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Grau en Enginyeria de l'Energia

ENERGY EFFICIENCY COMPARISON BETWEEN HUMAN DRIVERS AND ADAPTIVE CRUISE CONTROL SYSTEM

Memòria i Annexos

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Resum

En aquest projecte s'ha ampliat un model matemàtic implementat en MATLAB-Simulink amb la finalitat d'estudiar quin és el comportament dels vehicles en diferents escenaris de trànsit, tant a nivell de fluïdesa com a nivell de consum energètic.

L'estudi es centra principalment en la incorporació a les carreteres dels vehicles amb ACC (Adaptive Cruise Control), vehicles que regulen la seva velocitat de forma automàtica per evitar col·lisionar amb el vehicle precedent, mantenint sempre una distància de seguretat. S'han dut a terme simulacions amb diferent nombre de vehicles d'aquest tipus per comprovar quin és l'impacte que tenen en la fluïdesa de la circulació i en el consum mig d'energia.

A la memòria s'explica el model desenvolupat per dur a terme les simulacions i es mostren els resultats obtinguts, juntament amb una valoració dels beneficis que comporta per a la circulació i l'estalvi energètic la incorporació de vehicles amb ACC.

Resumen

En el presente proyecto se ha ampliado un modelo matemático implementado en MATLAB-Simulink con la finalidad de estudiar cuál es comportamiento de los vehículos en diferentes escenarios de tráfico, tanto a nivel de fluidez como a nivel de consumo energético.

El estudio se centra principalmente en la incorporación a las carreteras de los vehículos con ACC (Adaptive Cruise Control), vehículos que regulan su velocidad de forma automática para evitar colisionar con el vehículo precedente, manteniendo siempre una distancia de seguridad. Se han llevado a cabo simulaciones con diferente número de vehículos de este tipo para comprobar cuál es el impacto que tienen en la fluidez de circulación y en el consumo medio de energía.

En la memoria se explica el modelo desarrollado para llevar a cabo las simulaciones y se muestran los resultados, además de una valoración de los beneficios que comporta para la circulación y el ahorro energético la incorporación de vehículos con ACC.

Abstract

In this project, a mathematical model implemented in MATLAB-Simulink has been developed with the aim of studying how vehicles behave in different traffic scenarios, not only in fluidity terms but also in energetic consumption.

The study mainly focuses on the incorporation into roads of vehicles with ACC (Adaptive Cruise Control), vehicles that regulate their speed automatically to avoid colliding with the vehicle in front, always keeping a safety distance. Some simulations with different number of vehicles of this type have been carried out in order to find out how the impact on traffic fluidity and average energy consumption is.

In the project report, the model developed to perform simulations is explained and results are shown, as well as an appraisal about benefits for traffic and energy savings that the incorporation of vehicles with ACC involves.

Acknowledgments

First of all, I would like to thank the director of the project, Arnau Dòria Cerezo, not only for proposing me to develop this topic but also for guiding me on how to focus each part of the project and correcting some mistakes. I also appreciate the work done by Jaume Cartró Benavides who permitted me to use his model, something which helped me to quickly decide to carry on with the project. Finally, I am grateful to all those who use the Internet to share their knowledge, without such a helpful online community I could not have solved many of the problems I found while working on this project.

Glossary

MATLAB: it is one of the most used software in the field of science and engineering. It works with matrices, something which simplifies the way to work and program.

Simulink: it is a complement for MATLAB which allows to develop models in a more schematic way, using blocks and links to perform different actions.

Adaptive Cruise Control (ACC): automatic system which calculates the speed difference between the own vehicle and the vehicle in front and corrects speed to keep a safety distance.

Energy usage: in road transport, total amount of energy used to perform a displacement. Its units can be kJ, kWh, kcal or other energy units.

Energy consumption: in road transport, amount of energy to perform a displacement divided by the distance covered. Its unit are usually kWh/km or kWh/100km.

OEM (Original Equipment Manufacturer): company that produces original components of a vehicle.

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1. Preface

1.1. Context and motivation

Transport has always been an important issue for the human being, the need to move has been present since the beginnings of humanity. The invention of the wheel more than 5000 years ago made an important change on the way to transport, not only persons but commodities, but the appearance of the modern car was the turning point where the road transport as we currently know started.

The first modern car invention is attributed to Karl Benz, in 1885. This car, and others produced in the following years were moved by very inefficient combustion engines (engines about 1000 cc produced around 2 hp). During the 20th century the industry of automotion made important improvements in engines efficiency and started to care about greenhouse gases emissions. Nowadays, vehicles can still improve but the room of improvement is getting narrow.

The point where energy efficiency in road transport can still improve is the way how vehicles are driven. Not everybody drives at the same speed or accelerates and brakes equally. These differences between drivers are one of the most important contributors to the generation of traffic jams. Situations where vehicles have to accelerate and brake continuously are not efficient because the energy consumed by the engine to accelerate is wasted later in the braking.

Some OEMs have already developed vehicles with adaptive cruise control systems (ACC). The performance of this driving systems is based on a radar or cameras located at the front of the vehicle. These radars or cameras measure the distance to the vehicle in front continuously, hence the system is able to know whether we are approximating to the vehicle ahead or if it is driving faster and moving away from us.

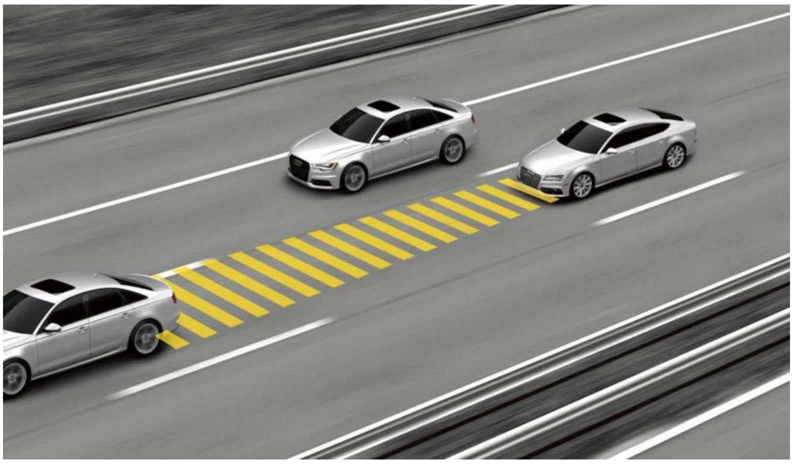

Fig. 1.1. Radar performance in ACC (*cartelligent.com)*

Every OEM of vehicles uses different ACC algorithms but most of them are customizable, selecting the desired speed or the safety distance among others. To simplify the study, a single algorithm for ACC will be used supposing that all vehicles use this algorithm when driving in ACC mode.

1.2. Origin of the project

The project has been developed from a previous work done by Jaume Cartró Benavides [2]. The work consists on a program that is able to simulate traffic situations and show the results in an animation. The model takes into account different driving profiles but does not include the possibility of mixing human drivers and vehicles with ACC in the same traffic situation.

2. Introduction

2.1. Objective of the project

The first objective of this project includes the modification of the model already developed adding some improvements, mainly the energetic model which had not been considered in the previous work. Once the energetic model has been implemented, one can extract some conclusions about the energy consumption related to different driving profiles.

The second objective, and the main one, is to study how the fluidity of traffic and the average energy consumption are affected by the inclusion of vehicles with ACC. Given that this technology is still in growth and there will be a long period of time in which autonomous vehicles and conventional ones share the road, the study will be based on different percentages of vehicles driving in ACC mode. This way, the results will show if we are moving to a better energy efficiency in road transport or if, instead, we are improving our comfort at the expense of a higher energy consumption.

2.2. Scope of the project

The scope of the project goes from the implementation of the energetic model and some other improvements into the existing model to the study of the traffic fluidity and energy consumption considering different amounts of vehicles with ACC. An environmental impact assessment will also be carried out in order to quantify and analyse possible savings in greenhouse gases emissions.

3. Mathematical model

In this chapter, the mathematical model used to run the simulations is explained. There are two main parts of the mathematical model: the driving models which describe how drivers behave (how they accelerate and brake or the safety distance they keep, among others); and the mechanical model which adds physic limitations to the behaviour of the drivers, due to friction forces or vehicles characteristics.

3.1. Driving models

As it was explained before, the purpose of the project is comparing two different driver models. The first model is an approximation to a human driver, while the second one is a simplified adaptive cruise control algorithm. Both models have been implemented in the Simulink model to combine different driver types in different traffic situations.

3.1.1. Human driver model

There is an open source simulation package called SUMO (Simulation of Urban MObility) [9] which contains a lot of different models. Among others, there are lane change models, car-to-car communications and driving behaviour of humans. However, the model used to describe the human behaviour when driving has been extracted from [6]. It is called IDM (Intelligent Driver Model). This model only takes into account longitudinal variables of the traffic, which simplifies the algorithm significantly.

In the IDM model, the acceleration of a vehicle k, driving at speed v_k, with a distance s_k to the vehicle in front of it is given by:

$$\dot{v}_k = \frac{dv_k}{dt} = a \cdot \left[1 - \left(\frac{v_k}{v_0} \right)^{\delta} - \left(\frac{s^*(v_k, \Delta v_k)}{s_k} \right)^2 \right] \qquad \textbf{(Eq. 3.1)}$$

where s^* is the desired dynamical distance. This distance increases when approaching to a slower vehicle and decreases when the vehicle ahead is faster and is given by:

$$s^*(v_k, \Delta v_k) = s_0 + \max\left[0, \left(v_k \cdot T + \frac{v_k \cdot \Delta v_k}{2 \cdot \sqrt{a \cdot b}} \right) \right] \qquad \textbf{(Eq. 3.2)}$$

The different parameters which appear in the previous formulas have the following meanings:

- a. Acceleration in everyday traffic.
- b. Maximum comfortable deceleration in everyday traffic.
- T. Desired safety time headway when following other vehicles.
- v_0. Desired speed when driving in a free road.
- s_0. Minimum bumper-to-bumper distance to the previous vehicle.
- Δv_k. Speed difference between the analysed vehicle and the previous vehicle (positive when approaching). $\Delta v_k = v_k - v_{k-1}$
- Acceleration exponent δ. This value is fixed to 10 and adds information about how fast the driver accelerates to its desired speed.

Equation 3.1 is divided into two different parts. The part containing $a[1-(v/v_0)^\delta]$ corresponds to the desired acceleration on a free road and will tend to zero when approaching to the desired speed. The second part adds the decelerations that are necessary to keep the safety distance with the vehicle ahead. This second part is mainly a function of the own vehicle speed and the speed difference between the own vehicle and the preceding one, but it also takes into account some parameters of the driver such as the acceleration and deceleration in everyday traffic or the desired safety time headway.

Typical values of the parameters associated to drivers are shown in the following table.

Parameter	**Value for a car**	**Value for a truck**
Desired speed v_0	Depending on the road type. About 120 km/h for a motorway and 80 km/h for a conventional road	Depending on the road type. About 90 km/h for a motorway and 70 km/h for a conventional road
Safety time headway T	1.3 - 1.5 s	1.5 - 1.7 s
Minimum gap s_0	2.0 m	2.0 m
Acceleration a	1.3 m/s^2	0.6 m/s^2
Deceleration b	3.0 m/s^2	2.0 m/s^2

Table 3.1. Typical values for parameters associated to drivers' behaviour

3.1.2. Adaptive cruise control model

The model used to simulate an adaptive cruise control system is a very simplified algorithm. It is based on the information in [3], [7] and [8]. The speed for a vehicle k is given by:

$$v_k = k_p \cdot (s_k - s_{ref}) + v_{k-1} \qquad \textbf{(Eq. 3.3)}$$

where s_k is the current distance between two vehicles, v_{k-1} is the speed of the vehicle ahead, k_p is a proportional constant set to 1 and s_{ref} is the reference safety distance. This safety distance increases as the own speed increases to avoid possible crashes:

$$s_{ref} = s_0 + T \cdot v_k \qquad \textbf{(Eq. 3.4)}$$

T and s_0 have the same meaning than the ones in the IDM model.

It may happen that the preceding vehicle is driving with a higher speed than the speed desired by us. In this case the speed would be fixed to V_0 (the desired speed on a free road).

$$v_k = \min\left[k_p \cdot (s_k - s_{ref}) + v_{k-1}, V_0\right] \qquad \textbf{(Eq. 3.5)}$$

In short, what the algorithm does is adapt the speed of the own vehicle until it is the same of the vehicle ahead but always trying to keep the safety distance related to T and v_k.

3.2. Mechanical model of the vehicles

In the previous section, it was explained how the speed or acceleration desired by the driver or the ACC is calculated. The calculated speed may not be the real speed transmitted to the wheels because there are some restrictions. These restrictions are first, the maximum power of the vehicle and second, the maximum force that can be transmitted to the ground from the wheels without slipping.

In the following sections the different forces acting on the vehicle will be explained, using some information in [7].

3.2.1. Traction force

The traction force is limited by the two factors commented. In one hand, the maximum force developed by the engine is given by:

$$F_{traction} = \frac{P_{vehicle}}{v_{vehicle}} \qquad \textbf{(Eq. 3.6)}$$

On the other hand, the maximum force transmitted from the wheels to the ground will depend on the friction coefficient μ between the two surfaces and the normal force N:

$$F_{traction} = \mu \cdot N \qquad \textbf{(Eq. 3.7)}$$

Joining the two previous expressions the maximum traction force developed by the vehicle will be:

$$F_{\max traction} = \min\left[\mu \cdot N, \frac{P_{vehicle}}{v_{vehicle}}\right] \qquad \textbf{(Eq. 3.8)}$$

3.2.2. Resistive forces

The traction force is not the only force acting on the vehicle, there are some resistive forces that require an extra power to be overcome. To simplify the model only three resistive forces have been considered: the drag force due to the friction of the air, the rolling resistance force due to the contact between the tyre and the ground and the gravity force. In the following figure the different forces acting on the vehicle are represented.

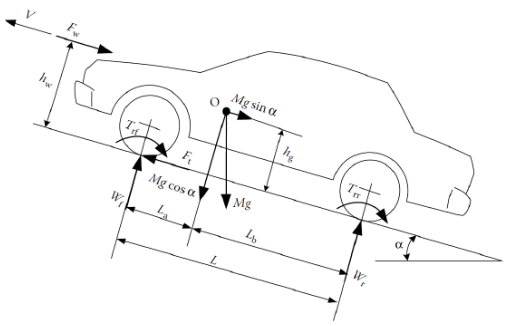

Fig. 3.1. Forces acting on the vehicle

3.2.2.1. Drag force

When considering an object moving through a fluid such as air, several forces act on the surfaces of the object. For competition cars, for example, the downforce created by the wings and diffuser is one of the most relevant but in the present study air forces can be simplified to the ones appearing in the following figure:

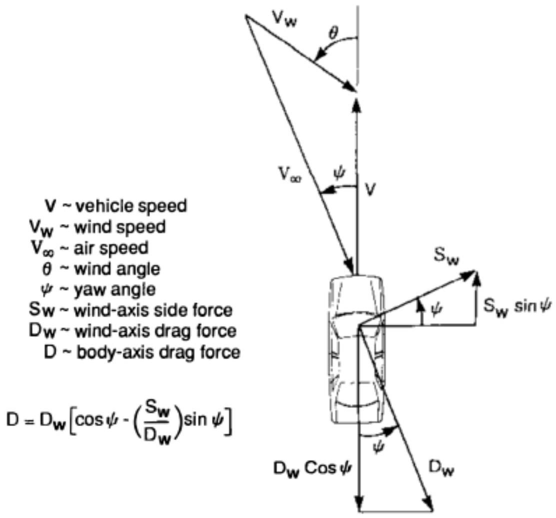

Fig. 3.2. Air forces acting on the vehicle [4]

To simplify the study, the wind has been considered null hence the air force is reduced to the drag force. This force is applied in the opposite direction of the movement of the vehicle and is given by:

$$F_a = \frac{1}{2} \cdot \rho \cdot A_f \cdot c_d \cdot v^2$$ **(Eq. 3.9)**

where ρ is the air density, A_f is the projected frontal area of the vehicle, c_d is the drag resistance coefficient and v is the current speed of the vehicle.

3.2.2.2. Rolling resistance force

Since the contact between the tyre and the road is not a punctual contact, there is a small surface that influences on the movement of the normal force to one side of the axis of the wheel. Because the normal force is not aligned with the axis a torque appears and opposes to the movement of the wheel. The pressure of the tyres is a relevant factor on the magnitude of this force. The rolling resistance force is given by:

$$F_r = f_r \cdot M \cdot g \cdot \cos(\alpha)$$ **(Eq. 3.10)**

where M is the mass of the vehicle, g is the gravity acceleration, α is the inclination angle of the road and f_r is the rolling resistance coefficient. This coefficient is sometimes considered as a constant but to have a more precise value the following equation is used:

$$f_r = 0.01 \cdot \left(1 + \frac{V}{160}\right)$$ **(Eq. 3.11)**

This equation is valid for speeds under 128 km/h. V is the speed of the vehicle in km/h.

3.2.2.3. Gravity force

When the road has a positive slope, the engine will have to overcome the gravity force. This force is given by:

$$F_g = M \cdot g \cdot \sin(\alpha)$$ **(Eq. 3.12)**

In the present work, this force has been omitted although it is one of the most important contributors to the power consumption. It has been omitted because the study only takes into account traffic situations in non-sloped roads.

3.2.3. Mechanical model overview

Using the Second Newton's Law the acceleration can be calculated as:

$$M \cdot \frac{dv}{dt} = F_{traction} - (F_a + F_r + F_g)$$ **(Eq. 3.13)**

We are interested on the power consumed by the vehicle, therefore the traction force can easily be found from the previous expression:

$$F_{traction} = M \cdot \frac{dv}{dt} + F_a + F_r + F_g$$ **(Eq. 3.14)**

The power consumed by the engine will be:

$$P_{traction} = M \cdot v \cdot \frac{dv}{dt} + F_a \cdot v + F_r \cdot v + F_g \cdot v$$ **(Eq. 3.15)**

To have an idea about the behaviour of the different variables, a simple simulation with a single car has been performed using the model explained in Section 4.5. The speed input given is a step of 120 km/h at time = 5 s. The parameters used are listed in the Table 3.2 and the results are shown in Figure 3.3.

Parameter	Mass [kg]	Power [kW]	Air density [kg/m^3]	Friction coefficient	Gravity acceleration [m/s^2]	Frontal area [m^2]	Drag coefficient
Value	1000	70	1.225	0.7	9.8	2.38 m^2	0.35

Table 3.2. Parameters used to perform an initial simulation

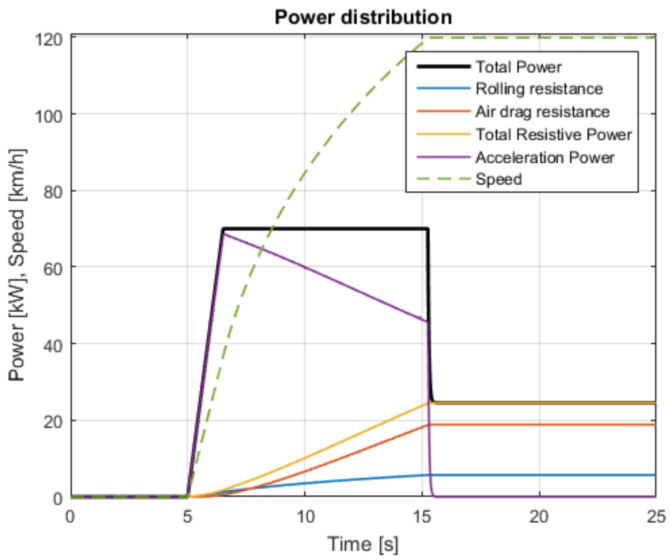

Fig. 3.3. Different powers involved in the acceleration

As it can be seen in the previous figure, the input given as a step does not mean a step in the speed output. This happens because there are the two restrictions commented in the previous sections: in the first seconds of the graph, the restriction of friction between the tyres and the ground acts and makes the total power increase until it arrives to the maximum power of the vehicle (70 kW); it is here when the power limitation appears.

From about 6 seconds on, the acceleration power starts to decrease because resistive forces increase their value while the maximum power of the car stays constant.

Once the vehicle has accelerated up to 120 km/h the power needed is only composed by the power to overcome resistive forces. This fact lets us know that accelerating and braking repeatedly will increase the energy consumption with respect to a constant speed driving.

3.2.4. Energetic model

To get results about energetic consumption, the main equation used is the one to calculate the instantaneous power of every vehicle, which is given by:

$$P_k = \vec{F}_{traction\_k} \bullet \vec{v}_k \qquad \textbf{(Eq. 3.16)}$$

where P_k is the instantaneous power of a vehicle k, $F_{traction\_k}$ is the traction force delivered by the wheels and v_k is the instantaneous speed. It must be noted that the product is a scalar product, but in the case of study the force and speed are considered to be applied in the same direction hence the result is a simple product.

Providing that the purpose of the project is analysing the energy efficiency of ACC systems versus human drivers, an energy consumption equation is needed. The equation for the energy used by one vehicle is:

$$E = \int_t^{t+T} P(t) \cdot dt \qquad \textbf{(Eq. 3.17)}$$

where $P(t)$ is the instantaneous power developed by a vehicle, t is the initial time where energy starts to be calculated and T is the time that the calculation lasts.

Normally, the energy used is not something shown in the car statistics, the variable used is usually the energy consumption per 100 kilometres. To get the distance covered in the time interval where we want to know the consumption we integrate the instantaneous speed $v(t)$:

$$\Delta r = \int_t^{t+T} v(t) \cdot dt \qquad \textbf{(Eq. 3.18)}$$

Finally, the energy consumption per 100 km will be:

$$C = \frac{E}{\Delta r} \cdot 100 \qquad \textbf{(Eq. 3.19)}$$

The units for the energy consumption will be [kWh/100 km]. In this way, there is no differentiation between electric, hybrid or combustion vehicles.

3.3. Test bench

Simulated vehicles will drive around a single-lane circular road, this means that there will not be new vehicles appearing on the simulation. This is not a perfect simulation of real traffic situations but its simplicity makes it much easier to implement than a real traffic simulation. The equation for the road is given by:

$$(x, y) = (R \cdot \cos(\theta), R \cdot \sin(\theta)) \qquad \text{where } \theta \in [0, 2\pi] \qquad \textbf{(Eq. 3.20)}$$

R is the radius of the circumference and θ is the angle in radian.

3.4. Calculations in some of the variables

3.4.1. Averaged variables

Some variables such as power, speed or consumption will have to be averaged to get a function that shows the behaviour of the whole system. This average is calculated for every time as:

$$f_{avg}(t) = \frac{\sum_{k=1}^{n} f_k(t)}{n} \qquad \textbf{(Eq. 3.21)}$$

where $f_{avg}(t)$ is the desired variable to be averaged, $f_k(t)$ is the variable value for every vehicle and n is the number of vehicles in the simulation.

3.4.2. Mean value for averaged variables

Some other variables will also be needed to handle. To better understand this section a plot of the speed is shown Figure 3.4.

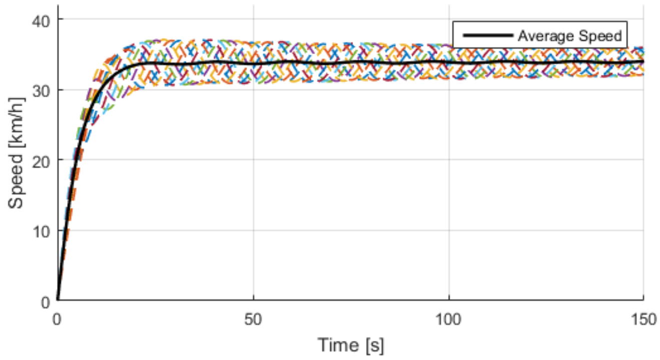

Fig. 3.4. Speed profiles and average speed of vehicles

Figure 3.4 shows the speed of every vehicle in a simulation (in coloured dashed lines) and the average speed (in solid black line). To avoid taking into account the first section of the plot where vehicles are accelerating because they started from null speed, the mean value will only be calculated from a certain point in time until the end of the simulation. The same will happen for other output variables. Figure 3.5 shows how the mean value of a function is represented.

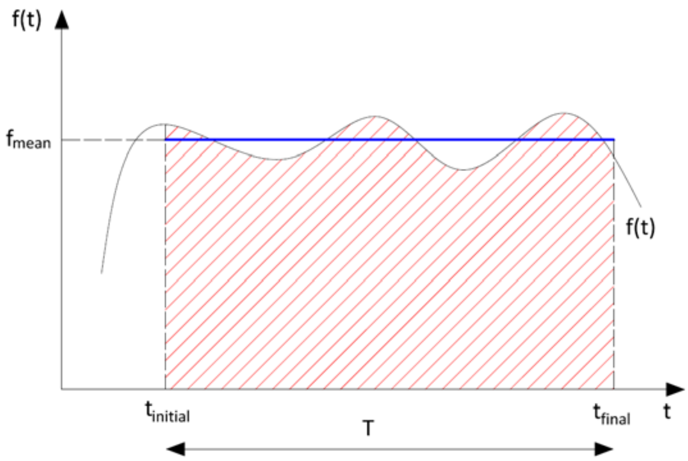

Fig. 3.5. Representation of the mean value of a function

To calculate the mean value of these variables such as average speed of all vehicles, average power of all vehicles or average energy consumption the expression used is:

$$f_{mean} = \frac{1}{T} \cdot \int_{t}^{t+T} f(t) \cdot dt$$ **(Eq. 3.22)**

where *t* is the initial time where the mean value starts to be calculated, *T* specifies the length of the interval and *f(t)* is the function whose mean value we want to get.

4. Implementation of the model

The implementation of the model has been done using the software MATLAB. MATLAB, which stands for "Matrix Laboratory", has the advantage of working with matrices. This fact makes it very suitable for the implementation of the model, because each column of a matrix will represent a vehicle and each row will represent the value of a variable in time.

The mechanical model of vehicles has been implemented in Simulink, a MATLAB complement which allows to perform operations in a schematic way, using blocks and links in a visual environment.

4.1. General structure of the implementation

The initial program used to develop all this project contained several files that do not have an important utility on the purpose of the study. For example, the program used to show an animation of vehicles driving around the circular road, which is not relevant in the current study. Other files that have been omitted are all those ones that referred to situations in a 3D circuit. At the end, the main files used have been reduced to a number of four:

- **Speed and consumption simulations.** It is a MATLAB script that has to be run to perform all the simulations and get all the plots needed for the present study. It contains a first part where all the parameters for the simulation can be changed, a second part of calculations and a third part of results.
- **Fundamental diagrams.** It has the same structure and performance than the previous one, but its purpose is to generate other figures which require different calculations.
- **Vehicles and driving behaviour parameters.** It is a MATLAB function file that generates all the parameters related to driving behaviours and vehicles characteristics.
- **Schematic model of operation.** It is a Simulink model that performs the simulations ordered by "Speed and consumption simulations" or "Fundamental diagrams".

4.2. Speed and consumption simulations

The file `Speed_and_consumption_simulations.m` is the main file of the program. It contains all the parameters needed to perform simulations and plot the results.

The idea is to run several simulations varying some parameters of the system and analyse the results. These variations will be implemented using "for" loops in MATLAB. Loops will contain variations in:

- Traffic density. To perform simulations where the number of vehicles is different and, therefore, the probability of traffic jams is also different, the traffic density will be varied from 10 vehicles per kilometre to 150 vehicles per kilometre.
- Percentage of vehicles driving in ACC mode. The purpose of the study is analysing the impact of the incorporation of ACC vehicles in our roads but, as one can imagine, the adaptation to this new technology will not be instantaneous. As time goes on, more autonomous vehicles will occupy our roads, hence the study will be based on different percentage of ACC vehicles from 0% (all vehicles driven by humans) to 100%.
- Repeating simulations for the same input parameters. Given that some parameters related to drivers' behaviour are generated randomly, simulations will be repeated several times to get a wide range of results for the same input parameters. Some of these parameters that can change among simulations with same input parameters are safety distance, desired speed, desired acceleration or even position of ACC cars inside the traffic distribution.

The following figure briefly shows how loops in the file work.

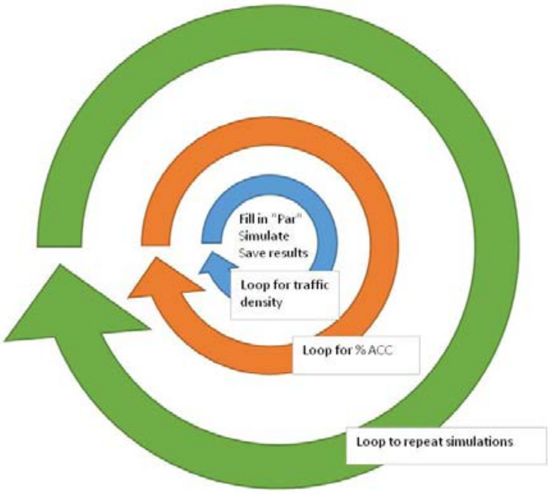

Fig. 4.1. Loop structure of the MATLAB file

For each simulation inside the three loops, the program follows this structure:

1. Fill in the matrix containing all the information about vehicles in the simulation. The matrix is saved as "Par".
2. Perform the simulation using the information stored in the matrix of parameters and other constant parameters.
3. Get results from the simulation and store them in a matrix of results called "Res".

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The matrix of parameters contains one column for each vehicle in the simulation and one row for each parameter stored. The following figure shows how the information is organized:

$$\begin{bmatrix} w_1 & w_2 & \cdots & w_n \\ l_1 & l_2 & \cdots & l_n \\ h_1 & h_2 & \cdots & h_n \\ m_1 & m_2 & \cdots & m_n \\ P_1 & P_2 & \cdots & P_n \\ Pos_1 & Pos_2 & \cdots & Pos_n \\ V_1 & V_2 & \cdots & V_n \\ s_{0-1} & s_{0-2} & \cdots & s_{0-n} \\ T_1 & T_2 & \cdots & T_n \\ a_1 & a_2 & \cdots & a_n \\ b_1 & b_2 & \cdots & b_n \\ K_1 & K_2 & \cdots & K_n \\ DT_1 & DT_2 & \cdots & DT_n \end{bmatrix}$$

1. Width of vehicle
2. Length of vehicle
3. Height of vehicle
4. Mass of vehicle
5. Power of vehicle
6. Initial position of vehicle
7. Desired speed
8. Minimum distance
9. Desired time headway
10. Maximum acceleration
11. Comfortable deceleration
12. Type of vehicle (Car, motorcycle, bus, etc.)
13. Driver type (Human or ACC)

Fig. 4.2. Structure of matrix of parameters

Row 12 for the type of vehicle gives the possibility of setting up the type of vehicle (bus, truck, motorcycle, low-performance car or high-performance car). For the current study only low performance cars have been used, considering that the rest of the vehicles are not likely to use an ACC system.

The matrix of results is a four-dimensional matrix, containing percentage of ACC vehicles, traffic density, average speed and average consumption. If the simulations were performed only once, a three-dimensional matrix would be enough but given that the simulations are repeated to get a wide range of results the fourth dimension is needed.

The four different dimensions have the following meanings:

- Rows. Each row contains data for a certain percentage of ACC vehicles.
- Columns. Each column means a different traffic density.
- Depth. Values in the first position of this dimension are values for average consumption of vehicles and second position contains values for average speed.
- Fourth dimension. The three previous dimensions are repeated several times to get different results on each repetition.

The structure of the matrix is shown in the following figure.

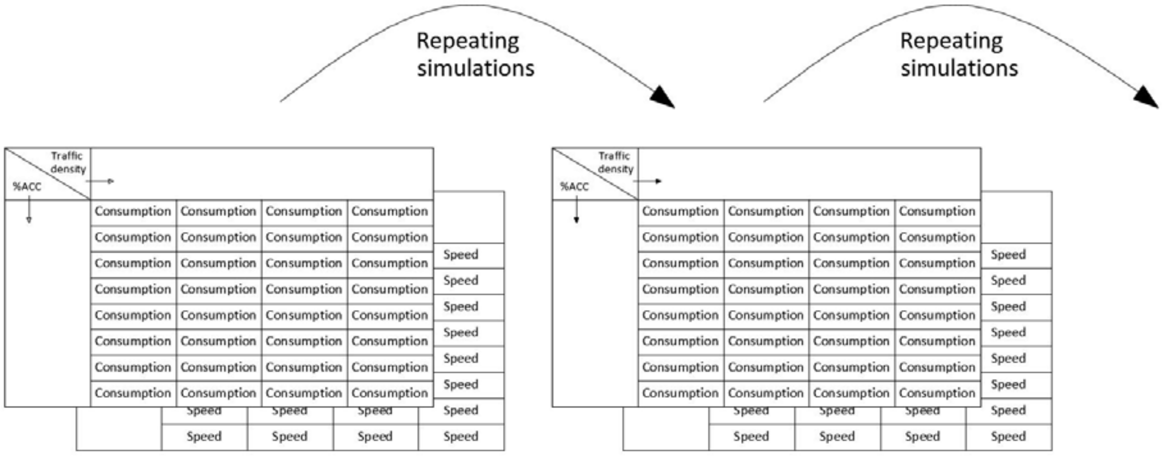


Fig. 4.3. Structure of matrix of results

4.2.1. Setting up variable parameters on each simulation

As explained before, traffic density and probability of vehicles with ACC vary for each simulation.

The Simulink model works with number of vehicles, not traffic density, therefore the input given as traffic density has to be changed to number of vehicles on the road. Knowing that the road is a round circuit the total number of vehicles will be calculated as:

$$n_{Total} = round\left[\rho \cdot (2\pi \cdot R)\right] \qquad \textbf{(Eq. 4.1)}$$

where ρ is the traffic density in vehicles/km and R is the radius of the circuit in kilometres.

The percentage of vehicles driving in ACC mode has to be updated too. To make a difference between human drivers and ACC systems, every vehicle is identified with a "1" for ACC and "0" for human drivers. These zeros and ones are the values in the 13^{th} row of the matrix "Par". Giving that the percentage of vehicles with ACC is P_{ACC} the differentiation is made following these steps:

1. Calculating the number of vehicles with ACC ($n_{ACC}=n_{Total} \cdot P_{ACC}/100$).
2. To make the ACC cars appear in random positions, a vector of random numbers from 1 to n_{Total} with no repeating is generated (Example: [4 6 2 3 1 5]).
3. A vector with length n_{Total}, filled in with "zeros" is generated, to consider for the moment that all drivers are human.

4. This last vector is updated changing some “zeros” by “ones”. The positions that will suffer a change are the ones specified by the first generated vector (until we reach n_{ACC}).

The following figure better shows how this operation is done using an example:

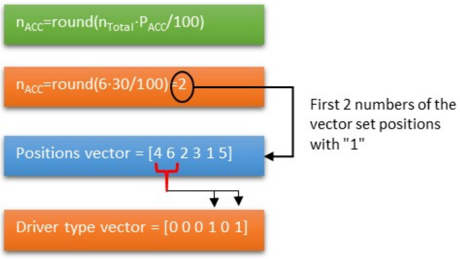


Fig. 4.4. Creation of human drivers and ACC

4.3. Fundamental diagrams

Like the file `Speed_and_consumption_simulations.m` , this script contains almost the same code. The main difference is that the variables calculated to show in the results are not speed and consumption, they are variables related with traffic fluidity.

In reference [10] they introduce the concept of fundamental diagram of traffic. *It describes a statistical relation between the macroscopic traffic flow variables of flow, density and speed.* The aspect of this diagram is the following:

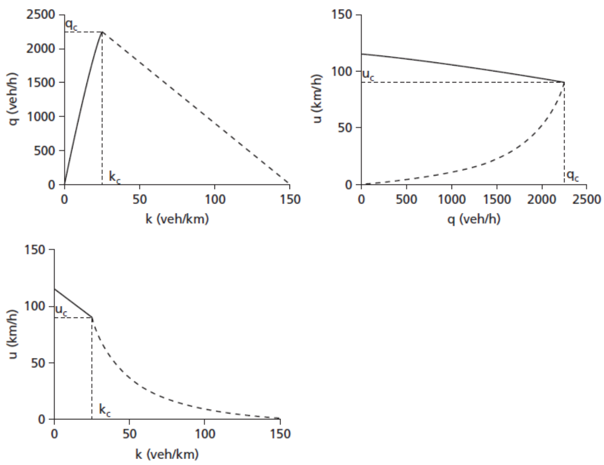


Fig. 4.5. Theoretical fundamental diagram

The points q_c, k_c and u_c correspond to the critical flow, critical density and critical speed respectively. These critical points are situations where traffic jams occur, and they go worse as the traffic density increases.

The three variables in the previous figure are:

- Average speed, u [km/h]. It is the mean value of the average speed of all vehicles.
- Traffic density, k [vehicles/km]. It is an input but it is also saved as an output to be related to the other variables.
- Traffic flow, q [vehicles/h]. It gives the rate of vehicles circulating per unit of time. The relationship among the three variables is given by:

$$q = k \cdot u \qquad \textbf{(Eq. 4.2)}$$

The results of the operations performed by `Fundamental_diagrams.m` are saved in a matrix "Dia" which has the same structure than "Res", the only difference is that there is no fourth dimension and the third dimension contains three positions (one for each of the variables explained above).

4.4. Vehicles and driving behaviour parameters

When one is driving in a highway it is easy to note that not everybody drives the same way: there are differences mainly in the acceleration, braking and safety distances. These differences are one of the most important contributors to the formation of traffic jams which affect significantly to the energy consumption.

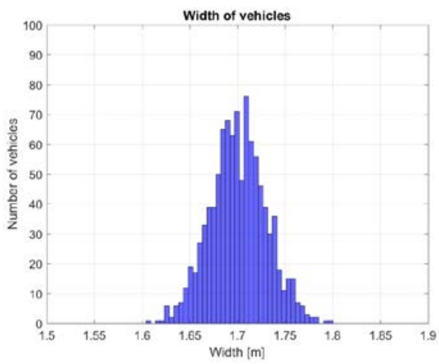
The MATLAB function `Vehicles_and_Driving_behaviour_parameters.m` generates all those differences which affect to the way how drivers (or ACC systems) behave. It also contains all the parameters related to vehicles such as power, dimensions, type of driver (human or ACC). This function is called from the main program to generate the matrix "Par".

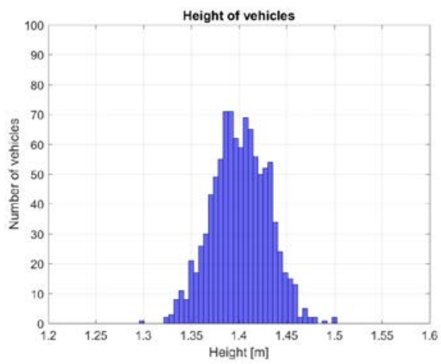
To implement different driving profiles the normal distribution has been used. It is considered that every parameter involving driving behaviours or vehicles characteristics has a mean value and a certain deviation. Mean values for each parameter are shown in the following table, as well as the associated deviation.

Parameter	Mean value	Deviation
Width	1.7 m	0.03
Length	3.9 m	0.1
Height	1.4 m	0.03
Mass	1 000 kg	100
Power	70 000 kW	2 000
Desired speed	80 km/h	5
Minimum distance	2 m	0.2
Desired time headway	1.3 s	0.1
Maximum acceleration	1.3 m/s^2	0.3
Comfortable deceleration	3.5 m/s^2	0.4

Table 4.1. Mean values and deviations for vehicles and driving parameters

To have an idea about how the parameters in Table 4.1 vary, the following figures show the distribution of each parameter for a sample of 1000 cars.





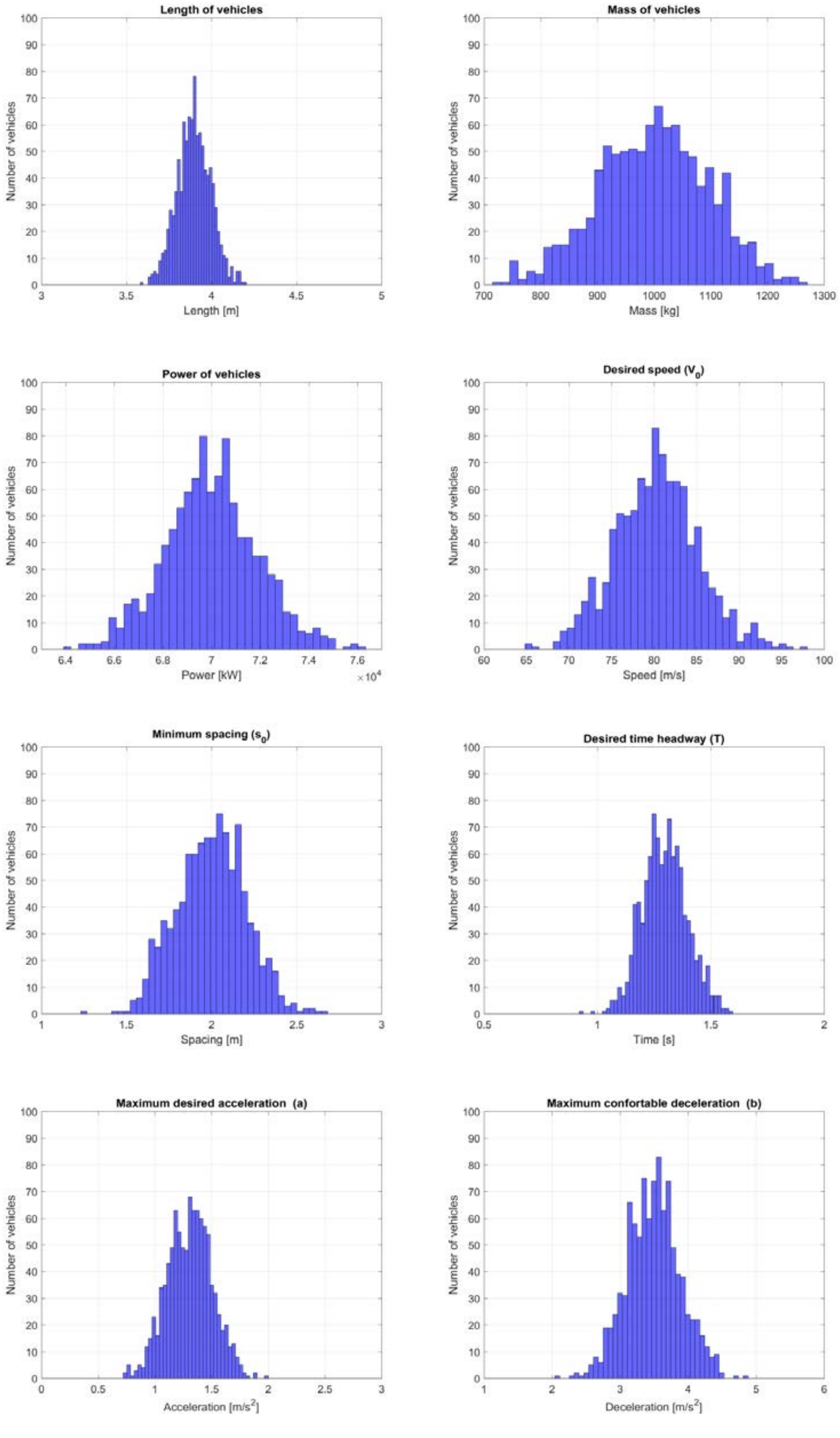


Fig. 4.6. Distribution of vehicles and driving parameters

4.5. Simulink model (Schematic model of operation)

4.5.1. Model overview

The whole model used to perform all the simulation is shown in Annex A. To simplify the understanding of the Simulink file, the following figure shows in a schematic way how the model works.

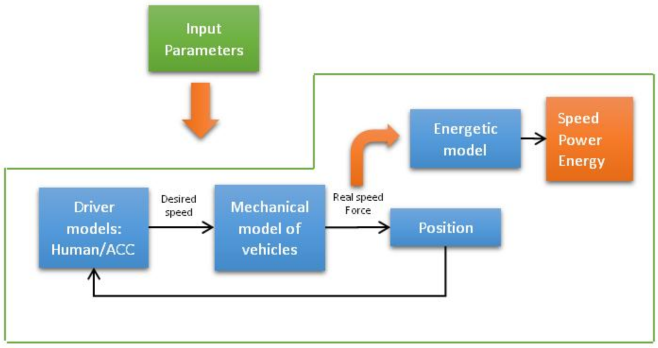


Fig. 4.7. Schematic model of operation

The performance of the model is the following:

1. First, some input parameters are defined. Among these parameters we have length of the simulation, physical parameters such as gravity or road friction, vehicles and drivers' characteristics defined by `Vehicles_and_Driving_behaviour_parameters.m`, traffic density, percentage of vehicles ACC and some others.
2. The program places each vehicle on its initial position with its initial speed and calculates the distance to the front vehicle.
3. Having all this data, driver models calculate the desired speed. This desired speed goes through the mechanical model of vehicles and we get as an output the new speed, new position and the force.
4. The process is repeated until the time reaches the final time defined at the beginning.
5. Simultaneously, and for each simulation step, the force and speed are recorded and manipulated at the energetic model.

4.5.2. ACC and human drivers combination

One of the purposes of the project is to study what happens when human drivers and vehicles in ACC mode coexist on the road. To study this, every vehicle has been identified with a "1" for ACC vehicles and "0" for human drivers as explained in Section 4.2.1.

The developed Simulink model calculates the desired speed by the driver or the ACC system without taking into account the type of driver. That means that for each vehicle we have two desired speeds: one considering that the vehicle is driven by human driver and another one considering it is an ACC system. To select the correct speed for the type of driver the following equation is used:

$$v_{desired} = v_{ACC} \cdot A + v_{human} \cdot (1 - A) \quad \textbf{(Eq. 4.3)}$$

A is a row matrix containing "1" for ACC vehicles and "0" for human drivers. v_{ACC} and v_{human} are matrices in which each column represents a vehicle.

The following picture shows in a more schematic way how this operation is performed:

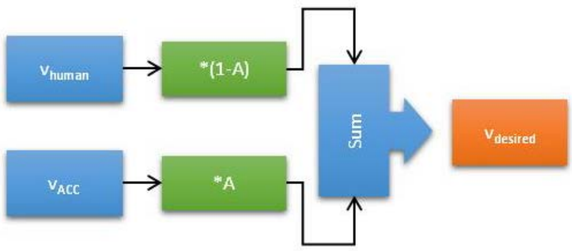


Fig. 4.8. Combination of human drivers and vehicles with ACC

Using this strategy two complementary matrices are obtained: one containing the speed for human drivers and other positions filled in with zeros, and a second matrix containing the speed for vehicles with ACC and the other positions filled in with zeros. Summing these two matrices only means joining them, because there is always a zero in one of the two matrices for each position.

It must be noted that the products used are element-by-element products.

4.5.3. Implementation of the energetic model

The energetic model implemented in Simulink has three main parts. Power calculation, speed calculation (even though it is not directly related to energy) and energy consumption calculation.

Both power and speed follow the same structure, therefore only speed calculation is explained.

1. The most primitive speed signal that we find is a group of the instantaneous speeds for every vehicle in the simulation. This signal is saved as "Vehicles_Speed" in a matrix that contains

one column for each vehicle and as many rows as integration steps done to perform the simulation.

2. The variable "Vehicles_Speed" is averaged to get the average instantaneous speed for the whole set of vehicles. The result is a matrix containing one single column and as many rows as the previous one. It is saved as "Average_Speed".
3. To get a mean value as explained in Section 3.4.2. the signal "Average_Speed" is integrated and divided by the time gap where we want to calculate the mean value and the result is saved as "Global_Speed". This last variable is also a matrix containing one column but not as many rows as the previous matrices. The result on which we are interested is the last value of the vector "Global_Speed", because as explained in Section 3.4.2., this variable is calculated using an integral which sums a value for each integration step, and thus, the correct result is the last sum performed.

The following figure better shows the three variables explained above.

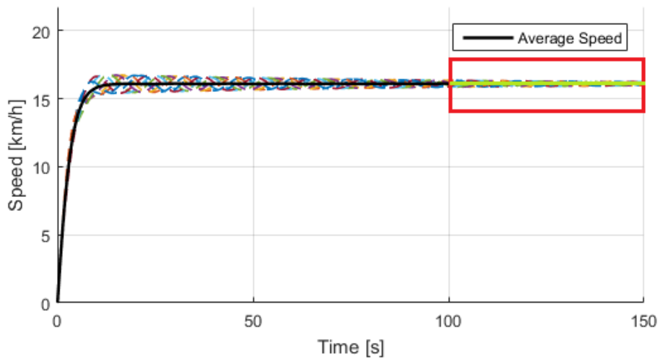


Fig. 4.9. Variables related to speed

Coloured lines show the instantaneous speed for every vehicle and the black line shows the instantaneous average speed for all vehicles. The mean value of the average speed is the one coloured in green inside the red box ("Global_Speed").

For the power calculation, the same steps are followed. The only difference is that the instantaneous power for every vehicle "Vehicles_Power" is first calculated by using equation (Eq. 3.16).

The energy consumption is calculated in a slightly different way:

1. First, both "Vehicles_Power" and "Vehicles_Speed" are integrated. This way we obtain the covered distance and the energy used. The integral is reset to zero at the time where we want to start calculating the energy consumption.

2. Energy is divided by distance covered, adding some unit changes, and the result is saved as "Vehicles_Consumption". This variable contains a column for each vehicle and each row contains the energy consumption from where the counter was reset until the current time instant.
3. As done in speed and power, "Vehicles_Consumption" is passed through a MATLAB function to get the average energy consumption of all cars and saved into "Global_Consumption".

The following figure shows all these variables involved.

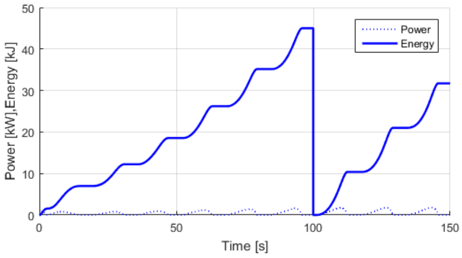


Fig. 4.10. Power and energy for one vehicle

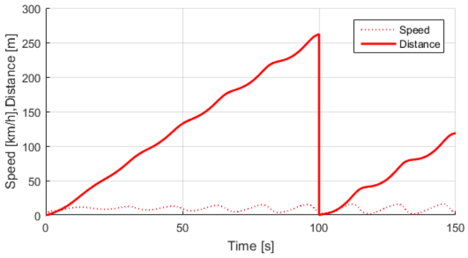


Fig. 4.11. Speed and distance for one vehicle

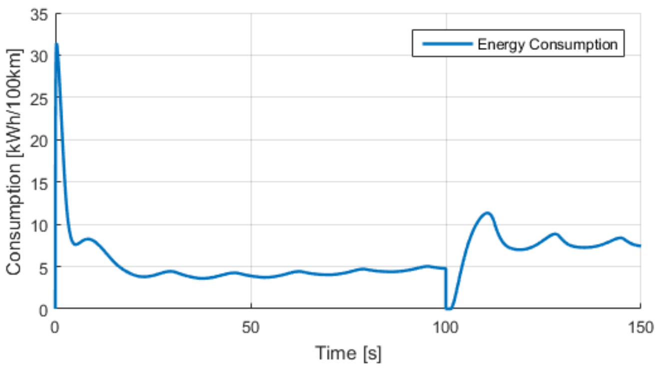


Fig. 4.12. Energy consumption for one vehicle

The three last figures only show variables for one vehicle.

As it can be observed, from 100 seconds on, energy, distance and energy consumption are reset to zero. This is done as it was explained in previous sections to avoid considering transitional states where vehicles are accelerating from zero.

For the Figure 4.12 about energy consumption it must be noted that the instantaneous value of the function returns the average energy consumption (in kWh/100km) from the point where the signal was reset until the point where the function is being evaluated. This is why the function gets smoother as time goes on.

The value on which we are interested is the last value, which returns the energy consumption in the specified time interval (in the example case, last 50 seconds).

5. Simulations

5.1. Initial simulations

To start understanding how vehicles behave in different situations, three simulations have been carried out, one where all vehicles are driven by humans, another one where all vehicles are driving in ACC mode and a last one where there is a mix of the two previous ones.

5.1.1. All vehicles driven by humans

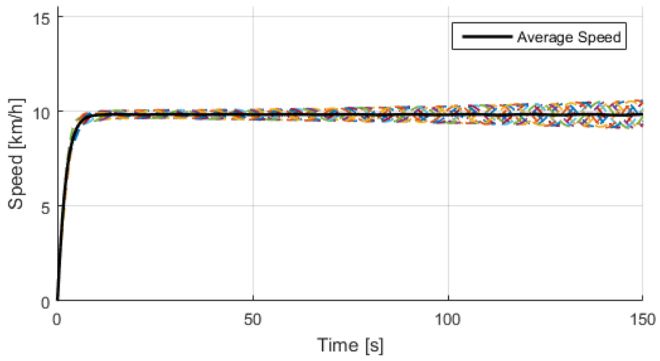


Fig. 5.1. Speed for all vehicles driven by humans

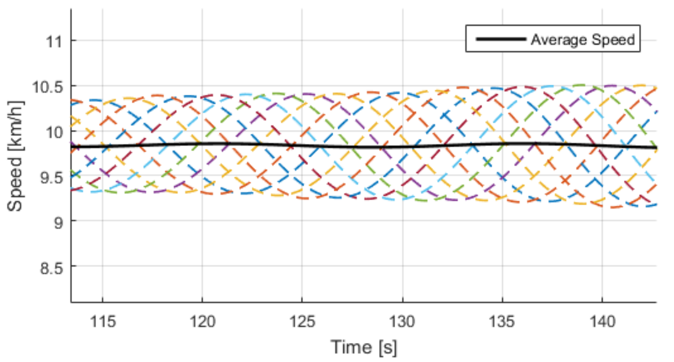


Fig. 5.2. Speed for all drivers driven by humans (Zoomed in)

As shown in the two previous figures, the speed when all drivers are human oscillates. In the performed simulation, this oscillation seems to increase as time goes on. There are other situations where there is not an overcrowd on the road and therefore the oscillation tends to disappear.

5.1.2. All vehicles in ACC mode

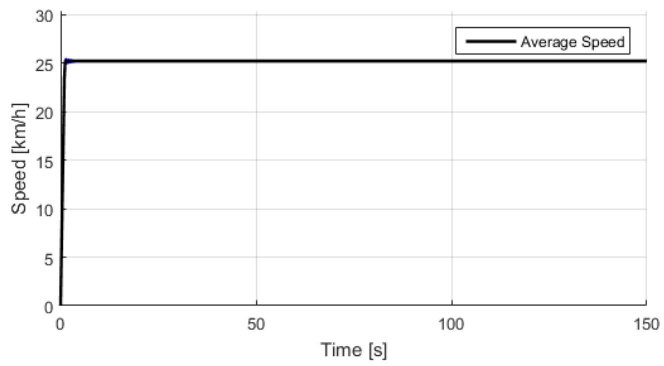


Fig. 5.3. Speed for all vehicles with ACC

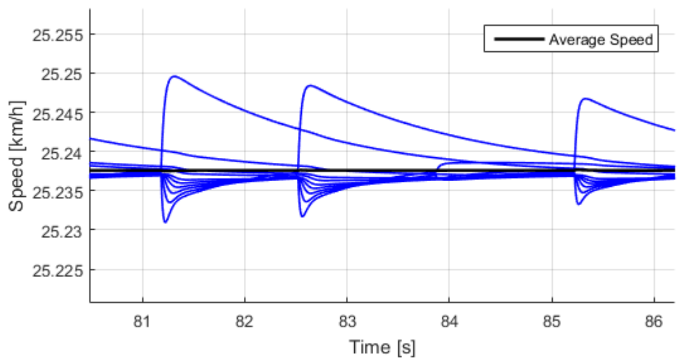


Fig. 5.4. Speed for all vehicles with ACC (Zoomed in)

When all vehicles are driving in ACC mode one can see that the speed for all vehicles is almost the same. In the zoomed image, we see that the speed oscillates in a very small range, correcting slight deviations to avoid exceeding the safety distance.

This difference in the amplitude of the oscillation when we have human drivers or ACC makes a difference on the consumption as it will be explained later.

5.1.3. Combination of human drivers and ACC

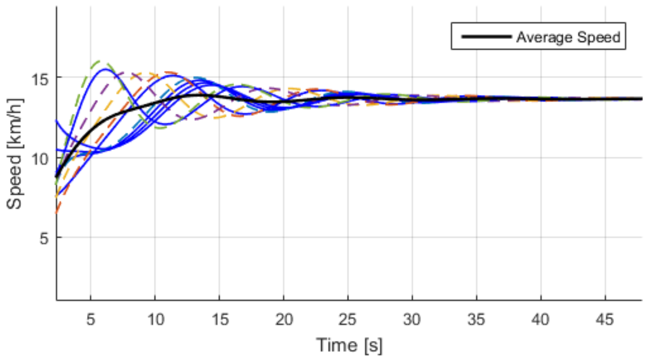


Fig. 5.5. Speed in a combination of human drivers and ACC

When there is a mix of human drivers and vehicles with ACC, we see that the second ones follow the speed of the first ones. In the previous picture, solid blue lines show ACC speed and dashed lines show human drivers speed.

5.2. Impact of the driver type in energy usage

5.2.1. Initial approximation

As seen in the previous section, the speed profile is different for vehicles in ACC mode than for human drivers. This difference in the speed profile is translated into a difference in the power profile.

First of all, to have a global idea about why there is a difference in the energy usage we will consider that a human driver follows a speed profile given by $v(t)=2\cdot\sin(\pi/6\cdot t)+20$ (in m/s) and the ACC vehicle drives with a constant speed. This is a simplification but it is useful to overview what happens. All the parameters used in the simulation are shown in Table 5.1.

Parameter	**Mass [kg]**	**Air density [kg/m^3]**	**Gravity acceleration [m/s^2]**	**Frontal area [m^2]**	**Drag coefficient**
Value	1000	1.225	9.8	2.55	0.35

Table 5.1. Parameters used to perform the initial approximation simulation

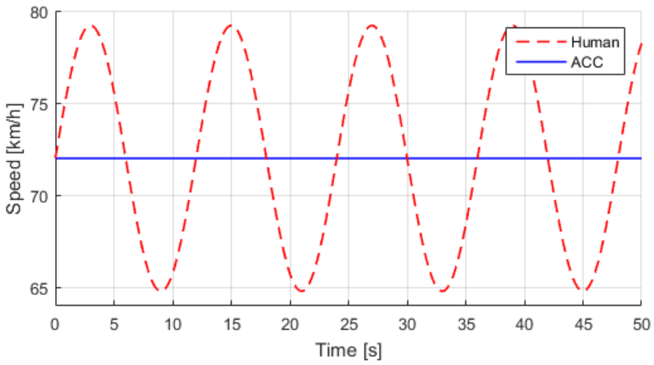


Fig. 5.6. Speed setpoint for human driver vs. ACC

As we can see, both speed profiles have the same mean value but with power will not happen the same.

Using the model explained in Section 3.2 we get the instantaneous power shown in Figure 5.7.

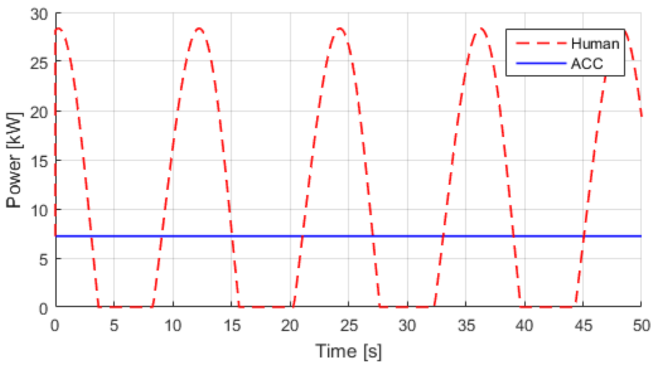


Fig. 5.7. Instantaneous power for human driver vs. ACC

The power for both drivers is limited to zero, considering that when power is a negative value, the vehicle is braking and thus not using or recovering energy.

The first conclusion that one can extract from the previous figure is that driving in a constant speed the power is only used to overcome resistive forces. When driving accelerating and braking continuously all the energy used to perform the acceleration is quickly wasted on the braking. To prove that the energy usage is different for each one of the two drivers, the energy has been calculated integrating the power curve. The result is shown in the following figure.

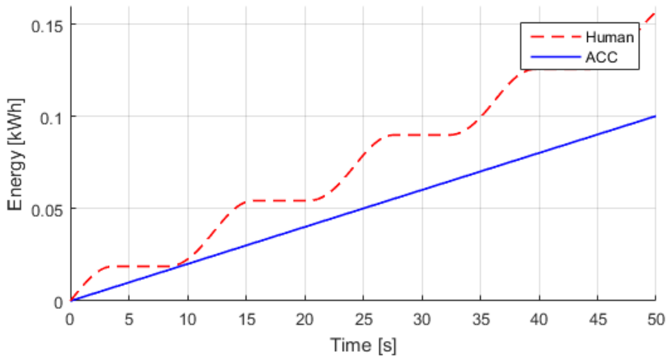


Fig. 5.8. Energy usage for human driver vs. ACC

Human driver uses more energy than the ACC system to develop the same mean speed. The energy usage of the ACC vehicle increases constantly without peaks, something which could help to lengthen batteries lifetime if we used an electric car.

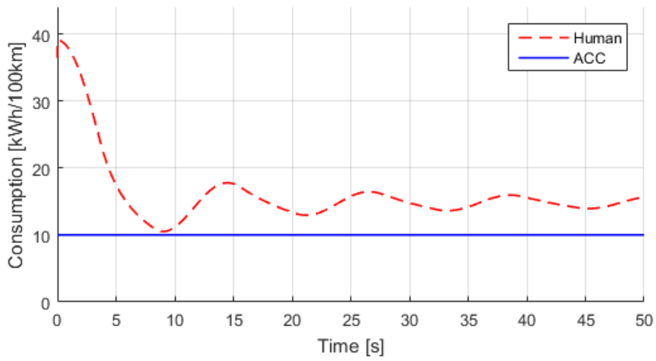


Fig. 5.9. Energy consumption for human driver vs. ACC

Energy consumption per 100 kilometres also shows that ACC vehicles use less energy than human drivers to develop the same mean speed.

5.2.2. Real speed scenarios

In the previous section, the approximation for the speed profile of the two driver types helped to understand why human drivers tend to waste more energy than ACC vehicles. In the current section speed profiles are extracted from two simulations to get more realistic results.

Using the data shown in Table 4.1, a circuit with radius 200/π m (equivalent to 400m of road) and a number of vehicles of 40 the results obtained for power are the ones shown in the following figures.

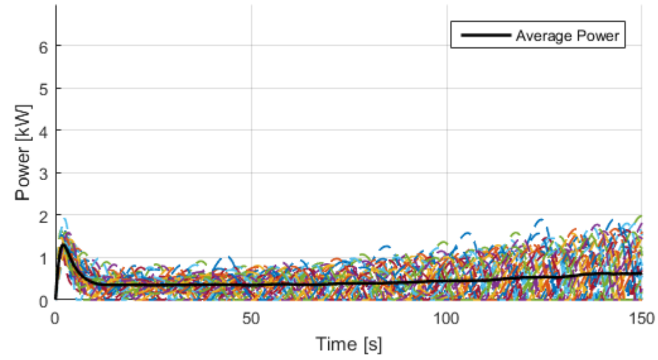


Fig. 5.10. Power profiles for human drivers

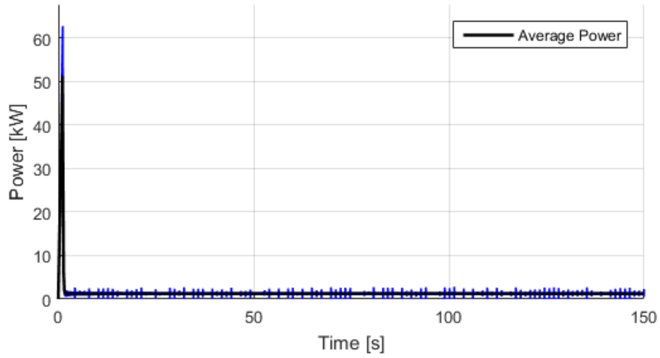


Fig. 5.11. Power profiles for ACC

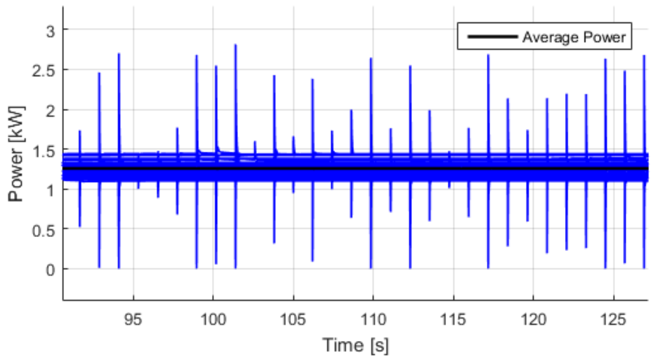


Fig. 5.12. Power profiles for ACC (Zoomed in)

As it can be appreciated on the previous figures, the power for a situation with all vehicles driven by humans constantly reaches zero and stays there for a time. All this time the vehicle is braking and thus, wasting energy.

On the other hand, when all vehicles are driven in ACC mode, the power only reaches zero in some points, and only stays there for a very short time. This means that there is a very small braking to slightly correct the speed, but the loss of energy is almost negligible.

Note: the average power for ACC is higher than for human drivers because both average speed and resistive forces to overcome are higher.

5.3. Impact of different percentages of vehicles with ACC

As explained in previous sections, vehicles with ACC are starting to appear in our roads, but their appearance is not punctual. There will a time during which conventional cars and autonomous vehicles will share the road.

For different percentage of vehicles with ACC the fluidity of traffic and the energy consumption have been evaluated. From this section on, simulations are performed until 175 seconds and averaged variables start to be recorded at 100 seconds.

5.3.1. Traffic fluidity

Based on the fundamental diagram explained in Section 4.3, and using the model developed, some simulations varying the traffic density and the percentage of ACC vehicles have been run. The radius of the circuit has been fixed to 200 m (equivalent to 1256 m of road). Results obtained are shown in the following figures.

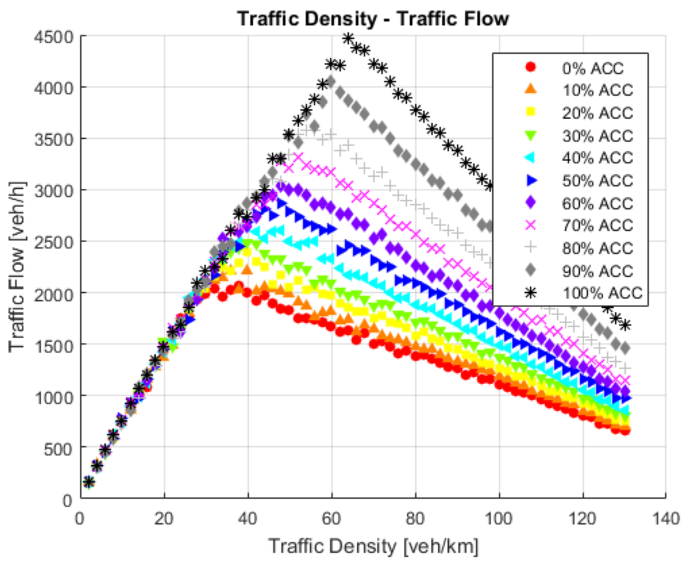


Fig. 5.13. Fundamental diagram Traffic Density vs. Traffic Flow

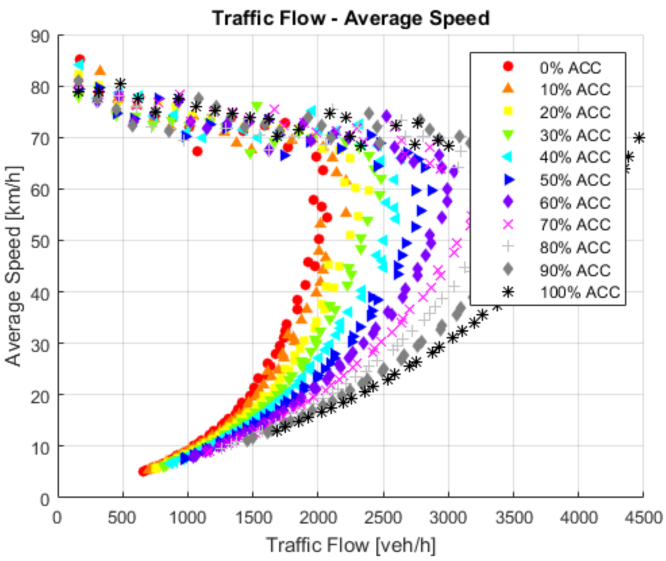


Fig. 5.14. Fundamental diagram Traffic Flow vs. Average Speed

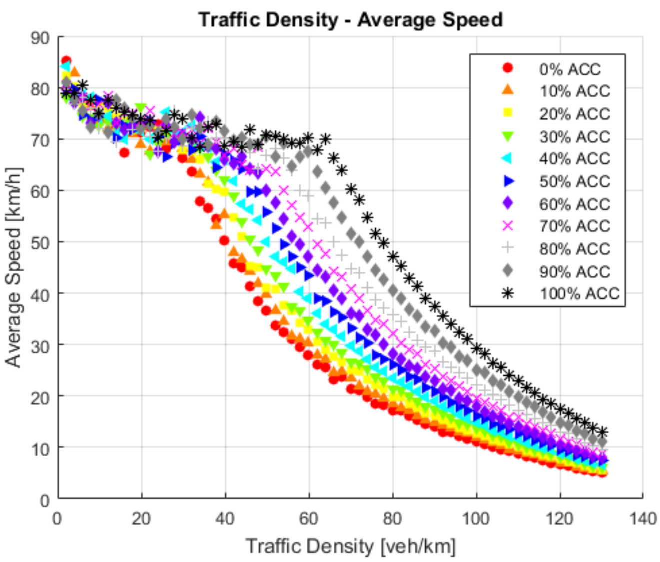


Fig. 5.15. Fundamental diagram Traffic Density vs. Average Speed

As it can be observed in the previous figures, different percentages of vehicles with ACC bring into different traffic behaviours.

The first, and most important fact is that the critical points commented in Section 4.3 improve when increasing the percentage of ACC. For the critical density there is an improvement about 100%, passing from 30 vehicles/km when all drivers are human to 60 vehicles/km when all vehicles are autonomous. The critical flow improves even more, about a 120% of difference between human drivers and autonomous drivers.

Another fact to note is that this improvement when increasing the percentage of vehicles with ACC is only visible when the road is overcrowded. For situations below the critical point, the difference is almost insignificant and the results are chaotic. Theoretically, the fundamental diagram should be a linear function when traffic is under the critical point, but the results do not say the same. This happens because the speed and flow are more influenced by the desired speed of drivers than the capacity of the road.

5.3.2. Energy efficiency in consumption

In terms of energy consumption, one could think that as the percentage of vehicle with ACC increases, the energy consumption decreases; it is true but with some remarks. The following figure shows how the energy consumption is related to speed and percentage of vehicles with ACC. Each point of the plot corresponds to one simulation with different traffic density although simulations are repeated several times with the same input parameters.

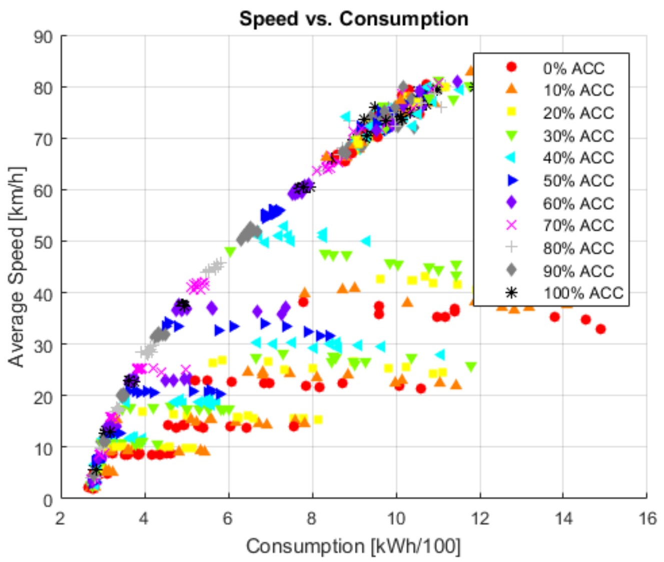


Fig. 5.16. Energy consumption vs. Average Speed for different percentages of ACC

In first place, as it can be seen in the figure, average speed and energy consumption are related but with some exceptions. The relationship seems to follow a curve in which when speed increases, consumption also increases. Values on the top of the plot correspond to low traffic density situations where vehicles can drive at the desired speed and the lower part of the plot corresponds to high traffic densities.

Exceptions appear in some cases where for the same average speed, the consumption is higher. The explanation for this fact is the formation of traffic jams, which make the consumption increase although the average speed is the same.

Note that these exceptions only occur for percentages of ACC under 70% approximately. When the percentage of autonomous vehicles decreases, the number of points where the consumption is out of range goes up.

Finally, for low traffic density situations, the percentage of vehicles with ACC does not make a difference because the average speed only depends on the speed desired by drivers, and thus the consumption too.

To generalize the relationship between average speed and average consumption, some simulations varying the traffic density have been performed. For each traffic density and percentage of vehicles with ACC, the number of simulations is 30 to generate different situations with different random parameters such as position of the ACC cars or driving parameters. Results are shown in form of statistical boxes in the following figures.

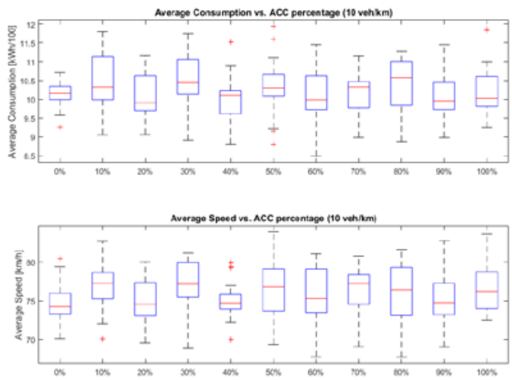


Fig. 5.17. Average speed and average consumption vs. percentage of ACC (10 vehicles/km)

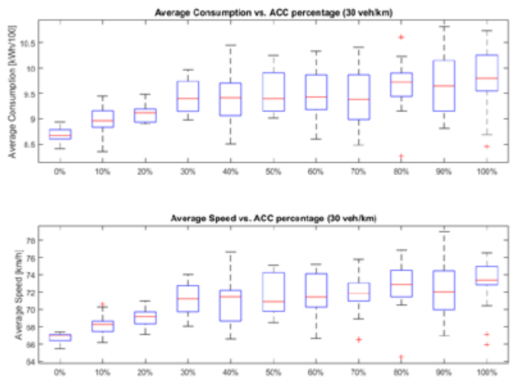


Fig. 5.18. Average speed and average consumption vs. percentage of ACC (30 vehicles/km)

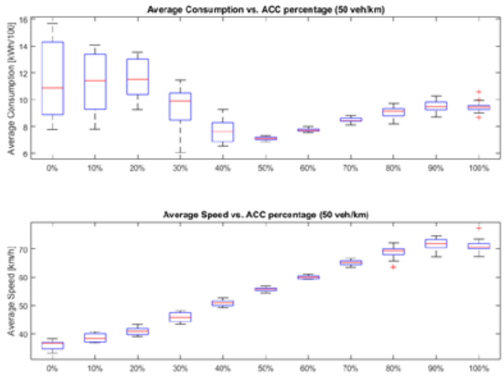


Fig. 5.19. Average speed and average consumption vs. percentage of ACC (50 vehicles/km)

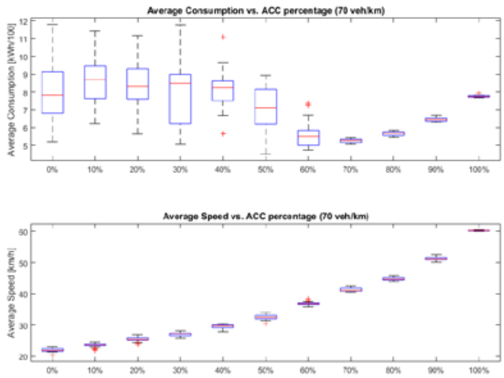


Fig. 5.20. Average speed and average consumption vs. percentage of ACC (70 vehicles/km)

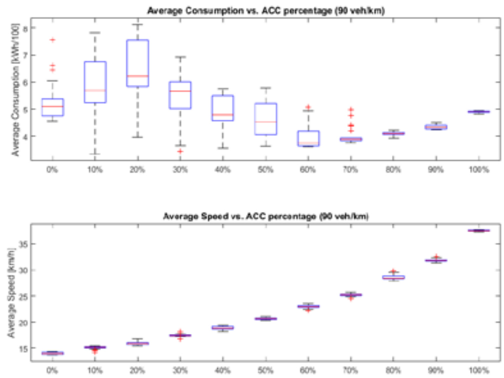


Fig. 5.21. Average speed and average consumption vs. percentage of ACC (90 vehicles/km)

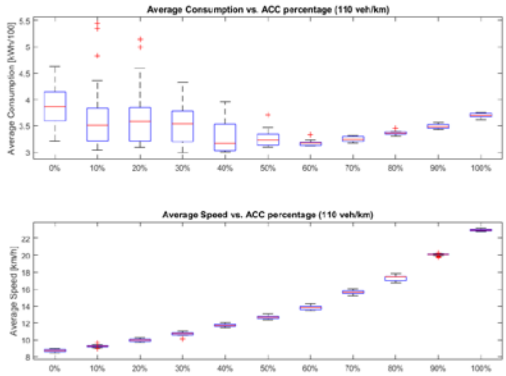


Fig. 5.22. Average speed and average consumption vs. percentage of ACC (110 vehicles/km)

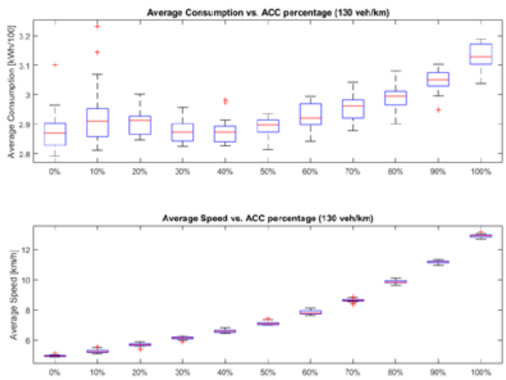


Fig. 5.23. Average speed and average consumption vs. percentage of ACC (130 vehicles/km)

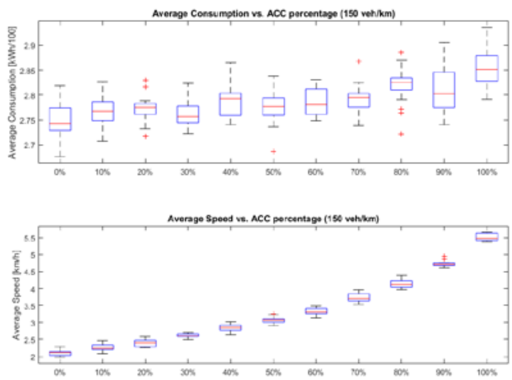


Fig. 5.24. Average speed and average consumption vs. percentage of ACC (150 vehicles/km)

The previous box plots show different statistical values to prove that there is a variability in results. Each box has the same form and contains the following information:

- Blue box contains values from the 25% quartile to 75% quartile, which means that it contains 50% of the total data.
- Red line shows the median, the value in the middle once the results are sorted.
- Extremes of dashed lines extending from the central box are the top and lower values of the sample.
- Red crosses are outliers, strange values which are out of the range of 3/2 times the height of the central box.

As it can be observed in the box plots there is a high variability not only in average speed but also in consumption for low traffic density situations. This happens because vehicles have a lot of space in front of them and the speed is the desired speed by the driver. Given that the speed varies depending on the driver, the consumption also does.

If we increase the traffic density there is an improvement in speed data. There are minimum deviations for each situation because the average speed is given by the road capacity. It can also be observed that the average speed increases when the percentage of vehicles with ACC also increases.

For energy consumption, it is more difficult to extract clear conclusions. For low traffic densities, the consumption is directly related to speed, but when the traffic density goes over 50 vehicles per kilometre there is an improvement in energy savings when the percentage of vehicles with ACC increases. This does not happen always, in most cases consumption increases when percentage of ACC increases because the speed is also higher. Anyway, even though the consumption increments, it does it in a lower rate than the speed.

To better see what happens when the percentage of ACC increases, the following figures show the percentage of increment with respect to human drivers for speed and consumption in different traffic densities.

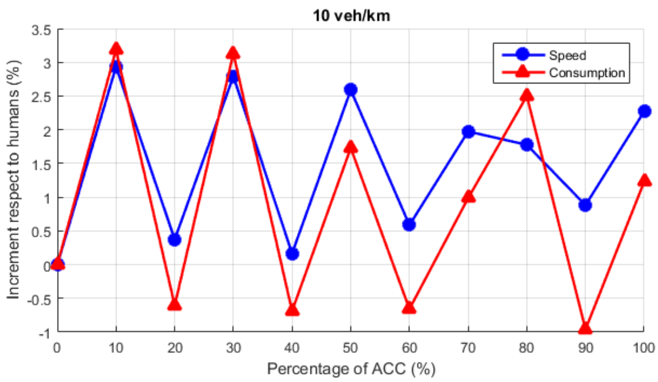


Fig. 5.25. Increment of speed and consumption with respect to human drivers (10 vehicles/km)

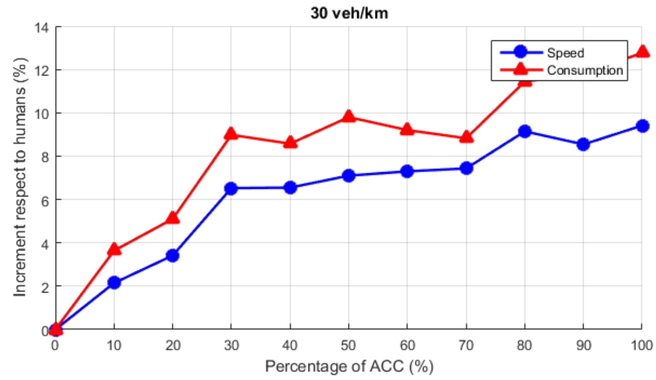


Fig. 5.26. Increment of speed and consumption with respect to human drivers (30 vehicles/km)

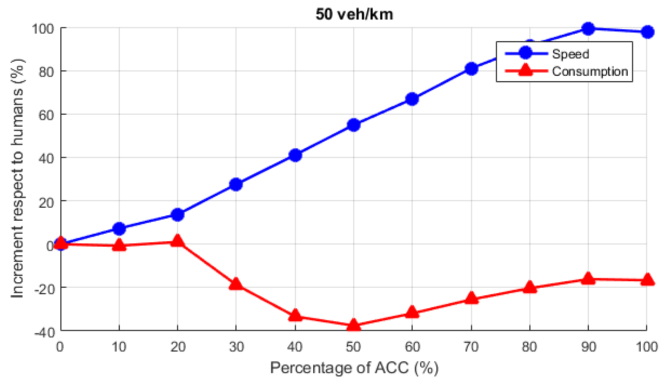


Fig. 5.27. Increment of speed and consumption with respect to human drivers (50 vehicles/km)

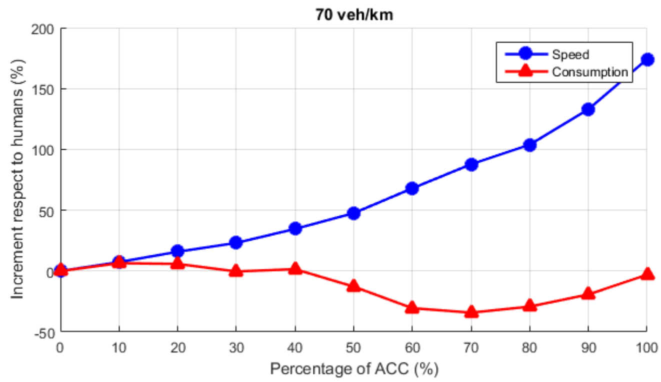


Fig. 5.28. Increment of speed and consumption with respect to human drivers (70 vehicles/km)

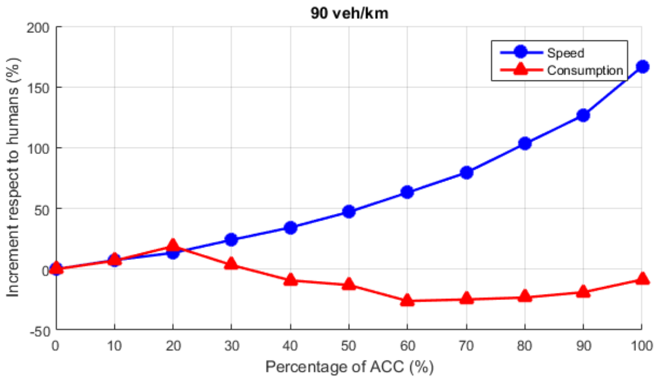


Fig. 5.29. Increment of speed and consumption with respect to human drivers (90 vehicles/km)

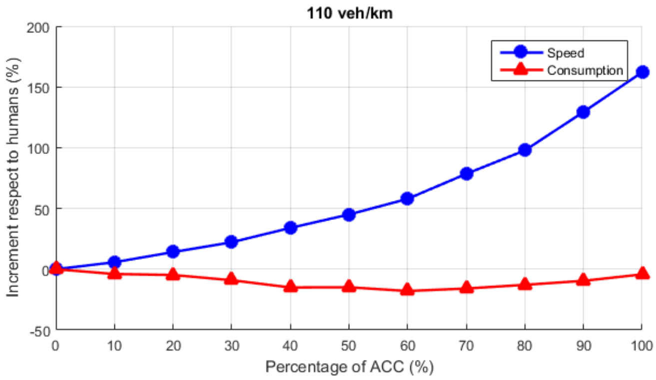


Fig. 5.30. Increment of speed and consumption with respect to human drivers (110 vehicles/km)

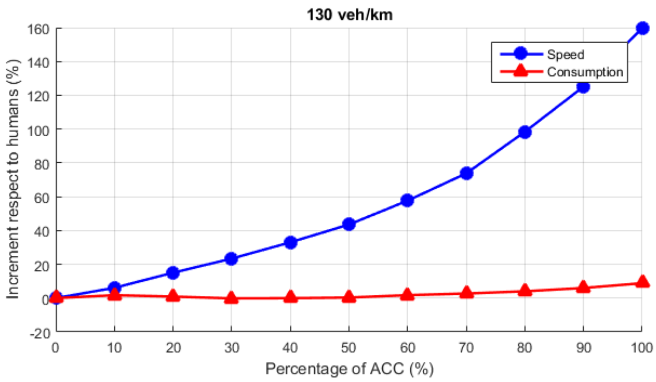


Fig. 5.31. Increment of speed and consumption with respect to human drivers (130 vehicles/km)

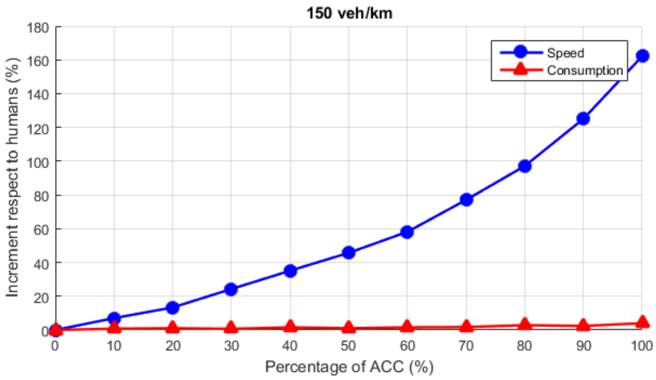


Fig. 5.32. Increment of speed and consumption with respect to human drivers (150 vehicles/km)

As we can observe, for low traffic densities the percentage of improvement is almost unpredictable, both speed and consumption are completely random. As the density increases we find out that even though speed increases, consumption decreases, for example the case of 50 vehicles/km and 50% of ACC.

For very high traffic densities, the speed increases a lot (in terms of percentage) while consumption only experiments a slight rising.

6. Environmental impact assessment

The current project is itself an environmental impact assessment, since the energy consumption in different traffic situations is evaluated. Even so, in this chapter a study about CO_2 emissions will be carried out to compare some of the situations explained in previous sections.

6.1. Emissions depending on the type of engine

Not all vehicles use the same type of engine, most of them use conventional gasoline or diesel engines but nowadays electric vehicles are starting to drive on our roads. Electric vehicles might seem to be zero-emission but they indirectly involve some contamination, due to the generation of electrical power in coal-fired or combined cycle power plants. In reference [5] they use these two diagrams to difference different types of engine and emissions associated to each of them.

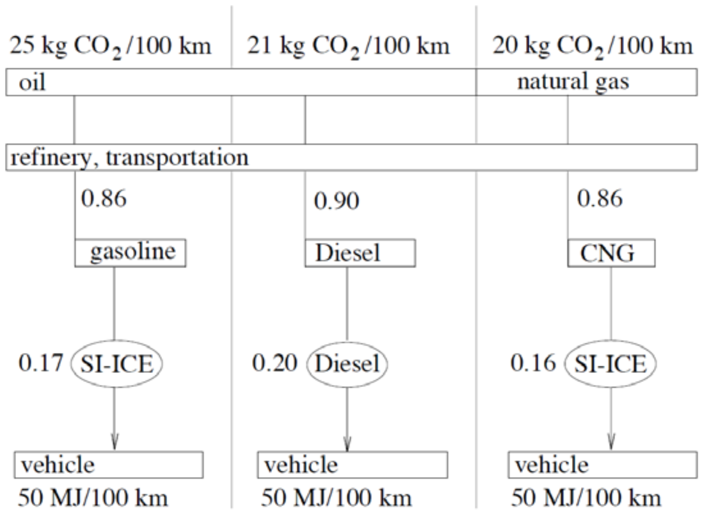


Fig. 6.1. Emissions associated to conventional-fuel engines

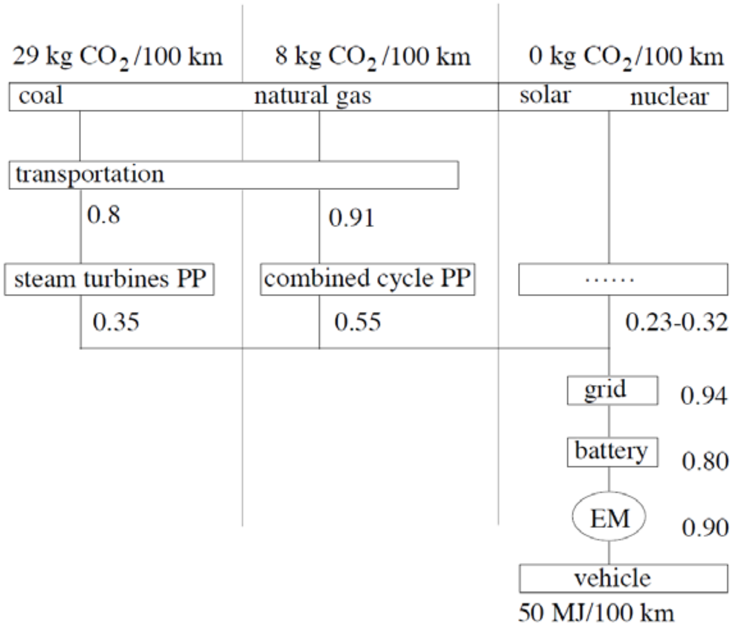


Fig. 6.2. Emissions associated to electric vehicles

As it can be appreciated in the two diagrams, the difference between conventional engines and electric engines depends on how the electrical power has been generated. If we focus on the coal, for example, the energy generated in a coal-fired power plant needed to cover 100 km with an electric car involves more CO_2 emissions than a conventional gasoline engine.

The point where this could improve is in the generation of energy using renewable energy sources to reduce CO_2 emissions.

6.2. CO_2 emissions for different percentage of ACC vehicles

Considering the values of the previous figures, and supposing that the relationship between useful energy and CO_2 emissions is linear, the emissions per unit of energy are the ones in the following table.

Type of engine	Emissions per useful kWh
Gasoline	1.8 kg CO_2/kWh
Diesel	1.512 kg CO_2/kWh
CNG	1.44 kg CO_2/kWh
Electric vehicle (Energy from coal)	2.088 kg CO_2/kWh
Electric vehicle (Energy from natural gas)	0.576 kg CO_2/kWh
Electric vehicle (Renewable energy or nuclear)	0 kg CO_2/kWh

Table 6.1. CO_2 emissions per useful kWh for different engines

In the following tables, the estimation of CO_2 emissions is collected for each density, each type of engine and each percentage of vehicles with ACC. Results are proportional to the consumption, thus CO_2 savings are the same than savings in consumption shown in the previous chapter.

10 veh/km	**Avg. Consumption (kWh/100)**	**kg CO_2 / 100 km**				
		Gasoline	**Diesel**	**CNG**	**Electric (Coal)**	**Electric (Gas)**
0% ACC	10.13	18.23	15.32	14.59	21.15	5.84
10% ACC	10.45	18.82	15.80	15.05	21.83	6.02
20% ACC	10.07	18.12	15.22	14.50	21.02	5.80
30% ACC	10.45	18.81	15.80	15.04	21.81	6.02
40% ACC	10.06	18.11	15.21	14.49	21.01	5.79
50% ACC	10.31	18.55	15.58	14.84	21.52	5.94
60% ACC	10.06	18.11	15.22	14.49	21.01	5.80
70% ACC	10.23	18.41	15.47	14.73	21.36	5.89
80% ACC	10.38	18.69	15.70	14.95	21.68	5.98
90% ACC	10.03	18.06	15.17	14.45	20.95	5.78
100% ACC	10.25	18.46	15.51	14.77	21.41	5.91

Table 6.2. CO_2 emissions per 100 km (10 vehicles/km)

30 veh/km	**Avg. Consumption (kWh/100)**	**kg CO_2 / 100 km**				
		Gasoline	**Diesel**	**CNG**	**Electric (Coal)**	**Electric (Gas)**
0% ACC	8.67	15.61	13.11	12.48	18.10	4.99
10% ACC	8.99	16.17	13.59	12.94	18.76	5.18
20% ACC	9.11	16.40	13.78	13.12	19.03	5.25
30% ACC	9.45	17.01	14.29	13.61	19.73	5.44
40% ACC	9.41	16.94	14.23	13.55	19.65	5.42
50% ACC	9.52	17.13	14.39	13.71	19.88	5.48
60% ACC	9.47	17.04	14.31	13.63	19.77	5.45
70% ACC	9.43	16.98	14.27	13.59	19.70	5.43
80% ACC	9.66	17.39	14.61	13.91	20.17	5.57
90% ACC	9.69	17.44	14.65	13.95	20.23	5.58
100% ACC	9.78	17.60	14.78	14.08	20.41	5.63

Table 6.3. CO_2 emissions per 100 km (30 vehicles/km)

50 veh/km	Avg. Consumption (kWh/100)	kg CO_2 / 100 km				
		Gasoline	Diesel	CNG	Electric (Coal)	Electric (Gas)
0% ACC	11.38	20.49	17.21	16.39	23.77	6.56
10% ACC	11.30	20.34	17.09	16.28	23.60	6.51
20% ACC	11.50	20.70	17.39	16.56	24.01	6.62
30% ACC	9.25	16.65	13.99	13.32	19.31	5.33
40% ACC	7.59	13.67	11.48	10.93	15.85	4.37
50% ACC	7.11	12.80	10.75	10.24	14.85	4.10
60% ACC	7.76	13.96	11.73	11.17	16.19	4.47
70% ACC	8.48	15.26	12.82	12.21	17.71	4.88
80% ACC	9.07	16.33	13.72	13.07	18.95	5.23
90% ACC	9.55	17.19	14.44	13.75	19.94	5.50
100% ACC	9.49	17.08	14.35	13.67	19.82	5.47

Table 6.4. CO_2 emissions per 100 km (50 vehicles/km)

70 veh/km	Avg. Consumption (kWh/100)	kg CO_2 / 100 km				
		Gasoline	Diesel	CNG	Electric (Coal)	Electric (Gas)
0% ACC	8.00	14.39	12.09	11.52	16.70	4.61
10% ACC	8.52	15.33	12.88	12.26	17.78	4.90
20% ACC	8.47	15.24	12.80	12.19	17.68	4.88
30% ACC	7.97	14.34	12.05	11.48	16.64	4.59
40% ACC	8.12	14.62	12.28	11.70	16.96	4.68
50% ACC	6.97	12.55	10.54	10.04	14.56	4.02
60% ACC	5.56	10.00	8.40	8.00	11.61	3.20
70% ACC	5.27	9.48	7.96	7.58	11.00	3.03
80% ACC	5.66	10.19	8.56	8.15	11.82	3.26
90% ACC	6.46	11.63	9.77	9.30	13.49	3.72
100% ACC	7.76	13.97	11.73	11.17	16.20	4.47

Table 6.5. CO_2 emissions per 100 km (70 vehicles/km)

90 veh/km	Avg. Consumption (kWh/100)	kg CO2 / 100 km				
		Gasoline	Diesel	CNG	Electric (Coal)	Electric (Gas)
0% ACC	5.36	9.64	8.10	7.71	11.18	3.08
10% ACC	5.73	10.31	8.66	8.25	11.97	3.30
20% ACC	6.36	11.46	9.62	9.16	13.29	3.67
30% ACC	5.54	9.97	8.37	7.98	11.57	3.19
40% ACC	4.86	8.75	7.35	7.00	10.16	2.80
50% ACC	4.66	8.39	7.04	6.71	9.73	2.68
60% ACC	3.96	7.12	5.98	5.70	8.26	2.28
70% ACC	4.02	7.24	6.08	5.79	8.40	2.32
80% ACC	4.11	7.39	6.21	5.91	8.58	2.37
90% ACC	4.34	7.82	6.57	6.25	9.07	2.50
100% ACC	4.90	8.82	7.41	7.06	10.23	2.82

Table 6.6. CO_2 emissions per 100 km (90 vehicles/km)

110 veh/km	Avg. Consumption (kWh/100)	kg CO_2 / 100 km				
		Gasoline	Diesel	CNG	Electric (Coal)	Electric (Gas)
0% ACC	3.86	6.94	5.83	5.56	8.06	2.22
10% ACC	3.71	6.67	5.60	5.34	7.74	2.13
20% ACC	3.68	6.62	5.56	5.29	7.67	2.12
30% ACC	3.51	6.32	5.31	5.05	7.33	2.02
40% ACC	3.28	5.90	4.96	4.72	6.85	1.89
50% ACC	3.29	5.91	4.97	4.73	6.86	1.89
60% ACC	3.17	5.70	4.79	4.56	6.61	1.82
70% ACC	3.25	5.84	4.91	4.67	6.78	1.87
80% ACC	3.36	6.05	5.08	4.84	7.02	1.94
90% ACC	3.49	6.28	5.28	5.02	7.29	2.01
100% ACC	3.69	6.65	5.59	5.32	7.71	2.13

Table 6.7. CO_2 emissions per 100 km (110 vehicles/km)

130 veh/km	Avg. Consumption (kWh/100)	kg CO_2 / 100 km				
		Gasoline	Diesel	CNG	Electric (Coal)	Electric (Gas)
0% ACC	2.88	5.18	4.35	4.14	6.01	1.66
10% ACC	2.93	5.27	4.43	4.22	6.11	1.69
20% ACC	2.90	5.23	4.39	4.18	6.06	1.67
30% ACC	2.87	5.17	4.34	4.14	6.00	1.65
40% ACC	2.88	5.18	4.35	4.14	6.01	1.66
50% ACC	2.89	5.20	4.37	4.16	6.03	1.66
60% ACC	2.93	5.27	4.43	4.22	6.11	1.69
70% ACC	2.96	5.32	4.47	4.26	6.17	1.70
80% ACC	2.99	5.39	4.53	4.31	6.25	1.72
90% ACC	3.05	5.49	4.61	4.39	6.37	1.76
100% ACC	3.13	5.64	4.74	4.51	6.54	1.80

Table 6.8. CO_2 emissions per 100 km (130 vehicles/km)

150 veh/km	Avg. Consumption (kWh/100)	kg CO_2 / 100 km				
		Gasoline	Diesel	CNG	Electric (Coal)	Electric (Gas)
0% ACC	2.74	4.94	4.15	3.95	5.73	1.58
10% ACC	2.77	4.98	4.18	3.98	5.78	1.59
20% ACC	2.77	4.99	4.19	3.99	5.79	1.60
30% ACC	2.76	4.97	4.18	3.98	5.77	1.59
40% ACC	2.79	5.02	4.22	4.01	5.82	1.61
50% ACC	2.77	4.99	4.19	3.99	5.79	1.60
60% ACC	2.79	5.02	4.22	4.01	5.82	1.61
70% ACC	2.79	5.03	4.22	4.02	5.83	1.61
80% ACC	2.82	5.08	4.27	4.06	5.89	1.63
90% ACC	2.81	5.06	4.25	4.05	5.87	1.62
100% ACC	2.86	5.14	4.32	4.11	5.96	1.64

Table 6.9. CO_2 emissions per 100 km (150 vehicles/km)

Conclusions

The two main goals of the project, which included developing the existing MATLAB/Simulink model and studying the behaviour of traffic for different percentages of vehicles with ACC, both can be considered as accomplished.

The development of the model did not require a big amount of time, but the programming of the code to save and plot results entailed some problems.

The main conclusion of the project is that vehicles with ACC improve both the traffic fluidity and energy savings. This improvement is due to the almost instantaneous correction of little speed deviations with the vehicle in front which human drivers cannot do.

These improvements start to be noticeable from low percentages of intrusion of ACC cars in the roads, which is good news for the traffic comfort and energy efficiency. As time goes on and more autonomous vehicles occupy our roads, the benefits will be more remarkable.

ACC systems still need to be improved, mainly in terms of safety, because the autonomous driving involves some risks of mistake in the computer or radars, which could be serious when the distance to the front vehicle is small.

As a proposal for future research, the implementation of different type of engines in the developed model could give more precise results on how energy is used depending on the throttle position or the gear which is being used. The tendency seems to show that in future, conventional combustion vehicles will disappear progressively and the most part of road transport will be done by using electric vehicles, hence the development of electric motors and batteries can also be something to be included in the model in future projects.

Another improvement that could be added to the model is the development of the lane change behaviour of drivers. This would simulate more realistic traffic situations where drivers have the opportunity to overtake if they find a slower car in front of them.

Finally, I want to state that developing this project has been a great experience which has helped me to understand lots of things about traffic. The use of engineering software has been a challenging but at the same time an entertaining experience in which I have faced some problems and solved them by using some of the skills obtained during my engineering studies.

Budget

CONCEPT		UNIT COST	UNITS	TOTAL
Engineering costs				
	Initial research and contextualization	20 €/h	100 h	2 000 €
	Programming	20 €/h	200 h	4 000 €
	Preparing and correcting simulations	20 €/h	150 h	3 000 €
	Redaction of the project report	20 €/h	150 h	3 000 €
Technological resources				
	MATLAB and Simulink Student Suite	69 €/u	1	69 €
	Microsoft Office Home and Students	149 €/u	1	149 €
	Mid-range performance PC	600 €/u	1	600 €
Subtotal				12 818 €
IVA (21%)				2 691.78 €
TOTAL				15 509.78 €

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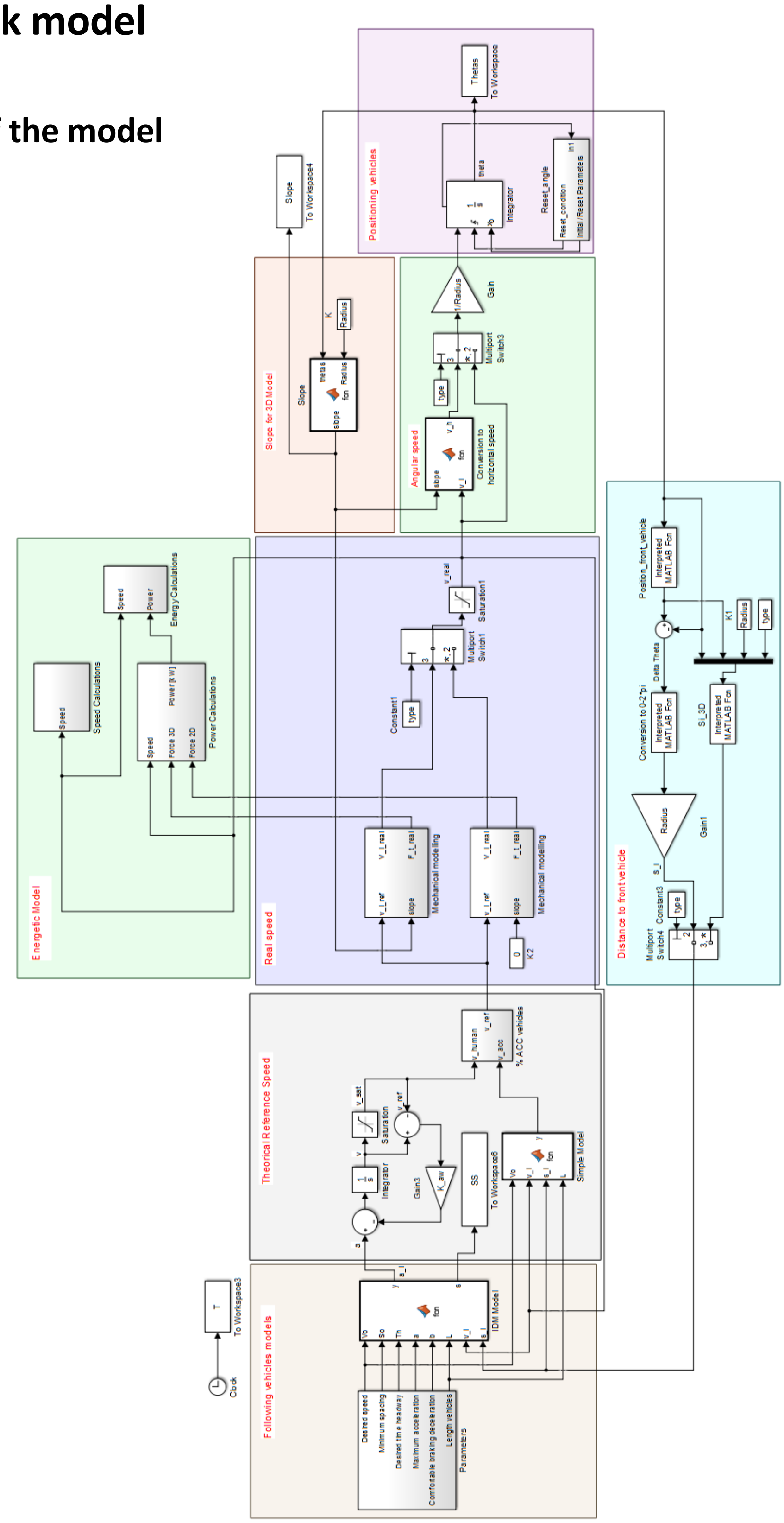
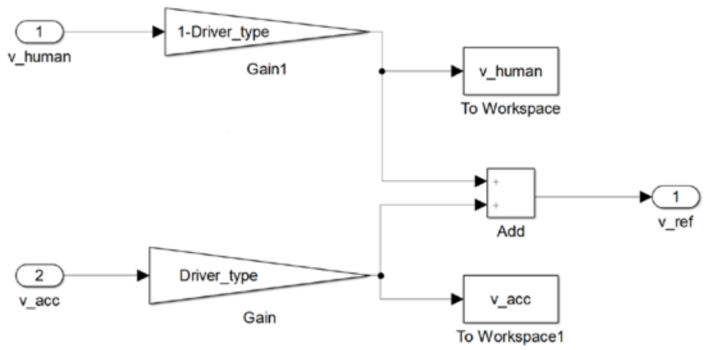
Annex A. Simulink model

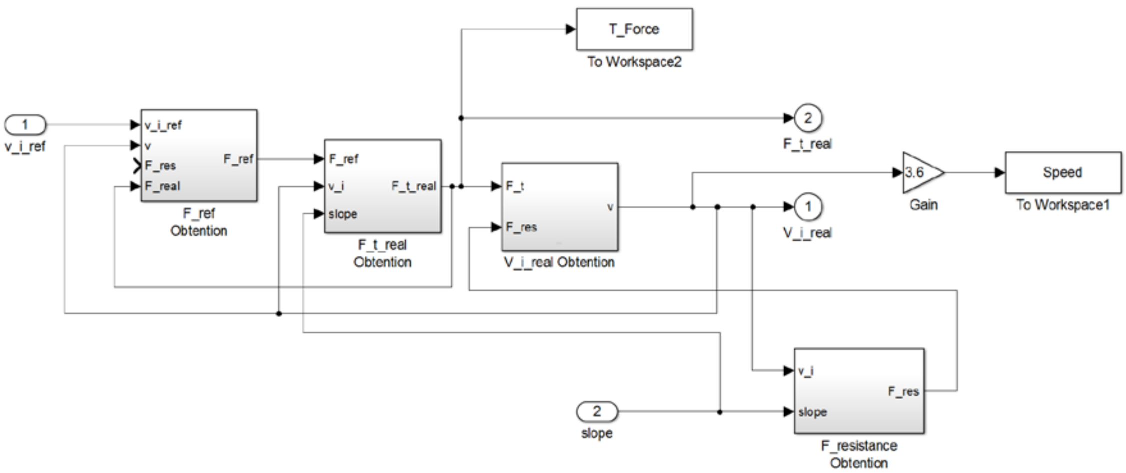
A1. General view of the model



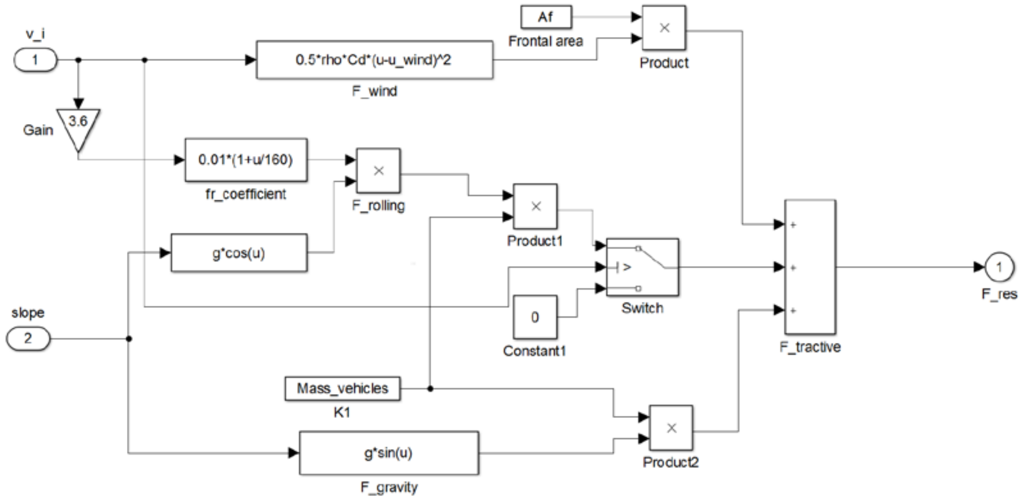
A2. Combination of human drivers and ACC



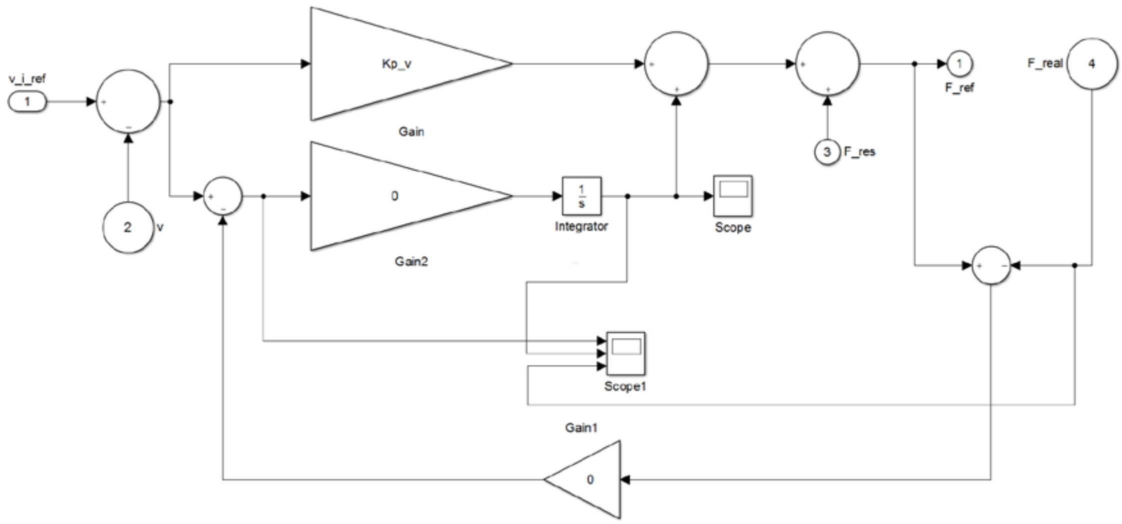
A3. Mechanical model. General view



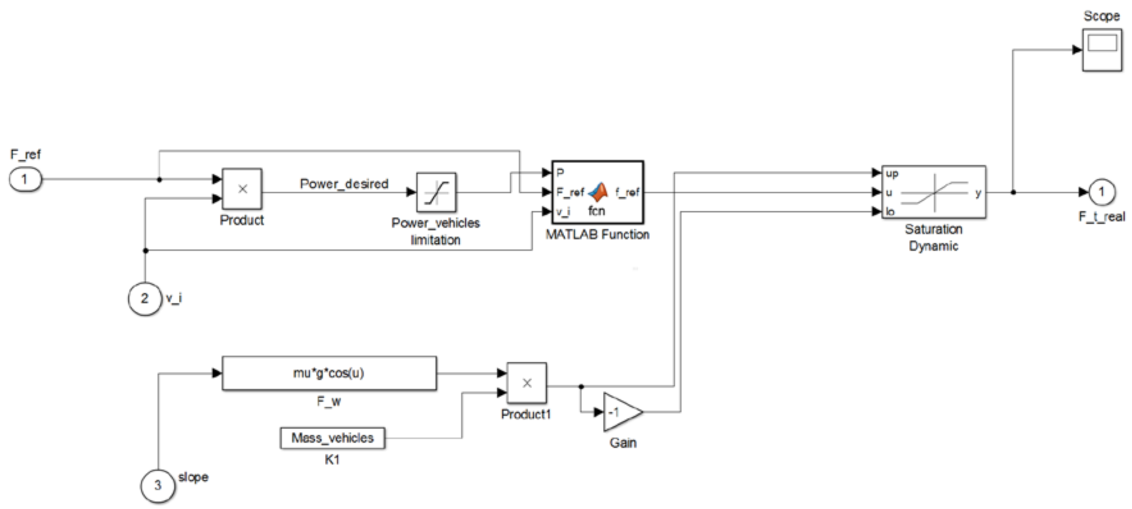
A4. Mechanical model. Resistive forces obtention



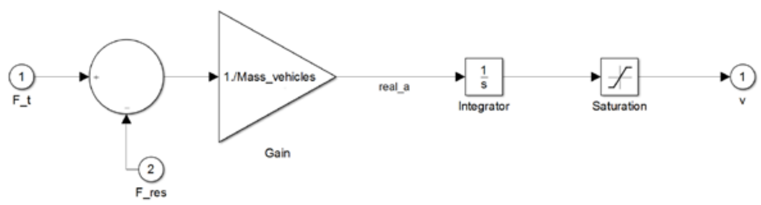
A5. Mechanical model. Reference force obtention



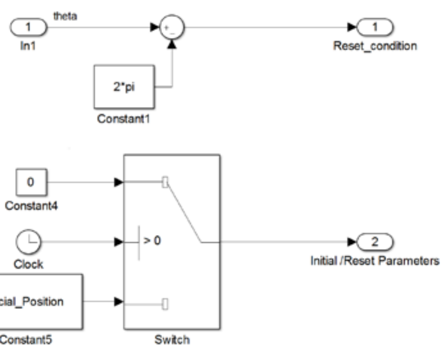
A6. Mechanical model. Real force obtention



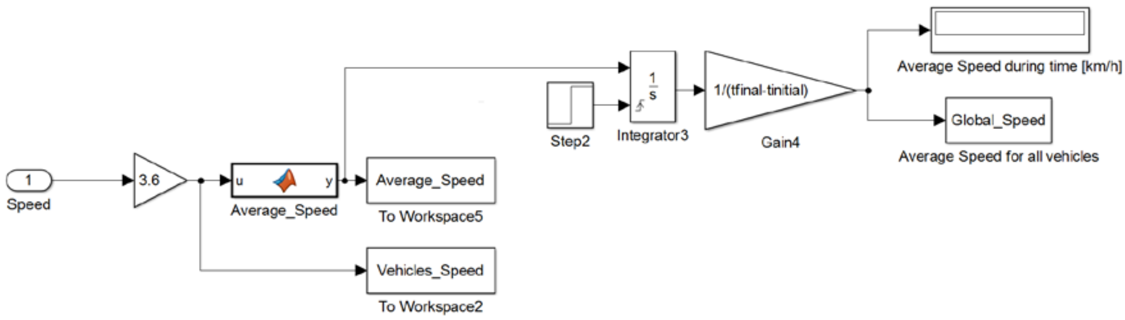
A7. Mechanical model. Real speed obtention



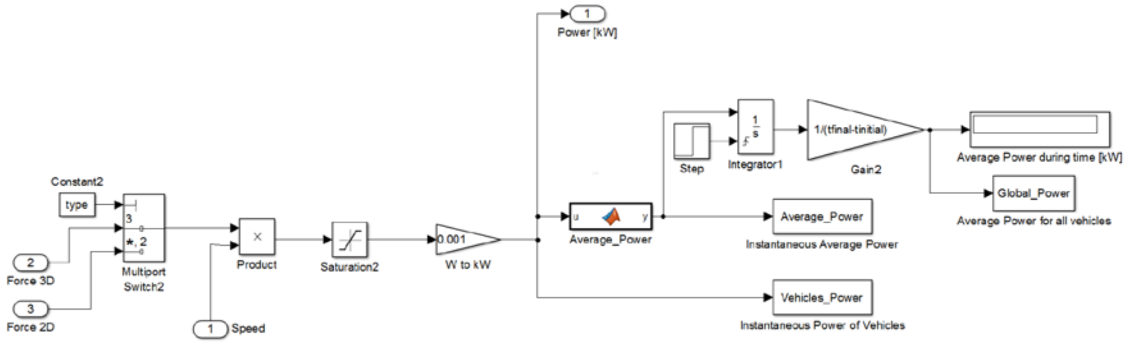
A8. Integrator reset for speed and position of vehicles



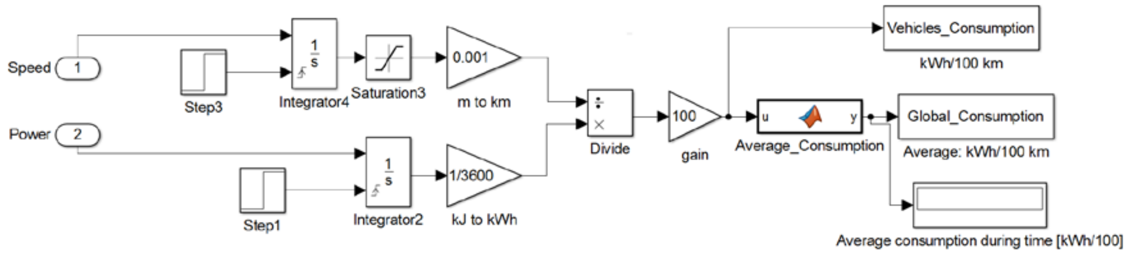
A9. Energetic model. Speed calculations



A10. Energetic model. Power calculations



A11. Energetic model. Energy calculations



Annex B. MATLAB code

B1. Speed_and_consumption_simulations.m

```
clear all
close all
clc

%% Initial data
Radius = 200/pi;
P_1=00/100; %Percentage of trucks
P_2=00/100; %Percentage of motorcycles
P_3=00/100; %Percentage of buses
P_4=00/100; %Percentage of high performance cars
%The rest are low performance cars
type=2; %Type model 2=2D/3D without slope or 3=3D with slope

%% Simulation parameters
tinitial = 100;  %Time when the average power,speed,consumption begin to
be calculated
tfinal = 175;  %Time to stop simulation
%DeltaT = 0.5; %Used only to make an animation

step_acc = 10; %Percentage of ACC vehicles step
step_dens = 20; %Vehicles per km step
final_dens = 150; %Final density to simulate
n_iter = 30; %Number of iterations

for iter = 1:n_iter
for p_acc = 0:step_acc:100 %Loop for %ACC
for dens = 10:step_dens:final_dens %Loop for traffic density
       msgbox({'Simulating...' 'Iter = ',num2str(iter),...
       'Percentage ACC = ',num2str(p_acc),' %' 'Traffic density = ',...
       num2str(dens),' veh/km'},'Progress','replace');

%% Creation of parameters involving driving profiles and vehicles
characteristics
P_ACC = p_acc/100; %Percentage of ACC vehicles
Traffic_Density = dens; %Number of vehicles per km
Number_of_Vehicles = round(Traffic_Density*2*pi*Radius/1000);
Average_Speed = 80;                           Deviation_Speed = 5;
Average_Minimum_Space = 2;                    Deviation_Minimum_Space =
0.2;
Average_Time_Headway = 1.3;                   Deviation_Time_Headway =
0.1;
Average_Vehicles_Acceleration = 1.3;          Deviation_Acceleration =
0.2;
Average_Vehicles_Deceleration = 3.5;
Deviation_Vehicles_Deceleration = 0.4;

Par = Vehicles_and_Driving_behaviour_parameters(Number_of_Vehicles,...
    Average_Speed,Deviation_Speed,Average_Minimum_Space,...

Deviation_Minimum_Space,Average_Time_Headway,Deviation_Time_Headway,...
```

```
    Average_Vehicles_Acceleration,Deviation_Acceleration,...
Average_Vehicles_Deceleration,Deviation_Vehicles_Deceleration,Radius,...
    P_1,P_2,P_3,P_4,P_ACC);

%% Vehicles characteristics
[m,n]=size(Par); %where n is the number of vehicles
Width_vehicles = Par(1,:);
Length_vehicles = Par(2,:);
Height_vehicles = Par(3,:);
Mass_vehicles = Par(4,:)';
Power_vehicles = Par(5,:);
Inicial_Position = Par(6,:);
Desired_velocity = Par(7,:)./3.6;
Minum_spacing  = Par(8,:);
Desired_time_headway = Par(9,:);
Maximum_vehicle_acceleration = Par(10,:);
Comfortable_braking_deceleration = Par(11,:);
Driver_type = Par(13,:);

%% More Vehicle Parameters
Cd = 0.35;      % Drag coeficient
Af = Width_vehicles'.*Height_vehicles';
Initial_speed = ones(n,1)*0./3.6; %Set to zero to avoid crashes at the
begining of simulations
rho = 1.22521;  % Air density (kg/m^3)
g = 9.8;        % Gravity constant (m/s^2)

%% Antiwindup constant
K_aw = 20;

%% Speed Controller
tr_v = 0.1;
alpha_control_v = log(9)/tr_v;
m = 1000;
b = 0.5;
Kp_v = alpha_control_v * m;
Ki_v = 10;%alpha_control_v * b;

%% Enviroment parameter
mu = 0.7;                      % road frictional coeficient
u_wind = 0;                    % Wind speed (m/s)

%% Run simulation and save results
sim('Schematic_model_of_operation');

Res(p_acc/step_acc+1,(dens-10)/step_dens+1,1,iter) =
Global_Consumption(end); %Average Consumption
Res(p_acc/step_acc+1,(dens-10)/step_dens+1,2,iter) = Global_Speed(end);
%Average Speed
Res(p_acc/step_acc+1,(dens-10)/step_dens+1,3,iter) = Global_Power(end);
%Average Power

end
end
end
%save Res;
```

```
msgbox('Finished. Plotting...','Progress','replace');

%% %%%%%%%%%%%%%%%%%%      Plots      %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Scatter plot (initial approximation)
figure(1)
title('Speed vs. Consumption');
xlabel('Consumption [kWh/100]');
ylabel('Average Speed [km/h]');
grid on;
hold on;
mrk_color = {'[1 0 0]','[1 0.50196 0]','[1 1 0]','[0.50196 1 0]','[0 1
1]','[0 0 1]','[0.49804 0 1]','[1 0 1]','[0.75294 0.75294
0.75294]','[0.50196 0.50196 0.50196]','[0 0 0]'};
for iter = 1:n_iter
for dens = 10:step_dens:final_dens
    point_00 = scatter(Res(1,(dens-10)/step_dens+1,1,iter),Res(1,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{1},'MarkerEdgeColor'
,'none','Marker','o');
    point_10 = scatter(Res(2,(dens-10)/step_dens+1,1,iter),Res(2,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{2},'MarkerEdgeColor'
,'none','Marker','^');
    point_20 = scatter(Res(3,(dens-10)/step_dens+1,1,iter),Res(3,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{3},'MarkerEdgeColor'
,'none','Marker','s');
    point_30 = scatter(Res(4,(dens-10)/step_dens+1,1,iter),Res(4,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{4},'MarkerEdgeColor'
,'none','Marker','v');
    point_40 = scatter(Res(5,(dens-10)/step_dens+1,1,iter),Res(5,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{5},'MarkerEdgeColor'
,'none','Marker','<');
    point_50 = scatter(Res(6,(dens-10)/step_dens+1,1,iter),Res(6,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{6},'MarkerEdgeColor'
,'none','Marker','>');
    point_60 = scatter(Res(7,(dens-10)/step_dens+1,1,iter),Res(7,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{7},'MarkerEdgeColor'
,'none','Marker','d');
    point_70 = scatter(Res(8,(dens-10)/step_dens+1,1,iter),Res(8,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{8},'MarkerEdgeColor'
,mrk_color{8},'Marker','x');
    point_80 = scatter(Res(9,(dens-10)/step_dens+1,1,iter),Res(9,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{9},'MarkerEdgeColor'
,mrk_color{9},'Marker','+');
    point_90 = scatter(Res(10,(dens-
10)/step_dens+1,1,iter),Res(10,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{10},'MarkerEdgeColor
','none','Marker','d');
    point_100 = scatter(Res(11,(dens-
10)/step_dens+1,1,iter),Res(11,(dens-
10)/step_dens+1,2,iter),'MarkerFaceColor',mrk_color{11},'MarkerEdgeColor
',mrk_color{11},'Marker','*');
end
end
legend([point_00,point_10,point_20,point_30,point_40,point_50,point_60,p
oint_70,point_80,point_90,point_100],'0% ACC','10% ACC','20% ACC','30%
ACC','40% ACC','50% ACC','60% ACC','70% ACC','80% ACC','90% ACC','100%
ACC');
hold off;
```

```
%% Boxplots
for dens = 10:step_dens:final_dens
figure(dens)
hold on;

ax1 = subplot(2,1,1);
avg_c = squeeze(Res(:,(dens-10)/step_dens+1,1,:))';
boxplot(avg_c,'Labels',{'0% ACC','10% ACC','20% ACC','30% ACC','40%
ACC','50% ACC','60% ACC','70% ACC','80% ACC','90% ACC','100% ACC'});
title(ax1,['Average Consumption vs. ACC percentage (',num2str(dens),'
veh/km)']);
ylabel(ax1,'Average Consumption [kWh/100]');

ax2 = subplot(2,1,2);
avg_v = squeeze(Res(:,(dens-10)/step_dens+1,2,:))';
boxplot(avg_v,'Labels',{'0% ACC','10% ACC','20% ACC','30% ACC','40%
ACC','50% ACC','60% ACC','70% ACC','80% ACC','90% ACC','100% ACC'});
title(ax2,['Average Speed vs. ACC percentage (',num2str(dens),'
veh/km)']);
ylabel(ax2,'Average Speed [km/h]');

end
```

B2. Fundamental_diagrams.m

```
clear all
close all
clc

%% Initial data
Radius = 200;
P_1=00/100; %Percentage of trucks
P_2=00/100; %Percentage of motorcycles
P_3=00/100; %Percentage of buses
P_4=00/100; %Percentage of high performance cars
%The rest are low performance cars
type=2; %Type model 2=2D/3D without slope or 3=3D with slope

%% Simulation parameters
tinitial = 100;  %Time when the average power,speed,consumption begin to
be calculated
tfinal = 175;   %Time to stop simulation
DeltaT = 0.5; %Used only to make an animation

step_acc = 10; %Percentage of ACC vehicles step
step_dens = 2; %Vehicles per km step
final_dens = 130; %Final density to simulate


for p_acc = 0:step_acc:100 %Loop for %ACC
for dens = 2:step_dens:final_dens %Loop for traffic density
       msgbox({'Simulating...' ,...
       'Percentage ACC = ',num2str(p_acc),' %' 'Traffic density = ',...
       num2str(dens),' veh/km'},'Progress','replace');
```

```
%% Creation of parameters involving driving profiles and vehicles
characteristics
P_ACC = p_acc/100; %Probability of ACC vehicles
Traffic_Density = dens; %Number of vehicles per km
Number_of_Vehicles = round(Traffic_Density*2*pi*Radius/1000);
Average_Speed = 80;                         Deviation_Speed = 5;
Average_Minimum_Space = 2;                  Deviation_Minimum_Space =
0.2;
Average_Time_Headway = 1.3;                 Deviation_Time_Headway =
0.1;
Average_Vehicles_Acceleration = 1.3;        Deviation_Acceleration =
0.2;
Average_Vehicles_Deceleration = 3.5;
Deviation_Vehicles_Deceleration = 0.4;

Par = Vehicles_and_Driving_behaviour_parameters(Number_of_Vehicles,...
    Average_Speed,Deviation_Speed,Average_Minimum_Space,...

Deviation_Minimum_Space,Average_Time_Headway,Deviation_Time_Headway,...
    Average_Vehicles_Acceleration,Deviation_Acceleration,...

Average_Vehicles_Deceleration,Deviation_Vehicles_Deceleration,Radius,...
    P_1,P_2,P_3,P_4,P_ACC);

%% Vehicles characteristics
[m,n]=size(Par); %where n is the number of vehicles
Width_vehicles = Par(1,:);
Length_vehicles = Par(2,:);
Height_vehicles = Par(3,:);
Mass_vehicles = Par(4,:)';
Power_vehicles = Par(5,:);
Inicial_Position = Par(6,:);
Desired_velocity = Par(7,:)./3.6;
Minum_spacing  = Par(8,:);
Desired_time_headway = Par(9,:);
Maximum_vehicle_acceleration = Par(10,:);
Comfortable_braking_deceleration = Par(11,:);
Driver_type = Par(13,:);

%% More Vehicle Parameters
Cd = 0.35;      % Drag coeficient
Af = Width_vehicles'.*Height_vehicles';
Initial_speed = ones(n,1)*0./3.6; %Set to zero to avoid crashes at the
begining of simulations
rho = 1.22521;  % Air density (kg/m^3)
g = 9.8;        % Gravity constant (m/s^2)

%% Antiwindup constant
K_aw = 20;

%% Speed Controller
tr_v = 0.1;
alpha_control_v = log(9)/tr_v;
m = 1000;
b = 0.5;
Kp_v = alpha_control_v * m;
Ki_v = 10;%alpha_control_v * b;
```

```
%% Enviroment parameter
mu = 0.7;                      % road frictional coeficient
u_wind = 0;                    % Wind speed (m/s)

%% Run simulation and save results
sim('Schematic_model_of_operation');

Dia(p_acc/step_acc+1,(dens-2)/step_dens+1,1) = Global_Speed(end);
%Average Speed (u)
Dia(p_acc/step_acc+1,(dens-2)/step_dens+1,2) = Global_Speed(end)*dens;
%veh/h (q)
Dia(p_acc/step_acc+1,(dens-2)/step_dens+1,3) = dens; %veh/km (k)


end
end

%% %%%%%%%%%%%%%%%%%%%%%      Plots      %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

%% Three fundamental diagrams
figure(1)
title('Traffic Density - Average Speed');
xlabel('Traffic Density [veh/km]');
ylabel('Average Speed [km/h]');
grid on;
hold on;
mrk_color = {'[1 0 0]','[1 0.50196 0]','[1 1 0]','[0.50196 1 0]','[0 1
1]','[0 0 1]','[0.49804 0 1]','[1 0 1]','[0.75294 0.75294
0.75294]','[0.50196 0.50196 0.50196]','[0 0 0]'};
    point_00 =
scatter(Dia(1,:,3),Dia(1,:,1),'MarkerFaceColor',mrk_color{1},'MarkerEdge
Color','none','Marker','o');
    point_10 =
scatter(Dia(2,:,3),Dia(2,:,1),'MarkerFaceColor',mrk_color{2},'MarkerEdge
Color','none','Marker','^');
    point_20 =
scatter(Dia(3,:,3),Dia(3,:,1),'MarkerFaceColor',mrk_color{3},'MarkerEdge
Color','none','Marker','s');
    point_30 =
scatter(Dia(4,:,3),Dia(4,:,1),'MarkerFaceColor',mrk_color{4},'MarkerEdge
Color','none','Marker','v');
    point_40 =
scatter(Dia(5,:,3),Dia(5,:,1),'MarkerFaceColor',mrk_color{5},'MarkerEdge
Color','none','Marker','<');
    point_50 =
scatter(Dia(6,:,3),Dia(6,:,1),'MarkerFaceColor',mrk_color{6},'MarkerEdge
Color','none','Marker','>');
    point_60 =
scatter(Dia(7,:,3),Dia(7,:,1),'MarkerFaceColor',mrk_color{7},'MarkerEdge
Color','none','Marker','d');
    point_70 =
scatter(Dia(8,:,3),Dia(8,:,1),'MarkerFaceColor',mrk_color{8},'MarkerEdge
Color',mrk_color{8},'Marker','x');
    point_80 =
scatter(Dia(9,:,3),Dia(9,:,1),'MarkerFaceColor',mrk_color{9},'MarkerEdge
Color',mrk_color{9},'Marker','+');
```

```
    point_90 =
scatter(Dia(10,:,3),Dia(10,:,1),'MarkerFaceColor',mrk_color{10},'MarkerE
dgeColor','none','Marker','d');
    point_100 =
scatter(Dia(11,:,3),Dia(11,:,1),'MarkerFaceColor',mrk_color{11},'MarkerE
dgeColor',mrk_color{11},'Marker','*');
legend([point_00,point_10,point_20,point_30,point_40,point_50,point_60,p
oint_70,point_80,point_90,point_100],'0% ACC','10% ACC','20% ACC','30%
ACC','40% ACC','50% ACC','60% ACC','70% ACC','80% ACC','90% ACC','100%
ACC');
hold off;

figure(2)
title('Traffic Flow - Average Speed');
xlabel('Traffic Flow [veh/h]');
ylabel('Average Speed [km/h]');
grid on;
hold on;
mrk_color = {'[1 0 0]','[1 0.50196 0]','[1 1 0]','[0.50196 1 0]','[0 1
1]','[0 0 1]','[0.49804 0 1]','[1 0 1]','[0.75294 0.75294
0.75294]','[0.50196 0.50196 0.50196]','[0 0 0]'};
    point_00 =
scatter(Dia(1,:,2),Dia(1,:,1),'MarkerFaceColor',mrk_color{1},'MarkerEdge
Color','none','Marker','o');
    point_10 =
scatter(Dia(2,:,2),Dia(2,:,1),'MarkerFaceColor',mrk_color{2},'MarkerEdge
Color','none','Marker','^');
    point_20 =
scatter(Dia(3,:,2),Dia(3,:,1),'MarkerFaceColor',mrk_color{3},'MarkerEdge
Color','none','Marker','s');
    point_30 =
scatter(Dia(4,:,2),Dia(4,:,1),'MarkerFaceColor',mrk_color{4},'MarkerEdge
Color','none','Marker','v');
    point_40 =
scatter(Dia(5,:,2),Dia(5,:,1),'MarkerFaceColor',mrk_color{5},'MarkerEdge
Color','none','Marker','<');
    point_50 =
scatter(Dia(6,:,2),Dia(6,:,1),'MarkerFaceColor',mrk_color{6},'MarkerEdge
Color','none','Marker','>');
    point_60 =
scatter(Dia(7,:,2),Dia(7,:,1),'MarkerFaceColor',mrk_color{7},'MarkerEdge
Color','none','Marker','d');
    point_70 =
scatter(Dia(8,:,2),Dia(8,:,1),'MarkerFaceColor',mrk_color{8},'MarkerEdge
Color',mrk_color{8},'Marker','x');
    point_80 =
scatter(Dia(9,:,2),Dia(9,:,1),'MarkerFaceColor',mrk_color{9},'MarkerEdge
Color',mrk_color{9},'Marker','+');
    point_90 =
scatter(Dia(10,:,2),Dia(10,:,1),'MarkerFaceColor',mrk_color{10},'MarkerE
dgeColor','none','Marker','d');
    point_100 =
scatter(Dia(11,:,2),Dia(11,:,1),'MarkerFaceColor',mrk_color{11},'MarkerE
dgeColor',mrk_color{11},'Marker','*');
legend([point_00,point_10,point_20,point_30,point_40,point_50,point_60,p
oint_70,point_80,point_90,point_100],'0% ACC','10% ACC','20% ACC','30%
ACC','40% ACC','50% ACC','60% ACC','70% ACC','80% ACC','90% ACC','100%
ACC');
hold off;
```

```
figure(3)
title('Traffic Density - Traffic Flow');
xlabel('Traffic Density [veh/km]');
ylabel('Traffic Flow [veh/h]');
grid on;
hold on;
mrk_color = {'[1 0 0]','[1 0.50196 0]','[1 1 0]','[0.50196 1 0]','[0 1
1]','[0 0 1]','[0.49804 0 1]','[1 0 1]','[0.75294 0.75294
0.75294]','[0.50196 0.50196 0.50196]','[0 0 0]'};
    point_00 =
scatter(Dia(1,:,3),Dia(1,:,2),'MarkerFaceColor',mrk_color{1},'MarkerEdge
Color','none','Marker','o');
    point_10 =
scatter(Dia(2,:,3),Dia(2,:,2),'MarkerFaceColor',mrk_color{2},'MarkerEdge
Color','none','Marker','^');
    point_20 =
scatter(Dia(3,:,3),Dia(3,:,2),'MarkerFaceColor',mrk_color{3},'MarkerEdge
Color','none','Marker','s');
    point_30 =
scatter(Dia(4,:,3),Dia(4,:,2),'MarkerFaceColor',mrk_color{4},'MarkerEdge
Color','none','Marker','v');
    point_40 =
scatter(Dia(5,:,3),Dia(5,:,2),'MarkerFaceColor',mrk_color{5},'MarkerEdge
Color','none','Marker','<');
    point_50 =
scatter(Dia(6,:,3),Dia(6,:,2),'MarkerFaceColor',mrk_color{6},'MarkerEdge
Color','none','Marker','>');
    point_60 =
scatter(Dia(7,:,3),Dia(7,:,2),'MarkerFaceColor',mrk_color{7},'MarkerEdge
Color','none','Marker','d');
    point_70 =
scatter(Dia(8,:,3),Dia(8,:,2),'MarkerFaceColor',mrk_color{8},'MarkerEdge
Color',mrk_color{8},'Marker','x');
    point_80 =
scatter(Dia(9,:,3),Dia(9,:,2),'MarkerFaceColor',mrk_color{9},'MarkerEdge
Color',mrk_color{9},'Marker','+');
    point_90 =
scatter(Dia(10,:,3),Dia(10,:,2),'MarkerFaceColor',mrk_color{10},'MarkerE
dgeColor','none','Marker','d');
    point_100 =
scatter(Dia(11,:,3),Dia(11,:,2),'MarkerFaceColor',mrk_color{11},'MarkerE
dgeColor',mrk_color{11},'Marker','*');
legend([point_00,point_10,point_20,point_30,point_40,point_50,point_60,p
oint_70,point_80,point_90,point_100],'0% ACC','10% ACC','20% ACC','30%
ACC','40% ACC','50% ACC','60% ACC','70% ACC','80% ACC','90% ACC','100%
ACC');
hold off;
```

B3. Vehicles_and_driving_behaviour_parameters.m

```
function AutoPar=
Vehicles_and_Driving_behaviour_parameters(n_vehicles,Average_Speed,Devia
tion_Speed,Average_Minimum_Space,Deviation_Minimum_Space,Average_Time_He
adway,...
```

```
Deviation_Time_Headway,Average_Vehicles_Acceleration,Deviation_Accelerat
ion,Average_Vehicles_Deceleration,Deviation_Vehicles_Deceleration,Radius
,P_1,P_2,P_3,P_4,P_ACC)

%% Situate vehicles (equally spaced)
Pos_0 = 0;
Delta = 2*pi/n_vehicles;
Pos_actual = Pos_0;
for e = 1:n_vehicles
      Par(6,e) = Pos_actual;
      Pos_actual = Pos_actual + Delta;
end

%% Type of driver: Human=0, ACC=1
n_vehicles_acc = round(n_vehicles*P_ACC);    %Number of vehicles with
ACC
indexes = randperm(n_vehicles);              %Random locations with no
repeating
dt = zeros(1,n_vehicles);                    %All the vector filled with
zeros
dt(indexes(1:n_vehicles_acc)) = 1;           %Locate ones in random
positions
Par(13,:) = dt;

%% Vehicles_parameters (Percentage distribution)
for e = 1:n_vehicles
    k = rand;

    %% Truck type
    if k < P_1
        % Vehicles_parameters
        Par(1,e) = 2.1;
        Par(2,e) = 7;
        Par(3,e) = 3.5;
        Par(4,e) = 9000;
        Par(5,e) = 125000;
        Par(12,e) = 1;
        % Driving Profile Parameters (with normal distribution)
        Par(7,e) = Deviation_Speed.*randn + Average_Speed - 20;
        Par(8,e) = Deviation_Minimum_Space.*randn +
Average_Minimum_Space + 1;
        Par(9,e) = Deviation_Time_Headway.*randn + Average_Time_Headway
+ 2;
        Par(10,e) = Deviation_Acceleration.*randn +
Average_Vehicles_Acceleration - 0.5;
        Par(11,e) = Deviation_Vehicles_Deceleration.*randn +
Average_Vehicles_Deceleration - 1;

    %% Motorcycle type
    elseif (k >= P_1) && (k <= P_1+P_2)
        % Vehicles_parameters
        Par(1,e) = 0.8;
        Par(2,e) = 2;
        Par(3,e) = 1.1;
        Par(4,e) = 180;
        Par(5,e) = 70000;
        Par(12,e) = 2;
```

```
        % Driving Profile Parameters (with normal distribution)
        Par(7,e) = Deviation_Speed.*randn + Average_Speed;
        Par(8,e) = Deviation_Minimum_Space.*randn +
Average_Minimum_Space;
        Par(9,e) = Deviation_Time_Headway.*randn + Average_Time_Headway;
        Par(10,e) = Deviation_Acceleration.*randn +
Average_Vehicles_Acceleration;
        Par(11,e) = Deviation_Vehicles_Deceleration.*randn +
Average_Vehicles_Deceleration;

    %% Bus type
    elseif (k >= P_1+P_2) && (k <= P_1+P_2+P_3)
        % Vehicles_parameters
        Par(1,e) = 2.5;
        Par(2,e) = 10;
        Par(3,e) = 3;
        Par(4,e) = 12000;
        Par(5,e) = 330000;
        Par(12,e) = 3;
        %% Driving Profile Parameters (with normal distribution)
        Par(7,e) = Deviation_Speed.*randn + Average_Speed - 20;
        Par(8,e) = Deviation_Minimum_Space.*randn +
Average_Minimum_Space + 1;
        Par(9,e) = Deviation_Time_Headway.*randn + Average_Time_Headway
+ 2;
        Par(10,e) = Deviation_Acceleration.*randn +
Average_Vehicles_Acceleration - 0.5;
        Par(11,e) = Deviation_Vehicles_Deceleration.*randn +
Average_Vehicles_Deceleration - 1;

    %% High performance car
    elseif (k >= P_1+P_2+P_3) && (k <= P_1+P_2+P_3+P_4)
        % Vehicles_parameters
        Par(1,e) = 1.9;
        Par(2,e) = 5;
        Par(3,e) = 1.5;
        Par(4,e) = 1900;
        Par(5,e) = 200000;
        Par(12,e) = 4;
        % Driving Profile Parameters (with normal distribution)
        Par(7,e) = Deviation_Speed.*randn + Average_Speed;
        Par(8,e) = Deviation_Minimum_Space.*randn +
Average_Minimum_Space;
        Par(9,e) = Deviation_Time_Headway.*randn + Average_Time_Headway;
        Par(10,e) = Deviation_Acceleration.*randn +
Average_Vehicles_Acceleration;
        Par(11,e) = Deviation_Vehicles_Deceleration.*randn +
Average_Vehicles_Deceleration;

    %% Low perfomance car
    else
        % Vehicles_parameters
        Par(1,e) = 1.7 + 0.03*randn;
        Par(2,e) = 3.9 + 0.1*randn;
        Par(3,e) = 1.4 + 0.03*randn;
        Par(4,e) = 1000 + 100*randn;
        Par(5,e) = 70000 + 2000*randn;
        Par(12,e) = 5;
```

```
        % Driving Profile Parameters (with normal distribution)
        Par(7,e) = Deviation_Speed.*randn + Average_Speed;
        Par(8,e) = Deviation_Minimum_Space.*randn +
Average_Minimum_Space;
        Par(9,e) = Deviation_Time_Headway.*randn + Average_Time_Headway;
        Par(10,e) = Deviation_Acceleration.*randn +
Average_Vehicles_Acceleration;
        Par(11,e) = Deviation_Vehicles_Deceleration.*randn +
Average_Vehicles_Deceleration;
    end
end
AutoPar = Par;
end
```

B4. Normal properties plots

```
load Par;
%% Minimum spacing
a_1=[];
a_2= [];

for e = 1:length(Par)
    if Par(12,e) == 1 || Par(12,e) == 3
        a_1 = [a_1,Par(8,e)];
    else
        a_2 = [a_2,Par(8,e)];
    end
end
figure(1)
h1 = a_1;
h2 = a_2;
histogram(h1,25);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
title('Minimum spacing (s_0)');
xlabel('Spacing [m]');ylabel('Number of vehicles');
axis([1 3 0 100]);

%% Desired speed
v_1= [];
v_2= [];

for e = 1:length(Par)
    if Par(12,e) == 1 || Par(12,e) == 3
        v_1 = [v_1,Par(7,e)];
    else
        v_2 = [v_2,Par(7,e)];
    end
end
figure(2)
h1 = v_1;
h2 = v_2;
histogram(h1,30);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
```

```
title('Desired speed (V_0)');
xlabel('Speed [m/s]');ylabel('Number of vehicles');
axis([60 100 0 100]);

%% Desired time headway
T_1= [];
v_2= [];

for e = 1:length(Par)
    if Par(12,e) == 1 || Par(12,e) == 3
        T_1 = [T_1,Par(9,e)];
    else
        v_2 = [v_2,Par(9,e)];
    end
end
figure(3)
h1 = T_1;
h2 = v_2;
histogram(h1,20);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
title('Desired time headway (T)');
xlabel('Time [s]');ylabel('Number of vehicles');
axis([0.5 2 0 100]);

%% Deceleration
a_1=[];
a_2= [];

for e = 1:length(Par)
    if Par(12,e) == 1 || Par(12,e) == 3
        a_1 = [a_1,Par(11,e)];
    else
        a_2 = [a_2,Par(11,e)];
    end
end

figure(4)
h1 = a_1;
h2 = a_2;
histogram(h1,25);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
title('Maximum confortable deceleration  (b)');
xlabel('Deceleration [m/s^2]');ylabel('Number of vehicles');
axis([1 6 0 100]);

%% Acceleration
a_1=[];
a_2= [];

for e = 1:length(Par)
    if Par(12,e) == 1 || Par(12,e) == 3
        a_1 = [a_1,Par(10,e)];
    else
        a_2 = [a_2,Par(10,e)];
    end
```

```
end

figure(5)
h1 = a_1;
h2 = a_2;
histogram(h1,30);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
title('Maximum desired acceleration  (a)');
xlabel('Acceleration [m/s^2]');ylabel('Number of vehicles');
axis([0 3 0 100]);

%% Width
a_1=[];
a_2= [];
for e = 1:length(Par)
    if Par(12,e) == 1 || Par(12,e) == 3
        a_1 = [a_1,Par(1,e)];
    else
        a_2 = [a_2,Par(1,e)];
    end
end

figure(6)
h1 = a_1;
h2 = a_2;
histogram(h1,25);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
title('Width of vehicles');
xlabel('Width [m]');ylabel('Number of vehicles');
axis([1.5 1.9 0 100]);

%% Length
a_1=[];
a_2= [];
for e = 1:length(Par)
    if Par(12,e) == 1 || Par(12,e) == 3
        a_1 = [a_1,Par(2,e)];
    else
        a_2 = [a_2,Par(2,e)];
    end
end

figure(7)
h1 = a_1;
h2 = a_2;
histogram(h1,25);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
title('Length of vehicles');
xlabel('Length [m]');ylabel('Number of vehicles');
axis([3 5 0 100]);

%% Height
a_1=[];
a_2= [];
for e = 1:length(Par)
```

```
    if Par(12,e) == 1 || Par(12,e) == 3
        a_1 = [a_1,Par(3,e)];
    else
        a_2 = [a_2,Par(3,e)];
    end
end

figure(8)
h1 = a_1;
h2 = a_2;
histogram(h1,25);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
title('Height of vehicles');
xlabel('Height [m]');ylabel('Number of vehicles');
axis([1.2 1.6 0 100]);

%% Mass
a_1=[];
a_2= [];
for e = 1:length(Par)
    if Par(12,e) == 1 || Par(12,e) == 3
        a_1 = [a_1,Par(4,e)];
    else
        a_2 = [a_2,Par(4,e)];
    end
end

figure(9)
h1 = a_1;
h2 = a_2;
histogram(h1,25);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
title('Mass of vehicles');
xlabel('Mass [kg]');ylabel('Number of vehicles');
axis([700 1300 0 100]);

%% Power
a_1=[];
a_2= [];
for e = 1:length(Par)
    if Par(12,e) == 1 || Par(12,e) == 3
        a_1 = [a_1,Par(5,e)];
    else
        a_2 = [a_2,Par(5,e)];
    end
end

figure(10)
h1 = a_1;
h2 = a_2;
histogram(h1,25);hold on;grid on;
histogram(h2,40,'FaceColor','b');
set(gca,'fontsize',14);
title('Power of vehicles');
xlabel('Power [kW]');ylabel('Number of vehicles');
axis([63000 77000 0 100]);
```

```
%%
saveas(figure(1),'figure1.bmp');
saveas(figure(2),'figure2.bmp');
saveas(figure(3),'figure3.bmp');
saveas(figure(4),'figure4.bmp');
saveas(figure(5),'figure5.bmp');
saveas(figure(6),'figure6.bmp');
saveas(figure(7),'figure7.bmp');
saveas(figure(8),'figure8.bmp');
saveas(figure(9),'figure9.bmp');
saveas(figure(10),'figure10.bmp');
```

B5. Plots of percentages of improvement with respect to humans

```
%% Average value for matrix Res
tot = zeros(11,8,3);
for n =1:n_iter
tot = tot + Res(:,:,:,n);
end
Avg = tot/n_iter;

%% Plots
for dens = 10:20:150
x = [0,10,20,30,40,50,60,70,80,90,100];
    for p = 0:10:100
        y_cons(p/10+1) = (Avg(p/10+1,(dens-10)/20+1,1)-Avg(1,(dens-
10)/20+1,1))*100/Avg(1,(dens-10)/20+1,1);
        y_speed(p/10+1) = (Avg(p/10+1,(dens-10)/20+1,2)-Avg(1,(dens-
10)/20+1,2))*100/Avg(1,(dens-10)/20+1,2);
    end

figure(dens)
set(figure(dens), 'Position', [70 150 700 350]);hold on;
set(gca,'FontSize',10);

ch_speed = plot(x,y_speed,'-
o','LineWidth',1.8,'Color','b','MarkerSize',8,'MarkerFaceColor','b');
ch_cons = plot(x,y_cons,'-
^','LineWidth',1.8,'Color','r','MarkerSize',8,'MarkerFaceColor','r');

grid on;hold on;

legend([ch_speed,ch_cons],'Speed','Consumption');
xlabel('Percentage of ACC (%)');ylabel('Increment respect to humans
(%)');
title([num2str(dens),' veh/km']);

end
```

B6. IDM model

```
function [y,s] = fcn(Vo,So,Th,a,b,L,v_i,s_i)
%Inputs
%Vo = Desired_Speed;
%So = Minum_spacing;
%T = Desired_time_headway;
%a = Maximum_vehicle_acceleration;
%b = Comfortable_braking_deceleretion

Delta = 10;
%% Net distance (distance to the vehicle in front)
L_front = [L(2:length(v_i));L(1)]; %Changing colums to get length of
vehicle in front
s_i = s_i - 0.5*(L+L_front);

%% Aproching rate (Speed difference with the car in front)
v_i_front = [v_i(2:length(v_i));v_i(1)]; %Changing colums to get speed
of vehicle in front
Delta_V = v_i-v_i_front;

%% Model definition of acceleration
Acceleration = a.*[1-((v_i./Vo).^Delta)-
((So+max(0,v_i.*Th+(v_i.*Delta_V)./(2*sqrt(a.*b))))./s_i).^2];

y = Acceleration;
s = s_i;
end
```

B7. Simple model

```
function y = fcn(Vo,v_i,s_i,L)
%% Speed vehicle in front
v_i_front = [v_i(2:length(v_i));v_i(1)];%Changing colums to get speed of
vehicle in front

%% Net distance (distance to the vehicle in front)
L_front = [L(2:length(v_i));L(1)]; %Changing colums to get length of
vehicle in front
s_i = s_i - 0.5*(L+L_front);

%% Model parameters
T = 0.5;    % Safety distance time
k = 1;      % Proporcional constant
s_o = 2;  % Minimum distance
s_ref = s_o*ones(length(Vo),1) + T.*v_i;

%% Speed control algorithm
v=k*(s_i-s_ref)+v_i_front;
v=min(Vo,v);
y=v;
end
```

B8. Average value calculation

```
function y = fcn(u)
n = 0;
sum = 0;
for e = u'
    n = n + 1;
    sum = sum + e;
end
y = sum/n;
```

Annex C. Simulation results data

C1. Speed and consumption simulations

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
1	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	73.32	66.43	38.26	21.86	14.10	8.63	4.92	2.11	10.34	8.64	7.80	8.85	5.17	4.22	2.83	2.76
10% ACC	78.32	69.06	37.14	23.84	15.30	9.16	5.20	2.25	11.14	9.16	13.40	8.69	4.12	3.42	3.00	2.72
20% ACC	73.07	68.35	40.72	25.26	16.13	10.11	5.68	2.43	9.81	8.94	11.52	7.62	6.09	3.56	2.94	2.75
30% ACC	76.72	73.09	45.70	27.30	17.31	10.57	6.10	2.49	10.44	9.97	8.65	6.21	4.85	3.19	2.87	2.74
40% ACC	73.94	70.26	50.34	29.91	18.48	11.59	6.81	2.74	9.51	9.15	6.54	7.80	5.76	3.03	2.87	2.80
50% ACC	83.92	71.40	56.95	32.51	20.51	12.67	7.04	2.93	11.60	9.73	7.27	6.36	5.69	3.70	2.91	2.74
60% ACC	71.34	74.69	59.29	36.57	22.46	14.26	7.95	3.24	10.33	9.87	7.69	5.73	3.64	3.13	2.90	2.77
70% ACC	78.39	73.07	65.19	40.73	25.22	15.48	8.81	3.87	10.40	9.87	8.45	5.07	3.91	3.25	2.98	2.81
80% ACC	77.89	74.49	70.17	44.77	28.49	17.82	9.82	4.23	11.27	9.90	9.35	5.70	4.08	3.34	2.99	2.83
90% ACC	73.19	71.88	73.29	51.26	32.57	20.14	11.20	4.74	9.35	9.81	9.98	6.41	4.34	3.56	3.04	2.78
100% ACC	74.65	73.16	70.60	60.29	37.44	23.02	12.82	5.40	9.81	9.64	9.45	7.80	4.83	3.68	3.12	2.90

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
2	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	76.02	66.39	36.95	21.46	13.96	8.76	5.03	2.17	10.16	8.66	10.77	9.13	4.73	3.21	2.81	2.73
10% ACC	75.60	66.89	36.71	23.50	15.24	9.29	5.15	2.22	9.99	8.62	13.51	9.48	6.75	3.13	2.90	2.75
20% ACC	78.55	69.73	41.86	25.93	16.27	9.82	5.89	2.26	10.92	9.19	9.32	9.19	5.94	3.59	2.93	2.83
30% ACC	78.81	68.81	46.58	27.17	17.37	10.15	6.26	2.61	10.38	9.01	10.04	8.86	5.79	3.65	2.90	2.80
40% ACC	74.10	76.60	51.06	30.07	19.15	11.76	6.46	2.93	9.93	10.45	6.93	8.18	4.62	3.06	2.88	2.76
50% ACC	76.82	69.79	55.18	32.34	20.92	12.78	7.07	3.08	10.30	9.10	7.12	8.23	4.05	3.30	2.92	2.79
60% ACC	75.32	70.39	59.48	37.81	23.02	13.79	7.96	3.35	9.72	9.21	7.73	5.50	4.06	3.13	2.95	2.76
70% ACC	77.29	70.98	64.39	40.57	25.29	15.69	8.59	3.68	10.16	8.98	8.48	5.14	3.81	3.24	2.88	2.77
80% ACC	73.33	71.42	69.10	44.59	28.83	17.49	9.97	4.04	10.57	9.53	9.13	5.52	4.03	3.34	3.00	2.83
90% ACC	77.16	70.20	71.17	50.40	32.35	20.07	11.25	4.68	10.22	9.15	9.27	6.37	4.47	3.45	3.10	2.74
100% ACC	74.01	75.34	72.78	60.30	37.24	23.02	12.97	5.55	9.88	10.26	9.93	7.79	4.91	3.73	3.10	2.86

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
3	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	73.71	66.31	33.17	22.46	13.79	8.98	4.90	2.13	10.03	8.41	15.69	6.80	4.60	3.94	2.84	2.74
10% ACC	78.65	68.46	38.33	23.42	15.09	9.22	5.19	2.40	11.01	8.90	12.92	9.68	5.28	3.51	2.90	2.78
20% ACC	74.53	69.54	39.61	25.27	15.63	9.93	5.75	2.28	9.91	9.12	13.54	8.64	5.84	3.21	2.87	2.78
30% ACC	79.95	74.00	47.02	26.04	17.27	10.73	6.18	2.66	11.07	9.75	6.15	10.91	6.93	3.22	2.82	2.75
40% ACC	75.83	66.57	49.81	28.84	18.72	11.62	6.57	2.93	10.24	8.51	8.20	8.34	4.55	3.30	2.84	2.80

50% ACC	79.15	74.21	56.20	32.03	20.74	13.07	7.11	3.09	10.66	10.09	7.21	8.05	4.32	3.47	2.81	2.78
60% ACC	80.71	74.90	60.46	36.34	23.25	13.84	7.78	3.31	10.65	10.00	7.97	5.00	3.83	3.17	2.92	2.81
70% ACC	77.23	73.98	64.80	41.17	25.20	15.22	8.60	3.57	10.39	9.89	8.41	5.35	3.77	3.20	2.93	2.80
80% ACC	72.46	70.62	69.27	45.27	28.26	16.74	9.89	4.38	9.84	9.15	9.02	5.77	4.15	3.33	3.07	2.83
90% ACC	77.26	77.36	70.38	50.35	31.67	20.09	10.94	4.88	10.51	10.62	9.49	6.30	4.40	3.55	3.00	2.83
100% ACC	76.98	73.44	69.63	60.05	37.36	22.89	12.92	5.63	10.61	10.26	9.24	7.72	4.90	3.73	3.17	2.85

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
4	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	72.09	66.71	33.43	22.20	14.34	8.89	4.99	2.01	9.99	8.43	14.30	6.02	5.04	3.82	2.88	2.68
10% ACC	81.80	68.64	39.39	23.58	15.04	9.30	5.48	2.34	11.15	9.21	10.91	7.76	5.69	3.59	2.91	2.81
20% ACC	73.44	68.97	38.99	25.44	15.71	9.77	5.63	2.45	9.70	9.12	13.01	7.92	7.54	3.87	2.93	2.78
30% ACC	80.64	68.02	44.09	28.25	17.39	10.98	6.00	2.70	11.30	8.98	9.91	5.06	5.50	3.77	2.84	2.78
40% ACC	74.76	71.59	50.42	29.22	18.85	12.01	6.49	2.92	10.10	9.56	8.39	7.42	3.88	3.53	2.88	2.76
50% ACC	77.56	69.68	55.93	31.44	20.35	12.40	7.01	3.25	10.41	9.23	7.04	8.17	4.76	3.11	2.91	2.80
60% ACC	73.83	68.10	59.72	36.76	22.27	13.60	7.62	3.28	9.57	8.94	7.60	6.38	3.63	3.13	2.99	2.78
70% ACC	75.90	68.90	65.97	42.54	25.52	16.05	8.69	3.64	10.47	8.98	8.68	5.29	3.84	3.30	3.03	2.80
80% ACC	81.64	75.52	69.99	44.07	28.02	17.49	10.10	3.98	10.73	9.76	9.37	5.56	4.06	3.35	2.94	2.87
90% ACC	74.00	76.44	71.98	51.40	31.30	20.10	11.34	4.69	9.76	10.36	9.49	6.62	4.27	3.46	3.06	2.87
100% ACC	76.23	74.95	71.91	60.20	37.41	23.18	12.92	5.66	9.88	9.90	9.52	7.72	4.95	3.72	3.17	2.94

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
5	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	73.32	66.43	38.26	21.86	14.10	8.63	4.92	2.11	10.34	8.64	7.80	8.85	5.17	4.22	2.83	2.76
10% ACC	78.32	69.06	37.14	23.84	15.30	9.16	5.20	2.25	11.14	9.16	13.40	8.69	4.12	3.42	3.00	2.72
20% ACC	73.07	68.35	40.72	25.26	16.13	10.11	5.68	2.43	9.81	8.94	11.52	7.62	6.09	3.56	2.94	2.75
30% ACC	76.72	73.09	45.70	27.30	17.31	10.57	6.10	2.49	10.44	9.97	8.65	6.21	4.85	3.19	2.87	2.74
40% ACC	73.94	70.26	50.34	29.91	18.48	11.59	6.81	2.74	9.51	9.15	6.54	7.80	5.76	3.03	2.87	2.80
50% ACC	83.92	71.40	56.95	32.51	20.51	12.67	7.04	2.93	11.60	9.73	7.27	6.36	5.69	3.70	2.91	2.74
60% ACC	71.34	74.69	59.29	36.57	22.46	14.26	7.95	3.24	10.33	9.87	7.69	5.73	3.64	3.13	2.90	2.77
70% ACC	78.39	73.07	65.19	40.73	25.22	15.48	8.81	3.87	10.40	9.87	8.45	5.07	3.91	3.25	2.98	2.81
80% ACC	77.89	74.49	70.17	44.77	28.49	17.82	9.82	4.23	11.27	9.90	9.35	5.70	4.08	3.34	2.99	2.83
90% ACC	73.19	71.88	73.29	51.26	32.57	20.14	11.20	4.74	9.35	9.81	9.98	6.41	4.34	3.56	3.04	2.78
100% ACC	74.65	73.16	70.60	60.29	37.44	23.02	12.82	5.40	9.81	9.64	9.45	7.80	4.83	3.68	3.12	2.90

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
6	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	76.02	66.39	36.95	21.46	13.96	8.76	5.03	2.17	10.16	8.66	10.77	9.13	4.73	3.21	2.81	2.73
10% ACC	75.60	66.89	36.71	23.50	15.24	9.29	5.15	2.22	9.99	8.62	13.51	9.48	6.75	3.13	2.90	2.75

20% ACC	78.55	69.73	41.86	25.93	16.27	9.82	5.89	2.26	10.92	9.19	9.32	9.19	5.94	3.59	2.93	2.83
30% ACC	78.81	68.81	46.58	27.17	17.37	10.15	6.26	2.61	10.38	9.01	10.04	8.86	5.79	3.65	2.90	2.80
40% ACC	74.10	76.60	51.06	30.07	19.15	11.76	6.46	2.93	9.93	10.45	6.93	8.18	4.62	3.06	2.88	2.76
50% ACC	76.82	69.79	55.18	32.34	20.92	12.78	7.07	3.08	10.30	9.10	7.12	8.23	4.05	3.30	2.92	2.79
60% ACC	75.32	70.39	59.48	37.81	23.02	13.79	7.96	3.35	9.72	9.21	7.73	5.50	4.06	3.13	2.95	2.76
70% ACC	77.29	70.98	64.39	40.57	25.29	15.69	8.59	3.68	10.16	8.98	8.48	5.14	3.81	3.24	2.88	2.77
80% ACC	73.33	71.42	69.10	44.59	28.83	17.49	9.97	4.04	10.57	9.53	9.13	5.52	4.03	3.34	3.00	2.83
90% ACC	77.16	70.20	71.17	50.40	32.35	20.07	11.25	4.68	10.22	9.15	9.27	6.37	4.47	3.45	3.10	2.74
100% ACC	74.01	75.34	72.78	60.30	37.24	23.02	12.97	5.55	9.88	10.26	9.93	7.79	4.91	3.73	3.10	2.86

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
7	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	73.71	66.31	33.17	22.46	13.79	8.98	4.90	2.13	10.03	8.41	15.69	6.80	4.60	3.94	2.84	2.74
10% ACC	78.65	68.46	38.33	23.42	15.09	9.22	5.19	2.40	11.01	8.90	12.92	9.68	5.28	3.51	2.90	2.78
20% ACC	74.53	69.54	39.61	25.27	15.63	9.93	5.75	2.28	9.91	9.12	13.54	8.64	5.84	3.21	2.87	2.78
30% ACC	79.95	74.00	47.02	26.04	17.27	10.73	6.18	2.66	11.07	9.75	6.15	10.91	6.93	3.22	2.82	2.75
40% ACC	75.83	66.57	49.81	28.84	18.72	11.62	6.57	2.93	10.24	8.51	8.20	8.34	4.55	3.30	2.84	2.80
50% ACC	79.15	74.21	56.20	32.03	20.74	13.07	7.11	3.09	10.66	10.09	7.21	8.05	4.32	3.47	2.81	2.78
60% ACC	80.71	74.90	60.46	36.34	23.25	13.84	7.78	3.31	10.65	10.00	7.97	5.00	3.83	3.17	2.92	2.81
70% ACC	77.23	73.98	64.80	41.17	25.20	15.22	8.60	3.57	10.39	9.89	8.41	5.35	3.77	3.20	2.93	2.80
80% ACC	72.46	70.62	69.27	45.27	28.26	16.74	9.89	4.38	9.84	9.15	9.02	5.77	4.15	3.33	3.07	2.83
90% ACC	77.26	77.36	70.38	50.35	31.67	20.09	10.94	4.88	10.51	10.62	9.49	6.30	4.40	3.55	3.00	2.83
100% ACC	76.98	73.44	69.63	60.05	37.36	22.89	12.92	5.63	10.61	10.26	9.24	7.72	4.90	3.73	3.17	2.85

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
8	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	72.09	66.71	33.43	22.20	14.34	8.89	4.99	2.01	9.99	8.43	14.30	6.02	5.04	3.82	2.88	2.68
10% ACC	81.80	68.64	39.39	23.58	15.04	9.30	5.48	2.34	11.15	9.21	10.91	7.76	5.69	3.59	2.91	2.81
20% ACC	73.44	68.97	38.99	25.44	15.71	9.77	5.63	2.45	9.70	9.12	13.01	7.92	7.54	3.87	2.93	2.78
30% ACC	80.64	68.02	44.09	28.25	17.39	10.98	6.00	2.70	11.30	8.98	9.91	5.06	5.50	3.77	2.84	2.78
40% ACC	74.76	71.59	50.42	29.22	18.85	12.01	6.49	2.92	10.10	9.56	8.39	7.42	3.88	3.53	2.88	2.76
50% ACC	77.56	69.68	55.93	31.44	20.35	12.40	7.01	3.25	10.41	9.23	7.04	8.17	4.76	3.11	2.91	2.80
60% ACC	73.83	68.10	59.72	36.76	22.27	13.60	7.62	3.28	9.57	8.94	7.60	6.38	3.63	3.13	2.99	2.78
70% ACC	75.90	68.90	65.97	42.54	25.52	16.05	8.69	3.64	10.47	8.98	8.68	5.29	3.84	3.30	3.03	2.80
80% ACC	81.64	75.52	69.99	44.07	28.02	17.49	10.10	3.98	10.73	9.76	9.37	5.56	4.06	3.35	2.94	2.87
90% ACC	74.00	76.44	71.98	51.40	31.30	20.10	11.34	4.69	9.76	10.36	9.49	6.62	4.27	3.46	3.06	2.87
100% ACC	76.23	74.95	71.91	60.20	37.41	23.18	12.92	5.66	9.88	9.90	9.52	7.72	4.95	3.72	3.17	2.94

Iteration	Average Speed (km/h)	Average Consumption (kWh/100km)

9	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	78.04	67.11	38.28	20.35	13.77	8.82	4.92	2.10	10.48	8.78	7.92	11.80	6.61	3.39	2.90	2.77
10% ACC	79.54	68.29	38.53	23.74	14.87	9.39	5.21	2.08	11.21	9.05	8.67	7.77	6.41	3.04	2.95	2.77
20% ACC	74.57	67.13	43.01	23.96	15.93	10.02	5.77	2.40	9.84	8.90	9.28	11.18	6.46	3.72	2.92	2.73
30% ACC	76.87	70.20	44.29	26.62	17.23	11.01	6.08	2.59	10.44	9.34	10.49	8.93	6.16	3.57	2.88	2.76
40% ACC	69.98	72.19	49.24	30.30	19.33	11.89	6.59	2.87	9.53	9.41	8.53	5.67	4.89	3.71	2.98	2.80
50% ACC	73.70	74.67	56.95	33.12	20.52	12.70	7.06	3.10	10.17	9.90	7.32	4.75	5.20	3.21	2.89	2.76
60% ACC	75.15	70.25	60.09	38.35	23.16	13.45	7.80	3.13	10.00	9.18	7.68	5.11	3.73	3.22	2.87	2.83
70% ACC	73.82	72.87	65.30	42.03	25.06	15.57	8.67	3.71	9.57	9.72	8.38	5.36	3.88	3.17	2.97	2.79
80% ACC	79.33	72.54	65.68	45.65	28.37	16.90	9.82	4.36	11.00	9.53	8.42	5.85	4.14	3.38	3.01	2.82
90% ACC	74.70	69.96	71.83	51.26	31.42	20.26	11.24	4.95	9.73	9.65	9.64	6.37	4.37	3.44	3.09	2.77
100% ACC	78.78	67.16	70.45	60.27	37.41	22.94	12.80	5.63	10.93	8.69	9.43	7.71	4.90	3.74	3.10	2.85

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
10	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	75.48	67.12	37.03	21.86	13.80	8.60	4.98	1.99	9.91	8.62	8.88	7.81	4.95	4.14	2.96	2.82
10% ACC	72.07	70.26	40.47	24.17	15.09	9.42	5.32	2.24	9.54	9.45	9.30	7.64	3.60	3.84	2.84	2.82
20% ACC	79.19	69.80	39.14	26.15	15.87	10.22	5.72	2.47	10.63	9.24	12.91	6.43	7.65	3.15	2.86	2.77
30% ACC	68.88	72.14	44.01	26.49	16.81	10.57	5.91	2.61	8.91	9.64	11.07	6.51	6.25	3.54	2.90	2.76
40% ACC	79.30	73.84	51.57	29.69	19.16	11.84	6.64	2.89	10.87	9.85	8.16	8.75	4.98	3.02	2.83	2.79
50% ACC	69.38	70.42	54.58	32.60	20.45	12.48	7.27	3.01	9.22	9.15	7.00	6.28	5.09	3.34	2.87	2.69
60% ACC	80.10	74.09	61.09	36.87	22.82	13.74	7.67	3.41	11.33	10.09	8.01	5.24	4.34	3.17	2.90	2.81
70% ACC	72.71	68.99	64.48	40.48	25.64	15.38	8.63	3.70	9.77	8.81	8.30	5.28	4.77	3.21	2.99	2.79
80% ACC	76.96	72.72	66.87	44.69	28.40	17.71	9.67	4.04	10.15	9.82	8.80	5.64	4.18	3.46	2.98	2.86
90% ACC	74.42	67.82	70.07	51.66	31.82	20.07	11.19	4.74	9.93	8.97	9.22	6.54	4.32	3.50	3.03	2.80
100% ACC	76.73	72.81	71.22	60.28	37.63	22.82	13.04	5.46	10.28	9.70	9.46	7.73	4.95	3.62	3.14	2.80

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
11	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	76.72	67.06	35.79	21.66	14.38	8.94	5.01	2.14	10.60	8.76	12.72	9.23	5.26	4.03	2.87	2.73
10% ACC	75.28	67.45	40.59	23.22	15.23	9.20	5.32	2.20	10.05	8.88	9.64	9.13	5.73	4.83	2.81	2.79
20% ACC	70.74	67.21	41.22	25.61	16.10	10.09	5.84	2.26	9.42	8.90	10.88	7.61	6.53	3.53	2.91	2.76
30% ACC	73.15	71.99	47.89	27.11	17.48	10.78	6.21	2.70	9.58	9.68	8.53	7.23	5.98	3.42	2.84	2.72
40% ACC	73.32	67.58	51.62	29.79	18.68	11.61	6.55	2.67	9.61	8.85	7.77	8.80	4.67	3.02	2.83	2.74
50% ACC	75.20	75.08	55.58	33.09	20.64	12.64	7.16	2.91	10.08	10.25	7.04	6.19	3.63	3.26	2.88	2.76
60% ACC	67.79	67.86	61.01	36.54	22.88	13.98	8.12	3.47	8.49	8.96	7.79	5.85	3.63	3.20	2.99	2.76
70% ACC	78.06	71.98	65.38	41.12	24.90	15.69	8.42	3.54	11.15	9.25	8.49	5.31	3.93	3.30	2.91	2.78
80% ACC	73.11	70.47	69.42	45.08	28.84	17.50	9.95	4.00	9.34	9.40	9.20	5.78	4.23	3.36	2.90	2.80
90% ACC	82.80	69.52	74.69	51.91	31.97	20.12	11.09	4.65	11.45	9.00	10.29	6.60	4.25	3.48	3.07	2.87
100% ACC	83.64	73.33	70.73	60.34	37.45	22.88	12.96	5.42	11.83	9.56	9.39	7.80	4.82	3.63	3.07	2.84

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
12	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	74.19	67.00	36.82	22.50	14.05	8.80	5.01	2.11	10.34	8.67	10.82	6.88	6.61	3.72	2.96	2.70
10% ACC	70.08	67.15	39.95	24.27	15.26	9.37	5.26	2.23	9.06	8.82	8.86	6.22	7.42	3.21	2.92	2.75
20% ACC	77.38	68.21	41.39	25.27	15.99	10.13	5.68	2.34	10.85	8.92	11.30	9.32	5.36	3.16	2.90	2.72
30% ACC	74.62	70.37	47.53	27.74	18.13	10.66	6.14	2.62	10.13	9.39	8.38	5.85	5.33	3.91	2.89	2.82
40% ACC	75.79	74.34	51.98	28.81	18.85	11.57	6.71	2.84	10.14	9.84	6.54	8.58	4.58	3.16	2.91	2.83
50% ACC	71.41	70.92	55.82	30.38	20.77	12.79	7.12	3.06	8.81	9.42	7.16	8.94	4.15	3.20	2.93	2.79
60% ACC	75.63	71.43	60.05	37.04	22.88	13.57	7.95	3.26	9.90	9.54	7.66	4.79	4.20	3.18	2.84	2.78
70% ACC	78.98	71.84	65.75	41.39	24.87	15.59	8.63	3.96	11.13	9.29	8.64	5.38	4.38	3.31	2.97	2.77
80% ACC	81.57	74.63	71.16	45.24	28.40	17.09	9.62	3.97	11.24	10.23	9.38	5.62	4.07	3.39	2.98	2.81
90% ACC	69.71	72.20	72.94	51.00	31.63	20.14	11.30	4.70	9.22	9.53	9.64	6.46	4.27	3.44	3.07	2.85
100% ACC	73.90	71.72	67.37	60.51	37.64	22.96	12.91	5.48	9.34	9.45	8.70	7.74	4.87	3.68	3.19	2.81

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
13	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	73.32	66.43	38.26	21.86	14.10	8.63	4.92	2.11	10.34	8.64	7.80	8.85	5.17	4.22	2.83	2.76
10% ACC	78.32	69.06	37.14	23.84	15.30	9.16	5.20	2.25	11.14	9.16	13.40	8.69	4.12	3.42	3.00	2.72
20% ACC	73.07	68.35	40.72	25.26	16.13	10.11	5.68	2.43	9.81	8.94	11.52	7.62	6.09	3.56	2.94	2.75
30% ACC	76.72	73.09	45.70	27.30	17.31	10.57	6.10	2.49	10.44	9.97	8.65	6.21	4.85	3.19	2.87	2.74
40% ACC	73.94	70.26	50.34	29.91	18.48	11.59	6.81	2.74	9.51	9.15	6.54	7.80	5.76	3.03	2.87	2.80
50% ACC	83.92	71.40	56.95	32.51	20.51	12.67	7.04	2.93	11.60	9.73	7.27	6.36	5.69	3.70	2.91	2.74
60% ACC	71.34	74.69	59.29	36.57	22.46	14.26	7.95	3.24	10.33	9.87	7.69	5.73	3.64	3.13	2.90	2.77
70% ACC	78.39	73.07	65.19	40.73	25.22	15.48	8.81	3.87	10.40	9.87	8.45	5.07	3.91	3.25	2.98	2.81
80% ACC	77.89	74.49	70.17	44.77	28.49	17.82	9.82	4.23	11.27	9.90	9.35	5.70	4.08	3.34	2.99	2.83
90% ACC	73.19	71.88	73.29	51.26	32.57	20.14	11.20	4.74	9.35	9.81	9.98	6.41	4.34	3.56	3.04	2.78
100% ACC	74.65	73.16	70.60	60.29	37.44	23.02	12.82	5.40	9.81	9.64	9.45	7.80	4.83	3.68	3.12	2.90

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
14	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	76.02	66.39	36.95	21.46	13.96	8.76	5.03	2.17	10.16	8.66	10.77	9.13	4.73	3.21	2.81	2.73
10% ACC	75.60	66.89	36.71	23.50	15.24	9.29	5.15	2.22	9.99	8.62	13.51	9.48	6.75	3.13	2.90	2.75
20% ACC	78.55	69.73	41.86	25.93	16.27	9.82	5.89	2.26	10.92	9.19	9.32	9.19	5.94	3.59	2.93	2.83
30% ACC	78.81	68.81	46.58	27.17	17.37	10.15	6.26	2.61	10.38	9.01	10.04	8.86	5.79	3.65	2.90	2.80
40% ACC	74.10	76.60	51.06	30.07	19.15	11.76	6.46	2.93	9.93	10.45	6.93	8.18	4.62	3.06	2.88	2.76
50% ACC	76.82	69.79	55.18	32.34	20.92	12.78	7.07	3.08	10.30	9.10	7.12	8.23	4.05	3.30	2.92	2.79
60% ACC	75.32	70.39	59.48	37.81	23.02	13.79	7.96	3.35	9.72	9.21	7.73	5.50	4.06	3.13	2.95	2.76
70% ACC	77.29	70.98	64.39	40.57	25.29	15.69	8.59	3.68	10.16	8.98	8.48	5.14	3.81	3.24	2.88	2.77

80% ACC	73.33	71.42	69.10	44.59	28.83	17.49	9.97	4.04	10.57	9.53	9.13	5.52	4.03	3.34	3.00	2.83
90% ACC	77.16	70.20	71.17	50.40	32.35	20.07	11.25	4.68	10.22	9.15	9.27	6.37	4.47	3.45	3.10	2.74
100% ACC	74.01	75.34	72.78	60.30	37.24	23.02	12.97	5.55	9.88	10.26	9.93	7.79	4.91	3.73	3.10	2.86

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
15	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	73.71	66.31	33.17	22.46	13.79	8.98	4.90	2.13	10.03	8.41	15.69	6.80	4.60	3.94	2.84	2.74
10% ACC	78.65	68.46	38.33	23.42	15.09	9.22	5.19	2.40	11.01	8.90	12.92	9.68	5.28	3.51	2.90	2.78
20% ACC	74.53	69.54	39.61	25.27	15.63	9.93	5.75	2.28	9.91	9.12	13.54	8.64	5.84	3.21	2.87	2.78
30% ACC	79.95	74.00	47.02	26.04	17.27	10.73	6.18	2.66	11.07	9.75	6.15	10.91	6.93	3.22	2.82	2.75
40% ACC	75.83	66.57	49.81	28.84	18.72	11.62	6.57	2.93	10.24	8.51	8.20	8.34	4.55	3.30	2.84	2.80
50% ACC	79.15	74.21	56.20	32.03	20.74	13.07	7.11	3.09	10.66	10.09	7.21	8.05	4.32	3.47	2.81	2.78
60% ACC	80.71	74.90	60.46	36.34	23.25	13.84	7.78	3.31	10.65	10.00	7.97	5.00	3.83	3.17	2.92	2.81
70% ACC	77.23	73.98	64.80	41.17	25.20	15.22	8.60	3.57	10.39	9.89	8.41	5.35	3.77	3.20	2.93	2.80
80% ACC	72.46	70.62	69.27	45.27	28.26	16.74	9.89	4.38	9.84	9.15	9.02	5.77	4.15	3.33	3.07	2.83
90% ACC	77.26	77.36	70.38	50.35	31.67	20.09	10.94	4.88	10.51	10.62	9.49	6.30	4.40	3.55	3.00	2.83
100% ACC	76.98	73.44	69.63	60.05	37.36	22.89	12.92	5.63	10.61	10.26	9.24	7.72	4.90	3.73	3.17	2.85

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
16	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	72.09	66.71	33.43	22.20	14.34	8.89	4.99	2.01	9.99	8.43	14.30	6.02	5.04	3.82	2.88	2.68
10% ACC	81.80	68.64	39.39	23.58	15.04	9.30	5.48	2.34	11.15	9.21	10.91	7.76	5.69	3.59	2.91	2.81
20% ACC	73.44	68.97	38.99	25.44	15.71	9.77	5.63	2.45	9.70	9.12	13.01	7.92	7.54	3.87	2.93	2.78
30% ACC	80.64	68.02	44.09	28.25	17.39	10.98	6.00	2.70	11.30	8.98	9.91	5.06	5.50	3.77	2.84	2.78
40% ACC	74.76	71.59	50.42	29.22	18.85	12.01	6.49	2.92	10.10	9.56	8.39	7.42	3.88	3.53	2.88	2.76
50% ACC	77.56	69.68	55.93	31.44	20.35	12.40	7.01	3.25	10.41	9.23	7.04	8.17	4.76	3.11	2.91	2.80
60% ACC	73.83	68.10	59.72	36.76	22.27	13.60	7.62	3.28	9.57	8.94	7.60	6.38	3.63	3.13	2.99	2.78
70% ACC	75.90	68.90	65.97	42.54	25.52	16.05	8.69	3.64	10.47	8.98	8.68	5.29	3.84	3.30	3.03	2.80
80% ACC	81.64	75.52	69.99	44.07	28.02	17.49	10.10	3.98	10.73	9.76	9.37	5.56	4.06	3.35	2.94	2.87
90% ACC	74.00	76.44	71.98	51.40	31.30	20.10	11.34	4.69	9.76	10.36	9.49	6.62	4.27	3.46	3.06	2.87
100% ACC	76.23	74.95	71.91	60.20	37.41	23.18	12.92	5.66	9.88	9.90	9.52	7.72	4.95	3.72	3.17	2.94

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
17	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	78.04	67.11	38.28	20.35	13.77	8.82	4.92	2.10	10.48	8.78	7.92	11.80	6.61	3.39	2.90	2.77
10% ACC	79.54	68.29	38.53	23.74	14.87	9.39	5.21	2.08	11.21	9.05	8.67	7.77	6.41	3.04	2.95	2.77
20% ACC	74.57	67.13	43.01	23.96	15.93	10.02	5.77	2.40	9.84	8.90	9.28	11.18	6.46	3.72	2.92	2.73
30% ACC	76.87	70.20	44.29	26.62	17.23	11.01	6.08	2.59	10.44	9.34	10.49	8.93	6.16	3.57	2.88	2.76
40% ACC	69.98	72.19	49.24	30.30	19.33	11.89	6.59	2.87	9.53	9.41	8.53	5.67	4.89	3.71	2.98	2.80

50% ACC	73.70	74.67	56.95	33.12	20.52	12.70	7.06	3.10	10.17	9.90	7.32	4.75	5.20	3.21	2.89	2.76
60% ACC	75.15	70.25	60.09	38.35	23.16	13.45	7.80	3.13	10.00	9.18	7.68	5.11	3.73	3.22	2.87	2.83
70% ACC	73.82	72.87	65.30	42.03	25.06	15.57	8.67	3.71	9.57	9.72	8.38	5.36	3.88	3.17	2.97	2.79
80% ACC	79.33	72.54	65.68	45.65	28.37	16.90	9.82	4.36	11.00	9.53	8.42	5.85	4.14	3.38	3.01	2.82
90% ACC	74.70	69.96	71.83	51.26	31.42	20.26	11.24	4.95	9.73	9.65	9.64	6.37	4.37	3.44	3.09	2.77
100% ACC	78.78	67.16	70.45	60.27	37.41	22.94	12.80	5.63	10.93	8.69	9.43	7.71	4.90	3.74	3.10	2.85

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
18	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	75.48	67.12	37.03	21.86	13.80	8.60	4.98	1.99	9.91	8.62	8.88	7.81	4.95	4.14	2.96	2.82
10% ACC	72.07	70.26	40.47	24.17	15.09	9.42	5.32	2.24	9.54	9.45	9.30	7.64	3.60	3.84	2.84	2.82
20% ACC	79.19	69.80	39.14	26.15	15.87	10.22	5.72	2.47	10.63	9.24	12.91	6.43	7.65	3.15	2.86	2.77
30% ACC	68.88	72.14	44.01	26.49	16.81	10.57	5.91	2.61	8.91	9.64	11.07	6.51	6.25	3.54	2.90	2.76
40% ACC	79.30	73.84	51.57	29.69	19.16	11.84	6.64	2.89	10.87	9.85	8.16	8.75	4.98	3.02	2.83	2.79
50% ACC	69.38	70.42	54.58	32.60	20.45	12.48	7.27	3.01	9.22	9.15	7.00	6.28	5.09	3.34	2.87	2.69
60% ACC	80.10	74.09	61.09	36.87	22.82	13.74	7.67	3.41	11.33	10.09	8.01	5.24	4.34	3.17	2.90	2.81
70% ACC	72.71	68.99	64.48	40.48	25.64	15.38	8.63	3.70	9.77	8.81	8.30	5.28	4.77	3.21	2.99	2.79
80% ACC	76.96	72.72	66.87	44.69	28.40	17.71	9.67	4.04	10.15	9.82	8.80	5.64	4.18	3.46	2.98	2.86
90% ACC	74.42	67.82	70.07	51.66	31.82	20.07	11.19	4.74	9.93	8.97	9.22	6.54	4.32	3.50	3.03	2.80
100% ACC	76.73	72.81	71.22	60.28	37.63	22.82	13.04	5.46	10.28	9.70	9.46	7.73	4.95	3.62	3.14	2.80

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
19	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	76.72	67.06	35.79	21.66	14.38	8.94	5.01	2.14	10.60	8.76	12.72	9.23	5.26	4.03	2.87	2.73
10% ACC	75.28	67.45	40.59	23.22	15.23	9.20	5.32	2.20	10.05	8.88	9.64	9.13	5.73	4.83	2.81	2.79
20% ACC	70.74	67.21	41.22	25.61	16.10	10.09	5.84	2.26	9.42	8.90	10.88	7.61	6.53	3.53	2.91	2.76
30% ACC	73.15	71.99	47.89	27.11	17.48	10.78	6.21	2.70	9.58	9.68	8.53	7.23	5.98	3.42	2.84	2.72
40% ACC	73.32	67.58	51.62	29.79	18.68	11.61	6.55	2.67	9.61	8.85	7.77	8.80	4.67	3.02	2.83	2.74
50% ACC	75.20	75.08	55.58	33.09	20.64	12.64	7.16	2.91	10.08	10.25	7.04	6.19	3.63	3.26	2.88	2.76
60% ACC	67.79	67.86	61.01	36.54	22.88	13.98	8.12	3.47	8.49	8.96	7.79	5.85	3.63	3.20	2.99	2.76
70% ACC	78.06	71.98	65.38	41.12	24.90	15.69	8.42	3.54	11.15	9.25	8.49	5.31	3.93	3.30	2.91	2.78
80% ACC	73.11	70.47	69.42	45.08	28.84	17.50	9.95	4.00	9.34	9.40	9.20	5.78	4.23	3.36	2.90	2.80
90% ACC	82.80	69.52	74.69	51.91	31.97	20.12	11.09	4.65	11.45	9.00	10.29	6.60	4.25	3.48	3.07	2.87
100% ACC	83.64	73.33	70.73	60.34	37.45	22.88	12.96	5.42	11.83	9.56	9.39	7.80	4.82	3.63	3.07	2.84

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
20	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	74.19	67.00	36.82	22.50	14.05	8.80	5.01	2.11	10.34	8.67	10.82	6.88	6.61	3.72	2.96	2.70
10% ACC	70.08	67.15	39.95	24.27	15.26	9.37	5.26	2.23	9.06	8.82	8.86	6.22	7.42	3.21	2.92	2.75

20% ACC	77.38	68.21	41.39	25.27	15.99	10.13	5.68	2.34	10.85	8.92	11.30	9.32	5.36	3.16	2.90	2.72
30% ACC	74.62	70.37	47.53	27.74	18.13	10.66	6.14	2.62	10.13	9.39	8.38	5.85	5.33	3.91	2.89	2.82
40% ACC	75.79	74.34	51.98	28.81	18.85	11.57	6.71	2.84	10.14	9.84	6.54	8.58	4.58	3.16	2.91	2.83
50% ACC	71.41	70.92	55.82	30.38	20.77	12.79	7.12	3.06	8.81	9.42	7.16	8.94	4.15	3.20	2.93	2.79
60% ACC	75.63	71.43	60.05	37.04	22.88	13.57	7.95	3.26	9.90	9.54	7.66	4.79	4.20	3.18	2.84	2.78
70% ACC	78.98	71.84	65.75	41.39	24.87	15.59	8.63	3.96	11.13	9.29	8.64	5.38	4.38	3.31	2.97	2.77
80% ACC	81.57	74.63	71.16	45.24	28.40	17.09	9.62	3.97	11.24	10.23	9.38	5.62	4.07	3.39	2.98	2.81
90% ACC	69.71	72.20	72.94	51.00	31.63	20.14	11.30	4.70	9.22	9.53	9.64	6.46	4.27	3.44	3.07	2.85
100% ACC	73.90	71.72	67.37	60.51	37.64	22.96	12.91	5.48	9.34	9.45	8.70	7.74	4.87	3.68	3.19	2.81

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
21	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	71.95	65.64	35.42	21.91	14.39	8.68	4.95	2.07	9.64	8.55	11.18	10.08	4.93	4.63	3.10	2.76
10% ACC	74.31	68.03	38.06	22.95	14.66	9.07	5.24	2.46	9.44	8.88	13.61	10.13	6.73	4.35	2.83	2.76
20% ACC	70.80	70.98	41.56	25.41	15.51	9.72	5.66	2.58	9.24	9.48	11.47	8.01	7.80	5.13	2.85	2.77
30% ACC	69.74	70.96	47.42	28.13	17.88	10.54	6.14	2.60	9.11	9.34	8.50	7.30	4.62	3.12	2.92	2.78
40% ACC	79.47	71.37	51.81	30.39	19.32	11.66	6.64	2.84	11.52	9.70	6.68	7.52	4.87	3.11	2.90	2.74
50% ACC	73.78	69.63	56.14	33.35	20.78	12.53	7.45	3.24	10.12	9.19	7.20	4.78	5.14	3.11	2.93	2.83
60% ACC	75.74	66.63	60.83	37.07	22.91	14.17	7.78	3.36	9.83	8.60	7.82	7.37	3.61	3.33	2.96	2.82
70% ACC	75.17	66.47	65.84	40.51	25.37	15.57	8.63	3.78	10.06	8.48	8.59	5.17	3.83	3.27	2.95	2.78
80% ACC	67.71	74.54	69.60	45.07	28.77	17.13	9.65	4.21	8.88	9.86	9.27	5.67	4.08	3.37	3.05	2.80
90% ACC	79.34	78.95	72.38	51.02	31.76	20.10	11.26	4.67	10.87	10.83	9.49	6.47	4.33	3.45	3.07	2.90
100% ACC	79.00	72.85	69.71	60.35	37.56	23.08	12.92	5.37	10.33	9.55	9.00	7.78	4.87	3.67	3.17	2.83

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
22	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	78.45	67.13	36.35	21.44	14.23	8.88	5.14	2.03	10.14	8.84	11.40	10.59	5.27	3.26	2.84	2.77
10% ACC	79.68	67.87	40.75	24.62	15.26	9.27	5.28	2.21	10.73	9.08	9.01	6.48	5.55	3.22	2.86	2.79
20% ACC	76.39	68.78	43.27	26.55	15.53	10.27	5.39	2.28	10.05	9.17	10.69	6.94	6.61	3.85	2.90	2.78
30% ACC	79.63	70.99	45.40	25.83	17.49	10.68	6.12	2.64	10.90	9.37	11.43	11.78	5.52	3.07	2.85	2.72
40% ACC	75.26	67.88	51.03	30.26	18.60	11.45	6.66	2.83	9.60	9.10	6.72	6.68	5.50	3.18	2.91	2.81
50% ACC	79.89	69.97	55.20	33.96	20.48	12.58	7.04	3.01	11.11	9.36	6.89	6.87	5.51	3.17	2.89	2.79
60% ACC	67.98	71.96	60.90	35.86	22.97	13.57	7.61	3.41	8.94	9.28	7.93	7.26	4.70	3.18	2.96	2.81
70% ACC	78.63	71.58	64.44	41.96	25.02	15.45	8.85	3.86	10.27	9.66	8.33	5.37	3.84	3.19	2.95	2.82
80% ACC	77.08	64.46	69.51	43.93	28.90	16.73	9.83	4.14	10.64	8.26	9.08	5.46	4.13	3.38	3.03	2.83
90% ACC	69.03	73.19	74.08	51.62	31.85	19.98	11.15	4.71	8.98	9.52	9.82	6.48	4.43	3.43	3.04	2.76
100% ACC	76.08	71.12	73.24	60.18	37.44	22.84	12.74	5.51	9.50	9.43	9.92	7.81	4.93	3.69	3.12	2.84

Iteration	Average Speed (km/h)	Average Consumption (kWh/100km)

23	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	79.42	67.14	35.19	22.93	14.16	8.79	4.87	2.29	10.31	8.93	10.98	5.50	5.31	4.53	2.95	2.78
10% ACC	76.71	67.54	36.68	22.51	14.55	9.29	5.21	2.12	10.92	8.87	12.82	11.04	7.82	3.62	2.99	2.80
20% ACC	73.04	70.43	40.19	26.63	15.63	9.84	5.71	2.48	9.35	9.36	13.04	8.99	7.55	3.77	2.86	2.76
30% ACC	77.77	71.45	44.58	26.76	17.41	10.79	6.11	2.59	10.62	9.51	11.01	8.99	5.30	3.45	2.86	2.73
40% ACC	76.99	71.50	51.08	27.94	18.23	11.85	6.52	2.78	10.89	9.66	7.20	11.09	5.59	3.27	2.87	2.77
50% ACC	79.68	70.90	56.00	33.58	20.73	12.40	7.17	3.07	10.75	9.37	7.09	6.10	4.20	3.11	2.84	2.78
60% ACC	79.14	70.65	59.35	36.58	23.06	13.89	7.76	3.37	10.63	9.36	7.67	4.74	4.51	3.17	2.97	2.80
70% ACC	74.58	75.14	65.15	41.42	25.12	15.63	8.55	3.91	10.17	10.09	8.39	5.23	3.93	3.26	2.91	2.82
80% ACC	73.35	72.07	63.58	45.87	28.31	17.46	9.85	4.07	8.88	9.39	8.19	5.81	4.06	3.38	3.08	2.79
90% ACC	79.97	73.26	74.06	50.12	31.79	20.24	11.10	4.71	10.18	10.15	9.97	6.29	4.35	3.50	2.95	2.85
100% ACC	72.71	76.50	69.92	60.06	37.63	22.94	12.88	5.44	9.64	10.74	9.28	7.74	4.92	3.72	3.14	2.88

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
24	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	80.44	67.15	38.24	22.41	13.75	8.76	4.99	2.02	10.71	8.83	7.80	6.87	4.75	3.88	2.86	2.78
10% ACC	75.86	70.52	38.26	21.93	14.95	9.18	5.55	2.37	10.08	9.34	11.90	11.43	5.23	3.16	2.94	2.73
20% ACC	71.80	69.89	42.75	26.25	15.52	10.09	5.83	2.52	9.24	9.23	9.64	5.64	6.25	3.48	2.85	2.82
30% ACC	80.23	69.63	47.40	27.46	17.37	10.84	6.29	2.68	11.75	9.15	8.83	8.55	5.88	3.13	2.90	2.79
40% ACC	72.43	68.32	49.88	29.48	18.80	11.95	6.53	3.02	9.63	9.01	9.29	9.65	5.72	3.77	2.85	2.86
50% ACC	72.75	71.46	55.19	33.35	20.98	12.54	7.26	3.17	9.48	9.79	7.07	7.37	4.05	3.17	2.88	2.75
60% ACC	81.07	72.21	59.19	36.47	23.23	14.01	7.76	3.48	11.45	9.50	7.54	6.69	4.95	3.12	2.92	2.82
70% ACC	78.61	71.72	64.08	41.60	24.99	15.83	8.56	3.72	10.14	9.33	8.45	5.18	4.99	3.18	2.91	2.80
80% ACC	69.81	71.52	68.03	44.11	28.73	17.63	9.96	4.29	9.01	9.55	8.73	5.54	4.10	3.34	2.96	2.84
90% ACC	72.04	74.48	73.90	51.07	31.31	19.90	11.06	4.71	10.45	9.86	9.81	6.36	4.25	3.51	3.05	2.83
100% ACC	79.38	75.44	70.63	60.21	37.48	22.86	12.84	5.42	10.72	10.55	9.57	7.80	4.94	3.70	3.12	2.87

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
25	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	74.31	67.39	37.39	21.89	14.25	8.57	4.94	1.97	9.58	8.80	9.60	7.85	4.57	4.16	2.83	2.75
10% ACC	77.10	67.71	37.10	24.01	14.29	9.13	5.12	2.31	10.34	9.11	13.18	6.82	6.92	3.68	3.23	2.73
20% ACC	78.05	67.58	40.17	24.23	16.16	9.99	5.65	2.49	10.27	9.01	13.26	10.88	6.47	3.82	2.93	2.77
30% ACC	75.48	69.74	44.90	26.60	17.55	10.81	6.11	2.66	10.29	9.06	10.81	8.46	3.45	2.99	2.86	2.75
40% ACC	79.92	72.00	50.80	29.38	18.81	11.65	6.81	2.86	10.76	9.68	8.28	8.62	5.32	3.68	2.86	2.79
50% ACC	77.99	68.79	55.68	32.67	20.95	13.02	7.35	3.07	10.72	9.09	7.19	5.76	3.81	3.19	2.90	2.84
60% ACC	74.77	72.92	59.52	37.62	22.45	13.65	7.97	3.29	9.97	9.53	7.75	4.82	3.64	3.12	2.89	2.80
70% ACC	69.06	73.46	63.92	41.90	25.29	15.66	8.63	3.84	9.00	9.76	8.38	5.23	3.91	3.29	2.99	2.74
80% ACC	75.29	73.63	72.19	45.47	29.80	16.97	9.88	4.22	10.40	9.99	9.72	5.73	4.22	3.37	2.99	2.76
90% ACC	74.85	71.06	68.76	52.59	31.76	20.09	11.25	4.71	9.99	9.10	9.23	6.52	4.32	3.52	3.03	2.74
100% ACC	79.79	75.07	73.02	60.29	37.47	22.90	12.70	5.47	11.88	10.06	10.02	7.72	4.88	3.64	3.17	2.83

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
26	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	74.73	67.02	33.05	22.54	13.91	8.65	4.94	2.15	10.55	8.94	14.88	8.73	6.44	3.59	2.87	2.78
10% ACC	77.85	67.91	37.64	24.18	15.21	9.22	5.33	2.08	10.31	8.83	14.09	7.46	7.58	5.34	2.83	2.75
20% ACC	76.99	70.49	41.86	26.88	15.43	9.94	5.72	2.41	10.30	9.32	10.90	5.86	8.13	4.39	3.00	2.79
30% ACC	75.78	72.82	43.34	26.13	17.71	10.82	6.19	2.64	10.18	9.81	11.45	9.02	4.22	3.20	2.91	2.74
40% ACC	75.71	71.39	49.79	30.18	18.66	11.66	6.61	2.64	9.82	9.60	6.89	8.61	4.71	3.95	2.86	2.78
50% ACC	78.73	68.49	54.39	33.40	20.54	12.76	7.37	3.01	10.57	9.01	6.89	4.51	5.56	3.09	2.85	2.82
60% ACC	76.12	75.18	59.93	36.82	23.13	13.98	7.80	3.42	10.63	10.33	7.61	4.93	5.08	3.20	2.97	2.79
70% ACC	75.41	68.94	65.60	42.12	25.25	15.77	8.60	3.79	9.75	9.14	8.33	5.44	4.20	3.22	2.96	2.78
80% ACC	75.90	74.43	68.97	44.53	28.40	17.47	9.91	4.17	11.09	10.09	9.08	5.68	4.10	3.40	3.00	2.77
90% ACC	79.73	68.38	70.89	51.77	31.64	20.01	11.24	4.75	11.03	9.17	9.35	6.69	4.31	3.48	3.04	2.77
100% ACC	79.47	65.92	77.31	60.42	37.47	22.86	12.79	5.45	10.99	8.45	10.57	7.95	4.94	3.73	3.15	2.88

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
27	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	75.69	65.45	35.25	22.70	13.65	8.55	4.93	2.12	10.20	8.78	13.79	6.09	5.39	3.85	2.87	2.73
10% ACC	76.05	66.36	37.99	22.32	15.42	9.14	5.49	2.15	10.06	8.82	10.28	9.97	3.34	5.44	3.14	2.71
20% ACC	76.09	69.61	42.35	24.50	16.81	9.94	5.59	2.26	10.36	9.14	10.37	11.13	3.97	4.99	2.88	2.77
30% ACC	76.10	71.83	47.62	27.77	17.41	10.57	6.20	2.55	9.71	9.41	8.31	8.52	5.82	4.32	2.92	2.76
40% ACC	74.07	68.66	52.75	29.78	18.95	11.70	6.70	2.84	10.22	9.06	7.34	9.12	5.56	3.12	2.97	2.78
50% ACC	76.64	70.67	55.27	32.43	20.35	12.63	7.09	3.00	10.21	9.26	7.12	7.89	5.79	3.42	2.86	2.77
60% ACC	73.49	71.26	59.30	36.95	23.51	13.84	7.80	3.32	9.53	9.33	7.61	5.63	3.74	3.17	2.91	2.79
70% ACC	71.36	71.59	63.57	41.06	25.28	15.44	8.64	3.72	8.99	9.66	8.12	5.27	3.94	3.31	2.92	2.80
80% ACC	80.08	72.98	69.77	44.46	27.92	17.24	9.85	4.22	11.17	9.44	9.19	5.53	4.08	3.38	2.96	2.81
90% ACC	71.94	72.31	69.71	51.05	31.76	20.19	11.13	4.74	9.26	10.05	9.21	6.47	4.29	3.49	3.05	2.80
100% ACC	75.79	74.98	71.92	60.28	37.59	22.79	12.75	5.45	10.18	9.95	9.46	7.68	4.91	3.68	3.10	2.82

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
28	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	74.03	66.87	36.76	23.05	13.96	8.41	5.04	2.25	9.72	8.60	11.41	5.22	7.56	4.37	2.93	2.68
10% ACC	75.03	66.19	39.79	23.88	15.32	8.96	5.16	2.19	10.21	8.35	7.81	8.85	5.60	4.82	2.83	2.72
20% ACC	80.02	70.28	40.60	25.19	16.11	10.14	5.60	2.34	11.16	9.45	11.93	7.34	5.03	4.59	2.85	2.79
30% ACC	77.79	69.75	45.56	26.58	17.81	10.82	6.16	2.51	10.78	9.30	10.06	9.29	3.65	3.89	2.96	2.73
40% ACC	74.21	68.84	50.99	29.14	18.57	11.67	6.48	2.77	8.81	8.95	7.44	8.04	4.92	3.00	2.83	2.83
50% ACC	83.36	74.97	54.88	31.61	20.68	12.74	7.01	3.13	11.94	9.93	6.87	8.17	3.89	3.28	2.90	2.74
60% ACC	76.19	71.51	60.25	37.21	23.30	13.83	7.91	3.21	10.18	9.31	7.77	5.59	3.74	3.23	2.97	2.76
70% ACC	79.46	71.61	66.52	41.34	25.14	15.85	8.37	3.71	10.84	9.44	8.74	5.44	3.86	3.23	2.98	2.74

80% ACC	75.77	74.87	69.65	44.91	29.49	16.82	9.64	4.06	9.86	9.96	9.31	5.76	4.15	3.30	3.02	2.72
90% ACC	77.46	74.07	68.31	52.25	32.01	19.78	11.10	4.70	10.38	9.41	8.88	6.50	4.33	3.48	3.05	2.81
100% ACC	74.93	74.18	70.05	60.41	37.32	22.83	13.16	5.61	10.35	10.12	9.29	7.76	4.91	3.66	3.09	2.79

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
29	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	70.60	67.34	35.92	21.53	14.01	8.67	4.92	2.21	9.26	8.91	9.58	8.16	6.04	3.83	2.83	2.79
10% ACC	82.70	68.56	40.66	24.60	14.82	9.64	5.10	2.29	11.79	9.02	8.71	6.83	6.17	3.16	2.92	2.76
20% ACC	77.04	69.33	39.95	25.60	15.88	10.00	5.67	2.49	10.53	9.07	12.35	10.24	6.20	3.09	2.96	2.78
30% ACC	81.18	71.90	45.89	27.31	17.52	10.68	6.07	2.55	11.02	9.74	9.86	6.67	5.03	3.78	2.82	2.76
40% ACC	72.25	70.33	49.96	30.15	18.73	11.77	6.66	2.76	10.40	9.30	7.49	8.43	3.56	3.01	2.83	2.79
50% ACC	72.37	69.44	56.12	31.66	20.74	13.03	7.17	2.98	9.15	9.12	7.05	8.41	3.64	3.11	2.93	2.78
60% ACC	79.18	73.27	61.05	36.85	23.04	14.00	7.76	3.46	10.56	9.68	7.91	5.01	3.76	3.14	2.90	2.75
70% ACC	80.78	75.80	66.65	40.99	24.60	15.92	8.80	3.65	11.01	10.41	8.81	5.11	4.41	3.25	3.04	2.82
80% ACC	78.66	73.16	67.29	44.77	28.39	17.76	9.79	4.26	10.93	9.67	8.76	5.69	4.17	3.34	2.95	2.88
90% ACC	76.00	74.14	73.58	51.25	31.64	20.12	11.22	4.65	9.98	9.64	9.85	6.40	4.33	3.54	3.09	2.80
100% ACC	73.54	73.63	71.27	60.30	37.55	22.80	12.80	5.41	9.25	10.16	9.46	7.76	4.91	3.75	3.04	2.84

Iteration	Average Speed (km/h)								Average Consumption (kWh/100km)							
30	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km	10 veh/km	30 veh/km	50 veh/km	70 veh/km	90 veh/km	110 veh/km	130 veh/km	150 veh/km
0% ACC	70.10	67.12	34.68	22.43	14.34	8.66	4.89	2.05	9.58	8.82	14.55	6.98	4.96	3.52	2.79	2.76
10% ACC	77.39	69.20	37.26	23.38	15.35	9.20	5.25	2.19	10.12	9.19	12.52	8.11	5.13	3.58	3.07	2.83
20% ACC	69.59	68.90	42.28	25.37	16.28	9.99	5.70	2.48	9.07	9.13	10.39	9.83	4.70	3.31	2.90	2.79
30% ACC	77.51	72.72	48.09	27.41	17.37	11.08	6.15	2.51	11.36	9.54	6.05	10.36	6.00	3.94	2.88	2.77
40% ACC	74.69	72.21	51.69	29.93	19.31	11.84	6.58	2.83	10.53	9.41	8.28	7.08	5.50	3.68	2.89	2.81
50% ACC	75.18	72.78	55.37	34.13	21.04	12.71	7.07	3.04	9.63	9.52	7.06	4.57	5.57	3.13	2.82	2.76
60% ACC	72.49	71.38	60.28	36.71	22.85	13.86	7.79	3.40	9.93	9.53	7.77	4.88	3.67	3.13	2.90	2.75
70% ACC	71.64	72.71	65.17	40.58	25.19	15.92	8.56	3.63	9.18	9.80	8.63	5.35	3.86	3.21	2.93	2.87
80% ACC	72.24	76.87	66.68	44.07	28.42	17.31	9.81	4.09	9.98	10.61	8.65	5.53	3.93	3.39	3.00	2.82
90% ACC	75.30	66.92	67.29	51.99	31.97	19.82	11.06	4.61	9.73	8.81	8.71	6.61	4.50	3.48	3.02	2.79
100% ACC	72.51	70.40	73.42	60.43	37.45	23.08	13.01	5.55	9.52	9.32	9.77	7.78	4.95	3.64	3.17	2.84

C2. Fundamental diagrams

	Average Speed (km/h)											Traffic Flow (veh/h)										
	0 % ACC	10% ACC	20% ACC	30% ACC	40% ACC	50% ACC	60% ACC	70% ACC	80% ACC	90% ACC	100% ACC	0% ACC	10% ACC	20% ACC	30% ACC	40% ACC	50% ACC	60% ACC	70% ACC	80% ACC	90% ACC	100% ACC
2 veh/km	85.19	80.15	82.34	78.02	84.12	79.32	79.69	80.44	79.63	80.94	78.88	170	160	165	156	168	159	159	161	159	162	158
4 veh/km	78.81	82.89	80.07	79.28	77.47	79.66	76.92	78.32	76.73	77.59	78.75	315	332	320	317	310	319	308	313	307	310	315
6 veh/km	76.88	78.22	76.94	74.34	78.46	74.55	77.98	77.97	77.96	75.49	80.51	461	469	462	446	471	447	468	468	468	453	483
8 veh/km	77.83	76.34	73.72	74.10	77.98	73.60	73.02	76.21	76.07	72.20	77.43	623	611	590	593	624	589	584	610	609	578	619
10 veh/km	73.93	73.71	77.05	72.62	74.06	77.52	74.54	76.87	72.03	74.89	74.87	739	737	771	726	741	775	745	769	720	749	749
12 veh/km	73.81	71.93	75.86	73.39	74.43	77.18	77.08	78.21	71.75	71.27	77.61	886	863	910	881	893	926	925	939	861	855	931
14 veh/km	72.09	74.10	74.04	72.40	70.85	70.18	73.00	73.10	69.42	77.46	76.01	1009	1037	1037	1014	992	983	1022	1023	972	1084	1064
16 veh/km	67.29	72.92	73.76	72.95	69.87	72.66	71.79	74.95	74.51	76.04	75.29	1077	1167	1180	1167	1118	1163	1149	1199	1192	1217	1205
18 veh/km	73.73	71.07	71.86	71.99	72.73	71.81	72.52	74.81	71.71	74.12	74.73	1327	1279	1294	1296	1309	1293	1305	1347	1291	1334	1345
20 veh/km	71.16	68.82	71.93	76.28	71.42	72.74	73.11	73.25	73.62	71.99	73.88	1423	1376	1439	1526	1428	1455	1462	1465	1472	1440	1478
22 veh/km	72.26	67.47	72.83	67.14	70.00	73.42	73.28	75.52	70.50	72.56	73.54	1590	1484	1602	1477	1540	1615	1612	1662	1551	1596	1618
24 veh/km	72.77	70.89	71.69	69.15	70.92	70.58	67.61	72.18	67.45	71.18	70.32	1747	1701	1721	1660	1702	1694	1623	1732	1619	1708	1688
26 veh/km	67.97	69.30	71.70	71.09	75.10	66.63	72.53	72.94	70.17	73.79	71.38	1767	1802	1864	1848	1953	1732	1886	1896	1825	1919	1856
28 veh/km	69.30	69.71	69.97	69.87	71.57	69.15	69.31	71.02	75.40	72.26	74.64	1940	1952	1959	1956	2004	1936	1941	1989	2111	2023	2090
30 veh/km	66.20	68.04	67.90	69.95	71.27	69.87	70.65	71.26	68.64	70.04	73.88	1986	2041	2037	2099	2138	2096	2119	2138	2059	2101	2216
32 veh/km	63.65	66.08	67.49	69.17	72.56	67.84	69.84	71.83	71.99	74.64	70.14	2037	2115	2160	2214	2322	2171	2235	2299	2304	2388	2245
34 veh/km	57.73	63.03	66.06	68.18	68.73	70.50	74.13	69.13	72.35	72.05	68.41	1963	2143	2246	2318	2337	2397	2521	2351	2460	2450	2326
36 veh/km	56.45	61.43	61.34	66.47	68.40	68.76	68.54	71.95	73.25	68.80	72.21	2032	2212	2208	2393	2462	2476	2468	2590	2637	2477	2599
38 veh/km	54.43	53.18	60.20	63.97	65.34	64.48	68.05	69.43	70.15	73.31	72.79	2068	2021	2288	2431	2483	2450	2586	2638	2666	2786	2766
40 veh/km	50.14	55.26	59.77	62.07	65.98	67.08	65.98	66.84	70.06	71.53	68.53	2006	2211	2391	2483	2639	2683	2639	2674	2803	2861	2741
42 veh/km	45.68	47.86	54.81	58.92	61.67	65.72	65.13	68.06	69.41	69.77	69.52	1918	2010	2302	2475	2590	2760	2736	2859	2915	2930	2920
44 veh/km	44.93	46.70	51.01	54.00	57.36	64.03	66.63	64.83	70.23	70.07	68.28	1977	2055	2245	2376	2524	2818	2932	2853	3090	3083	3004
46 veh/km	41.34	44.24	45.22	50.49	56.26	59.66	64.09	63.86	67.39	68.83	71.64	1902	2035	2080	2323	2588	2745	2948	2937	3100	3166	3296
48 veh/km	38.35	41.98	45.11	48.49	54.13	59.75	63.37	68.25	64.10	68.83	68.76	1841	2015	2165	2327	2598	2868	3042	3276	3077	3304	3300
50 veh/km	36.73	39.64	41.18	44.78	50.04	55.76	59.84	64.08	66.75	70.49	70.73	1836	1982	2059	2239	2502	2788	2992	3204	3337	3525	3537
52 veh/km	33.76	36.72	40.73	43.41	47.23	52.67	57.59	63.68	68.05	66.57	70.57	1755	1910	2118	2257	2456	2739	2995	3311	3539	3462	3670
54 veh/km	32.34	34.58	37.62	41.26	46.15	49.47	54.57	59.95	66.28	69.19	69.84	1747	1867	2031	2228	2492	2672	2947	3238	3579	3736	3771
56 veh/km	31.01	31.55	36.56	37.32	44.64	47.18	51.05	57.03	63.78	64.60	69.17	1737	1767	2047	2090	2500	2642	2859	3194	3572	3618	3873
58 veh/km	29.47	31.19	34.28	36.65	40.24	44.91	49.44	54.83	60.08	66.45	69.26	1709	1809	1989	2126	2334	2605	2867	3180	3485	3854	4017
60 veh/km	27.87	30.39	33.00	34.85	38.90	43.52	47.04	52.82	58.95	67.53	70.26	1673	1823	1980	2091	2334	2612	2823	3169	3537	4052	4215
62 veh/km	26.07	27.88	30.60	32.46	35.98	38.85	44.58	49.36	54.53	63.56	67.86	1617	1729	1897	2013	2231	2409	2764	3061	3381	3941	4207
64 veh/km	25.52	27.15	29.07	30.90	34.02	38.36	43.12	47.51	53.56	60.42	69.82	1634	1738	1861	1978	2177	2455	2760	3041	3428	3867	4468
66 veh/km	23.33	24.46	27.60	30.14	32.89	36.47	40.45	44.30	50.01	57.48	66.38	1540	1614	1822	1989	2171	2407	2670	2924	3301	3794	4381
68 veh/km	23.73	24.87	26.74	28.53	31.53	35.32	39.01	43.24	47.24	54.84	63.92	1614	1691	1818	1940	2144	2402	2653	2940	3212	3729	4346
70 veh/km	21.48	23.53	25.00	26.76	29.84	33.12	36.17	40.88	44.72	51.64	60.26	1504	1647	1750	1873	2089	2319	2532	2862	3130	3615	4218
72 veh/km	21.23	21.92	24.71	26.40	28.64	31.46	35.68	38.89	43.93	50.11	58.02	1529	1578	1779	1901	2062	2265	2569	2800	3163	3608	4178
74 veh/km	19.90	20.93	23.19	25.39	27.07	30.41	32.95	36.56	41.08	47.22	54.67	1473	1549	1716	1879	2003	2251	2439	2706	3040	3494	4045
76 veh/km	18.56	20.34	22.29	23.64	25.65	27.96	31.89	34.84	38.81	44.48	51.68	1411	1546	1694	1797	1949	2125	2424	2648	2949	3381	3927
78 veh/km	18.34	19.46	21.28	22.86	24.92	27.22	30.09	33.86	37.14	42.67	49.79	1431	1518	1660	1783	1944	2123	2347	2641	2897	3329	3884

80 veh/km	17.24	18.37	19.70	21.42	23.48	26.11	28.33	32.10	35.74	40.59	47.07	1380	1469	1576	1714	1878	2089	2267	2568	2859	3247	3765
82 veh/km	17.11	17.73	19.81	21.08	22.68	25.03	27.23	30.26	34.37	38.91	45.18	1403	1454	1625	1729	1860	2053	2233	2482	2819	3191	3705
84 veh/km	16.23	17.31	18.55	20.10	21.95	23.76	25.77	28.95	32.42	36.81	42.78	1364	1454	1558	1688	1844	1996	2165	2431	2724	3092	3594
86 veh/km	15.26	16.19	17.74	18.94	20.78	23.14	25.29	28.17	30.85	35.58	41.20	1313	1393	1526	1629	1787	1991	2175	2422	2653	3060	3543
88 veh/km	14.50	15.44	16.68	18.00	19.87	21.54	23.77	26.09	29.64	33.56	38.96	1276	1358	1468	1584	1748	1895	2092	2296	2608	2953	3429
90 veh/km	14.04	14.82	16.09	17.54	18.90	20.92	22.96	25.23	28.63	32.71	37.50	1264	1334	1448	1579	1701	1883	2067	2270	2577	2944	3375
92 veh/km	13.00	14.22	15.24	16.54	17.93	19.75	21.39	23.88	26.69	30.43	35.49	1196	1309	1402	1521	1650	1817	1968	2197	2455	2799	3265
94 veh/km	13.06	13.79	14.64	15.81	17.32	18.73	21.07	23.02	25.47	29.39	33.98	1228	1296	1376	1486	1628	1761	1981	2164	2394	2763	3194
96 veh/km	12.11	13.04	13.78	14.74	16.35	18.07	19.46	21.84	24.65	27.70	32.32	1163	1252	1323	1415	1570	1735	1868	2097	2367	2660	3103
98 veh/km	11.79	12.63	13.29	14.46	15.56	17.30	19.02	20.97	23.37	26.93	30.97	1155	1238	1303	1418	1525	1695	1864	2055	2290	2640	3035
100 veh/km	11.03	11.89	12.69	13.71	14.88	16.21	18.08	19.60	22.15	25.07	29.34	1103	1189	1269	1371	1489	1621	1808	1960	2215	2507	2934
102 veh/km	10.59	11.40	12.19	13.22	14.32	15.50	17.00	18.88	21.08	24.47	28.22	1080	1163	1243	1349	1461	1581	1734	1926	2150	2496	2878
104 veh/km	9.99	10.80	11.43	12.45	13.34	14.60	16.21	17.99	20.28	22.87	26.48	1039	1123	1188	1294	1387	1518	1686	1871	2109	2378	2754
106 veh/km	9.69	10.33	11.26	12.08	12.87	14.15	15.57	17.07	19.23	22.06	25.51	1027	1095	1193	1281	1365	1500	1650	1810	2039	2338	2704
108 veh/km	9.34	9.64	10.51	11.26	12.08	13.44	14.68	15.96	18.21	20.75	23.95	1009	1041	1135	1217	1305	1452	1586	1724	1967	2241	2587
110 veh/km	8.79	9.21	9.99	10.73	11.58	12.78	14.16	15.76	17.27	19.81	23.03	967	1013	1099	1181	1273	1405	1558	1734	1900	2179	2533
112 veh/km	8.22	8.80	9.35	10.16	10.91	12.21	13.26	14.62	16.45	18.86	21.63	920	985	1048	1138	1222	1368	1486	1637	1842	2112	2423
114 veh/km	7.92	8.46	9.16	9.68	10.43	11.49	12.63	14.16	15.69	17.88	20.67	903	964	1044	1103	1189	1310	1439	1615	1789	2038	2357
116 veh/km	7.55	7.97	8.48	9.30	9.84	10.79	11.96	13.17	14.76	16.81	19.41	875	924	984	1079	1141	1252	1387	1528	1712	1950	2251
118 veh/km	7.04	7.71	8.25	8.82	9.51	10.47	11.20	12.75	14.17	15.95	18.59	831	909	974	1041	1122	1235	1322	1505	1672	1882	2194
120 veh/km	6.77	7.05	7.66	8.17	8.84	9.66	10.69	11.73	13.11	14.91	17.48	812	846	919	981	1061	1159	1282	1407	1573	1789	2098
122 veh/km	6.48	6.85	7.33	7.94	8.47	9.34	10.13	11.06	12.68	14.26	16.59	790	836	894	969	1033	1139	1236	1350	1547	1740	2024
124 veh/km	5.89	6.29	6.83	7.35	7.78	8.64	9.40	10.58	11.77	13.23	15.55	731	780	846	911	965	1071	1166	1312	1459	1641	1928
126 veh/km	5.74	5.98	6.52	6.93	7.50	8.28	9.01	9.92	10.92	12.79	14.73	723	754	821	873	945	1043	1136	1249	1376	1612	1856
128 veh/km	5.32	5.61	5.94	6.49	6.99	7.62	8.30	9.08	10.38	11.74	13.65	681	718	761	830	895	976	1063	1163	1329	1503	1747
130 veh/km	5.06	5.41	5.76	6.22	6.63	7.49	7.98	8.85	9.71	11.25	12.92	658	703	749	809	862	974	1037	1150	1262	1462	1680