Methodological study to create a more sustainable supply for bus operators

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Abstract

Air pollution affects millions of people around the world, due to among the many causes also to road transport emissions. To cope with that the European Community, through the European Environment Agency (EEA) has promoted the creation of emissions inventories for all the European members states, and outside. Such inventories give rise to emissions models, which have different levels of interactions, due to the variety of input associated to the production of various kind of pollutants, either in running or start-up operations.

The aim of this thesis is to create a more accurate model, able to estimate the most common pollutants emitted by road transport, Carbon Dioxide (CO_2), Carbon Monoxide (CO), Nitrogen Oxides (NO_x), Particle Matters (PM), Sulphur Oxides (SO_x) and Ammonia (NH_3), for the most common buses fleet running in Europe, either for Euro standard IV, V and VI and under different operational conditions, temperature and road slope. For this purpose, the first model analysed was COPERT, a model developed by Emisia S.A. in collaboration with the EEA. Within COPERT the mileage parameter is neglected in the process to estimate emissions; To cope with such missing parameter, it is necessary to integrate COPERT with other software, and among them, IVE, a microscopic model developed by the International Sustainable Systems Research Center (ISSRC). IVE includes three different thresholds of mileage that are accounted in the estimation of the emissions, furthermore, this microscopic software includes other parameters (still unaccounted in COPERT) as the number of engine ignitions, which makes it more precise.

Leaving aside parameters such as mileage or ignitions can lead to the underestimation of emissions packages, a not negligible problem for public transport operators, who are usually not in the capacity of processing more models to assess the environmental performance of the fleet they are operating.

The model here developed overcomes these disadvantages and uses some characteristics of the current models in the market, to enable a single comprehensive calculation, more adequate to operators' needs.

To assess reliability and validity of the model, thus merging the IVE and COPERT methodologies into a single calculation process, the following methodological steps were undertaken: i) development of different multiplicative factors for each pollutant for each euro standard considered; ii) the creation of a database to "feed" the model by input data coming to the bus fleet to analyse; iii) the development of a case study whose results could evidence the quality of the model.

The study case involved a bus fleet in the city of Olbia, Italy, and information to feed the database and run the model were provided by the local operator and the IT-provider company Pluservice srl. Olbia is representative of a middle-size Italian city, with mixed bus fleet (13 types of vehicles, operating different lines). Olbia provided enough information to run the model 108 times per bus line, resulting into total of 1.404 simulations. Then, the multiplicative factors were processed s, obtaining a complete database of the emissions for the 6 pollutants assessed for the whole analysed fleet. From these simulations it is possible to analyse some pollutant trends more specifically how these emissions vary when the speed, temperature and road slope are modified, and when mileage increases markedly. All of the above enable to get accurate estimations, particularly fit for typical multi-type bus fleets, with different vehicles, operational age and mileage.

Eventually, the achieved results can be further exploited in an additional model based on Artificial Neural Networks (ANN). According to the dataset, the most suitable network to be used was a Multi-layer perceptron (MLP), that basically predicts the values through a series of different layers and

activation functions. In, this case a mix of Sigmoid and Rectified Linear Unit (ReLu) functions was used to predict CO_2, whereas a mix of Sigmoid and Softmax functions were used for the rest of pollutants. The mean absolute percentage error (MAPE) obtained by the MLP were the following: 2,49% for CO_2, 1,49% for NO_x, 4,12% for CO, 3,16% for SO_x, which can be considered accurate.

Acknowledgement

A road that started almost four years ago has ended, it has been a long time since I had this insane idea which take me to amazing places, to meet incredible people and know cultures that I have only read about them.

I just want to thank to all the people I met in these four years since I left my country, people in Australia, Russia and Italy, people that have lighted my road with knowledge, thoughts, smiles. Being far from home never is easy, but all you made me called home to every place I lived.

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It was never easy, but I did it.

INDEX

FIGURE INDEX

GRAPH INDEX

TABLE INDEX

1. INTRODUCTION

This graduation work focuses on the development of a model able to estimates the engine emissions of a fleet of buses, to comply with the sustainable development of public transport, starting from tools already available, further described.

The thesis moves from the concept of sustainability and how it is defined and achievable in public transport, thanks to several strategies for sustainable development, and namely those launched by the European Commission.

In this context air pollution is central within one of the three main pillars of sustainable transportation, environment, especially in the transport sector, and it is normally measured as the total vehicle emissions (Litman, 2011). The European Commission encourage the efforts for measure the emission in an efficient and accurate way, dealing with all misunderstandings caused by lack and reliability of data.

1.1. SUSTAINABILITY AND PUBLIC TRANSPORT

The concept of sustainability begins to take shape from the convention of the United Nations in Stockholm in 1972 with the focus between environment and development (United Nation Organization, 1972). The Stockholm conference can be considered as the kick off for an international change, for example, it is highlighted that after the conference the number of Environment Ministries slowly increased (Boudes, 2011). In addition, it was established that this type of conference will be held every ten years, with subsequent conferences in Nairobi 1982, Rio de Janeiro 1992, Johannesburg 2002, Rio de Janeiro 2012 and El Jadida 2018. In this context, the report of the World Commission of Environment and Development "Our Common Future" (United Nation Organization, 1987) defines the concept of sustainable development as: "Humanity has the capacity to make development sustainable to guarantee that it satisfies the needs of the present without compromising the ability of future generations to meet their own needs", this concept is widely recognized in studies related to sustainable transport (B. Regmi, et al., 2017) (Joumart, et al., 2010).

In terms of public transport, sustainability can be evaluated in various ways, however, current literary interpretations suggest that one of the pillars of sustainable development is the reduction of the use of private vehicles through the improvement of public transport (Susnienė, 2011), as well as the treatment of urban density (Sinha, 2003) or the reduction of polluting emissions (Boile, et al., 2018). Evaluations of the sustainability of public transport range from rational management models (Makarova, et al., 2016), quality measurement models (Mikhaylov, et al., 2015) processes of analytical hierarchy (Kumar, et al., 2015), measurement of indicators (Zegras, 2006), etc.

According to the European Environmental Agency (EEA) more than 40% of emissions of nitrogen oxides come from road transport and almost 40% of primary $PM_{2,5}$ emissions come from transport in Europe (European Environmental Agency, 2017). More in detail, in 2015, the transport sector was responsible for 24,7% of global energy related CO_2 emissions and for the 28,8% of global final energy consumption, where a 72,6% belonged to road transport (International Agency Energy Agency - International Union of Railways, 2017). In Italy the levels of carbon dioxide produced by transport is close to the 19,3%, however after reaching a peak in 2007 the levels of CO_2 generated by this industry seems to be reduced (ISPRA, 2016), especially between 2011 and 2012 where a reduction in around 10% occurred; nonetheless, this reduction may be explained by a reduction of the demand of transport therefore the decline of the demand attributable to the negative economic situation of recent years to have determined - at least in part - the reduction of emissions (Zambrini, 2016).

The European Commission has set different goals related to greenhouse gas (GHG) emissions in order to reduce the global temperature below 2° in 2050. In transport the reduction of GHG emissions must be around the 20% below their 2008 level (European Commission, 2011). According to this Italy should reduce the level of emissions in transport to the same levels that it was before 1990.

1.2. DEVELOPING A METHODOLOGY FOR MODELS

The EMEP/EE guidebook 2016, by the European Environment Agency, about the calculation of emissions on road transport gives a very clear decision tree to choose the appropriate method according to the different levels of detail in the data collected. This decision tree (Figure 1) has tree levels of complexity called TIERS, being the more completed one TIER 3, which comprises the inclusion of data relevant to the availability of vehicle-km and mean travelling speed, either split by mode and by vehicle technology (European Environment Agency, 2016).

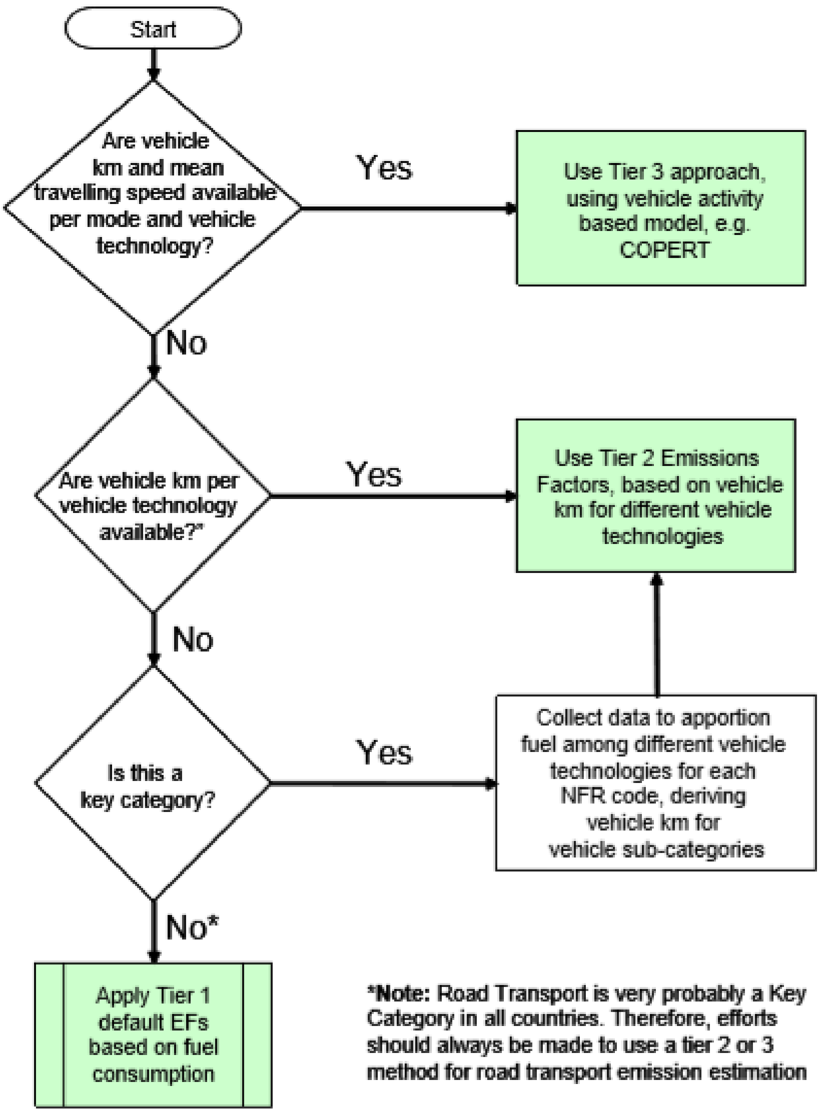


Figure 1: Decision tree for exhaust emissions from road transport given by the EMEP/EEA air pollutant emission inventory guidebook 2016 (European Environment Agency, 2016)

Despite the goals set by the European Commission, the measurement of emissions may be scant and misleading. For example, models based on fuel sales give aggregate measure but not details, which depends on the information on vehicles, such as, displacement and weight of the car (larger engines and cars emit more Co_2), age of the car (an old car will emit more than a new one of the same type), number of passenger (more passenger means lower emission per person), driving mode of the car (speed, starts and stops, acceleration, braking) and so on. However, since 1996 the European Environment Agency has provided guidebooks (formerly called the EMEP CORINAIR emission inventory guidebook) to prepare national emission inventories, grouping and classifying vehicles and pollutants. The methods within those guidebooks are accorded to the quality of input available, which assign different levels of methodology complexity (European Environment Agency, 2016), from those levels some software, either in USA as in EUROPE.

1.3. EMISSION MODELS USED IN USA AND EUROPE

The literature commonly divides these emission calculation models in 5 main categories (Boulter, et al., 2007):

- Aggregated emission factor models: Operates with a single emission factor being used to represent a particular type of vehicle and a general type of driving (distinction between urban roads, rural roads and motorways). Example: NAEI

- Average speed models: Those models are based upon the principle that the average emission factor for a certain pollutant and a given type of vehicle varies according to the average speed during the trip. Some of these models incorporate a "corrected average speed" factor to adjust the emission in terms of congestion, green time percentage, link length. Example: COPERT

- Traffic situation models: These models incorporate either speed and cycle dynamics, involving traffic situation modelling. So they can model specific traffic situations known by the user, where the average speed may not be the best indicator of emissions. However, some models use some specific emission factors by vehicle where each one is also associated with a particular traffic situation, mainly these models are based on the Handbook of Emission Factors (HBEFA). Example: ARTEMIS.

- Multiple linear regression models: These models normally use a weighted-least-squares multiple regression approach based on tests on a large number of vehicles over more than 50 different driving cycles with a large number of descriptive parameters and their derivate. For each pollutant and type of vehicle a regression model is fitted to the average emission value over the various driving cycles predicting emission. Example: VERSIT.

- Modal models: The term of "modal" refers to the different vehicle operations during a trip, where the emissions rates are related to the behaviour of the vehicle during a series of short time steps (often one second). Several different terms have been used to describe the more detailed type of model, including 'instantaneous' (which is the most well-known and used one), 'microscale', 'continuous' and 'on-line'. Example: IVE.

Tier 3 group some well-known calculators, previously categorized as it was mentioned before. In this aspect USA and Europe have financed and develop a large list of models, which is shown in the table 1:

Model (Acronym)	Stands for	Developer	Type of model	Countries or Continents used
GREET	Greenhouse gases, regulated emissions and energy use in transportation	U.S. Department of Energy Office of Science	Life cycle assessment (LCA) of both fuel and vehicle	USA
MOBILE		U.S. Environmental Protection Agency	Aggregated emission factor	USA
MOVES	Motor vehicle emissions simulator	U.S. Environmental Protection Agency	Aggregated emission factor	USA
CMEM	Comprehensive Modal Emission Model	University of California at Riverside	Modal models	USA
IVE	International Vehicle Emission	International Sustainable Systems Research Centre and the University of California at Riverside	Modal models	USA, China, Mexico, India, Brazil, Kazakhstan, Chile, Kenya, Turkey
EMFAC	The emission factors	California Air Resources Board	Aggregated emission factor	California area
ARTEMIS	Assessment of road transport emission mode	Structural Vibration Solutions A/S	Traffic situation	Europe, Australia, Bolivia, Brazil, Canada, Chile, China, Colombia, Costa Rica, Ecuador, Egypt, India, Honk Kong, Indonesia, Iran, Japan, Malasya, Mexico, Peru, Qatar, Russia, Saudi Arabia, Singapor, South Africa, South Korea, Tunisia, USA

Model (Acronym)	Stands for	Developer	Type of model	Countries or Continents used
VERSIT+		Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek	Multiple linear regression models	Netherlands
NEMO	The natural emission model	Institute of Communication and Computer Systems	Traffic situation	Europe
TREFIC	Traffic Emission Factors Improved Calculation	ARIA Technologies	Traffic situation	Europe
TREMOD	Transport Emission Model	Institut für Energie- und Umweltforschung Heidelberg	Traffic situation	Germany
PHEM	Passenger Car and Heavy Duty Emission Model	TU Graz	Modal models	Europe
NAEI	National Atmospheric Emissions Inventory	UK Department for Business, Energy & Industrial Strategy	Aggregated emission	United Kingdom
HBEFA	Handbook Emission Factor for Road Transport	Environmental Protection Agencies of Germany, Switzerland and Austria	Traffic situation	Europe (Germany, Switzerland and Austria)
COPERT	Computer Programme to Calculate Emissions from Road Transport)	EMISIA SA, European Environment Agency, Joint Research Centre and Aristotle University of Thessaloniki	Average speed	Europe

Table 1: Emissions models in USA and Europe (based on their respective website information and researches, own elaboration)

Each model has their strengths and limitations, these aspects are taking from different publications and might show an idea of the potential of each model to overcome the mileage problem and also add some information to the model to be created. These advantages and disadvantages have been summarized in the table 2.

Model	Advantages	Limitations
GREET	• A large set of fuels available • Provides full fuel-cycle emissions analysis from all phases of production, distribution, and use of transportation fuels (Wang, 2007)	• Model applied only for light-duty vehicles • Short amount of pollutants (CO_2, CH_4 and N_2O)
MOVES	• Estimate air pollution emissions from car, trucks, and motorcycles. Future model will cover nonroad emissions (Innovation Center for Energy and transportation, 2015) • Estimates future emissions by energy consumption more precisely (Carroll, et al., 2016)	Emission estimation based on fuel sales may lead to over- or underestimation of the GHGs (Carroll, et al., 2016)

Model	Advantages	Limitations
CMEM	Inherently handling of issues of grade, variable weight, and variable fuel injection timing strategies	Designed only for passenger vehicles and heavy-duty diesel vehicles operating in California
MOBILE	• Estimating emission of unregulated pollutants (CH4 and NH3) (Negm, et al., 2013) • Emission factors can be combined with estimates of total vehicle kilometres travelled (VKT) to develop highway vehicle emission inventories (in terms of tons per day, per month, per season, per year) (Innovation Center for Energy and transportation, 2015)	No engine size breakdown for light vehicles (Carroll, et al., 2016)
IVE	• It considers the different technologies and conditions that exist in most developing countries and vehicle driving patterns, such as vehicle specific power (VSP) and engine stress distributions which have a profound effect on the tailpipe emissions of vehicles (Guo, et al., 2007) • It considers a set of thresholds for mileage for each vehicle	The calculation of VSP requires more specific information provided by GPS systems
EMFAC	Assess emissions from on-road vehicles including cars, trucks, and buses	Estimates on-road vehicles emissions only California standards
ARTEMIS	Use a large emission database improved upon COPERT and HBEFA (Boulter, et al., 2007)	Large number of subsystems make the process complex (Boulter, et al., 2007)
VERSIT+	It considers the complex emission behaviour for the modern light duty vehicles. (Boulter, et al., 2007)	Suitable for light duty vehicles only.
NEMO	Combines both detailed calculation of the vehicle fleet composition and simulation of emission factors on a vehicle level (Innovation Center for Energy and transportation, 2015)	
TREFIC	• Calculation based on COPERT 4 • Especially oriented to feed atmospheric dispersion models and its output is compatible with all the main model types: Gaussian, puff, Lagrangian particle and Eulerian photochemical ones, including speciation and lumping (Innovation Center for Energy and transportation, 2015)	
TREMOD	Analyses all means of passenger transportation (cars, two-wheelers, busses, trains, aircraft) and all means of freight transportation (lorries, light-duty commercial vehicles and articulated trucks, trains, inland navigation vessels, aircraft)	Only suitable for Germany
PHEM	It gives consistent results for most of the vehicle categories. Calculates emission factors for different road gradients, different vehicle loadings and different gear shift behaviours of drivers in a consistent way. The model PHEM can set up engine emission maps from all sources of measurements as long as high-quality instantaneous test results are available. (Boulter, et al., 2007)	
HBEFA	Uses traffic situation approach (Boulter, et al., 2007)	Only suitable for Germany, Switzerland and Austria

Model	Advantages	Limitations
NAEI	Suitable for light vehicle Calculates pollution for variety of pollutants (Boulter, et al., 2007)	Emission factors for heavy vehicle are not good (Boulter, et al., 2007)
COPERT	• A large set of pollutants and vehicles • No big amount of input necessary	Not include millage degradation for EURO 3 and beyond (NAEI National Atmospheric Emission Inventory, 2012)

Table 2:Advantages and disadvantages of emission models (based on their respective website information and researches, own elaboration)

There are several studies that compare the accurate of each model, for example, the technical paper "Comparison of the MOVES2010a, MOBILE6.2, and EMFAC2007 mobile source emission models with on-road traffic tunnel and remote sensing measurements" (Fujita, et al., 2012) indicates the underestimation for hydrocarbons and CO by EMFAC and the lack of sensibility of MOVES, MOBILE and EMFAC during hot periods. Another article, called "Research on Transportation-Related Emissions: Current Status and Future Directions" (Yu, et al., 2012), scores a group of emission models according to the use, accuracy, implementation and user interface. In this research IVE Model got the highest overall ranking (3.4/5), as shown figure 4, beating models like MOBILE, CMEM and COPERT.

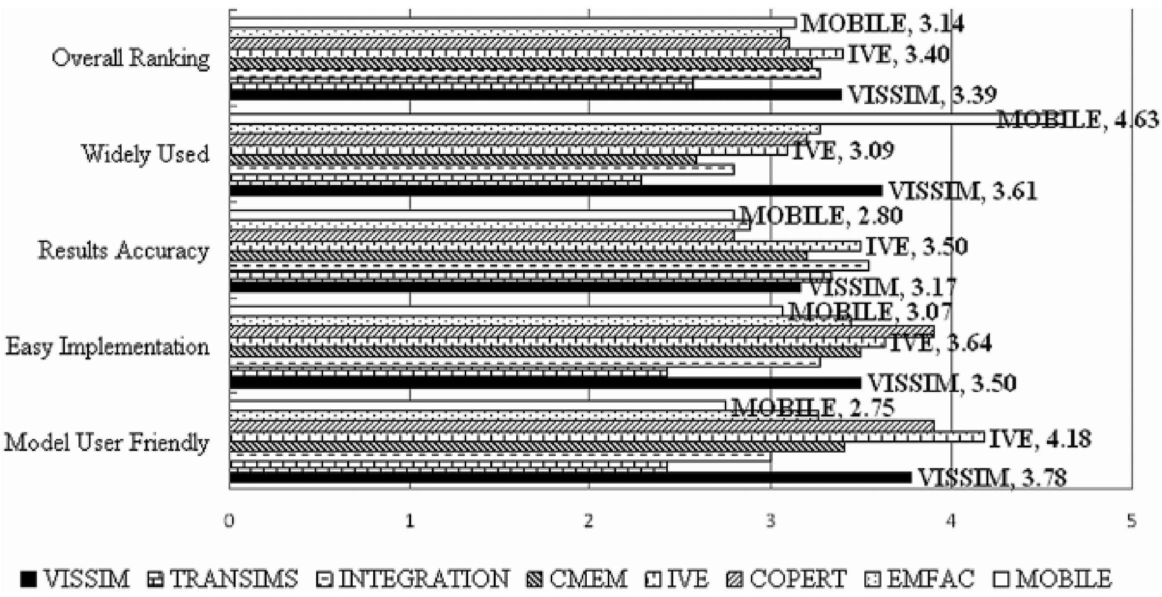


Figure 2: Ratings of emission models by the report "Research on Transportation-Related Emissions: Current Status and Future Directions" (Yu, et al., 2012)

Beside this analysis, it is known that COPERT is the main tool used in European countries, furthermore it is used in 22 out 27 member states of the European Community (Ntziachristos, et al., 2009), furthermore, COPERT is insert as the main example in the methodology CORINAIR, which gives an official acceptance from to develop national emission inventories, however its limitation about the mileage does not allow to analyse the emission considering the age of the vehicle, which basically has an effect on the total emission levels (Díaz Gutiérrez, 2002) (Center for Transportation Research and Education, 2012). As it seems in the table 6, IVE Model may overcome this disadvantage, providing thresholds to evaluate the emissions in 3 different categories of mileage, beside this, IVE has the feature to be a microscopic model, so can estimate emission having a detail trip data. A brief description of both models is presented bellowing.

1.4. COPERT (COMPUTER PROGRAMME TO CALCULATE EMISSIONS FROM ROAD TRANSPORT) MODEL

COPERT is one of the main models suggested by the European Environment Agency and its guidebook CORINAIR, in the market there are several other emission models developed, which consider different technologies and conditions.

developed in the Laboratory of Applied Thermodynamics (LAB) in the Aristotle University of Thessaloniki. This software works estimating three modes of emissions, which are presented in figure 2:

- Hot emissions (exhaust emissions produced due to thermal stabilised engine operation)
- Cold-start emissions (exhaust emissions produced in the warming-up phase)
- Non-exhaust emissions (from fuel evaporation, abrasion of tyres, break wear emissions and refuelling losses)

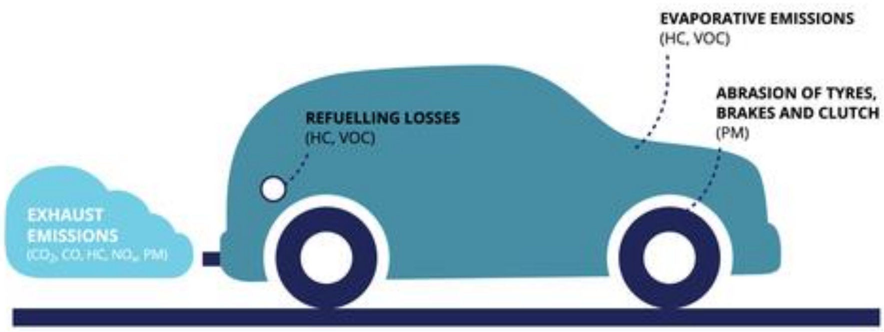


Figure 3: The different types of emissions from vehicles (European Environment Agency, 2016)

This model also includes a large number of vehicle types with different technology, previously divided in 5 macro categories according to the EMEP/EE guidebook 2016 methodology. Those categories are:

- Passenger cars
- Light commercial vehicles
- Heavy duty trucks
- Buses
- L-category

Then those categories are split in types according to their fuel (petrol, diesel, petrol hybrid, LPG bifuel, CNH biofuel, biodiesel), segment (mainly divided by rigid or articulated and/or their gross vehicle weight) and by the EURO emission standard according to the legislation (since conventional to EURO VI). Table 3 represents the different segments or subdivision according to the technology available in COPERT for passenger cars and light commercial vehicles, while Table 4 and Table 5 represent the same but for heavy trucks/buses and L-category, respectively.

Category	Segment	Category	Segment
Passenger Cars	Petrol Mini	Light Commercial Vehicles	Petrol N1-I
	Petrol Small		Petrol N1-II
	Petrol Medium		Petrol N1-III
	Petrol Large-SUV Executive		Diesel N1-I
	Diesel Mini		Diesel N1-II
	Diesel Small		Diesel N1-III
	Diesel Medium		
	Diesel Large-SUV Executive		
	Petrol Hybrid all categories		
	LPG Bi-fuel Mini		
	LPG Bi-fuel Small		
	LPG Bi-fuel Medium		
	LPG Bi-fuel Large-SUVExecutive		
	CNG Bi-fuel all categories		

Table 3: Vehicle sub-categories for Passenger Cars and Light Duty Vehicles (European Environment Agency, 1997)

Category	Segment	Category	Segment
Heavy Duty Trucks	Petrol >3,5 t	Buses	Urban Buses all categories
	All Rigid/Articulated categories		Coaches all categories
			Urban CNG Buses
			Urban Biodiesel Buses

Table 4: Vehicle sub-categories for Heavy Duty Trucks and Buses (European Environment Agency, 1997)

Category	Segment
L-Category	Mopeds all categories
	Motorcycles all categories
	Mini-cars
	All Terrain Vehicles (ATVs)

Table 5: Vehicle sub-categories for L-Category (European Environment Agency, 1997)

Among the most important input values of the programme, as it is indicated in its website (Emisia S.A.), are:

- Environmental factors: monthly average minimum and maximum temperatures and relative humidity
- Trip characteristics: country's average trip length [km] and trip duration [h]
- Fuel specifications
- Vehicles: fleet composition and behaviour of the current run

However, the most important input values for the model are given by the emission factors, which describe the performance of a vehicle depending on various conditions like the speed, acceleration, deceleration, environment conditions and altitude in different urban driving cycles. It is also important to highlight that COPERT is built around the average-speed approach, that is, emission factors are expressed as functions of the mean travelling speed over a complete driving cycle. Those emission factors functions have been derived from several research project conducted by the Laboratory of Applied Thermodynamics and other research institutes in Europe (Ntziachristos, et al., 2009). It also important to distinct emission factor for every pollutant (i), vehicle category (j) and road class (k), then an emission factor is defined as $e_{i,j,k}$ (European Environment Agency, 1997).

As it was described before, COPERT distinct between three main emissions, which have different calculation processes. For exhaust pollutants the programme computes the following formula:

$$E_{EXH}[g] = E_{HOT}[g] + E_{COLD}[g] \qquad (1)$$

The calculation of the exhaust emission consists in two parts, one part where the engine and the emission control system are thermally stabilized (E_{HOT}) and the other refers to the cold-start emission (E_{COLD}), which occur before the vehicle subsystems have reached their normal operation temperature. However, those factors act in function of the activity level for a given stock of vehicles (NM_r), expressed in veh-km, then two new expressions are developed.

$$E_{HOT\ i,j,k}[g] = NM_j[km] \times e_{hot\ i,j,k}[\frac{g}{km}] \qquad (2)$$

$$E_{COLD\ i,j,k}[g] = \beta_j \times NM_j[km] \times e_{hot\ i,j,k}[\frac{g}{km}] \times (\frac{e^{COLD}}{e^{HOT}} - 1) \qquad (3)$$

Where β_j is the fraction of mileage driven with cold engines (defined as those with a water temperature below 70°C (Bell, et al., 1997)) and $\frac{e^{COLD}}{e^{HOT}}$ is the cold/hot ratio of emissions and the whole expression $\frac{e^{COLD}}{e^{HOT}} - 1$)expresses the over-emission level compared to hot emissions (Ntziachristos, et al., 2009). Both parameters depending on the ambient temperature (European Environment Agency, 1997).

Beside the exhaust emissions, COPERT is able to calculate non-exhaust emissions, which are originated from friction processes by tires on the road surface, brakes and re-suspension of particle due to traffic induced turbulence (Keuken, et al., 2010). The importance of this calculation lies on one of the main pollutant produced in this process , the particulate matter (PM), especially because high concentrations of fine particulate matter ($PM_{2.5}$) and its concentrations were responsible for about 432.000 premature deaths in 2012, produced by long-term exposure in Europe (European Environment Agency, 2015). COPERT is specifically focused on the evaporation losses (fuel which evaporates via the fuel system). These may occur either when the vehicle is stationary or when it is operating, and in this software the evaporation is considered to originate from three operation phases described in the equation 4 (Ntziachristos, et al., 2009).

$$E_{EVAP} = E_{DIURNAL} + E_{SOAK} + E_{RUNNING} \qquad (4)$$

Fuel losses may occur when temperature varies during the day ($E_{DIURNAL}$), after operation (E_{SOAK}) when hot fuel is contained in the reservoir (called hot soak) and during the operation ($E_{RUNNING}$) (Ntziachristos, et al., 2009).

From the input given by the activity level of the vehicle stock plus the emission factors it is possible to calculate the amount of pollutants generated by the fleet of vehicles for the following chemical components:

- AS
- BC
- Cd
- CH_4
- CO
- CO_2
- Cr
- Cu
- FC
- Hg
- N_2O
- NH_3
- Ni
- NMVOC
- NO
- NO_2
- OM
- Pb
- PM_{10}
- $PM_{2.5}$
- Se
- SO_2
- VOC
- Zn

1.4.1. THE MILEAGE PROBLEM FOR COPERT

An important parameter to measure related to emissions is the age of the vehicle, it is understood that a new vehicle should not pollute as much as a vehicle of a large mileage.

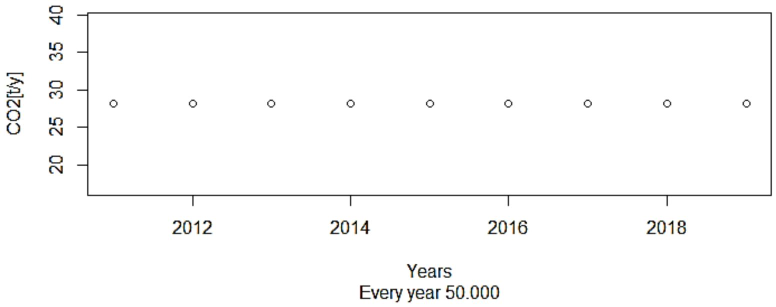
In this sense, COPERT includes a parameter called "Mileage degradation" that describes how annual miles driven decreases as vehicles get older, for example, over 80.000 km there is an increase by 60% of CO and NO_x and an increase by 30% on NMVOCs in vehicles with technology Euro 1 and Euro 2 (Boulter, 2009). However, those factors are only given for EURO I and later passenger cars and light duty vehicles only and apply to hot emissions only (Ntziachristos, et al., 2006), but not for diesel buses. In a way to corroborate this disadvantage of the model, this thesis demonstrates this fact with a small simulation setting 8 years of continuously operation for a single EURO III standard bus diesel, in table 6.

Year	Mean activity [km]	Lifetime cumulative activity [km]
2011	50.000	0
2012	50.000	50.000
2013	50.000	100.000
2014	50.000	150.000
2015	50.000	200.000
2016	50.000	250.000
2017	50.000	300.000

Year	Mean activity [km]	Lifetime cumulative activity [km]
2018	50.000	350.000
2019	50.000	400.000

Table 6: Example of the effect of lifetime cumulative activity simulated by COPERT (own elaboration)

The result is shown in the following graph 1.



Graph 1:Bus diesel Euro III with cumulative activity simulated by COPERT (own elaboration)

As it is shown, there is no change among the different years of operation. This observation was also made by the NAEI (National atmospheric emission inventory) from the U.K. (NAEI National Atmospheric Emission Inventory, 2012). Even more, lastly studies done in the U.K. propose scaling factors for cars and LGV (goods/commercial vehicles less than 3.5 tones) vehicles (Boulter, 2009).

1.5. IVE MODEL TO OVERCOME MILEAGE PROBLEM

The international vehicle emissions (IVE) model, funded by the US Environmental Protection Agency, Office of International Affairs, is a micromodel characterized by its flexibility; this advantage makes it very useful also for developing countries, where the data and know-how are not always fully available.

This model has three components

- Vehicle emission rates
- Vehicle activity
- Vehicle fleet distribution

Among the inputs it is possible to configure the vehicle technology distribution, air conditioning distribution and the base emission factor adjustment by technology and pollutant.

In the case of the vehicle technology distribution, there are 1372 predefined technologies. Among the types they can be divided into fuel types (petrol, natural gas, propane, ethanol, diesel, CNG/LPG, special), air/fuel (carburettor, single-point fuel injection, multi-point fuel injection, pre-chamber injection, direct injection, 2-cycle, 4-cycle) and also into three categories of vehicles (motorcycles, passenger vehicles and buses). An interesting characteristic of this model is a fourth categorization, a split between 3 mileage ranges: more specifically, in the case of cars and buses there are three kinds of total mileage, under 79.000 km, between 80.000 km and 161.000 km and over 161.000 km; for motorcycles and small engines vehicles it divides them into under 25.000 km, between 26.000 km and 50.000 km and over 51.000 km.

IVE Model is able to calculate the amount of pollutants per hour during a day. This is done due to the information given by the driving behaviour, that is to say, analysing the velocity, acceleration and deceleration, which display emissions in function of the engine power and its levels of demand and stress. It demonstrated that the level of emission of CO may be increased 200 times under certain driving conditions (ISSRC, 2008).

The previous attributes are useful to calculate two parameters used in IVE

- Vehicle specific power (VSP)
- Engine Stress

The manual proposed the following formulas to estimate these parameters:

$$VSP = v[1.1a + 9.81(\text{atan}(\sin(grade))) + 0.132] + 0.0000302v^3 \quad (5)$$

Where:

v is velocity (m/s),

a is acceleration (m/s^2) and

grade must be calculated getting the altitude second-by-second $grade = (h_{t=0} - h_{t=-1})/v_{(t=-1to0seconds)}$, with h altitude (m).

$$Engine\ Stress = RPMIndex + \left(0.08 \frac{ton}{kW}\right) * PreaveragePower \quad (6)$$

Where:

$PreaveragePower = Average(VSP_{t=-5\sec to-25sec})$(kW/ton) and

$RPMIndex = Velocity_{t=0}/SpeedDivider$

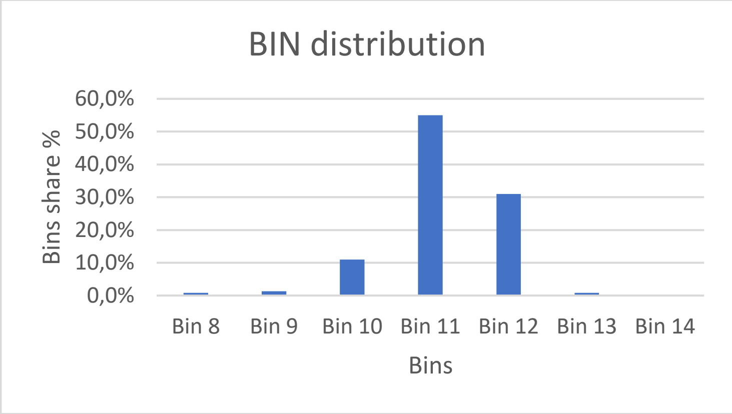
Notice that the parameter "SpeedDivider" is a value given by the table 7, according to the speed and the engine power.

Speed Cutpoints (m/s)		Power Cutpoints (kW/ton)		Speed Divider (s/m)
Min	Max	Min	Max	
0.0	5.4	-20	400	3
5.4	8.5	-20	16	5
5.4	8.5	16	400	3
8.5	12.5	-20	16	7
8.5	12.5	16	400	5
12.5	50	-20	16	13
12.5	50	16	400	5

Table 7:Cutpoints used in RPMIndex Calculations (ISSRC, 2008)

It is important to highlight that the VSP formula has been developed in 1999 in USA (Jiménez-Palacios, 1999), its coefficient may vary slightly (Zhai, et al., 2008). However, the original formula is still being in use, furthermore is the main parameter of IVE model.

Once the requested data for VSP and Engine stress parameters is collected (for example via remote by GPS), it is possible to get 60 emissions variations, or 'bins', which are very useful at the moment of the calculation of emissions, since a correction factor is associated to each bin or VSP condition. Those matches are expressed in Table 9. The total amount of running simulated must be contained in some of the 60 bins proposed, shown in table 8. For example, considering a distribution of the VSP, a bus may travel a 55% in bin 11 and the rest in bin 8 to bin 14, as it shown the graph 2.



Graph 2: VPS distribution and bin assignation example (own elaboration)

Bin	VSP [kW/Ton]		Engine Stress	
	Lower	Upper	Lower	Upper
0	-80.0	-44.0	-1.6	3.1
1	-44.0	-39.9	-1.6	3.1
2	-39.9	-35.8	-1.6	3.1
3	-35.8	-31.7	-1.6	3.1
4	-31.7	-27.6	-1.6	3.1
5	-27.6	-23.4	-1.6	3.1
6	-23.4	-19.3	-1.6	3.1
7	-19.3	-15.2	-1.6	3.1
8	-15.2	-11.1	-1.6	3.1
9	-11.1	-7.0	-1.6	3.1
10	-7.0	-2.9	-1.6	3.1
11	-2.9	1.2	-1.6	3.1
12	1.2	5.3	-1.6	3.1
13	5.3	9.4	-1.6	3.1
14	9.4	13.6	-1.6	3.1
15	13.6	17.7	-1.6	3.1
16	17.7	21.8	-1.6	3.1
17	21.8	25.9	-1.6	3.1
18	25.9	30.0	-1.6	3.1
19	30.0	1000.0	-1.6	3.1
20	-80.0	-44.0	3.1	7.8
21	-44.0	-39.9	3.1	7.8
22	-39.9	-35.8	3.1	7.8
23	-35.8	-31.7	3.1	7.8
24	-31.7	-27.6	3.1	7.8
25	-27.6	-23.4	3.1	7.8
26	-23.4	-19.3	3.1	7.8
27	-19.3	-15.2	3.1	7.8
28	-15.2	-11.1	3.1	7.8
29	-11.1	-7.0	3.1	7.8
30	-7.0	-2.9	3.1	7.8
31	-2.9	1.2	3.1	7.8
32	1.2	5.3	3.1	7.8
33	5.3	9.4	3.1	7.8
34	9.4	13.6	3.1	7.8
35	13.6	17.7	3.1	7.8
36	17.7	21.8	3.1	7.8
37	21.8	25.9	3.1	7.8
38	25.9	30.0	3.1	7.8
39	30.0	1000.0	3.1	7.8
40	-80.0	-44.0	7.8	12.6
41	-44.0	-39.9	7.8	12.6
42	-39.9	-35.8	7.8	12.6
43	-35.8	-31.7	7.8	12.6
44	-31.7	-27.6	7.8	12.6
45	-27.6	-23.4	7.8	12.6
46	-23.4	-19.3	7.8	12.6
47	-19.3	-15.2	7.8	12.6
48	-15.2	-11.1	7.8	12.6
49	-11.1	-7.0	7.8	12.6
50	-7.0	-2.9	7.8	12.6
51	-2.9	1.2	7.8	12.6
52	1.2	5.3	7.8	12.6
53	5.3	9.4	7.8	12.6
54	9.4	13.6	7.8	12.6
55	13.6	17.7	7.8	12.6
56	17.7	21.8	7.8	12.6
57	21.8	25.9	7.8	12.6
58	25.9	30.0	7.8	12.6
59	30.0	1000.0	7.8	12.6

Table 8: Boundaries Assumed in VSP/Engine Stress Binning (by IVE Model)

As it can be seen in the Figure 4, the emission estimation process starts with the base emission rate for each technology by each of the correction factors ($K_{[\mathrm{dt}]}$) , which are defined for each vehicle technology, and the amount of vehicle travel for each technology to arrive to a total amount of emissions produced.

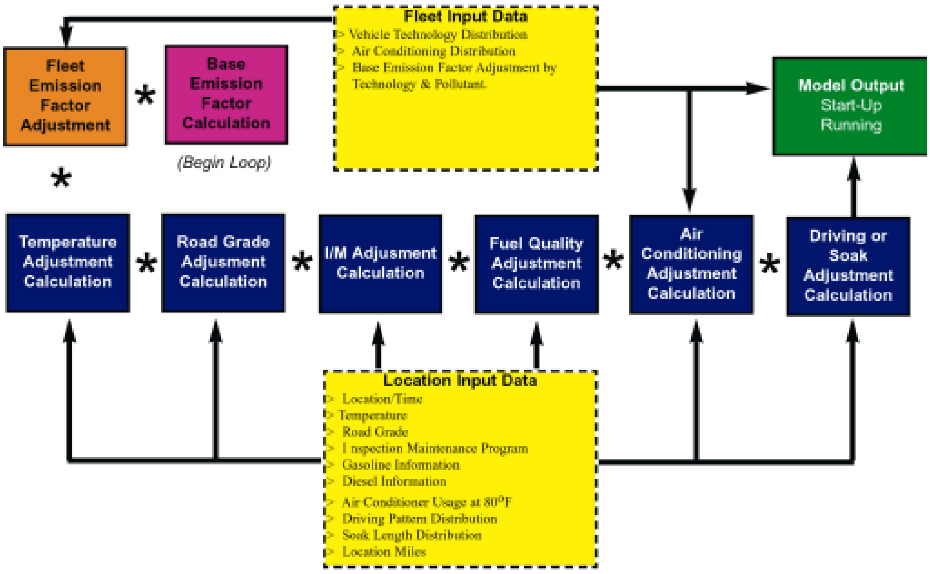


Figure 4: IVE Model's architecture (ISSRC, 2008)

IVE Model distinguishes two kinds of base emission rates, one for running emissions ($Q_{running}$) and one for start emissions (Q_{start}), similar to COPERT and its hot and cold emissions. The IVE model's base emission rates are based on the United States' Federal Test Procedure (FTP) driving cycle. (ISSRC, 2008)

$$Q_{running}[\frac{g}{km}] = \sum_t\{f_{[\mathrm{t}]} \times \sum_d[Q_{[\mathrm{t}]} \times \bar{U}_{FTP} \times f_{[\mathrm{dt}]} \times K_{[\mathrm{dt}]}]\}/\bar{U}_C \qquad (7)$$

Equation 1: Running base emission rate

$$Q_{start}[\frac{g}{start}] = \sum_t\{f_{[\mathrm{t}]} \times Q_{[\mathrm{t}]} \times \sum_d[f_{[\mathrm{dt}]} \times K_{[\mathrm{dt}]}]\} \qquad (8)$$

Equation 2:Start base emission rate

Where:

$f_{[\mathrm{dt}]}$ is the travel fraction given in percent time spent at each VSP condition and;

$\bar{U}_{FTP}$ is the average velocity of the FTP cycle, to convert gr/km to gr/time when $f_{[\mathrm{dt}]}$ is applied.

Then the average velocity of the cycle is applied, $\bar{U}_C$, to convert back to gr/distance (This process is only applied for running base emission rate because for starts the units are gr/start).

As seen, the model evaluates two kinds of outputs, start-up and running emissions for 15 different pollutants described as follows:

- CO
- VOC
- VOC_{evap}
- NO_x

- SO_x
- PM_{10}
- Lead
- 1,3 Butadine
- Acetaldehyde
- Formaldehyde
- NH_3
- Benzene
- CO_2
- N_2O
- CH_4

These results can be expressed either hourly or daily (which is basically the aggregation of each hour).

1.6. COMPARISON BETWEEN MODELS

After understanding the architecture, input and output of the models, it is possible to do a comparison between COPERT and IVE with the purpose to analyse their advantages and disadvantages.

According to those categories we can locate COPERT as an average speed model and IVE-MODEL as a modal model and it is possible to create a more detailed table with the main characteristics, as it is shown in table 9.

Characteristics	COPERT	IVE - MODEL
Type of model	Average speed model	Modal Model – Instantaneous
	INPUT VARIABLES	
Environmental information	Annual average minimum and maximum temperature [C°], humidity [%]	Altitude [m]
Fuel specifications	Energy content [MJ/kg], H:C ratio, O:C ratio, Density, S, Pb, Cd, Cu, Cr, Ni, Se, Zn, Hg, As	Gasoline (Fuel quality, S, Pb, Benzeno, % Oxygenate), Diesel (Fuel quality, S)
Lubricant specifications	S, Pb, Cd, Cu, Cr, Ni, Se, Zn, Hg, As, H:C ratio, O:C ratio	No specifications
Stock configuration	448 different vehicles with different technology available	1372 different vehicles with different technology available
Stock data per vehicle per technology	Annual mean activity [km]; Lifetime cumulative activity [km];	Distance [km] and average speed [km/h] in the hour evaluated. Acceleration, Deceleration and grade of slope, second-by-second
Circulation mode per vehicle per technology	Emission factors defined by % in rural, urban or highway and their average speed in each mode [km/h]	Emission factors using the VSP and engine stress calculated by the user and the table of BINs
Emission calculation method	Vehicle activity × Emission factor (see equation 2 and equation 3)	Vehicle activity disaggregated by specific mode × Emission factor (see equation 7 and equation 8)
	OUTPUTS	
Types of emissions	Hot and cold emissions	Running and start-up
Output	25 pollutants, including GHG (CO_2, CH_4, N_2O)	15 pollutants, including GHG (CO_2, CH_4, N_2O)

OUTPUTS		
Default output units	tons/year	kg/h; kg/day
ADVANTAGES & DISADVANTAGES		
Advantages	• It needs just a few input data to get a detailed emission calculation • Input information on kilometres travelled and average speed is relatively easy to obtain from traffic models or field measurements. • As a macro point of view it has a sufficient degree of certainty • It has a large list of exhaust and non-exhaust pollutants • It is no necessary to manage a large amount of data from the driving conditions	• It has a large library of vehicles and technologies • Emission factors are differentiated for various traffic conditions and driving patters (VSP and BIN) • It can get a detailed behaviour of the emission during a single run
Disadvantages	• Some parameters like Mileage degradation are not available for all the vehicles and all technologies • It has a low amount of types of vehicles and technologies in comparison with other models.	• Beside consider the effect of mileage degradation it is not truly accurate (the three groups cover too many km) • It does not consider the effect of the lubricant • Data may not be easy to get without other devices, like GPS • It does not include Euro VI standard.

Table 9: COPERT vs IVE Model (own elaboration)

COPERT as an "average speed model" has an advantage in terms of the data, which is easy to get or estimate under basic assumptions, however the concept "average speed" may not be estimated correctly as it runs as a uniform operation, not considering possible operational conditions given with a vary of speeds (Cappiello, et al., 2002), like it would do a "cycle dynamic" model. Another unfavourable point is that the modern vehicles, catalyst-equipped, have a large proportion of total emission produced as very short, sharp peaks, often occurring during gear changes and periods of high acceleration, making average speed a less reliable indicator for the estimation of emissions (Boulter, 2009).

For another side, there are several studies that give more importance to the variation of speed and engine load (Kean, et al., 2003), as IVE-Model does. However, a lack of this model is the absence of the Euro standard VI, a solution for this problematic is cover further.

As seen in the disadvantages, both models cannot consider the mileage degradation in a precise way, for one hand COPERT does not include this parameter in the calculation of the emission of vehicles with technology diesel and IVE Model, despite it does include this technology, performs too broad analysis ranges. This study has the intention of using both models as complement of each other in order to get the data enough to be executed by an artificial neural network.

1.7. ARTIFICIAL NEURAL NETWORK TO PREDICT EMISSIONS

This thesis considers multiple parameters in which the bus emissions are based on. These parameters are also taken into consideration by the software used, however, in both cases, the application of these elements may be time consuming. Alternatively, the pollutants emitted in function of driving cycle, temperature and road slope, knowing previously the euro standard and mileage, can be predicted modelled using Artificial Neural Networks (ANN), which can be used to obtain the output parameters of the system as long as enough experimental data the main three steps of ANN: building, training and testing.

An ANN is an interconnected assembly of simple processing elements, units or nodes. The processing ability of the network is stored in interunit connection strengths, or weights, obtained by a process of adaptation to, or learning from, a set of training patters (Gurney, 1997), it is basically the homologation of the neural communication via electrical signals in the human brain, by a mathematical representation as it shows in the following figure 4.

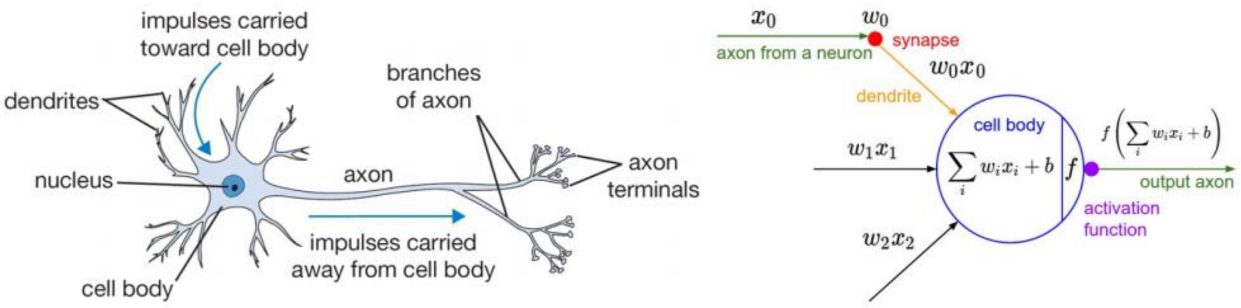


Figure 5: A biological neuron (left) and its mathematical model (right) (Konaté, 2019)

Basically, an ANN use a learning-by-example paradigm, which collects a large set of examples and learn the nature of the task by adjusting the network synapses connection, so the number of errors is small as possible. This paradigm differs from physical modelling because it has no properties of features to make a decision based on the presence or absence of these properties.

This process of learning is done by input layers that follows a process through a next layer called hidden layers, which following determinate weights and connection transform the input into output. This process can be represented in the following figure 6.

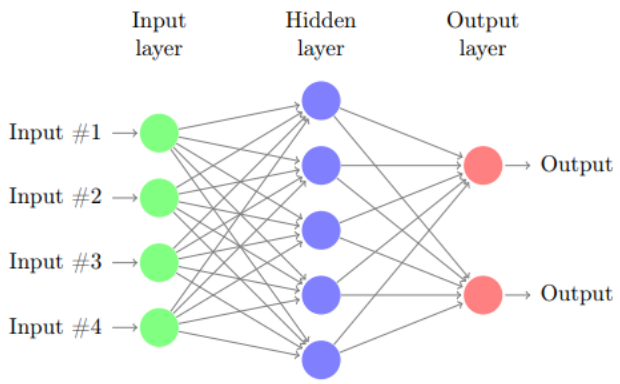


Figure 6: A neural network process representation (Konaté, 2019)

The mathematical way to represent this network can be described, by Gurney (Gurney, 1997) as follows:

$$f(x, w) = \emptyset(x \times w) = \emptyset(\sum_{i=1}^{p}(x_i \times w_i) \quad (9)$$

Where x is the input signal and w is the weight, both represent the input vector and weight vector of the neuron when there are p inputs. Meanwhile Φ represent the activation function.

Understanding that the target is finding the optimal value to reduce the error, this process is done by calculating the gradient in which the error stream moves, as the figure 11 shows.

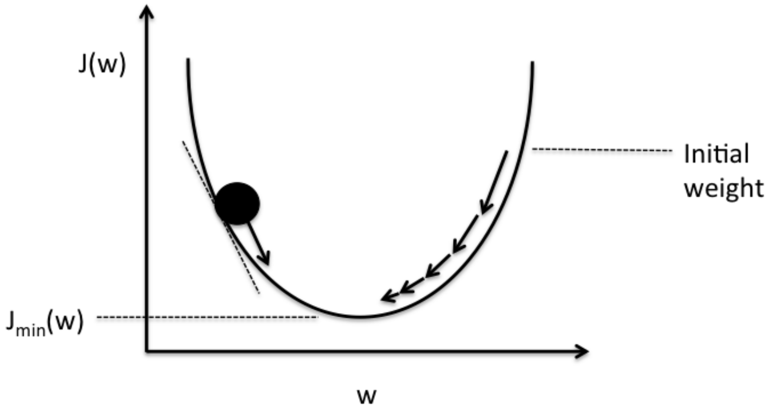


Figure 7: Schematic of gradient descent (Gurney, 1997)

It is in this gradient process when the activation function has more prominence, due to they compute the weighted sum of input and biases of which is used to decide of a neuron can be fire or not, manipulating the current data across some gradient processing usually gradient descent and afterwards produce an output for the neural network, that contains the parameters in the data.

Activation functions can be either linear or non-linear. Some of the most used can be the following:

- Sigmoid function: This is a non-linear activation function mostly used in FNN. It is bounded differentiable real function, defined for real input values, with positive derivates everywhere and some degrees of smoothness. (Han, et al., 1995).
- SoftMax function: Used to compute probability distribution from a vector of real numbers, it produces an output which is a range of values between 0 and 1, the same like sigmoid, but the difference is Sigmoid is used in binary classification while SoftMax is used for multivariate classification task (Nwankpa, et al., 2018), giving back a probabilities of each class.
- The Rectified linear unit (ReLU): It is a fast learning activation function, since it was proposed in 2010 (Nair, et al., 2010) it has been widely used, due to its good performance in comparison with Sigmoid functions. The ReLU activation function performs a threshold operation to each input element where values less than zero are set to zero.

Table 10 shows the different activation functions ant their mathematical representations.

Activation function	Computation equation
Sigmoid	$f(x) = (\frac{1}{1+e^{-x}})$
SoftMax	$f(xi) = \log(1 + exp^x)$
ReLU	$f(x) = \max(0, x) = \{ \begin{matrix} x_i, if\ x_i \geq 0 \\ 0, if\ x_i < 0 \end{matrix}$

Table 10:Types of Activation Functions (Han, et al., 1995)

To be able to predict, ANN has a previous phase called training, where it checks the variation of the error adjusting the weights in each step both the chain all the way back, this process is called backpropagation, and it is one of the most well-researched training algorithms in neural networks. (Gurney, 1997). From this it can be understand that the more input the best is the training and by consequence, the best is the prediction.

ANN has been applied in several studies of transportation, for example, signal recognizing, as shown figure 6. The input may be different aspects of the signal, for example, the colour of each pixel, these input multiply by a weight, once all connections are summed an activation function is applied to get a hidden node or a new input vector for the forward layer. After the last propagation the output can be evaluated by the thresholds.

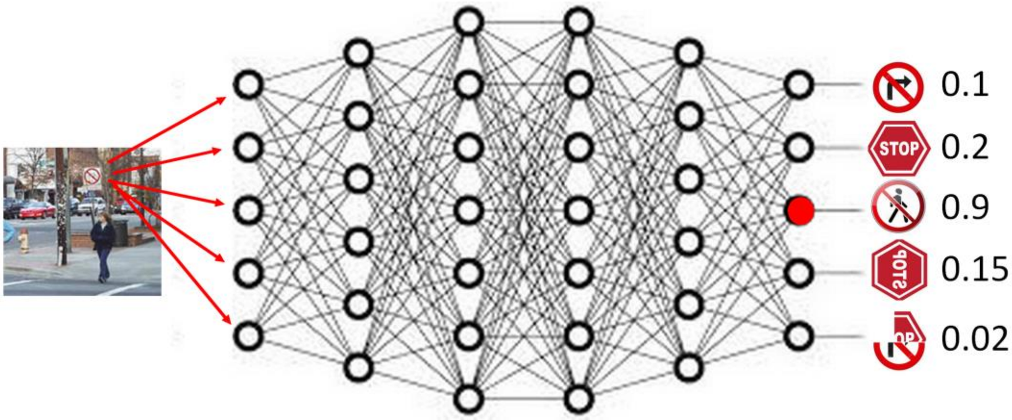


Figure 8: Applied example of ANN in transport signal recognition (own elaboration)

However, this is not only the unique application on transportation. ANN has been used to predict emission of road transport in several studies (Bhandari, et al., 2006) (Mugdal, et al., 2011) (Aydin, 2018). A proposed ANN structure can be the one as shows figure 8, where in base a different input it is possible to estimate different pollutants.

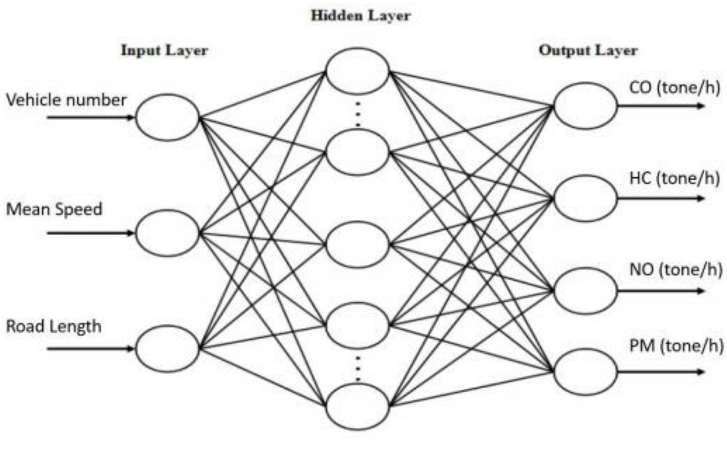


Figure 9: ANN structure for estimating road transport pollutants (Aydin, 2018)

However, it is important to define how the flow of information will behave, in other words, how the ANN takes the input and give the output. In this sense, there are 3 most commonly used types of ANN in artificial intelligence:

- Feedforward Neural Networks (FNN)
- Recurrent Neural Networks (RNN)
- Convolutional Neural Networks (CNN)

The first group, FNN, may be considered the most commonly used, the name "Feedforward" comes from the fact that the flow of information through the network is unidirectional, without any loops, the quantity of layers can be vary, being single-layered the basic form with two layers of neurons and no hidden layers between them, other case is the Multi-layered Perceptron (MLP), which consist of multiple hidden layers between the input and the output layers, allowing multiple stages of information processing. FNN are widely used for basic patter recognition. The second group, RNN, involves the recurrence of operations in the form of loops, while FNN has connections that lead only from one neuron to neurons in the subsequent layers without any feedback, RNN allows connections to lead back to neuron in the same layer, another difference between FNN and RNN is that feed-forward neural networks have no memory of the input they receive due to its structure, in other words, it only consider the current input and it has no notion or order in time. Figure 9 shows the difference structure between FNN and RNN.

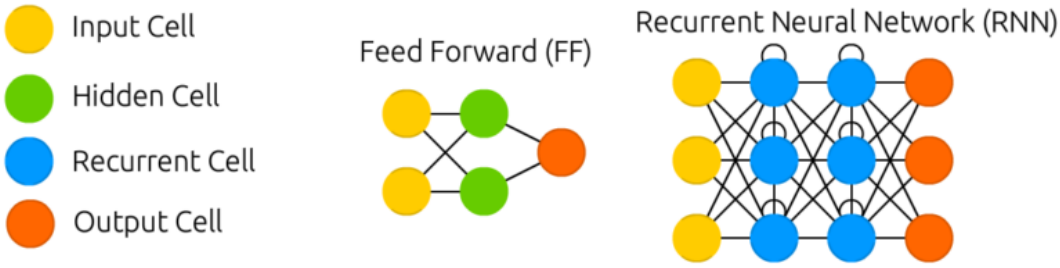


Figure 10: Feedforward Neural Network (FNN) and Recurrent Neural Network (RNN) (The Asimov Institute, 2019)

The third group, CNN, is defined by a three-dimensional arrangement of neurons, instead of the standard two-dimensional array. The first layer is called conventional layer, each neuron in this layer only process the information from a small part of the whole field. It can be said that CNN, is one of the kinds of FNN (Tianyi, et al., 2015) and it widely used in pattern recognition and image processing.

The model of estimation emissions of a fleet of buses can be reduced to a linear regression structured as it follows:

$$Y = \beta_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_k X_k + \delta \qquad (10)$$

Where:

Y is dependent variable, which basically is the value that the regressions model is aiming to predict, in this case the amount of pollutant emitted [ton/year],

X_k is is the independent variable, using as output,

β_k is is the coefficient or weight giving to the independent variable to predict the dependent variable and,

δ is the error or the distance between the value predicted by the model and the actual dependent variable Y.

Then this regression model can be built in a neural network, being the independent variables in the input layer, the coefficient as weights which are run through a sigmoid activation function and a unit step function with an error in the operation.

In this linear regression, the flow of information goes in only one direction, there is no need of feedbacks, then this problem may be modeled with FNN, specifically a Multilayer Perceptron Neural Network.

1.7.1. MULTILAYER PERCEPTRON NEURAL NETWORK

A Multilayer Perceptron (MLP) is one of the most frequent ANN, as any FNN, the signals are transmitted from input to output, within the network, in only one direction, without loop and any interaction beyond the output.

The greatest advantage of MLP is that a priori knowledge of the specific functional form is not required. MLPs are not only a 'black box' tool. In fact, they have the potential to significantly enhance scientific understanding of empirical phenomena subject to neural network modelling (Du, et al., 2013). The application of MLPs are wide, but focused in the estimation of pollutants, this ANN is recognized as a well data predictor, forecasting using the current data modelling relationships between input variables (Guo, et al., 2012).

MLP may be one or more hidden layers of nodes between input and output layers, basically the relation between them and the quality of the output is directly, but not always accurate. Each layer is composed of one or more neuron in parallel, then a single layer can assign different inputs x_i (i = 1,2, . . N), each neuron calculates a linear combination of the inputs using synaptic weights w_i to generate the weighted input Σ; then, it provides an output y via an activation function $f(z)$, as figure 10 shows.

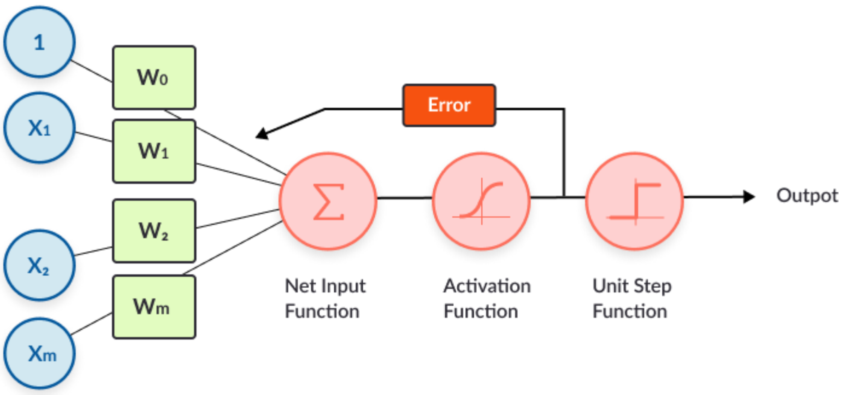


Figure 11: Linear regression to Neural Network (Mirjalili, et al., 2014)

In the literature a clear 3-steps model is defined to build a MLP (Mirjalili, et al., 2014):

- Step 1: Equation below first calculates the weighted sums of inputs:

$$S_j = \sum_{i=1}^{n}(w_{ij}x_i) - \theta_j, \qquad j=1,2,\ldots,h \qquad (12)$$

Where:

n is the number of input nodes

W_{ij} shows the connection weight from the ith node in the input layer to the jth node in the hidden layer

θ_j is the bias (threshold) of the jth hidden node

x_i indicates the ith input

- Step 2: The output of each hidden node is calculated using the activation function for each layer.
- Step 3: After calculating the outputs of hidden nodes, the final output are defined as below:

$$0_k = \sum_{i=1}^{h}(W_{jk}S_j) - \theta'_k, \qquad k=1,2,\ldots m \qquad (14)$$

Where:

W_{jk} is the connection weight form the jth hidden node to the kth output node and,

θ'_k is the bias (threshold) of the kth output node

Training an MLP consists in finding optimum values for weight and biases to achieve desirable outputs from certain inputs (Mirjalili, et al., 2014), reducing the error, this process as it was seen before it is called backpropagation

Backpropagation, for MLP and any ANN, is basically an iteration process to reduce the error, some steps can be mentioned (Ur Rehman Khan, 2017) as it follows:

- Step 1: Randomize the weight w to small random values,
- Step 2: Select an instance t, a pair of input and output patterns, from the training set,
- Step 3: Apply the network input vector to the network,
- Step 4: Calculate the network output vector z,
- Step 5: Calculate the error for each of the outputs k, the difference (δ) between the desired output and the network output,
- Step 6: Calculate the necessary updates for weight Δw in a way that minimizes this error,
- Step 7: Add up the calculated weights' updates Δw to accumulated total updates Δw,
- Step 8: Repeat steps 2-7 for several instances comprising an epoch,
- Step 9: Adjust the weights w of the network by the updates Δw,
- Step 10: Repeat steps 2-9 until all instances in the training set are processed. This constitutes one-iteration,
- Step 11: Repeat the iteration of steps 2-10 until the error for the entire system (error δ defined above or the error on cross-validation set) is acceptable low, or the predefined number of iterations is reached.

2. GOALS OF THE THESIS

The main aim of the thesis is to develop a model able to calculate emissions from a fleet of buses:

- EURO IV,
- EURO V and
- EURO VI

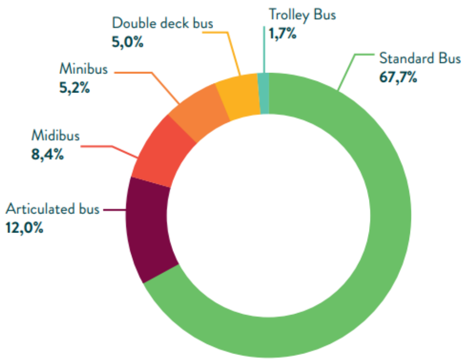
For different pollutants, as:

- Carbon dioxide CO_2;
- Nitrogen oxide NO_x;
- Carbon monoxide CO;
- Particular matter, 10 micrometres or less in diameter, PM_{10};
- Sulphur dioxide SO_x; and
- Ammonia NH_3

Trying to cope with the above-mentioned model limitations, further described, to create a tool available for public transport operators.

The selection of these components responds to the different effects on the environment. In the case of CO_2 is one of the main components of GHG, playing a direct role in the thermal energy trapped in the atmosphere causing the global warming, the same for CO but in with a lower impact. By other side, NO_x has an important role in the formation of smog, which may affect directly the irritation of the lungs, creating in short time breathing problems, like asthma (U.S. Environmental Protection Agency, 1998). This problem is also produced by the PM_{10} and, besides the problems on health, the EPA in USA also mentions the effects on the environment as its contribution to acid rain effects, making lakes and streams acid and damaging sensitive forest and farm crops, to which contribute also SO_x and NH_3.

The next step is focusing in a group of determinate bus fleet, for this purpose, is taken the report "Global Bus Survey" (International Association of Public Transport, 2019), figure 13, by the International Association of Public Transport (UITP) which reports that among 32 bus operators in 46 countries, including 29 European countries, a 67,7% of the bus fleet are standard buses (as regular 12-meter buses), being diesel the most popular fuel, represented 50% of all bus fleet. From these vehicles a respective a 17,2% belongs to Euro IV, 28,3% to Euro V and a 15,2% to Euro VI, in practice terms, this study covers a 60% of the total fleet of European standard buses.



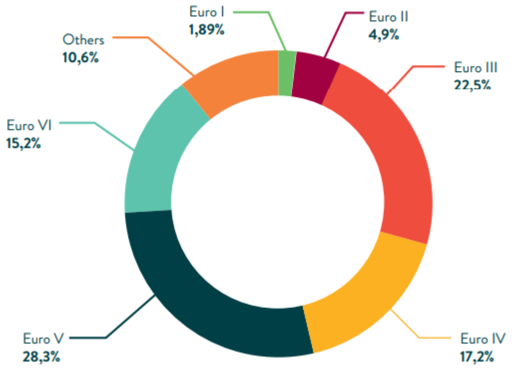


Figure 12: European bus fleet composition in 2019 (International Association of Public Transport, 2019)

Beside the calculation the thesis includes a detail analyses of the European Union emission framework for different vehicles, with the purpose to indicate in the model, if the measures are according to the limit set by the regulations.

The calculation will be done through a model will be able to estimate the amount of gases exhausted by a fleet of buses giving a set of parameters, as quantity of ignitions of the engine during a day, average daily speed, average daily travelled distance. For this a case of study is analysed, simulated and calibrated according to the limitations and strengths of the models to be chosen.

2.1. RESEARCH GOALS

The specific research goals can be list as follows:

- Analyse and identify the current regulations of emissions for different vehicles, understanding the limits of emissions applicable to each vehicle studied;
- Analyse the calculation mechanism of emissions from the different software/models studied;
- Identify possible barriers and problems in the software/models studied;
- Create a database to feed the development of the model using a case of study;
- Develop and implement the model; and
- Testing and calibration of the model implementing it for the case of study.

3. METHODOLOGY

This thesis has the purpose to create a model to calculate the emissions from a fleet of buses, which is taken as a study case, under different parameters, namely average daily amount of ignition of the engine, average yearly speed, average maximum temperature, percentage of slope.

For this a group of steps care be set in order to reach the right model

- Step 1: Analysis of the literature based on environmental policies and current emission calculators and models present in the market, in terms of maximum levels of emission by each pollutant assessed and for getting the mechanism of function of the different calculators.
- Step 2: Once the calculation methods and the limits are set, it necessary to feed the model using a series of data giving by the company of study
- Step 3: With all the input given in the previous steps is possible to create an analytic model able to find different results from a matrix of data.
- Step 4: Application of Artificial Neural Network to get trends of data and improve the prediction level of the analytic model previously created.

These steps are shown in the figure 14.

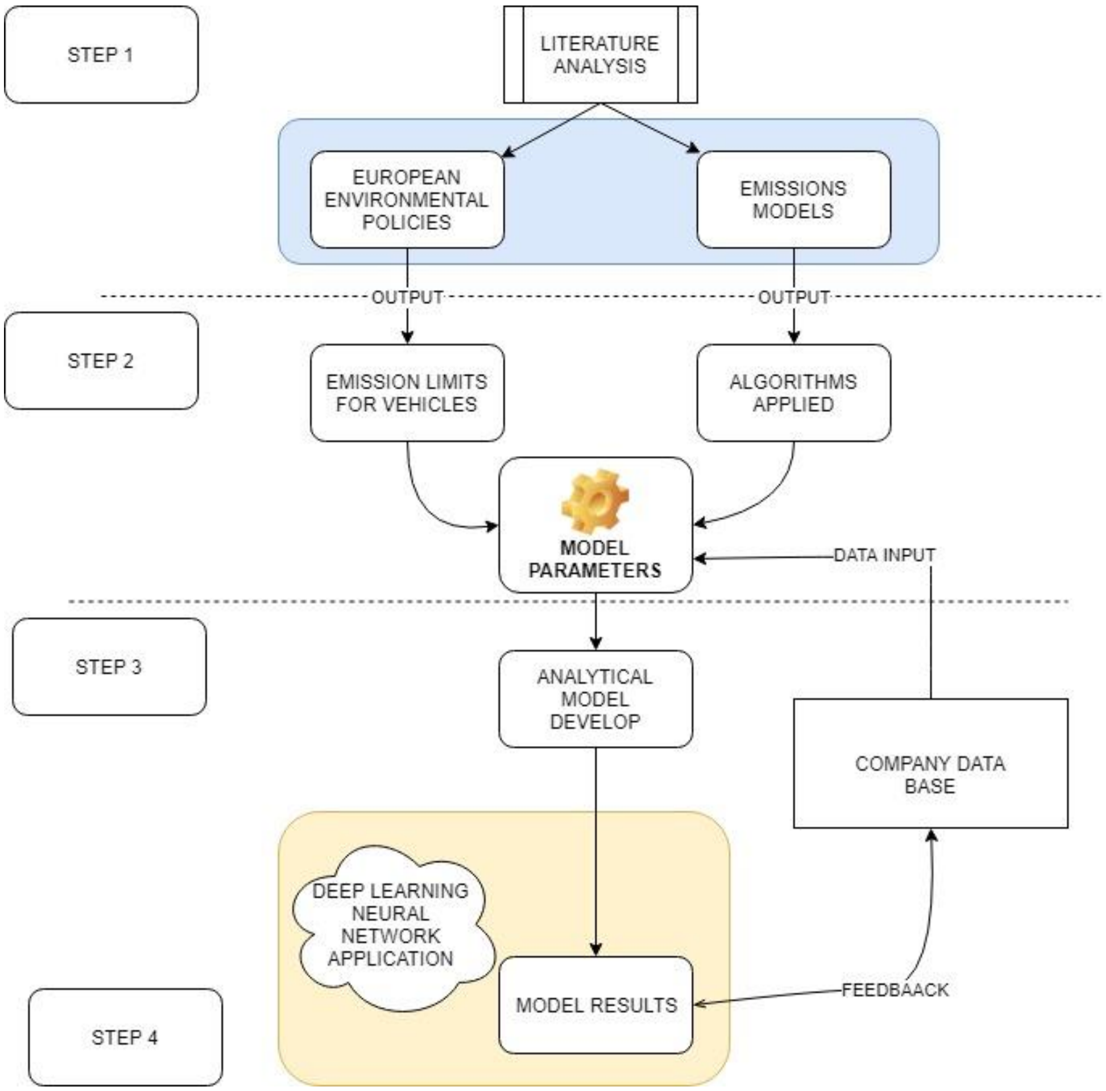


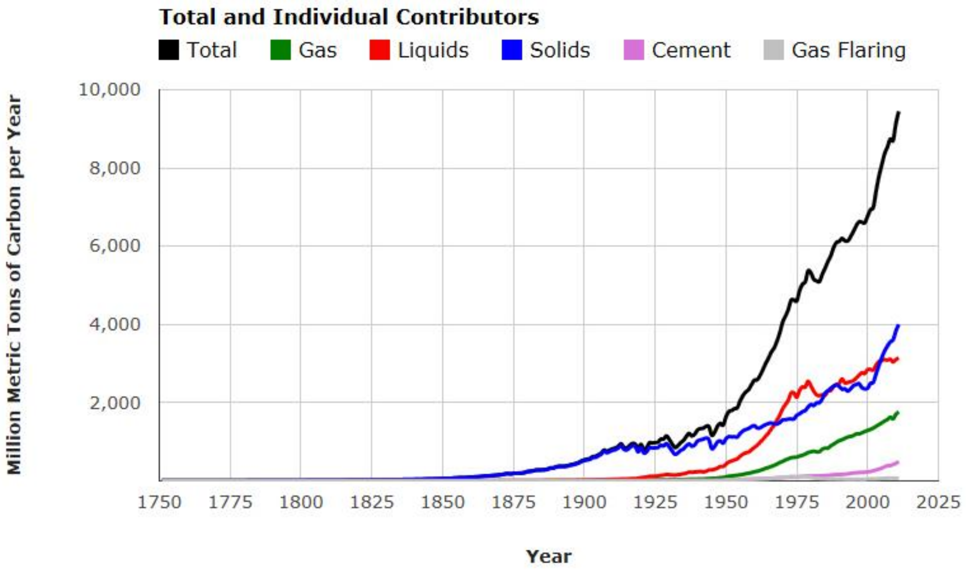
Figure 13: Methodology diagram (own elaboration)

4. ENVIRONMENTAL FRAMEWORK

As the thesis involves directly the development of a model to calculate emissions from vehicles, it is important to understand the development of certain policies related to the limitation of production of pollutants into the environment.

4.1. AIR QUALITY STANDARDS

Since the industrial revolution from the beginning of 1780 (graph 2), the quality of the air has been affected by human activities, due to the need for energy production for the vary emerging industries, the fossil fuels and biomass were consumed, this plus the increase of traffic on road contributed to the degradation of the air quality, which leads problems in health and environment, starting from the smog, water pollution (mainly from chemical industry), acid rain and climate change. This is shown in graph 3.



Graph 3: Total and individual carbon emissions in a global level (Boden, et al., 2010)

The World Health Organization (WHO) estimates that nine out then people breath polluted air every day which effects kill around 7 million people from diseases such cancer, stroke, heart and lung diseases every year (World Health Organization, 2019). In Europe this figure is not negligible reaching around 390.000 deaths every year (European Comission, 2019).

4.2. STANDARDIZATION FOR THE EMISSION CONTROL

Since 1970 the European Union has been controlling the emissions of pollutants into the environment, improving fuel quality and enforcing environmental protection requirements into transport and energy sectors, understanding that the local emissions released in one country may be transported in the atmosphere resulting in poor air quality elsewhere.

Even though some air pollutants emissions have decreased over the past decades, the levels are still too high, and several countries are still dealing with the reduction of these levels.

In terms of transportation, this sector is responsible for a large emission of greenhouse gases, due to it consumes one third of the total energy in the European Union, It is also important to mention that while most of all economic sectors have reduced the emissions of pollutants into the atmosphere, transportation has risen them (European Environment Agency, 2008). This plus the Paris Agreement of 2016 which set to cut greenhouse gas emissions by at least 40% by 2030, has contributed to generate different goals for the transportation sector:

- Shifting transportation to the least pollution and most efficient modes
- Developing more sustainable transport technology, fuel and infrastructure
- Ensuring transport prices in order to fully reflect adverse environment and health impacts.

By the EEA, the European Commission collects data of vehicles registered in Europe (so far for new cars and vans), it also collects national inventory data for greenhouse gases and air pollutants. Another of the main institution of the EEA is the Transport and Environment Reporting Mechanism (TERM), which measure the progress toward transportation policies by using a set of indicators like population exposure, transportation fuel prices and taxes, etc.

The first European emission standards were introduced in 1988 for heavy-duty vehicles, submitting laws for the member states relating to the measures to be taken against the emissions of pollutants from diesel engines in vehicles (European Communities, 1987), the target of these regulations was the reduction of CO_2. The first standard is called EURO 0. Later from 1992 to 2015 a series of EURO standards were applied under different directives and regulations. It is important to note that those standards vary in its nomenclature, denoting light-duty vehicles (those which mass is lower than 2.610 kg) with Arabic numerals and heavy-duty vehicles (those which mass is bigger than 2.610 kg) are denoted by Roman numerals.

The current last standards belong to EURO 6, for light-duty vehicles, were implemented in 2015, introducing a series of new limitations for emissions, vehicles adopting these standards are the cleanest car in the history.

The tables 11 and 12 show a summary of the year of application and regulation and directive associated to each standard.

Standards	Implementation date for all vehicle sales and registrations	Regulations / Directive (D.)
Euro 0	1970	70/220/EEC (updated multiple times)
Euro 1	1992	91/441/EEC (passenger cars only)
Euro 2	1997	94/12/EC*96/44EC96/69/EC*
Euro 3	2001	D. 98/69/EC*98/77/EC
		1999/102/EC
		2001/1/EC
		2001/100/EC
		2000/80/EC D. 2002/80/EC
Euro 4	2006	2003/76/EC2006/96/EC
Euro 5	2011 / 2013	715/2007
		692/2008
Euro 6	2015	70/220/EEC
		ECE R 83/01-06

Table 11: Timeline and regulations of Euro standards for light-duty vehicles (source: own elaboration)

Standards	Implementation date for all vehicle sales and registrations	Regulations / Directive (D.)
Euro I	1992	91/441/EEC (passenger cars only)
Euro II	1996	94/12/EC*96/44EC96/69/EC*
Euro III	2000	1999/96/EC
		2001/27/EC
Euro IV	2005	2005/55/EC
		2005/78/EC
Euro V	2009	715/2007/EC
Euro VI	2014	595/2009

Table 12: Timeline and regulations of Euro standards for heavy-duty vehicles (source: own elaboration)

Analysing the regulations and directives of each euro standard it is possible to summarize the intrinsic characteristic as follows:

- Euro I/1, obligate all cars to have a catalytic convert and run on unleaded petrol cutting carbon monoxide emissions.
- Euro II/2, cuts the limits of carbon monoxide, unburned hydrocarbons and oxides of nitrogen with different emissions limits for patrol and diesel
- Euro III/3, reduction of limits in carbon monoxide and diesel particulates, separating HC and NOx limits for petrol engines
- EURO IV/4, focus on cleaning up emissions from diesel cars, especially PM and nitrogen oxides
- EURO V/5, particulate emissions for diesel cut, application of filters, reduction of NOx limits
- EURO VI/6, significant reduction in limits of NOx emissions from diesel engines. Petrol and diesel cars must comply under the same rules.

European Union emission limits for each standard are summarized in the following table 13 where:

- For Euro 1/2 Class I ≤ 1250 kg, Class II 1250-1700 kg, Class III > 1700 kg
- a. until 1999.09.30 (after that date DI engines must meet the IDI limits)
- b. 2011.01 for all models
- c. 2012.01 for all models
- d. 2013.01 for all models
- e. applicable only to vehicles using DI engines
- f. 0.0045 g/km using the PMP measurement procedure
- g. and NMHC = 0.068 g/km
- h. and NMHC = 0.090 g/km
- i. and NMHC = 0.108 g/km
- j. 6.0×10^{12} 1/km within first three years from Euro 6 effective dates

EU Emission Standards for Light Commercial Vehicles (N_1, N_2) and for Passenger Cars (M1, M2)								
Category†	Stage	Date	CO	HC	HC+NOx	NOx	PM	PN
			g/km					#/km
Compression Ignition (Diesel)								
M1, M2	Euro 1†	1992.07	2.72 (3.16)	–	0.97 (1.13)	–	0.14 (0.18)	–
	Euro 2, IDI	1996.01	1.0	–	0.7	–	0.08	–
	Euro 2, DI	1996.01[a]	1.0	–	0.9	–	0.10	–
	Euro 3	2000.01	0.64	–	0.56	0.50	0.05	–
	Euro 4	2005.01	0.50	–	0.30	0.25	0.025	–
	Euro 5a	2009.09[b]	0.50	–	0.23	0.18	0.005[f]	–
	Euro 5b	2011.09[c]	0.50	–	0.23	0.18	0.005[f]	6.0×10^{11}
	Euro 6	2014.09	0.50	–	0.17	0.08	0.005[f]	6.0×10^{11}
Positive Ignition (Gasoline)								
M1, M2	Euro 1†	1992.07	2.72 (3.16)	–	0.97 (1.13)	–	–	–
	Euro 2	1996.01	2.2	–	0.5	–	–	–
	Euro 3	2000.01	2.30	0.20	–	0.15	–	–
	Euro 4	2005.01	1.0	0.10	–	0.08	–	–
	Euro 5	2009.09[b]	1.0	0.10[d]	–	0.06	0.005[e,f]	–
	Euro 6	2014.09	1.0	0.10[d]	–	0.06	0.005[e,f]	6.0×10^{11} [e,g]
Compression Ignition (Diesel)								
N_1, Class I	Euro 1	1994.10	2.72	–	0.97	–	0.14	–
	Euro 2 IDI	1998.01	1.0	–	0.70	–	0.08	–
	Euro 2 DI	1998.01[a]	1.0	–	0.90	–	0.10	–
	Euro 3	2000.01	0.64	–	0.56	0.50	0.05	–
	Euro 4	2005.01	0.50	–	0.30	0.25	0.025	–
	Euro 5a	2009.09[b]	0.50	–	0.23	0.18	0.005[f]	–
	Euro 5b	2011.09[d]	0.50	–	0.23	0.18	0.005[f]	6.0×10^{11}
	Euro 6	2014.09	0.50	–	0.17	0.08	0.005[f]	6.0×10^{11}
N_1, Class II	Euro 1	1994.10	5.17	–	1.40	–	0.19	–
	Euro 2 IDI	1998.01	1.25	–	1.0	–	0.12	–
	Euro 2 DI	1998.01[a]	1.25	–	1.30	–	0.14	–
	Euro 3	2001.01	0.80	–	0.72	0.65	0.07	–
	Euro 4	2006.01	0.63	–	0.39	0.33	0.04	–
	Euro 5a	2010.09[c]	0.63	–	0.295	0.235	0.005[f]	–
	Euro 5b	2011.09[d]	0.63	–	0.295	0.235	0.005[f]	6.0×10^{11}
	Euro 6	2015.09	0.63	–	0.195	0.105	0.005[f]	6.0×10^{11}
N_1, Class III	Euro 1	1994.10	6.90	–	1.70	–	0.25	–
	Euro 2 IDI	1998.01	1.5	–	1.20	–	0.17	–
	Euro 2 DI	1998.01[a]	1.5	–	1.60	–	0.20	–
	Euro 3	2001.01	0.95	–	0.86	0.78	0.10	–
	Euro 4	2006.01	0.74	–	0.46	0.39	0.06	–
	Euro 5a	2010.09[c]	0.74	–	0.350	0.280	0.005[f]	–
	Euro 5b	2011.09[d]	0.74	–	0.350	0.280	0.005[f]	6.0×10^{11}
	Euro 6	2015.09	0.74	–	0.215	0.125	0.005[f]	6.0×10^{11}
N_2	Euro 5a	2010.09[c]	0.74	–	0.350	0.280	0.005[f]	–
	Euro 5b	2011.09[d]	0.74	–	0.350	0.280	0.005[f]	6.0×10^{11}
	Euro 6	2015.09	0.74	–	0.215	0.125	0.005[f]	6.0×10^{11}
Positive Ignition (Gasoline)								
N_1, Class I	Euro 1	1994.10	2.72	–	0.97	–	–	–
	Euro 2	1998.01	2.2	–	0.50	–	–	–
	Euro 3	2000.01	2.3	0.20	–	0.15	–	–
	Euro 4	2005.01	1.0	0.1	–	0.08	–	–
	Euro 5	2009.09[b]	1.0	0.10[g]	–	0.06	0.005[e,f]	–
	Euro 6	2014.09	1.0	0.10[g]	–	0.06	0.005[e,f]	6.0×10^{11} [e,j]
N_1, Class II	Euro 1	1994.10	5.17	–	1.40	–	–	–
	Euro 2	1998.01	4.0	–	0.65	–	–	–
	Euro 3	2001.01	4.17	0.25	–	0.18	–	–
	Euro 4	2006.01	1.81	0.13	–	0.10	–	–
	Euro 5	2010.09[c]	1.81	0.13[h]	–	0.075	0.005[e,f]	–
	Euro 6	2015.09	1.81	0.13[h]	–	0.075	0.005[e,f]	6.0×10^{11} [e,j]
N_1, Class III	Euro 1	1994.10	6.90	–	1.70	–	–	–
	Euro 2	1998.01	5.0	–	0.80	–	–	–
	Euro 3	2001.01	5.22	0.29	–	0.21	–	–
	Euro 4	2006.01	2.27	0.16	–	0.11	–	–
	Euro 5	2010.09[c]	2.27	0.16[i]	–	0.082	0.005[e,f]	–
	Euro 6	2015.09	2.27	0.16[i]	–	0.082	0.005[e,f]	6.0×10^{11} [e,j]
N_2	Euro 5	2010.09[c]	2.27	0.16[i]	–	0.082	0.005[e,f]	–
	Euro 6	2015.09	2.27	0.16[i]	–	0.082	0.005[e,f]	6.0×10^{11} [e,j]

Table 13: EU Emission Standards for Light Commercial Vehicles (N1, N2) and for Passenger Cars (M1, M2) (European Environment Agency, 2016)

Beside the emission limits, the durability has been controlled, that is to say, since 2005 for new type approvals and since 2006 for all engine sales and registrations, manufacturers should demonstrate that engines comply with the emission limit values for useful life periods which depend on the vehicle category, as shown in the table 14:

Vehicle Category	Period (km or year period, whichever is the sooner)	
	Euro IV-V	Euro VI
N1 and M2	100.000 km / 5 years	160.000 / 5 years
N2 N3 ≤ 16 ton M3 class I, class 2, class A and class B ≤ 75 ton	200.000 km / 6 years	300.000 km / 6 years
N3 ≥16 ton M3 class III, class B ≥75 ton	500.000 km / 7 years	700.000 km / years

Table 14: Emission Durability Periods (European Communities, 2009)

5. DEVELOPING AN ANALYTICAL MODEL

After the review of the current literature, it is possible to establish certain conditions to develop a model to calculate emissions:

i. Knowing that COPERT is a calculator of emission recognized by the EEA (European Environment Agency, 2016), it is important to validate IVE Model under some parameters for Euro standard IV and Euro standard V.
ii. The assessing of the environmental policies makes possible to establish certain levels of tolerance in the level of emissions, this information can be added in the model as a way of alarm.

5.1. VALIDATION OF THE DATASET

IVE Model as any other model can be modify according to several adjustment factors and parameters. The validation tasks consist in comparing the results of the microscopic model and the global results of the macroscopic model, adjusting parameters in a way that the global results of both models can be within a common threshold. This will allow to prove that, under certain conditions and adjustments, both models can get a similar result.

Four pollutant results are tested in this chapter: CO_2, NO_x, CO and NH_3, that corresponds to 4 out 6 of the elements described in the objectives of this research, either PM_{10} and SO_x are not presented in COPERT's outputs then its validation is not possible, however the outcome of these pollutants will be entirely measured by IVE Model.

In this step, it is important to recall one of the disadvantages of IVE Model, mentioned in chapter 1.5 and 1.6 of this thesis, and it is its lack of Euro standard VI within the options. Having this in consideration, the validation, analyses of scenarios and trends, described above, is done only for scenarios of Euro IV and Euro V.

5.1.1. INPUT VALIDATION DATA

For these validation, two type of buses are set. These buses are within the set of vehicles provided either by COPERT as for IVE Model, so the ambiguities can be discarded. Table 15 shows a summary of the information for both models.

Category	Fuel	Segment	Euro Standard
Buses	Diesel	Urban Buses Standard 15 – 18t	Euro IV and EURO V
Input parameter	Value	Unit	
Mean Activity[2]	60.000	km	
Life Cumulative Activity[23]	300.000	km	
Share	Value	Unit	
Urban Peak	15	%	
Urban Off Peak	85	%	
Speed	Value	Unit	
Urban Peak	15	km/h	
Urban Off Peak	25	km/h	

Table 15: Validation Data, COPERT Trip characteristics and vehicle composition input (own elaboration)
[1]Measured as annual daily average, [2]Measured as annual average, [3]Understanding Life Cumulative Activity has no effect over the results, still being necessary to run the software

Beside the trip characteristics and fleet composition and as it was described in the previous chapter, COPERT allows to access and modify if it is necessary the parameters related to the fuel, this will be important in the moment of calibrating the results of the microscopic model in a way to validate the results. The election of this fuel is valid for both Euro Standard vehicles and has validation for both models. The detail of the components is giving in the table 16.

Input parameter	Value	Unit
Primary Fuel	DIESEL	
Energy Content	42,6950	MJ/Kg
H:C Ratio	1,8600	Dimensionless
O:C Ratio	0	Dimensionless
Density	840	Kg/m^3
S Content	0	ppm wt
Pb Content	0,0005	ppm wt
Cd Content	0,0001	ppm wt
Cu Content	0,0057	ppm wt
Cr Content	0,0085	ppm wt
Ni Content	0,0002	ppm wt
Se Content	0,0001	ppm wt
Zn Content	0,0180	ppm wt
Hg Content	0,0053	ppm wt
As Content	0,0001	ppm wt

Table 16: Validation Data. COPERT Fuel input (own elaboration)

With all these inputs is possible to run the software getting the following results (table 17 and table 18).

Output parameter	Value	Unit
CO_2	59,094	t/year
NO_x	0,3777	t/year
CO	0,0776	t/year
NH_3	0,0002	t/year

Table 17: Validation Data. COPERT Results for EURO IV (own elaboration)

Output parameter	Value	Unit
CO_2	53,3945	t/year
NO_x	0,4224	t/year
CO	0,1348	t/year
NH_3	0,00066	t/year

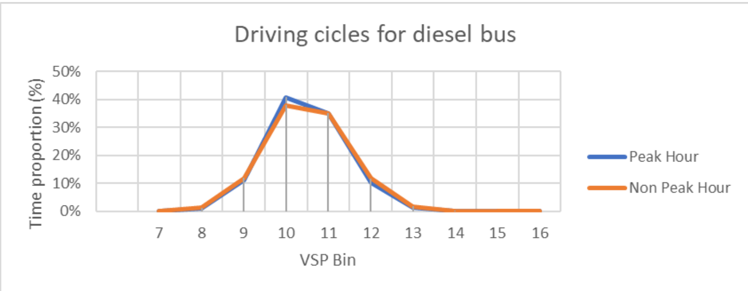
Table 18:Validation Data. COPERT Results for EURO V (own elaboration)

Now having those parameters, IVE Model can be run and adjusted to get parameters under the 3 thresholds given by the 3 ranges of mileage available in the software. Those are under 79.000 km, between 80.000 and 160.000 and over 161.000 km. Beside this, the vehicle has a route adjusted by hour and the average speed per hour. These two values (in table 19) have been set according to an average, taken by the data given by the study case, describe in the next chapter. It is important to mention that the amount of engine ignition have been set in 2 each hour, also according to the study case.

Hour	Speed [km/h]
08:00	15
09:00	25
10:00	25
11:00	25
12:00	15
13:00	25
14:00	25
15:00	25
16:00	25
17:00	25
18:00	15

Table 19: Validation Data, IVE Model time and an average speed (own elaboration)

Beyond the data related to speed and start-ups, IVE Model requires information about the engine operation in a way to set up the VSP and bin, as it is explained in chapter 1,5. For this task a group of studies were analyzed (Liao, et al., 2018), (Onchang, et al., 2017), (Lai, et al., 2013), finding a defined group of bin percentage where the bus operates. Two cases are described, peak hour (08:00, 12:00 and 18:00) and non-peak hour, which can be seen in the graph 4 and table 20.



Graph 4: Validation Data, IVE driving cycles for diesel bus (own elaboration)

Bin	Peak Hour	Non Peak Hour
7	0,0%	0,0%
8	1,0%	1,2%
9	11,1%	11,9%
10	40,8%	38,0%
11	34,9%	35,0%
12	10,3%	11,7%
13	1,3%	1,7%
14	0,0%	0,1%
15	0,0%	0,0%
16	0,0%	0,0%

Table 20:Validation Data, IVE driving cycles for diesel bus (own elaboration)

Once all those previous parameters are set, It is possible to run simulation of the 3 categories of mileage. Getting as first results, daily outcomes as table 21 shows.

EURO IV				
Daily consume				
Output parameter	<79 K km	80-160 K km	>161 K km	Units
	Value	Value	Value	
CO_2	0,066213	0,16422	0,1631	t/day
NO_x	0,001086997	0,001101977	0,001124449	mm/day
CO	3,89783E-05	4,0895E-05	4,37701E-05	mm/day
NH_3	3,83446E-06	3,83495E-06	3,83325E-06	mm/day
EURO V				
Daily consume				
Output parameter	<79 K km	80-160 K km	>161 K km	Units
	Value	Value	Value	
CO_2	0,06601	0,16422	0,1631	t/day
NO_x	0,000619588	0,000628127	0,000640936	mm/day
CO	3,8978E-05	4,0895E-05	4,37701E-05	mm/day
NH_3	3,83446E-06	3,83495E-06	3,83325E-06	mm/day

Table 21: Validation Data. IVE Model daily results (own elaboration)

These results must be taken into annual consume. Considering 330 uniform operative days, these results can be simply multiplying them, and also, a unique measure, for this, tons were chosen. The results are provided in the table 22:

EURO IV				
Yearly consume				
Output parameter	<79 K km	80-160 K km	>161 K km	Units
	Value	Value	Value	
CO_2	21,85029	54,1926	53,823	t/year
NO_x	0,358708875	0,363652572	0,371068121	t/year
CO	0,012862839	0,01349536	0,01444414	t/year
NH_3	0,001265372	0,001265534	0,001264973	t/year

EURO V				
Yearly consume				
Output parameter	<79 K km	80-160 K km	>161 K km	Units
	Value	Value	Value	
CO_2	21,8505	54,1926	53,823	t/year
NO_x	0,20446406	0,207281966	0,211508827	t/year
CO	0,012862839	0,01349536	0,01444414	t/year
NH_3	0,001265372	0,001265534	0,001264973	t/year

Table 22: Validation Data. IVE Model yearly results (own elaboration)

Finally, the table 23 makes a comparison between both results, either COPERT and IVE Model.

EURO IV				EURO V			
Yearly consume				Yearly consume			
Output parameter	<79 K km Value	COPERT	Differences %	Output parameter	<79 K km Value	COPERT	Differences %
CO_2 [t/year]	21,85029	59,094	170%	CO_2 [t/year]	21,8505	53,3945	144%
Nox [t/year]	0,358708875	0,3777	5%	Nox [t/year]	0,20446406	0,4224	107%
CO [t/year]	0,012862839	0,0776	503%	CO [t/year]	0,01286284	0,1348	948%
NH_3 [t/year]	0,001265372	0,0002	-84%	NH_3 [t/year]	0,00126537	0,00066	-48%
Output parameter	80-160 K km Value	COPERT	Differences	Output parameter	80-160 K km Value	COPERT	Differences
CO_2 [t/year]	54,1926	59,094	9%	CO_2 [t/year]	54,1926	53,3945	-1%
Nox [t/year]	0,363652572	0,3777	4%	Nox [t/year]	0,20728197	0,4224	104%
CO [t/year]	0,01349536	0,0776	475%	CO [t/year]	0,01349536	0,1348	899%
NH_3 [t/year]	0,001265534	0,0002	-84%	NH_3 [t/year]	0,00126553	0,00066	-48%
Output parameter	>161 K km Value	COPERT	Differences	Output parameter	>161 K km Value	COPERT	Differences
CO_2 [t/year]	53,823	59,094	10%	CO_2 [t/year]	53,823	53,3945	-1%
Nox [t/year]	0,371068121	0,3777	2%	Nox [t/year]	0,21150883	0,4224	100%
CO [t/year]	0,01444414	0,0776	437%	CO [t/year]	0,01444414	0,1348	833%
NH_3 [t/year]	0,001264973	0,0002	-84%	NH_3 [t/year]	0,00126497	0,00066	-48%

Table 23: Validation Data. Comparison IVE Model yearly results (own elaboration)

The previous table shows the different results getting them by COPERT and IVE Model for a set of four major pollutants for two Euro standards. It is important to highlight that due to the sample got, the differences between Euro standards is not as widely as it was expected, but this test has no interest in this but to clarify and validate the results of the micro simulator and COPERT.

Among the results, it is possible to infer two main things:

- In terms of CO_2, COPERT and IVE Model have a common measure of this element when the vehicle mileage is over 80.000 km.
- In terms of NO_x, both models show similar results for Euro IV standards.
- The measure of CO is widely different in both models, having differences even close to a 1000%.

According to this analysis and following the main premise (i), IVE Model will be used to calculate CO_2 distinguishing the 3 mileages proposed, due to the lack of this ability by COPERT. However, especial treatment will have the rest of the pollutants measured, in the case of NO_x for Euro IV standards these values are perfectly consistent to the measured by COPERT. Nonetheless for the case of EURO V a factor must be introduced in a way to have similar data, the same proceed must be done in the case of CO and NH_3.

A table that summarize the factor applied for the different pollutants, can be seen, as following in table 24:

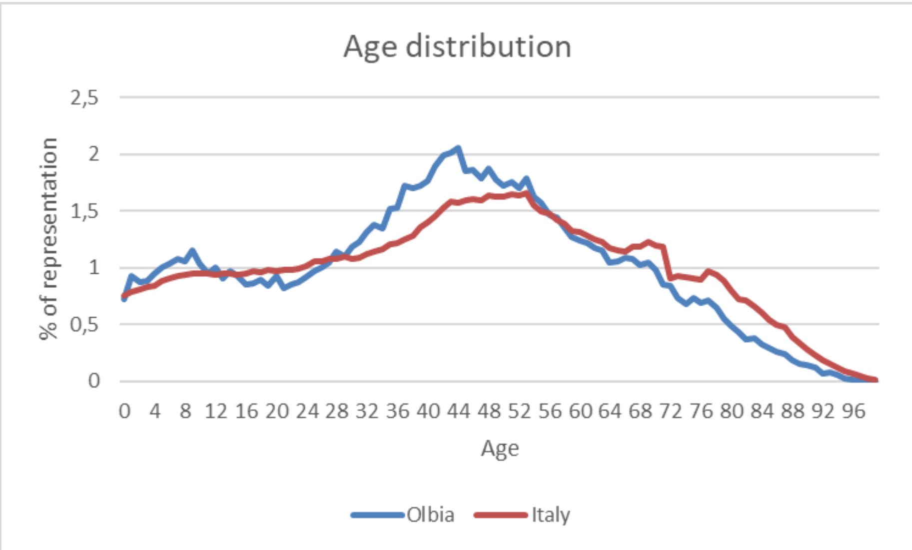
Pollutant	Factor	
	EURO IV	EURO V
NO_x	NO FACTOR NEEDED	2
CO	5	
NH_3	0,15	0,55

Table 24: Pollutant factors list applied for IVE Model (own elaboration)

5.2. CASE OF STUDY

Once the microscopic values are adjusted under the process of validation, it is possible to assess the measure of pollutants under the 3 thresholds proposed by the software, for this a set of study provides the fleet of buses to be used in the application of the model.

The case of study is based in Olbia, a coastal city in the province of Sassari, northeast Sardinia, Italy. Olbia has a population of 60.261 inhabitants, which over 65% is over 35 years old, a very representative demographic vision of Italy as graph 5 shown (Istituto nazionale di statistica ISTAT, 2018):



Graph 5: Total Population in Italy 2018, (Istituto nazionale di statistica ISTAT, 2018)

This city also faces weather conditions that maybe considered normal in the southern Italy, with average temperatures that vary between 9°C and 23°C, getting maximum close to 30° (Figure 15).

	January	February	March	April	May	June	July	August	September	October	November	December
Average temperature (°C)	9.5	10	11.5	13.6	17	20.8	23.7	23.6	21.5	17.6	13.9	11
Minimum temperature (°C)	6	6.4	7.9	9.9	13	16.6	19.1	19.2	17.4	13.9	10.5	7.7
Maximum temperature (°C)	13.1	13.6	15.1	17.3	21	25	28.3	28.1	25.6	21.3	17.3	14.4
Rainfall (mm)	56	62	55	43	30	18	5	14	35	71	72	78

Figure 14: Olbia weather conditions (based on information by Meteo Aeronautica Militare)

The company ASPO Spa provides public transport services in the city, having a network composed by 12 lines, where 31 vehicles operate, the fleet is composed by vehicle of 8 meters, 10 meters and 12 meters-long for regular services and a special 7-meter-long for school services, these vehicles can be seen in figure 16.

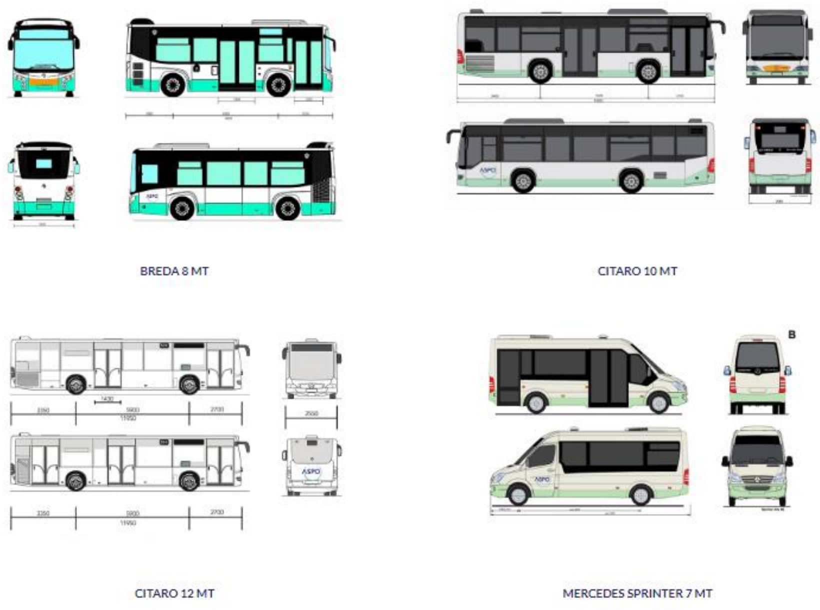


Figure 15: Olbia bus fleet (ASPO Olbia, 2019)

Regarded to Olbia SPA, the company Pluservice has compilated information related to transport parameters of a sample of the total fleet, useful to run the emission model, these parameters are the following:

- Quantity of times of ignitions of the engine during a day
- Average daily time in the deposit
- Average length of a single trip
- Average slope in the trip
- Average speed in peak hour and non-peak hour
- Time in peak hour and non-peak hour
- Time of AC turned on
- Distance and average time from the end of the rout to deposit

In total, 13 vehicles are evaluated with all the parameters previously described, all these vehicles belong to the same brand and model, Mercedes 0153K diesel, Euro IV. The information is summarized in table 25.

ID	Maximum height (meters)	Working time (hh:mm)	Ignitions of the engine during a day	Average speed in peak hour (km/h)	Average speed in non-peak hour (km/h)	Time working in peak hour (hh:mm)	Time working in non-peak hour (hh:mm)	Time AC is turned on (%)	Distance to deposit (km)	Time to deposit (hh:mm)	Operative Line
1051	10	17:20	38	25	30	3:15	9:25	100	3	0:10	9
1052	65	12:10	12	31	38	3:23	6:31	100	2,5	0:07	5
1053	50	11:15	15	20	26	2:31	6:04	100	2,5	0:07	1
1054	50	13:35	19	20	26	3:13	6:40	100	2,5	0:07	1
1056	50	13:20	19	20	26	3:07	7:30	100	2,5	0:07	1
1057	55	12:45	25	20	26	3:15	6:38	100	2,5	0:07	2
1059	55	12:18	26	20	24	3:09	7:11	100	2,5	0:07	2
1060	100	12:20	10	32	39	2:59	7:44	100	7	0:15	3
1061	25	13:05	19	19	28	2:55	7:59	100	7	0:15	11
1062	50	13:40	19	20	26	3:08	7:11	100	2,5	0:07	1
1063	50	2:15	4	20	26	5:10	1:03	100	2,5	0:07	1
1064	65	12:25	13	31	38	3:31	7:36	100	2,5	0:07	5

Table 25: Case of study. Olbia Bus fleet (based on Pluservice company own elaboration)

As it was described in chapter 5.2. IVE Model uses the vehicle specific power (VSP) and the engine stress as input of the software. To get the value of these parameters, IVE Model includes a tool called "Speed/Emission Evaluation" (SEE) or just Emission Evaluation, which allows to get the bin according to table 9, which allows to assign values to those parameters.

SEE requires a complete detail of the route assigned in one hour in terms of speed and altitude, a complete simulation second-by-second. This is just possible due to keyhole markup languages (KMZ) of the difference lines where the vehicles circulating, shown in figure 17.

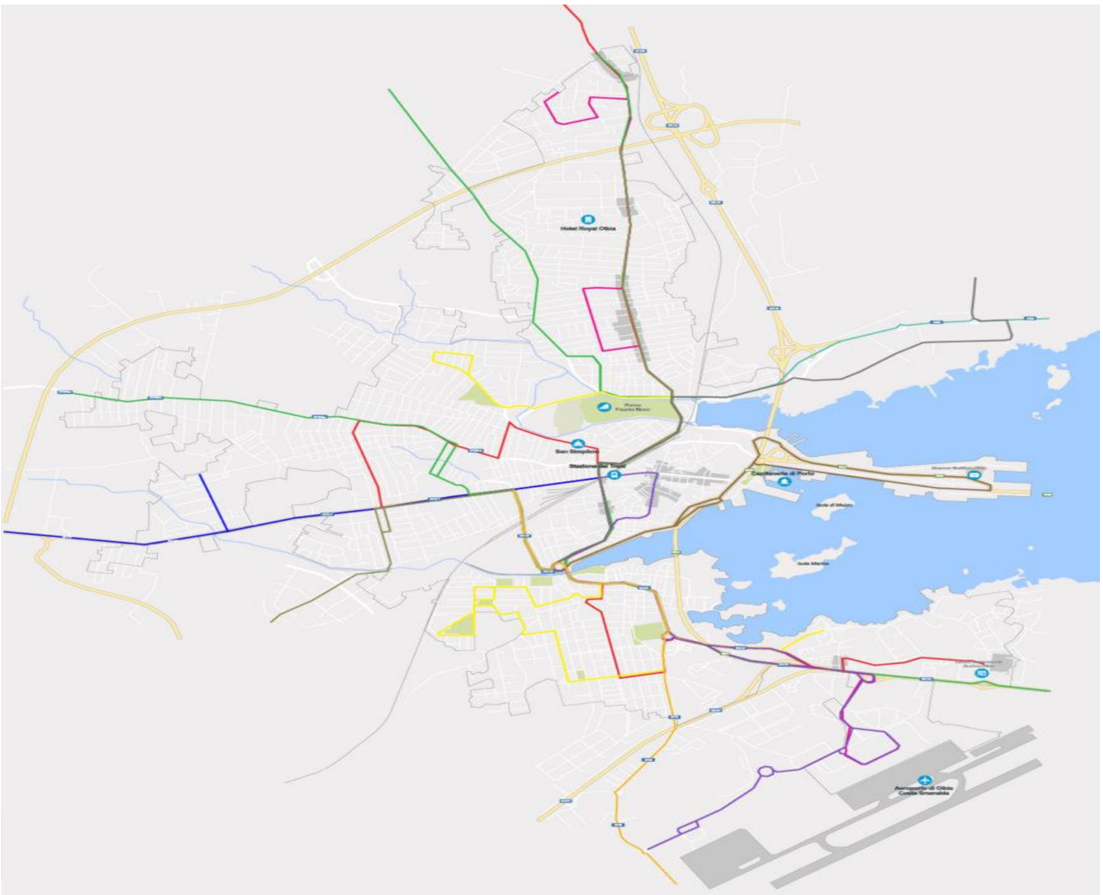


Figure 16: Map of all lines serving in Olbia (ASPO Olbia, 2019)

Using some other tools, like Waze (figure 18) or Google maps, it is possible to have an estimation of the speed in each section, getting an approximation of the speed second-by-second, considering intersections and bus stops.

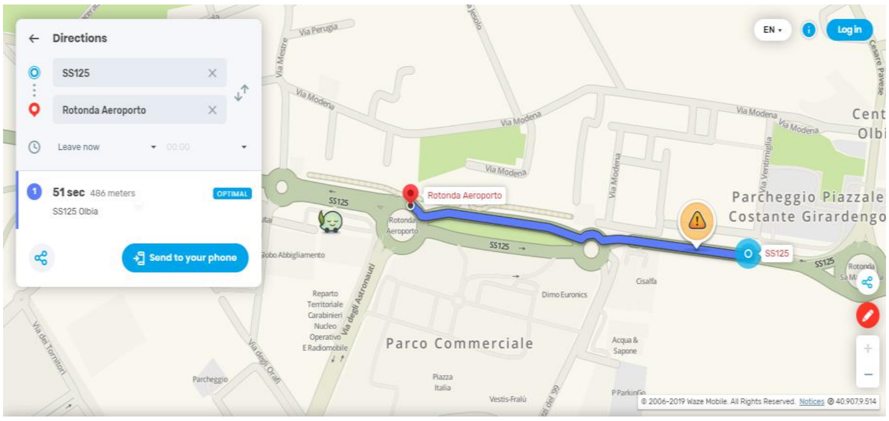
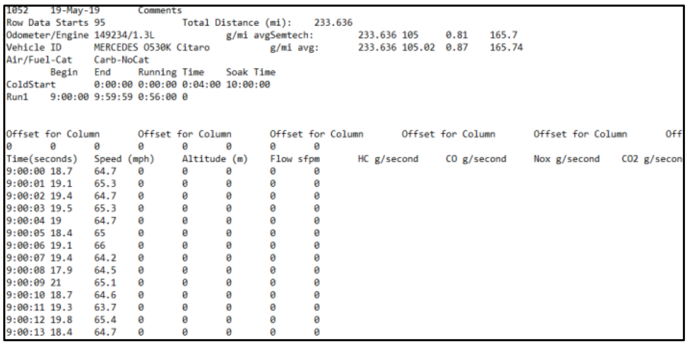


Figure 17: Use of Waze for calculating the speed by segment of each line (Waze online interface)

Assuming that the only big difference that can be seem in the operation along the whole day is between peak and non-peak hour, only two types of files are assessed, those files represent all the working operation hours of each vehicle. Different files are generated under this process, with the purpose to establish the bin that assign either the VSP as the engine stress. An example of the input giving by the second-by-second analysis and the output giving by the percentage of time using a determinate bin is shown in figure 19 and figure 20.



```
1052    19-May-19       Comments
Row Data Starts 95              Total Distance (mi):    233.636
Odometer/Engine 149234/1.3L             g/mi avgSemtech:        233.636 105     0.81    165.7
Vehicle ID      MERCEDES O530K Citaro           g/mi avg:       233.636 105.02  0.87    165.74
Air/Fuel-Cat    Carb-NoCat
        Begin   End     Running Time    Soak Time
ColdStart       0:00:00 0:00:00 0:04:00 10:00:00
Run1    9:00:00 9:59:59 0:56:00 0


Offset for Column       Offset for Column       Offset for Column       Offset for Column       Offset for Column       Off
0       0       0       0       0       0       0       0
Time(seconds)   Speed (mph)     Altitude (m)    Flow sfpm       HC g/second     CO g/second     Nox g/second    CO2 g/secon
9:00:00 18.7    64.7    0       0       0       0       0
9:00:01 19.1    65.3    0       0       0       0       0
9:00:02 19.4    64.7    0       0       0       0       0
9:00:03 19.5    65.3    0       0       0       0       0
9:00:04 19      64.7    0       0       0       0       0
9:00:05 18.4    65      0       0       0       0       0
9:00:06 19.1    66      0       0       0       0       0
9:00:07 19.4    64.2    0       0       0       0       0
9:00:08 17.9    64.5    0       0       0       0       0
9:00:09 21      65.1    0       0       0       0       0
9:00:10 18.7    64.6    0       0       0       0       0
9:00:11 19.3    63.7    0       0       0       0       0
9:00:12 19.8    65.4    0       0       0       0       0
9:00:13 18.4    64.7    0       0       0       0       0
```

Figure 18: Input data second-by-second SEE (own elaboration)

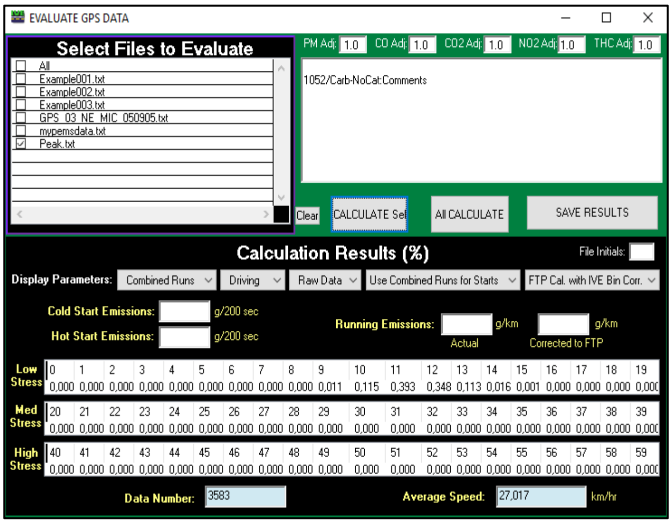


Figure 19: Speed/Emission Evaluation Output interface (SEE software)

Once the bins are set, it is possible to run the software with the purpose of getting results. For this, different parameters are tested in a way to create a big database with results under certain scenarios, those parameters are the slope and the temperature.

5.3. DEFINITION OF SCENARIOS

This thesis has its focus on formulate a model able to estimate pollutants of a fleet of vehicles under diverse circumstances, it is understood that a vehicle may face different trip characteristics along the year, that is to say, a variation of the average speed and different amounts of engine ignitions. In this sense, three modes of driving patters are set as table 26 shows.

Driving cycle	Average speed [km/h]	Average engine ignition [per hour]
Short urban cycle	12,5	2
Long urban cycle	25	1
Extra urban cycle	30	0,5

Table 26: Definition of Scenarios. Driving cycle (own elaboration)

Also, some other factors may affect the emissions, like the average maximum temperature and the slope of the road. In this case three different maximum temperature and four road slopes are set in table 27 and table 28.

Maximum temperature
20°C
25°C
30°C

Table 27: Definition of Scenarios. Maximum temperature (own elaboration)

Average road slope
0°
1°
2°
3°

Table 28: Definition of Scenarios. Average road slope (own elaboration)

In this sense, a matrix (table 29) can be build up according to the different scenarios.

Driving cycle	Average maximum temperature											
	20°C				25°C				30°C			
	Average road slope				Average road slope				Average road slope			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short urban cycle												
Long urban cycle												
Extra urban cycle												

Table 29:Definition of Scenarios. Final matrix (own elaboration)

A total of 468 matrices are built, one for each vehicle under the three mileage and by each euro standards (IV and V) analyzed and for each of the 6 pollutants estimated. However, before exhibit the results, it is important to analyze the behavior of each pollutants under the scenarios.

5.4. TREND ANALYSIS OF POLLUTANTS

The idea of this chapter is analyses the behavior of the different pollutants under the different scenarios proposed, how do they react in the case of the three mileages measured and under different temperature and road slopes. This will be helpful in a way to develop trends forecasted using Neural Network, understanding the emissions generated by different mileage-vehicles under different circumstances, for example, how pollutant a vehicle can be after operating a certain amount of years.

For this a sum of all the simulation for the 13 vehicles are used as a reference and all the data is expressed kg/day.

5.4.1. ANALYSIS OF CARBON DIOXIDE

The analysis of CO_2 is done totally based on IVE Model, due to the validation process done in the previous chapter. The interesting outcome from these results fell on the mileage. As it is possible to see in Table 30, either for Euro IV and Euro V, there is a low emission of this pollutants when the mileage is less than 79.000 km and then remains stable after 80.000 km.

EURO IV CO2												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	695,02935	702,71495	721,92253	741,48418	684,75237	702,54922	722,22146	741,12012	724,44313	741,33091	760,79907	779,8891
Long Urban (	468,55695	549,83728	578,41672	607,60384	508,56998	536,52567	565,2085	594,31904	505,46466	533,08894	564,13423	591,1031
Extra Urban (	1482,35067	1583,6142	1684,84737	1786,01984	1505,90083	1607,1698	1708,40802	1809,58532	1587,47736	1689,06483	1790,62129	1895,46046
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	1872,77458	1986,2474	1979,70413	2033,12886	1903,85181	1957,20977	2010,05986	2063,11389	2013,41936	2069,01246	2122,22113	2175,39773
Long Urban (	1442,88681	1503,91619	1584,92124	1665,87776	1395,72661	1474,76648	1553,78256	1632,75132	1397,25785	1580,58905	1554,63721	1629,23632
Extra Urban (	1479,60817	1580,68434	1681,73023	1782,71554	1503,11475	1604,19638	1705,24735	1806,2374	1584,54032	1685,93992	1787,30843	1888,62117
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	1860,0752	1913,18536	1966,27962	2008,78574	1890,94166	1943,46849	1996,42939	2049,12374	1938,60172	2054,9823	2107,83019	2160,64622
Long Urban (	1413,2381	1493,718	1574,17377	1654,58129	1487,58748	1567,29055	1646,94578	1654,58129	1387,78293	1469,95695	1544,09508	1618,18836
Extra Urban (	1469,5748	1569,96561	1670,32629	1770,62681	1492,92199	1593,31818	1693,68392	1793,98916	1573,7954	1674,50737	1775,18858	1875,81426

EURO V CO2												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	621,49	642,79	660,28	678,09	677,03	702,28	720,81	739,64	722,04	737,97	757,33	776,3
Long Urban (	481,47	509,61	536,41	563,07	488,16	514,54	541,63	569,11	512,29	540,2	568,3	593,94
Extra Urban (	553,49	591,38	629,25	667,17	551,69	589,75	626,54	663,49	580,6	618,42	654,59	693,45
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	1716,27	1765,25	1814,02	1862,75	1885,87	1959,85	2009,85	2062,81	2010,46	2063,45	2116,46	2169,4
Long Urban (	1321,41	1396,47	1471,58	1546,64	1348,86	1423,99	1499,13	1574,17	1418,75	1493,89	1569,02	1640,09
Extra Urban (	1479,61	1580,68	1681,71	1782,81	1508,13	1609,21	1710,27	1811,25	1584,57	1685,66	1786,7	1887,66
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	1770,32	1753,27	1805,7	1850,11	1873,03	1943,56	1996,21	2048,8	1998,48	2049,48	2102,09	2154,69
Long Urban (	1312,34	1386,98	1461,59	1536,22	1339,72	1414,32	1496	1563,51	1409,13	1483,76	1558,38	1632,96
Extra Urban (	1478,59	1569,96	1670,34	1770,62	1517,92	1598,29	1698,66	1798,97	1573,8	1664	1774,57	1874,84

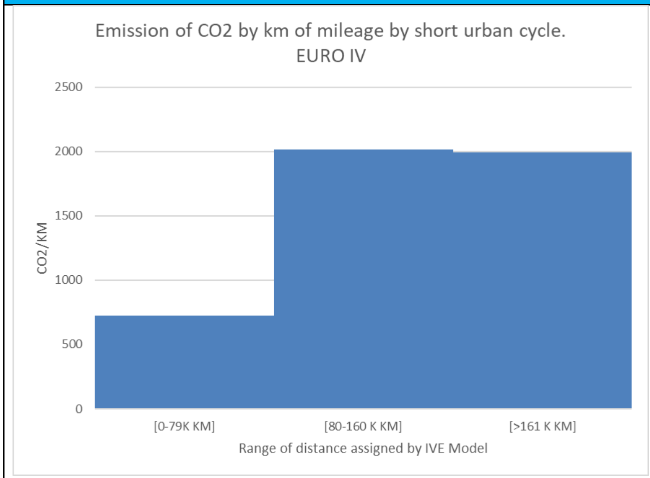
Table 30: Pollutants trends. Carbon Dioxide for Euro IV and Euro V (own elaboration)

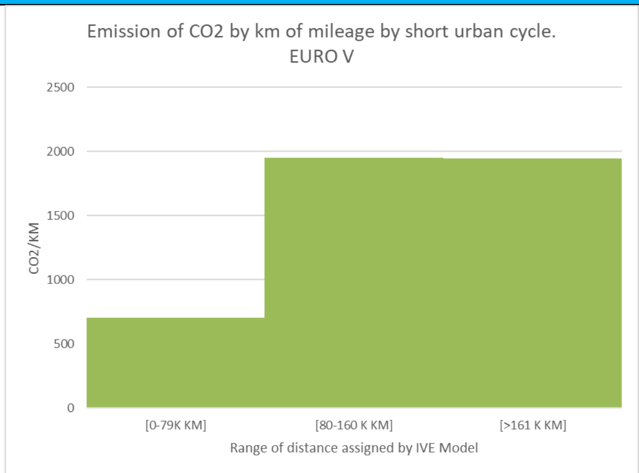
The observation done can be described better in the following graphs in table 31, where an average of the total values for each range of threshold mileage has been plotted.

EMISSION OF CO2 BY MILEAGE AND URBAN CYCLE

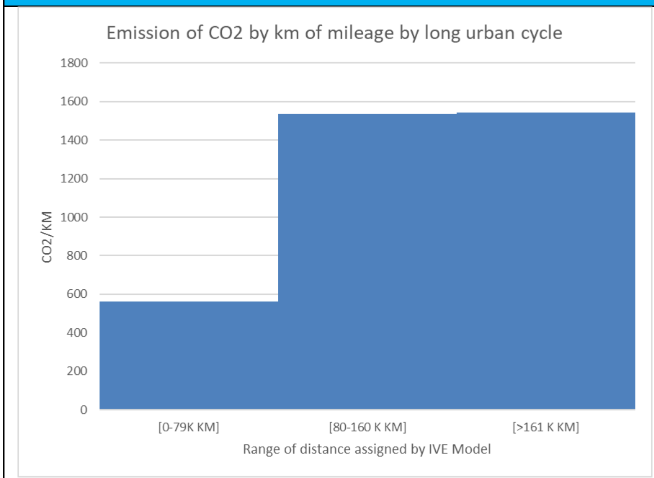
EURO IV | EURO V

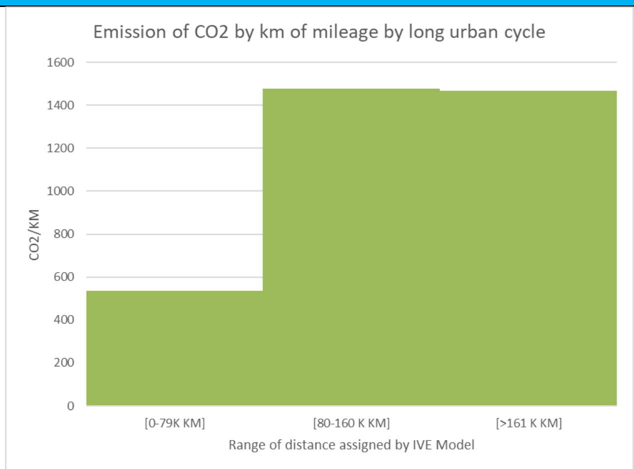
SHORT URBAN CYCLE



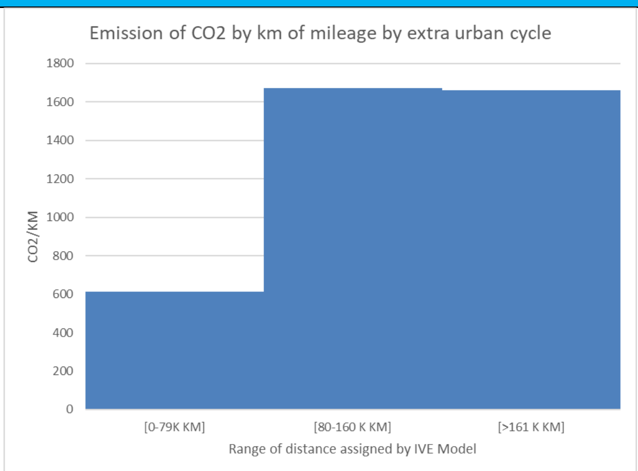


LONG URBAN CYCLE





EXTRA URBAN CYCLE



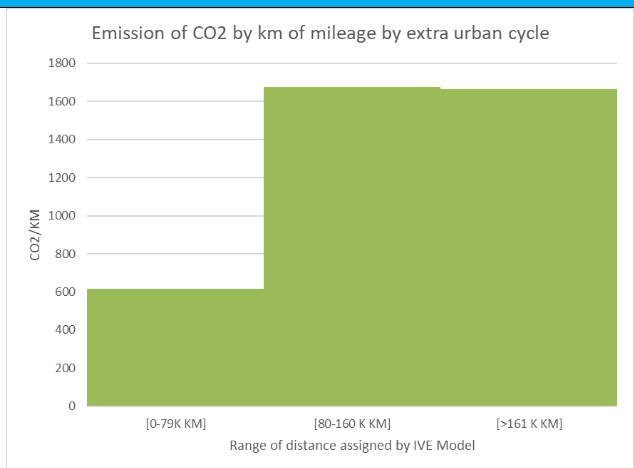


Table 31: Analysis of Carbon Dioxide by Urban cycle and Euro standard (own elaboration)

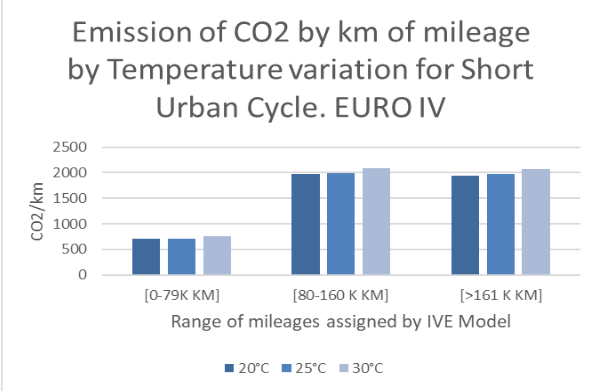
Based on the information provided by the graph, between 0 and 80.000 km, there a direct relation between the emission of CO_2. However, after the 160.000 km, the emissions remain the same for each km summed to the mileage.

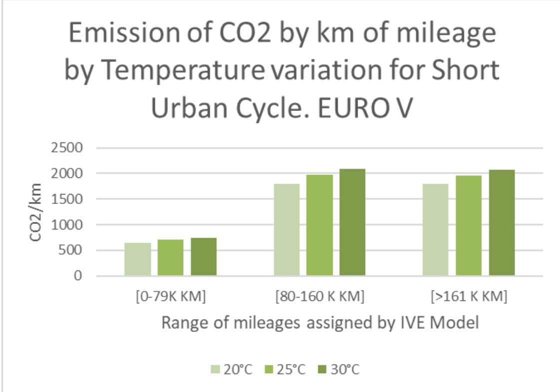
Beside the analysis regarded to the mileage and the urban cycles, a sensibility analysis is run, in order to establish certain relations between the temperature (table 32) and the slope (table 33).

EMISSION OF CO2 BY TEMPERATURE AND URBAN CYCLE

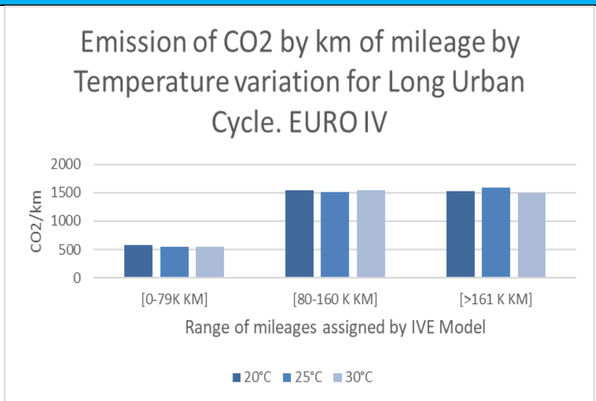
EURO IV | EURO V

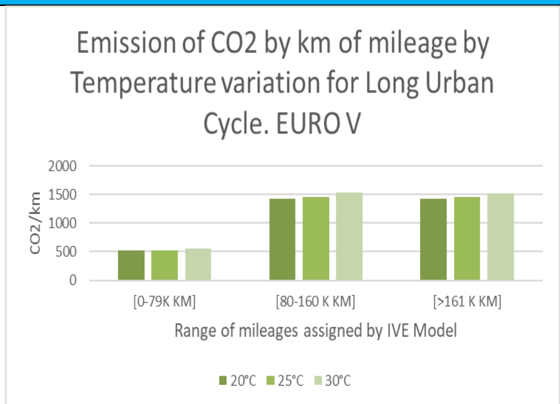
SHORT URBAN CYCLE



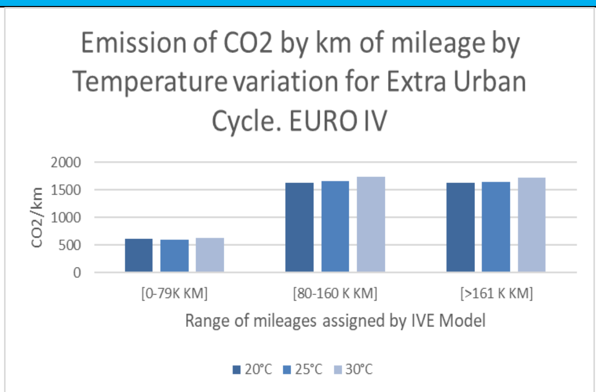


LONG URBAN CYCLE





EXTRA URBAN CYCLE



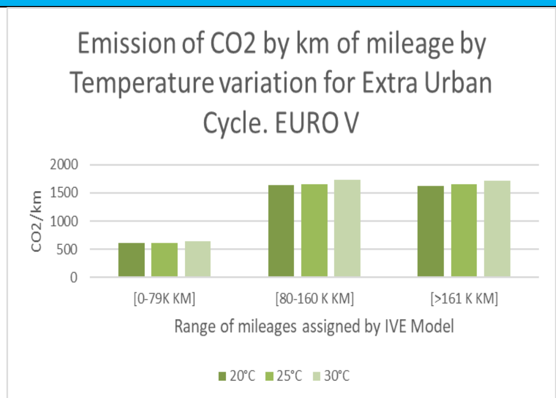


Table 32:Analysis of Carbon Dioxide. Sensibility Analysis of Temperature (own elaboration)

As it can be seen, the variation of temperature does not have an important impact over the emissions for each urban cycle, it can see a slightly increase of CO_2 by around 4% to 5% every 5 degrees.

In the case of the gradient of the road, this change is more pronounced. The greatest impact falls on the long urban cycle and extra urban cycle, where for each degree increased the emission of CO_2

increased in an order of 5% to 6%, not as the short urban cycle that the increase on CO_2 emitted to the atmosphere is no greater than 3%.

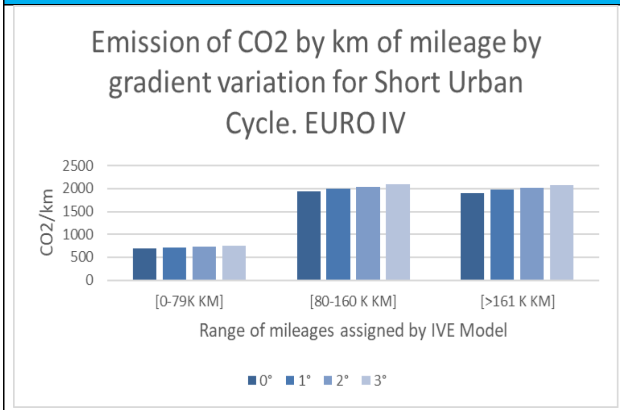
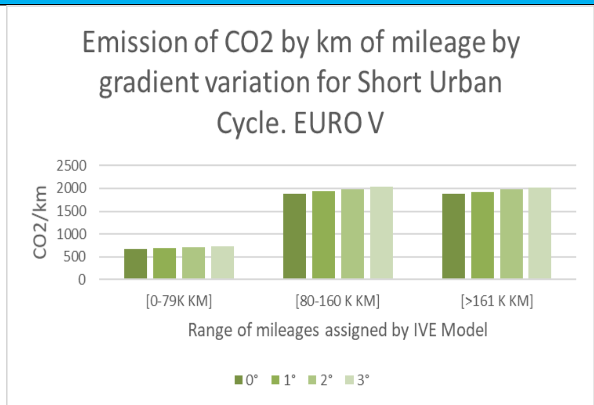
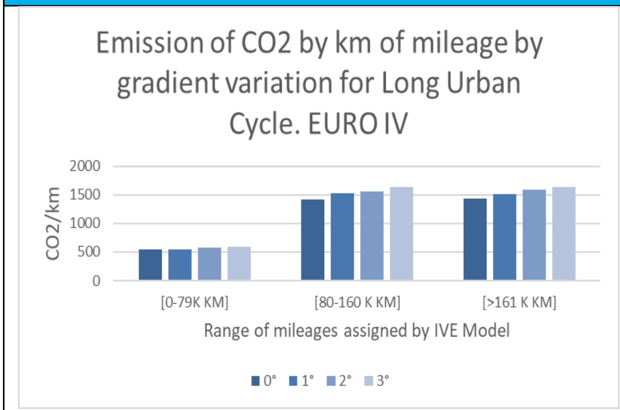
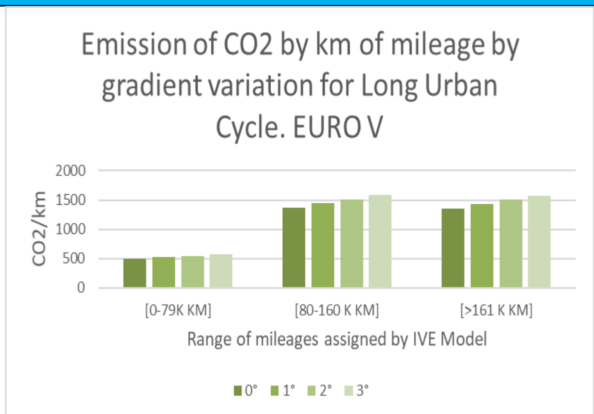
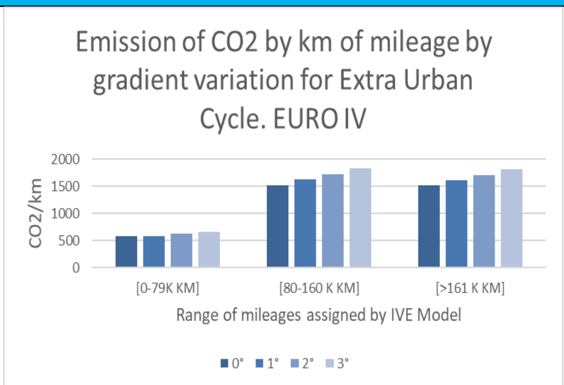
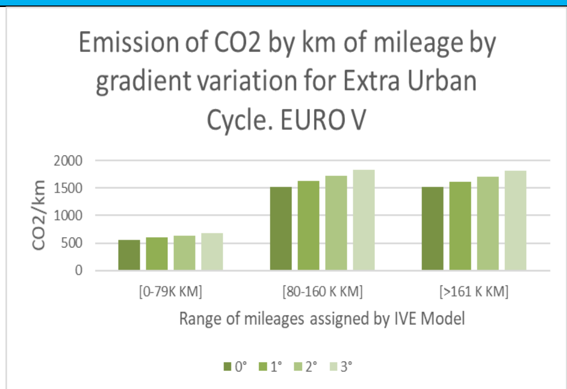
EMISSION OF CO2 BY SLOPE AND URBAN CYCLE	
EURO IV	EURO V
SHORT URBAN CYCLE	
	
LONG URBAN CYCLE	
	
EXTRA URBAN CYCLE	
	

Table 33: Analysis of Carbon Dioxide. Sensibility Analysis of Road Slope (own elaboration)

Observing the previous trends, It is possible to distinguish two different and notorious areas, first, what is happening from the first segment of mileage to the second, that is to say, passing from 0 to 80.000 km, there is a trend that indicates a direct relation between mileage and emissions, this relation can be expressed as a basic linear function:

$$y = ax + b \qquad (9)$$

With a slope of:

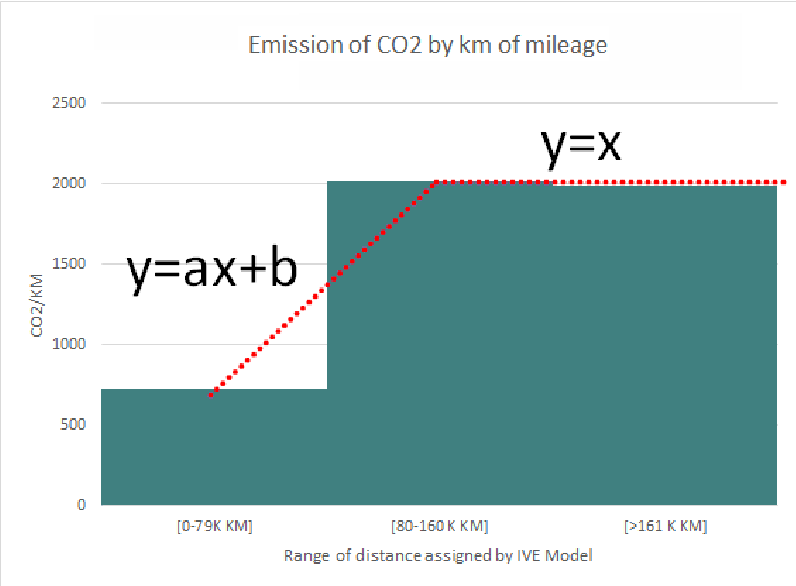
$$x = \frac{y_2 - y_1}{x_2 - x_1} \qquad (10)$$

These values will be varied for the input parameters that the user choose, given by the table 29, that is to say, driving cycle, temperature and road slope.

In the case of mileages over 81.000 km, they can be represented by a line:

$$y = x \qquad (11)$$

This is interpreted as the amount of CO_2 emitted by the vehicle per kilometer are in the same quantity as it is shown in graph 7.



Graph 6: Mathematical representation of CO2 emissions by mileage, for both euro standards (own elaboration)

5.4.2. ANALYSIS OF NITROGEN OXIDES

As it was seen in analysis done in chapter 5.1., a factor must be applied in the results done by IVE Model only for the euro standard EURO V. This allows to have the following results summarized in the table 34.

EURO IV Nox												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	12,84823	12,87471	13,06793	13,22504	12,80798	12,96432	13,12056	13,27673	13,15618	13,31379	13,47135	13,62878
Long Urban (	9,69114	9,93174	10,1723	10,41267	9,64415	9,8809	10,11753	10,35399	9,13315	9,35417	9,57391	9,79358
Extra Urban (	10,07045	10,37067	10,67077	10,97073	10,12076	10,42617	10,73139	11,03653	10,38015	10,67966	10,97915	11,27846
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	13,00658	13,088627	13,24733	13,40729	12,98448	13,13096	13,30139	13,45971	13,33749	13,49724	13,65698	13,81661
Long Urban (	9,82471	10,06864	10,31248	10,55619	9,8108	10,05235	10,27981	10,52716	9,15693	9,48314	9,70588	9,92857
Extra Urban (	10,20923	10,51357	10,82181	11,12191	10,26024	10,56982	10,8793	11,18867	10,52319	10,8269	11,13041	11,43386
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	13,19286	13,29253	13,51816	13,61646	13,24927	13,41098	13,57263	13,76119	13,60944	13,77249	13,93548	14,0984
Long Urban (	10,02505	10,27395	10,52277	10,77145	9,74655	9,97997	10,21323	10,77145	9,44905	9,6765	9,90381	10,13102
Extra Urban (	10,41743	10,72799	11,03845	11,34254	10,46949	10,78537	11,10116	11,41684	10,73776	11,04767	11,35745	11,66701
EURO V Nox												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	14,56898	14,72184	14,91464	15,1014	14,59728	14,88416	14,95618	15,13558	14,96268	15,14224	15,34172	15,50114
Long Urban (	11,04786	11,3222	11,60646	11,87046	10,32798	10,58294	10,83778	11,09252	10,49338	10,82036	11,074746	11,32996
Extra Urban (	11,4802	11,82254	12,16464	12,50658	11,5533	11,91934	12,26146	12,6034	11,83598	12,17822	12,52036	12,86232
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	14,77888	14,9148	15,10878	15,27936	14,810998	14,98038	15,16232	15,3441	15,16892	15,35092	15,53288	15,69672
Long Urban (	11,19936	11,47826	11,7562	12,03406	10,47032	10,72876	10,98716	11,24538	10,711	10,96948	11,22786	11,48608
Extra Urban (	11,63854	11,98548	12,3323	12,67898	11,72412	12,0836	12,43044	12,78218	11,99912	12,34608	12,69294	13,03958
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	15,07372	15,23186	15,40996	15,60242	15,10618	15,28586	15,4715	15,65842	15,4782	15,66394	15,84962	16,03514
Long Urban (	11,42854	11,7123	11,99598	12,27942	10,68384	10,94754	11,21124	11,4747	10,92944	11,19318	11,45682	11,72034
Extra Urban (	11,87588	12,24988	12,58384	12,93752	11,97598	12,33	12,7186	13,03764	12,24384	12,5978	12,95174	13,3055

Table 34: Pollutants trends. Nitrogen Oxides for Euro IV and Euro V (own elaboration)

At first glance, it is possible to distinguish a particular small increasing relation from Euro IV to Euro V, unlike other emissions, the NO_x emissions have been reported under a lack of progress (European Environmental Agency, 2016) and a notorious difference between Euro standard limits and real-life traffic measures (Franco, et al., 2014). The figure 21 by the EEA shown this phenomenon.

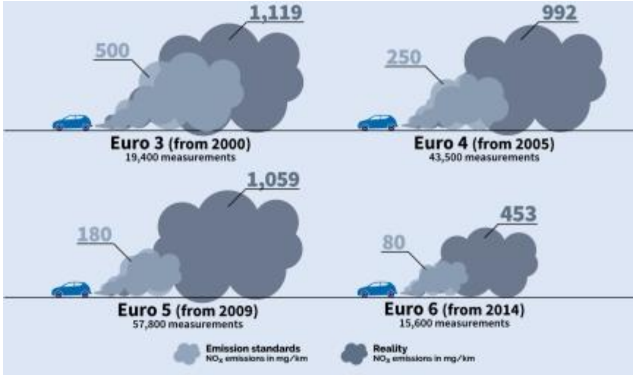


Figure 20: Comparison of NOx emissions and standards for different Euro classes (Transport & Environment, 2018)

Furthermore, this phenomenon, the emissions among different mileage follow an increasing patter within the different driving cycles, as the table 35 shows.

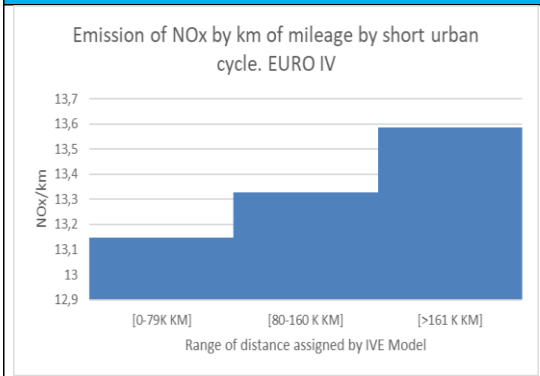
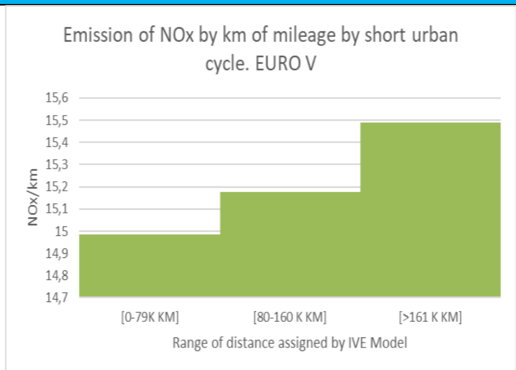
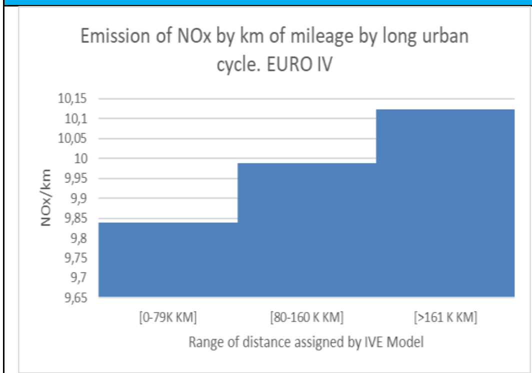
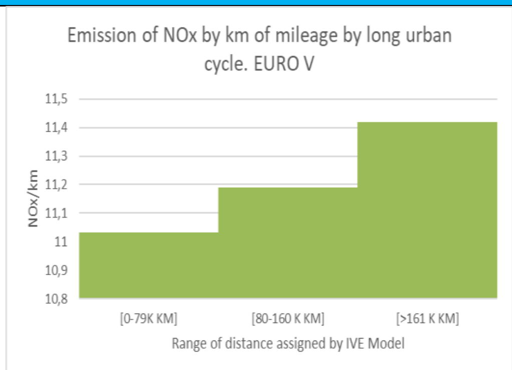
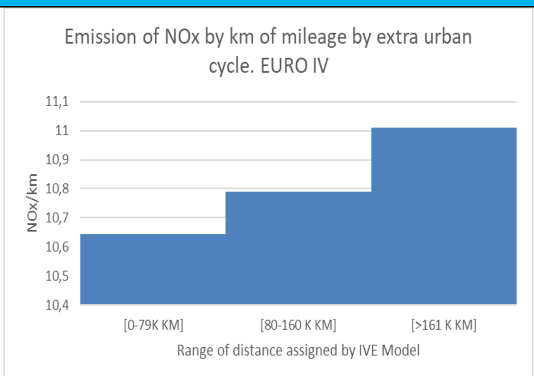
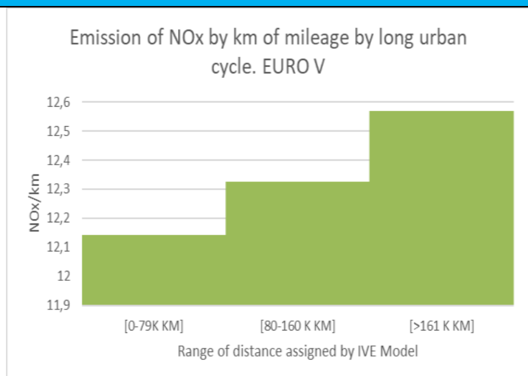
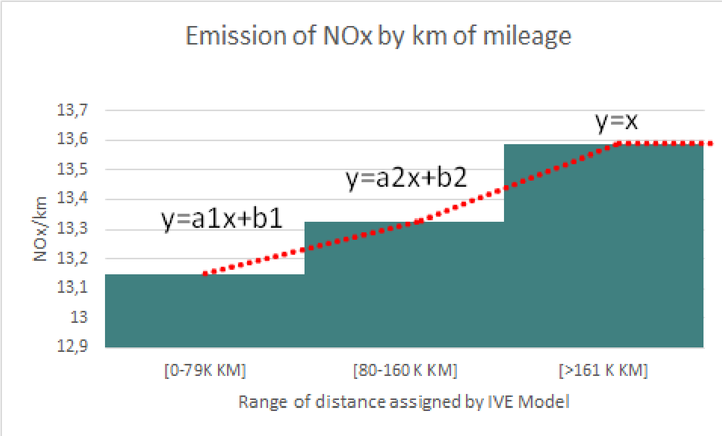
EMISSION OF NOx BY MILEAGE AND URBAN CYCLE	
EURO IV	EURO V
SHORT URBAN CYCLE	
	
LONG URBAN CYCLE	
	
EXTRA URBAN CYCLE	
	

Table 35: Analysis of Nitrogen Oxides by Urban cycle and Euro standard (own elaboration)

In the previous table it is possible to see a similar growth of emissions in terms of range of mileage for both euro standards, passing from 0-79K km to 80-160K km there is an increment of 1,4%, this increment is by 2% passing from 80-160K km to over 161K km. Using the same principle of linear representation, two different three different lines can be drawn to express the behavior, as the graph 8 shows.



Graph 7: Mathematical representation of NOx emissions by mileage, for both euro standards (own elaboration)

In terms of emissions rates is important to highlight that the total emissions for long urban cycle are less than the short urban and extra urban cycles, this is explained thought the emission curve of nitrogen oxides in relation to the speed, as shown the figure 22.

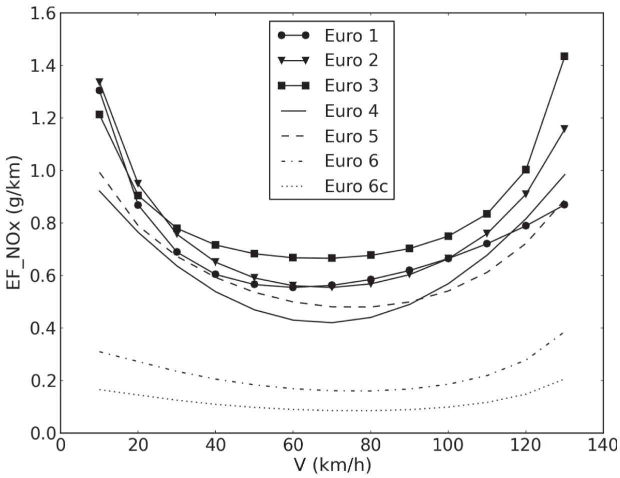
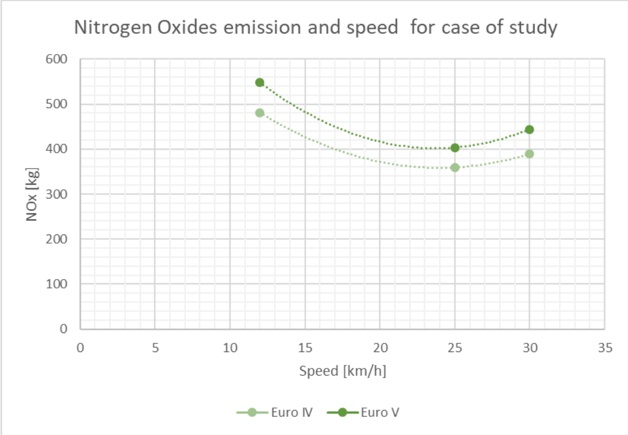


Figure 21: Nitrogen Oxides emission and speed (Seigneur, 2019)

The figure 18, shows a point where the emissions are the lowest, this related to a certain speed. This speed varies related to the vehicle and engine technology (Lozhkina, et al., 2016). In the case of study, it is possible to obtain similar polynomial curves using the data obtained for each euro standard, getting minimum speed of 23,67 km/h and 23,89 km/h for Euro IV and Euro V respectively as shown the graph 9.



Graph 8: Nitrogen Oxides emissions and speed for case of study (own elaboration)

Regarding to the influence of the temperature and road gradient. In the case of a maximum temperature of 30 degrees, the emissions increase around a 2,6% either for short urban cycle as extra urban cycle as table 36 shows.

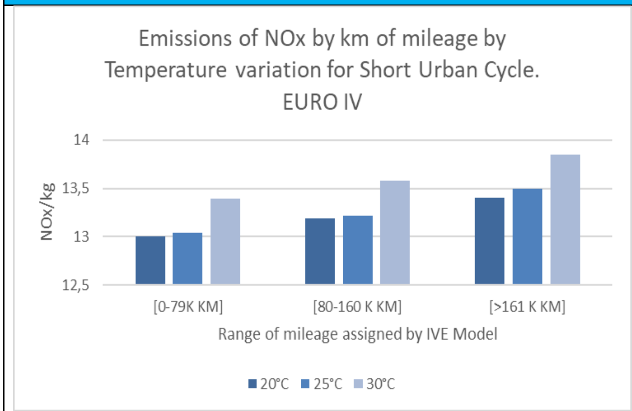
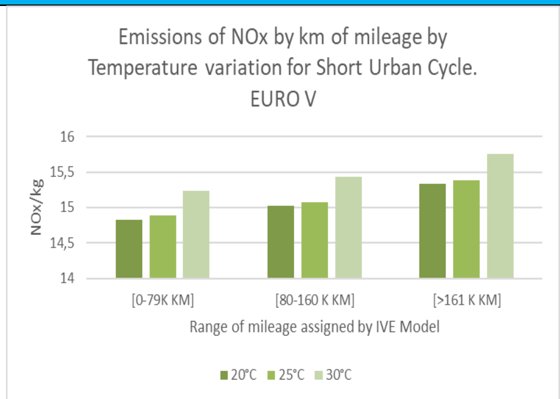
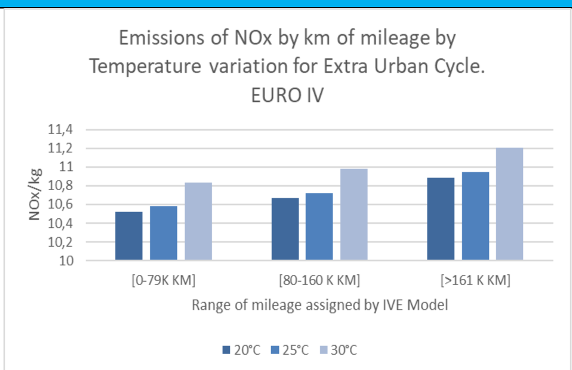
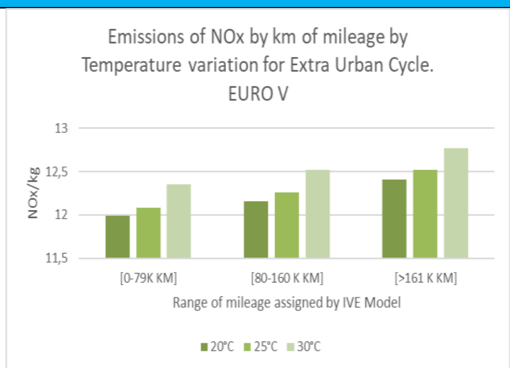
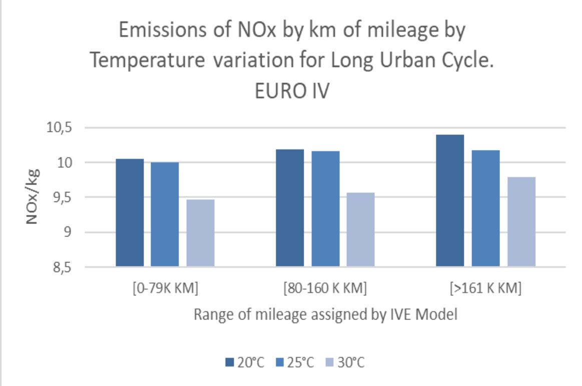
EMISSION OF NOx BY TEMPERATURE AND URBAN CYCLE	
EURO IV	EURO V
SHORT URBAN CYCLE	
	
EXTRA URBAN CYCLE	
	

Table 36: Analysis of Nitrogen Oxides. Sensibility Analysis of Temperature for Short Urban and Extra Urban cycles (own elaboration)

However, in the case of long urban cycle it is possible to observe certain variations from the previous case and a different behavior between Euro IV and Euro V.

MISSION OF NOx BY TEMPERATURE AND URBAN CYCLE	
EURO IV	EURO V
LONG URBAN CYCLE	



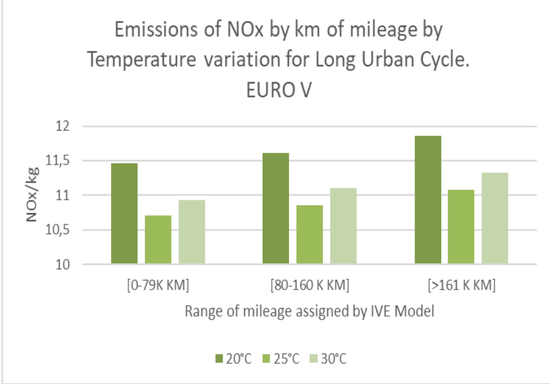


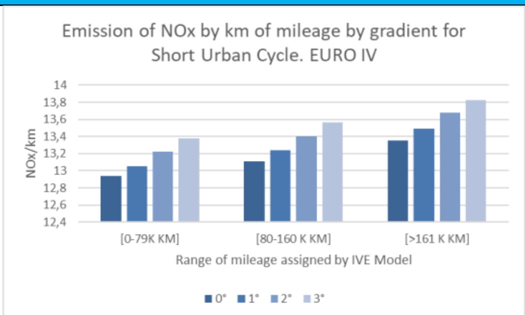
Table 37: Analysis of Nitrogen Oxides. Sensibility Analysis of Temperature for Long Urban Cycle (own elaboration)

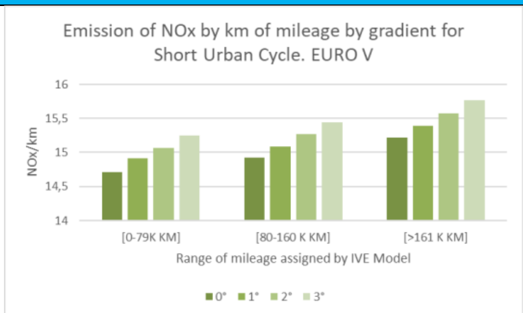
Table 37 indicates two important issues to consider further for long urban cycle, or better, for speed related to the lowest level of emissions:

- In the case of 20°, it shows there are no certain relevance either for mileage or euro standard,
- In the case of 25°, it seems for Euro IV has a slight effect on reducing the emissions, however this decrease is more notorious for Euro V standards, reaching variation up 7% less with respect 20°.
- In the case of 30°, the decrease in the quantification of emissions is for both standards, obtaining 5% less for Euro IV and 6% less for Euro V in comparison with 20°.

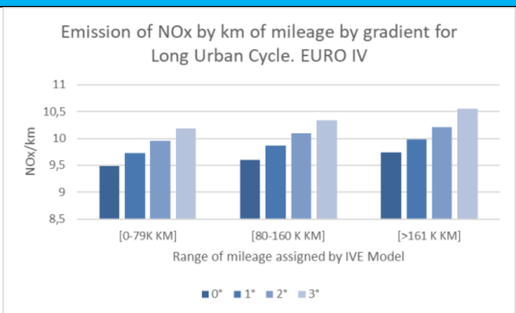
With respect the road gradation, shown in table 37, the NO_x follows a direct increase relation in terms of emissions and slope, as table 36 shows. These increases are in an order of 1% every grade of slope for short urban cycles and around 2,7% for long urban and extra urban cycles.

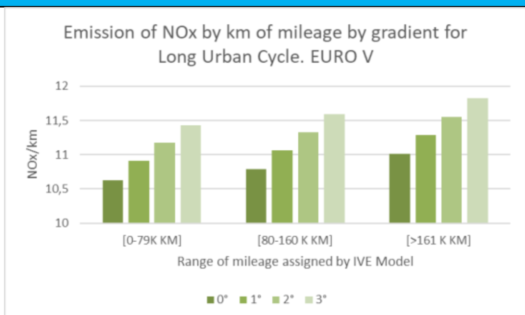
EMISSION OF NOx BY SLOPE AND URBAN CYCLE	
EURO IV	EURO V
SHORT URBAN CYCLE	



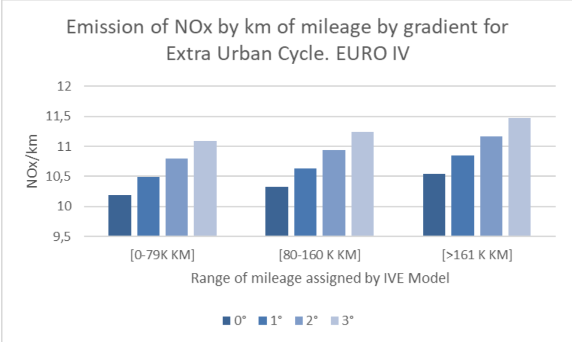


LONG URBAN CYCLE





EXTRA URBAN CYCLE



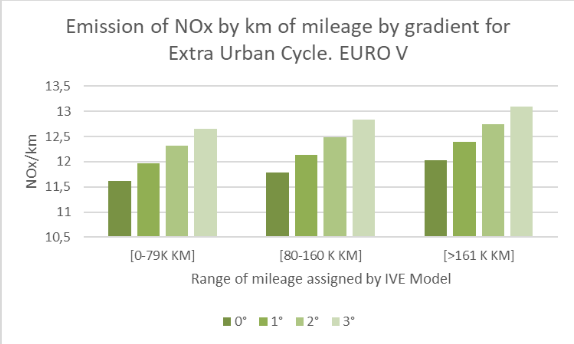


Table 38: Analysis of Nitrogen Oxides. Sensibility Analysis of Road Slope (own elaboration)

5.4.3. ANALYSIS OF CARBON MONOXIDE

The validation results indicated that the measure of CO, as NO_x, must be combined with a factor in a way to get more reliable results in terms of COPERT. From simulations the following table 39 have been made.

EURO IV CO												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	2,29475	2,34345	2,34585	2,38225	2,2881	2,3242	2,3603	2,39635	2,36255	2,3987	2,4353	2,47195
Long Urban C	1,72445	1,7801	1,8355	1,891	1,7732	1,83	1,8867	1,94355	1,6394	1,6901	1,74085	1,79205
Extra Urban C	1,78895	1,85835	1,92765	1,99685	1,80125	1,8721	1,94275	2,01375	1,8617	1,93085	2,0005	2,0697
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	2,38545	2,42332	2,461405	2,49945	2,4056	2,4308	2,4764	2,5142	2,47875	2,517	2,55505	2,5933
Long Urban C	1,8092	1,86755	1,9257	1,98395	1,89805	1,9587	2,01935	2,08005	1,7195	1,7731	1,8265	1,88005
Extra Urban C	1,87695	1,9496	2,0225	2,0952	1,88965	1,96395	2,03835	2,1127	1,9531	2,026	2,09895	2,1717
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	2,5529	2,59355	2,63435	2,64775	2,56935	2,6099	2,6503	2,6909	2,6529	2,694	2,7349	2,7759
Long Urban C	1,9364	1,9988	2,06105	2,1234	1,74425	1,7982	1,85255	2,1234	1,841	1,8978	1,955	2,0123
Extra Urban C	2,00895	2,0868	2,1647	2,2424	2,0226	2,1022	2,18165	2,2611	2,0906	2,16835	2,2465	2,2904
EURO V CO												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	2,2777	2,3086	2,33945	2,38055	2,3455	2,3838	2,3552	2,39655	2,36155	2,3978	2,433	2,46555
Long Urban C	1,72445	1,77885	1,8355	1,891	1,6163	1,6679	1,7196	1,7712	1,66445	1,71615	1,76765	1,8194
Extra Urban C	1,78895	1,99335	1,92765	1,9969	1,8086	1,87595	1,9472	2,0143	1,8612	1,93045	1,99975	2,06905
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	2,34095	2,39425	2,48735	2,51955	2,3455	2,4231	2,47635	2,5144	2,47765	2,51575	2,55395	2,59205
Long Urban C	1,8092	1,86755	1,9257	1,98395	1,6163	1,75	1,8041	1,75742	1,74625	1,8005	1,8647	1,9088
Extra Urban C	1,877	1,9496	2,0225	2,095	1,90755	1,9702	2,04295	2,11875	1,9526	2,0254	2,0981	2,17075
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	2,56465	2,5993	2,6341	2,67895	2,5687	2,6096	2,6503	2,6912	2,49074	2,6927	2,7335	2,7744
Long Urban C	1,93645	1,9988	2,06105	2,1234	1,815	1,87295	1,93095	1,989	1,86905	1,927	1,98505	2,0657
Extra Urban C	2,0089	2,0868	2,1647	2,2424	2,031	2,1088	2,1943	2,26435	2,08995	2,16775	2,2457	2,3234

Table 39: Pollutants trends. Carbon Monoxide for Euro IV and Euro V (own elaboration)

Analyzing lightly the results, it is possible to see a certain similitude between the euro standards, this is supported by limits established by the EEA, as the table 40 indicates.

Diesel	Date	CO [g/km]
Euro I	July 1992	2,72
Euro II	January 1996	1
Euro III	January 2000	0,64
Euro IV	January 2005	0,5
Euro V	September 2009	0,5
Euro VI	September 2014	0,5

Table 40: Emission limits for Euro Standards for CO (European Environmental Agency, 2016)

Based on this information, it is possible to confirm the variation given by the data in terms of euro standards as shows table 41.

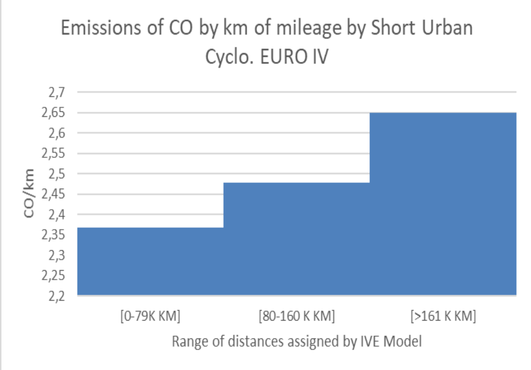
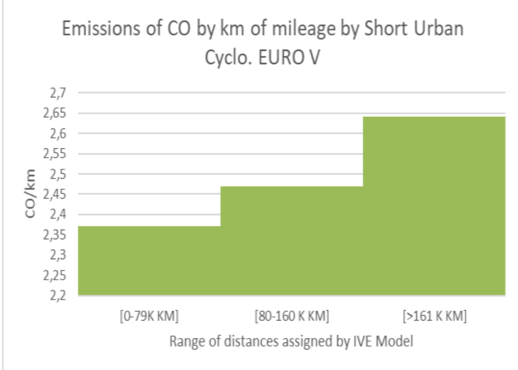
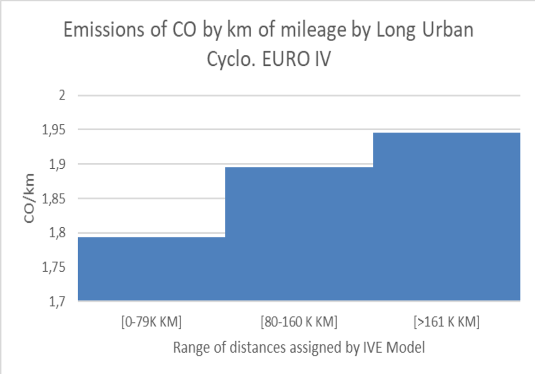
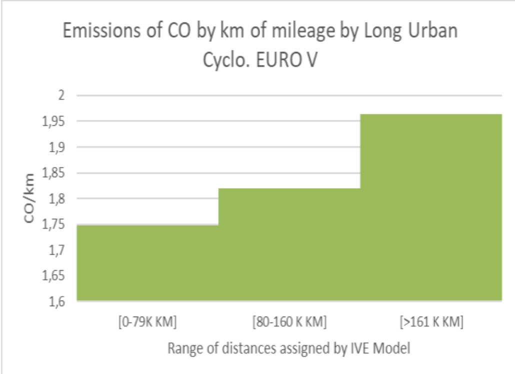
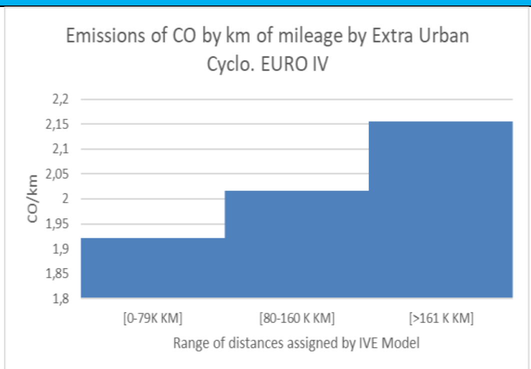
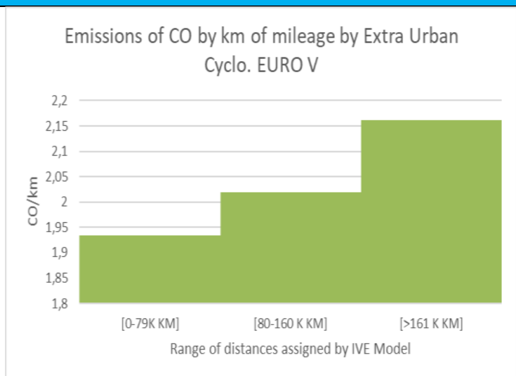
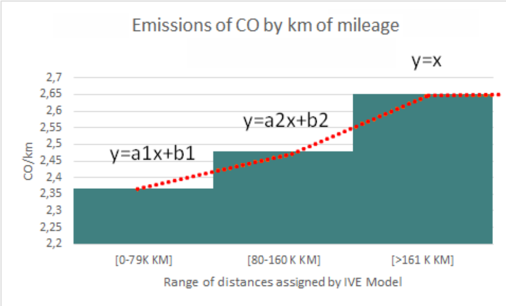
EMISSION OF CO BY MILEAGE AND URBAN CYCLE	
EURO IV	EURO V
SHORT URBAN CYCLE	
	
LONG URBAN CYCLE	
	
EXTRA URBAN CYCLE	
	

Table 41: Analysis of Carbon Monoxide by Urban cycle and Euro standard (own elaboration)

It is possible to establish certain percentages of growth between the ranges of mileages, passing from the first range (0 – 79.000 km) to the second range (80.000 to 160.000 km) there is an homogeneous increment by 4,5% for both standards, in the second case, passing from second range (80.000 to 160.000) to the third range (over 161.000 km) there is an increment by 6%, beyond that value it is possible to assume the growth stops and the emissions rate remain the same for each kilometer of mileage added, mathematically talking it is possible to stablish three different lines, two increasing with a slope determinate by the values given by each parameter and another line with no slope, which represents the values over 161.000 km. This may be represented by the graph 10.



Graph 9: Mathematical representation of CO emissions by mileage (own elaboration)

In the case of the sensibility analysis of the temperature, there is an expected direct relation between the increase of temperatures and the increase of the amount of emissions emitted by mileage as table 42 shows. This increment is in an order of 1% from 20°C to 25°C and by 3% from 25°C to 30°C.

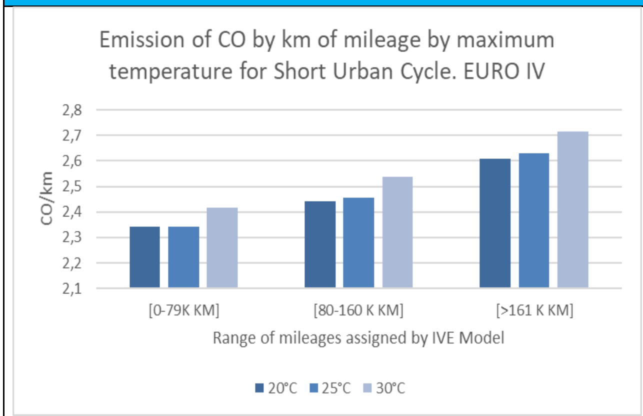
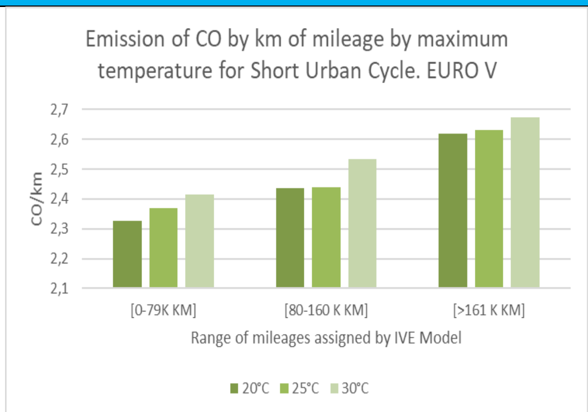
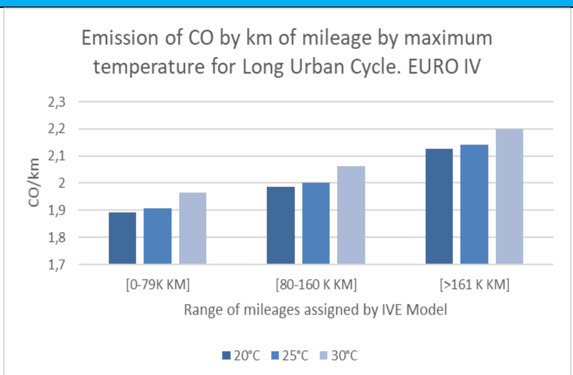
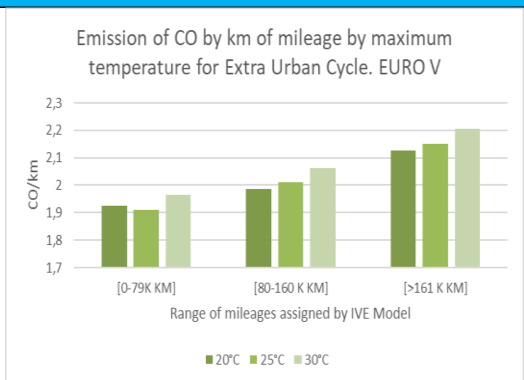
EMISSION OF NOx BY TEMPERATURE AND URBAN CYCLE	
EURO IV	EURO V
SHORT URBAN CYCLE	
	
EXTRA URBAN CYCLE	
	

Table 42: Analysis of Carbon Monoxide. Sensibility Analysis of Temperature for Short Urban and Extra Urban cycles (own elaboration)

However, as CO, there is a different behavior in the case of long urban cycles, as the table 43 indicates.

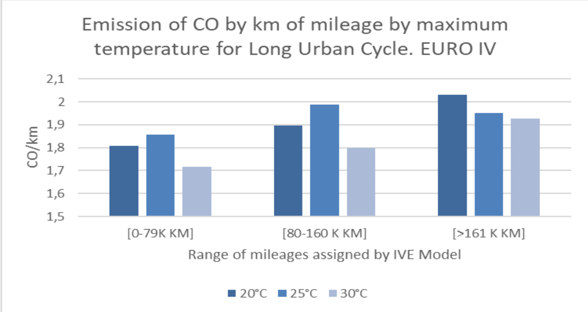
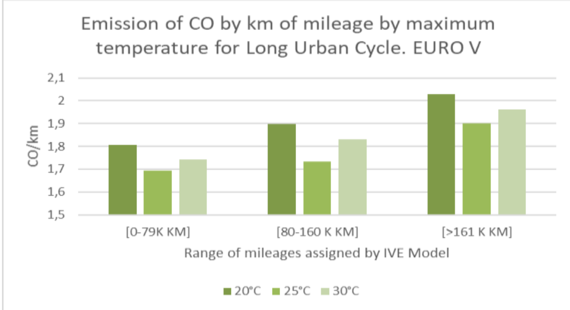
EMISSION OF CO BY TEMPERATURE AND URBAN CYCLE	
EURO IV	EURO V
LONG URBAN CYCLE	
	

Table 43: Analysis of Carbon Monoxide. Sensibility Analysis of Temperature for Long Urban Cycle (own elaboration)

Regarded to the analysis of sensibility of road, as the table 44 shows, there is an expected increase in the amount of CO per kilometer in the meantime the grade of the road is increased. This increment may be quantified in 1,5% every degree for short urban cycles and 3,3% for long urban and extra urban cycles.

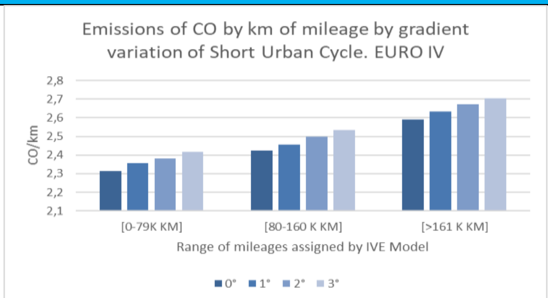
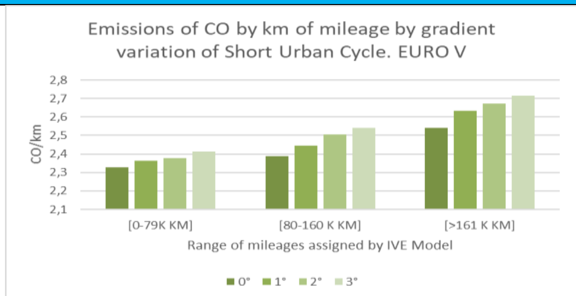
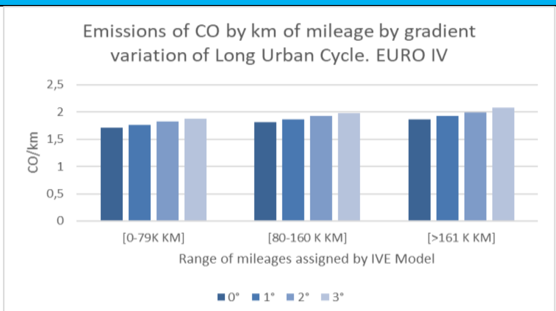
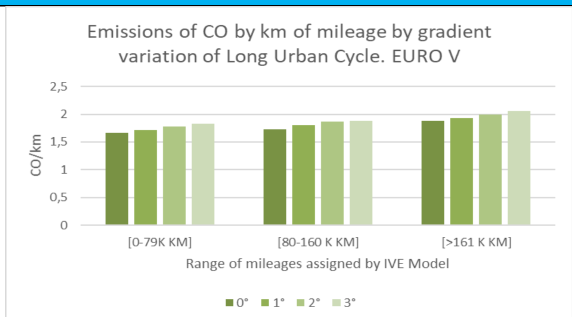
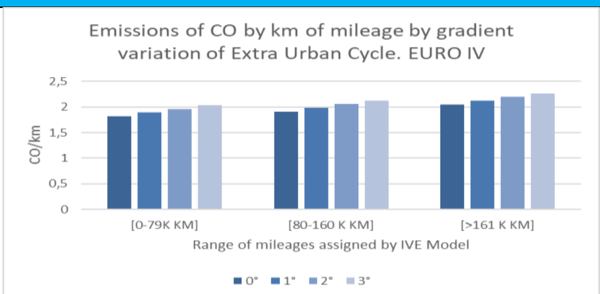
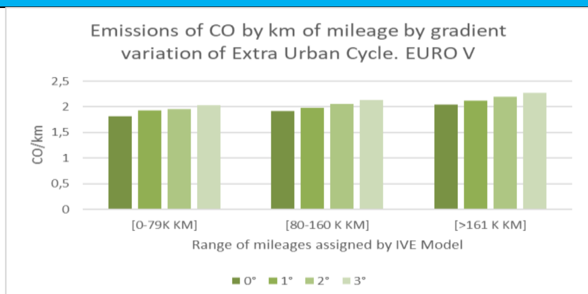
EMISSION OF CO BY SLOPE AND URBAN CYCLE	
EURO IV	EURO V
SHORT URBAN CYCLE	
	
LONG URBAN CYCLE	
	
EXTRA URBAN CYCLE	
	

Table 44: Analysis of Carbon Oxide. Sensibility Analysis of Road Slope (own elaboration)

5.4.4. ANALYSIS OF PARTICLE MATTERS

Particle matters is not in the current list of pollutants measure by COPERT, it is in this sense as the results are completely done using IVE Model, as they are described in the following table 45.

EURO IV PM												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,139805	0,14076	0,14293	0,14508	0,13911	0,14065	0,14341	0,14554	0,14355	0,14568	0,1479	0,15009
Long Urban (	0,10436	0,10767	0,11097	0,11428	0,10429	0,10754	0,11072	0,115336	0,09883	0,10192	0,10492	0,10793
Extra Urban (	0,10757	0,11166	0,11584	0,11993	0,10826	0,11247	0,11671	0,12096	0,11188	0,116	0,12016	0,12426
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,27722	0,281539	0,28583	0,29018	0,27823	0,27295	0,28679	0,2911	0,28705	0,29144	0,29576	0,30006
Long Urban (	0,20872	0,21534	0,22195	0,22854	0,20214	0,20857	0,21502	0,22142	0,19767	0,20377	0,20979	0,21591
Extra Urban (	0,21513	0,2234	0,23164	0,23986	0,2165	0,22493	0,23337	0,24186	0,22363	0,23203	0,24027	0,24854
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	1,44378	1,46627	1,48876	1,61552	1,44904	1,47146	1,49371	1,51614	1,49518	1,51779	1,54032	1,56304
Long Urban (	1,08711	1,12155	1,15596	1,19037	1,05268	1,08624	1,11983	1,19037	1,02961	1,06119	1,09283	1,10734
Extra Urban (	1,12045	1,16343	1,20641	1,24936	1,12757	1,17161	1,21566	1,25971	1,16521	1,20836	1,25144	1,29453
EURO V CO												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,09639	0,10094	0,110203	0,13168	0,119837	0,1255	0,14341	0,14557	0,13749	0,14566	0,14781	0,14998
Long Urban (	0,10436	0,10767	0,11097	0,11428	0,0977	0,10054	0,10387	0,10693	0,10058	0,10366	0,10675	0,10981
Extra Urban (	0,10767	0,11163	0,11584	0,11993	0,10874	0,11285	0,11698	0,12111	0,11186	0,11598	0,12012	0,12423
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,21498	0,22839	0,29216	0,29354	0,27817	0,28251	0,28682	0,29114	0,28698	0,29131	0,29564	0,29995
Long Urban (	0,20872	0,21534	0,22195	0,22854	0,19544	0,20157	0,20773	0,21737	0,20116	0,20732	0,21345	0,21963
Extra Urban (	0,21513	0,2234	0,23164	0,23986	0,21747	0,22573	0,23396	0,24222	0,22371	0,22843	0,24021	0,24846
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	1,40001	1,42839	1,49169	1,5118	1,45273	1,47133	1,49386	1,51641	1,49464	1,51719	1,53975	1,56228
Long Urban (	1,08711	1,12155	1,15596	1,19037	1,03784	1,08888	1,13593	1,11395	1,04772	1,07974	1,1118	1,1438
Extra Urban (	1,12045	1,16346	1,20641	1,24936	1,13263	1,1756	1,2188	1,26152	1,08271	1,20814	1,25113	1,29409

Table 45: Pollutants trends. Particle Matters for Euro IV and Euro V (own elaboration)

The trends show a slightly reduction of emissions of PM, this negative variation, between Euro IV and Euro V, is also presented either in the euro standard limits as measured in real fleet around Europe (Commissioned by the Federal Office for the Environment (FOEN), 2018). These differences come from 5% for short urban cycle, 2% for long urban cycle and 1% for extra urban cycle.

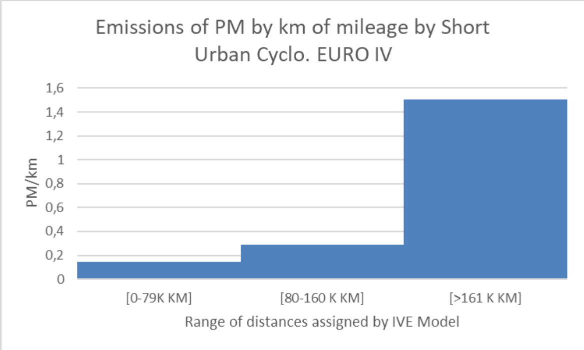
Analyzing the behavior of the emission under each urban cycle, some defined trends are drawn as table 45 exhibited.

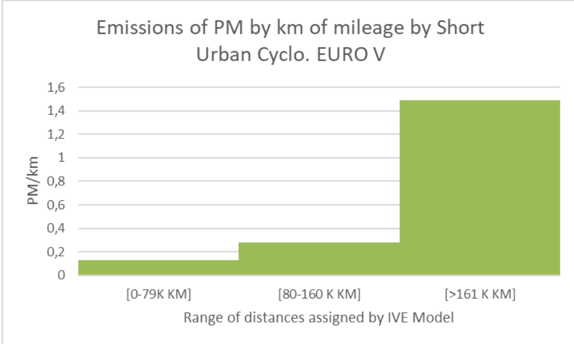
From table 46 can be read that after 160.000 km of mileage, the emission of PM has an exponential growth. This sentence is also concluded by other studies like "Influence of mileage accumulation on the particle mass and number emissions of two gasoline direct injection vehicle" (Maricq, et al., 2013), which set 150.000 km as an increased point.

EMISSION OF PM BY MILEAGE AND URBAN CYCLE

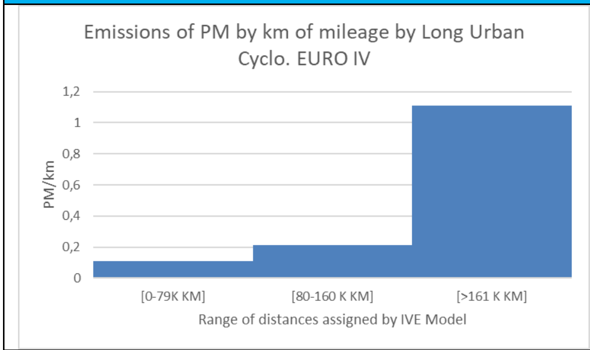
EURO IV | **EURO V**

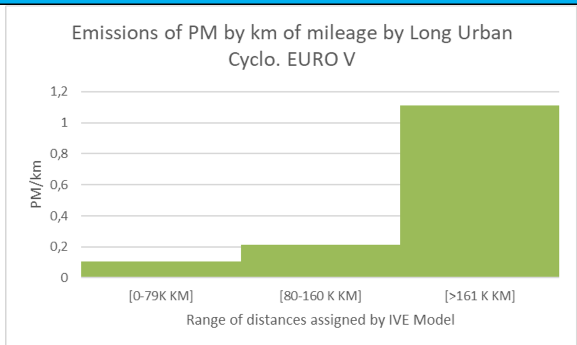
SHORT URBAN CYCLE



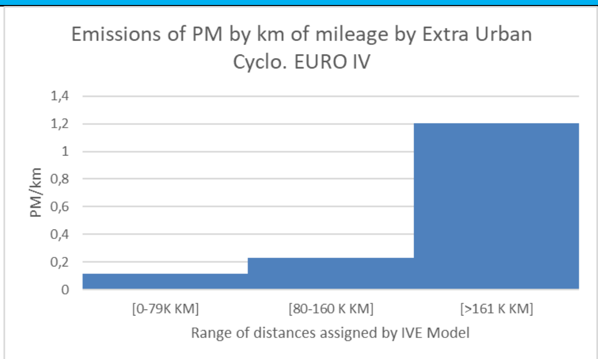


LONG URBAN CYCLE





EXTRA URBAN CYCLE



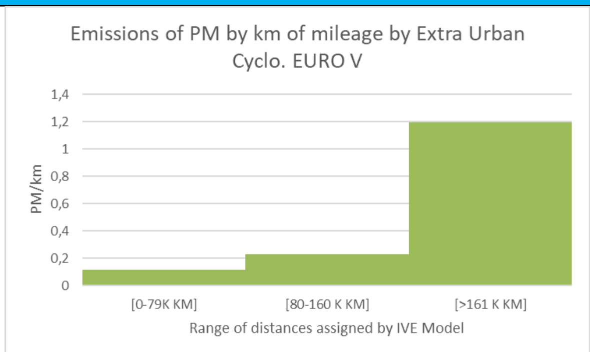
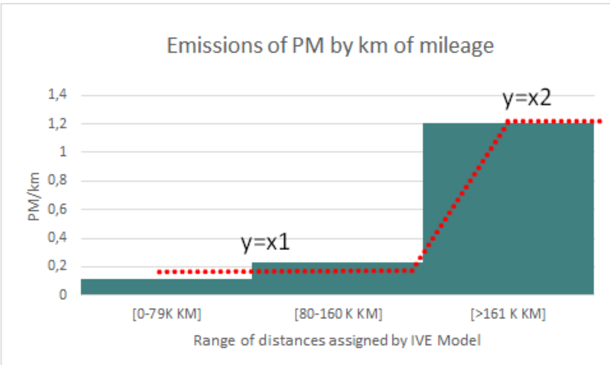


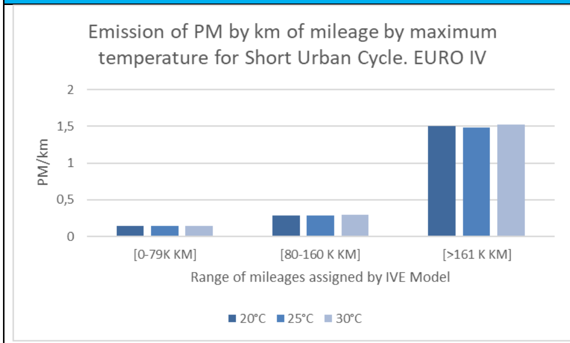
Table 46: Analysis of Particle Matter by Urban cycle and Euro standard (own elaboration)

Based on the previous information, two different lines will represent the emissions of PM, assuming they have two still phases, before 160.000 km and after 160.000 km, graph 11 represents this idea.



Graph 10: Mathematical representation of PM emissions by mileage (own elaboration)

Related to the analysis of temperature sensibility, a higher temperature affect directly in the amount of PM emitted in an order of 1% to 3%, except for the mileage over 160.000 km, either in Euro IV and Euro V, it is possible to distinguish a slightly decrease in the amount of PM by 3% to 4% less for every 5°C risen, as table 47 shows.

<table>
<tr><th colspan="2">EMISSION OF PM BY TEMPERATURE AND URBAN CYCLE</th></tr>
<tr><th>EURO IV</th><th>EURO V</th></tr>
<tr><th colspan="2">SHORT URBAN CYCLE</th></tr>
<tr><td>


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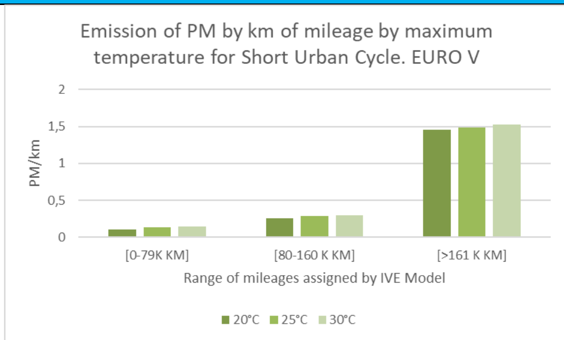

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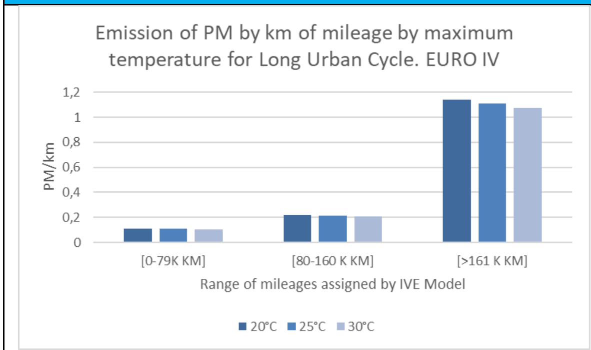
<tr><th colspan="2">LONG URBAN CYCLE</th></tr>
<tr><td>


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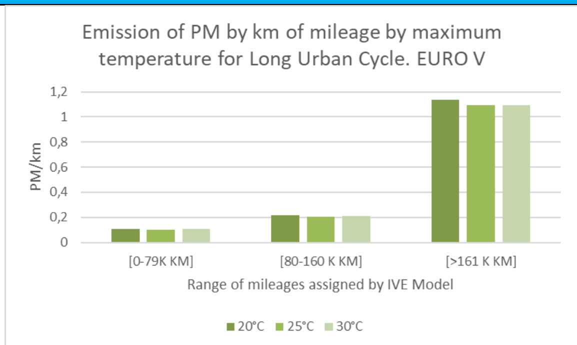

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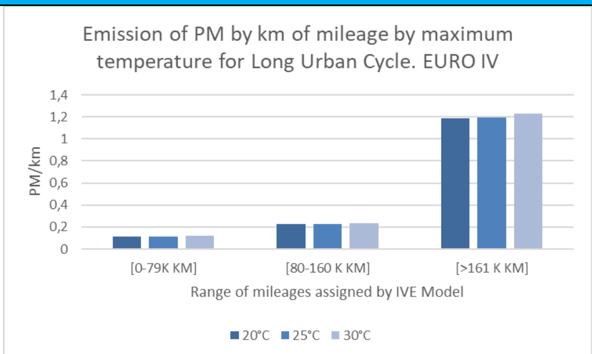
<tr><th colspan="2">EXTRA URBAN CYCLE</th></tr>
<tr><td>


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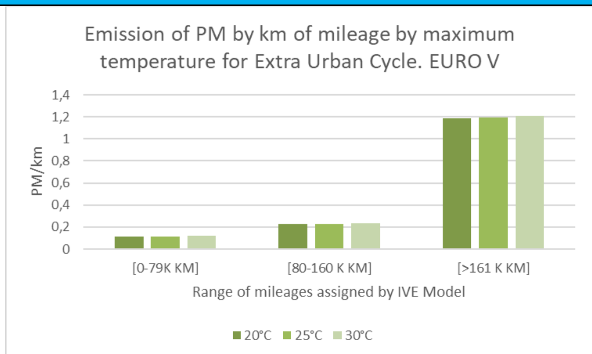

</td></tr>
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Table 47: Analysis of Particle Matter. Sensibility Analysis of Temperature (own elaboration)

Regarded to the analysis of road grade sensibility, table 48 shows that for every grade of slope increased, it is possible to find an increment around 3% of PM emitted for all cases.

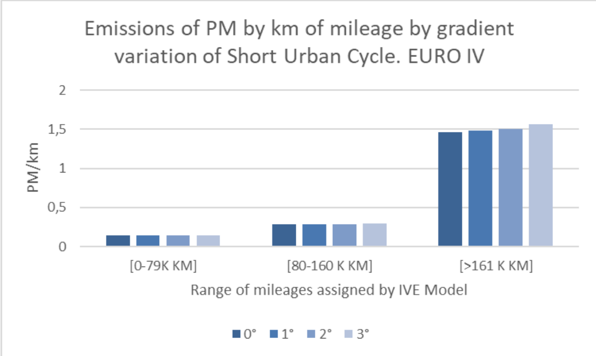
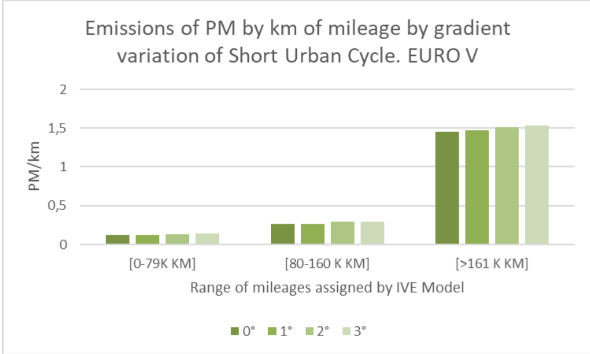
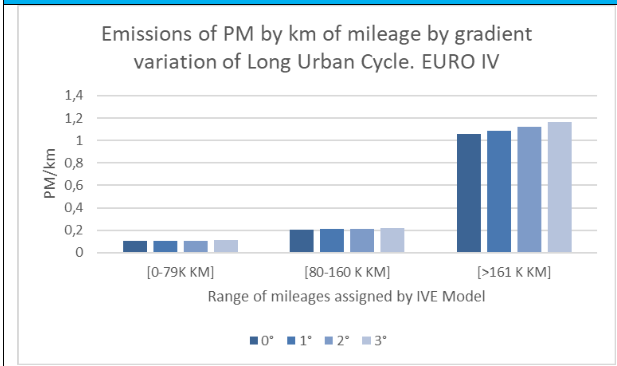
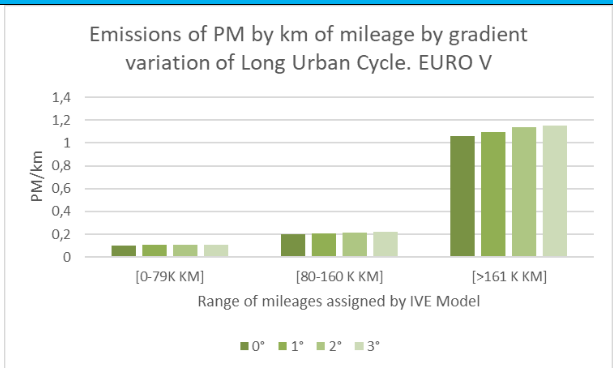
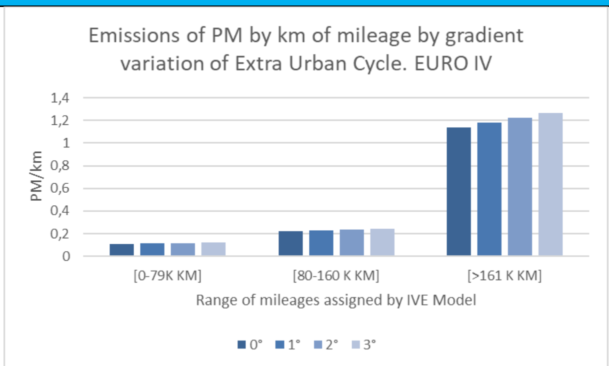
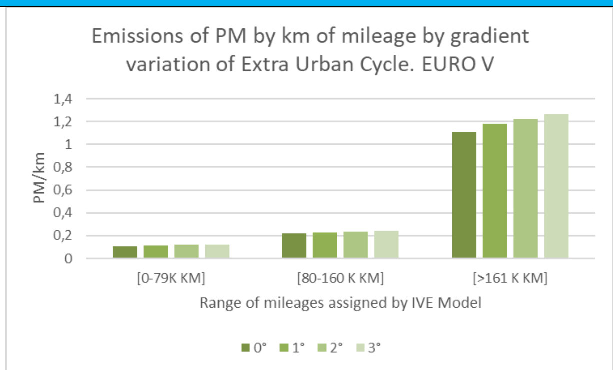
<table>
<tr><th colspan="2">EMISSION OF PM BY SLOPE AND URBAN CYCLE</th></tr>
<tr><th>EURO IV</th><th>EURO V</th></tr>
<tr><th colspan="2">SHORT URBAN CYCLE</th></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="2">LONG URBAN CYCLE</th></tr>
<tr><td></td><td></td></tr>
<tr><th colspan="2">EXTRA URBAN CYCLE</th></tr>
<tr><td></td><td></td></tr>
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Table 48: Analysis of Particle Matter. Sensibility Analysis of Road Slope (own elaboration)

5.4.5. ANALYSIS OF SULPHUR OXIDES

For Sulphur oxides emissions, the results show a small decrescent gap from Euro IV to Euro V . This is also validated in the recommendation endorsed by the World Forum for Harmonization of Vehicle regulation's working party of Energy and Pollution (GRPE) on 2019 (United Nation Economic Comission for Europe UNECE, 2019), which decrease the recommended SO_x limit for euro standard, as it is shown in table 49:

Euro standard	*Recommended sulphur level (ppm)*
Euro 2	<500
Euro 3	<350 and <150
Euro 4	<50
Euro 5	<10
Euro 6	<10

Table 49: Recommended SOx level by the UNECE (United Nation Economic Comission for Europe UNECE, 2019)

In the case of the driving cycles, it is observed in the table 50 and 51 that the number of SO_x is being reduced when the mileage is increased. A relation can be established in terms of percentages, from the first segment, 0-79.000 km to 80.000-160.000 there is an average different of 0,2% for all the cases, however, when the mileage passes the 161.000 km the reduction of SO_x in the environment has a higher reduction of an average of 0,5%. Despite the differences, the relation between mileage and the amount of sulphur oxides is very low. This is mainly due to the composition of SO_x is 98% SO_2 (suplhur dioxide) (National Research Council, 1975), these emissions reach a point of decreasing after a certain mileage, normally under 80.000 km. (Cooper, 1976), as it shown in the tables.

EURO IV Sox												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,19088	0,19654	0,20202	0,20745	0,1943	0,19945	0,20514	0,21051	0,2055	0,21091	0,21633	0,22174
Long Urban C	0,1452	0,15349	0,16174	0,17002	0,14326	0,15138	0,15917	0,16758	0,14258	0,15013	0,15774	0,16528
Extra Urban C	0,151	0,16129	0,17162	0,18193	0,15338	0,16369	0,17401	0,18435	0,16166	0,17203	0,18236	0,1927

80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,19091	0,196394	0,20183	0,20729	0,19412	0,19957	0,20495	0,21037	0,20535	0,21075	0,21613	0,22157
Long Urban C	0,1451	0,15336	0,16162	0,16987	0,14256	0,1506	0,15868	0,16674	0,14245	0,15	0,1576	0,16512
Extra Urban C	0,15087	0,16116	0,17149	0,18177	0,15326	0,16357	0,17371	0,18418	0,16155	0,17189	0,18223	0,19254

> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,18997	0,19536	0,2008	0,20511	0,19314	0,19852	0,20391	0,20929	0,20426	0,20961	0,21511	0,22046
Long Urban C	0,14435	0,15256	0,16077	0,169	0,13959	0,15247	0,1612	0,16366	0,14174	0,14927	0,15679	0,16434
Extra Urban C	0,15009	0,16033	0,17059	0,18085	0,15246	0,16274	0,17301	0,18324	0,16076	0,17101	0,18128	0,19154

EURO V Sox												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,19191	0,19651	0,20113	0,20987	0,19423	0,19937	0,20503	0,21041	0,20488	0,21057	0,21598	0,22138
Long Urban C	0,1452	0,15349	0,16174	0,17002	0,13766	0,14533	0,15296	0,16065	0,14478	0,15244	0,16011	0,16776
Extra Urban C	0,151	0,1613	0,17162	0,18193	0,1539	0,16423	0,17453	0,18482	0,16169	0,17203	0,18231	0,19264

80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,19177	0,1964	0,20098	0,20781	0,19404	0,19946	0,20486	0,21026	0,205	0,21041	0,2158	0,22119
Long Urban C	0,1451	0,15335	0,16162	0,16987	0,13755	0,145204	0,15286	0,16051	0,14466	0,15233	0,15997	0,16776
Extra Urban C	0,15087	0,16116	0,17149	0,18177	0,15377	0,16409	0,17439	0,18469	0,16106	0,170102	0,18218	0,19247

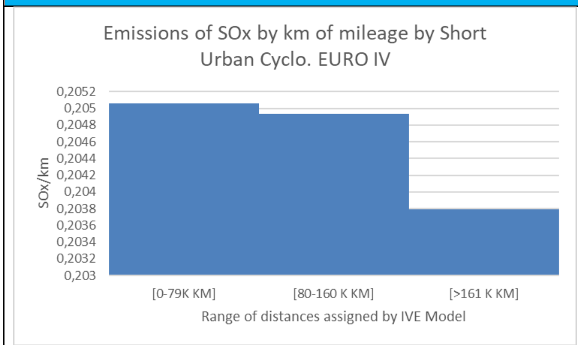
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,19094	0,19552	0,2001	0,20683	0,19306	0,19843	0,2038	0,2144	0,20394	0,20932	0,21471	0,22007
Long Urban C	0,14435	0,15256	0,16077	0,169	0,136844	0,14445	0,15279	0,15966	0,14392	0,15384	0,15916	0,16678
Extra Urban C	0,15009	0,16033	0,17029	0,18085	0,15296	0,16322	0,17445	0,18373	0,16074	0,171	0,18124	0,19149

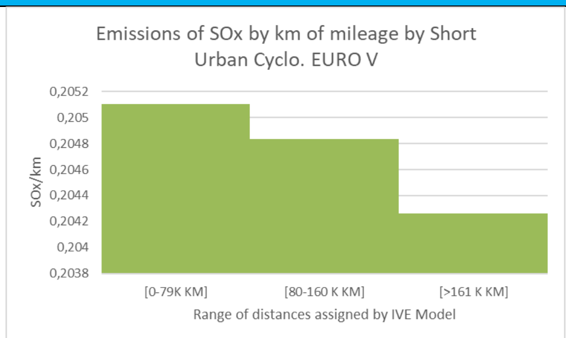
Table 50: Pollutants trends. Sulphur Oxides for Euro IV and Euro V (own elaboration)

EMISSION OF SOx BY MILEAGE AND URBAN CYCLE

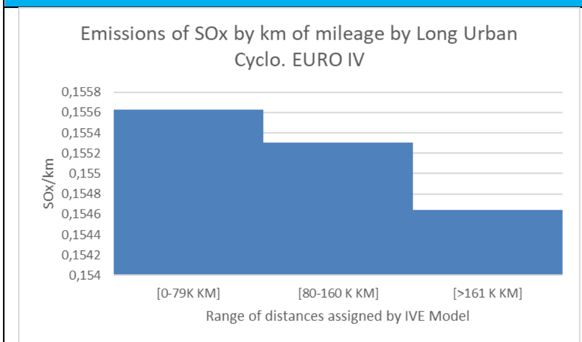
EURO IV | EURO V

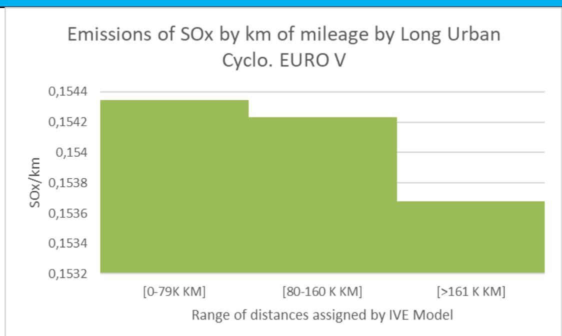
SHORT URBAN CYCLE



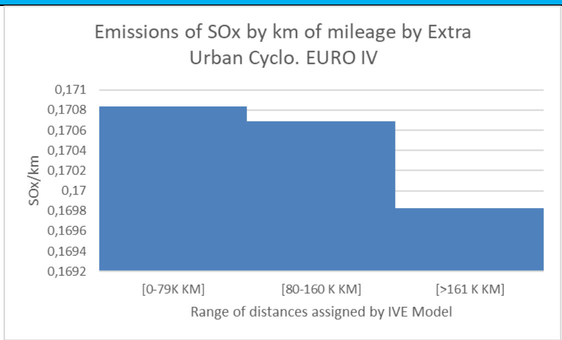


LONG URBAN CYCLE





EXTRA URBAN CYCLE



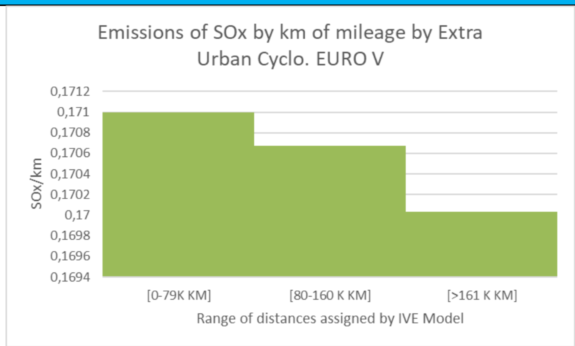
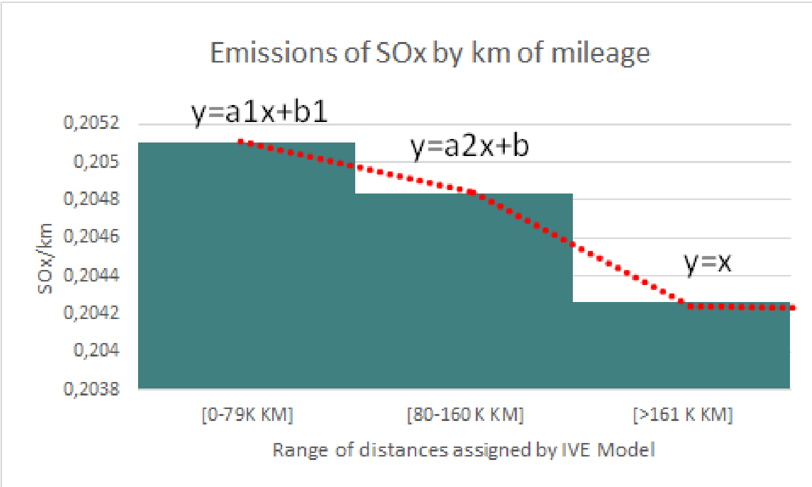


Table 51: Analysis of Sulphur Oxides by Urban cycle and Euro standard (own elaboration)

Despite the reduction between range is small, it is possible to model it mathematically with two different lines, assuming a negative slope for the first two segments and a steady line with slope 0 to model emissions over 161.000 km. Graph 12 shows this.



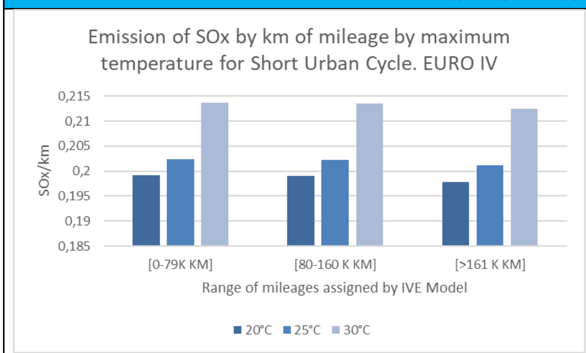
Graph 11: Mathematical representation of SOx emissions by mileage (own elaboration)

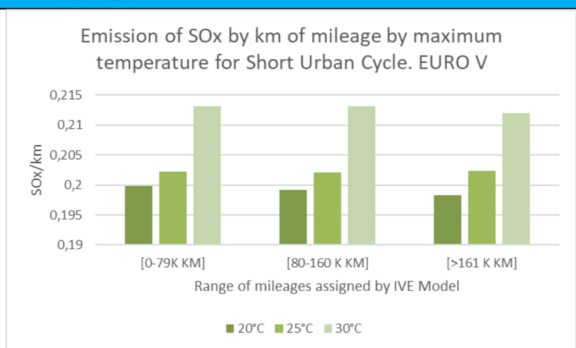
In terms of sensibility analysis, there are some important relation established between temperature and SO_x emissions. First off, there is a common distribution for urban cycle and extra urban cycle, as table 52 shows. In these cases, the relation is directly, the higher temperature, the larger amount of SO_x/km. There is a certain average increased from 20°C to 25°C, around 1,5%, however this percentage gets higher when it comes the maximum daily temperature reach the 30°C, in this case it is possible to observe increment of Sulphur oxide by 5% higher.

EMISSION OF SOx BY TEMPERATURE AND URBAN CYCLE

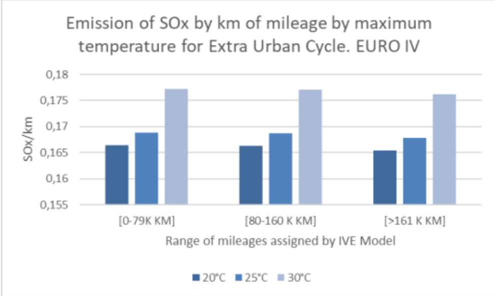
EURO IV | EURO V

SHORT URBAN CYCLE





EXTRA URBAN CYCLE



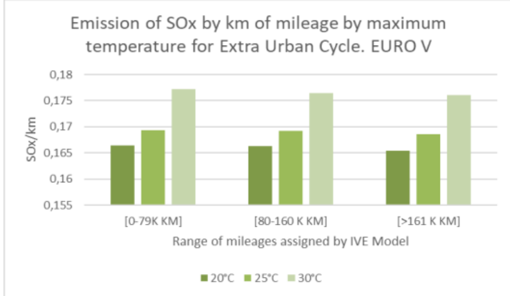


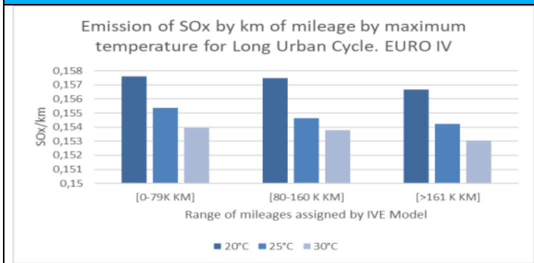
Table 52: Analysis of Sulphur Oxides. Sensibility Analysis of Temperature for Short Urban and Extra Urban cycles

With respect to the long urban cycle, 25 km/h as average speed, there is a downward trend, as table 53 exhibits, the higher the temperature, the less is the number of SO_x emitted by the fleet. It can be measured in order to 2% from 20°C to 25°C and 0,8% less from 25°C to 30°C.

EMISSION OF SOx BY TEMPERATURE AND URBAN CYCLE

EURO IV	EURO V

LONG URBAN CYCLE



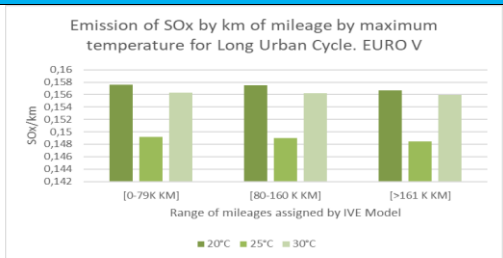


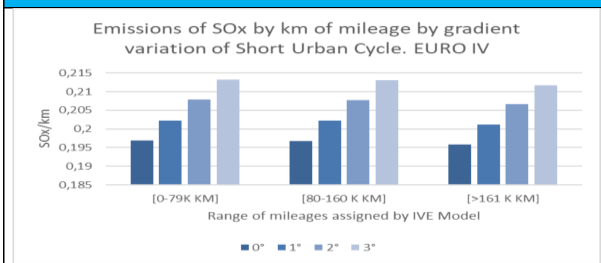
Table 53: Analysis of Sulphur oxide. Sensibility Analysis of Temperature for Long Urban Cycle (own elaboration)

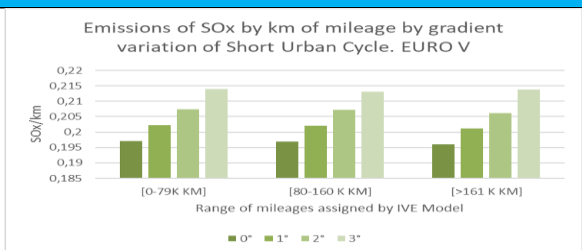
For road slope sensibility analysis, a homogeneous increased is seen for all the driving cycle for both euro standards as table 54 displays. In this analysis it is possible to split the increment by driving cycle, in the case of short urban cycle for every grade increased the number of SO_x rise by 2,5%, in the case of long urban cycle this number is an average of 5%, in the case of extra urban cycle the total Sulphur oxide increase by 6%.

EMISSION OF SOx BY SLOPE AND URBAN CYCLE

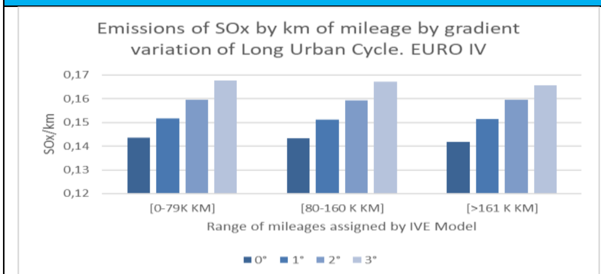
EURO IV	EURO V

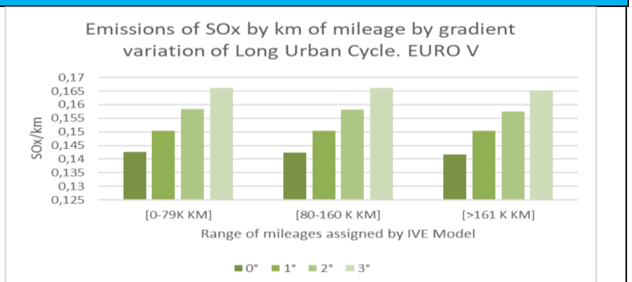
SHORT URBAN CYCLE





LONG URBAN CYCLE





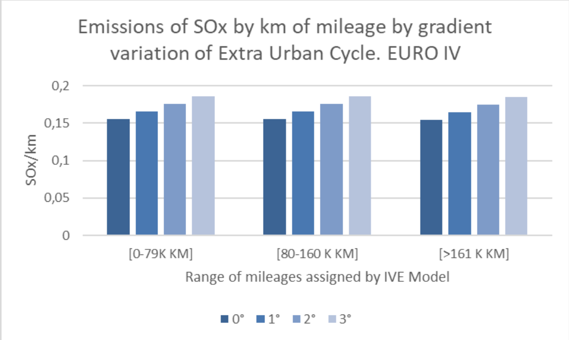
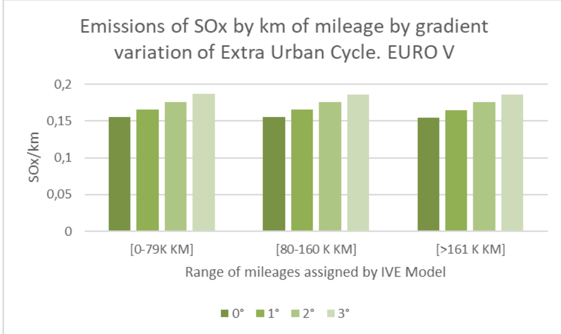
EXTRA URBAN CYCLE	
	

Table 54: Analysis of Sulphur Oxide. Sensibility Analysis of Road Slope (own elaboration)

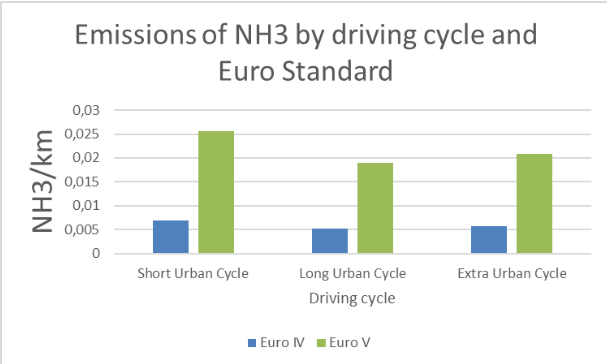
5.4.6. ANALYSIS OF AMMONIA

Ammonia or NH_3 is a pollutant that appears in the cold-start emissions stage. The importance of measuring lies on the fact that NH_3 is a precursor of $PM_{2,5}$ which deteriorates urban air quality, affect human health and impacts the global radiation budget (Suarez, et al., 2017). This element is mainly in agriculture industry, but it has had a giant growth in road transport, around 320% since 1991 to 2011 (European Environment Agency, 2013). It is important to highlight that NH_3 had not being included in the euro standard limits until Euro VI, when the regulation also includes a Portable Emissions Measurement System (PEMS) to control these emissions.

Related to the analysis, it is possible to observe no variation among the mileage, basically the age of the vehicle does not influence the NH_3 emitted, as table 55 shows. However, there are differences among the driving cycles, as graph 13 indicates, being the long driving cycle the less pollutant, this may suggest a relation similar than other pollutants in relation with speed, having a parabolic description of the emissions in terms of velocity.

EURO IV NH3												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,006705	0,0068175	0,006924	0,0070305	0,006756	0,006864	0,0069705	0,0070635	0,0069555	0,0070635	0,007176	0,0072825
Long Urban C	0,0051	0,005304	0,0054285	0,0055965	0,0050235	0,0051855	0,005343	0,0055005	0,0048495	0,005004	0,0051585	0,0053115
Extra Urban C	0,005307	0,0055125	0,005718	0,005922	0,005337	0,0055485	0,0057615	0,005973	0,0055245	0,0057375	0,005934	0,0061485
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,006705	0,0068175	0,006924	0,0070305	0,006756	0,006864	0,0069705	0,0070635	0,0069555	0,0070635	0,007176	0,0072825
Long Urban C	0,0051	0,005304	0,0054285	0,0055965	0,0050235	0,0051855	0,005343	0,0055005	0,0048495	0,005004	0,0051585	0,0053115
Extra Urban C	0,0053055	0,0055125	0,005718	0,005922	0,005337	0,0055485	0,0057615	0,005973	0,0055245	0,0057375	0,005934	0,0061485
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,006705	0,0068175	0,006924	0,007029	0,006756	0,006864	0,0069705	0,0070635	0,0069555	0,0070635	0,007176	0,0072825
Long Urban C	0,0051	0,005304	0,0054285	0,0055965	0,0050235	0,0051855	0,005343	0,0055965	0,0048495	0,005004	0,005133	0,0053115
Extra Urban C	0,0053055	0,0055125	0,005718	0,005922	0,005337	0,0055485	0,0057615	0,005973	0,0055245	0,0057375	0,005934	0,0061485
EURO V NH3												
< 79K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,0246565	0,02508	0,0254815	0,025883	0,0247665	0,0251075	0,025553	0,025784	0,025575	0,0259655	0,026367	0,0267575
Long Urban C	0,0187	0,019305	0,0199045	0,0205205	0,017523	0,0181005	0,0186505	0,019228	0,018062	0,018612	0,019184	0,0197505
Extra Urban C	0,019459	0,020196	0,020966	0,021714	0,0196515	0,020416	0,021175	0,0219285	0,02024	0,0210045	0,0217415	0,022495
80K km > X < 160K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,0246565	0,02508	0,0254815	0,025883	0,0247665	0,0251075	0,025553	0,025784	0,025575	0,0259655	0,026367	0,0267575
Long Urban C	0,0187	0,019305	0,0199045	0,0205205	0,017523	0,0181005	0,0186505	0,019228	0,018062	0,018612	0,019184	0,0197505
Extra Urban C	0,019459	0,020196	0,020966	0,021714	0,0196515	0,020416	0,021175	0,0219285	0,02024	0,0210045	0,0217415	0,022495
> 161K km												
Driving Cycle	20°C				25°C				30°C			
	0°	1°	2°	3°	0°	1°	2°	3°	0°	1°	2°	3°
Short Urban	0,0246565	0,02508	0,0254815	0,0258775	0,0247665	0,0251075	0,025553	0,025784	0,025575	0,0259655	0,026367	0,0267575
Long Urban C	0,0187	0,019305	0,0199045	0,0205205	0,017523	0,0181005	0,0186505	0,019228	0,018062	0,018612	0,019184	0,0197505
Extra Urban C	0,019459	0,020196	0,020966	0,021714	0,0196515	0,020416	0,021175	0,0219285	0,02024	0,0210045	0,0217415	0,022495

Table 55: Pollutants trends. Ammonia for Euro IV and Euro V (own elaboration)



Graph 12: Analysis of Ammonia by Urban cycle and Euro standard (own elaboration)

Related to the sensibility analysis, like other pollutants, the NH_3 has a different behaviour for short and extra urban cycle than for long urban cycle, the first case, shown in table 56, has a direct increment of the amount of pollutants while the mileage is increased. In the case of short urban cycle, the increment from 20°C to 25°C is 0,6% for Euro IV and 1% for Euro V, in the case of extra urban cycle, this increment is of 0,7% for Euro IV and 1,1% for Euro V. A bigger increased has place when the temperature rise from 25°C to 30°C, for both driving cycles the amount of NH_3 increases by 3%.

Mathematically related to the model, a simple way it is to get the value given by the set of parameters, driving cycle, temperature and road slope.

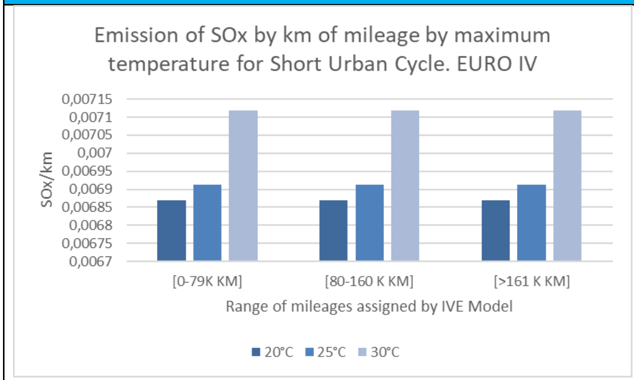
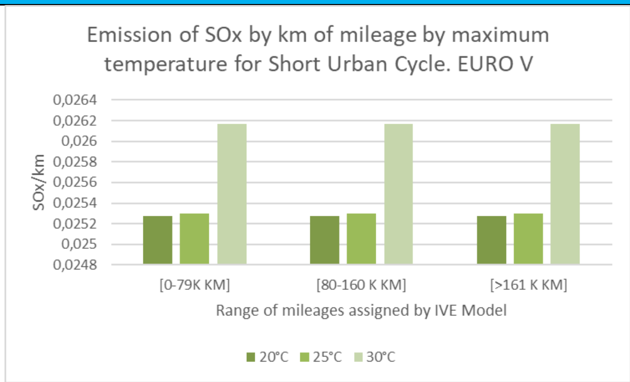
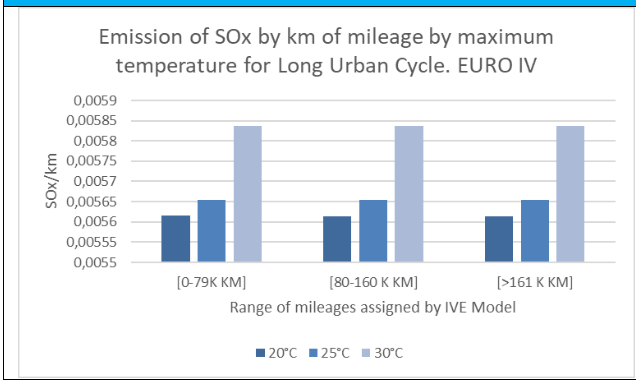
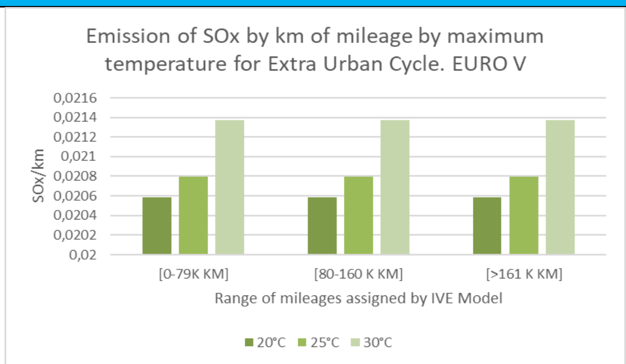
<table>
<tr><th colspan="2">EMISSION OF NH3 BY TEMPERATURE AND URBAN CYCLE</th></tr>
<tr><th>EURO IV</th><th>EURO V</th></tr>
<tr><th colspan="2">SHORT URBAN CYCLE</th></tr>
<tr><td>
</td><td>
</td></tr>
<tr><th colspan="2">EXTRA URBAN CYCLE</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Table 56: Analysis of Ammonia. Sensibility Analysis of Temperature for Short Urban and Extra Urban cycles (own elaboration)

In the case of the long driving cycle, as shows table 57, the amount of NH_3 emitted by the fleet, tends to decrease with the temperature, this decreasing varies from 1,5% to 3% from 20°C to 25°C and from 25°C to 30°C, respectively.

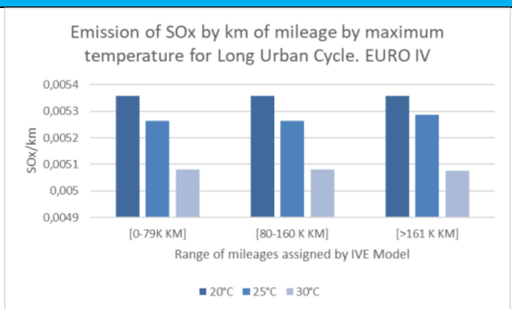
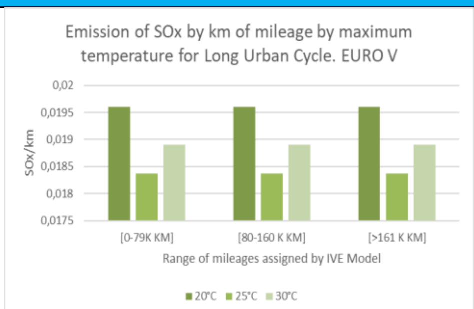
<table>
<tr><th colspan="2">EMISSION OF NH3 BY TEMPERATURE AND URBAN CYCLE</th></tr>
<tr><th>EURO IV</th><th>EURO V</th></tr>
<tr><th colspan="2">LONG URBAN CYCLE</th></tr>
<tr><td>
</td><td>
</td></tr>
</table>

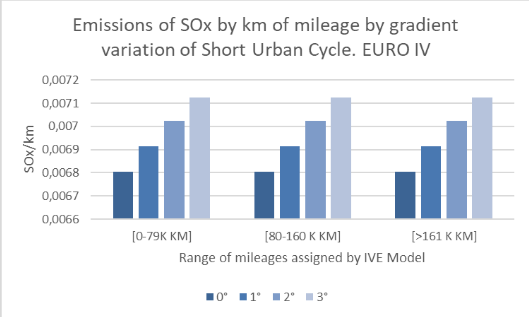
Table 57: Analysis of Ammonia. Sensibility Analysis of Temperature for Long Urban Cycle (own elaboration)

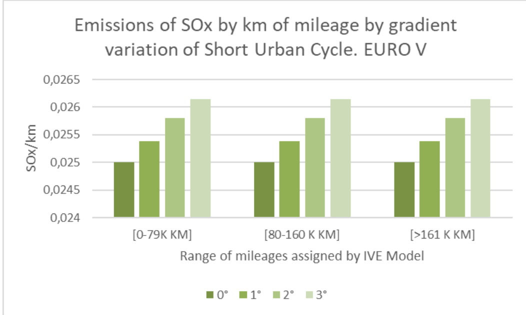
Related to the road slope analysis, in both standards it Is possible to see homologous increases as the average slope of the route increases, table 58 shows it. These increments vary from 3% for short and extra urban cycle for each euro standard to 1,5% for long urban cycle, for each standard.

EMISSION OF SOx BY SLOPE AND URBAN CYCLE

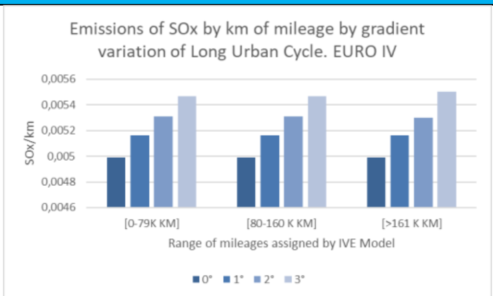
EURO IV | EURO V

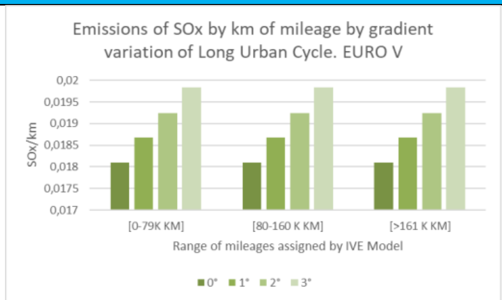
SHORT URBAN CYCLE



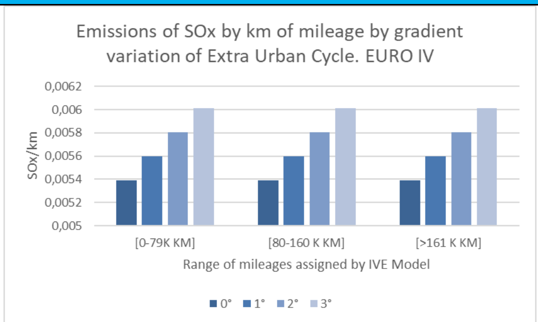


LONG URBAN CYCLE





EXTRA URBAN CYCLE



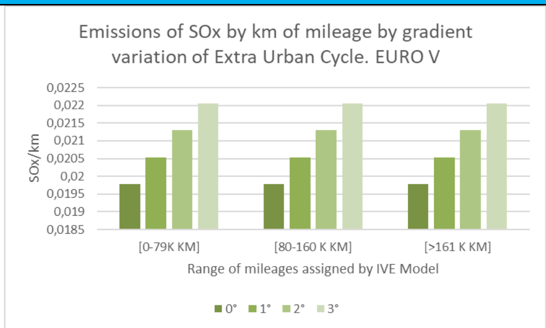


Table 58: Analysis of Ammonia. Sensibility Analysis of Road Slope (own elaboration)

5.5. EURO VI

The analysis done in the previous chapter was done comparing two-euro standards, Euro IV and Euro V, this is mainly due to those two standards are included in the software IVE, so the detail calculation is possible. However, it is also important to consider Euro VI standards, introduced in regulation 595/2009 and amended by regulations 582/2011 and 133/2014.

Euro VI has been implemented in around 15,2% of the total European fleet of standard buses (International Association of Public Transport, 2019), among their changes are included the following:

- NH_3 concentration limits of 10 ppm applied to diesel and gas engine
- A maximum limit for the NO_2 component of NO_x emissions may be defined in the implementing regulation
- New testing requirements for off-cycle emissions and in-service conformity

Also related to the policies, in this sense, the EU member states can use tax incentives in order to stimulate marketing and sales of vehicle meeting new standards giving a regulatory deadline. These incentives may be applied to all new vehicles offered on the market of EU members, they end when the new limit values come into effect and they cannot exceed the additional cost of the technical solutions introduces for each type of vehicle.

For this calculation, COPERT is used, in terms of a group of factors is applied for each pollutant. This process is like the validation test done in chapter 5.1.1, but with the difference that the factors are not applied in the same category, so these factors are not are not for calibrating the existing results, but these are done to get new data.

Basically, using the same data giving by the table 14, it is possible to compare a similar database of input and get the result analyzing euro standards, for this, the previous euro standard is used, Euro V, then factors are taken as it follows in table 59.

Euro Standard	CO_2 [t]	NO_x [t]	CO [t]	PM [t]	NH_3 [t]
Euro V	694,517318	2,573	1,415545	0,094854	0,005809
Euro VI	707,652716	0,1942	0,134157	0,060358	0,004753
Factors, from Euro V to Euro VI	1	0,0755	0,0947741	0,6363253	0,81821312

Table 59: Euro VI factor values giving by COPERT (own elaboration)

As it can be seen, the SO_x is not in the table, that is due to COPERT does not include this value in the software. Then this is the only value that cannot be provide, inasmuch as there is not certain about its behaviour for Euro VI.

5.6. ANALITICAL MODEL FOR CALCULATION OF POLLUTANTS

The previous worked gives the idea of the trends followed by the emissions in terms of mileage in a way to get the functions necessary to calculate the exact emission by pollutant by the mileage input by the user. It is important to understand that the data used in this model is an individual information by each vehicle of the study case, this data is shown in appendix 1. In this appendix the Euro VI standard is not applied, however, the model contemplates the use of the factors giving in table 58, in a way to convert Euro V to Euro VI.

It is important to highlight that a vehicle may operate under different circumstances during the year, either intrinsic or external. For example, the temperature will not remain the same during the year, in some period it can oscillate in the 20°C, other can reach 30°C, this information provided by the user, gives to the model the percentage of operating during the year, as the table gives the daily emissions, this model allows to the user to set up two types of operation during the year, one it can be during summer time where the temperature are higher and another may be the rest of the year.

The model operates in two layers, first off, the user layer, where the inputs are defined. There are two types of inputs, general and operation data, the first one is related to the information that does not vary according the different types of operation, that is to say, mileage, type of vehicle, euro standard and quantity of vehicles of the same type, the second group of inputs is related to the operation, defining two set of them, each set has a driving cycle, temperature, road slope, working hours and working days. The input interface is shown in the table 60. It is important to indicate that the parameters type of vehicle, euro standard, driving cycle, temperature and road slope are define under a limited group of options, in way to provide to the model, the instruction to find a unique matrix.

User settings			
Mileage	572541		km
Type of Vehicle	Olbia 1064		
Euro Standard	EURO V		
# of vehicles	1		
Operation Type 1		Operation type 2	
Driving Cycle	Long urban	Driving Cycle	Long urban
Temperature	20°C	Temperature	20°C
Road Slope	2°	Road Slope	2°
Working hours	10	Working hours	16
Working days	100	Working days	200

Table 60: User interface, input (own elaboration)

Once these values are defined, the model locates a unique matrix among 156 matrixes with different parameters, giving by the dataset, as it shown in table 61, for each of the 6 pollutants mentioned. Each raw of matrix is associated to 3 different ranges of mileage, then the mileage defined by the user is evaluated in the function giving by the parameters, obtaining a singular value. This one means the daily emissions of a vehicle under the parameters set.

Driving cycle	Temperature	Road Slope	Mileage			[0-70.000]		Hidden A	[70.000-160.000]		Hidden B	>160.000
			0	80.000	160.000	a	b		a	b		b
Short urban	20°C	0°	146,06889	401,45585	398,73355	0,003192337	146,06889	401,45585	0	401,45585	401,45585	401,45585
		1°	150,67928	413,03456	410,23374	0,003279441	150,67928	413,03456	0	413,03456	413,03456	413,03456
		2°	154,83899	424,6098	421,73049	0,003372135	154,83899	424,6098	0	424,6098	424,6098	424,6098
		3°	159,07461	436,1781	433,22035	0,003463794	159,07461	436,1781	0	436,1781	436,1781	436,1781
	25°C	0°	143,07062	397,78652	395,0891	0,003183949	143,07062	397,78652	0	397,78652	397,78652	397,78652
		1°	146,84245	409,03447	406,26077	0,0032774	146,84245	409,03447	0	409,03447	409,03447	409,03447
		2°	151,00771	420,27904	417,4291	0,003365892	151,00771	420,27904	0	420,27904	420,27904	420,27904
		3°	155,01124	431,51688	428,59072	0,003456321	155,01124	431,51688	0	431,51688	431,51688	431,51688
	30°C	0°	149,37738	415,1593	412,34407	0,003322274	149,37738	415,1593	0	415,1593	415,1593	415,1593
		1°	152,78248	426,40724	423,51574	0,00342031	152,78248	426,40724	0	426,40724	426,40724	426,40724
		2°	156,89463	437,65182	434,68407	0,003509465	156,89463	437,65182	0	437,65182	437,65182	437,65182
		3°	160,9288	448,88965	445,8457	0,003599511	160,9288	448,88965	0	448,88965	448,88965	448,88965
Long urban	20°C	0°	27,38575	200,73683	199,37562	0,002166889	27,38575	200,73683	0	200,73683	200,73683	200,73683
		1°	77,62335	212,31555	210,87582	0,001683653	77,62335	212,31555	0	212,31555	212,31555	212,31555
		2°	81,76237	223,89079	222,37257	0,001776605	81,76237	223,89079	0	223,89079	223,89079	223,89079
		3°	85,88016	235,45909	233,86242	0,001869737	85,88016	235,45909	0	235,45909	235,45909	235,45909
	25°C	0°	71,88248	197,27529	210,25912	0,00156741	71,88248	197,27529	0	210,25912	210,25912	210,25912
		1°	75,8338	208,44697	221,52454	0,001657665	75,8338	208,44697	0	221,52454	221,52454	221,52454
		2°	79,8879	219,61529	232,7832	0,001746592	79,8879	219,61529	0	232,7832	232,7832	232,7832
		3°	84,00245	230,77692	233,86242	0,001834681	84,00245	230,77692	0	233,86242	233,86242	233,86242
	30°C	0°	74,69615	206,48285	215,08268	0,001647334	74,69615	206,48285	0	215,08268	215,08268	215,08268
		1°	78,87876	277,7308	216,25435	0,002485651	78,87876	277,7308	0	277,7308	277,7308	277,7308
		2°	83,08874	228,97538	227,42268	0,001823583	83,08874	228,97538	0	228,97538	228,97538	228,97538
		3°	87,15173	240,21321	238,58431	0,001913269	87,15173	240,21321	0	240,21321	240,21321	240,21321
Extra Urban	20°C	0°	27,9093194	204,19609	202,81142	0,002203585	27,9093194	204,19609	0	204,19609	204,19609	204,19609
		1°	79,94311277	218,25603	216,77601	0,001728911	79,94311277	218,25603	0	218,25603	218,25603	218,25603
		2°	84,99485538	232,31175	230,73642	0,001841461	84,99485538	232,31175	0	232,31175	232,31175	232,31175
		3°	90,02230167	246,35904	244,68846	0,001954209	90,02230167	246,35904	0	246,35904	246,35904	246,35904
	25°C	0°	75,48231214	206,77146	205,36933	0,001641114	75,48231214	206,77146	0	206,77146	206,77146	206,77146
		1°	80,48821488	220,8314	219,33392	0,00175429	80,48821488	220,8314	0	220,8314	220,8314	220,8314
		2°	85,601597	234,88712	233,29433	0,001866069	85,601597	234,88712	0	234,88712	234,88712	234,88712
		3°	90,77970145	248,93441	247,24637	0,001976934	90,77970145	248,93441	0	248,93441	248,93441	248,93441
	30°C	0°	77,78212776	214,61563	213,16031	0,001710419	77,78212776	214,61563	0	214,61563	214,61563	214,61563
		1°	65,06688835	228,67557	227,1249	0,002045109	65,06688835	228,67557	0	228,67557	228,67557	228,67557
		2°	88,24363344	242,73129	241,08531	0,001931096	88,24363344	242,73129	0	242,73129	242,73129	242,73129
		3°	93,33448956	256,77858	255,03735	0,002043051	93,33448956	256,77858	0	256,77858	256,77858	256,77858

Table 61: Mathematical expression of the database extraction (own elaboration)

Understanding that the value is associated to a singular type of vehicle and this one by itself was calculated according to a determinate working type, the user has the option to modify this value, increasing or decreasing the working hours, this plus the working days and the number of vehicle in the fleet, can provide the final amount of pollutants by emitted yearly by a defined fleet of buses, as it shown in table 62.

Results		
CO2	60,73900000	t/year/fleet
NOx	0,42809900	t/year/fleet
CO	0,07448000	t/year/fleet
PM	0,04159050	t/year/fleet
SOx	0,00616000	t/year/fleet
NH3	0,00071995	t/year/fleet

Table 62: User interface, results (own elaboration)

A simplified diagram to explain it, it is shown in the figure 23:

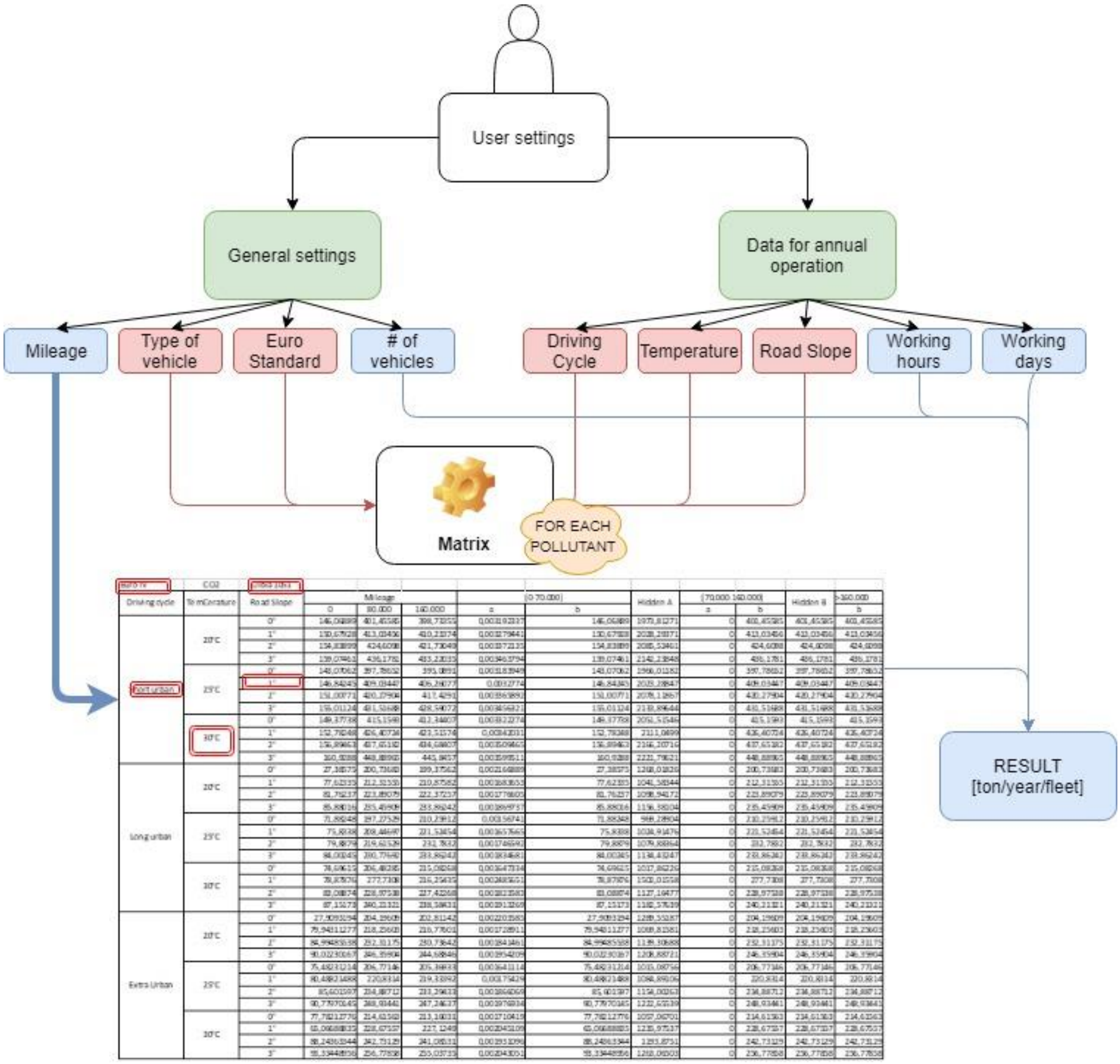


Figure 22: Model to estimate pollutants diagram (own elaboration)

6. NEURAL NETWORK AS A MODEL FORECASTING

The model is an analytical solution as a tool to estimate the emissions of a fleet of buses under parameters previously set by the user, the same database used for the analytical model is used for developing a neural network, in this case, a Multilayer Perceptron.

The model, like the analytical one, must be able to, through independent variables, predict the depend variables with a minimum error, under a training stage, that is basically the 70% of the model.

A step-by-step point can be seen as follows:

- Step 1: Definition of the variables. For this step is simply indicate to the model which are the independent variables and the dependent variables, as follows:

```
X=df[["Mileage","Urban Cycle","Temperature","Road Slope","Euro Standard","Bus model"]]
output_names=["CO2","NOX","CO","PM","SOX","NH3"]
```

- Step 2: Definition of the training set. In this step the amount of dataset is split into test (30%) and training (70%), beside this this the random component is locked, in another way, it fix the split in every running

```
onehotencoder = OneHotEncoder(categorical_features = [0])
x2=OneHotEncoder().fit_transform(X)


def train_test(x,y):
x_train, x_test, y_train, y_test = train_test_split(x2, y, test_size=0.3, random_state=42)
print( x_train.shape, y_train.shape)
print (x_test.shape, y_test.shape)
return x_train, x_test, y_train, y_test
```

- **Step 3:** Definition of the model to be used for each pollutant. This step is essential, due to it is not possible to run the same structure for each output, the activation functions and the architecture (neurons and connections) differ between them. For example, the next model has been defined to estimate CO_2. This model contains 8 layers and two activation functions within them, ReLU and Sigmoid. As a summary, 4 models where used in this ANN.

```
def bmodel1():
model = Sequential()
model.add(Dense(1058, activation='relu',
            kernel_regularizer = 'l2',
            kernel_initializer = 'normal',
            input_shape=(27,)))
```

```
model.add(BatchNormalization())

model.add(Dropout(0.5))

model.add(Dense(529, activation='relu',

            kernel_regularizer = 'l2',

            kernel_initializer = 'normal'))

model.add(BatchNormalization())

model.add(Dropout(0.5))

model.add(Dense(1, activation='linear',

            kernel_regularizer = 'l2',

            kernel_initializer='normal'))
```

It is important to mention that each model used have a mean absolute percentage error (MAPE), associated to the final output, the list of error by model can be check in the table 63.

Model	Pollutant	Error
Model 1	CO_2	2,49%
Model 2	NO_x	1,49%
	CO	4,12%
	SO_x	3,16%
Model 3	PM	15,59%
Model 4	NH_3	8,58%

Table 63: MLP - Models and errors for pollutants (own elaboration)

- Step 4: Training using a supervised learning technique, minimizing the error in each epoch, assigning a checkpoint every time it finds the optimal.

```
def train(filepath,epochs,batch_size,model,x_train,y_train,x_test,y_test):


model.compile(loss='mse', optimizer="adam", metrics=['mse','mae','mape'])

checkpoint = ModelCheckpoint(filepath,monitor="val_mean_absolute_percentage_error",

  verbose=1 , save_best_only=True , mode='min')

callbacks_list = [checkpoint]

history = model.fit(x_train, y_train,validation_data=(x_test,y_test), epochs=epochs,

  batch_size=batch_size, callbacks=callbacks_list, verbose=1)


return history,model
```

- Step 5: Saving the model, in terms of weights and history

```
  def saveModels(model,history,name_model,name_weights,name_history):
```

```
        f= open(name_history,'wb')
        pickle.dump(history.history,f)
        f.close()
        model.save(name_model)
```

- Step 6: Print the results, in this last step, all the models are called to be trained and test, showing the respond for the 6 variables assigned. For this 500 epochs and 64 batches.

```
epochs=500
batch_size=64
for resp in output_names:
        y=df[[resp]]
        x_train, x_test, y_train, y_test = train_test(x2,y)
        if (resp=="CO2"):
                model=bmodel1()
                #pass
        if (resp=="NOX" or resp=="CO" or resp=="SOX"):
                model=bmodel2()
                #pass

        if (resp=="PM"):
                model=bmodel3()
                #pass

        if (resp=="NH3"):
                model=bmodel4()
        name_weights="weights_" + "resp"
        H,model=train(name_weights,epochs,batch_size,model,x_train,y_train,x_test,y_test)
        load_predict(model,name_weights)
        name_history="history_" + "resp"
        name_model="model_" + "resp"
        saveModels(model,H,name_model,name_weights,name_history)
        plot(H,epochs)
```

The final code either for creating the models and load the user interface are in appendix 2 and appendix 3.

The interface of the model demand to the user the following parameters:

- Type the mileage in order of 1000 (type just an integer)
- Type the Driving Cycle (Short Urban, Long Urban, Extraurban)
- Type the temperature (20°, 25°, 30°)
- Type the road slope (0°, 1°, 2°, 3°)
- Type the Euro Standard (Euro IV, Euro V, Euro VI)
- Type the type of vehicle to be used

In based of these input the program can provide through the different models, an answer like it shows in table 64.

CO2	[[188.775941]]
NOX	[[1.2337506]]
CO	[[0.04866069]]
PM	[[0.1388514]]
SOX	[[0.01956316]]
NH3	[[0.00438046]]

Table 64: MLP output example (own elaboration)

7. CONCLUSION AND FUTHER APPLICATIONS

Transport sector is one of the most pollutant among the economic sectors, reaching levels of 30% of the total greenhouse gases emitted, this is why different environmental agencies either in Europe or in other continents had put especial attention to the development of the sector.

As the European Environmental Agency has declared, measuring exhaust emissions from vehicle is a complex issue (Bruyninckx, 2018), especially due to the gap between tested and real-world driving emissions. It is in this purpose as this thesis explored the different models available in the market, their advantages and disadvantages and how these last could be overcome by other models, in this way, it was possible to create a singular database using two main software, IVE Model and COPERT, and a study case, that provide real elements to feed the collection of data. This database allowed to analyse the trends of the 6 main pollutants emitted by road transportation, conceding space for a more specific estimation of pollutants giving a certain mileage, either for Euro IV as Euro V.

A wide knowledge of the behaviour of the different pollutants in different scenarios, which are temperature variation, road slope and driving cycles (including speed and engine ignitions), favoured the inclusion of factors obtained by COPERT to add the Euro standard VI to the dataset. With these a 60% of the buses circulating in Euro are covered by the model.

Nonetheless, this thesis proposes the use of deep learning as a tool to estimate pollutants under the scenarios before mentioned. Artificial Neural Network has been developed for urban applications as a way to facilitate the analysis of big datasets, saving time and work. It is under this concept as a Multilayer Perceptron (MLP) model has been created, model belonging to the family of Feedforward artificial neural networks. As it is explained, this model suits with the architecture and structure of the dataset.

The different MLP used in this thesis had different results in the measure of the mean absolute percentage error (MAPE), being the best performance in the estimation of CO_2, NOx, CO and SO_x, which models have a MAPE under 5%, however the model 3 and model 4, used for estimating emissions of PM and NH_3, respectively, showed MAPE between 8% and 15%, these results are considered insufficient, nevertheless, it is important to indicate that the probably reason is the non-regular behaviour of these elements, as it could be seen in the scenarios related to euro standard and temperature, in which the emissions of these pollutants were hard to predict.

Some additional features that may be applied in the models, either analytical as MLP, is eventually more pollutants, as N_2O and F-gases (fluorinated gases) coming from air conditioning equipment and also, enlarge the type of vehicle, as for this thesis it was used a standard bus, it is possible to add articulated buses to reach an 80% of the average global bus fleet (International Association of Public Transport, 2019). Beside this new feature, this application must be updated according to the new models and new upgrading of the existent ones, in a way to estimate more accurately the emissions in the environment.

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APPENDIX 1: DATASET

Ciclo urbano breve											20°C	0°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	146,06889	71,80382	46,17296	41,62061	41,26779	28,589	36,35856	83,61012	55,60828	43,279	4,61243	96,03789
Daily NOx [kg]	2,84484	1,17398	0,76463	0,89389	0,89084	0,85266	0,85522	1,1005	1,12893	0,95687	0,19051	1,19536
Daily CO [kg]	0,09835	0,04261	0,02767	0,03134	0,03224	0,03085	0,03094	0,03912	0,04087	0,03467	0,00687	0,04342
Daily PM [kg]	0,030765	0,01279	0,00835	0,00976	0,00971	0,00933	0,00935	0,01204	0,01227	0,01044	0,00203	0,01297
Daily SOx [kg]	0,04072	0,01796	0,01126	0,01313	0,01309	0,01233	0,01238	0,01738	0,01685	0,01421	0,00282	0,01875
Daily NH3 [kg]	0,00964	0,00412	0,00267	0,00313	0,00312	0,00298	0,00299	0,00388	0,00395	0,00335	0,00067	0,0042

Ciclo urbano breve											20°C	0°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	401,45585	175,94634	110,33659	128,69572	128,24844	120,83164	121,27028	170,30283	165,13267	139,25188	27,60718	183,69516
Daily NOx [kg]	2,87799	1,19016	0,77516	0,90621	0,90312	0,86441	0,86701	1,11567	1,14449	0,97006	0,1914	1,2009
Daily CO [kg]	0,10259	0,04397	0,02858	0,03341	0,0333	0,03189	0,03198	0,04138	0,0422	0,0358	0,0071	0,04489
Daily PM [kg]	0,05907	0,02558	0,01669	0,01952	0,01941	0,01866	0,01871	0,02408	0,02455	0,02088	0,00407	0,026
Daily SOx [kg]	0,04093	0,01794	0,01125	0,01312	0,01308	0,01232	0,01237	0,01737	0,01684	0,0142	0,00281	0,01868
Daily NH3 [kg]	0,00964	0,00412	0,00267	0,00313	0,00312	0,00298	0,00299	0,00388	0,00395	0,00335	0,00067	0,0042

Ciclo urbano breve											20°C	0°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	398,73355	174,75323	109,58839	127,82303	127,37878	120,01227	120,44793	169,14799	164,01289	138,3076	27,41998	182,44956
Daily NOx [kg]	2,84484	1,21443	0,79097	0,92469	0,92153	0,88204	0,88469	1,13842	1,16782	0,98984	0,19707	1,23652
Daily CO [kg]	0,1098	0,04706	0,03059	0,03576	0,03564	0,03414	0,03423	0,04429	0,04517	0,03832	0,00759	0,04799
Daily PM [kg]	0,30765	0,13324	0,08695	0,10166	0,10111	0,09717	0,09742	0,12542	0,12785	0,10873	0,02119	0,13539
Daily SOx [kg]	0,04072	0,01785	0,01119	0,01306	0,01301	0,01226	0,0123	0,01728	0,01675	0,01413	0,0028	0,01862
Daily NH3 [kg]	0,00964	0,00412	0,00267	0,00313	0,00312	0,00298	0,00299	0,00388	0,00395	0,00335	0,00067	0,0042

Ciclo urbano breve											20°C	1°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	150,67928	66,00187	41,40484	48,29402	48,12954	45,33913	45,50123	63,85208	61,95956	52,25741	10,36022	68,93577
Daily Nox [kg]	2,78413	1,18904	0,77387	0,90466	0,90158	0,82661	0,8652	1,11521	1,1429	0,96863	0,19285	1,21003
Daily CO [kg]	0,1098	0,04191	0,02724	0,03185	0,03174	0,0304	0,03048	0,03944	0,0422	0,03413	0,00676	0,04274
Daily PM [kg]	0,03	0,013	0,00847	0,00991	0,00985	0,00946	0,00949	0,01224	0,01247	0,0106	0,00207	0,0132

Daily SOx [kg]	0,04215	0,01846	0,01158	0,01351	0,01346	0,01268	0,01273	0,01786	0,01733	0,01462	0,0029	0,01926
Daily NH3 [kg]	0,00979	0,00419	0,00272	0,00318	0,00317	0,00303	0,00304	0,00394	0,00402	0,00341	0,00068	0,00428

Ciclo urbano breve											20°C	1°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	413,03456	180,92107	113,49691	132,38117	191,93032	124,28137	124,72571	175,02816	169,84049	143,24541	28,398919	188,963306
Daily Nox [kg]	2,8225	1,20543	0,78454	0,91712	0,914	0,87449	0,87712	1,13058	1,15866	0,98198	0,195505	1,226702
Daily CO [kg]	0,10423	0,0447	0,02903	0,03394	0,03382	0,03237	0,03246	0,04209	0,04288	0,03638	0,007206	0,045558
Daily PM [kg]	0,06	0,026	0,01695	0,01982	0,01971	0,01893	0,01898	0,02449	0,02493	0,0212	0,004132	0,026397
Daily SOx [kg]	0,04211	0,01845	0,01157	0,0135	0,01345	0,01267	0,01272	0,01785	0,01732	0,01461	0,002895	0,019249
Daily NH3 [kg]	0,00979	0,00419	0,00272	0,00318	0,00317	0,00303	0,00304	0,00394	0,00402	0,00341	0,00068	0,00428

Ciclo urbano breve											20°C	1°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	410,23374	179,69423	112,72728	131,48349	131,03569	123,43861	123,87993	173,84128	168,68879	142,27405	28,20634	187,68193
Daily Nox [kg]	2,88006	1,23001	0,80054	0,93583	0,93264	0,82933	0,89501	1,15363	1,18228	1,002	0,19949	1,25171
Daily CO [kg]	0,11156	0,04785	0,03107	0,03632	0,0362	0,03464	0,03474	0,04505	0,04589	0,03893	0,00771	0,04875
Daily PM [kg]	0,31252	0,13541	0,08827	0,1032	0,10265	0,09858	0,09883	0,12753	0,12985	0,11042	0,02152	0,13749
Daily SOx [kg]	0,0419	0,01835	0,01151	0,01343	0,01337	0,01261	0,01265	0,01776	0,01723	0,01453	0,00288	0,01914
Daily NH3 [kg]	0,00979	0,00419	0,00272	0,00318	0,00317	0,00303	0,00304	0,00394	0,00402	0,00341	0,00068	0,00428

Ciclo urbano breve											20°C	2°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	154,83899	67,78856	42,54009	49,6179	49,45219	46,57828	46,74239	65,54872	63,65059	53,69199	10,64463	70,8282
Daily NOx [kg]	2,81817	1,2041	0,78312	0,91542	0,91231	0,87255	0,87517	1,12991	1,15688	0,98039	0,19519	1,22472
Daily CO [kg]	0,10092	0,04331	0,0281	0,03284	0,03273	0,0313	0,03139	0,0408	0,04151	0,03521	0,00697	0,04409
Daily PM [kg]	0,03047	0,01321	0,0086	0,01006	0,01	0,0096	0,00962	0,01245	0,01266	0,01076	0,0021	0,0134
Daily SOx [kg]	0,04333	0,01897	0,01191	0,01389	0,01384	0,01304	0,01308	0,01834	0,01781	0,01503	0,00298	0,0198
Daily NH3 [kg]	0,00995	0,00426	0,00276	0,00322	0,00322	0,00309	0,00308	0,00401	0,00408	0,00346	0,00069	0,00434

Ciclo urbano breve											20°C	2°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	424,6098	185,89431	116,65628	136,06552	135,6111	127,73007	128,1801	179,75207	174,54689	147,23775	29,19041	194,22983
Daily Nox [kg]	2,85701	1,22069	0,79391	0,92804	0,92488	0,88457	0,88723	1,14548	1,17282	0,9939	0,1978	1,241

Daily CO [kg]	0,10588	0,04544	0,02948	0,03446	0,03434	0,03284	0,03293	0,04281	0,04356	0,03695	0,007319	0,046272
Daily PM [kg]	0,06094	0,02641	0,0172	0,02011	0,02	0,0192	0,01925	0,02489	0,02532	0,02152	0,004194	0,026796
Daily SOx [kg]	0,04329	0,01896	0,0119	0,01387	0,01383	0,01302	0,01307	0,01833	0,0178	0,01501	0,002974	0,019776
Daily NH3 [kg]	0,00995	0,00426	0,00276	0,00322	0,00322	0,00309	0,00308	0,00401	0,00408	0,00346	0,00069	0,00434

Ciclo urbano breve											20°C	2°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	421,73049	184,63374	115,86523	135,14285	134,69151	126,86392	127,3109	178,53316	173,36328	146,23932	28,99247	192,91275
Daily Nox [kg]	2,91527	1,24559	0,8101	0,94696	0,94374	0,90261	0,90532	1,16884	1,19674	1,01417	0,20191	1,26691
Daily CO [kg]	0,11333	0,04863	0,03155	0,03688	0,03675	0,03515	0,03525	0,04582	0,04662	0,03954	0,00783	0,04952
Daily PM [kg]	0,31739	0,13758	0,0896	0,10475	0,10418	0,09998	0,10024	0,12965	0,13186	0,1121	0,02185	0,13958
Daily SOx [kg]	0,04307	0,01886	0,01183	0,0138	0,01376	0,01296	0,013	0,01823	0,01771	0,01494	0,00296	0,01968
Daily NH3 [kg]	0,00995	0,00426	0,00276	0,00322	0,00322	0,00309	0,00308	0,00401	0,00408	0,00346	0,00069	0,00434

Ciclo urbano breve											20°C	3°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	159,07461	69,60851	43,6962	50,96611	50,79909	47,84028	48,00648	67,27755	65,37284	55,1529	10,93426	72,75535
Daily Nox [kg]	2,85218	1,21915	0,79236	0,92618	0,92304	0,88248	0,88514	1,14461	1,17084	0,99214	0,19753	1,23939
Daily CO [kg]	0,10249	0,04401	0,02852	0,03334	0,03323	0,03176	0,03184	0,04148	0,04216	0,03576	0,00708	0,04478
Daily PM [kg]	0,03094	0,01342	0,00873	0,0102	0,01015	0,00973	0,00976	0,01265	0,01285	0,01092	0,00213	0,0136
Daily SOx [kg]	0,04451	0,01948	0,01223	0,01426	0,01421	0,01339	0,01343	0,01883	0,01829	0,01543	0,00306	0,02033
Daily NH3 [kg]	0,01011	0,00433	0,0028	0,00327	0,00327	0,00312	0,00313	0,00408	0,00415	0,00351	0,0007	0,0044

Ciclo urbano breve											20°C	3°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	436,1781	190,86457	119,81376	139,74765	139,28967	131,1767	131,63242	184,47316	179,25048	151,2277	29,98144	199,49321
Daily Nox [kg]	2,89149	1,23595	0,80328	0,93894	0,93576	0,89464	0,89734	1,16038	1,18698	1,00581	0,20025	1,25647
Daily CO [kg]	0,10753	0,04617	0,02993	0,03498	0,03486	0,03332	0,03341	0,04352	0,04423	0,03752	0,00743	0,04699
Daily PM [kg]	0,06187	0,02683	0,01746	0,02041	0,0203	0,01947	0,01952	0,0253	0,0257	0,02185	0,00426	0,02721
Daily SOx [kg]	0,04447	0,01946	0,01222	0,01425	0,0142	0,01338	0,01342	0,01881	0,01828	0,01542	0,00306	0,02032
Daily NH3 [kg]	0,01011	0,00433	0,0028	0,00327	0,00327	0,00312	0,00313	0,00408	0,00415	0,00351	0,0007	0,0044

Ciclo urbano breve											20°C	3°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	433,22035	189,5703	119,00129	138,80001	138,34516	130,28718	130,73981	183,22223	178,03497	150,20221	28,39892	188,96331

Daily Nox [kg]	2,95045	1,26115	0,81966	0,95809	0,95484	0,91289	0,91563	1,18404	1,21118	1,02632	0,19551	1,2267
Daily CO [kg]	0,11509	0,04942	0,03203	0,03744	0,03731	0,03566	0,03576	0,04658	0,04734	0,04015	0,00721	0,04556
Daily PM [kg]	0,32226	0,13975	0,09092	0,10629	0,10572	0,10139	0,10165	0,13176	0,13386	0,11379	0,00413	0,264
Daily SOx [kg]	0,04425	0,01936	0,01215	0,01418	0,01413	0,01331	0,01335	0,01871	0,01818	0,01534	0,0029	0,01925
Daily NH3 [kg]	0,01011	0,00432	0,0028	0,00327	0,00327	0,00312	0,00313	0,00408	0,00415	0,00351	0,0007	0,0044

Ciclo urbano breve											25°C	0°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	143,07062	64,60028	40,87842	47,52612	47,42458	44,50956	44,7697	62,61698	60,67927	51,32302	9,92939	67,42443
Daily Nox [kg]	2,701	1,18514	0,77436	0,90397	0,90138	0,86108	0,86447	1,11236	1,13961	0,96704	0,19051	1,20706
Daily CO [kg]	0,09593	0,04243	0,02769	0,03231	0,03223	0,03078	0,0309	0,03999	0,04072	0,0346	0,00676	0,04328
Daily PM [kg]	0,02865	0,01295	0,00848	0,0099	0,00985	0,00944	0,00948	0,0122	0,01242	0,01058	0,00203	0,01313
Daily Sox [kg]	0,04059	0,01833	0,0116	0,01349	0,01346	0,01263	0,0127	0,01777	0,01722	0,01456	0,00282	0,01913
Daily NH3 [kg]	0,0095	0,00417	0,00272	0,00317	0,00317	0,00302	0,00303	0,00393	0,004	0,0034	0,00067	0,00426

Ciclo urbano breve											25°C	0°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	397,78652	179,61145	113,65635	132,13929	131,85695	123,7522	124,47546	174,09717	168,70967	142,696	27,60718	187,46357
Daily Nox [kg]	2,73823	1,20147	0,78503	0,91643	0,9138	0,87295	0,87638	1,12767	1,15531	0,98037	0,19314	1,2237
Daily CO [kg]	0,10065	0,04551	0,02905	0,0339	0,03381	0,0323	0,03242	0,04195	0,04272	0,0363	0,0071	0,04541
Daily PM [kg]	0,05729	0,02589	0,01696	0,0198	0,0197	0,01889	0,01896	0,02441	0,02484	0,02116	0,00407	0,02626
Daily Sox [kg]	0,04056	0,01831	0,01159	0,01347	0,01345	0,01262	0,01269	0,01775	0,0172	0,01455	0,00281	0,01912
Daily NH3 [kg]	0,0095	0,00417	0,00272	0,00317	0,00317	0,00302	0,00303	0,00393	0,004	0,0034	0,00067	0,00426

Ciclo urbano breve											25°C	0°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	395,0891	178,39349	112,88564	131,24324	130,96282	122,91303	123,63138	172,9166	167,56564	141,72837	27,41998	186,19237
Daily Nox [kg]	2,79407	1,22597	0,80104	0,93511	0,93244	0,89075	0,89425	1,15069	1,17887	1,00036	0,19707	1,24865
Daily CO [kg]	0,10772	0,04764	0,0311	0,03629	0,03619	0,03457	0,0347	0,0449	0,04572	0,03885	0,00759	0,0486
Daily PM [kg]	0,29841	0,13484	0,08834	0,10311	0,10262	0,09836	0,09873	0,12712	0,12938	0,11019	0,02119	0,13675
Daily Sox [kg]	0,04035	0,01822	0,01153	0,01341	0,01338	0,01255	0,01263	0,01766	0,01711	0,01448	0,0028	0,01902
Daily NH3 [kg]	0,0095	0,00417	0,00272	0,00317	0,00317	0,00302	0,00303	0,00393	0,004	0,0034	0,00067	0,00426

Ciclo urbano breve											25°C	1°

< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	146,84245	66,26602	41,93692	48,76077	48,65813	45,6652	45,9269	64,19687	62,25649	52,66121	10,19581	69,18245
Daily Nox [kg]	2,73413	1,2002	0,78361	0,91474	0,91212	0,87103	0,87445	1,12707	1,15359	0,9788	0,19284	1,22174
Daily CO [kg]	0,09746	0,04313	0,02812	0,03281	0,03272	0,03124	0,03136	0,04067	0,04136	0,03514	0,00687	0,04396
Daily PM [kg]	0,0291	0,01315	0,00861	0,01005	0,01	0,00958	0,00961	0,01241	0,01261	0,01047	0,00207	0,01299
Daily Sox [kg]	0,04147	0,01884	0,01192	0,01386	0,01383	0,01298	0,01306	0,01825	0,0177	0,01497	0,0029	0,01967
Daily NH3 [kg]	0,00965	0,00424	0,00276	0,00322	0,00322	0,00307	0,00308	0,004	0,00407	0,00345	0,00068	0,00432

Ciclo urbano breve											25°C	1°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	409,03447	184,58618	116,81667	135,82474	135,53884	127,4377	127,93089	178,8225	173,41749	146,68954	28,40076	192,70999
Daily Nox [kg]	2,77181	1,21674	0,79441	0,92734	0,92469	0,87103	0,8865	1,1426	1,16948	0,99229	0,19549	1,23858
Daily CO [kg]	0,10225	0,04525	0,0295	0,03442	0,03433	0,03124	0,0329	0,04267	0,0434	0,03687	0,00721	0,04612
Daily PM [kg]	0,05821	0,02631	0,01722	0,02009	0,02	0,00958	0,01923	0,02481	0,02523	0,02148	0,00413	0,02666
Daily Sox [kg]	0,04171	0,01882	0,01191	0,01385	0,01382	0,01298	0,01305	0,01823	0,01768	0,01496	0,0029	0,01966
Daily NH3 [kg]	0,00965	0,00424	0,00276	0,00322	0,00322	0,00307	0,00308	0,004	0,00407	0,00345	0,00068	0,00432

Ciclo urbano breve											25°C	1°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	406,26077	183,33449	116,02453	134,9037	134,61974	126,33936	126,82829	177,60989	172,24153	145,69482	28,20817	191,4032
Daily Nox [kg]	2,82834	1,24155	0,81061	0,94625	0,94354	0,90104	0,90457	1,1659	1,19333	1,01253	0,19948	1,26384
Daily CO [kg]	0,10944	0,04843	0,03158	0,03684	0,03675	0,03508	0,03521	0,04567	0,04645	0,03946	0,00771	0,04936
Daily PM [kg]	0,30317	0,13702	0,08967	0,10465	0,10416	0,09977	0,10014	0,12924	0,13139	0,11188	0,02152	0,13885
Daily Sox [kg]	0,04149	0,01873	0,01185	0,01378	0,01375	0,0129	0,01298	0,01814	0,01759	0,01488	0,00288	0,01955
Daily NH3 [kg]	0,00965	0,00424	0,00276	0,00322	0,00322	0,00307	0,00308	0,004	0,00407	0,00345	0,00068	0,00432

Ciclo urbano breve											25°C	2°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	151,00771	68,10936	43,10781	50,12609	50,02209	46,94322	47,20719	65,94886	64,00053	54,14052	10,48222	71,12586
Daily Nox [kg]	2,76725	1,21526	0,79285	0,9255	0,92285	0,88097	0,88442	1,14177	1,16756	0,99056	0,19515	1,23642
Daily CO [kg]	0,09899	0,04383	0,02855	0,03331	0,03322	0,03169	0,03181	0,04135	0,04201	0,03569	0,00697	0,04464
Daily PM [kg]	0,02956	0,01336	0,00874	0,01019	0,01015	0,00971	0,00975	0,01261	0,01281	0,0109	0,0021	0,01353
Daily Sox [kg]	0,04289	0,01934	0,01224	0,01424	0,01421	0,01333	0,01341	0,01873	0,01818	0,01538	0,00298	0,02021
Daily NH3 [kg]	0,0098	0,00431	0,0028	0,00327	0,00326	0,00311	0,00312	0,00407	0,00413	0,00351	0,00069	0,0044

Ciclo urbano breve											25°C	2°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	420,27904	189,55942	119,97605	139,50908	139,21961	130,65063	131,38528	183,54641	178,1239	150,68188	29,17372	197,95484
Daily Nox [kg]	2,80539	1,23201	0,80378	0,93825	0,93557	0,89311	0,89661	1,15751	1,18365	1,00421	0,19784	1,25346
Daily CO [kg]	0,10386	0,04598	0,02995	0,03495	0,03485	0,03325	0,03338	0,04339	0,04408	0,03744	0,00732	0,04683
Daily PM [kg]	0,05912	0,02672	0,01747	0,02039	0,02029	0,01943	0,0195	0,02522	0,02561	0,0218	0,00419	0,02705
Daily Sox [kg]	0,04285	0,01933	0,01223	0,01423	0,0142	0,01332	0,0134	0,01872	0,01816	0,01536	0,00297	0,02018
Daily NH3 [kg]	0,0098	0,00431	0,0028	0,00327	0,00326	0,00311	0,00312	0,00407	0,00413	0,00351	0,00069	0,0044

Ciclo urbano breve											25°C	2°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	417,4291	188,274	119,16248	138,56306	138,27555	129,76467	130,49435	182,3017	176,91602	149,66009	28,97589	196,61248
Daily Nox [kg]	2,86259	1,25713	0,82017	0,95739	0,95465	0,91132	0,91489	1,18111	1,20779	1,02469	0,20188	1,27902
Daily CO [kg]	0,11116	0,04921	0,03206	0,0374	0,0373	0,03558	0,03572	0,04644	0,04717	0,04007	0,00783	0,05012
Daily PM [kg]	0,30792	0,13919	0,091	0,10619	0,10569	0,10117	0,10155	0,13125	0,13339	0,11357	0,02185	0,14094
Daily Sox [kg]	0,04263	0,01923	0,01217	0,01415	0,01412	0,01325	0,01333	0,01862	0,01807	0,01529	0,00296	0,02009
Daily NH3 [kg]	0,0098	0,00431	0,0028	0,00327	0,00326	0,00311	0,00312	0,00407	0,00413	0,00351	0,00069	0,0044

Ciclo urbano breve											25°C	3°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	155,01124	69,87974	44,23252	51,43773	51,33246	48,17096	48,43691	67,63021	65,67603	55,56184	10,7574	72,99308
Daily Nox [kg]	2,80035	1,23031	0,80209	0,93626	0,93358	0,8909	0,89439	1,15647	1,18152	1,00231	0,19747	1,25108
Daily CO [kg]	0,10053	0,04453	0,02897	0,0338	0,03371	0,03214	0,03227	0,04203	0,04266	0,03623	0,00708	0,04532
Daily PM [kg]	0,03002	0,01357	0,00886	0,01034	0,01029	0,00985	0,00988	0,01281	0,013	0,01106	0,00213	0,01373
Daily Sox [kg]	0,04403	0,01985	0,01257	0,01461	0,01458	0,01368	0,01376	0,01921	0,01866	0,01578	0,00305	0,02073
Daily NH3 [kg]	0,00996	0,00438	0,00285	0,00323	0,00331	0,00315	0,00317	0,00413	0,00419	0,00356	0,0007	0,00446

Ciclo urbano breve											25°C	3°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	431,51688	194,52968	123,13353	143,19121	142,89818	134,09726	134,8376	188,2675	182,82748	154,67182	29,94622	203,19653
Daily Nox [kg]	2,83894	1,24726	0,81315	0,94916	0,94644	0,90318	0,90671	1,17241	1,19781	1,01613	0,20019	1,26833
Daily CO [kg]	0,10547	0,04672	0,0304	0,03547	0,03537	0,03372	0,03385	0,0441	0,04475	0,03801	0,00743	0,04755
Daily PM [kg]	0,06003	0,02714	0,01773	0,02068	0,02059	0,01969	0,01977	0,02562	0,026	0,02213	0,00426	0,02746
Daily Sox [kg]	0,044	0,01984	0,01256	0,0146	0,01457	0,01367	0,01375	0,0192	0,01864	0,01577	0,00305	0,02072

Daily NH3 [kg]	0,00996	0,00438	0,00285	0,00323	0,00331	0,00315	0,00317	0,00413	0,00419	0,00356	0,0007	0,00446

Ciclo urbano breve											25°C	3°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	428,59072	193,21056	122,29855	142,22022	141,92918	133,18793	133,92326	186,99084	181,58771	153,62298	29,74315	201,81864
Daily Nox [kg]	2,89683	1,2727	0,82973	0,96852	0,96574	0,9216	0,9522	1,19632	1,22223	1,03685	0,20427	1,2942
Daily CO [kg]	0,11288	0,05	0,03254	0,03796	0,03786	0,03609	0,03623	0,0472	0,0479	0,04068	0,00795	0,05089
Daily PM [kg]	0,31267	0,14135	0,09232	0,10773	0,10723	0,10258	0,10296	0,13346	0,13539	0,11525	0,02217	0,14303
Daily Sox [kg]	0,04377	0,01973	0,01249	0,01453	0,0145	0,0136	0,01368	0,0191	0,01855	0,01569	0,00304	0,02061
Daily NH3 [kg]	0,00996	0,00438	0,00285	0,00323	0,00331	0,00315	0,00317	0,00413	0,00419	0,00356	0,0007	0,00446

Ciclo urbano breve											30°C	0°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	149,37738	68,62913	43,60381	50,264	50,39259	47,28233	47,47503	66,35391	64,42429	54,49154	10,55232	71,5968
Daily Nox [kg]	2,75228	1,21887	0,79644	0,9258	0,92501	0,88277	0,91144	1,14563	1,17036	0,99275	0,1956	1,23923
Daily CO [kg]	0,09832	0,04399	0,02872	0,03332	0,03332	0,03177	0,03186	0,04153	0,04214	0,03578	0,00699	0,04477
Daily PM [kg]	0,02936	0,01341	0,00879	0,0102	0,01018	0,00974	0,00976	0,01266	0,01285	0,01093	0,0021	0,01357
Daily Sox [kg]	0,04236	0,01946	0,01237	0,01426	0,0143	0,01341	0,01347	0,01882	0,01828	0,01546	0,003	0,02031
Daily NH3 [kg]	0,00974	0,00432	0,00282	0,00318	0,00327	0,00311	0,00313	0,00407	0,00413	0,00351	0,00069	0,0044

Ciclo urbano breve											30°C	0°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	415,1593	190,73854	121,18654	139,69697	140,05435	131,41013	131,94568	184,41509	179,05219	151,44643	29,32768	198,98646
Daily Nox [kg]	2,79021	1,23566	0,80742	0,93856	0,93776	0,89494	0,924	1,16142	1,18649	1,00643	0,19829	1,25631
Daily CO [kg]	0,10315	0,04616	0,03013	0,03496	0,03496	0,03333	0,03343	0,04357	0,04421	0,03754	0,00734	0,04697
Daily PM [kg]	0,05872	0,02682	0,01757	0,02039	0,02035	0,01947	0,01952	0,02532	0,02569	0,02186	0,00421	0,02713
Daily Sox [kg]	0,04233	0,01945	0,01236	0,01425	0,01429	0,0134	0,01346	0,01881	0,01827	0,01545	0,00299	0,02029
Daily NH3 [kg]	0,00974	0,00432	0,00282	0,00318	0,00327	0,00311	0,00313	0,00407	0,00413	0,00351	0,00069	0,0044

Ciclo urbano breve											30°C	0°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	412,34407	189,44513	110,36476	134,90719	133,96822	124,09318	126,0775	175,58714	170,21748	144,29383	27,91565	189,38757
Daily Nox [kg]	2,84711	1,26086	0,82388	0,9577	0,95688	0,91318	0,94284	1,1851	1,21068	1,02695	0,20234	1,28192
Daily CO [kg]	0,1104	0,0494	0,03225	0,03742	0,03742	0,03567	0,03577	0,04663	0,04732	0,04018	0,00785	0,05027
Daily PM [kg]	0,30582	0,13971	0,09152	0,10622	0,106	0,10141	0,10169	0,1319	0,13379	0,11387	0,02191	0,14134

Daily Sox [kg]	0,04211	0,01935	0,01229	0,01418	0,01421	0,01333	0,01339	0,01871	0,01817	0,01536	0,00298	0,02018
Daily NH3 [kg]	0,00974	0,00432	0,00282	0,00318	0,00327	0,00311	0,00313	0,00407	0,00413	0,00351	0,00069	0,0044

Ciclo urbano breve											30°C	1°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	152,78248	70,12442	44,5537	51,46142	51,5916	48,40694	48,60904	67,93686	65,96193	55,79251	10,80417	73,30584
Daily Nox [kg]	2,78541	1,23393	0,80569	0,93691	0,9361	0,89325	0,92234	1,15931	1,18431	1,0046	0,19793	1,25401
Daily CO [kg]	0,09985	0,04469	0,02914	0,03383	0,03383	0,03224	0,03234	0,04216	0,04278	0,03633	0,0071	0,04545
Daily PM [kg]	0,02981	0,01362	0,00891	0,01035	0,01033	0,00988	0,00991	0,01285	0,01303	0,01109	0,00213	0,01377
Daily Sox [kg]	0,04351	0,01997	0,01269	0,01464	0,01467	0,01376	0,01382	0,01932	0,01876	0,01586	0,00307	0,02084
Daily NH3 [kg]	0,00989	0,00439	0,00286	0,00323	0,00332	0,00316	0,00317	0,00414	0,0042	0,00356	0,0007	0,00447

Ciclo urbano breve											30°C	1°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	426,40724	195,71327	124,34686	143,62589	143,98922	135,10101	135,66506	189,60793	184,096	155,71372	30,15381	204,59245
Daily Nox [kg]	2,8238	1,25093	0,81679	0,94982	0,949	0,90555	0,93505	1,17528	1,20063	1,01844	0,20066	1,27129
Daily CO [kg]	0,10476	0,04689	0,03058	0,0355	0,0355	0,03384	0,03394	0,04424	0,04489	0,03812	0,00745	0,04769
Daily PM [kg]	0,05963	0,02724	0,01783	0,0207	0,02066	0,01976	0,01982	0,02571	0,02608	0,02219	0,00427	0,02755
Daily Sox [kg]	0,04348	0,01996	0,01268	0,01463	0,01466	0,01375	0,01381	0,0193	0,01874	0,01585	0,00307	0,02082
Daily NH3 [kg]	0,00989	0,00439	0,00286	0,00323	0,00332	0,00316	0,00317	0,00414	0,0042	0,00356	0,0007	0,00447

Ciclo urbano breve											30°C	1°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	423,51574	194,38612	123,50365	142,65195	143,01282	134,18488	134,7451	188,32218	182,84762	154,65781	29,94934	203,20509
Daily Nox [kg]	2,88138	1,27644	0,83345	0,96919	0,96835	0,92402	0,95411	1,19925	1,22512	1,03921	0,20475	1,29722
Daily CO [kg]	0,11213	0,05019	0,03273	0,038	0,03799	0,03621	0,03633	0,04735	0,04805	0,0408	0,00797	0,05105
Daily PM [kg]	0,31057	0,14188	0,09284	0,10783	0,1076	0,10292	0,10322	0,13387	0,13579	0,11558	0,02224	0,14345
Daily Sox [kg]	0,04325	0,01985	0,01261	0,01455	0,01458	0,01367	0,01374	0,0192	0,01864	0,01576	0,00305	0,02071
Daily NH3 [kg]	0,00989	0,00439	0,00286	0,00323	0,00332	0,00316	0,00317	0,00414	0,0042	0,00356	0,0007	0,00447

Ciclo urbano breve											30°C	2°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	156,89463	71,94449	45,70995	52,81351	52,93608	49,67013	49,87983	69,70998	67,68436	57,24972	11,08626	75,22013
Daily Nox [kg]	2,81853	1,24899	0,81493	0,94802	0,94719	0,90372	0,93323	1,17298	1,19826	1,01644	0,20027	1,26879
Daily CO [kg]	0,10138	0,04539	0,02957	0,03435	0,03434	0,03273	0,03284	0,0428	0,04343	0,03688	0,00721	0,04614

Daily PM [kg]	0,03027	0,01383	0,00904	0,01051	0,01048	0,01003	0,01006	0,01304	0,01323	0,01126	0,00217	0,01398
Daily Sox [kg]	0,04466	0,02048	0,01301	0,01501	0,01505	0,01411	0,01417	0,01981	0,01924	0,01627	0,00315	0,02137
Daily NH3 [kg]	0,01004	0,00446	0,00291	0,00328	0,00337	0,00321	0,00323	0,0042	0,00427	0,00362	0,00071	0,00454

Ciclo urbano breve											30°C	2°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	437,65182	200,68651	127,50623	147,32134	147,66327	138,553	139,13795	194,45343	188,80306	159,69599	30,92473	209,8238
Daily Nox [kg]	2,85737	1,2662	0,82616	0,96109	0,96024	0,91617	0,94609	1,18914	1,21477	1,03045	0,20303	1,28627
Daily CO [kg]	0,10637	0,04763	0,03102	0,03604	0,03603	0,03434	0,03445	0,04491	0,04556	0,03869	0,00756	0,04841
Daily PM [kg]	0,06054	0,02766	0,01808	0,02101	0,02097	0,02005	0,02011	0,02608	0,02646	0,02252	0,00433	0,02795
Daily Sox [kg]	0,04462	0,02046	0,013	0,015	0,01503	0,0141	0,01416	0,01979	0,01922	0,01625	0,00315	0,02135
Daily NH3 [kg]	0,01004	0,00446	0,00291	0,00328	0,00337	0,00321	0,00323	0,0042	0,00427	0,00362	0,00071	0,00454

Ciclo urbano breve											30°C	2°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	434,68407	199,32564	126,6416	146,32235	146,66195	137,61346	138,19444	193,13483	187,52277	158,61308	30,71503	208,40097
Daily Nox [kg]	2,91564	1,29202	0,84301	0,98068	0,97982	0,93486	0,96538	1,21339	1,23954	1,05146	0,20717	1,31251
Daily CO [kg]	0,11385	0,05097	0,03321	0,03857	0,03857	0,03676	0,03688	0,04807	0,04877	0,04142	0,00809	0,05182
Daily PM [kg]	0,31532	0,14405	0,09415	0,10943	0,10918	0,10442	0,10474	0,13584	0,13779	0,11728	0,02256	0,14556
Daily Sox [kg]	0,0444	0,02036	0,01294	0,01493	0,01496	0,01403	0,0141	0,0197	0,01913	0,01618	0,00313	0,02125
Daily NH3 [kg]	0,01004	0,00446	0,00291	0,00328	0,00337	0,00321	0,00323	0,0042	0,00427	0,00362	0,00071	0,00454

Ciclo urbano breve											30°C	3°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	160,9288	73,7288	46,84348	54,13934	54,25426	50,90863	51,12582	71,44845	69,37316	58,67848	11,36285	77,09703
Daily Nox [kg]	2,85162	1,26404	0,82417	0,95912	0,95827	0,91418	0,94411	1,18664	1,21219	1,02828	0,2026	1,28356
Daily CO [kg]	0,10292	0,04609	0,03	0,03487	0,03486	0,03322	0,03333	0,04344	0,04408	0,03743	0,00732	0,04683
Daily PM [kg]	0,03073	0,01404	0,00917	0,01066	0,01064	0,01017	0,01021	0,01324	0,01342	0,01143	0,0022	0,01418
Daily Sox [kg]	0,04581	0,02099	0,01333	0,01539	0,01542	0,01446	0,01453	0,0203	0,01971	0,01667	0,00323	0,0219
Daily NH3 [kg]	0,01019	0,00453	0,00295	0,00333	0,00342	0,00325	0,00327	0,00427	0,00433	0,00368	0,00072	0,00461

Ciclo urbano breve											30°C	3°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	448,88965	205,65676	130,66371	151,01455	151,33509	142,00291	142,60873	199,29602	193,50728	163,67586	31,69518	215,05199

Daily Nox [kg]	2,89092	1,28146	0,83553	0,97234	0,97148	0,92678	0,95712	1,20299	1,2289	1,04245	0,20539	1,30125
Daily CO [kg]	0,10798	0,04836	0,03147	0,03658	0,03657	0,03485	0,03496	0,04557	0,04624	0,03927	0,00768	0,04913
Daily PM [kg]	0,06145	0,02807	0,01833	0,02132	0,02127	0,02034	0,0204	0,02646	0,02684	0,02284	0,00439	0,02835
Daily Sox [kg]	0,04577	0,02097	0,01332	0,01538	0,01541	0,01445	0,01452	0,02028	0,0197	0,01666	0,00323	0,02188
Daily NH3 [kg]	0,01019	0,00453	0,00295	0,00333	0,00342	0,00325	0,00327	0,00427	0,00433	0,00368	0,00072	0,00461

Ciclo urbano breve											30°C	3°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	445,8457	204,26219	129,77767	149,99051	150,30888	141,03998	141,6417	197,94458	192,19509	162,56596	31,48025	213,59371
Daily Nox [kg]	2,94988	1,30759	0,85257	0,99217	0,99129	0,94569	0,97664	1,22753	1,25396	1,06371	0,20958	1,32779
Daily CO [kg]	0,11557	0,05176	0,03369	0,03915	0,03915	0,0373	0,03743	0,04878	0,0495	0,04204	0,00822	0,05259
Daily PM [kg]	0,32007	0,14621	0,09549	0,11105	0,11079	0,10594	0,10628	0,13783	0,1398	0,119	0,02289	0,14769
Daily Sox [kg]	0,04553	0,02086	0,01326	0,0153	0,01533	0,01438	0,01444	0,02019	0,0196	0,01658	0,00321	0,02178
Daily NH3 [kg]	0,01019	0,00453	0,00295	0,00333	0,00342	0,00325	0,00327	0,00427	0,00433	0,00368	0,00072	0,00461

Ciclo urbano lungo											20°C	0°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	27,38575	20,86505	17,59708	22,14432	22,18566	28,97542	22,97239	17,72612	237,62041	22,88962	10,23024	17,96489
Daily NOx [kg]	1,37525	0,93738	0,76151	0,75009	0,74814	0,75594	0,75836	0,87874	0,85397	0,76396	0,15299	0,95481
Daily CO [kg]	0,0489	0,03339	0,02705	0,02665	0,02659	0,02686	0,02694	0,03142	0,03036	0,02718	0,00547	0,03408
Daily PM [kg]	0,01478	0,0101	0,00819	0,00807	0,00805	0,00814	0,00816	0,0095	0,00919	0,00823	0,00168	0,01027
Daily SOx [kg]	0,02048	0,01435	0,01118	0,01101	0,01098	0,01094	0,01099	0,01389	0,01277	0,01135	0,00227	0,01499
Daily NH3 [kg]	0,00482	0,00329	0,00267	0,00263	0,00262	0,00265	0,00265	0,0031	0,00299	0,00268	0,00054	0,00336

Ciclo urbano lungo											20°C	0°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	200,73683	140,6172	109,5329	107,87763	107,55463	107,21427	107,71793	136,09972	125,15048	111,2643	22,22889	166,89203
Daily NOx [kg]	1,3942	0,9503	0,77201	0,76043	0,75845	0,76636	0,76881	0,89085	0,86574	0,77449	0,1551	0,96797
Daily CO [kg]	0,05131	0,03503	0,02838	0,02796	0,0279	0,02818	0,02826	0,03296	0,03186	0,02851	0,00574	0,03575
Daily PM [kg]	0,02956	0,02019	0,01638	0,01614	0,01611	0,01627	0,01632	0,019	0,01838	0,01646	0,00337	0,02054
Daily SOx [kg]	0,02047	0,01434	0,01117	0,011	0,01097	0,01093	0,01098	0,01388	0,01276	0,01135	0,00227	0,01498
Daily NH3 [kg]	0,00482	0,00329	0,00267	0,00263	0,00262	0,00265	0,00265	0,0031	0,00299	0,00268	0,00054	0,00336

Ciclo urbano lungo											20°C	0°

> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	199,37562	139,66366	108,79015	107,14611	106,82529	106,48725	106,98749	135,17681	124,30182	110,50981	22,07815	145,89594
Daily NOx [kg]	1,42264	0,96968	0,78775	0,77594	0,77391	0,78198	0,78449	0,90902	0,88339	0,79028	0,15826	0,98771
Daily CO [kg]	0,05492	0,03749	0,03037	0,02992	0,02986	0,03016	0,03025	0,03528	0,0341	0,03052	0,00614	0,03827
Daily PM [kg]	0,15398	0,10517	0,08533	0,08408	0,0839	0,08474	0,08499	0,09898	0,09571	0,08572	0,01754	0,10697
Daily SOx [kg]	0,02036	0,01426	0,01111	0,01094	0,01091	0,01088	0,01093	0,01381	0,0127	0,01129	0,00226	0,0149
Daily NH3 [kg]	0,00482	0,00329	0,00267	0,00263	0,00262	0,00265	0,00265	0,0031	0,00299	0,00268	0,00054	0,00336

Ciclo urbano lungo											20°C	1°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	77,62335	54,32021	42,34153	41,70153	41,58139	41,43951	41,63124	52,52271	48,36621	43,01472	8,59118	56,7037
Daily NOx [kg]	1,40929	0,96148	0,77983	0,76813	0,76613	0,77361	0,77613	0,90228	0,87519	0,78278	0,15671	0,98018
Daily CO [kg]	0,05048	0,03451	0,0279	0,02748	0,02742	0,02767	0,02775	0,03251	0,03135	0,02805	0,00564	0,03526
Daily PM [kg]	0,01525	0,01043	0,00844	0,00832	0,0083	0,00838	0,0084	0,00983	0,00948	0,00849	0,00173	0,01062
Daily SOx [kg]	0,02167	0,01516	0,01182	0,01164	0,01161	0,01157	0,01162	0,01466	0,0135	0,01201	0,0024	0,01583
Daily NH3 [kg]	0,00498	0,0034	0,00275	0,00271	0,0027	0,00273	0,00274	0,0032	0,00336	0,00276	0,00055	0,00348

Ciclo urbano lungo											20°C	1°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	212,31555	148,57676	115,81263	114,06212	113,73352	113,34545	113,86987	143,66025	132,29137	117,65396	23,49861	155,0961
Daily NOx [kg]	1,42872	0,97474	0,79058	0,77872	0,77669	0,78427	0,78682	0,91471	0,88726	0,79357	0,15887	0,99369
Daily CO [kg]	0,05296	0,0362	0,02927	0,02883	0,02877	0,02903	0,02911	0,03411	0,03289	0,02943	0,00592	0,03699
Daily PM [kg]	0,0305	0,02086	0,01689	0,01664	0,0166	0,01675	0,0168	0,01965	0,01896	0,01698	0,00347	0,02124
Daily SOx [kg]	0,02165	0,01515	0,01181	0,01163	0,0116	0,01156	0,01161	0,01465	0,01349	0,012	0,0024	0,01581
Daily NH3 [kg]	0,00498	0,0034	0,00275	0,00271	0,0027	0,00273	0,00274	0,0032	0,00336	0,00276	0,00055	0,00348

Ciclo urbano lungo											20°C	1°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	210,87582	147,56925	115,0273	113,28865	112,96228	112,57685	113,09771	142,68607	131,39429	116,85614	23,33926	154,04438
Daily NOx [kg]	1,45785	0,99461	0,8067	0,7946	0,79253	0,80027	0,80287	0,93336	0,90535	0,80975	0,16211	1,01395
Daily CO [kg]	0,05668	0,03875	0,03132	0,03086	0,03079	0,03107	0,03116	0,03651	0,0352	0,0315	0,00633	0,03959
Daily PM [kg]	0,15885	0,10864	0,08795	0,08666	0,08647	0,08724	0,0875	0,10237	0,09876	0,08842	0,01807	0,11062
Daily SOx [kg]	0,02154	0,01507	0,01175	0,01157	0,01154	0,0115	0,01155	0,01457	0,01342	0,01194	0,00238	0,01573
Daily NH3 [kg]	0,00498	0,0034	0,00275	0,00271	0,0027	0,00273	0,00274	0,0032	0,00336	0,00276	0,00055	0,00348

Ciclo urbano lungo											20°C	2°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	81,76237	57,16441	44,58605	43,53355	43,78997	43,63083	43,82992	55,22328	50,91829	45,29862	9,04497	59,63446
Daily NOx [kg]	1,44333	0,98558	0,79815	0,78617	0,78412	0,79128	0,79389	0,9258	0,89642	0,80159	0,16043	1,00554
Daily CO [kg]	0,05205	0,03563	0,02874	0,02831	0,02825	0,02847	0,02856	0,0336	0,03233	0,02892	0,00581	0,03643
Daily PM [kg]	0,01572	0,01076	0,00869	0,00857	0,00855	0,00861	0,00864	0,01015	0,00977	0,00875	0,00179	0,01097
Daily SOx [kg]	0,02285	0,01597	0,01246	0,01227	0,01224	0,01219	0,01225	0,01543	0,01423	0,01266	0,00253	0,01666
Daily NH3 [kg]	0,00513	0,00351	0,00283	0,00279	0,00278	0,00281	0,00282	0,00331	0,00319	0,00285	0,00057	0,0036

Ciclo urbano lungo											20°C	2°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	223,89079	156,53395	122,09048	120,24475	119,91055	119,47479	120,01996	151,21851	139,43012	124,0417	24,76794	163,2977
Daily NOx [kg]	1,46322	0,99916	0,80915	0,797	0,79492	0,80218	0,80483	0,93856	0,90877	0,81264	0,16265	1,0194
Daily CO [kg]	0,05461	0,03738	0,03015	0,0297	0,02964	0,02987	0,02996	0,03525	0,03392	0,03034	0,0061	0,03822
Daily PM [kg]	0,03143	0,02153	0,01739	0,01713	0,0171	0,01723	0,01728	0,0203	0,01955	0,0175	0,00357	0,02194
Daily SOx [kg]	0,02283	0,01596	0,01245	0,01226	0,01223	0,01218	0,01224	0,01542	0,01422	0,01265	0,00253	0,01665
Daily NH3 [kg]	0,00513	0,00351	0,00283	0,00279	0,00278	0,00281	0,00282	0,00331	0,00319	0,00285	0,00057	0,0036

Ciclo urbano lungo											20°C	2°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	222,37257	155,47248	121,26258	119,42936	119,09743	118,66462	119,2061	150,19308	138,48463	123,20056	24,59999	162,19037
Daily NOx [kg]	1,49306	1,01954	0,82565	0,81325	0,81113	0,81854	0,82124	0,9577	0,9273	0,82921	0,16596	1,04019
Daily CO [kg]	0,05844	0,04001	0,03227	0,03179	0,03172	0,03197	0,03207	0,03773	0,0363	0,03247	0,00653	0,04091
Daily PM [kg]	0,16372	0,11211	0,09057	0,08923	0,08904	0,08974	0,09001	0,10575	0,1018	0,09112	0,0186	0,11427
Daily SOx [kg]	0,02271	0,01588	0,01239	0,0122	0,01216	0,01212	0,01218	0,01534	0,01414	0,01258	0,00251	0,01656
Daily NH3 [kg]	0,00513	0,00351	0,00283	0,00279	0,00278	0,00281	0,00282	0,00331	0,00319	0,00285	0,00057	0,0036

Ciclo urbano lungo											20°C	3°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	85,88016	59,99392	46,81904	46,11113	45,9872	45,81088	46,01728	57,90979	53,45723	47,57078	9,49643	62,55
Daily NOx [kg]	1,47734	1,00966	0,81645	0,80419	0,80209	0,80894	0,81164	0,94931	0,91762	0,82039	0,16415	1,03089
Daily CO [kg]	0,05362	0,03675	0,02958	0,02914	0,02908	0,02928	0,02937	0,03469	0,03331	0,02979	0,00598	0,03761
Daily PM [kg]	0,01618	0,0111	0,00895	0,00881	0,00879	0,00885	0,00888	0,01048	0,01007	0,00901	0,00184	0,01132
Daily SOx [kg]	0,02403	0,01679	0,0131	0,0129	0,01287	0,01282	0,01288	0,0162	0,01496	0,01331	0,00266	0,0175
Daily NH3 [kg]	0,00529	0,00362	0,00292	0,00287	0,00287	0,00289	0,0029	0,00342	0,00329	0,00294	0,00059	0,00371

Ciclo urbano lungo											20°C	3°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	235,45909	164,48636	128,36457	126,42367	126,08389	125,60046	126,16637	158,77224	146,56459	130,42561	26,03652	171,49439
Daily NOx [kg]	1,4977	1,02357	0,8277	0,81527	0,81315	0,82008	0,82283	0,9624	0,93027	0,8317	0,16642	1,0451
Daily CO [kg]	0,05625	0,03855	0,03104	0,03057	0,03051	0,03072	0,03081	0,0364	0,03495	0,03125	0,00628	0,03946
Daily PM [kg]	0,03237	0,02219	0,01789	0,01763	0,01759	0,01771	0,01776	0,02095	0,02013	0,01801	0,00367	0,02264
Daily SOx [kg]	0,02401	0,01677	0,01309	0,01289	0,01286	0,01281	0,01286	0,01619	0,01494	0,0133	0,00266	0,01749
Daily NH3 [kg]	0,00529	0,00362	0,00292	0,00287	0,00287	0,00289	0,0029	0,00342	0,00329	0,00294	0,00059	0,00371

Ciclo urbano lungo											20°C	3°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	233,86242	163,37096	127,49412	125,56638	125,2289	124,74875	125,31082	157,69559	145,57072	129,54119	25,85996	170,33148
Daily NOx [kg]	1,52824	1,04444	0,84458	0,8319	0,82973	0,83681	0,83961	0,98202	0,94924	0,84866	0,16981	1,06641
Daily CO [kg]	0,06021	0,04126	0,03322	0,03272	0,03265	0,03288	0,03298	0,03896	0,0374	0,03345	0,00672	0,04223
Daily PM [kg]	0,16859	0,11558	0,09318	0,09181	0,09161	0,09223	0,09252	0,10913	0,10484	0,09382	0,01914	0,11792
Daily SOx [kg]	0,02389	0,01669	0,01302	0,01282	0,01279	0,01274	0,0128	0,01611	0,01487	0,01323	0,00264	0,0174
Daily NH3 [kg]	0,00529	0,00362	0,00292	0,00287	0,00287	0,00289	0,0029	0,00342	0,00329	0,00294	0,00059	0,00371

Ciclo urbano lungo											25°C	0°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	71,88248	50,21546	39,18797	38,59544	38,49171	38,34412	38,51689	48,47102	44,74419	39,81718	7,9486	52,35492
Daily NOx [kg]	1,3683	0,93513	0,75619	0,74484	0,74289	0,74923	0,75174	0,87925	0,8499	0,75984	0,15204	0,9548
Daily CO [kg]	0,05028	0,03446	0,02774	0,02732	0,02727	0,02746	0,02754	0,03253	0,03123	0,02793	0,00561	0,03527
Daily PM [kg]	0,01477	0,01013	0,00816	0,00804	0,00803	0,00808	0,00811	0,00956	0,00918	0,00822	0,00168	0,01033
Daily SOx [kg]	0,02025	0,01415	0,01104	0,01087	0,01084	0,0108	0,01085	0,01366	0,0126	0,01121	0,00224	0,01475
Daily NH3 [kg]	0,00475	0,00325	0,00262	0,00258	0,00258	0,00259	0,0026	0,00307	0,00295	0,00264	0,00053	0,00333

Ciclo urbano lungo											25°C	0°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	197,27529	137,81202	107,54802	105,92187	105,63718	105,23215	105,70629	133,02455	122,79658	109,27483	21,81424	143,68359
Daily NOx [kg]	1,3762	0,9542	0,77161	0,76002	0,75804	0,76451	0,76707	0,89717	0,86723	0,77534	0,15514	0,96427
Daily CO [kg]	0,05382	0,03688	0,02969	0,02925	0,02918	0,02939	0,02948	0,03483	0,03343	0,0299	0,00601	0,03775

Daily PM [kg]	0,02863	0,01963	0,01582	0,01559	0,01556	0,01566	0,01571	0,01853	0,0178	0,01593	0,00325	0,02003
Daily SOx [kg]	0,02015	0,01408	0,01098	0,01081	0,01079	0,01075	0,0108	0,01359	0,01254	0,01116	0,00223	0,01468
Daily NH3 [kg]	0,00475	0,00325	0,00262	0,00258	0,00258	0,00259	0,0026	0,00307	0,00295	0,00264	0,00053	0,00333

Ciclo urbano lungo											25°C	0°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	210,25912	146,88223	114,62638	112,8932	112,58978	112,15809	112,66343	141,77967	130,87854	116,46684	23,24996	153,14024
Daily NOx [kg]	1,38283	0,94506	0,76422	0,75275	0,75078	0,75719	0,75972	0,88858	0,85892	0,76791	0,15365	0,96494
Daily CO [kg]	0,05046	0,03589	0,02929	0,02888	0,02882	0,02801	0,02809	0,034	0,03072	0,02948	0,00552	0,03769
Daily PM [kg]	0,14909	0,10221	0,0824	0,08119	0,08101	0,08156	0,08182	0,09651	0,09271	0,08297	0,01693	0,10428
Daily SOx [kg]	0,0202	0,01326	0,01	0,01	0,01	0,01	0,01	0,014	0,013	0,01186	0,00237	0,0149
Daily NH3 [kg]	0,00475	0,00325	0,00262	0,00258	0,00258	0,00259	0,0026	0,00307	0,00295	0,00264	0,00053	0,00333

Ciclo urbano lungo											25°C	1°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	75,8338	52,97577	41,3421	40,717	40,60757	40,45187	40,63413	51,13543	47,20374	42,0059	8,38553	55,23283
Daily NOx [kg]	1,40189	0,95809	0,77475	0,76312	0,76113	0,76763	0,77019	0,90083	0,87076	0,7785	0,15577	0,97824
Daily CO [kg]	0,05189	0,03556	0,02863	0,0282	0,02814	0,02834	0,02842	0,03358	0,03223	0,02883	0,00579	0,03639
Daily PM [kg]	0,01523	0,01044	0,00842	0,00829	0,00828	0,00833	0,00836	0,00986	0,00947	0,00848	0,00173	0,01065
Daily SOx [kg]	0,0214	0,01495	0,01166	0,01148	0,01146	0,01141	0,01147	0,01443	0,01332	0,01185	0,00236	0,01559
Daily NH3 [kg]	0,0049	0,00335	0,0027	0,00266	0,00266	0,00268	0,00269	0,00317	0,00305	0,00272	0,00055	0,00344

Ciclo urbano lungo											25°C	1°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	208,44697	145,61631	113,63845	111,92021	111,61941	111,19144	111,69242	140,55772	129,75054	115,46305	23,04958	151,82038
Daily NOx [kg]	1,41047	0,97762	0,79055	0,77868	0,77665	0,78327	0,7859	0,91919	0,88851	0,79437	0,15895	0,98819
Daily CO [kg]	0,05554	0,03806	0,03064	0,03018	0,03012	0,03033	0,03042	0,03594	0,0345	0,03086	0,0062	0,03895
Daily PM [kg]	0,02954	0,02025	0,01633	0,01609	0,01605	0,01616	0,01621	0,01912	0,01837	0,01644	0,00335	0,02066
Daily SOx [kg]	0,02129	0,01487	0,0116	0,01142	0,0114	0,01135	0,01141	0,01436	0,01325	0,01179	0,00235	0,01551
Daily NH3 [kg]	0,0049	0,00335	0,0027	0,00266	0,00266	0,00268	0,00269	0,00317	0,00305	0,00272	0,00055	0,00344

Ciclo urbano lungo											25°C	1°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	221,52454	154,752	120,76791	118,94187	118,6222	118,16738	118,6998	149,37604	137,89085	122,70699	24,49567	161,3453
Daily NOx [kg]	1,41595	0,9677	0,78252	0,77077	0,76876	0,77532	0,77792	0,90986	0,87949	0,7863	0,15733	0,98805

Daily CO [kg]	0,05499	0,03794	0,02813	0,02771	0,02765	0,02785	0,02793	0,03499	0,03367	0,03033	0,006	0,03776
Daily PM [kg]	0,15384	0,10547	0,08503	0,08378	0,0836	0,08416	0,08443	0,09958	0,09567	0,08561	0,01747	0,1076
Daily SOx [kg]	0,021	0,015	0,0119	0,0118	0,0117	0,01198	0,012	0,0144	0,0136	0,01189	0,0024	0,0148
Daily NH3 [kg]	0,0049	0,00335	0,0027	0,00266	0,00266	0,00268	0,00269	0,00317	0,00305	0,00272	0,00055	0,00344

Ciclo urbano lungo											25°C	2°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	79,8879	55,80787	43,55226	42,89374	42,77846	42,61444	42,80644	53,86915	49,72727	44,25155	8,83382	58,1856
Daily NOx [kg]	1,43546	0,98103	0,79331	0,7814	0,77936	0,78601	0,78864	0,9224	0,89161	0,79714	0,1595	1,00167
Daily CO [kg]	0,0535	0,03666	0,02952	0,02907	0,02901	0,02922	0,0293	0,03462	0,03323	0,02972	0,00597	0,03752
Daily PM [kg]	0,01568	0,01075	0,00867	0,00854	0,00852	0,00858	0,0086	0,01015	0,00975	0,00873	0,00178	0,01097
Daily SOx [kg]	0,0225	0,01572	0,01226	0,01207	0,01205	0,012	0,01206	0,01517	0,014	0,01246	0,00249	0,01639
Daily NH3 [kg]	0,00505	0,00346	0,00279	0,00274	0,00274	0,00276	0,00277	0,00326	0,00314	0,00281	0,00056	0,00354

Ciclo urbano lungo											25°C	2°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	219,61529	153,41824	119,72705	117,91675	117,59983	117,14893	117,67676	148,08862	136,70241	121,64941	24,28455	159,95472
Daily NOx [kg]	1,44473	1,00104	0,80948	0,79733	0,79525	0,80203	0,80472	0,93121	0,90979	0,80339	0,15875	1,02209
Daily CO [kg]	0,05726	0,03924	0,03159	0,03112	0,03105	0,03127	0,03136	0,03705	0,03557	0,03181	0,00639	0,04016
Daily PM [kg]	0,03045	0,02088	0,01683	0,01658	0,01655	0,01666	0,01671	0,01971	0,01894	0,01695	0,00346	0,0213
Daily SOx [kg]	0,02243	0,01567	0,01222	0,01204	0,01201	0,01196	0,01202	0,01513	0,01396	0,01242	0,00248	0,01634
Daily NH3 [kg]	0,00505	0,00346	0,00279	0,00274	0,00274	0,00276	0,00277	0,00326	0,00314	0,00281	0,00056	0,00354

Ciclo urbano lungo											25°C	2°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	232,7832	162,61704	126,90576	124,98692	124,651	124,17306	124,73254	156,96786	144,89895	128,94339	25,74062	169,54544
Daily NOx [kg]	1,44904	0,99031	0,80081	0,78879	0,78673	0,79344	0,7961	0,93113	0,90005	0,80468	0,16101	1,01114
Daily CO [kg]	0,05553	0,038	0,03098	0,03055	0,03049	0,03069	0,03077	0,03699	0,03463	0,03018	0,00586	0,03884
Daily PM [kg]	0,1586	0,10873	0,08766	0,08637	0,08618	0,08676	0,08704	0,10266	0,09863	0,08826	0,01801	0,11093
Daily SOx [kg]	0,0218	0,01589	0,0129	0,01234	0,0126	0,012	0,01204	0,01569	0,014	0,01282	0,00262	0,0165
Daily NH3 [kg]	0,00505	0,00346	0,00279	0,00274	0,00274	0,00276	0,00277	0,00326	0,00314	0,00281	0,00056	0,00354

Ciclo urbano lungo											25°C	3°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	84,00245	58,6822	45,79538	45,10295	44,98173	44,80926	45,01115	56,64363	52,28842	46,53068	9,2888	61,18239

Daily NOx [kg]	1,46901	1,00396	0,81185	0,79966	0,79757	0,80438	0,80707	0,94396	0,91245	0,81577	0,16323	1,02508
Daily CO [kg]	0,05511	0,03777	0,03041	0,02995	0,02988	0,03009	0,03019	0,03566	0,03423	0,03062	0,00615	0,03865
Daily PM [kg]	0,016335	0,011199	0,009028	0,008896	0,008876	0,008936	0,008964	0,010574	0,010158	0,00909	0,001855	0,011425
Daily SOx [kg]	0,02369	0,01655	0,01291	0,01271	0,01268	0,01263	0,01269	0,01598	0,01475	0,01312	0,00262	0,01725
Daily NH3 [kg]	0,0052	0,00356	0,00287	0,00282	0,00282	0,00284	0,00285	0,00336	0,00323	0,00289	0,00058	0,00365

Ciclo urbano lungo											25°C	3°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	230,77692	161,2155	125,81201	123,9097	123,57667	123,10286	123,65751	155,61501	143,65011	127,83207	25,51877	168,08419
Daily NOx [kg]	1,47897	1,02444	0,8284	0,81597	0,81384	0,82078	0,82353	0,96321	0,93106	0,83241	0,16656	1,02799
Daily CO [kg]	0,05898	0,04042	0,03254	0,03205	0,03198	0,03221	0,03231	0,03816	0,03664	0,03277	0,00658	0,04137
Daily PM [kg]	0,03136	0,0215	0,01733	0,01708	0,01704	0,01716	0,01721	0,0203	0,0195	0,01745	0,00356	0,02193
Daily SOx [kg]	0,02357	0,01647	0,01285	0,01265	0,01262	0,01257	0,01263	0,01589	0,01467	0,01305	0,0026	0,01717
Daily NH3 [kg]	0,0052	0,00356	0,00287	0,00282	0,00282	0,00284	0,00285	0,00336	0,00323	0,00289	0,00058	0,00365

Ciclo urbano lungo											25°C	3°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	233,86242	163,37096	127,49412	125,56638	125,2289	124,74875	125,31082	157,69559	145,57072	129,54119	25,85996	170,33148
Daily NOx [kg]	1,52824	1,04444	0,84458	0,8319	0,82973	0,83681	0,83961	0,98202	0,94924	0,84866	0,16981	1,06641
Daily CO [kg]	0,06021	0,04126	0,03322	0,03272	0,03265	0,03288	0,03298	0,03896	0,0374	0,03345	0,00672	0,04223
Daily PM [kg]	0,16859	0,11558	0,09318	0,09181	0,09161	0,09223	0,09252	0,10913	0,10484	0,09382	0,01914	0,11792
Daily SOx [kg]	0,02289	0,01669	0,01189	0,01182	0,01179	0,01274	0,0128	0,0159	0,01487	0,01223	0,00264	0,0174
Daily NH3 [kg]	0,00529	0,00362	0,00292	0,00287	0,00287	0,00289	0,0029	0,00342	0,00329	0,00294	0,00059	0,00371

Ciclo urbano lungo											30°C	0°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	74,69615	54,74292	34,7276	38,79464	38,25437	36,8765	38,01258	47,54144	43,69201	39,07676	7,78621	51,26348
Daily NOx [kg]	1,3729	0,96988	0,63345	0,7146	0,70185	0,68476	0,70616	0,82006	0,78927	0,70937	0,14165	0,8892
Daily CO [kg]	0,04901	0,0349	0,02276	0,02558	0,02517	0,02452	0,02527	0,02965	0,02834	0,02548	0,00511	0,03209
Daily PM [kg]	0,01463	0,01055	0,00689	0,00771	0,00761	0,00741	0,00763	0,00894	0,00855	0,00769	0,00157	0,00965
Daily SOx [kg]	0,02107	0,01544	0,0098	0,01094	0,01079	0,0104	0,01072	0,01341	0,01233	0,01102	0,0022	0,01446
Daily NH3 [kg]	0,00485	0,00344	0,00224	0,00252	0,00248	0,00242	0,00249	0,00292	0,0028	0,00251	0,0005	0,00316

Ciclo urbano lungo	30°C	0°

80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	206,48285	151,32607	95,99763	107,24016	105,74669	101,93786	105,0783	131,41898	120,77799	108,02002	21,52345	141,70785
Daily NOx [kg]	1,39182	0,98325	0,62418	0,71768	0,70266	0,68267	0,70673	0,81976	0,78858	0,70926	0,14158	0,88876
Daily CO [kg]	0,05142	0,03661	0,02387	0,02683	0,0264	0,02572	0,0265	0,0311	0,02972	0,02672	0,00536	0,03365
Daily PM [kg]	0,02927	0,02109	0,01378	0,01542	0,01522	0,01482	0,01526	0,01789	0,01711	0,01539	0,00313	0,01929
Daily SOx [kg]	0,02105	0,01543	0,00979	0,01093	0,01078	0,01039	0,01071	0,0134	0,01232	0,01101	0,00219	0,01445
Daily NH3 [kg]	0,00485	0,00344	0,00224	0,00252	0,00248	0,00242	0,00249	0,00292	0,0028	0,00251	0,0005	0,00316

Ciclo urbano lungo											30°C	0°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	215,08268	150,29992	99,34666	108,51295	107,02961	106,24661	109,36576	137,52782	121,95898	107,28753	21,3775	140,74691
Daily NOx [kg]	1,4202	1,0033	0,65527	0,73935	0,72617	0,70849	0,73063	0,84848	0,81663	0,73396	0,14655	0,92002
Daily CO [kg]	0,05503	0,03922	0,02555	0,02872	0,02827	0,02754	0,02838	0,03329	0,03182	0,02861	0,00574	0,03603
Daily PM [kg]	0,15244	0,10985	0,07179	0,08034	0,07927	0,07719	0,07948	0,09317	0,08911	0,08015	0,01632	0,1005
Daily SOx [kg]	0,02095	0,01535	0,00974	0,01087	0,01073	0,01034	0,01066	0,01333	0,01225	0,01096	0,00218	0,01438
Daily NH3 [kg]	0,00485	0,00344	0,00224	0,00252	0,00248	0,00242	0,00249	0,00292	0,0028	0,00251	0,0005	0,00316

Ciclo urbano lungo											30°C	1°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	78,87876	57,70545	36,60954	40,91933	40,33383	38,88404	40,0851	50,1296	46,07179	41,20552	8,21026	54,05572
Daily NOx [kg]	1,40603	0,99398	0,64824	0,73196	0,71891	0,70123	0,72327	0,83991	0,80834	0,72653	0,14507	0,9107
Daily CO [kg]	0,05054	0,03602	0,02344	0,02637	0,02595	0,02528	0,02605	0,03056	0,02921	0,02626	0,00527	0,03307
Daily PM [kg]	0,01509	0,01088	0,0071	0,00795	0,00785	0,00764	0,00787	0,00922	0,00882	0,00793	0,00162	0,00995
Daily SOx [kg]	0,02222	0,01625	0,01031	0,01152	0,01136	0,01095	0,01129	0,01412	0,01298	0,0116	0,00231	0,01522
Daily NH3 [kg]	0,00501	0,00355	0,00231	0,0026	0,00256	0,00249	0,00257	0,00301	0,00289	0,00259	0,00052	0,00326

Ciclo urbano lungo											30°C	1°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	277,7308	159,28564	101,05414	123,3258	114,7433	111,71435	116,67074	144,17991	132,9898	119,12923	23,68336	156,08198
Daily NOx [kg]	1,42541	1,00768	0,65718	0,74205	0,72882	0,7109	0,73324	0,85149	0,81949	0,73655	0,14707	0,92326
Daily CO [kg]	0,05303	0,03779	0,02459	0,02767	0,02722	0,02652	0,02733	0,03206	0,03064	0,02755	0,00552	0,0347
Daily PM [kg]	0,03018	0,02176	0,01419	0,0159	0,01569	0,01527	0,01573	0,01844	0,01763	0,01586	0,00323	0,01989
Daily SOx [kg]	0,0222	0,01624	0,0103	0,01151	0,01135	0,01094	0,01128	0,01411	0,01296	0,01159	0,00231	0,01521
Daily NH3 [kg]	0,00501	0,00355	0,00231	0,0026	0,00256	0,00249	0,00257	0,00301	0,00289	0,00259	0,00052	0,00326

Ciclo urbano lungo											30°C	1°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	216,25435	158,20551	100,36888	113,66878	111,22959	107,40559	110,93455	138,49165	127,35158	113,9267	22,69245	149,42732
Daily NOx [kg]	1,45447	1,02823	0,67058	0,75718	0,74368	0,72539	0,74819	0,86885	0,8362	0,75157	0,15007	0,94209
Daily CO [kg]	0,05675	0,04045	0,02632	0,02961	0,02914	0,02838	0,02925	0,03432	0,0328	0,02949	0,00591	0,03714
Daily PM [kg]	0,15719	0,11332	0,07391	0,08281	0,0817	0,07953	0,08191	0,09602	0,09182	0,08259	0,01682	0,10357
Daily SOx [kg]	0,02209	0,01616	0,01025	0,01145	0,01129	0,01089	0,01122	0,01404	0,0129	0,01154	0,0023	0,01514
Daily NH3 [kg]	0,00501	0,00355	0,00231	0,0026	0,00256	0,00249	0,00257	0,00301	0,00289	0,00259	0,00052	0,00326

Ciclo urbano lungo											30°C	2°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	83,08874	60,68773	38,50403	43,62773	42,67658	41,21223	42,56933	53,14019	48,8668	43,71581	8,7074	57,33766
Daily NOx [kg]	1,43915	1,01807	0,66303	0,74918	0,73582	0,71756	0,74023	0,85958	0,82725	0,74355	0,14847	0,93202
Daily CO [kg]	0,05207	0,03714	0,02412	0,02716	0,02673	0,02603	0,02683	0,03148	0,03008	0,02705	0,00542	0,03406
Daily PM [kg]	0,01555	0,01121	0,0073	0,00819	0,00808	0,00786	0,0081	0,00949	0,00908	0,00816	0,00166	0,01024
Daily SOx [kg]	0,02337	0,01707	0,01083	0,0121	0,01193	0,0115	0,01186	0,01483	0,01363	0,01219	0,00243	0,016
Daily NH3 [kg]	0,00516	0,00366	0,00238	0,00268	0,00264	0,00257	0,00265	0,00311	0,00297	0,00267	0,00054	0,00336

Ciclo urbano lungo											30°C	2°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	228,97538	167,24282	106,10914	120,22898	117,60782	113,57238	117,31226	146,44336	134,66679	120,47173	23,99581	158,01074
Daily NOx [kg]	1,45898	1,03211	0,67217	0,75951	0,74597	0,72745	0,75043	0,87143	0,83865	0,7538	0,15051	0,94487
Daily CO [kg]	0,05463	0,03896	0,02531	0,0285	0,02804	0,02731	0,02815	0,03303	0,03156	0,02838	0,00569	0,03574
Daily PM [kg]	0,03109	0,02242	0,0146	0,01637	0,01615	0,01572	0,01619	0,01898	0,01815	0,01633	0,00332	0,02047
Daily SOx [kg]	0,02335	0,01705	0,01082	0,01209	0,01192	0,01149	0,01185	0,01482	0,01362	0,01218	0,00243	0,01598
Daily NH3 [kg]	0,00516	0,00366	0,00238	0,00268	0,00264	0,00257	0,00265	0,00311	0,00297	0,00267	0,00054	0,00336

Ciclo urbano lungo											30°C	2°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	227,42268	166,10874	105,3896	119,4137	116,81031	112,80223	116,51676	145,45032	133,7536	119,6548	23,83309	156,93925
Daily NOx [kg]	1,48873	1,05315	0,68588	0,775	0,76118	0,74229	0,76574	0,8892	0,85575	0,76917	0,15358	0,96414
Daily CO [kg]	0,05848	0,0417	0,02709	0,03051	0,03002	0,02923	0,03013	0,03535	0,03378	0,03037	0,00609	0,03825
Daily PM [kg]	0,16195	0,11679	0,07604	0,08529	0,08413	0,08188	0,08435	0,09886	0,09454	0,08504	0,01732	0,10664
Daily SOx [kg]	0,02323	0,01697	0,01076	0,01203	0,01186	0,01143	0,01179	0,01474	0,01355	0,01212	0,00241	0,0159

Daily NH3 [kg]	0,00516	0,0036	0,00238	0,00267	0,00262	0,00256	0,00264	0,00309	0,00296	0,00266	0,00053	0,00335

Ciclo urbano lungo											30°C	3°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	87,15173	63,56257	40,33035	45,71753	44,70662	43,17532	44,59992	55,67147	51,1956	45,79947	9,12232	60,0702
Daily NOx [kg]	1,47224	1,04215	0,67782	0,7664	0,75273	0,73389	0,75719	0,87925	0,84615	0,76056	0,15186	0,95334
Daily CO [kg]	0,05361	0,03826	0,02481	0,02796	0,02752	0,02679	0,02762	0,0324	0,03096	0,02784	0,00558	0,03506
Daily PM [kg]	0,016	0,01155	0,0075	0,00842	0,00831	0,00808	0,00833	0,00976	0,00934	0,0084	0,00171	0,01053
Daily SOx [kg]	0,02451	0,01788	0,01134	0,01268	0,0125	0,01205	0,01243	0,01554	0,01428	0,01277	0,00254	0,01676
Daily NH3 [kg]	0,00531	0,00377	0,00245	0,00276	0,00272	0,00265	0,00273	0,0032	0,00306	0,00275	0,00055	0,00346

Ciclo urbano lungo											30°C	3°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	240,21321	175,19523	111,1611	126,00959	123,22324	119,00258	122,92916	153,44528	141,10861	126,23543	25,14353	165,56936
Daily NOx [kg]	1,49253	1,05652	0,68716	0,77697	0,76311	0,74401	0,76762	0,89137	0,85781	0,77104	0,15396	0,96647
Daily CO [kg]	0,05624	0,04014	0,02603	0,02934	0,02887	0,0281	0,02897	0,03399	0,03248	0,02921	0,00586	0,03678
Daily PM [kg]	0,03201	0,02309	0,01501	0,01685	0,01662	0,01617	0,01666	0,01953	0,01868	0,0168	0,00342	0,02107
Daily SOx [kg]	0,02449	0,01786	0,01133	0,01267	0,01249	0,01204	0,01241	0,01552	0,01427	0,01276	0,00254	0,01674
Daily NH3 [kg]	0,00531	0,00377	0,00245	0,00276	0,00272	0,00265	0,00273	0,0032	0,00306	0,00275	0,00055	0,00346

Ciclo urbano lungo											30°C	3°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	238,58431	174,00722	110,40731	125,15511	122,38766	118,19561	122,09557	152,40476	140,15174	125,37942	24,97303	164,44662
Daily NOx [kg]	1,52297	1,07806	0,70117	0,79281	0,77867	0,75918	0,78327	0,90954	0,8753	0,78677	0,1571	0,98618
Daily CO [kg]	0,0602	0,04296	0,02786	0,0314	0,0309	0,03008	0,03101	0,03638	0,03477	0,03126	0,00627	0,03937
Daily PM [kg]	0,1667	0,12026	0,07515	0,08663	0,08508	0,08229	0,08525	0,09976	0,09533	0,08584	0,01747	0,10758
Daily SOx [kg]	0,02437	0,01777	0,01128	0,01261	0,01243	0,01198	0,01236	0,01545	0,0142	0,0127	0,00253	0,01666
Daily NH3 [kg]	0,00531	0,00377	0,00245	0,00276	0,00272	0,00265	0,00273	0,0032	0,00306	0,00275	0,00055	0,00346

Ciclo extraurbano breve											20°C	0°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	27,90932	21,76532	18,35556	23,45323	23,49674	30,22403	23,98902	18,49183	246,90758	23,87640	10,60065	16,49513
Daily NOx [kg]	1,39774	0,97508	0,79211	0,79211	0,79002	0,78630	0,79170	0,91421	0,88485	0,79466	0,15842	0,99325
Daily CO [kg]	0,04953	0,03468	0,02809	0,02809	0,02803	0,02789	0,02819	0,03264	0,03142	0,02822	0,00561	0,03540

Daily PM [kg]	0,01478	0,01042	0,00845	0,00845	0,00843	0,00839	0,00863	0,00981	0,00945	0,00849	0,00167	0,01060
Daily SOx [kg]	0,02084	0,01494	0,01164	0,01164	0,01160	0,01139	0,01146	0,01446	0,01325	0,01182	0,00235	0,01561
Daily NH3 [kg]	0,00491	0,00343	0,00278	0,00278	0,00277	0,00276	0,00277	0,00323	0,00310	0,00279	0,00056	0,00350

Ciclo extraurbano breve											20°C	0°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	204,19609	146,41308	114,04270	114,04270	113,69993	111,62746	112,27684	141,71609	129,80128	115,84624	22,99114	152,95462
Daily NOx [kg]	1,41700	0,98852	0,80302	0,80302	0,80091	0,79714	0,80261	0,92681	0,89705	0,80561	0,16060	1,00694
Daily CO [kg]	0,05197	0,03637	0,02947	0,02947	0,02941	0,02927	0,02958	0,03425	0,03296	0,02961	0,00589	0,03714
Daily PM [kg]	0,02956	0,02083	0,01690	0,01690	0,01686	0,01678	0,01725	0,01963	0,01890	0,01698	0,00334	0,02120
Daily SOx [kg]	0,02082	0,01493	0,01163	0,01163	0,01159	0,01138	0,01145	0,01445	0,01324	0,01181	0,00234	0,01560
Daily NH3 [kg]	0,00491	0,00343	0,00278	0,00278	0,00277	0,00276	0,00276	0,00323	0,00310	0,00279	0,00056	0,00350

Ciclo extraurbano breve											20°C	0°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	202,81142	145,42024	113,26936	113,26936	112,92892	110,87051	111,51548	140,75510	128,92109	115,06067	22,83523	151,91742
Daily NOx [kg]	1,44590	1,00868	0,81940	0,81940	0,81724	0,81339	0,81898	0,94571	0,91534	0,82204	0,16387	1,02748
Daily CO [kg]	0,05562	0,03894	0,03155	0,03155	0,03148	0,03132	0,03166	0,03665	0,03528	0,03169	0,00630	0,03975
Daily PM [kg]	0,15396	0,10851	0,08801	0,08801	0,08783	0,08740	0,08986	0,10223	0,09843	0,08842	0,01739	0,11040
Daily SOx [kg]	0,02071	0,01485	0,01157	0,01157	0,01153	0,01132	0,01139	0,01438	0,01317	0,01175	0,00233	0,01552
Daily NH3 [kg]	0,00491	0,00343	0,00278	0,00278	0,00277	0,00276	0,00276	0,00323	0,00310	0,00279	0,00056	0,00350

Ciclo extraurbano breve											20°C	1°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	79,94311	57,27268	44,64690	44,64690	44,51877	43,69422	43,94158	55,36956	50,80038	45,35783	9,00257	59,78066
Daily NOx [kg]	1,43915	1,00521	0,81501	0,81501	0,81286	0,80839	0,81391	0,94363	0,91128	0,81818	0,16307	1,02497
Daily CO [kg]	0,05145	0,03608	0,02915	0,02915	0,02908	0,02890	0,02921	0,03401	0,03264	0,02931	0,00582	0,03687
Daily PM [kg]	0,01535	0,01083	0,00876	0,00876	0,00874	0,00869	0,00893	0,01022	0,00981	0,00880	0,00173	0,01104
Daily SOx [kg]	0,02227	0,01596	0,01244	0,01244	0,01240	0,01217	0,01224	0,01543	0,01415	0,01264	0,00250	0,01665
Daily NH3 [kg]	0,00510	0,00357	0,00288	0,00288	0,00287	0,00286	0,00287	0,00336	0,00323	0,00290	0,00058	0,00365

Ciclo extraurbano breve											20°C	1°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	218,25603	156,36254	121,89236	121,89236	121,54256	119,29143	119,96676	151,16675	138,69226	123,83331	24,57828	163,20970

Daily NOx [kg]	1,45898	1,01906	0,82624	0,82624	0,82406	0,81953	0,82513	0,95663	0,92384	0,82945	0,16532	1,03909
Daily CO [kg]	0,05398	0,03785	0,03058	0,03058	0,03051	0,03032	0,03064	0,03568	0,03424	0,03075	0,00611	0,03868
Daily PM [kg]	0,03070	0,02167	0,01753	0,01753	0,01749	0,01738	0,01786	0,02044	0,01963	0,01763	0,00347	0,02207
Daily SOx [kg]	0,02225	0,01594	0,01243	0,01243	0,01239	0,01216	0,01223	0,01541	0,01414	0,01263	0,00251	0,01664
Daily NH3 [kg]	0,00510	0,00357	0,00288	0,00288	0,00287	0,00286	0,00287	0,00336	0,00323	0,00290	0,00058	0,00365

Ciclo extraurbano breve											20°C	1°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	216,77601	155,30223	121,06580	121,06580	120,71837	118,48251	119,15325	150,14168	137,75178	122,99359	24,41162	162,10297
Daily NOx [kg]	1,48874	1,03984	0,84309	0,84309	0,84087	0,83624	0,84196	0,97614	0,94268	0,84637	0,16869	1,06028
Daily CO [kg]	0,05778	0,04051	0,03273	0,03273	0,03266	0,03245	0,03280	0,03819	0,03665	0,03292	0,00654	0,04140
Daily PM [kg]	0,15991	0,11285	0,09129	0,09129	0,09106	0,09052	0,09300	0,10646	0,10222	0,09180	0,01806	0,11497
Daily SOx [kg]	0,02214	0,01586	0,01236	0,01236	0,01233	0,01210	0,01217	0,01533	0,01407	0,01256	0,00249	0,01656
Daily NH3 [kg]	0,00510	0,00357	0,00288	0,00288	0,00287	0,00286	0,00287	0,00336	0,00323	0,00290	0,00058	0,00365

Ciclo extraurbano breve											20°C	2°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	84,99486	60,84672	47,46727	47,05817	47,33672	46,44776	46,70433	58,76334	53,99464	48,22766	9,57285	63,46366
Daily NOx [kg]	1,48055	1,03532	0,83790	0,83790	0,83569	0,83048	0,83612	0,97304	0,93771	0,84169	0,16770	1,05667
Daily CO [kg]	0,05337	0,03748	0,03020	0,03020	0,03014	0,02991	0,03022	0,03537	0,03386	0,03040	0,00604	0,03834
Daily PM [kg]	0,01592	0,01125	0,00908	0,00908	0,00906	0,00899	0,00923	0,01063	0,01018	0,00914	0,00180	0,01148
Daily SOx [kg]	0,02371	0,01697	0,01324	0,01324	0,01320	0,01296	0,01303	0,01639	0,01506	0,01345	0,00267	0,01770
Daily NH3 [kg]	0,00529	0,00370	0,00299	0,00299	0,00298	0,00296	0,00297	0,00350	0,00335	0,00300	0,00060	0,00379

Ciclo extraurbano breve											20°C	2°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	232,31175	166,30901	129,73967	129,73967	129,38284	126,95311	127,65437	160,61458	147,58058	131,81799	26,16495	173,46171
Daily NOx [kg]	1,50095	1,04959	0,84945	0,84945	0,84721	0,84192	0,84764	0,98645	0,95063	0,85329	0,17400	1,07123
Daily CO [kg]	0,05599	0,03932	0,03169	0,03169	0,03162	0,03138	0,03170	0,03711	0,03553	0,03190	0,00634	0,04023
Daily PM [kg]	0,03184	0,02250	0,01816	0,01816	0,01812	0,01798	0,01846	0,02125	0,02035	0,01827	0,00360	0,02295
Daily SOx [kg]	0,02369	0,01696	0,01323	0,01323	0,01319	0,01294	0,01302	0,01638	0,01505	0,01344	0,00267	0,01769
Daily NH3 [kg]	0,00529	0,00370	0,00299	0,00299	0,00298	0,00296	0,00297	0,00350	0,00335	0,00300	0,00060	0,00379

Ciclo extraurbano breve											20°C	2°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064

Daily CO2 [kg]	230,73642	165,18126	128,85990	128,85990	128,50548	126,09223	126,78874	159,52544	146,57982	130,92412	25,98753	172,28545
Daily NOx [kg]	1,53156	1,07100	0,86677	0,86677	0,86449	0,85909	0,86492	1,00656	0,97002	0,87069	0,17350	1,09308
Daily CO [kg]	0,05993	0,04208	0,03392	0,03392	0,03384	0,03359	0,03393	0,03972	0,03803	0,03414	0,00678	0,04306
Daily PM [kg]	0,16585	0,11719	0,09456	0,09456	0,09435	0,09364	0,09614	0,11068	0,10601	0,09517	0,01873	0,11953
Daily SOx [kg]	0,02357	0,01687	0,01316	0,01316	0,01312	0,01288	0,01295	0,01629	0,01497	0,01337	0,00265	0,01760
Daily NH3 [kg]	0,00529	0,00370	0,00299	0,00299	0,00298	0,00296	0,00297	0,00350	0,00335	0,00300	0,00060	0,00379

Ciclo extraurbano breve											20°C	3°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	90,02230	64,40351	50,27407	50,27408	50,14112	49,18804	49,45376	62,14061	57,17351	51,08368	10,14040	67,12877
Daily NOx [kg]	1,52192	1,06542	0,86078	0,86078	0,85851	0,85255	0,85831	1,00243	0,96412	0,86519	0,17237	1,08835
Daily CO [kg]	0,05528	0,03888	0,03126	0,03126	0,03119	0,03090	0,03123	0,03673	0,03509	0,03149	0,00625	0,03981
Daily PM [kg]	0,01649	0,01167	0,00939	0,00939	0,00937	0,00929	0,00953	0,01103	0,01054	0,00946	0,00186	0,01191
Daily SOx [kg]	0,02514	0,01799	0,01404	0,01404	0,01400	0,01374	0,01381	0,01735	0,01597	0,01427	0,00283	0,01875
Daily NH3 [kg]	0,00548	0,00384	0,00309	0,00309	0,00308	0,00306	0,00307	0,00363	0,00347	0,00311	0,00062	0,00394

Ciclo extraurbano breve											20°C	3°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	246,35904	176,24953	137,58228	137,58228	137,21842	134,61019	135,33738	170,05674	156,46356	139,79788	27,75067	183,70757
Daily NOx [kg]	1,54289	1,08010	0,87264	0,87264	0,87034	0,86430	0,87014	1,01624	0,97740	0,87712	0,17475	1,10335
Daily CO [kg]	0,05800	0,04079	0,03280	0,03280	0,03272	0,03244	0,03277	0,03854	0,03681	0,03304	0,00656	0,04177
Daily PM [kg]	0,03298	0,02333	0,01878	0,01878	0,01874	0,01858	0,01906	0,02206	0,02108	0,01892	0,00372	0,02383
Daily SOx [kg]	0,02512	0,01797	0,01403	0,01403	0,01399	0,01373	0,01380	0,01734	0,01595	0,01425	0,00283	0,01873
Daily NH3 [kg]	0,00548	0,00384	0,00309	0,00309	0,00308	0,00306	0,00307	0,00363	0,00347	0,00311	0,00062	0,00394

Ciclo extraurbano breve											20°C	3°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	244,68846	175,05437	136,64932	136,64932	136,28793	133,69739	134,41964	168,90358	155,40257	138,84990	27,56249	182,46184
Daily NOx [kg]	1,57436	1,10213	0,89043	0,89043	0,88192	0,88192	0,88788	1,03697	0,99734	0,89500	0,17831	1,12585
Daily CO [kg]	0,06208	0,04365	0,03510	0,03510	0,03502	0,03472	0,03507	0,04125	0,03940	0,03536	0,00702	0,04471
Daily PM [kg]	0,17179	0,12153	0,09783	0,09783	0,09761	0,09676	0,09927	0,11491	0,10980	0,09854	0,01939	0,12410
Daily SOx [kg]	0,02499	0,01788	0,01396	0,01396	0,01392	0,01366	0,01373	0,01725	0,01587	0,01418	0,00281	0,01864
Daily NH3 [kg]	0,00548	0,00384	0,00309	0,00309	0,00308	0,00306	0,00307	0,00363	0,00347	0,00311	0,00062	0,00394

Ciclo extraurbano breve											25°C	0°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	75,48231	54,41495	42,31547	42,39618	42,24381	41,46058	41,67464	52,37206	48,18293	43,05201	8,54594	56,57397
Daily NOx [kg]	1,40536	0,98314	0,79457	0,79443	0,78688	0,78688	0,79221	0,92523	0,88987	0,79856	0,15910	1,00453
Daily CO [kg]	0,04989	0,03505	0,02820	0,02819	0,02813	0,02789	0,02817	0,03313	0,03165	0,02840	0,00564	0,03591
Daily PM [kg]	0,01489	0,01053	0,00848	0,00848	0,00846	0,00838	0,00860	0,00996	0,00951	0,00854	0,00168	0,01075
Daily SOx [kg]	0,02110	0,01521	0,01183	0,01185	0,01181	0,01159	0,01165	0,01464	0,01347	0,01203	0,00238	0,01582
Daily NH3 [kg]	0,00494	0,00346	0,00278	0,00278	0,00278	0,00276	0,00277	0,00327	0,00313	0,00280	0,00056	0,00355

Ciclo extraurbano breve											25°C	0°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	206,77146	149,06088	115,91631	116,13742	115,72001	113,57451	114,16086	143,46471	131,98925	117,93396	23,41021	154,97517
Daily NOx [kg]	1,42473	0,99669	0,80552	0,80538	0,79772	0,79772	0,80313	0,93798	0,90214	0,80956	0,16129	1,01838
Daily CO [kg]	0,05234	0,03677	0,02958	0,02957	0,02951	0,02926	0,02955	0,03476	0,03320	0,02980	0,00592	0,03767
Daily PM [kg]	0,02977	0,02106	0,01695	0,01695	0,01691	0,01677	0,01720	0,01991	0,01903	0,01708	0,00336	0,02151
Daily SOx [kg]	0,02108	0,01520	0,01182	0,01184	0,01180	0,01158	0,01164	0,01463	0,01346	0,01202	0,00238	0,01581
Daily NH3 [kg]	0,00494	0,00346	0,00278	0,00278	0,00278	0,00276	0,00277	0,00327	0,00313	0,00280	0,00056	0,00355

Ciclo extraurbano breve											25°C	0°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	205,36933	148,05008	115,13027	115,34988	114,93530	112,80435	113,38673	142,49186	131,09422	117,13424	23,25146	153,92427
Daily NOx [kg]	1,45378	1,01702	0,82195	0,82181	0,81399	0,81399	0,81951	0,95711	0,92053	0,82607	0,16458	1,03915
Daily CO [kg]	0,05602	0,03936	0,03166	0,03166	0,03159	0,03131	0,03163	0,03720	0,03554	0,03189	0,00633	0,04033
Daily PM [kg]	0,15507	0,10967	0,08830	0,08829	0,08809	0,08733	0,08959	0,10371	0,09909	0,08893	0,01750	0,11200
Daily SOx [kg]	0,02097	0,01512	0,01176	0,01178	0,01174	0,01152	0,01158	0,01455	0,01339	0,01196	0,00237	0,01572
Daily NH3 [kg]	0,00494	0,00346	0,00278	0,00278	0,00278	0,00276	0,00277	0,00327	0,00313	0,00280	0,00056	0,00355

Ciclo extraurbano breve											25°C	1°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	80,48821	57,95579	45,09538	45,16817	45,01243	44,17464	44,40433	55,80141	51,33844	45,87129	9,10560	60,27881
Daily NOx [kg]	1,44677	1,01327	0,81845	0,81855	0,81070	0,81070	0,81617	0,95322	0,91679	0,82272	0,16391	1,03492
Daily CO [kg]	0,05181	0,03645	0,02930	0,02931	0,02924	0,02899	0,02928	0,03444	0,03289	0,02952	0,00586	0,03733
Daily PM [kg]	0,01546	0,01094	0,00881	0,00881	0,00879	0,00871	0,00894	0,01034	0,00988	0,00887	0,00175	0,01117
Daily SOx [kg]	0,02253	0,01623	0,01263	0,01265	0,01260	0,01237	0,01243	0,01562	0,01437	0,01284	0,00254	0,01688
Daily NH3 [kg]	0,00513	0,00360	0,00289	0,00290	0,00289	0,00287	0,00288	0,00340	0,00325	0,00291	0,00058	0,00369

Ciclo extraurbano breve											25°C	1°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	220,83140	159,01034	123,72589	123,92560	123,49829	121,19970	121,82988	153,09947	140,85464	125,85471	24,98256	165,38390
Daily NOx [kg]	1,46671	1,02723	0,82973	0,82982	0,82187	0,82187	0,82741	0,96636	0,92942	0,83405	0,16617	1,04918
Daily CO [kg]	0,05435	0,03824	0,03074	0,03074	0,03067	0,03041	0,03072	0,03613	0,03451	0,03097	0,00615	0,03916
Daily PM [kg]	0,03091	0,02189	0,01761	0,01762	0,01757	0,01742	0,01787	0,02069	0,01977	0,01774	0,00349	0,02235
Daily SOx [kg]	0,02252	0,01621	0,01262	0,01264	0,01259	0,01236	0,01242	0,01561	0,01436	0,01283	0,00254	0,01687
Daily NH3 [kg]	0,00513	0,00360	0,00289	0,00290	0,00289	0,00287	0,00288	0,00340	0,00325	0,00291	0,00058	0,00369

Ciclo extraurbano breve											25°C	1°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	219,33392	157,93208	122,88689	123,08525	122,66084	120,37783	121,00374	152,06129	139,89949	125,00128	24,81315	164,26242
Daily NOx [kg]	1,49661	1,04818	0,84665	0,84675	0,83863	0,83863	0,84429	0,98606	0,94837	0,85106	0,16956	1,07058
Daily CO [kg]	0,05818	0,04093	0,03290	0,03291	0,03283	0,03255	0,03288	0,03867	0,03694	0,03315	0,00658	0,04192
Daily PM [kg]	0,16101	0,11401	0,09173	0,09176	0,09154	0,09075	0,09310	0,10777	0,10297	0,09241	0,01818	0,11638
Daily SOx [kg]	0,02240	0,01613	0,01255	0,01257	0,01253	0,01230	0,01236	0,01553	0,01429	0,01277	0,00253	0,01678
Daily NH3 [kg]	0,00513	0,00360	0,00289	0,00290	0,00289	0,00287	0,00288	0,00340	0,00325	0,00291	0,00058	0,00369

Ciclo extraurbano breve											25°C	2°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	85,60160	61,57415	47,93554	48,00053	47,84120	46,94773	47,19336	59,30534	54,56256	48,75188	9,67742	64,06421
Daily NOx [kg]	1,48816	1,04338	0,84232	0,84264	0,83451	0,83451	0,84011	0,98120	0,94369	0,84686	0,16872	1,06529
Daily CO [kg]	0,05372	0,03785	0,03040	0,03042	0,03034	0,03009	0,03039	0,03574	0,03414	0,03064	0,00608	0,03874
Daily PM [kg]	0,01603	0,01136	0,00914	0,00914	0,00912	0,00904	0,00927	0,01074	0,01026	0,00921	0,00181	0,01159
Daily SOx [kg]	0,02397	0,01724	0,01343	0,01344	0,01340	0,01315	0,01321	0,01660	0,01528	0,01365	0,00270	0,01794
Daily NH3 [kg]	0,00532	0,00374	0,00300	0,00301	0,00300	0,00298	0,00299	0,00353	0,00338	0,00303	0,00060	0,00383

Ciclo extraurbano breve											25°C	2°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	234,88712	168,95682	131,53309	131,71142	131,27419	128,82257	129,49656	162,73131	149,71733	133,77305	26,55443	175,78946
Daily NOx [kg]	1,50867	1,05776	0,85393	0,85426	0,84601	0,84601	0,85169	0,99472	0,95670	0,85853	0,17104	1,07998
Daily CO [kg]	0,05636	0,03971	0,03190	0,03192	0,03183	0,03157	0,03188	0,03750	0,03582	0,03215	0,00638	0,04065
Daily PM [kg]	0,03205	0,02272	0,01827	0,01828	0,01823	0,01808	0,01855	0,02147	0,02051	0,01841	0,00362	0,02318

Daily SOx [kg]	0,02395	0,01720	0,01340	0,01342	0,01337	0,01313	0,01319	0,01657	0,01525	0,01362	0,00270	0,01791
Daily NH3 [kg]	0,00532	0,00374	0,00300	0,00301	0,00300	0,00298	0,00299	0,00353	0,00338	0,00303	0,00060	0,00383

Ciclo extraurbano breve											25°C	2°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	233,29433	167,81111	130,64115	130,81828	130,38401	127,94901	128,61843	161,62781	148,70209	132,86593	26,37436	174,59741
Daily NOx [kg]	1,53944	1,07933	0,87134	0,87168	0,86326	0,86326	0,86906	1,01501	0,97621	0,87604	0,17453	1,10200
Daily CO [kg]	0,06033	0,04250	0,03414	0,03416	0,03407	0,03379	0,03412	0,04014	0,03834	0,03441	0,00683	0,04350
Daily PM [kg]	0,16695	0,11835	0,09517	0,09522	0,09498	0,09417	0,09660	0,11183	0,10685	0,09590	0,01887	0,12077
Daily SOx [kg]	0,02383	0,01714	0,01335	0,01336	0,01332	0,01307	0,01314	0,01651	0,01519	0,01357	0,00269	0,01784
Daily NH3 [kg]	0,00532	0,00374	0,00300	0,00301	0,00300	0,00298	0,00299	0,00353	0,00338	0,00303	0,00060	0,00383

Ciclo extraurbano breve											25°C	3°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	90,77970	65,23906	50,81194	50,86920	50,70614	49,75632	50,01807	62,85410	57,82792	51,66931	10,25657	67,89803
Daily NOx [kg]	1,52954	1,07348	0,86618	0,86673	0,85831	0,85831	0,86404	1,00917	0,97058	0,87100	0,17353	1,09566
Daily CO [kg]	0,05564	0,03925	0,03151	0,03154	0,03145	0,03119	0,03150	0,03705	0,03539	0,03176	0,00631	0,04016
Daily PM [kg]	0,01660	0,01178	0,00947	0,00948	0,00945	0,00937	0,00961	0,01113	0,01063	0,00954	0,00188	0,01202
Daily SOx [kg]	0,02540	0,01826	0,01422	0,01424	0,01419	0,01393	0,01400	0,01759	0,01618	0,01446	0,00287	0,01901
Daily NH3 [kg]	0,00551	0,00388	0,00311	0,00312	0,00311	0,00309	0,00310	0,00366	0,00350	0,00314	0,00063	0,00397

Ciclo extraurbano breve											25°C	3°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	248,93441	178,89733	139,33557	139,49255	139,04540	136,44083	137,15861	172,35733	158,57467	141,68662	28,12535	186,18873
Daily NOx [kg]	1,55062	1,08828	0,87812	0,87868	0,87014	0,87014	0,87596	1,02308	0,98396	0,88301	0,17592	1,11076
Daily CO [kg]	0,05837	0,04118	0,03306	0,03309	0,03300	0,03272	0,03305	0,03887	0,03713	0,03332	0,00662	0,04213
Daily PM [kg]	0,03319	0,02356	0,01893	0,01895	0,01890	0,01874	0,01922	0,02225	0,02126	0,01908	0,00375	0,02403
Daily SOx [kg]	0,02538	0,01824	0,01421	0,01423	0,01418	0,01392	0,01399	0,01757	0,01617	0,01444	0,00286	0,01899
Daily NH3 [kg]	0,00551	0,00388	0,00311	0,00312	0,00311	0,00309	0,00310	0,00366	0,00350	0,00314	0,00063	0,00397

Ciclo extraurbano breve											25°C	3°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	247,24637	177,68421	138,39072	138,54664	138,10252	135,51562	136,22853	171,18856	157,49936	140,72583	27,93463	184,92617
Daily NOx [kg]	1,58224	1,11047	0,89603	0,89660	0,88789	0,88789	0,89382	1,04394	1,00403	0,90101	0,17951	1,13341
Daily CO [kg]	0,06248	0,04407	0,03538	0,03541	0,03532	0,03502	0,03537	0,04160	0,03974	0,03566	0,00708	0,04509

Daily PM [kg]	0,17289	0,12269	0,09861	0,09869	0,09843	0,09759	0,10011	0,11589	0,11073	0,09938	0,01955	0,12515
Daily SOx [kg]	0,02525	0,01815	0,01414	0,01415	0,01411	0,01385	0,01392	0,01748	0,01608	0,01437	0,00285	0,01889
Daily NH3 [kg]	0,00551	0,00388	0,00311	0,00312	0,00311	0,00309	0,00310	0,00366	0,00350	0,00314	0,00063	0,00397

Ciclo extraurbano breve											30°C	0°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	77,78213	56,93681	44,75239	44,26145	44,34403	43,54305	43,67844	54,95353	50,55476	45,15525	8,96580	59,34985
Daily NOx [kg]	1,42851	1,00751	0,81970	0,81439	0,80810	0,80895	0,81324	0,95036	0,91410	0,82011	0,16341	1,03177
Daily CO [kg]	0,05097	0,03618	0,02937	0,02912	0,02912	0,02891	0,02915	0,03431	0,03278	0,02940	0,00584	0,03719
Daily PM [kg]	0,01521	0,01087	0,00883	0,00875	0,00876	0,00869	0,00890	0,01031	0,00985	0,00884	0,00174	0,01113
Daily SOx [kg]	0,02190	0,01603	0,01260	0,01246	0,01249	0,01226	0,01230	0,01546	0,01422	0,01271	0,00252	0,01671
Daily NH3 [kg]	0,00505	0,00358	0,00290	0,00288	0,00288	0,00287	0,00287	0,00339	0,00324	0,00291	0,00058	0,00368

Ciclo extraurbano breve											30°C	0°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	214,61563	157,09946	123,48030	122,12571	122,35357	120,14352	120,51707	151,62719	139,49016	124,59188	24,73834	163,75749
Daily NOx [kg]	1,44820	1,02140	0,83099	0,82562	0,81924	0,82009	0,82444	0,96345	0,92669	0,83141	0,16567	1,04599
Daily CO [kg]	0,05347	0,03796	0,03081	0,03055	0,03055	0,03033	0,03058	0,03599	0,03439	0,03085	0,00613	0,03901
Daily PM [kg]	0,03041	0,02170	0,01766	0,01750	0,01750	0,01737	0,01779	0,02061	0,01969	0,01767	0,00348	0,02225
Daily SOx [kg]	0,02188	0,01602	0,01259	0,01245	0,01248	0,01226	0,01229	0,01545	0,01421	0,01270	0,00252	0,01670
Daily NH3 [kg]	0,00505	0,00358	0,00290	0,00288	0,00288	0,00287	0,00287	0,00339	0,00324	0,00291	0,00058	0,00368

Ciclo extraurbano breve											30°C	0°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	213,16031	156,03415	122,64297	121,29756	121,52387	119,32882	119,69983	150,59899	138,54426	123,74701	24,57059	162,64704
Daily NOx [kg]	1,47773	1,04222	0,84794	0,84245	0,83594	0,83681	0,84126	0,98310	0,94559	0,84836	0,16904	1,06732
Daily CO [kg]	0,05723	0,04063	0,03298	0,03270	0,03270	0,03247	0,03273	0,03853	0,03681	0,03302	0,00656	0,04176
Daily PM [kg]	0,15841	0,11318	0,09196	0,09117	0,09117	0,09052	0,09269	0,10738	0,10261	0,09206	0,01811	0,11595
Daily SOx [kg]	0,02177	0,01594	0,01253	0,01239	0,01242	0,01220	0,01223	0,01538	0,01414	0,01264	0,00251	0,01661
Daily NH3 [kg]	0,00505	0,00358	0,00290	0,00288	0,00288	0,00287	0,00287	0,00339	0,00324	0,00291	0,00058	0,00368

Ciclo extraurbano breve											30°C	1°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	65,06689	60,63008	47,66595	43,20002	45,83255	44,56824	44,13295	56,18543	51,50287	45,93045	9,14011	60,44506
Daily NOx [kg]	1,46992	1,03764	0,84259	0,83796	0,83147	0,83208	0,83667	0,97771	0,94036	0,84371	0,16811	1,06144

Daily CO [kg]	0,05288	0,03758	0,03042	0,03020	0,03020	0,02998	0,03023	0,03558	0,03399	0,03049	0,00606	0,03856
Daily PM [kg]	0,01578	0,01128	0,00914	0,00908	0,00908	0,00901	0,00923	0,01069	0,01021	0,00916	0,00180	0,01154
Daily SOx [kg]	0,02334	0,01705	0,01340	0,01326	0,01328	0,01305	0,01309	0,01645	0,01513	0,01352	0,00268	0,01778
Daily NH3 [kg]	0,00524	0,00372	0,00301	0,00299	0,00299	0,00298	0,00298	0,00352	0,00337	0,00302	0,00061	0,00382

Ciclo extraurbano breve											30°C	1°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	228,67557	167,04892	131,32997	129,95863	130,14507	127,80823	128,21468	161,29838	148,39198	132,54380	26,31684	174,20785
Daily NOx [kg]	1,49018	1,05194	0,85421	0,84951	0,84294	0,84355	0,84821	0,99119	0,95333	0,85534	0,17043	1,07607
Daily CO [kg]	0,05549	0,03943	0,03192	0,03169	0,03169	0,03145	0,03172	0,03733	0,03567	0,03200	0,00635	0,04046
Daily PM [kg]	0,03156	0,02256	0,01829	0,01816	0,01815	0,01802	0,01845	0,02138	0,02043	0,01833	0,00361	0,02309
Daily SOx [kg]	0,02332	0,01703	0,01339	0,01325	0,01327	0,01304	0,01308	0,01644	0,01512	0,01351	0,00268	0,01776
Daily NH3 [kg]	0,00524	0,00372	0,00301	0,00299	0,00299	0,00298	0,00298	0,00352	0,00337	0,00302	0,00061	0,00382

Ciclo extraurbano breve											30°C	1°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1063
Daily CO2 [kg]	227,12490	165,91614	130,43941	129,07737	129,26254	126,94155	127,34524	160,20459	147,38572	131,64500	26,13838	173,02653
Daily NOx [kg]	1,52056	1,07339	0,87163	0,86683	0,86012	0,86075	0,86551	1,01140	0,97277	0,87278	0,17391	1,09802
Daily CO [kg]	0,05939	0,04220	0,03416	0,03392	0,03392	0,03366	0,03395	0,03996	0,03817	0,03424	0,00680	0,04330
Daily PM [kg]	0,16435	0,11752	0,09524	0,09456	0,09455	0,09383	0,09611	0,11134	0,10639	0,09546	0,01878	0,12023
Daily SOx [kg]	0,02320	0,01695	0,01332	0,01318	0,01320	0,01297	0,01301	0,01636	0,01504	0,01344	0,00267	0,01767
Daily NH3 [kg]	0,00524	0,00372	0,00301	0,00299	0,00299	0,00298	0,00298	0,00352	0,00337	0,00302	0,00061	0,00382

Ciclo extraurbano breve											30°C	2°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	88,24363	64,34571	50,59714	50,09248	50,14522	49,24959	49,40931	62,15397	57,18230	51,07555	10,14102	67,13031
Daily NOx [kg]	1,51132	1,06775	0,86549	0,86152	0,85484	0,85521	0,86011	1,00506	0,96662	0,86731	0,17281	1,09111
Daily CO [kg]	0,05480	0,03898	0,03148	0,03130	0,03129	0,03105	0,03132	0,03686	0,03521	0,03159	0,00627	0,03995
Daily PM [kg]	0,01635	0,01170	0,00946	0,00940	0,00940	0,00933	0,00956	0,01107	0,01058	0,00949	0,00187	0,01195
Daily SOx [kg]	0,02477	0,01806	0,01420	0,01406	0,01408	0,01383	0,01387	0,01744	0,01604	0,01433	0,00284	0,01884
Daily NH3 [kg]	0,00543	0,00385	0,00311	0,00310	0,00309	0,00308	0,00308	0,00364	0,00348	0,00312	0,00063	0,00395

Ciclo extraurbano breve											30°C	2°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064

Daily CO2 [kg]	242,73129	176,99539	139,17728	137,78910	137,93418	135,47057	135,90990	170,96658	157,29105	140,49325	27,89485	184,65499
Daily NOx [kg]	1,53214	1,08247	0,87741	0,87339	0,86662	0,86699	0,87196	1,01890	0,97994	0,87926	0,17519	1,10614
Daily CO [kg]	0,05750	0,04090	0,03303	0,03284	0,03284	0,03258	0,03286	0,03867	0,03694	0,03314	0,00658	0,04191
Daily PM [kg]	0,03270	0,02340	0,01891	0,01880	0,01880	0,01865	0,01911	0,02214	0,02115	0,01898	0,00373	0,02390
Daily SOx [kg]	0,02475	0,01805	0,01419	0,01405	0,01407	0,01382	0,01386	0,01742	0,01603	0,01432	0,00284	0,01883
Daily NH3 [kg]	0,00543	0,00385	0,00311	0,00310	0,00309	0,00308	0,00308	0,00364	0,00348	0,00312	0,00063	0,00395

Ciclo extraurbano breve											30°C	2°
> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	241,08531	175,79517	138,23351	136,85475	136,99884	134,55194	134,98829	169,80724	156,22445	139,54056	27,70569	183,40283
Daily NOx [kg]	1,56339	1,10454	0,89531	0,89121	0,88430	0,88468	0,88974	1,03969	0,99993	0,89719	0,17877	1,12870
Daily CO [kg]	0,06154	0,04378	0,03535	0,03515	0,03514	0,03487	0,03517	0,04139	0,03954	0,03547	0,00704	0,04486
Daily PM [kg]	0,17029	0,12186	0,09851	0,09794	0,09793	0,09714	0,09953	0,11529	0,11016	0,09885	0,01945	0,12449
Daily SOx [kg]	0,02462	0,01795	0,01412	0,01397	0,01399	0,01375	0,01379	0,01733	0,01595	0,01425	0,00283	0,01873
Daily NH3 [kg]	0,00543	0,00385	0,00311	0,00310	0,00309	0,00308	0,00308	0,00364	0,00348	0,00312	0,00063	0,00395

Ciclo extraurbano breve											30°C	3°
< 79K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	93,33449	67,94792	53,67025	53,00468	53,06795	52,15792	52,29933	65,79680	60,53993	54,06892	10,73574	71,06793
Daily NOx [kg]	1,55269	1,09785	0,88837	0,88507	0,87820	0,87833	0,88353	1,03239	0,99287	0,89089	0,17751	1,12076
Daily CO [kg]	0,05672	0,04038	0,03253	0,03238	0,03238	0,03211	0,03240	0,03813	0,03642	0,03268	0,00649	0,04132
Daily PM [kg]	0,01692	0,01211	0,00977	0,00973	0,00972	0,00964	0,00988	0,01145	0,01094	0,00981	0,00193	0,01236
Daily SOx [kg]	0,02620	0,01908	0,01500	0,01486	0,01487	0,01461	0,01466	0,01842	0,01695	0,01514	0,00300	0,01991
Daily NH3 [kg]	0,00562	0,00399	0,00322	0,00321	0,00321	0,00319	0,00319	0,00377	0,00361	0,00324	0,00065	0,00409

Ciclo extraurbano breve											30°C	3°
80K km > X < 160K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	256,77858	186,93591	147,01989	145,61531	145,71924	143,12886	143,60106	180,62972	166,18543	148,43852	29,47203	195,09662
Daily NOx [kg]	1,57409	1,11298	0,90061	0,89727	0,89030	0,89043	0,89570	1,04661	1,00655	0,90316	0,17996	1,13620
Daily CO [kg]	0,05951	0,04237	0,03413	0,03398	0,03397	0,03369	0,03400	0,04001	0,03822	0,03429	0,00681	0,04336
Daily PM [kg]	0,03384	0,02423	0,01954	0,01945	0,01945	0,01929	0,01977	0,02289	0,02187	0,01963	0,00386	0,02472
Daily SOx [kg]	0,02618	0,01906	0,01499	0,01484	0,01486	0,01460	0,01465	0,01841	0,01693	0,01513	0,00300	0,01989
Daily NH3 [kg]	0,00562	0,00399	0,00322	0,00321	0,00321	0,00319	0,00319	0,00377	0,00361	0,00324	0,00065	0,00409

Ciclo extraurbano breve											30°C	3°

> 161K km	Olbia 1051	Olbia 1052	Olbia 1053	Olbia 1054	Olbia 1056	Olbia 1057	Olbia 1059	Olbia 1060	Olbia 1061	Olbia 1062	Olbia 1063	Olbia 1064
Daily CO2 [kg]	255,03735	185,66828	146,02293	144,62788	144,73110	142,15829	142,62729	179,40485	165,05851	147,43195	29,27218	193,77365
Daily NOx [kg]	1,60619	1,13568	0,91897	0,91557	0,90845	0,90858	0,91397	1,06795	1,02707	0,92158	0,18363	1,15937
Daily CO [kg]	0,06369	0,04335	0,03653	0,03583	0,03565	0,03565	0,03583	0,04216	0,04033	0,03615	0,00718	0,04573
Daily PM [kg]	0,17623	0,12620	0,10178	0,10133	0,10130	0,10045	0,10295	0,11925	0,11393	0,10224	0,02011	0,12876
Daily SOx [kg]	0,02605	0,01896	0,01491	0,01477	0,01478	0,01452	0,01457	0,01831	0,01684	0,01505	0,00299	0,01979
Daily NH3 [kg]	0,00562	0,00399	0,00322	0,00321	0,00321	0,00319	0,00319	0,00377	0,00361	0,00324	0,00065	0,00409

APPENDIX 2: MLP MODEL

```
#################################################################
#########        ################################        IMPORTS
################################
#################################################################
#########


import pandas
as pd import
numpy as np
from sklearn.model_selection import
train_test_split from sklearn.preprocessing
import MultiLabelBinarizer from sklearn import
linear_model
from sklearn.preprocessing import
OneHotEncoder from keras import
Sequential
from keras.layers import
Dense from keras.layers
import Dropout from
keras.layers import
Activation
from keras.layers import
BatchNormalization import pickle
import matplotlib.pyplot as plt
from keras.callbacks import
ModelCheckpoint from
keras.optimizers import SGD
from keras.optimizers import RMSprop

#################################################################
#########      #############################      READ      DATASET
##############################
#################################################################
#########


file="Dataset_Paulo_
2.csv" df=
pd.read_csv(file,sep
=';')
print(df.info())
#Select features


X=df[["KILOMETRAJE","CICLO URBANO","TEMPERATURA","PENDIENTE","EURO","TIPO DE
VEHICULO"]] output_names=["CO2","NOX","CO","PM","SOX","NH3"]


#################################################################
#########      ##############################      PREPARE      DATA
#############################
#################################################################
#########


onehotencoder = OneHotEncoder(categorical_features = [0])
x2=OneHotEncoder().fit_transform(X)

def train_test(x,y):
    x_train, x_test, y_train, y_test = train_test_split(x2, y, test_size=0.3,
    random_sta print( x_train.shape, y_train.shape)
    print (x_test.shape,
```

```
    y_test.shape) return x_train,
    x_test, y_train, y_test

################################################################
#########    #############################    BASELINE    MODEL
############################
################################################################
#########

def bmodel1():
    model = Sequential()
    model.add(Dense(1058,
    activation='relu',
                    kernel_regularizer = 'l2',
                    kernel_initializer =
                    'normal',
                    input_shape=(27,)))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))
    model.add(Dense(529,
    activation='relu',
                    kernel_regularizer = 'l2',

                    kernel_initializer =
    'normal')) model.add(BatchNormalization())
    model.add(Dropout(0.5))
    model.add(Dense(1, activation='linear',
                    kernel_regularizer = 'l2',
                    kernel_initializer='normal')
                    )

    return

model def

bmodel2():
    model = Sequential()
    model.add(Dense(1058, activation='softmax', input_shape=(27,)))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))
    model.add(Dense(529,
    activation='softmax'))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))
    model.add(Dense(1,
    activation='linear')) return model

def bmodel3():
    model = Sequential()
    model.add(Dense(128,
    input_shape=(27,)))
    model.add(Activation('softmax')
    )
    model.add(BatchNormalization())
    model.add(Dropout(0.5))

    model.add(Dense(128))
    model.add(Activation('softmax'))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))

    model.add(Dense(64))
    model.add(Activation('softmax'))
    model.add(BatchNormalization())
```

```
    model.add(Dropout(0.5))

    model.add(Dense(64))
    model.add(Activation('softmax'))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))

    model.add(Dense(32))
    model.add(Activation('softmax'))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))

    model.add(Dense(1))
    model.add(Activation('linear'))

    return

model def

bmodel4():
    model = Sequential()
    model.add(Dense(128, input_shape=(27,)))
    model.add(Activation('softmax'))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))

    model.add(Dense(128))
    model.add(Activation('softmax'))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))

    model.add(Dense(64))
    model.add(Activation('softmax'))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))

    model.add(Dense(64))
    model.add(Activation('softmax'))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))

    model.add(Dense(32))
    model.add(Activation('softmax'))
    model.add(BatchNormalization())
    model.add(Dropout(0.5))

    model.add(Dense(1))
    model.add(Activation('linear'))

    return model

################################################################
#########        ################################        TRAINING
###############################
################################################################
#########


def train(filepath,epochs,batch_size,model,x_train,y_train,x_test,y_test):

    model.compile(loss='mse', optimizer="adam", metrics=['mse','mae','mape'])
    checkpoint =
    ModelCheckpoint(filepath,monitor="val_mean_absolute_percentage_error",
```

```
    callbacks_list = [checkpoint]
    history = model.fit(x_train, y_train,validation_data=(x_test,y_test),

    epochs=epochs, return history,model

#######################################################################

############################### SAVE MODEL ############################
#######################################################################


def saveModels(model,history,name_model,name_weights,name_history):
    #Save the model, weights and history


    f=
    open(name_history,'wb'
    )
    pickle.dump(history.his
    tory,f) f.close()
    model.save(name_model)

################################################################
#########     ############################     PLOT     RESULTS
##############################
################################################################
#########


def
    plot(hist
    ory,N):
    plt.figur
    e()

    plt.plot(np.arange(0,N), history.history["mean_squared_error"],
    label="train_mse") plt.plot(np.arange(0,N),
    history.history["val_mean_squared_error"], label="val_mse") plt.title("mse")
    plt.xlabel("Epoch #")
    plt.ylabel("mse")
    plt.legend(loc="upper
    right")
    plt.show()

    plt.plot(np.arange(0,N), history.history["mean_absolute_error"],
    label="train_mae") plt.plot(np.arange(0,N),
    history.history["val_mean_absolute_error"], label="val_mae" plt.title("mae")
    plt.xlabel("Epoch #")
    plt.ylabel("mae")
    plt.legend(loc="upper
    right") plt.show()

def load_predict(model,weights):
    model.load_weights(weights)
    model.compile(loss='mse', optimizer='adam', metrics=['mse','mae','mape'])
    print("MODEL created, WEIGHTS loaded")
    evaluation=model.evaluate(x_test,y_test,verbose=0)
    print(evaluation)
    print([model.metrics_names])

epochs=500
batch_size=64
#Now, the model will be trained for the 6 different response variables we are
dealingwi
```

```
for resp in output_names:
    y=df[[resp]]
    x_train, x_test, y_train, y_test =
    train_test(x2,y) if (resp=="CO2"):
        model=bmodel1()
        #pass

    if (resp=="NOX" or resp=="CO" or
        resp=="SOX"): model=bmodel2()
        #pass


    if
        (resp=="PM
        "):
        model=bmode
        l3() #pass

    if (resp=="NH3"):
        model=bmodel4()
    name_weights="weights_" + resp + ".h5"
    H,model=train(name_weights,epochs,batch_size,model,x_train,y_train,x_test,y_
    test) load_predict(model,name_weights)
    name_history="history_" + resp  + ".h5"
    name_model="model_" + resp + ".h5"
    saveModels(model,H,name_model,name_weights,name
    _history) plot(H,epochs)
```

APPENDIX 3: MLP USER INTERFACE CODE

```
from keras.models import
load_model import pandas as pd
from sklearn.preprocessing import
OneHotEncoder import numpy as np

file="Dataset_Paulo_
2.csv" df=
pd.read_csv(file,sep
=';')
print(df.info())
#Select features


columns_names=["MILEAGE","URBAN CYCLE","TEMPERATURE","ROAD SLOPE","EURO","TYPE
OF VEHICLE
X=df[columns_names]
output_names=["CO2","NOX","CO","PM","SOX","NH3
"]


##################################################################
#########     ###############################     PREPARE     DATA
##############################
##################################################################
#########



onehotencoder = OneHotEncoder()
x2=onehotencoder.fit(X)

MILEAGE = input("Type the mileage in order of 1000 (type just an
integer): ") CICLO = input("Type the Driving Cycle (Short urban, Long
urban or Extraurban) : ") TEMP = int(input("Type the temperature (20, 25
or 30): "))
ROAD SLOPE = int(input("Type the road slope (0, 1, 2 or
3): ")) EURO = int(input("Type the euro scenario (4 or
5): "))
VEHICLE = input("Type the type of vehicle (OLBIA 1051, OLBIA 1052, OLBIA 1053,
OLBIA 1

if int(MILEAGE) <=
    79: KM="< 79K
    km"
if 80 <= int(MILEAGE) <= 160:
    KM="80K km < X < 160K km"
if int(MILEAGE) >=
    161: KM="> 161K
    km"

x_input=[KM,CICLO,TEMP,PENDIENTE,EURO,VEHICULO]
print(x_input)



df_input = pd.DataFrame([x_input], columns = columns_names)
# Note that in version 3, the print()
function # requires the use of
parenthesis. x_i=df_input[columns_names]
x_in=onehotencoder.transform(x_i)
```

```
for i in output_names:
    model_path="model_"+ i +
    ".h5"
    weights_path="weights_"+ i
    + ".h5"



    model =
    load_model(model_path)
    model.load_weights(weights_
    path)
    model.compile(loss='mse', optimizer="adam",metrics=['mse','mae','mape'])
    predictions=model.predict(x_in)

    print(i , ": " , predictions)
```