	(4)	4 853	1,22 %		4,65 %
[redacted]	(5)	1 023	0,32 %		1,22 %
[redacted]	(6)	225	0,08 %	**26,25 %**	0,32 %
[redacted]	(7)	52	0,02 %		0,09 %
[redacted]	(8)	17	0,008 %		0,03 %
[redacted]	(9)	5	0,003 %		0,01 %
[redacted]	(10)	4	0,002 %		0,01 %
[redacted]	(11)	1	0,0007 %		0,00 %
[redacted]	(12)	0			
Total number of trucks and buses		1 591 936			

Distribution of truck groupings according to the number of trucks involved in

Figure 4 Distribution of truck groupings according to the number of trucks involved.

4.2. A phenomenon dependent to HGV traffic and independent of global traffic

Each day, two peaks are observed at the time slots 7-11 am and 3-7 pm (with maximums at 11 am and 4 pm respectively). Between the two, we distinguish a decrease during the lunch break (12:00-13:00) (**Figure 5**). The working hours therefore seem to be a little more decisive than the hours of circulation.

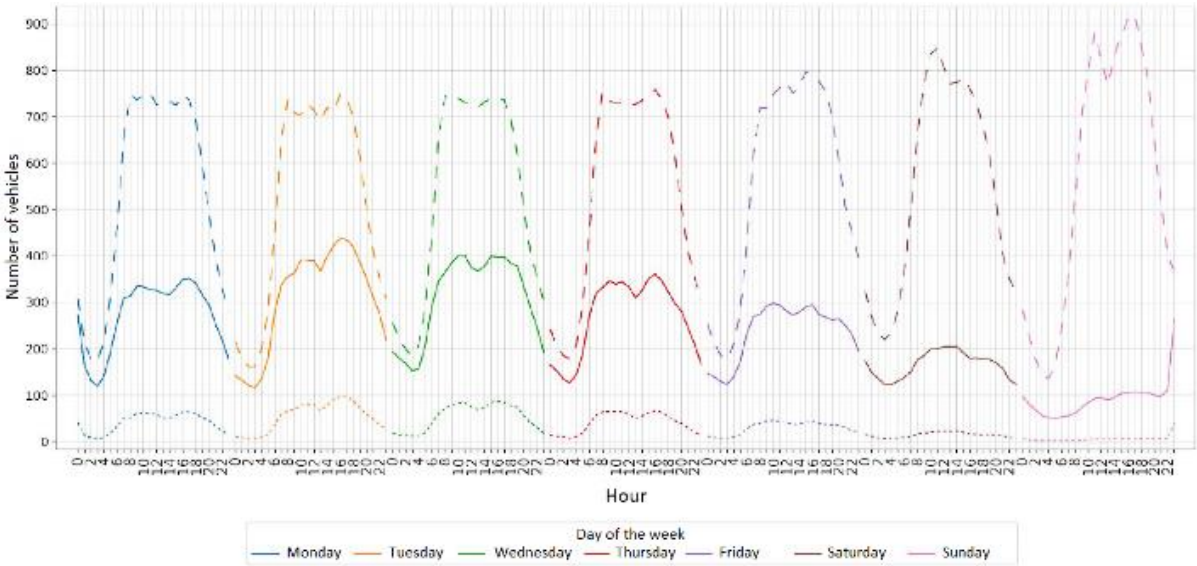


Figure 5: Comparison between overall traffic (dashed line), HGVs traffic (solid line), and the number of HGVs being less than two seconds of the preceding vehicle (dotted line) for each day of the week.

The proportion of HGVs following within two seconds of the HGV in front of them is highest in the middle of the week, on Tuesdays and Wednesdays. It is slightly lower on Monday and Thursday. The proportion continues to decrease on Friday. On weekends, contrary to the total number of vehicles which increases, the number of trucks decreases and becomes very low. In France, without special dispensation, heavy goods vehicles are not allowed to travel from Saturday (or the day before a public holiday) at 10 p.m. to Sunday (or public holiday) at 10 p.m. Contrary to the other days, on Sundays, a part of the truck drivers start driving at 10 pm, and not the next morning. This can be explained by the fact that drivers want to get to their loading or unloading site as quickly as possible, and not suffer the unloading and/or loading of vehicles before them (Hamelin, 1989).

The curve of HGV failing to meet the safety distance seems to be correlated more with the curve of the total number of HGV on lane 1, rather than the total number of vehicles on lane 1. Thus, the reduction in the time gap between vehicles seems to be related more to the density of HGV in the traffic than to the traffic itself.

4.3. Explanatory variables of the trucks grouping phenomenon

On the basis of the previous results, we tried to model the phenomenon and identify the variables that could explain it.

4.3.1. Logistic regression

The most important variables are driving speed, distance from the centre of the track (the “gap” variable); the weekday (especially week-ends), or the all-vehicle flow (AV) on lane 1. Moreover, the

meteorological conditions and the wind in particular do not seem to have an impact on the phenomenon (speed, gusts and direction). It is the same thing with the month (**Table 1**).

```
Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.90820  -0.48706   0.06616   0.47116   1.04575

Coefficients:
                                Estimate Std. Error t value Pr(>|t|)
(Intercept)                    1.482e+00  6.611e-02  22.412  < 2e-16 ***
length                        -5.958e-04  7.123e-05  -8.364  < 2e-16 ***
vvidth                         1.898e-03  2.514e-04   7.549 4.41e-14 ***
speed                         -1.664e-02  5.010e-04 -33.210  < 2e-16 ***
vveight                       -2.046e-04  1.889e-05 -10.835  < 2e-16 ***
gap                            2.416e-03  8.976e-05  26.915  < 2e-16 ***
deviation_leftposition         2.778e-02  4.003e-03   6.940 3.96e-12 ***
rain_lovv                     -1.526e-02  7.880e-03  -1.936  0.05283 .
rain_strong                   -9.521e-02  3.457e-02  -2.754  0.00588 **
rain_moderate                 -6.190e-02  2.620e-02  -2.362  0.01816 *
vvind_strong                   1.936e-02  4.760e-02   0.407  0.68422
direction_vvind_ahead          2.668e-03  5.007e-03   0.533  0.59410
direction_vvind_right         -2.874e-03  5.321e-03  -0.540  0.58908
direction_vvind_left           2.838e-03  5.172e-03   0.549  0.58316
gust                          -1.116e-04  1.618e-04  -0.690  0.49026
day_week_2                     6.669e-03  4.497e-03   1.483  0.13804
day_week_3                     4.791e-03  4.698e-03   1.020  0.30788
day_week_4                    -7.540e-03  4.410e-03  -1.710  0.08733 .
day_week_end of the week      -8.626e-02  5.096e-03 -16.926  < 2e-16 ***
day_week_middle of the week    1.950e-02  4.331e-03   4.503 6.72e-06 ***
day_week_weekend              -2.444e-01  9.685e-03 -25.240  < 2e-16 ***
night time                    -5.764e-02  7.006e-03  -8.228  < 2e-16 ***
flow_lane1                     2.423e-04  1.310e-05  18.496  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.2380341)

    Null deviance: 24652  on 98605  degrees of freedom
Residual deviance: 23466  on 98583  degrees of freedom
AIC: 138323
```

Table 1: Logistic regression with all variables

The faster the truck, the lower the probability that it will be within 2 seconds of the truck in front of it. In other words, the higher the speed, the more the driver increases the safety distance to the vehicle in front. The "isolated model" focussed on the speed confirms that the speed has a negative impact on the grouping of trucks (**Table 2**).

```
Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.79100  -0.48738  -0.03798   0.51262   0.71504

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  1.9717647  0.0435280   45.30   <2e-16 ***
vit         -0.0168681  0.0004985  -33.83   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.2471359)

    Null deviance: 24652  on 98605  degrees of freedom
Residual deviance: 24369  on 98604  degrees of freedom
AIC: 142003
```

Table 2: Logistic regression with only speed

Due to the high-class imbalance, adjusting the decision threshold does not significantly improve model performance. The confusion matrix indicates 38,1% of false positive predictions which illustrates the difficulty of measuring the phenomenon (**Table 3**).

```
Score : 56.4 %
Précision : 19.3 %
Recall : 62.8 %
```

Predicted	0	1	All
True			
0	0.472968	0.381731	0.854698
1	0.054055	0.091246	0.145302
All	0.527023	0.472977	1.000000

Table 3: Confusion matrix. Precision is the proportion of true positives among those who were classified as positive and the recall is the capacity of the model to find the positives (proportion of detected positives).

In order to isolate the truck grouping situations from the situations of preparation of overtaking, we considered that in the second case, the follower moves to the left of the lane in order to change lane, and preferably maintains a higher speed than the one of the vehicle in front. In addition to the inter-vehicle time of less than 2 seconds, zero speed differential and an alignment of the vehicles (eventually to benefit from the suction phenomenon) therefore characterize the truck grouping situations.

Nevertheless, the absence of alignment is not a sufficient condition for exclusion from grouping situations. The driver of the following truck may temporarily have to move out of the way of the vehicle in front, just to compensate for the lack of visibility and to obtain information on the road situation ahead, without intending to overtake it. A zero or almost zero speed differential can corroborate this hypothesis. On the other hand, a non-zero speed differential may suggest a catch-up situation and a potential intention to overtake. A gap to the left is assigned a positive value (preparation of overtaking +) while a gap to the right is assigned a negative value (preparation of overtaking -). A speed differential favourable to the following vehicle is assigned a positive value (preparation of overtaking +), in the opposite case, the value is negative (preparation of overtaking -).

4.3.2. Expanded grouping situations

Considering the previous results, the truck grouping situations have been extended to 100 meters vehicle following situations, between September and December. The flow variables are insignificant in the model (low t value). Although long vehicles are not present on the left lane and rarely on the middle lane, the flows on all three lanes were retained.

The higher the flow rate, the higher the probability of truck grouping (see **Table 4**) and **Table 5**. The increased density in traffic leads to a reduction of the distances between vehicles. As the speed in

the middle lane increases, so does the clustering of trucks in the right-hand lane. However, this grouping may be more unintended than intended. The driver of a following vehicle may reduce the distance to the vehicle in front in order to prepare for overtaking, which remains difficult due to the speed of the vehicles in the adjacent lane.

```
glm(formula = is_convoi ~ delta_gap + gap + deviation_position +
    delta_speed + delta_speed_signe + speed +  weight + width +
    length + length_previous  + width_previous + flow_TV_lane1 +
    flow_LV_lane1 +  flow_TV_lane2 + DPMv_speed_lane2 + flow_LV_lane3 +
    DPMv_speed_lane3 + hour +  deviation_position  + delta_speed:delta_speed_sign
    data = train)

Deviance Residuals:
     Min       1Q   Median       3Q      Max
-1.07436  -0.47780   0.08912   0.47299   1.17599

Coefficients:
                                            Estimate Std. Error t value Pr(>|t|)
(Intercept)                                1.964e+00  1.117e-01  17.579  < 2e-16 ***
delta_gap                                  5.220e-04  9.509e-05   5.490 4.03e-08 ***
gap                                       -8.823e-04  3.076e-04  -2.868 0.004129 **
deviation_leftposition                    -3.550e-02  7.065e-03  -5.024 5.07e-07 ***
delta_speed                               -3.826e-02  1.174e-03 -32.603  < 2e-16 ***
delta_speed_speeder                       -5.299e-03  5.352e-03  -0.990 0.322176
speed                                     -1.920e-02  7.109e-04 -27.013  < 2e-16 ***
weight                                    -2.524e-04  2.176e-05 -11.600  < 2e-16 ***
width                                      1.766e-03  2.910e-04   6.068 1.30e-09 ***
length                                    -1.066e-03  8.163e-05 -13.053  < 2e-16 ***
length_previous                            1.257e-03  7.990e-05  15.728  < 2e-16 ***
width_previous                            -1.245e-03  2.925e-04  -4.255 2.09e-05 ***
flow_TV_lane1                              8.906e-05  2.409e-05   3.696 0.000219 ***
flow_LV_lane1                              8.411e-05  2.102e-05   4.002 6.29e-05 ***
flow_TV_lane2                              1.962e-05  9.430e-06   2.080 0.037507 *
DPMv_speed_lane2                           9.440e-04  3.911e-04   2.414 0.015787 *
flow_LV_lane3                             -2.943e-04  1.840e-04  -1.599 0.109788
DPMv_speed_lane3                          -2.230e-04  1.342e-04  -1.661 0.096719 .
night time                                -3.431e-02  8.395e-03  -4.087 4.37e-05 ***
deviation_leftposition                     4.064e-03  3.176e-04  12.797  < 2e-16 ***
delta_speed:delta_speed_signplus_quick     1.190e-02  1.549e-03   7.684 1.56e-14 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for gaussian family taken to be 0.2355369)

    Null deviance: 18146  on 72585  degrees of freedom
Residual deviance: 17092  on 72565  degrees of freedom
AIC: 101062
```

Table 4: Logistic regression with stepwise variables selection

The confusion matrix indicates 21% of false positive predictions and near 20% of false negative predictions (**Table 5**).

```
Score : 59.7 %
Précision : 58.4 %
Recall : 60.4 %
```

Predicted	0	1	All
True			
0	0.303091	0.209655	0.512746
1	0.192858	0.294396	0.487254
All	0.495949	0.504051	1.000000

Table 5: Confusion matrix. Precision is the proportion of true positives among those who were classified as positive and the recall is the capacity of the model to find the positives (proportion of detected positives).

4.3.3. Linear regression model

Once again, the greater the speed, the greater the distance between trucks. It is the same with the weight and the length of the vehicle (**Table 6**).

On the other hand, the longer or the wider the previous truck, the more the inter-vehicle distance tends to decrease. This reduction also appears when the traffic density of the right and middle lanes increases. These situations may refer to cases of slowdowns that leads to catch-ups (**Table 6**).

A speed differential favourable to the following vehicle (likely catch-up situation) and its position shifted to the left in the lane cannot be considered as a stabilized situation of truck grouping. It corresponds to a situation of preparation for overtaking in which the driver is waiting for the favourable slot for the manoeuvre. When the vehicle shifts to the left of the lane, the median of the inter-vehicle distance tends to decrease while when it shifts to the right, it shows variations around the same position (**Figure 6**).

```
Coefficients:
                                          Estimate Std. Error t value Pr(>|t|)
(Intercept)                             -66,423223   4,402487 -15,088  < 2e-16 ***
delta_gap                                -0,046166   0,005616  -8,221  < 2e-16 ***
delta_deviation_leftposition              0,011408   0,231008   0,049  0,96061
gap                                       0,030114   0,012471   2,415  0,01575 *
deviation_leftposition                    1,109483   0,277589   3,997 6,42e-05 ***
delta_speed                               2,587817   0,045939  56,332  < 2e-16 ***
delta_speed_speeder                       0,099382   0,209184   0,475  0,63472
speed                                     1,490319   0,028053  53,126  < 2e-16 ***
weight                                    0,012546   0,000855  14,673  < 2e-16 ***
width                                    -0,098601   0,011439  -8,620  < 2e-16 ***
length                                    0,076295   0,003209  23,777  < 2e-16 ***
length_previous                          -0,068588   0,003143 -21,820  < 2e-16 ***
width_previous                            0,080418   0,011443   7,028 2,11e-12 ***
flow_TV_lane 1                           -0,003800   0,001106  -3,436  0,00059 ***
occupancy rate_lane 1                    -0,151137   0,064972  -2,326  0,02001 *
DPMv_speed_lane 1                        -0,006511   0,003382  -1,925  0,05420 .
occupancy rate_lane 2                    -0,280215   0,062424  -4,489 7,17e-06 ***
DPMv_speed_lane 2                        -0,071900   0,015000  -4,793 1,64e-06 ***
flow_LV_lane 3                            0,018774   0,007119   2,637  0,00836 **
night time                                1,852059   0,329319   5,624 1,87e-08 ***
day_week_end of the week                  0,685716   0,234237   2,927  0,00342 **
day_week_mid-week                         0,074609   0,202298   0,369  0,71227
day_week_weekend                          0,812894   0,629585   1,291  0,19665
delta_gap:delta_gap_leftposition          0,014438   0,007860   1,837  0,06625 .
deviation_leftposition                   -0,232797   0,013754 -16,926  < 2e-16 ***
delta_speed:delta_speed_signplus_quick   -1,483217   0,061018 -24,308  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0,001 ‘**’ 0,01 ‘*’ 0,05 ‘.’ 0,1 ‘ ’ 1

Residual standard error: 23,53 on 111242 degrees of freedom
Multiple R-squared:  0,09126,   Adjusted R-squared:  0,09106
F-statistic: 446,9 on 25 and 111242 DF,  p-value: < 2,2e-16
```

Table 6: Second logistic regression with stepwise variables selection

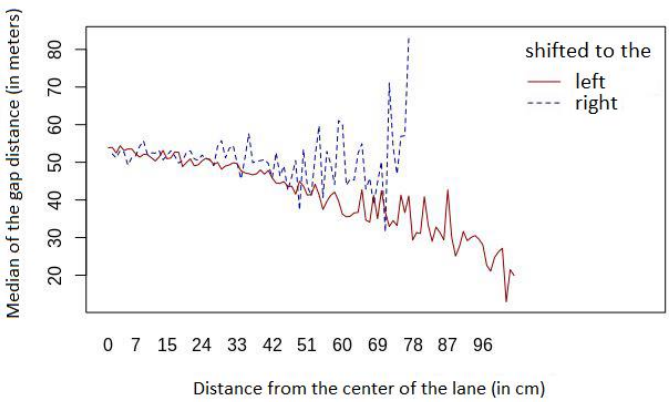


Figure 6: Interaction graph between the deviation from the centre of the lane and the side where the deviation occurs

The results of the regression remain very weak. The R^2 has a value of 0.09 and the ESR equal to 23.53. The percentage of error is equal to 21%.

4.3.4. Clustering

In order to distinguish drivers who try to overtake from those who stay behind the previous vehicle we limited our study to trucks that follow each other at 50 meters or less, by focusing on the speed differential, and on deviations from the centre of the lane and from the centre of the vehicle in front (**Figure 7**).

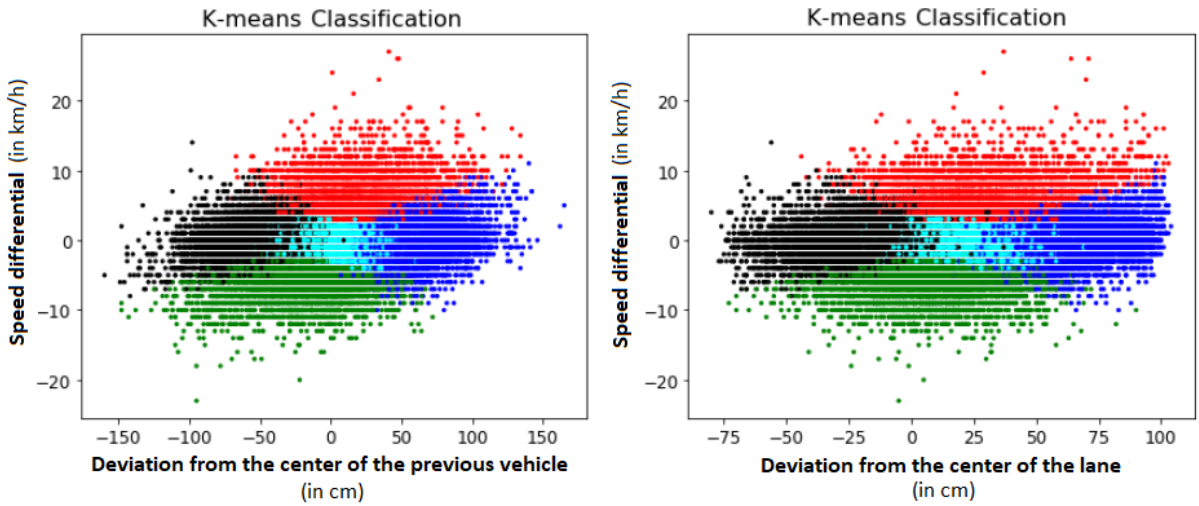
A first group of vehicles (cyan coloured group in the figure) is composed by the vehicles aligned with the previous one and for which the drivers adopt more or less the same speed than the preceding driver. Finally, they are positioned a little to the left of the lane. It can be assumed that **these drivers do not intend to overtake and could be satisfied to adapt their driving to the previous vehicle**.

A second group (red coloured group in the figure) concerns the vehicles in the centre of the lane but eccentric to the left of the previous vehicle. The positive speed differential is high. We assume that **these drivers intend to overtake or have started their overtaking manoeuvre**.

A third group (green group) gathers vehicles in the centre of the lane and to the right of the preceding vehicle. The drivers involved drive much slower than the previous vehicle. This latter has probably completed its overtake. We assume that **these drivers do not intent to follow another truck neither to overtake one**. They seem to want to drive alone.

A fifth and sixth group have both positive and negative speed differentials. The drivers in these groups might be in intermediate situations. In the fifth group (blue coloured group in the figure) the vehicles are placed on the left side of the lane and to the left of the previous vehicle. This gap may be due to the preparation of an overtaking or, given the speed differential, to the simple intention to see the road situation in front of the previous vehicle. There is no way to distinguish these two

scenarios where the drivers could be **simple observer followers** or **overtakers**. Drivers in the sixth group (black coloured group in the figure) are positioned to the right of the lane and to the right of the previous vehicle. They seem more willing to stay behind the vehicle in front of them. The speed differential might correspond to an end of catching up or a beginning of moving away. There is no way to distinguish these two scenarios where the drivers could be **followers** or **overtakers**.



A positive speed differential implies that the vehicle is driving faster than the one it is following, and a positive deviation implies that the that the gap is on the left side

Figure 7: Results of the K-Means classification focused on speed differential between trucks and deviation from the centre of the lane and from the centre of the preceding truck (with 5 clusters).

The linear regression model applied to the groups does not show satisfactory results and particularly for the drivers potentially in an intended grouping of trucks.

Group	Drivers preparing to overtake or in the process of overtaking (Red group)	Overtaken drivers (Green group)	Simple observer followers or overtakers? (Blue group)	Potential drivers in platoon (Cyan) group	Single followers or overtakers? (Black group)
R2[3]	0.103	0123	01	0068	0064
RSE[4]	9.903	9019	1086	106	10.14

In the aim to isolate the grouping of trucks and by considering the previous results, we made a second K-means classification on the trucks following another one at 15 meters or less, while being almost aligned (gap of 30 cm at most to the right or left). The "length of the following vehicle", the

[3] R2 or determination coefficient: statistical indicator between 0 and 1, which indicates the part of the variations of the phenomenon explained by the model (linear). The closer it is to 1, the greater the explanatory power of the model.
[4] RSE: statistical indicator that measures the prediction error in a linear model. The lower it is, the more accurate the model is.

"length of the preceding vehicle" and the "flow of all vehicles on lane 1" are variables to be considered.

Consideration of the traffic variable (see **Figure 8**, right figure) shows that the flow values for the right lane are around 700 vehicles/hour (between 600 and 900), except for the cyan coloured group. The traffic does not seem to affect the drivers in this group. This is also the case with low flow (< 500 vehicles/hour) (see **Figure 8**, bottom figure). In this group of drivers, the grouping of trucks is either intentional or imposed by other factors, such as speed in the middle lane. In all groups, the average speed on this lane is high (around 110 km/h, which is 20 km/h higher than the speed limit imposed on HGV in France). In all the cases, overtaking such a long vehicle cannot be done in a satisfactory time because of the small speed differential with the previous truck.

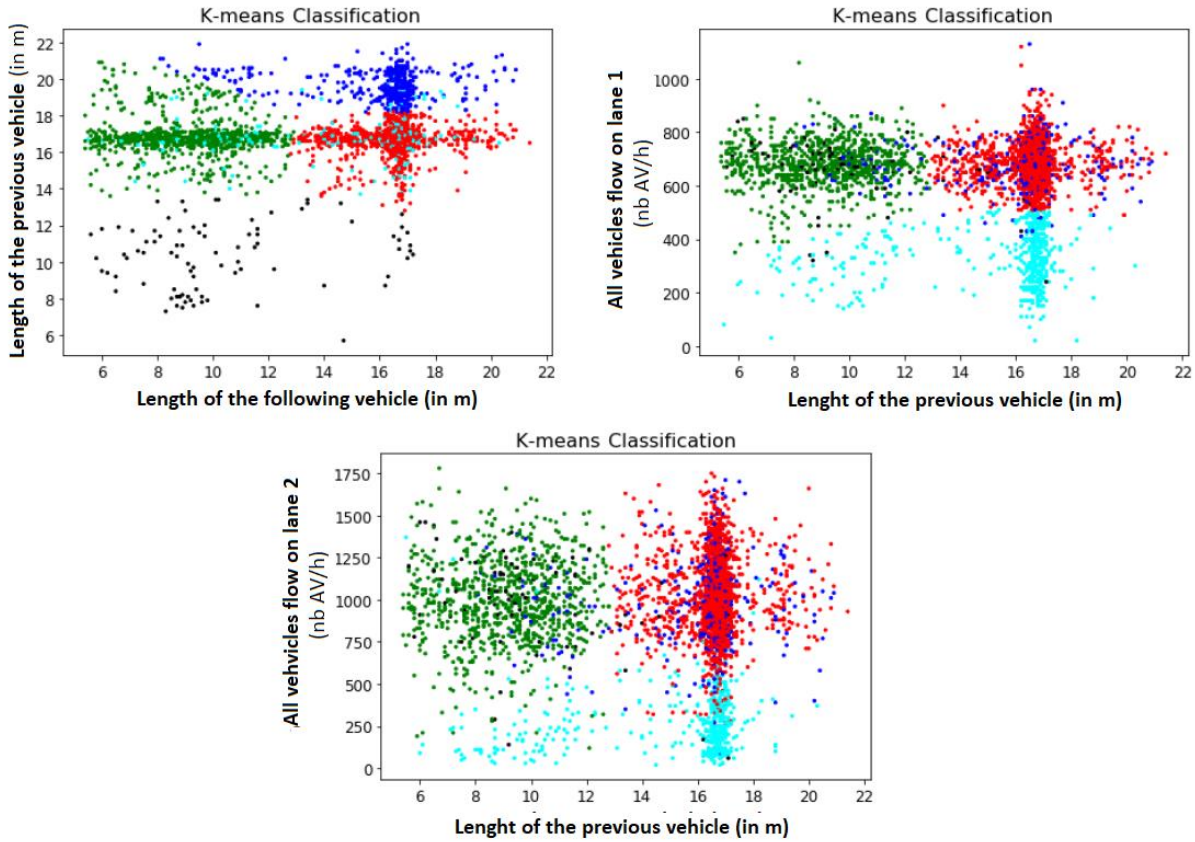


Figure 8: Results of K-Means classification focused on the lengths of the following and the preceding trucks, and the flow of all vehicles on lane 1 (with 5 clusters)

The linear regression model applied to each of these groups still does not show satisfactory results. The black group, with only 88 observations, is the best predicted. However, it has no significant variables and its points are scattered throughout the three figures.

Group	Vehicles of 16.5 meters that follow	"Short" vehicles following another	Vehicles of 16.5 meters that follow	Vehicles that following one	Black

	one of the same length	16.5 meters (Green)	a longer one (Blue)	another in a low flow (Cyan)	
R2	0.074	0.063	0.088	0.124	0.484
RSE	2.147	2.979	2.5	2.287	2.248

4.3.5. New filters to isolate drivers involved in the grouping of trucks phenomenon

Based on the results, and given the difficulties encountered in modelling the phenomenon of truck grouping, we carried out a new analysis of the data from the Fabrègues weigh-in-motion station. This consisted in eliminating from the database the vehicles that were about to overtake or had just been overtaken. For this, we kept only the trucks that had a zero speed differential with the truck in front of them. We then distinguished them according to their inter-vehicle time, which could vary from less than two seconds to five seconds.

The Fabrègues WIM station's database contains 1 590 259 records. There are 43,096 vehicles following a HGV with a zero speed differential and an inter-vehicle time less than or equal to 2 seconds, at an average speed of 87.2 km/h and an average distance of 41 m. The share of this population represents less than 2.7% of the registered vehicles. With higher inter-vehicle times, the proportion of vehicles involved remains low (less than 6% with an inter-vehicle time at least 5 seconds) (**Table 7**). Whatever the inter-vehicle time, the average speed is more or less always the same (around 87.5 km/h). This could be the combined effect of the speed limiters.

Inter-vehicle time	**Number of vehicles**	**Proportion** (%)	**Average speed** (km/h)	**Average inter-vehicle distance (m)**	**Average time (sec)**
at least 2 sec	43 096	2,71	87,2	41	1,71
at least 3 sec	65 638	4,12	87,3	52	2,15
at least 4 sec	82 035	5,15	87,5	61	2,52
at least 5 sec	94 772	5,95	87,6	70	2,85

Table 7: Distribution of the following HGVs according to the inter-vehicle time (for a zero speed differential with the HGV in front) for Fabrègues in 2015

Although there are even fewer trucks within two seconds of the one in front of them, we performed the same treatments on the Massay WIM station database in order to specify the importance of the phenomenon on this type of highway, but especially to check the speeds when it was present. The results are very similar to those of Fabrègues. The database of the Massay WIM station contains 557,383 records. There are 2,955 vehicles following a heavy vehicle with a zero speed differential and an inter-vehicle time less than or equal to 2 seconds, at an average speed of 87.3 km/h and an average distance of 36 m. This represents less than 0.5% of the vehicles recorded. Whatever the inter-vehicle time, we find the same speeds as Fabrègues (**Table 8**). It seems to be an effect of the speed limiters.

Inter-vehicle time	Number of vehicles	Proportion (%)	Average speed (km/h)	Average inter-vehicle distance (m)	Average time (sec)
at least 2 sec	2 955	0,53	87,2	36	1,49
at least 3 sec	6 220	1,12	87,4	49	2,02
at least 4 sec	9 282	1,67	87,5	61	2,51
at least 5 sec	12 028	2,16	87,6	72	2,96

Table 8: Distribution of the following HGVs according to the inter-vehicle time (for a zero speed differential with the HGV in front) for Massay in 2015.

4.4. Test phase, drivers' feedbacks

In addition to the analysis of the data from the weigh-in-motion stations, a questionnaire was distributed to the drivers in the multi-brand test phase. We asked them about their feeling during the six hours of driving, depending on whether they had been the platooning leader or the follower. We received 4 filled-in questionnaires.

For the drivers who were leaders, if the leader keeps the control of his driving activity, he must adapt to the performance of all the vehicles in the platooning. He must align his speed with that of the slowest vehicle in order to maintain contact between the latter and the platoon.

None of the drivers who were in the lead position felt that this position changed his information intake or his level of attention. The experience of being a platoon leader did not lead to any particular tension or feeling of stress for them. Only the driver who was never leader considers that this position could be more stressful. Another one declared that the hazard of technical incidents, as it was the case during the test, could be stressful[5]. The requirement to anticipate the road situation seems perhaps even more necessary for some drivers[6] [7]. In the event that a lighter vehicle stops in front of them, drivers agree to let the system manage the situation. However, one of them points out that it is important to keep in mind that the braking distance of a light vehicle is shorter. He wonders if it is necessary to anticipate these situations or that the system will be more effective than his own reaction time. According to him, sometimes the vehicle might brake late. This last driver and two others do not yet trust the system, which does not work as well as possible[8]. Only one driver has complete confidence in the system[9].

In the end, respondents who were leaders show a divergence of point of view about platooning. Two of them prefer driving outside a platoon. One of them considers that an ACC can perform some sufficient functions. Moreover, among the two drivers who indicated that they had already been in a

[5] *« It depends of the traffic situation, topography, load situations of the trucks and the engine power of the trucks. If there is all automatically working it is less demanding than classic driving. If you have to handle cut ins, and always working on closing the gaps because auf speed differences of truck weights and engine power it is more demanding »* DC.

[6] *« In front it is more attentive for the leader because he has to decide if the platoon has to overtake or not. The vehicle driving behind are not important for the platoon leader aspect of they doing a cut in while overtaking the platoon »* DC.

[7] *« Driving such a large truck, it is hard to see the smaller vehicle behind me. I always pay more attention to the vehicle in front of me, because the traffic situation is unpredictable »* CNH Ind.

[8] *« Not yet. I think the system needs to be refined » CNH Ind ; « Not now, but perhaps in the future »* VR.

[9] *« Yes, totally. I trust the system and feel especially as platoon leader totally save. » DC.*

prolonged driving situation with a short inter-vehicle distance, one emphasized that this reduction was ensured by this kind of assistance system. One driver puts the incidents into perspective and sees potential benefits to the system. At the same time, the driver, who has never been leader, feels that in certain conditions such as night driving with little traffic may be more suitable for driving in a platoon.

When drivers are followers, they report more changes than in non-platooning situations. The reduced field of vision due to the proximity of the vehicle in front causes the driver to give more attention to that vehicle. Overall, drivers feel that platooning requires greater attention because of the short distance between them and the vehicle in front and the probable need to be able to anticipate a deteriorated situation. Among the elements of the situation that require greater attention from drivers, they mention the road environment. Some drivers mentioned more frequent information research from the mirrors. The diversity of the characteristics of the vehicles that make up the group and possible technical incidents are also mentioned. All four drivers admit to have been more stressed by driving in a platoon, which would require more attention. One of them mentioned technical incidents that occurred during the test.

The distance between vehicles is a crucial dimension for drivers. It determines the time available to react to a system failure or to recover a safety distance in case of insertion. Drivers evocate the tension between the reduction of the intervehicle distance, which reduces the probability of a cut-in vehicle that would require regulation, and the increasing inter-vehicle distance, which could lead to more cut-in vehicles. For two of the drivers, the reduction in headway is more stressful than the risk of a cut-in. Only one driver mentions the risk of an accident due to a malfunction of the system and an inter-distance too short to allow the driver to catch up. In case of cut-in and braking of a light vehicle, three of the four drivers trust the system to regulate the situation and maintain a safe distance. However, when we ask them if they would adopt the system, three would not accept it at this level of development.One of them mentions the potential discomfort of the situations of catching up with the malfunctioning of the system.

On the other hand, the four drivers consider that the integration of a platoon did not lead to a change in their behaviour. Concerning the communication with the other drivers of the platoon, the drivers specify that they or their co-driver regularly exchanged with the other drivers via the HMI proposed by the system or the CB. One of the reasons for this was the organization of the platoon.

Finally, only one of the four drivers prefers to drive with platooning because of its greater responsiveness to sudden braking. Another one considers that the system could take over when driving in a sequence where environmental conditions would allow it and the driver could be relieved.

CONCLUSION AND DISCUSSION

The study described in this deliverable consisted of building a new database from existing data of weight-in-motion measurements of vehicles, the engineering of new features and the addition of data in open access. One of the main difficulties was inferring a dynamic phenomenon (the maintenance of an inter-vehicular time gap of less than two seconds) from static data. Nevertheless, the results suggest new directions to explore in order to determine the main variables explaining the grouping of trucks. While traffic density does not seem to be a determining factor, HGVs density appears to be one.

The main conclusion is that the formation of spontaneous, informal platoons, or convoys with an inter-vehicle time of less than 2 seconds, is uncommon on the type of roadway addressed in this study (French provincial highway near a regional agglomeration) Despite a significant number, no explanatory variable was identified as contributing to the phenomenon. Nevertheless, if overall traffic has no effect on the phenomenon, truck traffic, when it is sufficiently important, could contribute to its occurrence. The speed limit of the engines of the trucks could be the main cause.

What other crucial variables may be at the origin of this phenomenon? Whether they are exogenous (infrastructure, weather conditions…) or endogenous (engine performance, time constraints…), the knowledge and the understanding of the role of these variables could make it possible to set up the most favourable conditions for the adoption of platooning by drivers.

Concerning the questionnaire, the conditions under which the test was conducted and the small sample size of respondents do not allow us to conclude anything about the acceptability of the system by drivers. Questions are nevertheless raised about the level of automation that will be retained and the context of its implementation. Regardless of the situation, drivers seem eager to maintain a supervisory role in the event that they need to regain control of the vehicle (Banks and Stanton, 2016) even if some studies underline an over-trust in a second time (Banks et al, 2018). In that case, is it realistic to consider them as not being engaged in the travel task? Whatever, if the density of heavy vehicle traffic could be a facilitating factor in the adoption of platooning, a high overall traffic level could, on the other hand, place drivers in a more uncomfortable situation due to their particular apprehension of light vehicle insertions. What will be the consequences when the driver is engaged in a secondary task if he had to take-over from automated driving? Would the driver maintain the secondary task (Wandtner et al, 2018)? What would be the effect of the environment? If some studies underline the importance of a personalized driver readiness predictor as an input parameter for a safe and comfortable transition of control (Zhang et al, 2019*a*), it is also essential to forecast the driver intervention to ensure a sufficient take-over time (Zhang et al, 2019*b*).

BIBLIOGRAPHY

ACEA (2017), EU Roadmap for Truck Platooning <https://www.acea.be/publications/article/infographic-eu-roadmap-for-truck-platooning >

Banks, V. A., Stanton, N. A. (2016). Keep the driver in control: Automating automobiles of the future, *Applied Ergonomics*, 53, 389-395.

Banks, V. A., Eriksson, A., O'Donoghue, J., Stanton, N. A. (2018). Is partially automated driving a bad idea? Observations from on-road study, *Applied Ergonomics*, 68, 138-145.

Bhoopalam, A.K., Agatz, N., Zuidwijk, R. (2018). Planning of truck platoons: A literature review and directions for future research, *Transp. Res. Part B*, 107, 212-228.

Boysen, N., Briskorn, D., Schwerdfeger, S. (2018). The identical-path truck platooning problem, *Transp. Res. Part B*, 109, 26-39.

Wandtner, B., Schömig, Schmidt, G. (2018). Secondary task engagement and disengagement in the context of highly automated driving, *Transportation Research Part F*, 58, 253-263.

Zhang, B., Wilschutt, E. S., Willemsen, D. M.C., Martens, M. H. (2019*a*). Transitions to manual control from highly automated driving in non-critical truck platooning scenarios, *transportation Research Part F, 64, 84-97.*

Zhang, B., Winter, J. de, Varotto, S., Happee, R., Martens, M. (2019*b*). Determinants of take-over time from automated driving: A meta-analysis of 129 studies, *transportation Research Part F*, 64, 285-307.

APPENDIX A. GLOSSARY AND ACRONYMS

7.1. Glossary

7.1.1. Definitions

Term	Definition
Convoy	A truck platoon may be defined as trucks that travel together in convoy formation at a fixed gap distance typically less than 1 second apart up to 0.3 seconds. The vehicles closely follow each other using wireless vehicle-to-vehicle (V2V) communication and advanced driver assistance systems
Cut-in	A lane change manoeuvre performed by vehicles from the adjacent lane to the ego vehicle's lane, at a distance close enough (i.e., shorter than desired inter vehicle distance) relative to the ego vehicle.
Cut-out	A lane change manoeuvre performed by vehicles from the ego lane to the adjacent lane.
Cut-through	A lane change manoeuvre performed by vehicles from the adjacent lane (e.g. left lane) to ego vehicle's lane, followed by a lane change manoeuvre to the other adjacent lane (e.g. right lane).
Ego Vehicle	The vehicle from which the perspective is considered.
Emergency brake	Brake action with an acceleration of <-4 m/s2
Event	An event marks the time instant at which a transition of a state occurs, such that before and after an event, the system is in a different mode.
Following truck	Each truck that is following behind a member of the platoon, being every truck except the leading and the trailing truck, when the system is in platoon mode.
Leading truck	The first truck of a truck platoon
Legal Safe Gap	Minimum allowed elapsed time/distance to be maintained by a standalone truck while driving according to Member States regulation (it could be 2 seconds, 50 meters or not present)
Manoeuvre ("activity")	A particular (dynamic) behaviour which a system can perform (from a driver or other road user perspective) and that is different from standing still, is being considered a manoeuvre.

Term	Definition
ODD (operational design domain)	The ODD should describe the specific conditions under which a given automation function is intended to function. The ODD is the definition of where (such as what roadway types and speeds) and when (under what conditions, such as day/night, weather limits, etc.) an automation function is designed to operate.
Operational layer	The operational layer involves the vehicle actuator control (e.g. accelerating/braking, steering), the execution of the aforementioned manoeuvres, and the control of the individual vehicles in the platoon to automatically perform the platooning task. Here, the main control task is to regulate the inter-vehicle distance or velocity and, depending on the Platooning Level, the lateral position relative to the lane or to the preceding vehicle. Key performance requirements for this layer are vehicle following behaviour and (longitudinal and lateral) string stability of the platoon, where the latter is a necessary requirement to achieve a stable traffic flow and to achieve scalability with respect to platoon length, and the short-range wireless inter-vehicle communication is the key enabling technology.
Platoon	A group of two or more automated cooperative vehicles in line, maintaining a close distance, typically such a distance to reduce fuel consumption by air drag, to increase traffic safety by use of additional ADAS-technology, and to improve traffic throughput because vehicles are driving closer together and take up less space on the road.
Platoon Automation Levels	In analogy with the SAE automation levels subsequent platoon automation levels will incorporate an increasing set of automation functionalities, up to and including full vehicle automation in a multi-brand platoon in real traffic for the highest Platooning Automation Level. The definition of “platooning levels of automation” will comprise elements like e.g. the minimum time gap between the vehicles, whether there is lateral automation available, driving speed range, operational areas like motorways, etc. Three different levels are anticipated; called A, B and C.
Platoon candidate	A truck who intends to engage the platoon either from the front or the back of the platoon.
Platoon cohesion	Platoon cohesion refers to how well the members of the platoon remain within steady state conditions in various scenario conditions (e.g. slopes, speed changes).
Platoon disengaging	The ego-vehicle decides to disengage from the platoon itself or is requested by another member of the platoon to do so. When conditions are met the ego-vehicle starts to increase the gap between the trucks to a safe non-platooning gap. The disengaging is completed when the gap

Term	Definition
	is large enough (e.g. time gap of 1.5 seconds, which is depends on the operational safety based on vehicle dynamics and human reaction times is given). A.k.a. leave platoon
Platoon dissolve	All trucks are disengaging the platoon at the same time. A.k.a. decoupling, a.k.a. disassemble.
Platoon engaging	Using wireless communication (V2V), the Platoon Candidate sends an engaging request. When conditions are met the system starts to decrease the time gap between the trucks to the platooning time gap. A.k.a. join platoon
Platoon formation	Platoon formation is the process before platoon engaging in which it is determined if and in what format (e.g. composition) trucks can/should become part of a new / existing platoon. Platoon formation can be done on the fly, scheduled or a mixture of both. Platoon candidates may receive instructions during platoon formation (e.g. to adapt their velocity, to park at a certain location) to allow the start of the engaging procedure of the platoon.
Platoon split	The platoon is split in 2 new platoons who themselves continue as standalone entities.
Requirements	Description of system properties. Details of how the requirements shall be implemented at system level
Scenario	A scenario is a quantitative description of the ego vehicle, its activities and/or goals, its static environment, and its dynamic environment. From the perspective of the ego vehicle, a scenario contains all relevant events. Scenario is a combination of a manoeuvre ("activity"), ODD and events
Service layer	The service layer represents the platform on which logistical operations and new initiatives can operate.
Specifications	A group of two or more vehicles driving together in the same direction, not necessarily at short inter-vehicle distances and not necessarily using advanced driver assistance systems
Steady state	In systems theory, a system or a process is in a steady state if the variables (called state variables) which define the behaviour of the system or the process are unchanging in time. In the context of platooning this means that the relative velocity and gap between trucks is unchanging within tolerances from the system parameters.

Term	Definition
Strategic layer	The strategic layer is responsible for the high-level decision-making regarding the scheduling of platoons based on vehicle compatibility and Platooning Level, optimisation with respect to fuel consumption, travel times, destination, and impact on highway traffic flow and infrastructure, employing cooperative ITS cloud-based solutions. In addition, the routing of vehicles to allow for platoon forming is included in this layer. The strategic layer is implemented in a centralised fashion in so-called traffic control centres. Long-range wireless communication by existing cellular technology is used between a traffic control centre and vehicles/platoons and their drivers.
Tactical layer	The tactical layer coordinates the actual platoon forming (both from the tail of the platoon and through merging in the platoon) and platoon dissolution. In addition, this layer ensures platoon cohesion on hilly roads, and sets the desired platoon velocity, inter-vehicle distances (e.g. to prevent damaging bridges) and lateral offsets to mitigate road wear. This is implemented through the execution of an interaction protocol using the short-range wireless inter-vehicle communication (i.e. V2X). In fact, the interaction protocol is implemented by message sequences, initiating the manoeuvres that are necessary to form a platoon, to merge into it, or to dissolve it, also taking into account scheduling requirements due to vehicle compatibility.
Target Time Gap	Elapsed time to cover the inter vehicle distance by a truck indicated in seconds, agreed by all the Platoon members; it represents the minimum distance in seconds allowed inside the Platoon.
Time gap	Elapsed time to cover the inter vehicle distance by a truck indicated in seconds.
Trailing truck	The last truck of a truck platoon
Truck Platoon	Description of system properties. Details of how the requirements shall be implemented at system level
Use case	Use-cases describe how a system shall respond under various conditions to interactions from the user of the system or surroundings, e.g. other traffic participants or road conditions. The user is called actor on the system, and is often but not always a human being. In addition, the use-case describes the response of the system towards other traffic participants or environmental conditions. The use-cases are described as a sequence of actions, and the system shall behave according to the specified use-cases. The use-case often represents a desired behaviour or outcome. In the ensemble context a use case is an extension of scenario which add more information regarding specific internal system interactions, specific interactions with the actors (e.g. driver, I2V) and will add different flows (normal &

Term	Definition
	alternative e.g. successful and failed in relation to activation of the system / system elements).

7.1.2. Acronyms and abbreviations

Acronym / Abbreviation	Meaning
ACC	Adaptive Cruise Control
ADAS	Advanced driver assistance system
AEB	Autonomous Emergency Braking (System, AEBS)
ASIL	Automotive Safety Integrity Level
ASN.1	Abstract Syntax Notation One
BTP	Basic Transport Protocol
C-ACC	Cooperative Adaptive Cruise Control
C-ITS	Cooperative ITS
CA	Cooperative Awareness
CAD	Connected Automated Driving
CAM	Cooperative Awareness Message
CCH	Control Channel
DEN	Decentralized Environmental Notification
DENM	Decentralized Environmental Notification Message
DITL	Driver-In-the-Loop
DOOTL	Driver-Out-Of-the Loop
DSRC	Dedicated Short-Range Communications
ETSI	European Telecommunications Standards Institute
EU	European Union
FCW	Forward Collision Warning
FLC	Forward Looking Camera
FSC	Functional Safety Concept

Acronym / Abbreviation	Meaning
GN	GeoNetworking
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GUI	Graphical User Interface
HARA	Hazard Analysis and Risk Assessment
HIL	Hardware-in-the-Loop
HMI	Human Machine Interface
HW	Hardware
I/O	Input/Output
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ITL	In-The_Loop
ITS	Intelligent Transport System
IVI	Infrastructure to Vehicle Information message
LDWS	Lane Departure Warning System
LKA	Lane Keeping Assist
LCA	Lane Centring Assist
LRR	Long Range Radar
LSG	Legal Safe Gap
MAP	MapData message
MIO	Most Important Object
MRR	Mid Range Radar
OS	Operating system
ODD	Operational Design Domain
OEM	Original Equipment Manufacturer
OOTL	Out-Of The-Loop
PAEB	Platooning Autonomous Emergency Braking

Acronym / Abbreviation	Meaning
PMC	Platooning Mode Control
QM	Quality Management
RSU	Road Side Unit
SA	Situation Awareness
SAE	SAE International, formerly the Society of Automotive Engineers
SCH	Service Channel
SDO	Standard Developing Organisations
SIL	Software-in-the-Loop
SPAT	Signal Phase and Timing message
SRR	Short Range Radar
SW	Software
TC	Technical Committee
TOR	Take-Over Request
TOT	Take-Over Time
TTG	Target Time Gap
V2I	Vehicle to Infrastructure
V2V	Vehicle to Vehicle
V2X	Vehicle to any (where x equals either vehicle or infrastructure)
VDA	Verband der Automobilindustrie (German Association of the Automotive Industry)
WIFI	Wireless Fidelity
WLAN	Wireless Local Area Network
WP	Work Package