LIFE GreenYourRoute: A European innovative logistic platform for last mile delivery of goods in urban environment

Deliverable C1: *Emission inventory methodology and monitoring of the environmental impact of the project*

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Document Information Summary	
Action:	**C1 Monitoring of the environmental impact of the project**
Sub-action:	**Sub-action C1.1: Monitoring methodology for environmental impact** **Sub-action C1.2: Data collection and quantification of environmental impact**
Deliverable Number:	**C1**
Deliverable Title:	**Emission inventory methodology and monitoring of the environmental impact of the project**
Leader:	**UTH**
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Project website	**www.greenyourroute.com**
Status:	**Final**

Disclaimer:

The LIFE GYR[LIFE17 ENV/GR/000215] project is co-funded by the LIFE programme, the EU financial instrument for the environment.

Start Date: 01 September 2018 - Duration: 42 months

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Abbreviations

A/C	Air Conditioning
API	Application Programming Interface
CNG	Compressed Natural Gas
CH_4	Methane
GHG	Greenhouse gas
GYR	GreenYourRoute project
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon dioxide
CO_2 eq	Carbon dioxide equivalent
COPERT	EU standard vehicle emissions calculator
CP	Checkpoint
ERP	Enterprise resource planning
EEA	European Environment Agency
FC	Fuel Consumption
HDVs	Heavy duty vehicles
HI	Heat Index
JRC	Joint Research Centre
km/h	Kilometers per hour
LPG	Liquefied Petroleum Gas
LCVs	Light Commercial Vehicles
L-category	Vehicles including Mopeds , motorcycles, Quads and ATVs, and Micro Cars
LPG	Liquefied Petroleum Gas
N_2O	Nitrous Oxide
NH_3	Ammonia
NO_x	Nitrogen Oxides
PM	Particulate Matter

PN	Particle Numbers
PCI	Pavement Condition Index
QA / QC	Quality Assurance / Quality Control
SO_2	Sulfur Dioxide
SCR	Selective Catalytic Reduction
tkm	Tonne-kilometer
VOC	Volatile Organic Compounds
VRP	Vehicle Routing Problem

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Abstract

The purpose of this deliverable is to present the environmental impact of LIFE GYR project and the monitoring protocol followed to estimate this impact. The developed monitoring protocol is based on the EMEP/EEA air pollutant emission inventory guidebook 2019. The joint EMEP/EEA air pollutant emission inventory guidebook supports the 'Guidelines for Reporting Emissions and Projections Data' under the United Nations Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (LRTAP Convention). The guidebook provides concise guidance on how to compile an air pollutant emissions inventory. GYR team improve further the presented in the guidebook emissions calculation model by taking under consideration additional factors influencing the fuel consumption and emission emitted.

The monitoring protocol was applied for 2 check-points:

- CP1.1 (before the real life demonstration): we use the developed methodology and data routing plans which has been resulted without the use of GYR platform, using the simulation tool developed in the frame of Action C3 and we establish the baseline.

- CP1.2 (after the end of the real life demonstration): we use the developed methodology and data routing plans which has been resulted with the use of GYR platform and we establish the end of the project scenario.

After the estimation of the environmental impact of both scenarios (baseline scenario and end of the project scenario), we compare these impacts to define the overall environmental impact of the project.

1 Introduction

1.1 Action definition

The scope of *Action C.1 Monitoring of the environmental impact of the project* is to monitor and measure the project's impact on the environmental problem targeted. A monitoring protocol is established based on a novel emission inventory methodology, which is applied in the routing problems of the project's demonstrators in order to assess the environmental impact of the problem.

The expected emission reductions in terms of Fuel Consumption (FC), Carbon Dioxide (CO_2), Methane (CH_4), Carbon Monoxide (CO), Nitrous Oxide (N_2O), Ammonia (NH_3), Nitrogen Oxides (NO_x), Particulate Matter (PM), Volatile Organic Compounds (VOC) and Sulfur Dioxide (SO_2) are calculated during the project lifetime, based on the following Sub-Actions.

1.2 Description of each Sub-Action

Action C1 includes two sub-actions, namely Sub-Action C1.1 *Monitoring methodology for environmental impact* and Sub-Action C1.2 *Data collection and quantification of environmental impact*.

1.2.1 Sub-Action C1.1 Monitoring methodology for environmental impact

During this Sub-Action, a novel emission inventory methodology is developed for the accurate and case-tailored emission inventory estimation.

This novel emission inventory methodology is developed based on the EMEP/EEA air pollutant emission inventory guidebook 2019 and outcomes of previously implemented EU funded projects (i.e. emission calculation models developed in GreenRoute project and emission inventory methodology developed in LIFE GreenYourMove project). GYR team adjusts the approach developed in the frame of previous projects to cater the specific vehicles fleet (i.e. freight transportation vehicles instead of passenger vehicles and public transport means vehicles) of demonstrators.

1.2.2 Sub-action C1.2: Data collection and quantification of environmental impact

Routing planning data are collected regularly during a period of 17 months that routing planning is implemented with the use of GYR platform by 5 demonstrators/customers of GYR service and 3 new customers of GYR service. In the framework of this sub-action, the project team defines:

a) the precision of data required by the emission inventory methodology (developed in Sub-Action C1.1);

b) the amount of data collected (i.e. the daily routing plans per user);

c) the frequency of collecting dynamic data (i.e. 10 routing plans per user per week).

Additionally, the data collected by GYR team, and an external assistant from demonstrators and new users are homogenized (e.g. data per time frame), digitized (e.g. transformation of data to adequate digital form) and classified (e.g. data per truck).

UTH and external assistant with the support of demonstrators and new users collected data regularly (i.e. 10 days per month) during a period of 17 months that routing is implemented with the use of GYR platform.

The first and the second check point (i.e. CP1.1 and CP1.2) are both represented from the same data set in order to be properly compared.

A number of monitoring indicators are calculated based on the collected data. These indicators are defined in the following section.

2 Indicators

The indicators defined in the frame of LIFE GYR project for the assessment of the environmental impact of the project are in total 10 and are presented in the following table. We have to notice that these indicators are used also beyond other for the assessment of the socio-economic impact of the project in Action C2.

Table 1: Indicators

ID (as described in Action C2)	Criteria	Indicator	Direction	Unit
B.10.1	Fuel efficiency	Average amount of consumed fuels per travelled kilometers	Minimize	gr/kg per km
B.10.2	CO_2 efficiency	Emitted mass of CO2/transport work	Minimize	gr/kg per km
B.10.3	CH_4 efficiency	Average amount of emitted CH4 per travelled kilometers	Minimize	gr/kg per km
B.10.4	CO efficiency	Average amount of emitted CO per travelled kilometers	Minimize	gr/kg per km
B.10.5	N_2O efficiency	Average amount of emitted N2O per travelled kilometers	Minimize	gr/kg per km
B.10.6	NH_3 efficiency	Average amount of emitted NH3 per travelled kilometers	Minimize	gr/kg per km
B.10.7	NO_x efficiency	Average amount of emitted NOx per travelled kilometers	Minimize	gr/kg per km
B.10.8	PM efficiency	Average amount of emitted PM per travelled kilometers	Minimize	gr/kg per km
B.10.9	VOC efficiency	Average amount of emitted VOC per travelled kilometers	Minimize	gr/kg per km
B.10.10	SO_2 efficiency	Average amount of emitted SO2 per travelled kilometers	Minimize	gr/kg per km

The activity data needed for the assessment of these indicators are the vehicle attributes, the travelled distance, the occupancy rate of the trucks, the average circulate speed of the trucks, the road characteristics, and the on-road dynamics.

2.1 Vehicle attributes

The scope is to determine the **Vehicle Class ID** for all vehicles participating in the routing process (see **Annex I Vehicle Class IDs** for the complete list of the Vehicle Class IDs) based on the following criteria:

- Vehicle type (column vehicle_type): The vehicle type of each vehicle is determined. The classification used includes Light Motor Vehicles, Light Commercial Vehicles and Heavy Duty Vehicles, which are classified to light (less than 14 tons), medium (between 14 and 28 tons) and heavy (greater than 28 tons) trucks.

Table 2: Vehicle type

vehicleType_classID	description_en
1	L-Category
2	Light Commercial Vehicles
3	HDV < 14 t
4	14 t < HDV < 28 t
5	28 t < HDV

- Size of vehicle (column vehicle_description): The size of each vehicle based on its type is determined. The classification differs for each type of vehicle. For Light Motor Vehicles the engine size characteristic is used for the classification, i.e. two-stroke greater than 50 cm^3, four-stroke between 50 and 150 cm^3, etc. For Light Commercial Vehicles the maximum mass characteristic is used to classify vehicles; all vehicles of this type belong to category N1 (vehicles for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes), which is further divided into three weight classes (N1-I, N1-II and N1-III), based on the vehicles' reference mass, defined as the mass of the vehicle in running order less the uniform mass of the driver of 75 kg, and increased by a uniform mass of 100 kg. For Heavy Duty vehicles the maximum mass characteristic is used to classify vehicles; all vehicles of this type belong to categories N2 (vehicles for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes) and N3 (vehicles for the having a maximum mass exceeding 12 tonnes). These are further classified to rigid (single unit vehicles) and articulated (vehicles with a permanent or semi-permanent pivot joint in their construction). Rigid and articulated vehicles are then classified based on the vehicles' reference mass. See Annex I for the complete list.
- Emission control technology (column typeOfEngine): The exhaust emission standards the vehicle is compliant with according to the European legal framework, i.e. Euro I to Euro VI standards, is determined. For older vehicles, i.e. vehicles non-compliant with

European emission standards but already on the road when these standards were established, the conventional category is used to characterize emission classification.

- Fuel specifications (column typeOfFuel): The type of fuel of each vehicle is determined. The classification used includes petroleum fuels (petrol or Diesel fuels) and alternative fuels (electricity, compressed natural gas (CNG), liquefied petroleum gas (LPG) fuels).

Table 3: Fuel type

typeOfFuel_classID	description_en
1	Petrol
2	Diesel
3	Electricity
4	CNG
5	LPG

2.2 Travelled distance

The travelled distance is needed to define the total emissions produced through the routing process. For each possible combination of nodes the distance and time between nodes is computed via the GYR platform.

2.3 Occupancy rate

Occupancy rate is classified based on the average vehicle load compared to its capacity. The occupancy rate is equal to Freight loaded on the truck / Vehicle capacity. For each possible combination of nodes the occupancy rate between nodes is computed via the GYR platform.

Table 4: Occupancy rate

occupancy_min	occypancy_max	description_%
0	10	**10%**
10	20	**20%**
20	30	**30%**
30	40	**40%**
40	50	**50%**
50	60	**60%**
60	70	**70%**
70	80	**80%**
80	90	**90%**
90	100	**100%**

2.4 Average circulation speed

The average circulation speed can either be obtained from traffic models via online APIs or be assumed based on statistics. In cases where traffic monitoring is unavailable, the average circulation speed is defined based on the road classification. In such cases, minimum and maximum speed limits are obtained based on urban, rural and highway functional road types.

For each possible combination of nodes the average circulation speed between nodes is computed.

Table 5: Speed classes

speed_classID	speed_min	speed_max	description
1	0	5	km/h
2	5	10	km/h
3	10	15	km/h
4	15	20	km/h
5	20	25	km/h
6	25	30	km/h
7	30	35	km/h
8	35	40	km/h
9	40	45	km/h
10	45	50	km/h
11	50	55	km/h
12	55	60	km/h
13	60	65	km/h
14	65	70	km/h
15	70	75	km/h
16	75	80	km/h
17	80	85	km/h
18	85	90	km/h
19	90	95	km/h
20	95	100	km/h
21	100	105	km/h
22	105	110	km/h
23	110	115	km/h
24	115	120	km/h
25	120	125	km/h
26	125	130	km/h
27	130	135	km/h
28	135	140	km/h
29	0	200	km/h (general)
30	0	40	Urban (km/h)
31	40	70	Rural (km/h)
32	70	140	Highway (km/h)

2.5 Road characteristics

For each possible combination of nodes the road gradient and the pavement condition are computed between nodes via the GYR platform.

- Road gradient: Road gradient categories are defined based on the lateral slopes of the road's geometry. These vary between a minimum and a maximum incline of -20% and 0 respectively for downhill roads and between a minimum and a maximum incline of 0 and 20% respectively for uphill roads. In the case where it cannot be computed by the Cost Matrix API a nominal condition with 0% road gradient is considered.

Table 6: Gradient

gradient_min	gradient_max	Description
-20	-5	**-6%**
-5	-3	**-4%**
-3	-1	**-2%**
-1	0	**-1%**
0	0	**0%**
0	1	**1%**
1	3	**2%**
3	5	**4%**
5	20	**6%**

- Road surface characteristics: the road age is considered for road surface characteristics, ranging from 1 to 15 years. In the case where it cannot be computed a nominal condition of a newly constructed asphalt pavement is considered (i.e. year 1).

2.6 On-road dynamics

For each possible combination of nodes the traffic flow, the wind speed and direction and the A/C usage are computed between nodes.

- Traffic flow: Traffic flow is classified as low (increased vehicle speeds), medium (normal vehicle speeds) and heavy (decreased vehicle speeds) for each possible combination of nodes. Regarding the Traffic flow data, in the case where it cannot be computed by a Traffic API a nominal condition of low traffic situation is considered.
- Wind speed and direction: Wind speeds are classified between a minimum and maximum value of -80 to 0 km/h for headwinds, i.e. winds blowing against the direction of travel of the vehicle, and between 0 and 80 km/h for tailwinds, i.e. winds blowing in the direction of travel. Wind speed is computed for each possible combination of nodes via the weather API. Regarding the wind speed data, in the case where it cannot be computed by the weather API a nominal condition of a wind speed equal to zero is considered.

Table 7: Wind velocity

speed_min	speed_max	description
-80	-40	km/h
-40	-25	km/h
-25	-15	km/h

-15	-5	km/h
-5	5	km/h
5	15	km/h
15	25	km/h
25	40	km/h
40	80	km/h

- Use of Air Condition: Air condition usage is classified based on the heat index. The heat index is an index that combines air temperature and relative humidity and is also known as the felt air temperature. Differentiations occur for heat index values between 68 (actual temperature of 22°C and humidity 45%) and 110 (actual temperature over 40°C and humidity 100%). Regarding the heat index data, in the case where it cannot be computed via weather API, a nominal condition where an A/C operation is not required, i.e. temperature between 20 and 28°C with humidity of 20 to 30%, is considered.

3 Monitoring Protocol

3.1 Introduction

An emission inventory is a first step towards accounting and monitoring emissions. An emission inventory is a dataset of all quantified emissions, expressed by source for:

✓ A particular location (e.g. country);
✓ A particular time span (e.g. time-series or specified year);
✓ A particular pollutant (e.g. CO2).

Emission inventories can be useful to various logistics operators in order to assess and attempt to investigate ways to mitigate emissions, to research programs who wish to evaluate the current state, to health impact studies, to econometric studies.

The basic elements that are relevant to each emission inventory and need to be defined are the following:

Air pollutants to be included: the pollutants that are analyzed in the inventory;

Inventory baseline year: the baseline year against which all future emission inventories are compared;

Emission sources: the sources that produce emissions included in the inventory;

Activity data: the activity data for each emission source that are used in the emission calculations.

In order to compile and create the emission inventory, for each pollutant the emissions are estimated by multiplying the activity data for each source with a corresponding emission factor. The resulted emission inventory should ensure a high quality, which will promote its use. The basic quality criteria are the following[1]:

Accuracy: sufficient accuracy should be promoted in emission estimates. Emissions should not be systematically underestimated or overestimated.

Comparability: emission estimates should be comparable among different parties. Thus, parties should follow the methodologies proposed by the convention.

Completeness: the inventory should cover all the sources and air pollutants, as requested by the convention.

Consistency: consistent methodology should be used to estimate emission for all the time-series, which will enable meaningful comparison of inventories over the years.

Transparency: all the methodologies and assumptions used for the estimation of emissions should be clearly documented, in order to facilitate replication and assessment of the inventory by other users.

The basic equation used to estimate emissions is the following:

$$\text{Emissions} = \text{Activity Data} * \text{Emission Factor} \qquad \text{Eq. 1}$$

Activity data is a measurement of the activities that generate emissions, such as gasoline consumption in vehicles. Emission factor are ratios of the emissions per unit of activity data, i.e. gr CO_2 emitted by km travelled by a vehicle. In some cases, emission factors are calculated using laboratory data or real-world data, but also default emission factors are provided in guidance documents by EEA.

The general procedure for calculating emissions from each emission source is as follows:

Step 1: Determination of the needed activity data (e.g. fuel consumption) for each emission source;

Step 2: Collection of the activity data;

Step 3: Quality assurance / Quality Control (QA /QC) procedure (i.e. gap-filling);

Step 4: Selection of appropriate emission factors based on the available activity data;

Step 5: Calculation of emissions for each air pollutant (e.g. CO_2, CH_4, NO_x etc.).

In the frame of LIFE GreenYourRoute project the above 5 steps were followed in order to calculated the environmental impact of the real life demonstration period of 17 months.

3.2 Data

The monitoring protocol is based on the novel emission methodology, developed under the frame of Action C1 of LIFE GreenYourMove project. This monitoring protocol was applied to the Greek public transport network in order to assess the environmental impact of the problem targeted. The monitoring protocol and the novel emission methodology consist of 5

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[1] http://climatechange.transportation.org/pdf/NCHRPGHGGuidelinesJuly152011.pdf

steps and are based on the general procedure for calculation emissions, as described above in section 3.1.

As already mentioned, the steps for creating an emission inventory are 5. In the following, these 5 steps are described.

3.2.1 Step 1: Determination of the needed activity data

The activity data that are needed for the novel emission methodology as well as for the monitoring protocol are the vehicles' attributes, the distance travelled, each vehicle's occupancy rate and the average vehicle speed. A good understanding of the attributes of the vehicle is necessary for estimating their degree of environmental pressure. The emissions produced through road transport are obtained from functional relations that predict the quantity of a pollutant that is emitted per distance driven, energy consumed or amount of fuel used. Emissions produced are usually derived from vehicle categories and they depend on many parameters, such as vehicle characteristics, emission control technology and fuel specifications.

3.2.1.1 Vehicle attributes

All types of vehicles suitable for freight transport are classified based on European Commission's directives for vehicle classification as part of emission standards and other vehicles' regulations.

- Vehicle type: The vehicle type of each vehicle is determined. The classification used includes Light Motor Vehicles, Light Commercial Vehicles and Heavy Duty Vehicles, which are classified to light (less than 14 tons), medium (between 14 and 28 tons) and heavy (greater than 28 tons) trucks.
- Size of vehicle: The size of each vehicle based on its type is determined. The classification differs for each type of vehicle. For Light Motor Vehicles the engine size characteristic is used for the classification, i.e. two-stroke greater than 50 cm^3, four-stroke between 50 and 150 cm^3, etc. For Light Commercial Vehicles the maximum mass characteristic is used to classify vehicles; all vehicles of this type belong to category N1 (vehicles for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes), which is further divided into three weight classes (N1-I, N1-II and N1-III), based on the vehicles' reference mass, defined as the mass of the vehicle in running order less the uniform mass of the driver of 75 kg, and increased by a uniform mass of 100 kg. For Heavy Duty vehicles the maximum mass characteristic is used to classify vehicles; all vehicles of this type belong to categories N2 (vehicles for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes) and N3 (vehicles for the having a maximum mass exceeding 12 tonnes). These are further classified to rigid (single unit vehicles) and articulated (vehicles with a permanent or semi-permanent pivot joint in their construction). Rigid and articulated vehicles are then classified based on the vehicles' reference mass.

3.2.1.2 Fuel specifications

The type of fuel of each vehicle is determined. The classification used includes petroleum fuels (petrol or Diesel fuels) and alternative fuels (electricity, compressed natural gas (CNG), liquefied petroleum gas (LPG) fuels).

3.2.1.3 Emission control technology

The exhaust emission standards the vehicle is compliant with according to the European legal framework, i.e. Euro I to Euro VI standards, is determined. For older vehicles, i.e. vehicles non-compliant with European emission standards but already on the road when these standards were established, the conventional category is used to characterize emission classification.

3.2.1.4 Travelled distance

The travelled distance is needed to define the total emissions produced through the routing process.

3.2.1.5 Occupancy rate

Utilization efficiency is one of the main parameters that determine energy and emission efficiency. Higher load factor is likely to result in a significant increase in vehicle weight and therefore in more energy use and emissions. High load factors are still preferable, however, since low load factors imply a higher number of transport movements, which is generally more environmentally damaging. Occupancy rate is classified based on the average vehicle load compared to its capacity. This factor is not taken into account for two or three-wheeled vehicles (mopeds and motorcycles).

3.2.1.6 Average circulation speed

The average circulation speed can either be obtained from traffic models or be assumed based on the scientific literature and statistics. Speed classes to define the circulation speed are defined for both cases. In cases where average circulation speed can be obtained from traffic monitoring models, speed classes are determined based on the minimum and maximum speed that can be obtained in kilometers per hour (km/h). In cases where traffic monitoring is unavailable, the average circulation speed is defined based on the road classification. In such cases, minimum and maximum speed limits are obtained based on urban, rural and highway functional road types.

3.2.2 Step 2: Collection of the corresponding activity data

The second step concerns the collection of the identified activity data. The project beneficiaries acting as demonstrators, UTH and an external assistant collect, digitize and homogenize all the activity data concerning vehicle characteristics of their fleet. A vehicle class is defined for each vehicle based on its type, size, type of fuel and emission control technology specifications. Distance and average circulation speed data are collected through the Cost Matrix API, developed under the frame of Action B3. The Cost Matrix API is utilized both in the case when the routing process is defined by the demonstrators (i.e. for defining the baseline emissions data) and when the routing process is derived directly by the Vehicle Routing Problem (VRP) algorithm developed under the frame of Action B2. Occupancy rate data are either calculated based on the freight carried by each vehicle compared to its capacity when the routing process is defined by the demonstrators or are dynamic data derived from the VRP algorithm.

3.2.3 Step 3: Performance of a QA/QC analysis

In the case of missing activity data, an imputation process is followed, based on each activity. No missing data exist in the vehicle attributes category. The technical specifications for all vehicles are available through various sources, such as vehicle registration documents, online technical sheets, automotive brands' webpages, etc. No imputation process is therefore needed for the data of this category. Regarding the travelled distance, in case the Cost Matrix API is unable to provide the necessary data, distance approximation approaches, such as Manhattan distances calculation, are performed instead. Regarding the occupancy rate data, no missing activity data exist. However, in several cases order packages may be of vague dimensions. In these cases, the order's volume is calculated based on the order quantity and the most suitable defined package dimensions. Regarding the average circulation speed, in case the Cost Matrix API is unable to provide the necessary data, then the network where the routing process takes place is considered. In the case of urban areas a speed class with speed values ranging between 0 and 40 km/h is considered; in the case of rural areas a speed class with speed values ranging between 40 and 70 km/h is considered; and in the case of networks outside built-up areas including highways and national roads a speed class with speed values between 70 and 140 km/h is considered. In the case where the network cannot be categorized, a general speed class with speed values between 0 and 200 km/h is considered.

3.2.4 Step 4: Selection of the appropriate emission factors

Additional emission factors are determined by the ambient and operating conditions of the vehicle.

3.2.4.1 Road characteristics

Road characteristics include the road gradient and the road surface characteristics.

- Road gradient: The gradient of a road is an important factor that affects the exhaust emissions and the fuel consumption of a vehicle. It has the effect of increasing or decreasing the resistance of a vehicle to traction. The overall gradient effect on vehicle behavior is dependent on the vehicle's mass. In general, for light duty trucks the gradient effect is less important compared to heavy duty trucks, because of their higher masses. Road gradient categories are defined based on the lateral slopes of the road's geometry. These vary between a minimum and a maximum incline of -20% and 0 respectively for downhill roads and between a minimum and a maximum incline of 0 and 20% respectively for uphill roads. Regarding the road gradient, in the case where it cannot be computed by the Cost Matrix API a nominal condition with 0% road gradient is considered.
- Road surface characteristics: the condition of the pavement is defined by its surface roughness, the construction material used, its age and condition. Road surface characteristics affect both the rolling resistance and the suspension losses. These factors affect the fuel consumption. Road characteristics are collected through the Cost Matrix API, developed under the frame of Action B3. For each possible combination of nodes the road gradient and the pavement condition are computed along with the distance and time between nodes. Regarding the pavement condition, in the case where it cannot be computed by the Cost Matrix API a nominal condition of a newly constructed asphalt pavement is considered.

3.2.4.2 On-road dynamics

The dynamic conditions in which a vehicle is driven play a role in determining the level of its environmental activity.

- Traffic flow: Traffic flow is defined by the current traffic volume of the road compared to its designed capacity. Higher traffic volumes may lead to congestion, which increases the emissions emitted due to decreased vehicle speeds and more frequent stop-start activities. Traffic flow is classified as low (increased vehicle speeds), medium (normal vehicle speeds) and heavy (decreased vehicle speeds).
- Wind speed and direction: The air flow over a vehicle transmits an aerodynamic force to the vehicle through pressure and shear stress distribution acting on the surface of the vehicle. Wind speeds are classified between a minimum and maximum value of -80 to 0 km/h for headwinds, i.e. winds blowing against the direction of travel of the vehicle, and between 0 and 80 km/h for tailwinds, i.e. winds blowing in the direction of travel. Regarding the wind speed data, in the case where it cannot be computed by the Weather API a nominal condition of a wind speed equal to zero is considered.
- Use of Air Condition: The influence of air-conditioning activity on the emissions and fuel consumption of vehicles is an important issue. Temperature and humidity are the most important factors of A/C system demand. While temperature is a widely recognized influence, the load placed on the air conditioning system by humidity can account for over half of the total load under the ambient conditions. Therefore, air condition usage is classified based on the heat index. The heat index is an index that combines air temperature and relative humidity and is also known as the felt air temperature. Differentiations occur for heat index values between 68 (actual temperature of 22°C and humidity 45%) and 110 (actual temperature over 40°C and humidity 100%). Regarding the heat index data, in the case where it cannot be computed by the Weather API a nominal condition where an A/C operation is not required, i.e. temperature between 20 and 28□C with humidity of 20 to 30%, is considered.
- Traffic flow data are collected through the Traffic API, developed under the frame of Action B3. Wind speed and direction data and heat index data are collected through the Weather API developed under the frame of Action B3. Regarding the Traffic flow data, in the case where it cannot be computed by the Traffic API a nominal condition of low traffic situation is considered.

3.2.5 Step 5: Calculation of the environmental impact

The environmental impact of LIFE GYR is calculated during the 17 Months of real-life practice period of Action B5. During this period, all demonstrators and 3 new customers (for the last 7 months of the real life demonstration period) use GYR service for calculating their routing activities. The emissions produced through the implemented routing processes are calculated. In order to assess the environmental impact of LIFE GYR, the project team develops a simulation tool under the frame of Action C3. This simulation tool is an application simulating each demonstrators routing planning before the integration of GYR application. The emissions produced through the routing process proposed by the simulation tool are also calculated and compared to the emissions from the actual routing plan followed in order to assess the environmental impact.

4 Novel Emission Inventory Methodology

One of the main LIFE GreenYourRoute project goals is to update and produce a vehicles emission calculation model in the form of a database. The purpose of the emission calculation model is to imprint a database based on updated COPERT model and a thorough state of the art analysis concerning vehicles emission factors. This database operates as a new, improved and detailed database for emission factors. The database is used as a source for the GYR platform operations. More specifically, the platform is used as a tool where the user can automatically calculate the emissions of vehicles by selecting specific characteristics/parameters.

The model parameters that were updated and enriched are the model's correction factors. The new model produced, focused on different vehicle types including Light commercial, L-category, HDV (up to 14 tn) and HDV (more than 14 tn) vehicles. Furthermore, in the new database GYR team tried to focus and to find solutions (valid values) for a wide range of emission factors.

Current section of this deliverable accompanies the GYR database introduced at the back-end of GYR platform (Deliverable B1.2 in Action B2) and its main purpose is to provide the database methodology and structure description as well as the respective justifications using literature results in order to ensure the validity of the content (database). Moreover, this section provides with background information for the best comprehension of the methodology followed and database content as well as the choices made in this context.

4.1 Euro standards and Emission Reduction Technologies in Vehicles

4.1.1 Introduction

The EURO standards as well as emission reduction technologies have been used to reduce emissions derived from vehicles. The first focuses on the legislative reduction of final emissions concentrations that are produced by vehicles, while the second are technologies that are implemented in vehicles in order to directly (on the fly) reduce the produced emissions (between the engine and the end-pipe). These aspects are playing crucial role in the emission produced by a vehicle, thus they were taken into consideration for GYR's database development.

4.1.2 Euro Standards

Euro standards are emission regulations applied in vehicles of different categories. These regulations are defined by the EU and illustrated in different EU directives. Euro standards are progressively become tighter (as time passes and as technology evolves). According to EC website (European Commission) the emissions regulated by the EU are "particulate matter (PM), nitrogen oxides (NOx), unburnt hydrocarbons (HC) and carbon monoxide (CO)". Moreover, the EURO standards are illustrated with Arabic digits for LCVs and with roman digits for the HDVs.

Finally, the most recent standards are derived from the following EC regulations:

- Directive 2007/46/EC (common framework for road vehicles)

- Regulation 715/2007/EC (Euro 5 and 6 limits)
- Regulation 692/2008/EC (Amendments for 715/2007/EC, Euro 5 and Euro 6)
- Regulations 2017/1151 (LDV testing processes) and 2018/1832 (real driving testing)
- Regulation 595/2009/EC (new limits for HDVs)
- Regulation 582/2011/EC (amendments for 595/2009/EC which is related with HDVs Euro VI category.

Progressive implementation of EURO standards in both LCVs and HDVs have led to a significant decrease of those pollutants. In the following tables the emission limits for each Euro class, for LCVs and HDVs are illustrated. The pollutants are expressed as g/km. The PN stands for Particulate Number, the NMHC stands for Non-Methane Hydro Carbons and the THC stands for Total Hydro Carbons.

Table 8: Euro standards for LCVs ≤1305 kg reference mass (Category N1 Class I). Values are presented as g/km or Particles/Km for the case of PN.

Tier	CO	THC	NMHC	NOx	HC+NOx	PM	PN
Diesel							
Euro 1	2.72	-	-	-	0.970	0.1400	-
Euro 2	1.00	-	-	-	0.700	0.0800	-
Euro 3	0.64	-	-	0.50	0.560	0.0500	-
Euro 4	0.50	-	-	0.25	0.300	0.0250	-
Euro 5a	0.50	-	-	0.18	0.230	0.0050	-
Euro 5b	0.50	-	-	0.18	0.230	0.0045	6×10^{11}
Euro 6b	0.50	-	-	0.08	0.170	0.0045	6×10^{11}
Euro 6c	0.50	-	-	0.08	0.170	0.0045	6×10^{11}
Euro 6d-Temp	0.50	-	-	0.08	0.170	0.0045	6×10^{11}
Euro 6d	0.50	-	-	0.08	0.170	0.0045	6×10^{11}
Petrol (Gasoline)							
Euro 1	2.72	-	-	-	0.97	-	-
Euro 2	2.20	-	-	-	0.50	-	-
Euro 3	2.30	0.20	-	0.150	-	-	-
Euro 4	1.00	0.10	-	0.080	-	-	-
Euro 5a	1.00	0.10	0.068	0.060	-	0.0050*	-
Euro 5b	1.00	0.10	0.068	0.060	-	0.0045*	-
Euro 6b	1.00	0.10	0.068	0.060	-	0.0045*	6×10^{11}

Tier	CO	THC	NMHC	NOx	HC+NOx	PM	PN
Euro 6c	1.00	0.10	0.068	0.060	-	0.0045*	6×10^{11}
Euro 6d-Temp	1.00	0.10	0.068	0.060	-	0.0045*	6×10^{11}
Euro 6d	1.00	0.10	0.068	0.060	-	0.0045*	6×10^{11}

* The Value is applied for Vehicles equipped with Direct Injection Engines

Table 9: Euro standards for LCVs 1305–1760 kg reference mass (Category N1 Class II). Values are presented as g/km or Particles/Km for the case of PN.

Tier	CO	THC	NMHC	NOx	HC+NOx	PM	PN
Diesel							
Euro 1	5.17	-	-	-	1.400	0.1900	-
Euro 2	1.25	-	-	-	1.000	0.1200	-
Euro 3	0.80	-	-	0.65	0.720	0.0700	-
Euro 4	0.63	-	-	0.33	0.390	0.0400	-
Euro 5a	0.63	-	-	0.235	0.295	0.0050	-
Euro 5b	0.63	-	-	0.235	0.295	0.0045	6×10^{11}
Euro 6b	0.63	-	-	0.105	0.195	0.0045	6×10^{11}
Euro 6c	0.63	-	-	0.105	0.195	0.0045	6×10^{11}
Euro 6d-Temp	0.63	-	-	0.105	0.195	0.0045	6×10^{11}
Euro 6d	0.63	-	-	0.105	0.195	0.0045	6×10^{11}
Petrol (Gasoline)							
Euro 1	5.17	-	-	-	1.4	-	-
Euro 2	4.00	-	-	-	0.6	-	-
Euro 3	4.17	0.250	-	0.180	-	-	-
Euro 4	1.81	0.130	-	0.100	-	-	-
Euro 5a	1.81	0.130	0.090	0.075	-	0.0050*	-
Euro 5b	1.81	0.130	0.090	0.075	-	0.0045*	-
Euro 6b	1.81	0.130	0.090	0.075	-	0.0045*	6×10^{11}
Euro 6c	1.81	0.130	0.090	0.075	-	0.0045*	6×10^{11}
Euro 6d-Temp	1.81	0.130	0.090	0.075	-	0.0045*	6×10^{11}

Tier	CO	THC	NMHC	NOx	HC+NOx	PM	PN
Euro 6d	1.81	0.130	0.090	0.075	-	0.0045*	6×10^{11}

* The Value is applied for Vehicles equipped with Direct Injection Engines

Table 10: Euro standards for LCVs >1760 kg (max 3.500 kg) reference mass. Category N1 Class III and N2. Values are presented as g/km or Particles/Km for the case of PN.

Tier	CO	THC	NMHC	NOx	HC+NOx	PM	PN
Diesel							
Euro 1	6.90	-	-	-	1.700	0.2500	-
Euro 2	1.50	-	-	-	1.200	0.1700	-
Euro 3	0.95	-	-	0.780	0.860	0.1000	-
Euro 4	0.74	-	-	0.390	0.460	0.0600	-
Euro 5a	0.74	-	-	0.280	0.350	0.0050	-
Euro 5b	0.74	-	-	0.280	0.350	0.0045	6×10^{11}
Euro 6b	0.74	-	-	0.125	0.215	0.0045	6×10^{11}
Euro 6c	0.74	-	-	0.125	0.215	0.0045	6×10^{11}
Euro 6d-Temp	0.74	-	-	0.125	0.215	0.0045	6×10^{11}
Euro 6d	0.74	-	-	0.125	0.215	0.0045	6×10^{11}
Petrol (Gasoline)							
Euro 1	6.90	-	-	-	1.7	-	-
Euro 2	5.00	-	-	-	0.7	-	-
Euro 3	5.22	0.29	-	0.210	-	-	-
Euro 4	2.27	0.16	-	0.110	-	-	-
Euro 5a	2.27	0.16	0.108	0.082	-	0.0050*	-
Euro 5b	2.27	0.16	0.108	0.082	-	0.0045*	-
Euro 6b	2.27	0.16	0.108	0.082	-	0.0045*	6×10^{11}
Euro 6c	2.27	0.16	0.108	0.082	-	0.0045*	6×10^{11}
Euro 6d-Temp	2.27	0.16	0.108	0.082	-	0.0045*	6×10^{11}
Euro 6d	2.27	0.16	0.108	0.082	-	0.0045*	6×10^{11}

* The Value is applied for Vehicles equipped with Direct Injection Engines

Table 11: Euro standards for HDVs. Values are presented as g/km or as described in the relevant rows of the table.

Tier	Date	Test Cycle	CO	HC	NOx	NH3 [ppm]	PM	PN [particles/kWh]	Smoke $[m^{-1}]$
Euro I	1992, < 85 kW	ECE R49	4.5	1.10	8.00		0.612		
	1992, > 85 kW		4.5	1.10	8.00		0.36		
Euro II	October 1995		4.0	1.10	7.00		0.25		
	October 1997		4.0	1.10	7.00		0.15		
Euro III	October 1999 EEVs only	ESC & ELR	1.5	0.25	2.00		0.02		0.15
	October 2000		2.1	0.66	5.00		0.10 0.13*		0.8
Euro IV	October 2005		1.5	0.46	3.50		0.02		0.5
Euro V	October 2008		1.5	0.46	2.00		0.02		0.5
Euro VI	31 December 2012	WHSC	1.5	0.13	0.40	10	0.01	8×10^{11}	
		WHTC	4.0	0.16	0.46	10	0.01	6×10^{11}	

*It is applied for engines with swept volume <0.75 dm^3 per cylinder and a rated power speed >3,000/min.

- EEV stands for "Enhanced environmentally friendly vehicle".
- Smoke values represent opacity derived from the smoke and 0 m^{-1} represents completely clear while the 10 m^{-1} represents completely black (total opacity) (Emissions Analytics, 2018).

The test cycles presented in the above table are defined settings for the objective testing of the emissions produced by vehicles; furthermore, test cycles support the comparison of different vehicles measurements as well as they attempt to approximate real life conditions (Samuel, 2002).

4.1.3 Emission Reduction technologies

As initial vehicle emissions (produced directly from the internal combustion engines of vehicles) could be higher than the required limits (see euro standard section), vehicle producers have developed and applied several technologies for the reduction of different types of emissions (e.g. NOx and PM) (Leon Ntziachristos, updated (2018)).

According to COPERT model and based on the literature, current fleets could be equipped with the following categories of relevant technologies:

- DPF: DPF stands for “Diesel Particulate Filter”. DPF is a widely applied filter technology for the reduction of PM (Particulate Matter) emissions of diesel fueled vehicles; the technology is directly applied in exhaust gasses (Quan-shun, 2017).
- SCR: SCR stands for “Selective Catalytic Reduction”. This technology is widely applied in vehicles from the previous decade in order to reduce NOx emissions, while the highest reduction rate is around 90%; the technology is applied in exhaust gasses with the use of a catalyst and ammonia (Jaworski, 2015).
- DPF + SCR: This category represents the combination, i.e. when both technologies (Diesel Particulate Filter and Selective Catalytic Reduction) are applied in a vehicle.
- EGR: EGR stands for “Exhaust Gas Recirculation”. EGR systems are redirecting exhaust gasses to be used as engine intake in order to reduce NOx (vehicles with diesel engines). This is being achieved as this application reduces the oxygen concentration in the combustion chamber of the engine and thus the combustion temperature is decreased, a phenomenon that consequently leads to lower NOx emissions (Naresh, 2015).
- GDI: GDI stands for “Gasoline Direct Injection”. In engines that work with GDI technology the fuel is injected directly in the cylinders and as a result they present higher fuel economy (reduced FC and CO2) but also higher PM emissions (Yang, 2018).
- GDI +GPF: GPF stands for “Gasoline Particulate Filter”. As the GDI technology could lead to higher amounts of PM emissions, GPF technology could be used to decrease them; Since EURO 6c standard presents strict limits for PM emissions, GPF technology is widely installed in new vehicles as it has been reported that could reduce PN more than 89% (Yang, 2018). In this case, COPERT model refers to vehicles that combine both technologies.
- LNT+DPF: LNT stands for Lean NOx Trap. The LNT system is a technology with the same purpose with SCR (NOx reduction) and could be used as the only emission reduction method in a vehicle or combined with other technologies in order to increase efficiency (Wetzel, 2010). In this case LNT is combined with DPF filters.
- PFI: PFI stands for Port Fuel Injection. PFI engine is a common technology for vehicles. The vehicles that have PFI engines are currently more widely abundant (compared with GDI), but as the standard becoming stricter it is expected that this will be changed in new vehicles (GDI engines are expected to be used more widely); Moreover it has been found that PFI PM emissions are two times lower than GDI (Georges Saliba, 2017).

4.2 Database and Development Methodology Background

4.2.1 Introduction

As mentioned in the previous section, the database developed in the current project was based on COPERT (EMISIA, 2018). COPERT is an "EU standard vehicle emissions calculator" that uses several parameters to estimate fuel consumption and different types of emissions in different vehicle categories. COPERT model development has been managed generally by EEA while the scientific part has been managed by JRC. The development has been performed, as part of European Topic Centre for Air Pollution and Climate Change Mitigation (ETC/ACM) scheme. The COPERT model is used for the development of EU countries emission inventories as well as for several other purposes including academic purposes (EMISIA).

4.2.2 COPERT model analysis

The last version of COPERT model was downloaded from the website of EMISSIA ("spin off company of the Aristotle University of Thessaloniki / Laboratory of Applied Thermodynamics") in a form of an excel file accompanied by relevant documentation (report file) (EMISIA, 2018). The emission factors of the model were identified and relevant classes and respective emissions values were analyzed in order to identify gaps.

Table 12: COPERT Gaps for emission types and respective vehicle categories

Emission and Vehicle type	Identified gap of COPERT
CO2 – LCV	Road slope and load factors are missing.
CO2 – L-Category	Technology, road slope and load are missing.
CO2 – HDVs	No missing information for this category
CH4 – LCV	No road slope and load provided.
CH4 – L-Category	Technology, road slope and load are missing.
CH4 – HDVs	Road and slopes are missing. The min and max speed are different from CO2 case.
CO – LCV	No data on other fuel types (only diesel and petrol). In technology null category is probably normal while it possibly indicates vehicle that have not installed relevant technologies. Slope and load are missing.
CO – L-Category	Technology, road slope and load are missing.
CO – HDVs	Mode is missing. Max and min speed differs from other pollutants.
N2O– LCV	All Data are missing for this category.

Emission and Vehicle type	**Identified gap of COPERT**
N2O – L-Category	Microcars are missing from segment category, consequently diesel is missing too. Technology, road slope and load are missing.
N2O – HDVs	Road slope and load are missing. Max and min speed differs from other pollutants.
NH3– LCV	All Data are missing for this category.
NH3– L-Category	Microcars are missing from segment category, consequently diesel is missing too. Technology, road slope and load are missing. Min and Max speeds are different from other pollutants, but the same with N2O. Mode is applied in all vehicles.
NH3 – HDVs	Road slope and load are missing.
NOx – LCV	No data on other fuel types (only diesel and petrol). In technology null category is probably normal while it possibly indicates vehicle that have not installed relevant technologies. Slope and load are missing.
NOx – L-Category	Technology, road slope and load are missing.
NOx – HDVs	No data on other fuel types (only diesel and petrol).
PM exhaust – LCV	No data on other fuel types (only diesel and petrol). In technology null category is probably normal while it possibly indicates vehicle that have not installed relevant technologies. Slope and load are missing.
PM exhaust – L-Category	Technology, road slope and load are missing.
PM exhaust – HDVs	Values represent only diesel fuel. No other missing information for this category.
VOC – LCV	No data on other fuel types (only diesel and petrol). In technology null category is probably normal while it possibly indicates vehicle that have not installed relevant technologies. Slope and load are missing.
VOC – L-Category	Technology, road slope and load are missing.
VOC –HDVs	Mode is missing. Only diesel fuel is used.

Emission and Vehicle type	Identified gap of COPERT
All Emission categories – All Vehicle categories	The fuel types for HDVs, LCVs and L-Category vehicles are Petrol and Diesel.

Furthermore to the above table and following a relevant literature review, we identified the consecutive aspects that are not included in COPERT model, although they play important role in emissions of modern EU fleets.

New Emission factors playing important role in the emissions from vehicles (not present in COPERT):

- Road Conditions
- Wind
- A/C
- Traffic
- Fuel types not presented in the COPERT
    - LPG
    - CNG
    - Electricity (Electric powered vehicles)

4.3 GYR Database and Development Methodology

4.3.1 Introduction

Based on the background check performed in COPERT model and literature, we have the following aspects:

- The scope of the current database is to provide existing factors with more classes (i.e. more detailed information) where necessary and relevant literature exists and furthermore to introduce new factors based on literature results and modern EU fleets characteristics.
- The methodology followed included the customization into different emission types, while each emission was fed with all available information concerning factors that influence those emissions as well as for different types of vehicles.

In conclusion, all parameters used in the GYR database are summarized in the following tables.

Table 13: Parameters of Model and their types

Model's Parameter	Types	Comments
Emissions	CO2 / FC, CH4, CO, N2O, NH3, NOx, PM exhaust, VOC, SO2	These emissions were defined based on the COPERT model and they are considered representative of the emissions produced by vehicles.

Model's Parameter	**Types**	**Comments**
		Moreover, emissions types that include more than one chemical compounds (i.e. NOx, PM exhaust and VOC) were chosen based on current popular techniques for real life emissions measurements.
Vehicles	Light commercial, L-category, HDV (up to 14 tn) and HDVs (HDV < 14 t, 14 t < HDV < 28 t, 28 t < HDV)	These categories were chosen in order to reflect on an average vehicles fleet of EU countries. HDVs divided into three categories in order to optimize database results as this is a very large vehicle category with a high difference in weight (from less than 7.5 tonnes to 60 tonnes) and consequently with different behavior in emissions release.
Factors	Occupancy, Road Conditions, Road gradient, Type of Fuel, Wind, A/C, Traffic	Road Conditions, Wind, A/C and Traffic are new factors introduced.

Next section (4.3.2) is divided based on emission types. Detailed literature results are presented in the form of tables in order to justify and illustrate the final database content.

4.3.2 Factors Effect analysis (rationale)

4.3.2.1 Introduction

In the Table 12: COPERT Gaps for emission types and respective vehicle categories, we have illustrated the gaps of COPERT model by identifying missing information concerning correction factors. In this section, those gaps were filled by reviewing the literature and by identifying information that could be used as a justification for the database update. The aspects that were chosen to be used as well as the relevant justification are included in the following tables. In cases, no relevant literature was found COPERT model's results interpolation as well as methodology based on logical assumptions and steps took place in order to produce reliable values for the database.

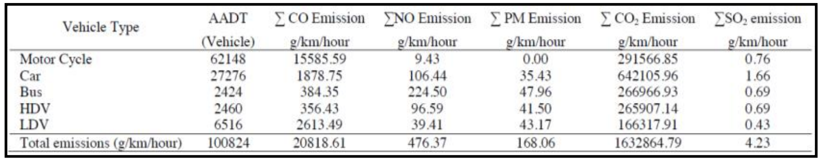
More specifically, each table represents the gaps identified in each pollutant/emission and divided by emission factors. The tables structure for each emission consists from information that includes a) the correction factor, b) the identified gap (missing information), c) the main findings, including the presentation of relevant literature and the derived quantitative result (tables, graphs and values from models and experiments) and d) the comments, including how we used those results in order to add or modify data in the database.

4.3.2.2 CO2 / FC

Table 14: Emission Factors for CO2 / FC – Gap analysis results, findings and applied solutions (in GYR database)

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
Occupancy	**L-category** no information **LCVs** no information **HDV - HDV < 14 t:** COPERT provides data (3 classes) **HDV -** **14 t < HDV < 28 t:**	**L-category:** No information was found. **LCVs:** No specific information was found for LCVs. **General Results:** According to Rizet et al (Christophe Rizet, 2012), the impact of load on fuel consumption derived from case studies (literature) show that: a) In distribution tracks the effect is 0.5 liter of additional fuel consumed per 100 km for every additional tone of load and furthermore the consumption of an empty distribution track is about 2/3 compared with the consumption of fully loaded track. b) For tipper trucks no specific result was found although the consumption increase was averagely estimated as 0.9 liters of fuel consumed per 100 km for every additional tone of load c) For Vans (2.5 to 3.5 tones – Euro 1 and 2 technology) the effect was 0.1 – 0.9 l of additional fuel per 100 km for urban conditions and 0.2 – 0.6 of additional fuel per 100 km for highway conditions	**L-category:** No values were produced for this category. **LCVs:** The occupancy effect was calculated by using the percentage increase described in the vehicles included in the type: HDV>3.5 t of COPERT. This increase was applied to all LCVs based on the respective euro categories. **Classes:**

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
	COPERT provides data (3 classes) **HDV -** **28 t < HDV:** COPERT provides data (3 classes)	**Conclusions:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have important storage capacity we can **assume** that they are **not affected by load or additional load is not applied for those cases.** **LCVs:** The information provided from the above article presented only actual fuel consumptions thus it was considered not representative for all LCVs as load capacities vary and different technologies (euro categories) can result a large difference in FC and consequently in CO2 emissions. In this context, values based on HDV occupancy effect (expressed as rates) as described in COPERT is considered a more reliable solution for LCVs occupancy estimation. The production of more detailed classes could be performed with the usage of interpolation.	COPERT model provided three occupancy classes. In this model new more detailed classes were produced for this correction factor (0-100% with a step of 10%) based on interpolation. This was performed to provide more detailed information since the effect from load is strong and significantly defines emissions calculation. **This classification is applied to all vehicle categories and emission types for the consistency of the database.**

<table>
<tr><th>Factors</th><th>Gap Analysis</th><th>Main Findings (all vehicles)</th><th>Final Solution</th></tr>
<tr>
<td>Road Conditions</td>
<td>L-category
no information
LCVs
no information
HDV - HDV < 14 t
no information
HDV -
14 t < HDV < 28 t:
no information
HDV -
28 t < HDV:
no information</td>
<td>L-category:
No specific information was found.
LCVs:
No specific information was found.
HDV (All types):
No specific information was found.
General Results:
In the article of Setyawan et al (Setyawan, 2015) the effect of road condition was examined using “PCI (Pavement Condition Index)” method and found that road conditions affect the speed of the vehicle and the total amount of CO2 and FC. For excellent to very poor pavement conditions the results for CO2 and other emissions are illustrated in the following table:

<table>
<tr><th>Vehicle Type</th><th>AADT
(Vehicle)</th><th>∑ CO Emission
g/km/hour</th><th>∑NO Emission
g/km/hour</th><th>∑ PM Emission
g/km/hour</th><th>∑ CO_2 Emission
g/km/hour</th><th>∑SO_2 emission
g/km/hour</th></tr>
<tr><td>Motor Cycle</td><td>62148</td><td>15585.59</td><td>9.43</td><td>0.00</td><td>291566.85</td><td>0.76</td></tr>
<tr><td>Car</td><td>27276</td><td>1878.75</td><td>106.44</td><td>35.43</td><td>642105.96</td><td>1.66</td></tr>
<tr><td>Bus</td><td>2424</td><td>384.35</td><td>224.50</td><td>47.96</td><td>266966.93</td><td>0.69</td></tr>
<tr><td>HDV</td><td>2460</td><td>356.43</td><td>96.59</td><td>41.50</td><td>265907.14</td><td>0.69</td></tr>
<tr><td>LDV</td><td>6516</td><td>2613.49</td><td>39.41</td><td>43.17</td><td>166317.91</td><td>0.43</td></tr>
<tr><td>Total emissions (g/km/hour)</td><td>100824</td><td>20818.61</td><td>476.37</td><td>168.06</td><td>1632864.79</td><td>4.23</td></tr>
</table>
Figure 1: The emission of several pollutants for each type of vehicle in the road section with PCI value of 100 (Setyawan, 2015).</td>
<td>L-category:
The equation of (Saharidis G. , 2013) was used to calculate the effect of road age express as rate of initial fuel consumption (road age is equal to 0).
LCVs:
The same methodology with L-Category was followed.
HDV - HDV < 14 t:
The same methodology with L-Category was followed.
HDV -
14 t < HDV < 28 t:</td>
</tr>
</table>

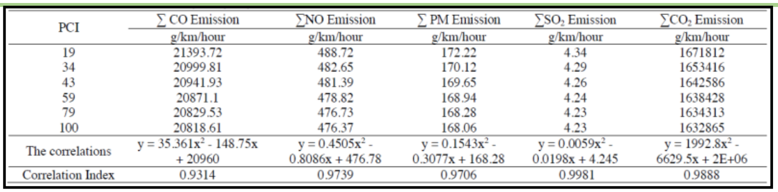
<table>
<tr><th>Factors</th><th>Gap Analysis</th><th>Main Findings (all vehicles)</th><th>Final Solution</th></tr>
<tr><td></td><td></td><td>

<table>
<tr><th rowspan="2">PCI</th><th>∑ CO Emission</th><th>∑NO Emission</th><th>∑ PM Emission</th><th>∑SO₂ Emission</th><th>∑CO₂ Emission</th></tr>
<tr><th>g/km/hour</th><th>g/km/hour</th><th>g/km/hour</th><th>g/km/hour</th><th>g/km/hour</th></tr>
<tr><td>19</td><td>21393.72</td><td>488.72</td><td>172.22</td><td>4.34</td><td>1671812</td></tr>
<tr><td>34</td><td>20999.81</td><td>482.65</td><td>170.12</td><td>4.29</td><td>1653416</td></tr>
<tr><td>43</td><td>20941.93</td><td>481.39</td><td>169.65</td><td>4.26</td><td>1642586</td></tr>
<tr><td>59</td><td>20871.1</td><td>478.82</td><td>168.94</td><td>4.24</td><td>1638428</td></tr>
<tr><td>79</td><td>20829.53</td><td>476.73</td><td>168.28</td><td>4.23</td><td>1634313</td></tr>
<tr><td>100</td><td>20818.61</td><td>476.37</td><td>168.06</td><td>4.23</td><td>1632865</td></tr>
<tr><td>The correlations</td><td>$y = 35.361x^2 - 148.75x + 20960$</td><td>$y = 0.4505x^2 - 0.8086x + 476.78$</td><td>$y = 0.1543x^2 - 0.3077x + 168.28$</td><td>$y = 0.0059x^2 - 0.0198x + 4.245$</td><td>$y = 1992.8x^2 - 6629.5x + 2E+06$</td></tr>
<tr><td>Correlation Index</td><td>0.9314</td><td>0.9739</td><td>0.9706</td><td>0.9981</td><td>0.9888</td></tr>
</table>

Figure 2: “The Total Emission of NO, CO2, SO, PM And CO at Various PCI Value and The Correlation between PCI and Total Emission” (Setyawan, 2015).

Based on the above figures we have the following table with values expressed as percentage compared with the excellent road conditions (PCI – 100).

Table 15: Several emissions values (representing different road conditions) derived from (Setyawan, 2015) expressed as rates (%) compared with values in excellent road conditions.

<table>
<tr><th>PCI</th><th>CO Increase (%)</th><th>NO Increase (%)</th><th>PM Increase (%)</th><th>SO2 Increase (%)</th><th>CO2 Increase (%)</th></tr>
<tr><td>19</td><td>2.76</td><td>4.57</td><td>2.48</td><td>2.60</td><td>2.39</td></tr>
<tr><td>34</td><td>0.87</td><td>3.27</td><td>1.23</td><td>1.42</td><td>1.26</td></tr>
<tr><td>43</td><td>0.59</td><td>3.00</td><td>0.95</td><td>0.71</td><td>0.60</td></tr>
<tr><td>59</td><td>0.25</td><td>2.45</td><td>0.52</td><td>0.00</td><td>0.34</td></tr>
<tr><td>79</td><td>0.05</td><td>0.08</td><td>0.13</td><td>0.00</td><td>0.09</td></tr>
<tr><td>100</td><td>0.00</td><td>0.00</td><td>0.00</td><td>0.00</td><td>0.00</td></tr>
</table>

Furthermore, for the NO emission and based on the study of Soltic and Weilenmann (Patrik Soltic, 2003) the NO2 is the 5.3% (mass) of end-pipe emissions for passenger
</td><td>
The same methodology with L-Category was followed.

HDV -

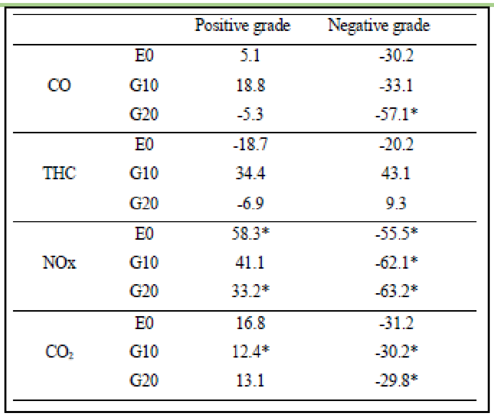
28 t < HDV:

The same methodology with L-Category was followed.

Classes:

Based on the results of the equation and as the road pavement conditions are strongly dependent from road age, we produced 15 classes describing road age expressed in years (from class 1 that equals 1st year from the road construction/renovation to class 15 that equals
</td></tr>
</table>

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
		cars and 18.4 for LCVs, thus we can assume that these values are also representative for NOx emissions as NO is on average the 90% of NOx. Finally, based on Saharidis et al (Saharidis G. , 2013) we have the following equation for extra fuel consumption caused by road conditions expressed as road age. The equation could be used for all vehicle types. $$ExtraFuelConsumption = 8 \times 10^{-6} \times RoadAge^2 + 0.0022 \times RoadAge + 2 \times 10^{-6}$$ *Eq. 2* **Conclusion:** The above equation is considered more reliable for FC estimation, as it expresses extra fuel consumption as a function of road age. Road age is a representative parameter of road conditions and at the same time it is easier to be defined in a quantitative manner (e.g. bad road conditions could not easily be quantified and consequently defined by a database user). The equation results are expressed as percentage of extra fuel needed, so they could be easily applied to all vehicle types. Based on the above, several classes could be created and each of them should represent years of road age.	15th year from road construction). **This classification is applied to all vehicle categories and emission types for the consistency of the database.**
Road gradient	**L-category:** no information **LCVs** no information	**L-category:** No specific information has been found for the effect of road gradient on **L-category** vehicles. Nevertheless, an experimental study (Prati, 2014) that examined a scooter (moped) that used pure gasoline and different percentages of bioethanol mixes, show the following influence of slope (E0=Case with pure petrol):	**L-category:** The same methodology with LCVs was followed.

<table>
<tr><th>Factors</th><th>Gap Analysis</th><th>Main Findings (all vehicles)</th><th>Final Solution</th></tr>
<tr>
<td></td>
<td>HDV - HDV < 14 t:
COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02)
HDV -
14 t < HDV < 28 t:
COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02)
HDV -
28 t < HDV:
COPERT provides data (13 classes - From -</td>
<td>
<table>
<tr><th></th><th></th><th>Positive grade</th><th>Negative grade</th></tr>
<tr><td>CO</td><td>E0</td><td>5.1</td><td>-30.2</td></tr>
<tr><td></td><td>G10</td><td>18.8</td><td>-33.1</td></tr>
<tr><td></td><td>G20</td><td>-5.3</td><td>-57.1*</td></tr>
<tr><td>THC</td><td>E0</td><td>-18.7</td><td>-20.2</td></tr>
<tr><td></td><td>G10</td><td>34.4</td><td>43.1</td></tr>
<tr><td></td><td>G20</td><td>-6.9</td><td>9.3</td></tr>
<tr><td>NOx</td><td>E0</td><td>58.3*</td><td>-55.5*</td></tr>
<tr><td></td><td>G10</td><td>41.1</td><td>-62.1*</td></tr>
<tr><td></td><td>G20</td><td>33.2*</td><td>-63.2*</td></tr>
<tr><td>CO$_2$</td><td>E0</td><td>16.8</td><td>-31.2</td></tr>
<tr><td></td><td>G10</td><td>12.4*</td><td>-30.2*</td></tr>
<tr><td></td><td>G20</td><td>13.1</td><td>-29.8*</td></tr>
</table>
Figure 3: “Emission percentage variation due to the road grade simulation (*significant difference at the 95% confidence interval)” (Prati, 2014) .
LCVs:
Zhang et al (Wendan Zhang, 2015) have performed a case study for the road gradient effect on HDV vehicles emissions. In the same study a literature review have concluded in the following results:</td>
<td>LCVs:
The Road gradient effect was calculated by using the percentage increase illustrated in the vehicles included in the type: HDV>3.5 t of COPERT. This increase was applied to all LCVs based on the respective euro categories.
Classes:
Since 13 classes of COPERT model were considered detailed enough they kept the same classification (13 classes - From -0.06 to 0.06 (per 0.02)) in this database.
This classification is applied to all vehicle</td>
</tr>
</table>

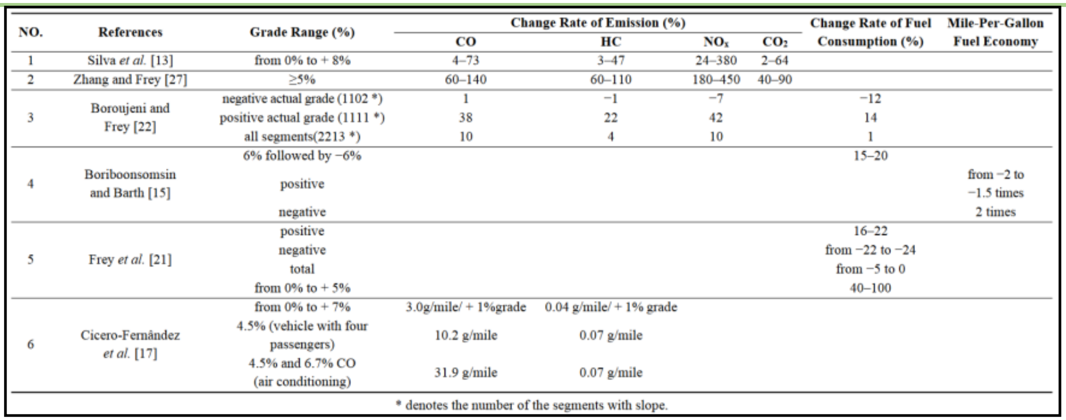
<table>
<tr><th>Factors</th><th>Gap Analysis</th><th>Main Findings (all vehicles)</th><th>Final Solution</th></tr>
<tr><td></td><td>0.06 to 0.06 (per 0.02)</td><td>

<table>
<tr><th rowspan="2">NO.</th><th rowspan="2">References</th><th rowspan="2">Grade Range (%)</th><th colspan="4">Change Rate of Emission (%)</th><th rowspan="2">Change Rate of Fuel Consumption (%)</th><th rowspan="2">Mile-Per-Gallon Fuel Economy</th></tr>
<tr><th>CO</th><th>HC</th><th>NO_x</th><th>CO₂</th></tr>
<tr><td>1</td><td>Silva <i>et al.</i> [13]</td><td>from 0% to + 8%</td><td>4–73</td><td>3–47</td><td>24–380</td><td>2–64</td><td></td><td></td></tr>
<tr><td>2</td><td>Zhang and Frey [27]</td><td>≥5%</td><td>60–140</td><td>60–110</td><td>180–450</td><td>40–90</td><td></td><td></td></tr>
<tr><td>3</td><td>Boroujeni and Frey [22]</td><td>negative actual grade (1102 *)</td><td>1</td><td>−1</td><td>−7</td><td></td><td>−12</td><td></td></tr>
<tr><td></td><td></td><td>positive actual grade (1111 *)</td><td>38</td><td>22</td><td>42</td><td></td><td>14</td><td></td></tr>
<tr><td></td><td></td><td>all segments(2213 *)</td><td>10</td><td>4</td><td>10</td><td></td><td>1</td><td></td></tr>
<tr><td>4</td><td>Boriboonsomsin and Barth [15]</td><td>6% followed by −6%</td><td></td><td></td><td></td><td></td><td>15–20</td><td></td></tr>
<tr><td></td><td></td><td>positive</td><td></td><td></td><td></td><td></td><td></td><td>from −2 to −1.5 times</td></tr>
<tr><td></td><td></td><td>negative</td><td></td><td></td><td></td><td></td><td></td><td>2 times</td></tr>
<tr><td>5</td><td>Frey <i>et al.</i> [21]</td><td>positive</td><td></td><td></td><td></td><td></td><td>16–22</td><td></td></tr>
<tr><td></td><td></td><td>negative</td><td></td><td></td><td></td><td></td><td>from −22 to −24</td><td></td></tr>
<tr><td></td><td></td><td>total</td><td></td><td></td><td></td><td></td><td>from −5 to 0</td><td></td></tr>
<tr><td></td><td></td><td>from 0% to + 5%</td><td></td><td></td><td></td><td></td><td>40–100</td><td></td></tr>
<tr><td>6</td><td>Cicero-Fernândez <i>et al.</i> [17]</td><td>from 0% to + 7%</td><td>3.0g/mile/ + 1%grade</td><td>0.04 g/mile/ + 1% grade</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>4.5% (vehicle with four passengers)</td><td>10.2 g/mile</td><td>0.07 g/mile</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>4.5% and 6.7% CO (air conditioning)</td><td>31.9 g/mile</td><td>0.07 g/mile</td><td></td><td></td><td></td><td></td></tr>
</table>
* denotes the number of the segments with slope.

Figure 4: “Studies on the changes of fuel consumption and emissions with the change of road grades” (Wendan Zhang, 2015).

These results are restricted as they are based on different assumptions or they have tested different aspects of vehicles characteristics. For example, 1st and 3rd reference are referring to LCVs and the 6th calculated emissions from trucks and passenger cars.

Conclusion:

Literature review show that there is a significant effect of slope in all types of vehicles. Nevertheless, results are not stable and are depending from different parameters. Since COPERT model provides with values for HDVs then we can perform the assumption that LCVs road grade effect has similar behavior. This assumption is considered more reliable and consistent.
</td><td>categories and emission types for the consistency of the database.</td></tr>
<tr><td>Type of Fuel</td><td>L-category</td><td>General:</td><td>L-category:</td></tr>
</table>

<table>
<tr><th>Factors</th><th>Gap Analysis</th><th>Main Findings (all vehicles)</th><th>Final Solution</th></tr>
<tr>
<td></td>
<td>Information for Diesel and Petrol

LCVs

Information for Diesel and Petrol

HDV - HDV < 14 t:

Information for Diesel and Petrol

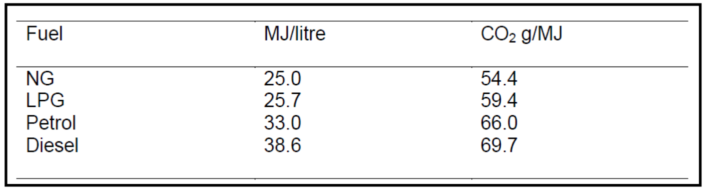
HDV -

14 t < HDV < 28 t:

Information for Diesel and Petrol

HDV -

28 t < HDV:</td>
<td>In general the energy content and the CO2 released to the environment due to combustion of different fuels used in vehicles is presented below (Honnery Damon, 2002):


<table><tr><th>Fuel</th><th>MJ/litre</th><th>CO_2 g/MJ</th></tr><tr><td>NG</td><td>25.0</td><td>54.4</td></tr><tr><td>LPG</td><td>25.7</td><td>59.4</td></tr><tr><td>Petrol</td><td>33.0</td><td>66.0</td></tr><tr><td>Diesel</td><td>38.6</td><td>69.7</td></tr></table>
Figure 5: “Energy density and CO2 emissions for various fuels (Source: Australian Greenhouse Office (AGO) 1998)” (Honnery Damon, 2002).

L-category:

No information was found.

LCVs:

According to an experimental study (Tasic T., 2011) that tested passenger bifuel cars using **LPG** and **Petrol**, **CO2** reduced 10% in Urban and 11% non-urban driving conditions (compared with petrol engine), while furthermore similar results were presented on the study of Saraf et al. (Saraf R.R., 2009) (8950 to 8051 ppm CO2 and 16509 to 14693 ppm CO2 for Urban and extra-urban conditions respectively).

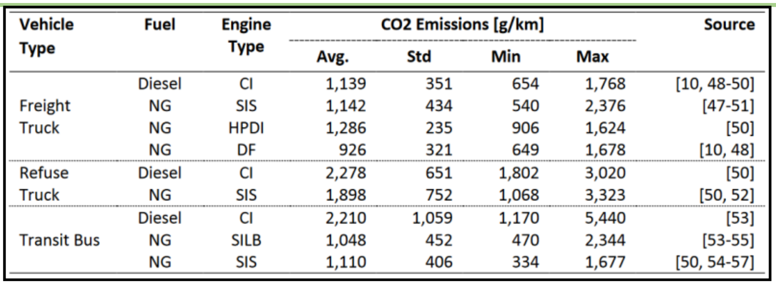
HDV (All types):

CO2 emissions for vehicles with engines that use **natural gas (NG)** are presented in the article of Stettler et al (Marc Stettler, 2019). The article presents the following CO2 emissions as illustrated below:</td>
<td>No additional fuel types were illustrated in this category.

LCVs:

FC for LPG and CNG fuel types were produced for LCVs. The increase of 10% in fuel consumption was used for both fuel types and applied for different LCV subcategories.

For electricity powered LCVs the average value of 0.310 KWh/km was used for all LCVs sub-types of the database. The CO2 emissions were calculated by multiplying the above value with the average emission factor of 995.8 g/KWh.</td>
</tr>
</table>

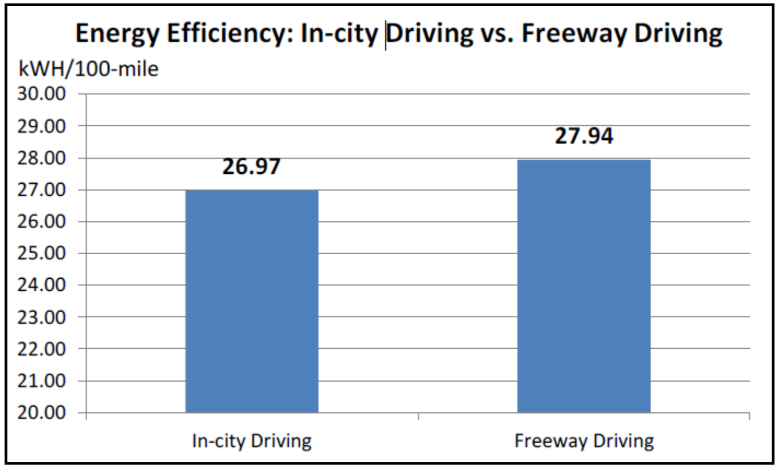
<table>
<tr><th>Factors</th><th>Gap Analysis</th><th>Main Findings (all vehicles)</th><th>Final Solution</th></tr>
<tr>
<td></td>
<td>Information for Diesel and Petrol</td>
<td>

<table>
<tr><th>Vehicle Type</th><th>Fuel</th><th>Engine Type</th><th>CO2 Emissions [g/km]</th><th></th><th></th><th></th><th>Source</th></tr>
<tr><th></th><th></th><th></th><th>Avg.</th><th>Std</th><th>Min</th><th>Max</th><th></th></tr>
<tr><td>Freight Truck</td><td>Diesel</td><td>CI</td><td>1,139</td><td>351</td><td>654</td><td>1,768</td><td>[10, 48-50]</td></tr>
<tr><td></td><td>NG</td><td>SIS</td><td>1,142</td><td>434</td><td>540</td><td>2,376</td><td>[47-51]</td></tr>
<tr><td></td><td>NG</td><td>HPDI</td><td>1,286</td><td>235</td><td>906</td><td>1,624</td><td>[50]</td></tr>
<tr><td></td><td>NG</td><td>DF</td><td>926</td><td>321</td><td>649</td><td>1,678</td><td>[10, 48]</td></tr>
<tr><td>Refuse Truck</td><td>Diesel</td><td>CI</td><td>2,278</td><td>651</td><td>1,802</td><td>3,020</td><td>[50]</td></tr>
<tr><td></td><td>NG</td><td>SIS</td><td>1,898</td><td>752</td><td>1,068</td><td>3,323</td><td>[50, 52]</td></tr>
<tr><td>Transit Bus</td><td>Diesel</td><td>CI</td><td>2,210</td><td>1,059</td><td>1,170</td><td>5,440</td><td>[53]</td></tr>
<tr><td></td><td>NG</td><td>SILB</td><td>1,048</td><td>452</td><td>470</td><td>2,344</td><td>[53-55]</td></tr>
<tr><td></td><td>NG</td><td>SIS</td><td>1,110</td><td>406</td><td>334</td><td>1,677</td><td>[50, 54-57]</td></tr>
</table>
<p>Figure 6: “Summary of tailpipe CO2 emissions from various diesel and natural gas engines”(Marc Stettler, 2019).</p>
<p>LPG and CNG vehicles:</p>
<p>The actual fuel consumption is difficult to be estimated for all vehicle types and LPG and CNG is a common fuel for LCVs and for relative low weighted HDVs (category HDV - HDV < 14 t). Based on this the average general fuel increase (expressed as rates) is the following:</p>

CNG engines: 2-12% FC increase (Jason Kwon, 2012)
LPG engine: 10% FC increase (Nikos Xydas, 2017)

<p>Furthermore, COPERT model provides with values for CNG and LPG buses and Passenger cars which are categories that could be corresponded with HDVs and LCVs respectively. Nevertheless, the values given for FC do not seem representative.</p>
<p>Electric Vehicles:</p>
<p>Moreover for electricity powered vehicles we have the following :</p>

The electricity powered vehicles are not so commercialized yet (Kolarova Viktoriya, 2018) thus, LCVs is the only category of vehicles that we found available on the market.

</td>
<td>
<p>HDV - HDV < 14 t:</p>
<p>The same methodology with LCVs was followed.</p>
<p>HDV-14 t < HDV < 28 t:</p>
<p>No additional fuel types were illustrated in this category.</p>
<p>HDV - 28 t < HDV:</p>
<p>No additional fuel types were illustrated in this category.</p>
</td>
</tr>
</table>

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
		• According to a website (Electric Vehicle Database) **the average consumption** of electric passenger cars is 0.178 KWh/Km. This was derived from many market available electric cars (not only for commercial usage). • According to an experimental study (Wu Xinkai, 2015) where a converted to electric vehicle was studied the average consumption was 0.168 KWh/Km for urban and 0.175 KWh/Km for free road conditions (see the following figure).  **Figure 7: "Energy efficiency for in-city driving vs. freeway driving" (Wu Xinkai, 2015).** • As literature results on LCVs are limited a search in ready available commercial solution was followed. In this context a specific cargo LCV vehicle characteristics (BD Auto) was studied and show a consumption of 0.31 KWh/Km (by dividing given range in Km with battery capacity in KWh).	

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
		Emissions from Electricity: Since all exclusive electric vehicles are charged using the grid, then the emissions (including CO2) produced from vehicles with this fuel type are defined by the emissions types and volumes produced in each country for the grids electricity production. In this framework the EU average CO2 is 995.8 grams per KWh (ECOINVENT). **Conclusion:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have alternative fuel types we can assume that the provision of values for relevant fuel types is not necessary. Since COPERT values do not seem reliable for this category the FC of CNG and LPG vehicles could be calculated by using the 10% increase of consumption as an average value for both fuels (see results section). Moreover, for electricity powered vehicles we can use the average CO2 emitted per KWh in Europe and multiply it with consumption expressed as KWh/km. Based on research performed in EU fleets it was assumed that only LCVs electric vehicles are available. Based on literature results the value of consumption for electric LCVs could be 0.31 KWh/Km as defined in the specific van. This is considered as the most representative value since it took into consideration a commercial light vehicle that better reflects the fleet illustrated in our database if we compare it with passenger cars which are in most of the cases smaller and thus less energy consuming.	
Wind	**L-category** no information	**L-category:** No specific information was found. **LCVs:**	**L-category:** The estimation was made by using the equation described in

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
	LCVs no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	No specific information was found. **HDV (All types):** No specific information was found. **General Results:** The effect of wind is related with the resistance from vehicle's drag within the air. This resistance could be significant especially in high speeds where it could have values up to 11% of the 20% (energy from fuel) needed for the vehicle to be dragged in the air. The effect in fuel consumption is described by the following equation (Saharidis G. , 2013) while : $\mathbf{F} = \boldsymbol{CD} \times \boldsymbol{A_{Frontal}} \times \boldsymbol{\rho/2} \times \boldsymbol{v^3}$ *Eq. 3* F: Power demand to overcome the air resistance [W]; CD: The air- resistance coefficient [dimensionless] (For buses = 0,65); $A_{Frontal}$: The frontal area [m2] of the vehicle (For buses = 6,5 m^2); p: The density of the air [kg/m3] (Assumed 1,225 kg/m^3); v: The wind velocity [m/s]. As it is described in the equation the effect takes into consideration the wind speed and wind direction For LCVs the $A_{frontal}$ and the CD are assumed as (Kühlwein, 2016):	literature results (Saharidis G. , 2013). Percentages of increase or decrease were calculated using the methodology described in the results cell of this table for all L-category vehicles and have as a baseline the initial emission factor for CO2/FC. The following calculation assumptions were made based on literature: $A_{frontal}$: 0.75 m2 CD: 0.570 Horsepower: 50 HP **LCVs:** The same methodology described for L-Category was followed.

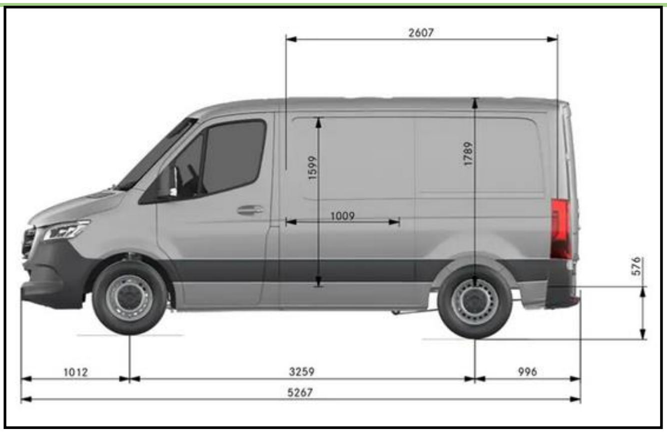
Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
		$A_{frontal}$: 4.06 CD: 0.34 As general values for motorcycles were not found for the L-Category and more specifically for motorcycles, we can assume the following values derived from a study of Fintelman et al (Fintelman D., 2015): $A_{frontal}$: 0.75 m^2 CD: 0.570 (coarse mesh at 15^o angle) Based on the above, wind effect in FC and consequently in CO2 emissions is directly correlated from the vehicles, frontal area and the relevant air- resistance coefficient. Based on that and since we have average $A_{frontal}$ and CD for all relevant vehicle categories we could perform the relevant calculations to estimate the power demand to overcome the air resistance expressed in Watts. Furthermore, in order to calculate the increase or decrease of fuel consumption for each vehicle category expressed in rates % we can perform the following: • Assume the average horsepower capacity of each vehicle type (see below); • Transform watts into horse power (1 kW = 1.34 Horsepower); • Estimate the horse power needed to overcome the air resistance (by using the equation). Perform this calculation for different wind classes (average wind speeds); • Calculate the percentage of increase by dividing the power needed with the average power of vehicle; • Use the resulted rates in the database.	The following calculation assumptions were made based on literature: $A_{frontal}$: 4.06 m^2 CD: 0.34 Horsepower: 137.5 HP **HDV - HDV < 14 t:** The same methodology described for L-Category was followed. The following assumptions were made based on literature: $A_{frontal}$: 6.5 m^2 CD: 0.65 Horsepower: 250 HP **HDV -** **14 t < HDV < 28 t:**

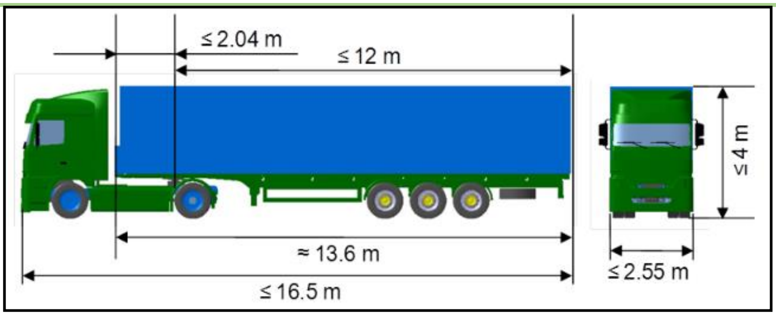
Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
		Assumptions for Average horsepower per vehicle category: **L-Category:** Since no literature was found for average horsepower of L-category vehicle and since the article of European commission's website about safety of motorcycles (European Commision, 2019) illustrates vehicles from 10 – 90 HP (although in some cases horsepower is higher) we can make the following assumption. • L-Category: 10-90 – Average: **50 HP** **LCVs:** According to the EQUA – Index (EQUA - INDEX - Independent real-world emissions data) the horsepower range between real LCVs included in their database is 74 to 201 HP. Based on this we can produce an average HP as follows. • LCVs: 74-201 – Average: **137.5 HP** **HDVs – Horsepower:** According to Ahanotu (Ahanotu, 1999), the HDVs horsepower ranges from 200 to 500. Considering this, we can reclassify the range based on HDV classes and extract a relevant horsepower average that could be used in relevant calculations (see above). • HDVs < 14t: 200-300 – Average: 250 HP • 14 t < HDV < 28 t: 300-400 – Average: 350 HP • 28 t < HDV: 400 -500 – Average: 450 HP	The same methodology described for L-Category was followed. The following assumptions were made based on literature: $A_{frontal}$: 6.5 m^2 CD: 0.65 Horsepower: 350 HP **HDV -** **28 t < HDV:** The same methodology (described for L-Category) was followed. The following assumptions were made based on literature: $A_{frontal}$: 6.5 m^2 CD: 0.65 Horsepower: 450 HP

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
		Conclusion: Based on the above methodology the database will be enriched with wind effect in FC for all vehicle categories. The wind classes will be produced in order to have representative values of real life wind speeds as well as to have a flexible database (not too many classes).	**Classes:** Based on the results of the equation and as the wind can significantly affect the fuel consumption (positive and negative effect as it depends from wind direction) the following 9 wind classes were produced in the database. 1) -80 to -40 km/h, 2)-40 to -25 km/h, 3) -25 to -15 km/h, 4) -15 to – 5 km/h, 5) -5 to 5 km/h, 6) 5 to 15 km/h, 7) 15 to 25 km/h, 8) 25 to 40 km/h and 9) 40 to 80 km/h. The above classes were considered representative in order to illustrate the wind effect in the emissions.

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
			This classification was applied to all vehicle categories and emission types for the consistency of the database.
A/C	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:**	**L-category:** No information was found. **LCVs:** No specific information was found. **HDV (All types):** No specific information was found. **General Results:** According to Konstantzos et al. (Konstantzos Giorgos, 2016) the Air Condition could significantly affect fuel consumption in HDVs and LDVs. Full load of AC depends on traffic mode since different factors exist for idling acceleration and cruise	**L-category:** No values were produced for this category. **LCVs:** The AC effect was calculated by combining the effect from HI and the traffic modes as presented in the results section. The volume cabin to body ration was assumed as 20%.

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
	no information **HDV -** **28 t < HDV:** no information	conditions (see the definition of traffic modes) (Konstantzos Giorgos, 2016); based on relevant traffic modes (see the next row) and from the fact that for LCVs a) Idling (0 km/h), b) Acceleration (0–6 km/h) and c) Cruise (6-80 km/h) have an air condition factor of 1.365, 1.254 and 1.16 (average) respectively then we can calculate the full load of LCVs in a) No - Low traffic, b) Medium traffic and c) Heavy traffic conditions. For the calculation of full load of AC in other HDV categories, we assumed that there is a difference between different vehicle types since there is a difference between cabin and total vehicle volume. This difference justifies changes of the full load effect since generally HDVs have smaller cabins (compared with the whole vehicle) than LCVs. For example the below figure illustrates the dimensions of a specific van produced by a common vehicle manufacturer. This case could be assumed that is representative of a typical LCV.	**HDV - HDV < 14 t:** The same methodology described for LCVs was followed. The volume cabin to body ration was assumed as 5%. **HDV -** **14 t < HDV < 28 t:** The same methodology described for LCVs was followed. The volume cabin to body ration was assumed as 5%. **HDV -** **28 t < HDV:** The same methodology described for LCVs was followed. The volume cabin to body ration was assumed as 5%.

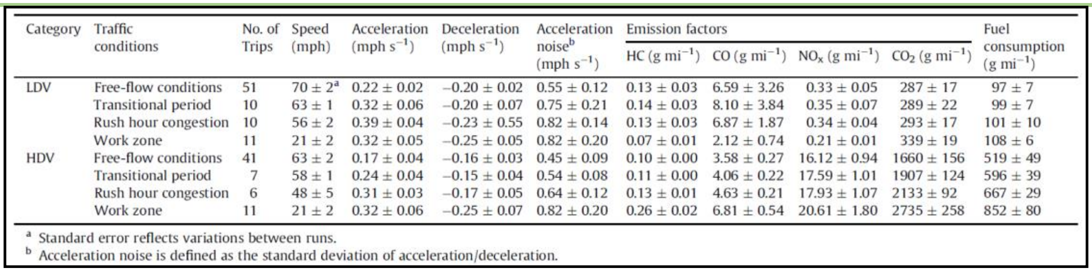
Factors	**Gap Analysis**	**Main Findings (all vehicles)**	**Final Solution**
		 **Figure 8: Dimensions expressed as mm of a van provided by Mercedes-Benz (Under the bonnet: specifications, dimensions and weight of the Sprinter Panel Van).** If we take only the length dimension then we can say that the cabin to body ratio in this case is around: Cabin to body ratio = (5267-2607)/5267 = 0.5 (i.e. 50%) For HDVs, we have the following figure with relevant dimensions (for HDVs) based on EU regulations. Even though there is a wide range of HDVs we can consider this case representative.	**Classes:** Based on the results of the equation for the 45 HI values and the 3 traffic modes, 135 AC effect classes were produced for each vehicle category. **This classification was applied to all vehicle categories and emission types for the consistency of the database.**

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
		 **Figure 9: Dimensions expressed as meters of an EU HGV tractor and trailer (Dings, 2012).** If we take only the length dimension then we can say that the cabin to body ratio in this case is around: Cabin to body ratio = (16.5-13.6)/16.5 = 0.18 (i.e. 18%) Based on this methodology we made the following assumptions: - LCVs full AC effect was considered the basis of calculations (since the available data are on LCV) and has 50% cabin's to body ratio - HDVs including all categories have a 18% cabin's to body ratio Moreover based on this study fuel consumption is also related with ambient temperature and humidity (the higher the temperature, the higher the A/C power usage). Based on the above and as HI illustrates temperature and humidity combinations, A/C FC could be measured with the usage of the following equation: $\boldsymbol{Demand\ factor = c + a \times HI + b * HI^2 Eq.\ 4}$ where, for HDVs *c* constant equals to -3.631541; *a*: coefficient equals to 0.072465;	

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
		b coefficient equals to -0.000276; and *HI*: the Heat index. Furthermore, given that temperature and humidity are known, then heat index could be calculated by using the following function. $\text{Heat Index} = -42.379 + 2.04901523T + 10.14333127R - 0.22475541TR - 6.83783 \times 10^{-3}T^2 - 5.481717 \times 10^{-2}R^2 + 1.22874 \times 10^{-3}T^2R + 8.5282 \times 10^{-4}TR^2 - 1.99 \times 10^{-6}T^2R^2$ T: Air temperature in Fahrenheit R: Relative humidity (expressed as rate %) **Conclusion:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have A/C systems we can **assume** that this factor **is not applied** for this vehicle types. **LCVs and HDVs (all types):** The equation could be applied to all vehicle categories based on the assumptions presented above. Different classes should be produced based on different HI values and different traffic modes. Such classes include the combination of the following 45 HI values and 3 traffic classes: • HI: <68, 68,…, 110, >110. • Traffic modes: ○ a) No - Low traffic, ○ b) Medium traffic and ○ c) Heavy traffic conditions	

Factors	**Gap Analysis**	**Main Findings (all vehicles)**	**Final Solution**
Traffic	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**L-category:** No information was found. **LCVs:** No specific information was found. **HDV (All types):** No specific information was found. **General Results:** Traffic conditions, especially in urban areas and during the peak hours can significantly affect vehicle emissions (Zhang Kai, 2011). Furthermore, this study presents the following results for LDVs and HDVs and for HC, CO, NOx and CO2 emissions.	**L-category:** Based on the methodology developed in the results cell the L-Category traffic modes were calculated as percentage of fuel consumption increase where the baseline was considered the traffic mode – No to Low traffic. **LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:**

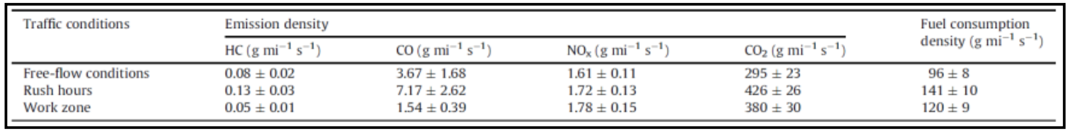
Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution



Category	Traffic conditions	No. of Trips	Speed (mph)	Acceleration (mph s^{-1})	Deceleration (mph s^{-1})	Acceleration noise[b] (mph s^{-1})	Emission factors				Fuel consumption (g mi^{-1})
							HC (g mi^{-1})	CO (g mi^{-1})	NO_x (g mi^{-1})	CO_2 (g mi^{-1})	
LDV	Free-flow conditions	51	70 ± 2[a]	0.22 ± 0.02	−0.20 ± 0.02	0.55 ± 0.12	0.13 ± 0.03	6.59 ± 3.26	0.33 ± 0.05	287 ± 17	97 ± 7
	Transitional period	10	63 ± 1	0.32 ± 0.06	−0.20 ± 0.07	0.75 ± 0.21	0.14 ± 0.03	8.10 ± 3.84	0.35 ± 0.07	289 ± 22	99 ± 7
	Rush hour congestion	10	56 ± 2	0.39 ± 0.04	−0.23 ± 0.55	0.82 ± 0.14	0.13 ± 0.03	6.87 ± 1.87	0.34 ± 0.04	293 ± 17	101 ± 10
	Work zone	11	21 ± 2	0.32 ± 0.05	−0.25 ± 0.05	0.82 ± 0.20	0.07 ± 0.01	2.12 ± 0.74	0.21 ± 0.01	339 ± 19	108 ± 6
HDV	Free-flow conditions	41	63 ± 2	0.17 ± 0.04	−0.16 ± 0.03	0.45 ± 0.09	0.10 ± 0.00	3.58 ± 0.27	16.12 ± 0.94	1660 ± 156	519 ± 49
	Transitional period	7	58 ± 1	0.24 ± 0.04	−0.15 ± 0.04	0.54 ± 0.08	0.11 ± 0.00	4.06 ± 0.22	17.59 ± 1.01	1907 ± 124	596 ± 39
	Rush hour congestion	6	48 ± 5	0.31 ± 0.03	−0.17 ± 0.05	0.64 ± 0.12	0.13 ± 0.01	4.63 ± 0.21	17.93 ± 1.07	2133 ± 92	667 ± 29
	Work zone	11	21 ± 2	0.32 ± 0.06	−0.25 ± 0.07	0.82 ± 0.20	0.26 ± 0.02	6.81 ± 0.54	20.61 ± 1.80	2735 ± 258	852 ± 80

[a] Standard error reflects variations between runs.
[b] Acceleration noise is defined as the standard deviation of acceleration/deceleration.

Figure 10: "Summary of speed/acceleration profiles, emission factors and fuel consumption rates for LDV and HDV grouped by traffic condition." (Zhang Kai, 2011).



Traffic conditions	Emission density				Fuel consumption density (g mi^{-1} s^{-1})
	HC (g mi^{-1} s^{-1})	CO (g mi^{-1} s^{-1})	NO_x (g mi^{-1} s^{-1})	CO_2 (g mi^{-1} s^{-1})	
Free-flow conditions	0.08 ± 0.02	3.67 ± 1.68	1.61 ± 0.11	295 ± 23	96 ± 8
Rush hours	0.13 ± 0.03	7.17 ± 2.62	1.72 ± 0.13	426 ± 26	141 ± 10
Work zone	0.05 ± 0.01	1.54 ± 0.39	1.78 ± 0.15	380 ± 30	120 ± 9

Figure 11: "Estimated emission density and fuel consumption density for traffic on the I-94 segment." (Zhang Kai, 2011).

As it can be seen in the table the effect of different traffic condition on emissions present fluctuation. Nevertheless, from the definition of traffic classes the average speeds were 70, 63, 56 and 21 mph for a) free flow, b) transitional period, c) Rush hour congestion and d) Work zone classes respectively. Based on the above facts and since average speeds were very high these results were considered not representative for our database.

Conclusion:

Since literature results are not consistent and thus not suitable we could follow a specific methodology based on reasonable and basic facts and assumptions. Traffic could be expressed as a combination of the following vehicle's conditions:

The same methodology described for L-Category was followed.

HDV -

14 t < HDV < 28 t:

The same methodology described for L-Category was followed.

HDV -

28 t < HDV:

The same methodology described for L-Category was followed.

Classes:

Finally three classes were identified for traffic conditions (a) No - Low traffic, b) Medium traffic and c) Heavy traffic).

<table>
<tr><th>Factors</th><th>Gap Analysis</th><th>Main Findings (all vehicles)</th><th>Final Solution</th></tr>
<tr><td></td><td></td><td>

Cruise time
Idling time
Minutes per km
Number of stops & Gos per Km

Based on the above parameters, the below table illustrates the assumptions that could be made:

Table 16: Assumptions of relevant parameters for the production of different traffic modes.
<table>
<tr><th>Traffic Modes</th><th>Cruise</th><th>Idling</th><th>min/km</th><th>No of Stop&Gos /km</th></tr>
<tr><td>No - Low</td><td>100%</td><td>0%</td><td>0.00</td><td>0</td></tr>
<tr><td>Medium</td><td>50%</td><td>50%</td><td>2.00</td><td>3</td></tr>
<tr><td>Heavy</td><td>30%</td><td>70%</td><td>6.00</td><td>6</td></tr>
</table>

Based on the above traffic effect could be calculated by having the idling consumption for each vehicle category and the baseline FC (already available in the database). According to a study performed in different cities in India (Kumar Pradeep, 2015) the consumption during idling could be the following:

L-Category (average from 2 wheelers and three wheelers): 0.180 lt/h
LCVs: 0.530 lt/h
HDV - HDV < 14 t: 0.621 lt/h
14 t < HDV < 28 t: 1.002 lt/h
HDV - 28 t < HDV: 2.514 lt/h

FC for one Stop & GO was calculated based on (Konstantzos Giorgos, 2016) methodology and the initial consumption. The FC for the following for the respective vehicle categories:
</td><td>This classification was applied in all vehicle and emission types.</td></tr>
</table>

Factors	Gap Analysis	Main Findings (all vehicles)	Final Solution
		• L-Category: 24.52 grams of fuel • LCVs: 56.25 grams of fuel • HDV - HDV < 14 t: 137.75 grams of fuel • HDV - 14 t < HDV < 28 t: 137.75 grams of fuel • HDV - 28 t < HDV: 137.75 grams of fuel The fuel density was assumed as 0.832 kg/l. Based on the above information the effect of traffic conditions in FC could be calculated. The class that represents no traffic should be used as the baseline FC.	

4.3.2.3 CH4

Table 17: Emission Factors for CH4 – Gap analysis results, findings and applied solutions (in GYR database)

Factors	Missing Info	Main Findings	Comments
Occupancy	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusion:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have important storage capacity we can assume that they are not affected by load or additional load is not applied for those cases. For other vehicle categories we perform the following assumption:	**L-category:** No values were produced for this category. **LCVs:** The occupancy effect was calculated by using the percentage increase in FC and multiplied with actual CH4 values for all LCVs types (including euro categories etc.). **HDV - HDV < 14 t:** The same methodology with LCV was followed. **HDV -**

Factors	Missing Info	Main Findings	Comments
	no information	Since the CH4 is linearly and positively correlated with CO2 emissions (Nam EK, 2004) and since occupancy affects directly the fuel consumption, then we can assume that methane follows the same pattern with FC. Since FC results are available for different occupancy classes and as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the CH4 produced (i.e. linear correlation). This solution supports also the consistency of the database.	**14 t < HDV < 28 t:** The same methodology with LCV was followed. **HDV -** **28 t < HDV:** The same methodology with LCV was followed.
Road Conditions	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found.	**L-category:** The road conditions effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual CH4 values for all L-category types (including euro categories etc.). **LCVs:** The same methodology with L-Category was followed.

Factors	Missing Info	Main Findings	Comments
	HDV - **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**Conclusions:** Since the CH4 is linearly and positively correlated with CO2 emissions (Nam EK, 2004) and since road conditions affects directly the fuel consumption, then we can assume that methane follows the same pattern with FC. Since FC results are available for all 15 classes and as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the CH4 produced (linear correlation). This solution supports also the consistency of the database.	**HDV – HDV < 14 t:** The same methodology with L-Category was followed. **HDV –** **14 t < HDV < 28 t:** The same methodology with L-Category was followed. **HDV –** **28 t < HDV:** The same methodology with L-Category was followed.
Road gradient	**L-category** no information **LCVs**	**L-category:** No information was found. **LCVs:**	**L-category:** The road gradient effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and

Factors	Missing Info	Main Findings	Comments
	no information **HDV – HDV < 14 t** no information **HDV –** **14 t < HDV < 28 t :** no information **HDV –** **28 t < HDV:** no information	No information was found. **HDV (All types):** No information was found. **Conclusions:** Since the CH4 is linearly and positively correlated with CO2 emissions (Nam EK, 2004) and since gradient affects directly the fuel consumption, then we can assume that methane follows the same pattern with FC. Since FC results are available for all 9 classes (gradient from +6% to -6%) and as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the CH4 produced (i.e. linear correlation) and the opposite. This solution supports also the consistency of the database.	multiplied with actual CH4 values for all L-category types (including euro categories etc.). **LCVs:** The same methodology with L-Category was followed. **HDV - HDV < 14 t:** The same methodology with L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with L-Category was followed. **HDV -** **28 t < HDV:**

Factors	Missing Info	Main Findings	Comments
			The same methodology with L-Category was followed.
Type of Fuel	**L-category** Information for Diesel and Petrol **LCVs** Information for Diesel and Petrol **HDV - HDV < 14 t:** Information for Diesel and Petrol **HDV -** **14 t < HDV < 28 t:** Information for Diesel and Petrol	**L-category:** No information was found. **LCVs:** Moreover for **LPG fuel** the article of Lipman and Dellucchi (Lipman Timothy, 2002) suggest that for **LPG LDVs** there is not a difference with petrol LDVs, as the main component of LPG (Propane) has similar properties with petrol. Moreover, for the Natural gas fueled LDVs the CH4 emissions are between 0.6 and 4 g/mi for dual fuel vehicles and 0.13 to 3 g/mi for natural gas only vehicles. **HDV (All types):** The same study suggests that new **LPG HDV** vehicles are emitting around 0.1 g/mi CH4 which is similar with the diesel ones). Moreover, CH4 emissions for vehicles with engines that use natural gas (NG) are presented in the electronic article of Stettler et al (Marc Stettler, 2019). The article presents the following methane emissions:	**L-category:** No additional fuel types were illustrated in this category. **LCVs:** Emission factors for LPG and CNG fuel types were produced for LCVs. The values of CH4 were based on relevant passenger car vehicles as provided by COPERT model. For electricity powered LCVs the average value of **0**.310 KWh/km was used for all LCVs sub-types of the database. The CH4 emissions were calculated by using the average emission factor of 2.05 g/KWh. **HDV - HDV < 14 t:**

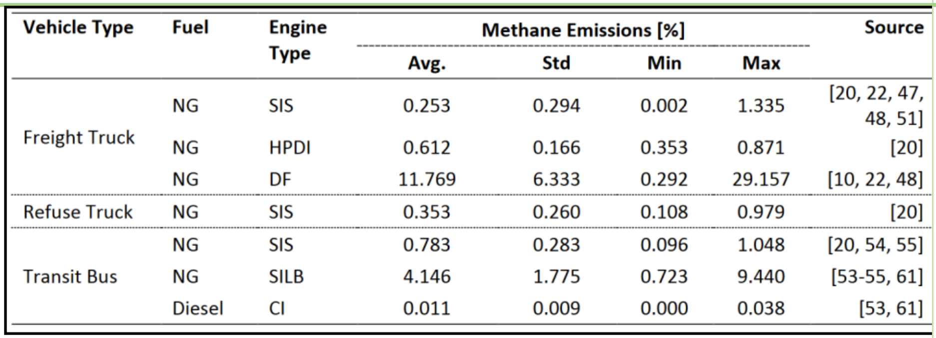
<table>
<tr><th>Factors</th><th>Missing Info</th><th>Main Findings</th><th>Comments</th></tr>
<tr>
<td></td>
<td>

HDV -

28 t < HDV:

Information for Diesel and Petrol

</td>
<td>



<table>
<tr><th>Vehicle Type</th><th>Fuel</th><th>Engine Type</th><th colspan="4">Methane Emissions [%]</th><th>Source</th></tr>
<tr><th></th><th></th><th></th><th>Avg.</th><th>Std</th><th>Min</th><th>Max</th><th></th></tr>
<tr><td>Freight Truck</td><td>NG</td><td>SIS</td><td>0.253</td><td>0.294</td><td>0.002</td><td>1.335</td><td>[20, 22, 47, 48, 51]</td></tr>
<tr><td></td><td>NG</td><td>HPDI</td><td>0.612</td><td>0.166</td><td>0.353</td><td>0.871</td><td>[20]</td></tr>
<tr><td></td><td>NG</td><td>DF</td><td>11.769</td><td>6.333</td><td>0.292</td><td>29.157</td><td>[10, 22, 48]</td></tr>
<tr><td>Refuse Truck</td><td>NG</td><td>SIS</td><td>0.353</td><td>0.260</td><td>0.108</td><td>0.979</td><td>[20]</td></tr>
<tr><td>Transit Bus</td><td>NG</td><td>SIS</td><td>0.783</td><td>0.283</td><td>0.096</td><td>1.048</td><td>[20, 54, 55]</td></tr>
<tr><td></td><td>NG</td><td>SILB</td><td>4.146</td><td>1.775</td><td>0.723</td><td>9.440</td><td>[53-55, 61]</td></tr>
<tr><td></td><td>Diesel</td><td>CI</td><td>0.011</td><td>0.009</td><td>0.000</td><td>0.038</td><td>[53, 61]</td></tr>
</table>

Figure 12: "Tailpipe methane emissions quantified as methane slip for various vehicle and engine types." (Marc Stettler, 2019).

Electric Vehicles:

Emissions from Electricity

Since all exclusive electric vehicles are charged using the grid, then the emissions (including CH4) produced from vehicles with this fuel type are defined by the emissions types and volumes produced in each country for the grids electricity production.

In this framework the EU average **CH4 is 2.05 grams per KWh** (ECOINVENT).

Conclusions:

</td>
<td>

Emission factors for LPG and CNG fuel types were produced for HDVs (<14 t). The values of CH4 were based on relevant buses vehicles as provided by COPERT model.

HDV -

14 t < HDV < 28 t:

No additional fuel types were illustrated in this category.

HDV -

28 t < HDV:

No additional fuel types were illustrated in this category.

</td>
</tr>
</table>

Factors	Missing Info	Main Findings	Comments
		L-Category: Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have alternative fuel types we can **assume** that the provision of values for relevant fuel types is not necessary. Since **COPERT** model provides with CNG and LPG CH4 values for passenger cars and buses, then we can use the relevant passenger cars (the most similar with LCVs – i.e. Large-SUV) to calculate the emissions for LCVs and the relevant Buses to calculate the emissions for HDVs. Moreover, for **electricity powered** vehicles we can use the average CH4 emitted per KWh in Europe and multiply it with consumption expressed as KWh/km. The average consumption was assumed as 0.31 KWh/Km.	
Wind	**L-category** no information **LCVs** no information	**L-category:** No information was found. **LCVs:** No information was found.	**L-category:** The wind effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual CH4 values for all L-category types (including euro categories etc.).

Factors	Missing Info	Main Findings	Comments
	HDV - HDV < 14 t no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**HDV (All types):** No information was found. **Conclusions:** Since the CH4 is linearly and positively correlated with CO2 emissions (Nam EK, 2004) and since wind affects directly the fuel consumption, then we can assume that methane follows the same pattern with FC. Since FC results are available for all 9 classes (wind from 40-80km/h to -40- -80km/h) and as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the CH4 produced (i.e. linear correlation) and the opposite. This solution supports also the consistency of the database.	**LCVs:** The same methodology with L-Category was followed. **HDV - HDV < 14 t:** The same methodology with L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with L-Category was followed. **HDV -** **28 t < HDV:** The same methodology with L-Category was followed.

Factors	Missing Info	Main Findings	Comments
A/C	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have A/C systems we can **assume** that this factor **is not applied** for this vehicle types. Since the CH4 is linearly and positively correlated with CO2 emissions (Nam EK, 2004) and since A/C affects directly the fuel consumption, then we can assume that methane follows the same pattern with FC. Since FC results are available for all 135 AC classes and are expressed as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the CH4 produced (i.e. linear correlation) and the opposite. This solution supports also the consistency of the database.	**L-category:** No values were produced for this category. **LCVs:** The A/C effect was calculated by using the percentage increase in FC (as presented in FC/CO2 table) and multiplied with actual CH4 values for all LCVs types (including euro categories etc.). **HDV - HDV < 14 t:** The same methodology with LCV was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with LCV was followed.

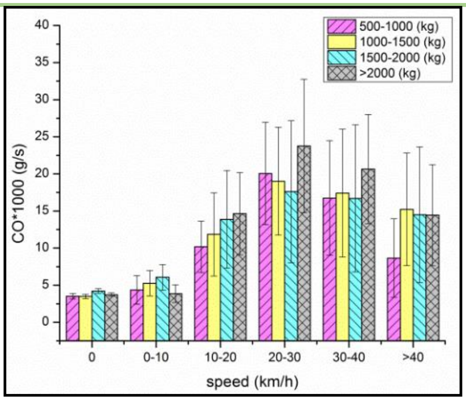
Factors	Missing Info	Main Findings	Comments
			HDV - **28 t < HDV:** The same methodology with LCV was followed.
Traffic	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information	**L-category:** No information was found. **LCVs:** No specific information was found. **HDV (All types):** No specific information was found. **Conclusion:** Since the CH4 is linearly and positively correlated with CO2 emissions (Nam EK, 2004) and since traffic affects directly the fuel consumption, then we can assume that methane follows the same pattern with FC.	**L-category:** The traffic effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual CH4 values for all L-category types (including euro categories etc.). **LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:**

Factors	Missing Info	Main Findings	Comments
	HDV - **28 t < HDV:** no information	Since FC results are available for all 3 traffic classes and as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the CH4 produced (i.e. linear correlation) and the opposite. This solution supports also the consistency of the database.	The same methodology described for L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology described for L-Category was followed. **HDV -** **28 t < HDV:** The same methodology described for L-Category was followed.

4.3.2.4 CO

Table 18: Emission Factors for CO – Gap analysis results, findings and applied solutions (in GYR database)

Factors	Missing Info	Main Findings	Comments
Occupancy	**L-category** no information **LCVs** no information **HDV - HDV < 14 t:** COPERT provides data (3 classes) **HDV -** **14 t < HDV < 28 t:** COPERT provides data (3 classes) **HDV -**	**L-category:** No specific information was found. **LCVs:** No specific information was found for LCVs. **HDV (All types):** No specific information was found for LCVs. **General Results:** There are no articles for occupancy effect on LCVs and L-categories CO emissions. Nevertheless Yu et al (Qian Yu, 2016) measured CO emissions on urban busses in four passenger load categories and found the results as presented in the following graph. The results show that the emission volumes are strongly related with speed.	**L-category:** No values were produced for this category. **LCVs:** The occupancy effect was calculated by using the percentage increase described in the vehicles included in the type: HDV>3.5 t of COPERT. This increase in CO emissions was applied to all LCVs based on the respective euro categories.

Factors	Missing Info	Main Findings	Comments
	28 t < HDV: COPERT provides data (3 classes)	 **Figure 13: "Emission rates for CO and rates for different speeds and passenger load" (Qian Yu, 2016)** Furthermore, occupancy effect in CO emissions of HDVs is well presented in COPERT model. LDVs have similar engines with HDVs and occupancy is directly correlated with FC. **Conclusion:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have important storage capacity we can assume that they are not affected by load or additional load is not applied for those cases.	

Factors	Missing Info	Main Findings	Comments
		LCVs: The information provided from the above article presented only actual fuel consumptions and focused only on buses, thus it was considered not representative for LCVs. In this context, values based on HDV occupancy effect (expressed as rates) as described in COPERT is considered a more reliable solution for LCVs occupancy estimation on CO emissions.	
Road Conditions	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information	**L-category:** No specific information was found. **LCVs:** No specific information was found for LCVs. **HDV (All types):** No specific information was found for LCVs. **General Results:** As illustrated for the case of CO2/FC factor, in the article of Setyawan et al (Setyawan, 2015) the effect of road condition was examined using "PCI (i.e. Pavement Condition Index)" method and found that road conditions affect the	**L-category:** Interpolation was performed by using the limits presented in the table 19 and based on 15 values. 0% CO increase corresponds to the basic emissions of our database and refers to excellent road conditions. **LCVs:**

<table>
<tr><th>Factors</th><th>Missing Info</th><th>Main Findings</th><th>Comments</th></tr>
<tr>
<td></td>
<td>HDV -
28 t < HDV:
no information</td>
<td>
<p>speed of the vehicle and consequently the total amount of CO and other emissions. For excellent to very poor pavement conditions the results for CO are illustrated in the following table:</p>
<p>Table 19: emissions values for CO (representing different road conditions) derived from (Setyawan, 2015) expressed as rates (%) compared with values in excellent road conditions.</p>
<table>
<tr><th>PCI</th><th>CO Increase (%)</th></tr>
<tr><td>19</td><td>2.76</td></tr>
<tr><td>34</td><td>0.87</td></tr>
<tr><td>43</td><td>0.59</td></tr>
<tr><td>59</td><td>0.25</td></tr>
<tr><td>79</td><td>0.05</td></tr>
<tr><td>100</td><td>0.02</td></tr>
</table>
<p>PCIs Described in the article are referring to “excellent”, “very good”, “good”, “fair”, “poor” and “very poor” road conditions for 100, 79, 60,44, 34, 19 PCI values respectively.</p>
<p>Conclusion:</p>
<p>For the calculation and production of CO values for this factor we can perform an interpolation based on the above table and the defined classes (15 years) in our database. PCI transformation to year classes is performed based on</p>
</td>
<td>
<p>The same methodology described for L-Category was followed.</p>
<p>HDV - HDV < 14 t:</p>
<p>The same methodology described for L-Category was followed.</p>
<p>HDV -</p>
<p>14 t < HDV < 28 t:</p>
<p>The same methodology described for L-Category was followed.</p>
<p>HDV -</p>
<p>28 t < HDV:</p>
<p>The same methodology described for L-Category was followed.</p>
</td>
</tr>
</table>

Factors	Missing Info	Main Findings	Comments
		qualitative characteristics described above and from the fact that road age expresses directly the road quality. Based on the above we can perform the following assumption in order to make the interpolation: • PCI 100 equals to the basic emissions (Road age is zero) – No increase at all • PCI 19 equals to the fifteenth class (15th year)	
Road gradient	**L-category** no information **LCVs** no information **HDV - HDV < 14 t:** COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02) **HDV -**	**L-category:** No information was found. **LCVs:** In the study of Zhang et al (Wendan Zhang, 2015) a literature review for the effect of road gradient in vehicular emissions was performed. This review is presented in the Figure 4: "Studies on the changes of fuel consumption and emissions with the change of road grades". As described in the FC/CO2 table these results are not consisted thus they are not suitable for usage in the database. **Conclusion:**	**L-category:** The same methodology with LCVs was followed. **LCVs:** The Road gradient effect was calculated by using the percentage increase of CO illustrated in the vehicles included in the type: HDV>3.5 t of COPERT. This increase was applied to all LCVs based on the respective euro categories.

Factors	Missing Info	Main Findings	Comments
	14 t < HDV < 28 t: COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02) **HDV -** **28 t < HDV:** COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02)	Since gradient affects directly the fuel consumption and since the CO is a product of non complete combustion (Nilrit S., 2013), then we can assume that CO follows the same pattern with other FC affected emissions. Moreover, COPERT provides with road gradient effect for HDVs. In this context, values based on HDV occupancy effect (expressed as rates) as described in COPERT is considered a more reliable solution for LCVs occupancy estimation on NOx emissions.	
Type of Fuel	**L-category** Information for Diesel and Petrol **LCVs** Information for Diesel and Petrol	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):**	**L-category:** **L-category:** No additional fuel types were illustrated in this category. **LCVs:**

<table>
<tr><th>Factors</th><th>Missing Info</th><th>Main Findings</th><th>Comments</th></tr>
<tr>
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HDV - HDV < 14 t:

Information for Diesel and Petrol

HDV -

14 t < HDV < 28 t:

Information for Diesel and Petrol

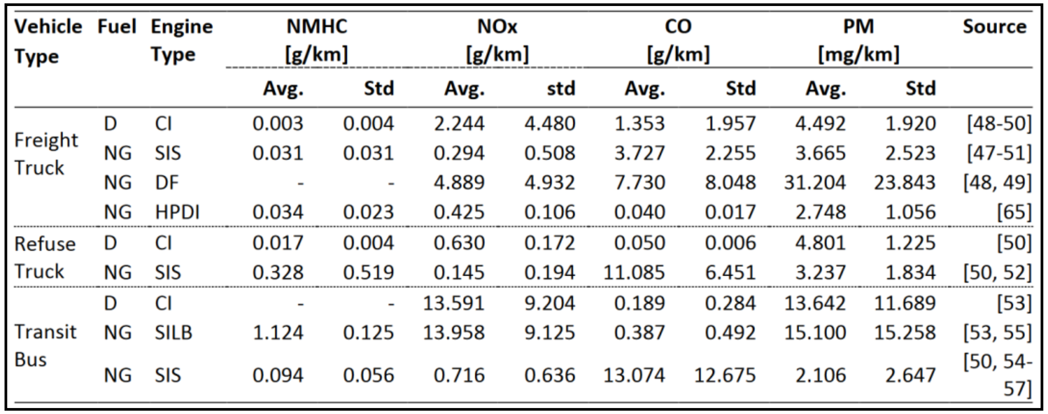
HDV -

28 t < HDV:

Information for Diesel and Petrol

</td>
<td>

CO emissions for HDV vehicles with engines that use natural gas (NG) are presented in the article of Stettler et al (Marc Stettler, 2019). The article presents the following CO exhaust emissions as illustrated in the following table:



<table>
<tr><th>Vehicle Type</th><th>Fuel</th><th>Engine Type</th><th colspan="2">NMHC [g/km]</th><th colspan="2">NOx [g/km]</th><th colspan="2">CO [g/km]</th><th colspan="2">PM [mg/km]</th><th>Source</th></tr>
<tr><th></th><th></th><th></th><th>Avg.</th><th>Std</th><th>Avg.</th><th>std</th><th>Avg.</th><th>Std</th><th>Avg.</th><th>Std</th><th></th></tr>
<tr><td>Freight Truck</td><td>D</td><td>CI</td><td>0.003</td><td>0.004</td><td>2.244</td><td>4.480</td><td>1.353</td><td>1.957</td><td>4.492</td><td>1.920</td><td>[48-50]</td></tr>
<tr><td></td><td>NG</td><td>SIS</td><td>0.031</td><td>0.031</td><td>0.294</td><td>0.508</td><td>3.727</td><td>2.255</td><td>3.665</td><td>2.523</td><td>[47-51]</td></tr>
<tr><td></td><td>NG</td><td>DF</td><td>-</td><td>-</td><td>4.889</td><td>4.932</td><td>7.730</td><td>8.048</td><td>31.204</td><td>23.843</td><td>[48, 49]</td></tr>
<tr><td></td><td>NG</td><td>HPDI</td><td>0.034</td><td>0.023</td><td>0.425</td><td>0.106</td><td>0.040</td><td>0.017</td><td>2.748</td><td>1.056</td><td>[65]</td></tr>
<tr><td>Refuse Truck</td><td>D</td><td>CI</td><td>0.017</td><td>0.004</td><td>0.630</td><td>0.172</td><td>0.050</td><td>0.006</td><td>4.801</td><td>1.225</td><td>[50]</td></tr>
<tr><td></td><td>NG</td><td>SIS</td><td>0.328</td><td>0.519</td><td>0.145</td><td>0.194</td><td>11.085</td><td>6.451</td><td>3.237</td><td>1.834</td><td>[50, 52]</td></tr>
<tr><td>Transit Bus</td><td>D</td><td>CI</td><td>-</td><td>-</td><td>13.591</td><td>9.204</td><td>0.189</td><td>0.284</td><td>13.642</td><td>11.689</td><td>[53]</td></tr>
<tr><td></td><td>NG</td><td>SILB</td><td>1.124</td><td>0.125</td><td>13.958</td><td>9.125</td><td>0.387</td><td>0.492</td><td>15.100</td><td>15.258</td><td>[53, 55]</td></tr>
<tr><td></td><td>NG</td><td>SIS</td><td>0.094</td><td>0.056</td><td>0.716</td><td>0.636</td><td>13.074</td><td>12.675</td><td>2.106</td><td>2.647</td><td>[50, 54-57]</td></tr>
</table>

Figure 14: "Summary of other air pollutant emissions produced by different types of diesel and natural gas heavy goods vehicles." (Marc Stettler, 2019).

Since standard deviation of CO is higher than or almost as high as the average the results of illustrated on the table could not be considered representative. This idea is supported also by the fact that the article refers to specific type of HDVs that have specific type of engines.

Electric Vehicles:

<u>Emissions from Electricity</u>

Since all exclusive electric vehicles are charged using the grid, then the emissions (including CO) produced from vehicles with this fuel type are defined by the

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Emission factors for LPG and CNG fuel types were produced for LCVs. The values of CO were based on relevant passenger car vehicles as provided by COPERT model.

For electricity powered LCVs the average value of 0.310 KWh/km was used for all LCVs sub-types of the database. The CO emissions were calculated by using the average emission factor of 194.37 mg/KWh.

HDV - HDV < 14 t:

Emission factors for LPG and CNG fuel types were produced for HDVs (<14 t). The values of CO were based on relevant buses

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</table>

Factors	Missing Info	Main Findings	Comments
		emissions types and volumes produced in each country for the grids electricity production. In this framework the EU average CO is 194.38 mg per KWh (ECOINVENT). **Conclusion:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have alternative fuel types we can assume that the provision of values for relevant fuel types is not necessary. Since COPERT model provides with CNG and LPG CO2/FC values for passenger cars and buses, then we can use the relevant passenger cars (the most similar with LCVs – i.e. Large-SUV) to calculate the emissions for LCVs and the relevant Buses to calculate the emissions for HDVs. Moreover, for electricity powered vehicles we can use the average CO emitted per KWh in Europe and multiply it with consumption expressed as KWh/km. The average consumption was assumed as 0.31 KWh/Km.	vehicles as provided by COPERT model. **HDV -** **14 t < HDV < 28 t:** No additional fuel types were illustrated in this category. **HDV -** **28 t < HDV:** No additional fuel types were illustrated in this category.
Wind	**L-category** no information	**L-category:** No information was found.	**L-category:** The wind effect was calculated by using the percentage increase in FC (calculated as presented in

Factors	Missing Info	Main Findings	Comments
	LCVs no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:** Since wind affects directly the fuel consumption and since the CO is a product of non complete combustion (Nilrit S., 2013), then we can assume that CO follows the same pattern with FC. Since FC results are available for all 9 classes (wind from 40-80km/h to -40- -80km/h) and as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the CO produced (linear correlation) and the opposite. This solution supports also the consistency of the database.	the FC/CO2 Table) and multiplied with actual CO values for all L-category types (including euro categories etc.). **LCVs:** The same methodology with L-Category was followed. **HDV - HDV < 14 t:** The same methodology with L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with L-Category was followed.

Factors	Missing Info	Main Findings	Comments
			HDV - **28 t < HDV:** The same methodology with L-Category was followed.
A/C	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:**	**L-category:** No values were produced for this category. **LCVs:** The A/C effect was calculated by using the percentage increase in FC (as presented in FC/CO2 Table) and multiplied with actual CO values for all LCVs types (including euro categories etc.).

Factors	Missing Info	Main Findings	Comments
	no information **HDV -** **28 t < HDV:** no information .	**L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have A/C systems we can assume that this factor is not applied for this vehicle types. Since A/C affects directly the fuel consumption and since the CO is a product of non complete combustion (Nilrit S., 2013), then we can assume that CO follows the same pattern with FC. Since FC results are available for all 135 AC classes and are expressed as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the CO produced (linear correlation) and the opposite. This solution supports also the consistency of the database.	**HDV - HDV < 14 t:** The same methodology with LCV was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with LCV was followed. **HDV -** **28 t < HDV:** The same methodology with LCV was followed.
Traffic	**L-category** no information **LCVs** no information	**L-category:** No information was found. **LCVs:** No specific information was found.	**L-category:** The traffic effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual CO

Factors	Missing Info	Main Findings	Comments
	HDV - HDV < 14 t no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**HDV (All types):** No specific information was found. **General Results:** In Zhang et al (Zhang Kai, 2011) study we have CO and other emissions results related with congestion as already presented in Figure 10: "Summary of speed/acceleration profiles, emission factors and fuel consumption rates for LDV and HDV grouped by traffic condition.".: As it is discussed in the table FC/CO2 the results of the study are not suitable for the database. **Conclusion:** Since CO could be considered that follows the same pattern with FC (see previous results), then we could multiply increase rates for different traffic conditions in FC with the actual and initial values of CO.	values for all L-category types (including euro categories etc). **LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:** The same methodology described for L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology described for L-Category was followed.

Factors	Missing Info	Main Findings	Comments
			HDV - **28 t < HDV:** The same methodology described for L-Category was followed.

4.3.2.5 N2O

Table 20: Emission Factors for N2O – Gap analysis results, findings and applied solutions (in GYR database)

Factors	Missing Info	Main Findings	Comments
General N2O emissions for LCVs	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:**	**LCVs:** Lipman and Delucchi (Lipman Timothy, 2002) presented a table (A-I) with measured N2O values for different LCVs derived from different studies. Based on this study and as the N2O concentrations are very low we can assume the following roughly estimated emission factors based on this table: • Petrol LDVs: 150 mg/mi (93 mg/km) N2O; • Diesel LDVs: 80 mg/mi (50 mg/km) N2O. Nevertheless, N2O emissions are seriously affected by catalysts and generally emission reduction systems and regulations (Euro categories), while this results are generalized. Furthermore, emission factors are generally very low and thus there are measurement issues (high standard deviations etc.). **Conclusion:** As literature results are very general and don't reflect the complicacy of real world fleets then the N2O emissions of LCV vehicles could be produced by using HDV relevant values. This could be performed by using the COPERT model and the values given for the smallest HDV.	**LCVs:** The LCV N2O emissions were calculated based on the smallest HDV vehicle type and followed the relative results for different euro categories and emission reduction technologies.

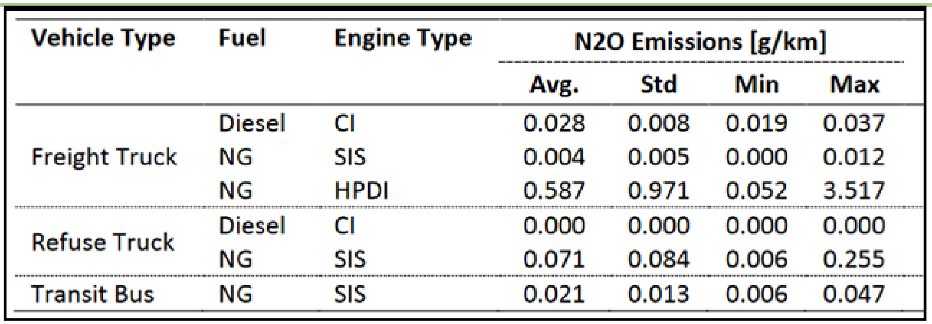
Factors	Missing Info	Main Findings	Comments
	no information		
Occupancy	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusion:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have important storage capacity we can assume that they are not affected by load or additional load is not applied for those cases. There is no information provided by literature or COPERT on effect of occupancy in N2O emissions. Since the N2O is related with NOx and the emission reduction technology we can assume that they follow the same	**L-category:** No values were produced for this category. **LCVs:** Based on the assumptions made. The N2O followed the same pattern with NOx and according to euro category and emission reduction technology. **HDV - HDV < 14 t:** The same methodology described for LCV was followed. **HDV -** **14 t < HDV < 28 t:**

Factors	Missing Info	Main Findings	Comments
		pattern. More specifically, for the estimation of the increase of N2O as a result of the occupancy effect, NOx relevant increase rates should be used for both HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	The same methodology described for LCV was followed. **HDV -** **28 t < HDV:** The same methodology described for LCV was followed.
Road Conditions	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusion:** There is no information provided by literature or COPERT on N2O emissions and road conditions. Since the N2O is related with NOx and	**L-category:** Based on the assumptions made. The N2O followed the same pattern with NOx and according to euro category and emission reduction technology. **LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:**

Factors	Missing Info	Main Findings	Comments
	no information **HDV -** **28 t < HDV:** no information	the emission reduction technology we can assume that they follow the same pattern. More specifically, for the estimation of the increase of N2O as a result of the road conditions, NOx relevant increase rates should be used for both HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	The same methodology described for L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology described for L-Category was followed. **HDV -** **28 t < HDV:** The same methodology described for L-Category was followed.
Road gradient	**L-category** no information **LCVs** no information	**L-category:** No information was found. **LCVs:**	**L-category:** Based on the assumptions made. The N2O followed the same pattern with NOx and according to euro category and emission reduction technology.

Factors	Missing Info	Main Findings	Comments
	HDV - HDV < 14 t no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	In the article of Lipman and Dellucchi (Lipman Timothy, 2002)**Error! Bookmark not defined.** is presented that road slope does not have an effect in diesel LDVs and has a negative effect in petrol LDVs (the higher the slope the lower the N20). The same happens with the increase of speed. More specifically a petrol vehicle produced N2O emissions from 2.6 mg/mi to 0.3 mg/mi for speeds 37 and 62 mi/h respectively and from 1.3 mg/mi to 0.6 mg/mi for gradients 2 and 4% respectively (stable speed at 27 mi/h). The results of the study present very high uncertainty and are very general (they do not include different technologies etc.). **HDV (All types):** No information was found. **Conclusion:** Since the literature results are general and they are based on previous old studies (1995) and furthermore, since engines and emission reduction technologies have been highly developed during that period (1995 – 2019) they cannot be considered as representative. Since the N2O is related with NOx and the emission reduction technology we can assume that they follow the same pattern. More specifically, for the estimation of the increase of N2O as a result of the road gradient effect NOx relevant increase rates should be used for both	**LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:** The same methodology described for L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology described for L-Category was followed. **HDV -** **28 t < HDV:** The same methodology described for L-Category was followed.

Factors	Missing Info	Main Findings	Comments
		HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	
Type of Fuel	**L-category** Information for Diesel and Petrol **LCVs** Information for Diesel and Petrol **HDV - HDV < 14 t:** Information for Diesel and Petrol **HDV -** **14 t < HDV < 28 t:** Information for Diesel and Petrol	**L-category:** No specific information was found. **LCVs:** No specific information was found for LCVs. **HDV (All types):** N2O emissions for vehicles with engines that use natural gas (NG) are presented in the article of Stettler et al (Marc Stettler, 2019). The article presents the following N2O emissions as illustrated in the following table:	**L-category:** No additional fuel types were illustrated in this category. **LCVs:** Emission factors for LPG and CNG fuel types were produced for LCVs. The values of N2O were based on relevant Passenger car vehicles as provided by COPERT model. For electricity powered LCVs the average value of 0.310 KWh/km was used for all LCVs sub-types of the database. The N2O emissions were calculated by using the average emission factor of 13.78 mg/KWh.

<table>
<tr><th>Factors</th><th>Missing Info</th><th>Main Findings</th><th>Comments</th></tr>
<tr>
<td></td>
<td>HDV -
28 t < HDV:
Information for Diesel and Petrol</td>
<td>

<table>
<tr><th>Vehicle Type</th><th>Fuel</th><th>Engine Type</th><th colspan="4">N2O Emissions [g/km]</th></tr>
<tr><th></th><th></th><th></th><th>Avg.</th><th>Std</th><th>Min</th><th>Max</th></tr>
<tr><td>Freight Truck</td><td>Diesel</td><td>CI</td><td>0.028</td><td>0.008</td><td>0.019</td><td>0.037</td></tr>
<tr><td></td><td>NG</td><td>SIS</td><td>0.004</td><td>0.005</td><td>0.000</td><td>0.012</td></tr>
<tr><td></td><td>NG</td><td>HPDI</td><td>0.587</td><td>0.971</td><td>0.052</td><td>3.517</td></tr>
<tr><td>Refuse Truck</td><td>Diesel</td><td>CI</td><td>0.000</td><td>0.000</td><td>0.000</td><td>0.000</td></tr>
<tr><td></td><td>NG</td><td>SIS</td><td>0.071</td><td>0.084</td><td>0.006</td><td>0.255</td></tr>
<tr><td>Transit Bus</td><td>NG</td><td>SIS</td><td>0.021</td><td>0.013</td><td>0.006</td><td>0.047</td></tr>
</table>
Figure 15: “Summary of the N2O emissions produced by various diesel and natural gas engines”. Results presented as defined in different studies” (Marc Stettler, 2019).
The above table presents very general results that do not reflect all HDVs. In most cases of NG fueled vehicle standard deviation is higher than average N2O emissions, meaning that the level of uncertainty is not adequate for current database.
Electric Vehicles:
<u>Emissions from Electricity</u>
Since all exclusive electric vehicles are charged using the grid, then the emissions (including N2O) produced from vehicles with this fuel type are defined by the emissions types and volumes produced in each country for the grids electricity production.
</td>
<td>HDV - HDV < 14 t:
Emission factors for LPG and CNG fuel types were produced for HDVs (<14 t) based on values from Buses presented in COPERT. The values of N2O were based on relevant buses vehicles as provided by COPERT model.
HDV -
14 t < HDV < 28 t:
No additional fuel types were illustrated in this category.
HDV -
28 t < HDV:
No additional fuel types were illustrated in this category.</td>
</tr>
</table>

Factors	Missing Info	Main Findings	Comments
		In this framework the EU average N2O is 13.78 mg per KWh (ECOINVENT). **Conclusions:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have alternative fuel types we can assume that the provision of values for relevant fuel types is not necessary. Since COPERT model provides with CNG and LPG CO2/FC values for passenger cars and buses, then we can use the relevant passenger cars (the most similar with LCVs – i.e. Large-SUV) to calculate the emissions for LCVs and the relevant Buses to calculate the emissions for HDVs. Moreover, for **electricity powered vehicles** we can use the average N2O emitted per KWh in Europe and multiply it with consumption expressed as KWh/km. The average consumption was assumed as 0.31 KWh/Km**.**	
Wind	**L-category** no information	**L-category:** No information was found.	**L-category:** The wind effect was calculated by using the percentage increase in NOx (calculated as presented in the NOx table) and multiplied with

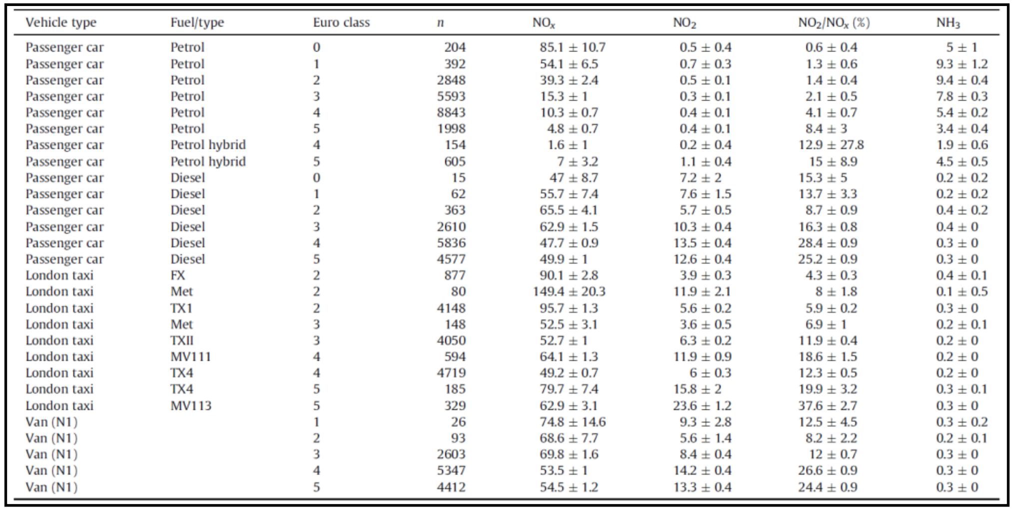
Factors	Missing Info	Main Findings	Comments
	LCVs no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:** Since the N2O is related with NOx and the emission reduction technology we can assume that they follow the same pattern. More specifically, for the estimation of the increase of N2O as a result of the wind effect, NOx relevant increase rates (see NOx table) should be used for both HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	actual N2O values for all L-category types (including euro categories etc.). **LCVs:** The same methodology with L-Category was followed. **HDV - HDV < 14 t:** The same methodology with L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with L-Category was followed. **HDV -** **28 t < HDV:**

Factors	Missing Info	Main Findings	Comments
			The same methodology with L-Category was followed.
A/C	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:** **L-Category:** Since, L-Category vehicles include motorcycles, ATVs and mini cars that usually do not have A/C systems we can assume that this factor is not applied for this vehicle types. Since the N2O is related with NOx and the emission reduction technology we can assume that they follow the same pattern. More specifically, for the estimation of the increase of N2O as a result of the	**L-category:** No values were produced for this category. **LCVs:** The A/C effect was calculated by using the percentage increase in NOx (as presented in NOx table – Results for AC emission factor) and multiplied with actual N2O values for all LCVs types (including euro categories etc.). **HDV - HDV < 14 t:** The same methodology with LCV was followed. **HDV -**

Factors	**Missing Info**	**Main Findings**	**Comments**
	no information	AC effect, NOx relevant increase rates (see NOx table) should be used for both HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	**14 t < HDV < 28 t:** The same methodology with LCV was followed. **HDV -** **28 t < HDV:** The same methodology with LCV was followed.

4.3.2.6 NH3

Table 21: Emission Factors for NH3 – Gap analysis results, findings and applied solutions (in GYR database)

<table>
<tr><th>Factors</th><th>Missing Info</th><th>Main Findings</th><th>Comments</th></tr>
<tr>
<td>General NH3 emissions for LCVs.</td>
<td>L-category
Information is provided by COPERT model.
LCVs
no information
HDV - HDV < 14 t
Information is provided by COPERT model.</td>
<td>LCVs:
Values of NH3 for LCVs are presented in following tables, while they represent volume ratios with CO2 that are multiplied by 10,000 (David C. Carslaw, 2013,). The tables present values for different types of vehicles.

<table>
<tr><th>Vehicle type</th><th>Fuel/type</th><th>Euro class</th><th>n</th><th>NO_x</th><th>NO_2</th><th>NO_2/NO_x (%)</th><th>NH_3</th></tr>
<tr><td>Passenger car</td><td>Petrol</td><td>0</td><td>204</td><td>85.1 ± 10.7</td><td>0.5 ± 0.4</td><td>0.6 ± 0.4</td><td>5 ± 1</td></tr>
<tr><td>Passenger car</td><td>Petrol</td><td>1</td><td>392</td><td>54.1 ± 6.5</td><td>0.7 ± 0.3</td><td>1.3 ± 0.6</td><td>9.3 ± 1.2</td></tr>
<tr><td>Passenger car</td><td>Petrol</td><td>2</td><td>2848</td><td>39.3 ± 2.4</td><td>0.5 ± 0.1</td><td>1.4 ± 0.4</td><td>9.4 ± 0.4</td></tr>
<tr><td>Passenger car</td><td>Petrol</td><td>3</td><td>5593</td><td>15.3 ± 1</td><td>0.3 ± 0.1</td><td>2.1 ± 0.5</td><td>7.8 ± 0.3</td></tr>
<tr><td>Passenger car</td><td>Petrol</td><td>4</td><td>8843</td><td>10.3 ± 0.7</td><td>0.4 ± 0.1</td><td>4.1 ± 0.7</td><td>5.4 ± 0.2</td></tr>
<tr><td>Passenger car</td><td>Petrol</td><td>5</td><td>1998</td><td>4.8 ± 0.7</td><td>0.4 ± 0.1</td><td>8.4 ± 3</td><td>3.4 ± 0.4</td></tr>
<tr><td>Passenger car</td><td>Petrol hybrid</td><td>4</td><td>154</td><td>1.6 ± 1</td><td>0.2 ± 0.4</td><td>12.9 ± 27.8</td><td>1.9 ± 0.6</td></tr>
<tr><td>Passenger car</td><td>Petrol hybrid</td><td>5</td><td>605</td><td>7 ± 3.2</td><td>1.1 ± 0.4</td><td>15 ± 8.9</td><td>4.5 ± 0.5</td></tr>
<tr><td>Passenger car</td><td>Diesel</td><td>0</td><td>15</td><td>47 ± 8.7</td><td>7.2 ± 2</td><td>15.3 ± 5</td><td>0.2 ± 0.2</td></tr>
<tr><td>Passenger car</td><td>Diesel</td><td>1</td><td>62</td><td>55.7 ± 7.4</td><td>7.6 ± 1.5</td><td>13.7 ± 3.3</td><td>0.2 ± 0.2</td></tr>
<tr><td>Passenger car</td><td>Diesel</td><td>2</td><td>363</td><td>65.5 ± 4.1</td><td>5.7 ± 0.5</td><td>8.7 ± 0.9</td><td>0.4 ± 0.2</td></tr>
<tr><td>Passenger car</td><td>Diesel</td><td>3</td><td>2610</td><td>62.9 ± 1.5</td><td>10.3 ± 0.4</td><td>16.3 ± 0.8</td><td>0.4 ± 0</td></tr>
<tr><td>Passenger car</td><td>Diesel</td><td>4</td><td>5836</td><td>47.7 ± 0.9</td><td>13.5 ± 0.4</td><td>28.4 ± 0.9</td><td>0.3 ± 0</td></tr>
<tr><td>Passenger car</td><td>Diesel</td><td>5</td><td>4577</td><td>49.9 ± 1</td><td>12.6 ± 0.4</td><td>25.2 ± 0.9</td><td>0.3 ± 0</td></tr>
<tr><td>London taxi</td><td>FX</td><td>2</td><td>877</td><td>90.1 ± 2.8</td><td>3.9 ± 0.3</td><td>4.3 ± 0.3</td><td>0.4 ± 0.1</td></tr>
<tr><td>London taxi</td><td>Met</td><td>2</td><td>80</td><td>149.4 ± 20.3</td><td>11.9 ± 2.1</td><td>8 ± 1.8</td><td>0.1 ± 0.5</td></tr>
<tr><td>London taxi</td><td>TX1</td><td>2</td><td>4148</td><td>95.7 ± 1.3</td><td>5.6 ± 0.2</td><td>5.9 ± 0.2</td><td>0.3 ± 0</td></tr>
<tr><td>London taxi</td><td>Met</td><td>3</td><td>148</td><td>52.5 ± 3.1</td><td>3.6 ± 0.5</td><td>6.9 ± 1</td><td>0.2 ± 0.1</td></tr>
<tr><td>London taxi</td><td>TXII</td><td>3</td><td>4050</td><td>52.7 ± 1</td><td>6.3 ± 0.2</td><td>11.9 ± 0.4</td><td>0.2 ± 0</td></tr>
<tr><td>London taxi</td><td>MV111</td><td>4</td><td>594</td><td>64.1 ± 1.3</td><td>11.9 ± 0.9</td><td>18.6 ± 1.5</td><td>0.2 ± 0</td></tr>
<tr><td>London taxi</td><td>TX4</td><td>4</td><td>4719</td><td>49.2 ± 0.7</td><td>6 ± 0.3</td><td>12.3 ± 0.5</td><td>0.2 ± 0</td></tr>
<tr><td>London taxi</td><td>TX4</td><td>5</td><td>185</td><td>79.7 ± 7.4</td><td>15.8 ± 2</td><td>19.9 ± 3.2</td><td>0.3 ± 0.1</td></tr>
<tr><td>London taxi</td><td>MV113</td><td>5</td><td>329</td><td>62.9 ± 3.1</td><td>23.6 ± 1.2</td><td>37.6 ± 2.7</td><td>0.3 ± 0</td></tr>
<tr><td>Van (N1)</td><td></td><td>1</td><td>26</td><td>74.8 ± 14.6</td><td>9.3 ± 2.8</td><td>12.5 ± 4.5</td><td>0.3 ± 0.2</td></tr>
<tr><td>Van (N1)</td><td></td><td>2</td><td>93</td><td>68.6 ± 7.7</td><td>5.6 ± 1.4</td><td>8.2 ± 2.2</td><td>0.2 ± 0.1</td></tr>
<tr><td>Van (N1)</td><td></td><td>3</td><td>2603</td><td>69.8 ± 1.6</td><td>8.4 ± 0.4</td><td>12 ± 0.7</td><td>0.3 ± 0</td></tr>
<tr><td>Van (N1)</td><td></td><td>4</td><td>5347</td><td>53.5 ± 1</td><td>14.2 ± 0.4</td><td>26.6 ± 0.9</td><td>0.3 ± 0</td></tr>
<tr><td>Van (N1)</td><td></td><td>5</td><td>4412</td><td>54.5 ± 1.2</td><td>13.3 ± 0.4</td><td>24.4 ± 0.9</td><td>0.3 ± 0</td></tr>
</table>
Figure 16: Table A - “Emission ratios (species/CO2) for different light duty vehicles types. The volume ratios have been multiplied by 10,000. The uncertainties are shown as the 95% confidence interval in the mean.nis the sample size. The uncertainties in the NO2/NOx ratio were calculated based on the mean uncertainties calculated for NO2and NOx.” (David C. Carslaw, 2013,).</td>
<td>LCVs:
The LCV NH3 emissions were calculated based on the smallest HDV vehicle type and followed the relative results for different euro categories and emission reduction technologies.</td>
</tr>
</table>

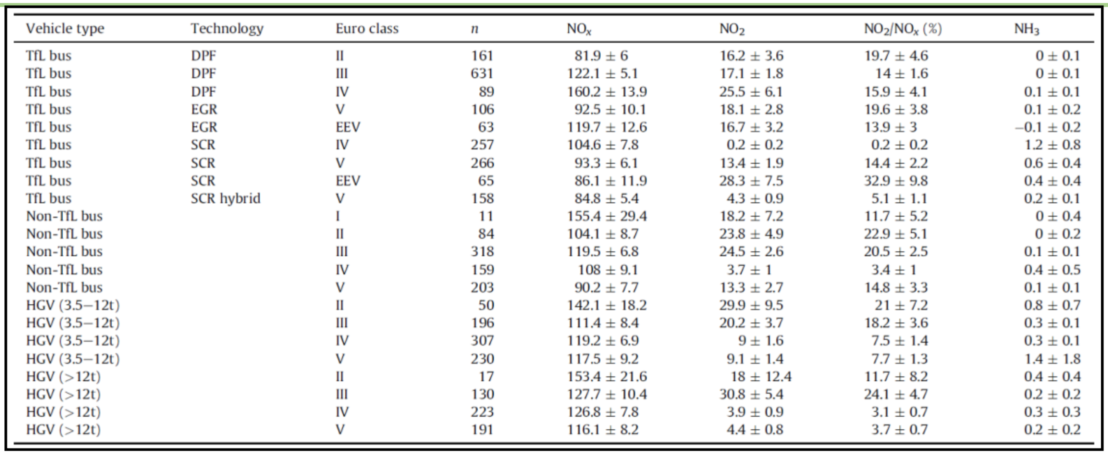
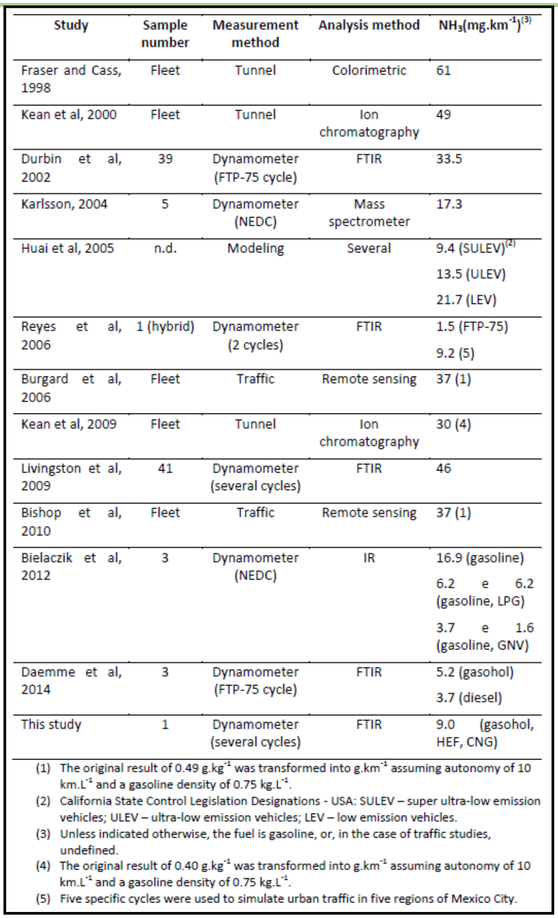
<table>
<tr><th>Factors</th><th>Missing Info</th><th>Main Findings</th><th>Comments</th></tr>
<tr>
<td></td>
<td>HDV -
14 t < HDV < 28 t:
Information is provided by COPERT model.
HDV -
28 t < HDV:
Information is provided by COPERT model.</td>
<td>

<table>
<tr><th>Vehicle type</th><th>Technology</th><th>Euro class</th><th>n</th><th>NO_x</th><th>NO_2</th><th>NO_2/NO_x (%)</th><th>NH_3</th></tr>
<tr><td>TfL bus</td><td>DPF</td><td>II</td><td>161</td><td>81.9 ± 6</td><td>16.2 ± 3.6</td><td>19.7 ± 4.6</td><td>0 ± 0.1</td></tr>
<tr><td>TfL bus</td><td>DPF</td><td>III</td><td>631</td><td>122.1 ± 5.1</td><td>17.1 ± 1.8</td><td>14 ± 1.6</td><td>0 ± 0.1</td></tr>
<tr><td>TfL bus</td><td>DPF</td><td>IV</td><td>89</td><td>160.2 ± 13.9</td><td>25.5 ± 6.1</td><td>15.9 ± 4.1</td><td>0.1 ± 0.1</td></tr>
<tr><td>TfL bus</td><td>EGR</td><td>V</td><td>106</td><td>92.5 ± 10.1</td><td>18.1 ± 2.8</td><td>19.6 ± 3.8</td><td>0.1 ± 0.2</td></tr>
<tr><td>TfL bus</td><td>EGR</td><td>EEV</td><td>63</td><td>119.7 ± 12.6</td><td>16.7 ± 3.2</td><td>13.9 ± 3</td><td>−0.1 ± 0.2</td></tr>
<tr><td>TfL bus</td><td>SCR</td><td>IV</td><td>257</td><td>104.6 ± 7.8</td><td>0.2 ± 0.2</td><td>0.2 ± 0.2</td><td>1.2 ± 0.8</td></tr>
<tr><td>TfL bus</td><td>SCR</td><td>V</td><td>266</td><td>93.3 ± 6.1</td><td>13.4 ± 1.9</td><td>14.4 ± 2.2</td><td>0.6 ± 0.4</td></tr>
<tr><td>TfL bus</td><td>SCR</td><td>EEV</td><td>65</td><td>86.1 ± 11.9</td><td>28.3 ± 7.5</td><td>32.9 ± 9.8</td><td>0.4 ± 0.4</td></tr>
<tr><td>TfL bus</td><td>SCR hybrid</td><td>V</td><td>158</td><td>84.8 ± 5.4</td><td>4.3 ± 0.9</td><td>5.1 ± 1.1</td><td>0.2 ± 0.1</td></tr>
<tr><td>Non-TfL bus</td><td></td><td>I</td><td>11</td><td>155.4 ± 29.4</td><td>18.2 ± 7.2</td><td>11.7 ± 5.2</td><td>0 ± 0.4</td></tr>
<tr><td>Non-TfL bus</td><td></td><td>II</td><td>84</td><td>104.1 ± 8.7</td><td>23.8 ± 4.9</td><td>22.9 ± 5.1</td><td>0 ± 0.2</td></tr>
<tr><td>Non-TfL bus</td><td></td><td>III</td><td>318</td><td>119.5 ± 6.8</td><td>24.5 ± 2.6</td><td>20.5 ± 2.5</td><td>0.1 ± 0.1</td></tr>
<tr><td>Non-TfL bus</td><td></td><td>IV</td><td>159</td><td>108 ± 9.1</td><td>3.7 ± 1</td><td>3.4 ± 1</td><td>0.4 ± 0.5</td></tr>
<tr><td>Non-TfL bus</td><td></td><td>V</td><td>203</td><td>90.2 ± 7.7</td><td>13.3 ± 2.7</td><td>14.8 ± 3.3</td><td>0.1 ± 0.1</td></tr>
<tr><td>HGV (3.5–12t)</td><td></td><td>II</td><td>50</td><td>142.1 ± 18.2</td><td>29.9 ± 9.5</td><td>21 ± 7.2</td><td>0.8 ± 0.7</td></tr>
<tr><td>HGV (3.5–12t)</td><td></td><td>III</td><td>196</td><td>111.4 ± 8.4</td><td>20.2 ± 3.7</td><td>18.2 ± 3.6</td><td>0.3 ± 0.1</td></tr>
<tr><td>HGV (3.5–12t)</td><td></td><td>IV</td><td>307</td><td>119.2 ± 6.9</td><td>9 ± 1.6</td><td>7.5 ± 1.4</td><td>0.3 ± 0.1</td></tr>
<tr><td>HGV (3.5–12t)</td><td></td><td>V</td><td>230</td><td>117.5 ± 9.2</td><td>9.1 ± 1.4</td><td>7.7 ± 1.3</td><td>1.4 ± 1.8</td></tr>
<tr><td>HGV (>12t)</td><td></td><td>II</td><td>17</td><td>153.4 ± 21.6</td><td>18 ± 12.4</td><td>11.7 ± 8.2</td><td>0.4 ± 0.4</td></tr>
<tr><td>HGV (>12t)</td><td></td><td>III</td><td>130</td><td>127.7 ± 10.4</td><td>30.8 ± 5.4</td><td>24.1 ± 4.7</td><td>0.2 ± 0.2</td></tr>
<tr><td>HGV (>12t)</td><td></td><td>IV</td><td>223</td><td>126.8 ± 7.8</td><td>3.9 ± 0.9</td><td>3.1 ± 0.7</td><td>0.3 ± 0.3</td></tr>
<tr><td>HGV (>12t)</td><td></td><td>V</td><td>191</td><td>116.1 ± 8.2</td><td>4.4 ± 0.8</td><td>3.7 ± 0.7</td><td>0.2 ± 0.2</td></tr>
</table>
Figure 17: Table B - “Emission ratios (species/CO2) for different heavy duty vehicles types. The volume ratios have been multiplied by 10,000. The uncertainties are shown as the 95% confidence interval in the mean.nis the sample size. The uncertainties in the NO2/NOx ratio were calculated based on the mean uncertainties calculated for NO2and NOx” (David C. Carslaw, 2013,).
As the above ratios are referring to volumes we could calculate masses in order to have factors that will be multiplied with CO2 emissions. The results will define specific emissions (mg/Km) for NOx, and NH3.
The following table was based on mass calculations and could be used directly to compute emissions in the database:
</td>
<td></td>
</tr>
</table>

Table 22: Actual emission ratios expressed as mass/mass of NH3/ CO2 and NOx/CO2 based on (David C. Carslaw, 2013,) results.

Paper results (mass ratios) - Factors			
Veh type	**tech**	**NH3**	**NOx**
Van	euro 1	0.000012	0.005372
Van	euro 2	0.000008	0.004927
Van	euro 3	0.000012	0.005013
Van	euro 4	0.000012	0.003842
Van	euro 5	0.000012	0.003914
HGV (3.5e12t)	Euro II	0.000031	0.010205
HGV (3.5e12t)	Euro III	0.000012	0.008000
HGV (3.5e12t)	Euro IV	0.000012	0.008561
HGV (3.5e12t)	Euro V	0.000054	0.008438
HGV (>12t	Euro II	0.000015	0.011017
HGV (>12t	Euro III	0.000008	0.009171
HGV (>12t	Euro IV	0.000012	0.009106
HGV (>12t	Euro V	0.000008	0.008338

For the calculation of NOx ratio we could assume that it is consisted from 10% NO2 and 90% NO. Furthermore, according to a study of Borsari and de Assunção (Borsari Vanderlei, 2017), we have the following table derived from literature review and acquired results:

Factors	Missing Info	Main Findings	Comments
		 Figure 18: "Average emissions of NH3 from light duty vehicles from several studies." (Borsari Vanderlei, 2017).	

Study	Sample number	Measurement method	Analysis method	$NH_3(mg.km^{-1})^{(3)}$
Fraser and Cass, 1998	Fleet	Tunnel	Colorimetric	61
Kean et al, 2000	Fleet	Tunnel	Ion chromatography	49
Durbin et al, 2002	39	Dynamometer (FTP-75 cycle)	FTIR	33.5
Karlsson, 2004	5	Dynamometer (NEDC)	Mass spectrometer	17.3
Huai et al, 2005	n.d.	Modeling	Several	9.4 (SULEV)$^{(2)}$ 13.5 (ULEV) 21.7 (LEV)
Reyes et al, 2006	1 (hybrid)	Dynamometer (2 cycles)	FTIR	1.5 (FTP-75) 9.2 (5)
Burgard et al, 2006	Fleet	Traffic	Remote sensing	37 (1)
Kean et al, 2009	Fleet	Tunnel	Ion chromatography	30 (4)
Livingston et al, 2009	41	Dynamometer (several cycles)	FTIR	46
Bishop et al, 2010	Fleet	Traffic	Remote sensing	37 (1)
Bielaczik et al, 2012	3	Dynamometer (NEDC)	IR	16.9 (gasoline) 6.2 e 6.2 (gasoline, LPG) 3.7 e 1.6 (gasoline, GNV)
Daemme et al, 2014	3	Dynamometer (FTP-75 cycle)	FTIR	5.2 (gasohol) 3.7 (diesel)
This study	1	Dynamometer (several cycles)	FTIR	9.0 (gasohol, HEF, CNG)

(1) The original result of 0.49 $g.kg^{-1}$ was transformed into $g.km^{-1}$ assuming autonomy of 10 $km.L^{-1}$ and a gasoline density of 0.75 $kg.L^{-1}$.
(2) California State Control Legislation Designations - USA: SULEV – super ultra-low emission vehicles; ULEV – ultra-low emission vehicles; LEV – low emission vehicles.
(3) Unless indicated otherwise, the fuel is gasoline, or, in the case of traffic studies, undefined.
(4) The original result of 0.40 $g.kg^{-1}$ was transformed into $g.km^{-1}$ assuming autonomy of 10 $km.L^{-1}$ and a gasoline density of 0.75 $kg.L^{-1}$.
(5) Five specific cycles were used to simulate urban traffic in five regions of Mexico City.

Factors	Missing Info	Main Findings	Comments
		Conclusion: Although literature presents ratios and actual values of NH3 emissions, the results are not stable and reliable as the actual emissions are very low (around some mg/mi) and the ratios are also low and present very high standard deviations (in most of the cases equal or higher than average). Based on the above and since COPERT provides with values for HDVs and L-Categories, LCVs values could be calculated based on the HDV relevant values (use values from the smallest HDVs – most similar with LCVs and according to euro categories and emission reduction technologies).	
Occupancy	**L-category** no information **LCVs** no information **HDV - HDV < 14 t**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found.	**L L-category:** No values were produced for this category. **LCVs:** Based on the assumptions made. The NH3 followed the same pattern with NOx (NOx increase rates as presented in the relevant NOx table) and according to

Factors	Missing Info	Main Findings	Comments
	no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**Conclusions:** **L-Category:** Since, L-Category vehicles include motorcycles, ATVs and mini cars that usually do not have important storage capacity we can assume that they are not affected by load or additional load is not applied for those cases. There is no information provided by literature or COPERT on effect of occupancy in NH3 emissions. Since the NH3 is related with NOx and the emission reduction technology we can assume that they follow the same pattern. More specifically, for the estimation of the increase of NH3 as a result of the occupancy effect NOx relevant increase rates should be used for both HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	euro category and emission reduction technology. **HDV - HDV < 14 t:** The same methodology described for LCV was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology described for LCV was followed. **HDV -** **28 t < HDV:** The same methodology described for LCV was followed.

Factors	Missing Info	Main Findings	Comments
Road Conditions	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:** There is no information provided by literature or COPERT on effect of road conditions in NH3 emissions. Since the NH3 is related with NOx and the emission reduction technology we can assume that they follow the same pattern. More specifically, for the estimation of the increase of NH3 as a result of the road conditions effect, NOx relevant increase rates should be used for both HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	**L-category:** Based on the assumptions made. The NH3 followed the same pattern with NOx (NOx increase rates as presented in the relevant NOx table) and according to euro category and emission reduction technology. **LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:** The same methodology described for L-Category was followed. **HDV -**

Factors	Missing Info	Main Findings	Comments
	HDV - **28 t < HDV:** no information		**14 t < HDV < 28 t:** The same methodology described for L-Category was followed. **HDV -** **28 t < HDV:** The same methodology described for L-Category was followed.
Road gradient	**L-category** no information **LCVs** no information	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):**	**L-category:** Based on the assumptions made. The NH3 followed the same pattern with NOx (NOx increase rates as presented in the relevant NOx table) and according to euro category and emission reduction technology.

Factors	Missing Info	Main Findings	Comments
	HDV - HDV < 14 t no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	No information was found. **Conclusions:** There is no information provided by literature or COPERT on effect of gradient in NH3 emissions. Since the NH3 is related with NOx and the emission reduction technology we can assume that they follow the same pattern. More specifically, for the estimation of the increase of NH3 as a result of the road gradient effect, NOx relevant increase rates should be used for both HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	**LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:** The same methodology described for L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology described for L-Category was followed. **HDV -** **28 t < HDV:**

Factors	Missing Info	Main Findings	Comments
			The same methodology described for L-Category was followed.
Type of Fuel	**L-category:** Information for Diesel and Petrol **LCVs:** Information for Diesel and Petrol **HDV - HDV < 14 t:** Information for Diesel and Petrol	**L-category:** No specific information was found. **LCVs:** Based on the same study (Borsari Vanderlei, 2017) (see the above Table 22) the NH3 emissions (expressed as mg/Km) are 16.9 (gasoline), 6.2 (gasoline, LPG) and 9.0 (gasohol, HEF, CNG) for LCVs. **HDV (All types):** No specific information was found. **Electric Vehicles:** <u>Emissions from Electricity</u> Since all exclusive electric vehicles are charged using the grid, then the emissions (including CH4) produced from vehicles with this fuel type are defined by the	**L-category:** No additional fuel types were illustrated in this category. **LCVs:** Emission factors for LPG and CNG fuel types were produced for LCVs. The values of NH3 were based on relevant Passenger car vehicles as provided by COPERT model. For electricity powered LCVs the average value of 0.310 KWh/km was used for all LCVs sub-types of the

Factors	Missing Info	Main Findings	Comments
	HDV - **14 t < HDV < 28 t:** Information for Diesel and Petrol **HDV -** **28 t < HDV:** Information for Diesel and Petrol	emissions types and volumes produced in each country for the grids electricity production. In this framework, the EU average NH3 is 1.72 mg per KWh (ECOINVENT). **Conclusion:** **L-Category:** Since, L-Category vehicles include motorcycles, ATVs and mini cars that usually do not have alternative fuel types we can assume that the provision of values for relevant fuel types is not necessary. Since COPERT model provides with CNG and LPG NH3 values for passenger cars and buses, then we can use the relevant passenger cars (the most similar with LCVs – i.e. Large-SUV) to calculate the emissions for LCVs and the relevant Buses to calculate the emissions for HDVs. Moreover, for electricity powered vehicles we can use the average NH3 emitted per KWh in Europe and multiply it with consumption expressed as KWh/km. The average consumption was assumed as 0.31 KWh/Km.	database. The NH3 emissions were calculated by using the average emission factor of 1.72 mg Kg/KWh. **HDV - HDV < 14 t:** Emission factors for LPG and CNG fuel types were produced for HDVs (<14 t). The values of NH3 were based on relevant buses vehicles as provided by COPERT model. **HDV -** **14 t < HDV < 28 t:** No additional fuel types were illustrated in this category. **HDV -**

Factors	Missing Info	Main Findings	Comments
			28 t < HDV: No additional fuel types were illustrated in this category.
Wind	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:** Since the NH3 is related with NOx and the emission reduction technology, we can assume that they follow the same pattern. More specifically, for the estimation of the increase of NH3 as a result of the occupancy effect NOx relevant increase rates (presented in the relevant NOx table – Wind emission factor) should be used for both	**L-category:** Based on the assumptions made. The NH3 followed the same pattern with NOx (NOx increase rates as presented in the relevant NOx table) and according to euro category and emission reduction technology. **LCVs:** The same methodology with L-Category was followed. **HDV - HDV < 14 t:**

Factors	**Missing Info**	**Main Findings**	**Comments**
	14 t < HDV < 28 t: no information **HDV -** **28 t < HDV:** no information	HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	The same methodology with L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with L-Category was followed. **HDV -** **28 t < HDV:** The same methodology with L-Category was followed.
A/C	**L-category** no information **LCVs**	**L-category:** No information was found. **LCVs:** No information was found.	**L-category:** No values were produced for this category. **LCVs:**

Factors	Missing Info	Main Findings	Comments
	no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**HDV (All types):** No information was found. **Conclusions:** **L-Category:** Since, L-Category vehicles include motorcycles, ATVs and mini cars that usually do not have A/C systems we can assume that this factor is not applied for this vehicle types. Since the NH3 is related with NOx and the emission reduction technology, we can assume that they follow the same pattern. More specifically, for the estimation of the increase of NH3 as a result of the AC effect NOx relevant increase rates should be used for both HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	The A/C effect was calculated by using the percentage increase in NOx (as presented in NOx table) and multiplied with actual NH3 values for all LCVs types (including euro categories etc.). **HDV - HDV < 14 t:** The same methodology with LCV was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with LCV was followed. **HDV -** **28 t < HDV:**

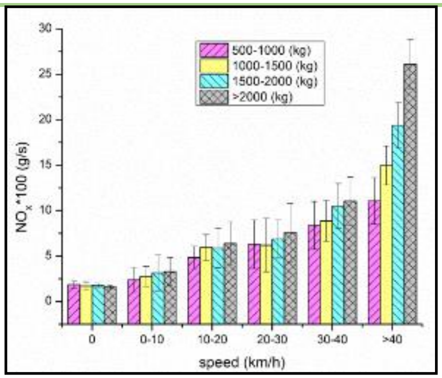
Factors	Missing Info	Main Findings	Comments
			The same methodology with LCV was followed.
Traffic	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:**	**L-category:** No information was found. **LCVs:** No specific information was found. **HDV (All types):** No specific information was found. **Conclusion:** Since the NH3 is related with NOx and the emission reduction technology, we can assume that they follow the same pattern. More specifically, for the estimation of the increase of NH3 as a result of the traffic effect, NOx relevant increase rates should be used for both HDVs and LCVs. The relative increase should take into consideration euro categories and emission reduction technologies.	**L-category:** The traffic effect was calculated by using the percentage increase in NOx (as presented in NOx table) and multiplied with actual NH3 values for all L-Category types (including euro categories etc.). **LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:**

Factors	Missing Info	Main Findings	Comments
	no information **HDV -** **28 t < HDV:** no information		The same methodology described for L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology described for L-Category was followed. **HDV -** **28 t < HDV:** The same methodology described for L-Category was followed.

4.3.2.7 NOx

Table 23: Emission Factors for NOx – Gap analysis results, findings and applied solutions (in GYR database)

Factors	Missing Info	Main Findings	Comments
Occupancy	**L-category** no information **LCVs** no information **HDV - HDV < 14 t:** COPERT provides data (3 classes) **HDV -**	**L-category:** No information was found. **LCVs:** No specific information was found for LCVs. **General results:** There are no articles for occupancy effect on LCVs and L-categories CO emissions. Yu et al (Qian Yu, 2016) measured NOx emissions on urban busses in four passenger load categories and found the results as presented in the following graph. The results show that the emission volumes are strongly related with speed.	**L-category:** No values were produced for this category. **LCVs:** The occupancy effect was calculated by using the percentage increase described in the vehicles included in the type: HDV>3.5 t of COPERT (closest category to LCVs). This increase in NOx emissions was applied to all LCVs based on the respective euro categories.

Factors	Missing Info	Main Findings	Comments
	14 t < HDV < 28 t: COPERT provides data (3 classes) **HDV -** **28 t < HDV:** COPERT provides data (3 classes)	 **Figure 19: "Emission rates for NOx and rates for different speeds and passenger load"(Qian Yu, 2016)** Furthermore, occupancy effect in NOx emissions of HDVs is presented in COPERT model. **Conclusion:** **L-Category:** Since, L-Category vehicles include motorcycles, ATVs and mini cars that usually do not have important storage capacity we can assume that they are not affected by load or additional load is not applied for those cases. **LCVs:** The information provided from the above article presents only actual fuel consumptions and focuses only on buses, thus it is considered not representative for LCVs.	

Factors	Missing Info	Main Findings	Comments
		In this context, the use of the same values based on HDV occupancy effect (expressed as rates) as described in COPERT is considered the most reliable solution for the estimation of LCVs occupancy effect on NOx emissions.	
Road Conditions	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:**	**L-category:** No specific information was found. **LCVs:** No specific information was found. **HDV (All types):** No specific information was found. **General Results:** In the article of Setyawan et al (Setyawan, 2015) the effect of road condition was examined using "PCI (Pavement Condition Index)" method and found that road conditions affect the speed of the vehicle and consequently the total amount of NO and other emissions. For excellent to very poor pavement conditions the results for are illustrated in the following table:	**L-category:** Extrapolation was performed by using the results presented in the table (see on the left cell) and based on 15 values. 0% NOx increase corresponds to the basic emissions of our database and refers to excellent road conditions. **LCVs:** The same methodology (described for L-Category) was followed. **HDV - HDV < 14 t:**

<table>
<tr><th>Factors</th><th>Missing Info</th><th>Main Findings</th><th>Comments</th></tr>
<tr>
<td></td>
<td>no information

HDV -

28 t < HDV:

no information</td>
<td>

Table 24: emissions values for NO (representing different road conditions) derived from (Setyawan, 2015) expressed as rates (%) compared with values in excellent road conditions.

<table>
<tr><th>PCI</th><th>NO Increase (%)</th></tr>
<tr><td>**19**</td><td>4.57</td></tr>
<tr><td>**34**</td><td>3.27</td></tr>
<tr><td>**43**</td><td>3.00</td></tr>
<tr><td>**59**</td><td>2.45</td></tr>
<tr><td>**79**</td><td>0.08</td></tr>
<tr><td>**100**</td><td>0.02</td></tr>
</table>

Conclusion:

Based on the above results and since we can assume that NO is the 90% of NOx (Patrik Soltic, 2003) then we assume that the increase of NO illustrated in the table is almost the same for NOx.

For the calculation and production of NOx values for this factor, we can perform an interpolation based on the above table and the defined classes (15 years) in our database. PCI transformation to year classes is performed based on qualitative characteristics described above and from the fact that road age expresses directly the road quality.

</td>
<td>The same methodology (described for L-Category) was followed.

HDV -

14 t < HDV < 28 t:

The same methodology (described for L-Category) was followed.

HDV -

28 t < HDV:

The same methodology (described for L-Category) was followed.</td>
</tr>
</table>

Factors	Missing Info	Main Findings	Comments
		Based on the above we can perform the following assumption in order to make the interpolation: • Initial emission value is related with the age of 0 year (completely new road); • PCI 100 equals to the basic emissions (Road age is 1 year); • PCI 19 equals to the fifteenth class (15th year).	
Road gradient	**L-category:** no information **LCVs** no information **HDV - HDV < 14 t:** COPERT provides data (13 classes - From -0.06	**L-category:** No specific information was found. **LCVs:** In the study of Zhang et al (Wendan Zhang, 2015) a literature review for the effect of road gradient in vehicular emissions was performed as presented in the table for FC/CO2 and the table for CO emission. This study also included effect in NOx emissions. As already described the result of this study results are not consisted, thus they are not suitable for usage in the database. **Conclusion:** As previously described, gradient affects directly the power needs of an engine and also affects directly the FC. Furthermore, NOx increases with the increase of power	**L-category:** The same methodology with LCVs was followed. **LCVs:** The Road gradient effect was calculated by using the percentage increase of NOx illustrated in the vehicles included in the type: HDV>3.5 t of COPERT. This increase was applied to all LCVs based on the respective euro categories.

Factors	Missing Info	Main Findings	Comments
	to 0.06 (per 0.02). **HDV -** **14 t < HDV < 28 t:** COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02). **HDV -** **28 t < HDV:** COPERT provides data (13 classes - From -0.06	need and acceleration of a vehicle (ICCT (The International Council on Clean Transportation)). Moreover, COPERT provides with road gradient effect for HDVs. In this context, values based on HDV occupancy effect (expressed as rates) as described in COPERT is considered a more reliable solution for LCVs occupancy estimation on NOx emissions.	

Factors	**Missing Info**	**Main Findings**	**Comments**
	to 0.06 (per 0.02).		
Type of Fuel	**L-category** Information for Diesel and Petrol. **LCVs** Information for Diesel and Petrol. **HDV - HDV < 14 t:** Information for Diesel and Petrol. **HDV -**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Electric Vehicles:** <u>Emissions from Electricity</u> Since all exclusive electric vehicles are charged using the grid, then the emissions (including CH4) produced from vehicles with this fuel type are defined by the emissions types and volumes produced in each country for the grids electricity production.	**L-category:** No additional fuel types were illustrated in this category. **LCVs:** Emission factors for LPG and CNG fuel types were produced for LCVs. The values of NOx were based on relevant Passenger car vehicles as provided by COPERT model. For electricity powered LCVs the average value of 0.310 KWh/km was used for all LCVs sub-types of the database. The CH4 emissions were

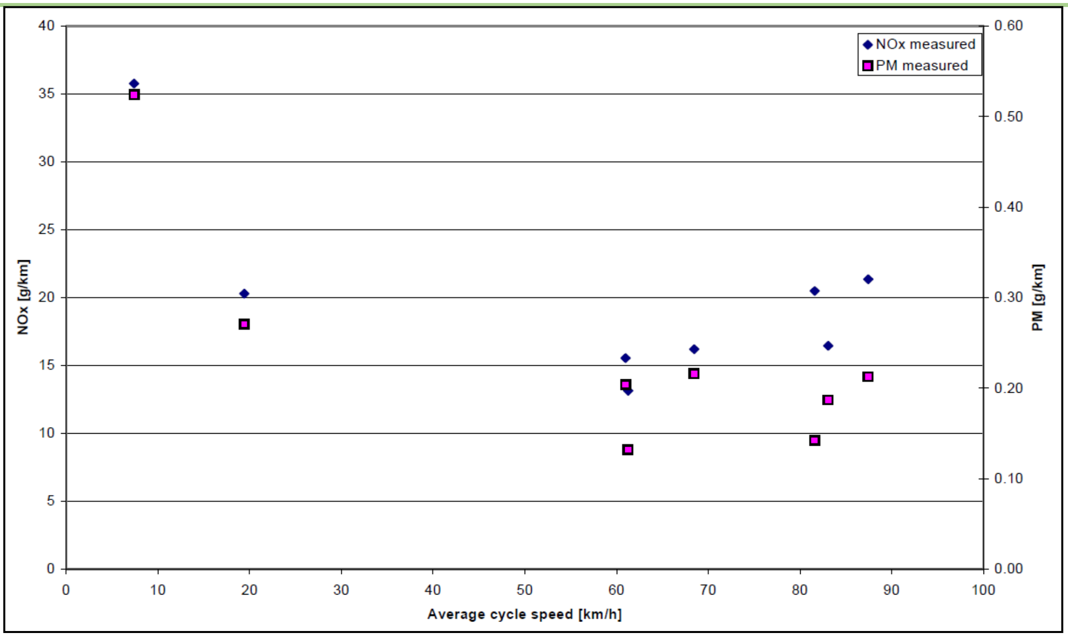
Factors	Missing Info	Main Findings	Comments
	14 t < HDV < 28 t: Information for Diesel and Petrol. **HDV -** **28 t < HDV:** Information for Diesel and Petrol.	In this framework the EU average NOx is 1.64 grams per KWh (ECOINVENT). **Conclusions:** **L-Category:** Since, L-Category vehicles include motorcycles, ATVs and mini cars that usually do not have alternative fuel types we can assume that the provision of values for relevant fuel types is not necessary. Since COPERT model provides with CNG and LPG NOx values for passenger cars and buses, then we can use the relevant passenger cars (the most similar with LCVs – i.e. Large-SUV) to calculate the emissions for LCVs and the relevant Buses to calculate the emissions for HDVs. Moreover, for **electricity powered** vehicles we can use the average NOx emitted per KWh in Europe and multiply it with consumption expressed as KWh/km. The average consumption was assumed as 0.31 KWh/Km.	calculated by using the average emission factor of **1.64 g/KWh**. **HDV - HDV < 14 t:** Emission factors for LPG and CNG fuel types were produced for HDVs (<14 t). The values of NOx were based on relevant buses vehicles as provided by COPERT model. **HDV -** **14 t < HDV < 28 t:** No additional fuel types were illustrated in this category. **HDV -** **28 t < HDV:** No additional fuel types were illustrated in this category.

Factors	**Missing Info**	**Main Findings**	**Comments**
Wind	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **General Results:** **Conclusions:** Wind affects directly the fuel consumption and the power needs of an engine. Furthermore, NOx increases with the increase of power need and acceleration of a vehicle (ICCT (The International Council on Clean Transportation)). Then we can assume that NOx follows the same pattern with FC. Since FC results are available for all 9 classes (wind from 40-80km/h to -40 - -80km/h) and as a percentage of FC increase, the same percentage could be used assuming that the more the fuel	**L-category:** The wind effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual NOx values for all L-category types (including euro categories etc.). **LCVs:** The same methodology with L-Category was followed. **HDV - HDV < 14 t:** The same methodology with L-Category was followed. **HDV -** **14 t < HDV < 28 t:**

Factors	Missing Info	Main Findings	Comments
	HDV - **28 t < HDV:** no information	consumed the more the NOx produced (linear correlation) and the opposite. This solution supports also the consistency of the database.	The same methodology with L-Category was followed. **HDV -** **28 t < HDV:** The same methodology with L-Category was followed.
A/C	**L-category** no information **LCVs** no information **HDV - HDV < 14 t**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:**	**L-category:** No values were produced for this category. **LCVs:** The A/C effect was calculated by using the percentage increase in FC (as presented in FC/CO2 table) and multiplied with actual NOx values for all LCVs types (including euro categories etc.).

Factors	Missing Info	Main Findings	Comments
	no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**L-Category:** Since, L-Category vehicles include motorcycles, ATVs and mini cars that usually do not have A/C systems we can assume that this factor is not applied for this vehicle types. A/C affects directly the fuel consumption and the power needed. Furthermore, NOx increases with the increase of power need and acceleration of a vehicle (ICCT (The International Council on Clean Transportation)). Then we can assume that NOx follows the same pattern with FC. Since FC results are available for all 135 AC classes and are expressed as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the NOx produced (linear correlation) and the opposite. This solution supports also the consistency of the database.	**HDV - HDV < 14 t:** The same methodology with LCV was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with LCV was followed. **HDV -** **28 t < HDV:** The same methodology with LCV was followed.
Traffic	**L-category** no information	**L-category:** No information was found.	**L-category:** The same methodology described for LCVs was followed.

Factors	Missing Info	Main Findings	Comments
	LCVs no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:**	**LCVs:** Results are presented along with HDVs. **HDV (All types):** In Zhang et al (2011) (Zhang Kai, 2011) study we have NOx and other emissions results related with congestion as presented in the Figure 10: "Summary of speed/acceleration profiles, emission factors and fuel consumption rates for LDV and HDV grouped by traffic condition.". As it is discussed in the table FC/CO2 the results of the study are not suitable for the database. Moreover based on COST 346 project (Martin Rexeis, 2005), the NOx and PM are affected from average speed as follows:	**LCVs:** The traffic effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual NOx values for all LCVs types (including euro categories etc.). An exception was made for the case of vehicles with SCR technology. In this case no effect of road conditions was taken into consideration (0% increase). **HDV - HDV < 14 t:** The same methodology described for LCVs was followed.

Factors	Missing Info	Main Findings	Comments
	no information	 **Figure 20: "NOx and PM -emissions measured for a EURO 2 HDV on the chassis dynamometer for different real-life driving cycles as a function of average cycle speed" (Martin Rexeis, 2005).** Since NOx are affected by Selective Catalytic Reduction (SCR) technologies COPERT model gives very different values for this emission (NOx) in all emission factors available.	**HDV -** **14 t < HDV < 28 t:** The same methodology described for LCVs was followed. **HDV -** **28 t < HDV:** The same methodology described for LCVs was followed.

Factors	Missing Info	Main Findings	Comments
		Conclusion: Based on the above, and since NOx could be considered that follows the same pattern with FC (see previous results) then we could multiply increase rates for different traffic conditions (as mentioned in the FC/CO2 table) with the actual and initial values of NOx. An exemption will be made in the cases of LCVs and HDVs using SCR technologies. In this case will present 0% increase.	

4.3.2.8 PM exhaust

Table 25: Emission Factors for PM exhaust – Gap analysis results, findings and applied solutions (in GYR database)

Factors	Missing Info	Main Findings	Comments
Occupancy	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusion:** **L-Category:** Since, L-Category vehicles include motorcycles, ATVs and mini cars that usually do not have important storage capacity we can assume that they are not affected by load or additional load is not applied for those cases. **LCVs:** The information provided from the above article presents only actual fuel consumptions and focuses only on buses, thus it is considered not representative for LCVs.	**L-category:** No values were produced for this category. **LCVs:** The occupancy effect was calculated by using the percentage increase described in the vehicles included in the type: HDV>3.5 t of COPERT (closest category to LCVs). This increase in PM emissions was applied to all LCVs based on the respective euro categories.

Factors	Missing Info	Main Findings	Comments
		In this context and as there is not available relevant literature; values based on HDV occupancy effect (expressed as rates) in PM emissions (as described in COPERT model) could be used to estimate LCVs occupancy effect on PM emissions.	
Road Conditions	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:**	**L-category:** No specific information was found. **LCVs:** No specific information was found for LCVs. **HDV (All types):** No specific information was found for LCVs. **General Results:** In the article Setyawan et al (Setyawan, 2015)**Error! Bookmark not defined.** the effect of road condition was examined using "PCI (Pavement Condition Index)" method and found that road conditions affect the speed of the vehicle and the total amount of PM and other emissions. For excellent to very poor pavement conditions the results for PM are illustrated in the following table:	**L-category:** Extrapolation was performed by using the results presented in the table (see on the left cell) and based on 15 values. 0% PM increase corresponds to the basic emissions of our database and refers to excellent road conditions. **LCVs:** The same methodology (described for L-Category) was followed. **HDV - HDV < 14 t:** The same methodology (described for L-Category) was followed.

<table>
<tr><th>Factors</th><th>Missing Info</th><th>Main Findings</th><th>Comments</th></tr>
<tr>
<td></td>
<td>no information</td>
<td>

Table 26: PM emissions values (representing different road conditions) derived from (Setyawan, 2015) expressed as rates (%) compared with values in excellent road conditions.

<table>
<tr><th>PCI</th><th>PM Increase (%)</th></tr>
<tr><td>19</td><td>2.48</td></tr>
<tr><td>34</td><td>1.23</td></tr>
<tr><td>43</td><td>0.95</td></tr>
<tr><td>59</td><td>0.52</td></tr>
<tr><td>79</td><td>0.13</td></tr>
<tr><td>100</td><td>0.02</td></tr>
</table>

Conclusion:

For the calculation and production of PM values for this factor we can perform an interpolation based on the above table and the defined classes (15 years) in our database. PCI transformation to year classes is performed based on qualitative characteristics described above and from the fact that road age expresses directly the road quality.

Based on the above we can perform the following assumption in order to make the interpolation:

- Initial emission value is related with the age of 0 year (completely new road)

</td>
<td>

HDV -

14 t < HDV < 28 t:

The same methodology (described for L-Category) was followed.

HDV -

28 t < HDV:

The same methodology (described for L-Category) was followed.

</td>
</tr>
</table>

Factors	Missing Info	Main Findings	Comments
		• PCI 100 equals to the basic emissions (Road age is 1 year) • PCI 19 equals to the fifteenth class (15th year)	
Road gradient	**L-category:** no information **LCVs** no information **HDV - HDV < 14 t:** COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02). **HDV -** **14 t < HDV < 28 t:** COPERT provides data (13 classes -	**L-category:** No information was found. **LCVs:** No information was found. **Conclusion:** There is not available information on literature. COPERT provides with road gradient effect for HDVs. In this context, values based on HDV occupancy effect (expressed as rates) as described in COPERT could be applied for LCVs occupancy estimation on PM emissions.	**L-category:** The same methodology with LCVs was followed. **LCVs:** The Road gradient effect was calculated by using the percentage increase of PM illustrated in the vehicles included in the type: HDV>3.5 t of COPERT. This increase was applied to all LCVs based on the respective euro categories.

Factors	Missing Info	Main Findings	Comments
	From -0.06 to 0.06 (per 0.02). **HDV -** **28 t < HDV:** COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02).		
Type of Fuel	**L-category** Information for Diesel and Petrol. **LCVs** Information for Diesel and Petrol. **HDV - HDV < 14 t:** Information for Diesel and Petrol	**L-category:** No information was found. **LCVs:** No information was found. **HDVs:** PM exhaust emissions for HDV vehicles with engines that use natural gas (NG) are presented in the article of Stettler et al (Marc Stettler, 2019)**Error! Bookmark not defined.**. The article presents the following PM exhaust emissions as illustrated in Figure 14: "Summary of other	**L-category:** No additional fuel types were illustrated in this category. **LCVs:** Emission factors for LPG and CNG fuel types were produced for LCVs. The values of PM were based on relevant Passenger car vehicles as provided by COPERT model.

Factors	Missing Info	Main Findings	Comments
	HDV - **14 t < HDV < 28 t:** Information for Diesel and Petrol. **HDV -** **28 t < HDV:** Information for Diesel and Petrol.	air pollutant emissions produced by different types of diesel and natural gas heavy goods vehicles.”. Since standard deviation of PM is almost as high as the average the results of illustrated on the table could not be considered representative. This idea is supported also by the fact that the article refers to specific type of HDVs that have specific type of engines. **Electric Vehicles:** <u>Emissions from Electricity</u> Since all exclusive electric vehicles are charged using the grid, then the emissions (including CH4) produced from vehicles with this fuel type are defined by the emissions types and volumes produced in each country for the grids electricity production. In this framework the EU average PM is the following (ECOINVENT): • Particulates, < 2.5 um: 238.52 mg/KWh • Particulates, > 10 um: 672.81 mg/KWh • Particulates, > 2.5 um, and < 10um: 35.38 mg/KWh The total PM produced (all categories) is **<u>946.72 mg per KWh</u>**. **Conclusion:**	For electricity powered LCVs the average value of **0.310 KWh/km** was used for all LCVs sub-types of the database. The PM emissions were calculated by using the average emission factor of **946.72 mg/KWh**. **HDV - HDV < 14 t:** Emission factors for LPG and CNG fuel types were produced for HDVs (<14 t). The values of PM were based on relevant buses vehicles as provided by COPERT model. **HDV -** **14 t < HDV < 28 t:** No additional fuel types were illustrated in this category. **HDV -** **28 t < HDV:**

Factors	Missing Info	Main Findings	Comments
		L-Category: Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have alternative fuel types we can **assume** that the provision of values for relevant fuel types is not necessary. Since **COPERT model provides with CNG and LPG PM values** for passenger cars and buses, then we can use the relevant passenger cars (the most similar with LCVs – i.e. Large-SUV) to calculate the emissions for LCVs and the relevant Buses to calculate the emissions for HDVs. Moreover, **for electricity powered vehicles** we can use the average PM emitted per KWh in Europe and multiply it with consumption expressed as KWh/km. The average consumption was assumed as **0.31 KWh/Km.**	No additional fuel types were illustrated in this category.
Wind	**L-category** no information **LCVs** no information **HDV - HDV < 14 t**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):**	**L-category:** The wind effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual PM values for all L-category types (including euro categories etc.).

Factors	Missing Info	Main Findings	Comments
	no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	No information was found. **Conclusions:** Since wind affects directly the fuel consumption and since PM is a product of non complete combustion (Mohsin Raza, 2018), then we can assume that PM follows the same pattern with FC. Since FC results are available for all 9 classes (wind from 40-80km/h to -40- -80km/h) and as a percentage of FC increase, the same percentage could be applied assuming that the more the fuel consumed the more the PM produced (linear correlation) and the opposite. This solution supports also the consistency of the database.	**LCVs:** The same methodology with L-Category was followed. **HDV - HDV < 14 t:** The same methodology with L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with L-Category was followed. **HDV -** **28 t < HDV:** The same methodology with L-Category was followed.
A/C	**L-category**	**L-category:**	**L-category:**

Factors	Missing Info	Main Findings	Comments
	no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have A/C systems we can **assume** that this factor **is not applied** for this vehicle types. Since A/C affects directly the fuel consumption and since the PM is a product of non complete combustion (Mohsin Raza, 2018), then we can assume that PM follows the same pattern with FC. Since FC results are available for all 135 AC classes and are expressed as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the PM produced (linear correlation) and the opposite. This solution supports also the consistency of the database.	No values were produced for this category. **LCVs:** The A/C effect was calculated by using the percentage increase in FC (as presented in FC/CO2 table) and multiplied with actual PM values for all LCVs types (including euro categories etc.). **HDV - HDV < 14 t:** The same methodology with LCV was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with LCV was followed.

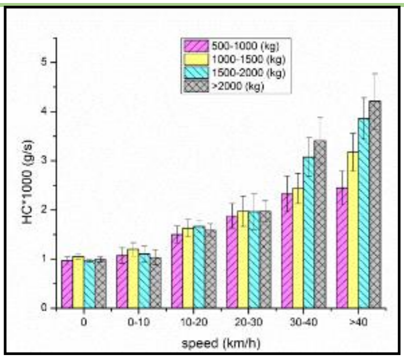
Factors	Missing Info	Main Findings	Comments
			HDV - **28 t < HDV:** The same methodology with LCV was followed.
Traffic	**L-category** no information **LCVs** no information **HDV - HDV < 14 t** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -**	**L-category:** No information was found. **LCVs:** No specific information was found. **HDV (All types):** No specific information was found. **Conclusion:** As it described in the table for NOx, since PM could be considered that follows the same pattern with FC (see previous results), then we could multiply increase rates for different traffic conditions with the actual-initial values of PM.	**L-category:** The traffic effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual NOx values for all L-category types (including euro categories etc.). **LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:** The same methodology described for L-Category was followed.

Factors	Missing Info	Main Findings	Comments
	28 t < HDV: no information		**HDV -** **14 t < HDV < 28 t:** The same methodology described for L-Category was followed. **HDV -** **28 t < HDV:** The same methodology described for L-Category was followed.

4.3.2.9 VOC

Table 27: Emission Factors for VOC – Gap analysis results, findings and applied solutions (in GYR database)

Factors	Missing Info	Main Findings	Comments
Occupancy	**L-category** no information **LCVs** no information **HDV - HDV < 14 t:** COPERT provides data (3 classes). **HDV -** **14 t < HDV < 28 t:** COPERT provides data (3 classes). **HDV -**	**L-category:** No information was found. **LCVs:** No specific information was found. **General:** There are no articles for occupancy effect on all types of vehicles for VOC emissions. Nevertheless Yu et al (Qian Yu, 2016) measured HC emissions on urban busses in four passenger load categories and found the results as presented in the following graph. The results show that the emission volumes are strongly related with speed.	**L-category:** No values were produced for this category. **LCVs:** The occupancy effect was calculated by using the percentage increase described in the vehicles included in the type: HDV>3.5 t of COPERT (closest category to LCVs). This increase in VOC emissions was applied to all LCVs based on the respective euro categories.

Factors	Missing Info	Main Findings	Comments
	28 t < HDV: COPERT provides data (3 classes).	 **Figure 21: "Emission rates for HC and rates for different speeds and passenger load" (Qian Yu, 2016)** Furthermore, the occupancy effect in VOC emissions of HDVs is presented in COPERT model. **Conclusion:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have important storage capacity we can **assume** that they are **not affected by load or additional load is not applied for those cases.** **LCVs:** The information provided from the above article presents only actual fuel consumptions and focuses only on buses, thus it is considered not representative for LCVs.	

Factors	Missing Info	Main Findings	Comments
		In this context and as there is not available relevant literature, values based on HDV occupancy effect (expressed as rates) in VOC emissions (as described in COPERT model) could be used to estimate LCVs occupancy effect on VOC emissions.	
Road Conditions	**L-category** no information **LCVs** no information **HDV - HDV < 14 t:** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:** Since Road conditions affects directly the fuel consumption and since the VOC is a product of non complete combustion (Mohsin Raza, 2018), then we can assume that VOC follows the same pattern with FC. Since FC results are available for all 15 classes and as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the VOC produced (linear correlation). This solution supports also the consistency of the database.	**L-category:** The road conditions effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual VOC values for all L-category types (including euro categories etc.). **LCVs:** The same methodology with L-Category was followed. **HDV - HDV < 14 t:** The same methodology with L-Category was followed.

Factors	Missing Info	Main Findings	Comments
	no information		**HDV -** **14 t < HDV < 28 t:** The same methodology with L-Category was followed. **HDV -** **28 t < HDV:** The same methodology with L-Category was followed.
Road gradient	**L-category:** no information **LCVs** no information **HDV - HDV < 14 t:** COPERT provides data (13 classes -	**L-category:** No information was found. **LCVs:** No information was found. **General Results:** Zhang et al (Wendan Zhang, 2015) have performed a case study for the road gradient effect on HDV vehicles emissions including HC.	**L-category:** The same methodology with LCVs was followed. **LCVs:** The Road gradient effect was calculated by using the percentage increase of VOC illustrated in the vehicles included in the type: HDV>3.5 t of COPERT. This increase was applied to all LCVs

Factors	Missing Info	Main Findings	Comments
	From -0.06 to 0.06 (per 0.02). **HDV -** **14 t < HDV < 28 t:** COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02). **HDV -** **28 t < HDV:** COPERT provides data (13 classes - From -0.06 to 0.06 (per 0.02).	As justified in the CO/FC table results could not be considered reliable in order to be used in this database. **Conclusion:** The available information from literature is not reliable. COPERT provides with road gradient effect on VOC for HDVs. In this context, values based on HDV occupancy effect (expressed as rates) as described in COPERT could be applied directly for LCVs occupancy estimation on VOC emissions.	based on the respective euro categories.
Type of Fuel	**L-category**	**L-category:** No information was found.	**L-category:**

Factors	Missing Info	Main Findings	Comments
	Information for Diesel and Petrol. **LCVs** Information for Diesel and Petrol. **HDV - HDV < 14 t:** Information for Diesel and Petrol. **HDV -** **14 t < HDV < 28 t:** Information for Diesel and Petrol. **HDV -** **28 t < HDV:**	**LCVs:** No information was found. **HDV (All types):** No information was found. **Electric Vehicles:** Emissions from Electricity Since all exclusive electric vehicles are charged using the grid, then the emissions (including CH4) produced from vehicles with this fuel type are defined by the emissions types and volumes produced in each country for the grids electricity production. In this framework the EU **average VOC (Non- Methane) is 60.08 mg per KWh** (ECOINVENT). **Conclusion:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have alternative fuel types we can **assume** that the provision of values for relevant fuel types is not necessary.	No additional fuel types were illustrated in this category. **LCVs:** Emission factors for LPG and CNG fuel types were produced for LCVs. The values of VOC were based on relevant Passenger car vehicles as provided by COPERT model. For electricity powered LCVs the average value of **0.310 KWh/km** was used for all LCVs sub-types of the database. The CH4 emissions were calculated by multiplying the value for LCVs with the average emission factor of **60.08 mg/KWh.** **HDV - HDV < 14 t:** Emission factors for LPG and CNG fuel types were produced for HDVs (<14 t). The values of VOC were

Factors	Missing Info	Main Findings	Comments
	Information for Diesel and Petrol.	Since **COPERT model provides with CNG and LPG VOC values** for passenger cars and buses, then we can use the relevant passenger cars (the most similar with LCVs – i.e. Large-SUV) to calculate the emissions for LCVs and the relevant Buses to calculate the emissions for HDVs. Moreover, **for electricity powered vehicles** we can use the average CH4 emitted per KWh in Europe and multiply it with consumption expressed as KWh/km. The average consumption was assumed as **0.31 KWh/Km.**	based on relevant buses vehicles as provided by COPERT model. **HDV -** **14 t < HDV < 28 t:** No additional fuel types were illustrated in this category. **HDV -** **28 t < HDV:** No additional fuel types were illustrated in this category.
Wind	**L-category** no information **LCVs** no information **HDV - HDV < 14 t :**	**L-category:** No information was found. **LCVs:** No information was found. **HDV (All types):**	**L-category:** The wind effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual VOC values for all L-category types (including euro categories etc.).

Factors	Missing Info	Main Findings	Comments
	no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	No information was found. **Conclusions:** Since wind affects directly the fuel consumption and since VOC is a product of non complete combustion (Mohsin Raza, 2018), then we can assume that PM follows the same pattern with FC. Since FC results are available for all 9 classes (wind from 40-80km/h to -40- -80km/h) and as a percentage of FC increase, the same percentage could be applied assuming that the more the fuel consumed the more the VOC produced (linear correlation) and the opposite. This solution supports also the consistency of the database.	**LCVs:** The same methodology with L-Category was followed. **HDV - HDV < 14 t:** The same methodology with L-Category was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with L-Category was followed. **HDV -** **28 t < HDV:** The same methodology with L-Category was followed.
A/C	**L-category** no information	**L-category:** No information was found.	**L-category:**

Factors	Missing Info	Main Findings	Comments
	LCVs no information **HDV - HDV < 14 t:** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -** **28 t < HDV:** no information	**LCVs:** No information was found. **HDV (All types):** No information was found. **Conclusions:** **L-Category:** Since, **L-Category** vehicles include motorcycles, ATVs and mini cars that usually do not have A/C systems we can **assume** that this factor **is not applied** for this vehicle types. Since A/C affects directly the fuel consumption and since the VOC is a product of non complete combustion (Mohsin Raza, 2018), then we can assume that VOC follows the same pattern with FC. Since FC results are available for all 135 AC classes and are expressed as a percentage of FC increase, the same percentage could be used assuming that the more the fuel consumed the more the VOC produced (linear correlation) and the opposite. This solution supports also the consistency of the database.	No values were produced for this category. **LCVs:** The A/C effect was calculated by using the percentage increase in FC (as presented in FC/CO2 table) and multiplied with actual VOC values for all LCVs types (including euro categories etc.). **HDV - HDV < 14 t:** The same methodology with LCV was followed. **HDV -** **14 t < HDV < 28 t:** The same methodology with LCV was followed.

Factors	Missing Info	Main Findings	Comments
			HDV - **28 t < HDV:** The same methodology with LCV was followed.
Traffic	**L-category** no information **LCVs** no information **HDV - HDV < 14 t:** no information **HDV -** **14 t < HDV < 28 t:** no information **HDV -**	**L-category:** No information was found. **LCVs:** Results are presented along with HDVs. **HDV (All types):** In Zhang et al (Zhang Kai, 2011) study we have the HC and other emissions results related with congestion as presented in Figure 10: "Summary of speed/acceleration profiles, emission factors and fuel consumption rates for LDV and HDV grouped by traffic condition.". **Conclusions:** Since VOC could be considered that follows the same pattern with FC (see previous results), then we could multiply increase rates for different traffic conditions with the actual-initial values of VOC.	**L-category:** The traffic effect was calculated by using the percentage increase in FC (calculated as presented in the FC/CO2 table) and multiplied with actual VOC values for all L-category types (including euro categories etc.). **LCVs:** The same methodology described for L-Category was followed. **HDV - HDV < 14 t:** The same methodology described for L-Category was followed.

Factors	Missing Info	Main Findings	Comments
	28 t < HDV: no information		**HDV -** **14 t < HDV < 28 t:** The same methodology described for L-Category was followed. **HDV -** **28 t < HDV:** The same methodology described for L-Category was followed.

4.3.2.10 SO2

General (for all vehicle categories):

The SO2 emitted is estimated by making the assumption that 100% of S (Sulphur) that is diluted in the fuel is converted into SO2.

So, the SO2 is calculated by using FC (Fuel consumption) and fuel concentration in Sulfur. For the estimation of SO2 by taking into consideration all other correction factors, the FC results will be also used along with the transformation function.

The transformation function from FC to SO2 is the following:

$$E_{SO2} = 2 \times K_S \times FC \times dF \qquad \text{Eq. 5}$$

Where,

E_{SO2}: SO2 emissions per year [kg/year]

K_s: Weight related sulphur content in fuel [kg/kg fuel].

FC: Total annual consumption of fuel [lt/year]

dF: Density of Fuel consumed [kg/lt]

By introducing sulphur content from fuel specification the equation is transformed as follows:

$$E_{SO2} = 2 \times 5 \times 10^{-5} \times FC \ \times dF \ \rightarrow$$

$$\boldsymbol{E_{SO2} = a \times 10^{-5} \times FC} \qquad \text{Eq. 6}$$

Where,

a: constant (~7.37 for gasoline and ~8.35 for diesel).

FC: Total annual consumption of fuel [lt/year]

Based on the above results the sulfur content should be estimated for all fuel types in order to estimate the final SO2 emissions with the usage of the above equation.

Diesel

The sulfur content limit in EU diesel is 10mg/kg of fuel (TranpsportPolicy.net).

For the purposes of our database the **sulfur content of diesel** will be estimated as **10mg/kg** of fuel.

Petrol

The sulfur content limit in EU petrol is 10mg/kg of fuel (TranpsportPolicy.net).

For the purposes of our database the **sulfur content of Petrol** will be estimated as **10mg/kg** of fuel.

CNG Vehicles:

The sulfur content of CNG fuel from a study of (Kado NY, 2005) was around 2 ppmv.

For the purposes of our database the **sulfur content of CNG** will be estimated as **2 mg/kg** of fuel.

LPG Vehicles:

The Sulfur content in LPG fuel is between **0.18 to 0.27 mg /kg** (Ruissen)**.**

For the purposes of our database the **sulfur content of CNG** will be estimated as **0.2 mg/kg** of fuel.

Electric Vehicles:

Since all exclusive electric vehicles are charged using the grid, then the emissions (including SO2) produced from vehicles with this fuel type are defined by the emissions types and volumes produced in each country for the grids electricity production. Furthermore, electricity was estimated only for LCV vehicles.

In this framework the EU average SO2 is **3.67 grams per KWh** (ECOINVENT). The average consumption for electric LCVs was assumed as **0.31 KWh/Km.**

Conclusions:

Based on the above justifications, SO2 emissions were calculated based on results presented in the table for FC/CO2 and the results derived from the above equations. The sulfur content for each fuel type was used in the equation as described above (estimations of average sulfur content for each fuel type).

Moreover, for the case of electric LCVs (special case) the average energy consumption (0.31 KWh/Km) was multiplied with the average SO2 derived from the grid power production (3.67 g/KWh).

4.3.3 Factors Classes

As explained above one of the main goals of GYR model was to update factors types in order to be more detailed and to reflect recent scientific literature results.

In this context the following table illustrates the emission factors classes as well as a relative description responding to why and how these classes where produced.

Table 28: GYR database emission factors and respective Classes

Emission Factors	Classes	Rationale
Occupancy	10 occupancy Classes representing loads from 0% to 100% (. Each Class represents a step of 10%.	When a vehicle is completely empty then it is considered that has the value of 0% and when a vehicle is loaded in the total of its capacity then it is considered that occupancy has a value of 100%.
Road Conditions	15 IDs. Each ID represents a road age from 1 to 15 years.	Road conditions refer to the quality of road tarmac. Based on literature (see relevant chapter) the main parameter affecting road condition is the number of years before the construction of the road (road age).
Road gradient	-6% to 6% with a step of 1%	This classification is considered detailed and it covers all road gradient cases (including the initial emissions for class with 0% gradient).
Type of Fuel	Petrol, Diesel, CNG, LPG and Electricity	CNG and LPG fueled vehicles for LCVs and lighter class of HDVs (HDV < 14 t) added in order to illustrate modern fleets. Electricity powered LCVs were added since they are recently market available solutions for commercial purposes.
Wind	9 wind classes from the range of -80 - -40 km/h to 40 – 80 km/h.	The wind range from -5 to 5 km/h illustrates the no wind effect (initial emissions – not affected by the wind). This classification is considered representative of the wind effect in vehicular emissions.
A/C	135 IDs related with the relevant a) HI and b) Traffic mode	Traffic mode and heat index are directly affecting A/C power consumption in each vehicle and consequently power consumption affects emissions release.

Emission Factors	Classes	Rationale
		Based on that this emission factor was formed as a combination of the above parameters.
Traffic	Three classes including a) No-Low Traffic, b) Medium Traffic and c) Heavy Traffic	Traffic classes are considered representative of the relevant effect since low speeds, stops and acceleration/deceleration affect consumption and consequently emissions.
Vehicle Types	L-Category, Light Commercial Vehicles, HDV < 14 t, 14 t < HDV < 28 t, 28 t < HDV	Each vehicle type consists of sub-types as described in the below rows. Each of these classes include also other aspects (vehicle subcategories) such as vehicles with specific EURO categories and with applied emission reduction technologies

5 Environmental impact of LIFE GYR project

5.1 Introduction

After the test and the evaluation of GYR platform by the demonstrators of LIFE GYR project, GYR Team started the real life demonstration of GYR platform into the operational business environment of the 5 demonstrators. The real life demonstration lasted for 17 months and it started on December 1st, 2021 and it ended on April 30th, 2023. In addition, the GYR platform was demonstrated also in the operational business environment of 3 new companies which agreed to use the GYR service for a period of 7 months free and based on the results of this period to decide to purchase or not the service after the end of the project.

5.2 Impact of the project

The environmental impact of the LIFE GYR project corresponds to the environmental benefices resulted by the use of GYR service. The GYR service is used during the real life demonstration period of 17 months. The obtained routing plans are compared using the simulation tool developed in Action C3 which simulated the corresponding routing plans if GYR service is not used and instead the heuristic approach based on the experience of the managers of the companies is used.

5.2.1 Impact - ATHINAKI, PLUS KOUKOUZELIS

The three Greek Demonstrators (ATHINAIKI, KOUKOUZELI and PLUS), after suggestion of UTH, have strategically decided that a synergy among them would not only acquire socio-economic benefits for them as companies but also significant environmental benefits, on which they and their customers strongly believe in. Moreover, the development of the GYR platform assisted towards the goal of the synergy since it is used by all three Demonstrators and it is a common tool that all three use in their procedures of routing.

ATHINAIKI, KOUKOUZELI and PLUS deal with the delivery and pickup of different products in Attica region by using a limited fleet of vehicles. The customers are scattered in the Attica region in different locations. The products are measured by using different types of packing (e.g., pallets, boxes, etc.) depending on the product that must be delivered or picked up. The delivery and pickup needs to be accomplished within one daily driving shift and some locations can or cannot be reached at certain hours of the day. The VRP of ATHINAKI, PLUS, KOUKOUZELIS is categorized as an Heterogeneous Capacitated Closed VRP with Time windows and Simultaneous Pick up-Delivery.

The impact of the Greek demonstrators is presented in the following table:

Table 29: Impact of ATHINAKI, PLUS KOUKOUZELIS

353 daily plans, Dec21-April23 (Actual and Simulation Estimated)				
	Actual	Simulation Estimated	Difference (Absolute)	Difference (%)
General indexes				
Kilometers	473,041.66	590,201.63	-117,159.97	-19.85%
Routes	3,530	3,883	353	-9.09%
Fuel consumed and Emissions emitted				
FC (Tones)	137.024	276.012	-138.988	-50.36%
CO2 (Tones)	434.229	874.682	-440.453	-50.36%
CH4 (Kilograms)	21.779	41.644	-19.865	-47.70%
CO (Kilograms)	978.502	1,908.724	-930.221	-48.74%
N2O (Kilograms)	10.075	20.439	-10.365	-50.71%
NH3 (Kilograms)	4.029	8.121	-4.092	-50.39%
NOx (Tones)	4.331	8.546	-4.216	-49.33%
PM (Kilograms)	71.875	139.427	-67.551	-48.45%
VOC (Kilograms)	201.259	387.445	-186.186	-48.05%
SO2 (Kilograms)	8.907	17.941	-9.034	-50.36%
			Average	-49.44%

The total kilometer travelled by the Greek demonstrators during the real life demonstration using GYR service were 473,041km and using the simulation tool they were 590,201km. The total kilometer saved using GYR service were equal to 117,159km, which correspond to a decrease of 19.85%. In addition to the total kilometer travelled the total number of route implemented were also decreased by 9.09%, resulting a reduced number of truck used, a reduced operational cost and a reduced maintenance cost (see deliverable of Action C2).

The emissions emitted were decreased by a minimum of 47.7% (i.e. CH4) to a maximum of 50.39% (i.e. NH3). The average decrease of emission emitted were 49.44%.

5.2.2 Impact – CEDA's customer

CEDA searched among its customers in order to find a demonstrator that suits the requirements of the LIFE GYR project and selected DS Logistic s.r.o. DS Logistic s.r.o. is a strong company that focuses on transport and forwarding, earthworks, construction work, vehicle servicing, and fuel sales. They offer both complete supplies of crushed aggregate, washed and kicked sands (material including transportation) as well as their own transportation. DS Logistic s.r.o. Company deals with the pickup and delivery of different types of products such as rocks, sands etc. The products are handled unpacked. The routing plan is composed throughout the day according to the demand of customers. The deliveries are realized as a transportation of a whole load from loading destination to unloading destination without partial deliveries along the route. In order to serve a consecutive order, a driver has to drive from an unloading destination to following loading destination. All the deliveries and pickups need to be accomplished within the working horary of the vehicles and by taking into consideration the time limitation of the customers and visiting locations. The optimization goal for DS Logistic s.r.o. Company accomplished by assigning the deliveries and pickups to the vehicles in the most convenient order. The vehicles start either from the home depot Strednice or from other specified location (usually place of unload from previous day) and, unlike the previously mentioned Demonstrators, it is not always necessary to return to the Depot after the completion of the day. The VRP of DS Logistic s.r.o. Company is categorized as a Heterogeneous Capacitated Open VRP with Time windows with two points of visits per route, the first for the pick-up of a bulk freight and the second for the delivery of the picked-up freight.

The impact of DS Logistic s.r.o. is presented in the following table:

Table 30: Impact of DS Logistic s.r.o.

356 daily plans, Dec21-April23 (Actual and Simulation Estimated)				
	Actual	Simulation Estimated	Difference (Absolute)	Difference (%)
General indexes				
Kilometers	1,723,205.88	1,958,387.77	-235,181.89	-12.01%
Routes	3,945	3,945	0	0.00%
Fuel consumed and Emissions emitted				
FC (Tones)	728.597	1,495.320	-766.723	-51.27%
CO2 (Tones)	2,308.924	4,738.669	-2,429.745	-51.27%
CH4 (Kilograms)	13.738	28.197	-14.459	-51.28%
CO (Kilograms)	3,338.832	6,959.486	-3,620.654	-52.02%
N2O (Kilograms)	31.365	64.374	-33.010	-51.28%
NH3 (Kilograms)	7.776	15.961	-8.184	-51.28%
NOx (Tones)	13.980	29.139	-15.160	-52.02%
PM (Kilograms)	99.398	207.234	-107.836	-52.04%
VOC (Kilograms)	133.604	273.401	-139.797	-51.13%
SO2 (Kilograms)	47.359	97.196	-49.837	-51.27%
			Average	-51.49%

The total kilometer travelled by the customer of CEDA during the real life demonstration using GYR service were 1,723,205km and using the simulation tool they were 1,958,387km. The total kilometer saved using GYR service were equal to 235,181km, which correspond to a decrease of 12.01%. The reduced kilometer travelled resulted a reduced number of truck used, a reduced maintenance cost and a reduced operational cost (see deliverable of Action C2). The number of routes implemented were the same in both scenarios (i.e. simulation and actual) as each route is consisted by a pair of visiting points (i.e. first point for pick-up and second point for delivery of the picked-up freight) and the visiting points are the same in both scenarios.

The emissions emitted were decreased by almost the same percentage with an average decrease of 51.49%.

5.2.3 Impact – ITACA's customer

ITACA proposed as a Demonstrator a courier company, namely GLS Company. It's a GLS (Courier Company) official licensee for Cosenza, operating in long route deliveries and also in urban ones. GLS Italy deals with the delivery and pickup of different products all over Italy. GLS Company focuses on the deliveries and pickups around Cosenza, Rende and Castrobilero by a limited fleet of vehicles. The customers are scattered in these regions in different locations. The delivery and pickup needs to be accomplished within the working time of the vehicles. The vehicles start from the depot and drivers know before they start which customers need to visit and the order of visiting the customers is decided based on their locations and their experience on driving at a specific region. The VRP of GLS Company is categorized as a homogeneous VRP with limited Time windows with pick-up and delivery.

The impact of the ITACA's customer which demonstrated the GYF service is presented in the following table:

Table 31: Impact of GLS Company

300 daily plans, Dec21-April23 (Actual and Simulation Estimated)				
	Actual	Simulation Estimated	Difference (Absolute)	Difference (%)
General indexes				
Kilometers	159,290.94	207,552.54	-48,262.00	-23.25%
Routes	3,746	3,746	0	0.00%
Fuel consumed and Emissions emitted				
FC (Tones)	32.653	65.224	-32.570	-49.94%
CO2 (Tones)	103.478	206.694	-103.215	-49.94%
CH4 (Kilograms)	33.775	67.463	-33.689	-49.94%
CO (Kilograms)	9,533.685	19,043.177	-9,509.492	-49.94%
N2O (Kilograms)	7.735	15.450	-7.715	-49.94%
NH3 (Kilograms)	0.748	1.493	-0.746	-49.94%
NOx (Tones)	0.596	1.191	-0.595	-49.94%
PM (Kilograms)	0.830	1.658	-0.828	-49.94%
VOC (Kilograms)	840.538	1,678.943	-838.405	-49.94%
SO2 (Kilograms)	2.122	4.240	-2.117	-49.94%
			Average	-49.94%

The total kilometer travelled during the real life demonstration using GYR service were 159,290km and using the simulation tool they were 207,552km. The total kilometer saved using GYR service were equal to 48,262km, which correspond to a decrease of 23.55%. The total number of route were not change as the company strategic decision is to use every day the entire available fleet of vehicles in order to decrease the workload of each driver and at the same time deliver the fright the soonest possible.

The emissions emitted were decreased by 49.94%. The decrease is the same for all the emission types for 2 reasons: 1) the vehicle fleet is homogenous, and 2) the traffic conditions were the same as the vehicles were circulating at the same limited urban region.

5.2.4 Impact - DIGICOM

The first new customer of GYR company is Digicom Systems S.A. which is an innovative Business software development company focusing on logistics applications as well as custom S/W solutions and integrations. Digicom Systems S.A. provides consulting services for S/W Analysis and Design, Business Intelligence Reporting and Performance Tuning upon specific RDBMS Systems and lastly routing planning services.

The impact of Digicom Systems S.A. is presented in the following table:

Table 32: Impact of DIGICOM

104 daily plans, Oct22-April23 (Actual and Simulation Estimated)				
	Actual	Simulation Estimated	Difference (Absolute)	Difference (%)
General indexes				
Kilometers	906,930.92	1,162,117.53	-255,186.61	-21.96%
Routes	6,768	7,646	-878	-11.48%
Fuel consumed and Emissions emitted				
FC (Tones)	263.561	545.240	-281.678	-51.66%
CO2 (Tones)	828.510	1,713.971	-885.461	-51.66%
CH4 (Kilograms)	41.707	81.903	-40.195	-49.08%
CO (Kilograms)	1,871.444	3,749.151	-1,877.707	-50.08%
N2O (Kilograms)	19.359	40.337	-20.978	-52.01%
NH3 (Kilograms)	7.784	16.113	-8.329	-51.69%
NOx (Tones)	8.318	16.858	-8.541	-50.66%
PM (Kilograms)	137.627	274.186	-136.558	-49.81%
VOC (Kilograms)	387.920	766.959	-379.039	-49.42%
SO2 (Kilograms)	16.893	34.947	-18.054	-51.66%
			Average	-50.77%

The total kilometer travelled during the real life demonstration using GYR service by the customers of Digicom Systems S.A. were 906,930km and using the simulation tool they were 1,162,117km. The total kilometer saved using GYR service were equal to 255,186km, which correspond to a decrease of 21.96%. In additional to the total kilometer travelled the total number of route implemented were also decreased by 11.48%, resulting a reduced number of truck used, a reduced maintenance cost and a reduced operational cost (see deliverable of Action C2).

The emission emitted were decreased by a minimum of 49.08% (i.e. CH4) to a maximum of 51.69% (i.e. NH3). The average decrease of emission emitted were 50.77%.

5.2.5 Impact - YOUTRADESMART

The second new customer of GYR company is YOUTRADESMART which is an innovative business consulting company focusing on logistics and environmental monitoring services beyond others. YOUTRADESMART have several 3PL companies to which provides consultant services. YOUTRADESMART provided as a re-seller GYR service to its customers.

The impact of YOUTRADESMART is presented in the following table:

Table 33: Impact of YOUTRADESMART

102 daily plans, Oct22-April23 (Actual and Simulation Estimated)				
	Actual	Simulation Estimated	Difference (Absolute)	Difference (%)
General indexes				
Kilometers	665,624.19	755,376.40	-89,752.20	-11.88%
Routes	4,967	5,102	-135	-2.65%
Fuel consumed and Emissions emitted				
FC (Tones)	193.436	354.406	-160.970	-45.42%
CO2 (Tones)	608.068	1,114.081	-506.012	-45.42%
CH4 (Kilograms)	30.610	53.237	-22.627	-42.50%
CO (Kilograms)	1,373.510	2,436.948	-1,063.438	-43.64%
N2O (Kilograms)	14.208	26.219	-12.011	-45.81%
NH3 (Kilograms)	5.713	10.474	-4.761	-45.46%
NOx (Tones)	6.105	10.958	-4.853	-44.29%
PM (Kilograms)	101.009	178.221	-77.212	-43.32%
VOC (Kilograms)	284.706	498.523	-213.817	-42.89%
SO2 (Kilograms)	12.398	22.715	-10.317	-45.42%
			Average	

The total kilometer travelled during the real life demonstration using GYR service by the customers of YOUTRADESMART were 665,624km and using the simulation tool they were 755,376km. The total kilometer saved using GYR service were equal to 89,752km, which correspond to a decrease of 11.88%. In additional to the total kilometer travelled the total number of route implemented were also decreased by 2.65%, resulting a reduced number of truck used, a reduced maintenance cost and a reduced operational cost (see deliverable of Action C2).

The emission emitted were decreased by a minimum of 42.5% (i.e. CH4) to a maximum of 45.46% (i.e. NH3). The average decrease of emission emitted were 44.42%.

5.2.6 Impact - DASCO S.A.

The third new customer of GYR Company is DASCO S.A. which is a 3PL company located in Peloponnese focusing on product delivery. DASCO S.A. has several type of customers such as mini markets and kiosks where fast-moving consumer goods (FMCG) are delivered. The FMCG are nondurable products that sell quickly at relatively low cost. FMCGs have low profit margins and high-volume sales. The FMCGs delivered by DASCO S.A. include gum, delicatessen, tobacco etc.

The impact of DASCO S.A. is presented in the following table:

Table 34: Impact of DASCO S.A

102 daily plans, Oct22-April23 (Actual and Simulation Estimated)				
	Actual	Simulation Estimated	Difference (Absolute)	Difference (%)
General indexes				
Kilometers	705,348.38	842,924.59	-137,576.20	-16.32%
Routes	5,264	5,546	-282.00	-5.08%
Fuel consumed and Emissions emitted				
FC (Tones)	211.136	401.453	-190.318	-47.41%
CO2 (Tones)	599.317	1,199.197	-599.880	-50.02%
CH4 (Kilograms)	31.407	58.467	-27.060	-46.28%
CO (Kilograms)	1,355.189	2,624.532	-1,269.343	-48.36%
N2O (Kilograms)	15.170	29.374	-14.204	-48.35%
NH3 (Kilograms)	6.199	11.829	-5.630	-47.59%
NOx (Tones)	6.655	12.405	-5.750	-46.35%
PM (Kilograms)	109.692	201.367	-91.675	-45.53%
VOC (Kilograms)	309.623	563.670	-254.047	-45.07%
SO2 (Kilograms)	13.511	25.710	-12.199	-47.45%
			Average	-47.24%

The total kilometer travelled during the real life demonstration using GYR service by DASCO S.A. trucks were 705,348km and using the simulation tool they were 842,924km. The total kilometer saved using GYR service were equal to 137,576km, which correspond to a decrease of 16.32%. In additional to the total kilometer travelled the total number of route implemented were also decreased by 5.08%, resulting a reduced number of truck used, a reduced maintenance cost and a reduced operational cost (see deliverable of Action C2).

The emission emitted were decreased by a minimum of 46.28% (i.e. CH4) to a maximum of 50.02% (i.e. CO2). The average decrease of emission emitted were 47.24%.

5.2.7 Impact - Total

The total impact of the real life demonstration of GYF service resulted by the 5 demonstrators and the 3 new customers of GYR company is given as a sum-up of the previously data presented, in the following table:

Table 35: Total impact of Real Life Demonstration

Real life Demonstration (Actual and Simulation Estimated)				
	Actual	Simulation Estimated	Difference (Absolute)	Difference (%)
General indexes				

Kilometers	4,633,441.58	5,516,560.45	-883,118.87	-16.01%
Routes	28,220.00	29,868.00	-1,648	-5.52%
Fuel consumed and Emissions emitted				
FC (Tones)	1,566.407	3,137.654	-1,571.247	-50.08%
CO2 (Tones)	4,882.527	9,847.293	-4,964.767	-50.42%
CH4 (Kilograms)	173.016	330.911	-157.895	-47.72%
CO (Kilograms)	18,451.162	36,722.018	-18,270.855	-49.75%
N2O (Kilograms)	97.912	196.194	-98.282	-50.09%
NH3 (Kilograms)	32.249	63.991	-31.742	-49.60%
NOx (Tones)	39.984	79.098	-39.114	-49.45%
PM (Kilograms)	520.432	1,002.093	-481.661	-48.07%
VOC (Kilograms)	2,157.650	4,168.942	-2,011.292	-48.24%
SO2 (Kilograms)	101.189	202.748	-101.559	-50.09%
			Average	-49.35%

The total kilometers travelled during the real life demonstration using GYR service were 4,633,441km and using the simulation tool they were 5,516,560km. The total kilometers saved using GYR service were equal to 883,118km, which correspond to a decrease of 16.01%. In additional to the total kilometers travelled the total number of routes implemented were also decreased by 5.52%, resulting a reduced number of truck used, a reduced maintenance cost and a reduced operational cost (see deliverable of Action C2).

The emission emitted were decreased by a minimum of 48.07% (i.e. PM) to a maximum of 50.42% (i.e. CO2). The average decrease of emission emitted were 49.35%.

5.2.8 Foreseen vs Actual environmental impact

The percentage achievement comparing the impact foreseen and the impact achieved is presented in the following table:

Table 36: Foreseen vs Actual environmental impact

Fuel consumed & Pollutant emitted (tns)	Savings Foreseen	Savings Actual	Percentage Achievement
FC	No foreseen	1571.247331	No foreseen
CO2	8885.697	4964.766548	55.87%
CH4	8.939	0.157894506	1.77%
CO	73.133	18.27085537	24.98%
N2O	No foreseen	0.098281616	No foreseen
NH3	1.869	0.031742329	1.70%
NOx	42.255	39.11386862	92.57%
PM	4.632	0.481660713	10.40%
VOC	10.564	2.011292094	19.04%
SO2	8.126	0.101558902	1.25%

The goal concerning the NOx saved was achieved by a high percentage which is equal to 92.57%. Additionally, more than 55% of the goal for CO2 was achieved. The goal for CO and VOC emitted were achieved by 25% and 19% respectively and the goal for PM by 10%. Finally, only a small percentage (less than 2%) of the goal for CH4, NH3 and SO2 was achieved. We have to notice that the impact associated with the fuel consumed and the N2O emitted was not foreseen in the frame of the project and for this reason there is not comparison between the fuel consumed and N2O emitted using GYR service and using the simulation tool.

5.2.9 Justification of deviations

The above deviations were resulted mainly by one major error to the initial calculations followed by GYR team to estimate the potential benefit using GYR service and one major wrong assumption taken when the environmental impact of the project was estimated.

5.2.9.1 Wrong calculation

The minimum requirements to approximate a baseline of emissions emitted by the demonstrators of the project used was the pollution emission factors per tonne-kilometre (tkm) for LDVs and the freight traffic demand in tkm of each demonstrator.

Ecoinvent database, for an average fleet of light duty vehicles up to 3,5 tones, gives the following emission factors: NOX=0.52, PM=0.057, CO=0.9, NH3=0.023, CO2=109.35, CH4=0.11, NMVOC=0,13 and SO2=0,1.

KOUKOUZELIS: The 12 months before the starting month of the project, the total distance travelled by KOUKOUZELIS's trucks was around 5,500 km during 140 trips (~39km/trip), and the total amount of freight transported was around 120 tn (~ 0,85 tn/trip). Hence, in each trip the traffic demand was 0.85 x 39 ≈ 33.7 tkm per trip. The total yearly tkm for KOUKOUZELIS is equal to 4,718tkm and results by multiplying the 33.7 tkm per trip by 140 trips. When the environmental impact was calculated, the total tkm was claculated wrongly by multiplying the tkm per trip by the total kilometers (33.7x5,500=185,204) which give a value to the total tkm 39 larger than the correct one.

PLUS: The 12 months before the starting month of the project, the total distance travelled by PLUS's trucks was around 172.602km during 1.040 trips (~166 km/trip), and the total amount of cold cargo transported was around 2.846 tn (~ 2,73tn/trip). Hence, in each trip the traffic demand was 166 x 2.73 ≈ 453.18 tkm per trip. The total yearly tkm for PLUS is equal to 471,307.2tkm and results by multiplying the 453.18 tkm per trip by 1,040 trips. When the environmental impact was calculated, the total tkm was calculated wrongly by multiplying the tkm per trip by the total kilometers (453.18x172.602=78,219,774.36) which give a value to the total tkm 166 larger than the correct one.

ATHINAKI: The 12 months before the starting month of the project, the total distance travelled by ATHINAKI's trucks was around 978.078km during 4.520 trips (~216 km/trip), and the total amount of dry cargo transported was around 11.023tn (~ 2,45tn/trip). Hence, in each trip the traffic demand was 216 x 2.45 ≈ 639.45 tkm per trip. The total yearly tkm for ATHINAKI is equal to 2,890,314.2tkm and results by multiplying the 639.45 tkm per trip by 4,520 trips. When the environmental impact was calculated, the total tkm was calculated wrongly by multiplying the tkm per trip by the total kilometers (639.45x978.078=625,431,977.1) which give a value to the total tkm 216 larger than the correct one.

CEDA and ITACA demonstrators: We assumed that the customer of CEDA and ITACA have a yearly traffic demand of at least 1.5% of the total demand of the Greek demonstrators which corresponds to a traffic demand of at least 10,000,000tkm both. Based on the wrong calculation that the Greek demonstrators would have a total demand of 703,836,955tkm (=185,204+78,219,774+625,431,977) the 1,5% of this demand is equal to 10,557,554.3tkm.

5.2.9.2 Wrong assumption

The above assessment of the environmental impact of the project was done based on the assumption that the tons of freight delivered or pick-up were transported for the entire km travelled by the trucks. This assumption was wrong for all demonstrators as for instance the trucks of ATHINAKI, PLUS, KOUKOUZELIS and ITACA start from the depot and progressively decrease their load factor by visiting one by one the delivery points and when the last point is served they return to depot empty. Additionally, the trucks of CEDA's demonstrator start form the depot with their freight and go to their final destination to deliver it and then go empty to the next visiting point to pick-up the next freight to deliver etc. As a consequence of this wrong assumption the total tkm of each demonstrator were 2-3 times overestimated.

6 Annex I

vehicle_classID	vehicle_type	vehicle_description	typeOfEngine	typeOfFuel
1	1	Mopeds 2-stroke <50 cm³	Conventional	1
2	1	Mopeds 2-stroke <50 cm³	Euro 1	1
3	1	Mopeds 2-stroke <50 cm³	Euro 2	1
4	1	Mopeds 2-stroke <50 cm³	Euro 3	1
5	1	Mopeds 2-stroke <50 cm³	Euro 4	1
6	1	Mopeds 2-stroke <50 cm³	Euro 5	1
7	1	Mopeds 4-stroke <50 cm³	Conventional	1
8	1	Mopeds 4-stroke <50 cm³	Euro 1	1
9	1	Mopeds 4-stroke <50 cm³	Euro 2	1
10	1	Mopeds 4-stroke <50 cm³	Euro 3	1
11	1	Mopeds 4-stroke <50 cm³	Euro 4	1
12	1	Mopeds 4-stroke <50 cm³	Euro 5	1
13	1	Motorcycles 2-stroke >50 cm³	Conventional	1
14	1	Motorcycles 2-stroke >50 cm³	Euro 1	1
15	1	Motorcycles 2-stroke >50 cm³	Euro 2	1
16	1	Motorcycles 2-stroke >50 cm³	Euro 3	1
17	1	Motorcycles 2-stroke >50 cm³	Euro 4	1
18	1	Motorcycles 2-stroke >50 cm³	Euro 5	1
19	1	Motorcycles 4-stroke <250 cm³	Conventional	1
20	1	Motorcycles 4-stroke <250 cm³	Euro 1	1
21	1	Motorcycles 4-stroke <250 cm³	Euro 2	1
22	1	Motorcycles 4-stroke <250 cm³	Euro 3	1
23	1	Motorcycles 4-stroke <250 cm³	Euro 4	1
24	1	Motorcycles 4-stroke <250 cm³	Euro 5	1
25	1	Motorcycles 4-stroke 250 - 750 cm³	Conventional	1
26	1	Motorcycles 4-stroke 250 - 750 cm³	Euro 1	1
27	1	Motorcycles 4-stroke 250 - 750 cm³	Euro 2	1
28	1	Motorcycles 4-stroke 250 - 750 cm³	Euro 3	1
29	1	Motorcycles 4-stroke 250 - 750 cm³	Euro 4	1
30	1	Motorcycles 4-stroke 250 - 750 cm³	Euro 5	1
31	1	Motorcycles 4-stroke >750 cm³	Conventional	1
32	1	Motorcycles 4-stroke >750 cm³	Euro 1	1
33	1	Motorcycles 4-stroke >750 cm³	Euro 2	1
34	1	Motorcycles 4-stroke >750 cm³	Euro 3	1
35	1	Motorcycles 4-stroke >750 cm³	Euro 4	1
36	1	Motorcycles 4-stroke >750 cm³	Euro 5	1
37	1	Quad & ATVs	Euro 1	1
38	1	Quad & ATVs	Euro 2	1

39	1	Quad & ATVs	Euro 3	1
40	1	Quad & ATVs	Euro 4	1
41	1	Quad & ATVs	Euro 5	1
42	1	Micro-car	Euro 1	2
43	1	Micro-car	Euro 2	2
44	1	Micro-car	Euro 3	2
45	1	Micro-car	Euro 4	2
46	1	Micro-car	Euro 5	2
47	2	N1-I	CNG	4
48	2	N1-I	Euro 1	1
49	2	N1-I	Euro 2	1
50	2	N1-I	Euro 3 (PFI)	1
51	2	N1-I	Euro 4 (PFI)	1
52	2	N1-I	Euro 5 (PFI)	1
53	2	N1-I	Euro 6 up to 2016 (GDI)	1
54	2	N1-I	Euro 6 up to 2016 (PFI)	1
55	2	N1-I	Euro 6 up to 2016 (GDI+GPF)	1
56	2	N1-I	Euro 6 2017-2019 (GDI)	1
57	2	N1-I	Euro 6 2017-2019 (PFI)	1
58	2	N1-I	Euro 6 2017-2019 (GDI+GPF)	1
59	2	N1-I	Euro 6 2020+ (GDI)	1
60	2	N1-I	Euro 6 2020+ (PFI)	1
61	2	N1-I	Euro 6 2020+ (GDI+GPF)	1
62	2	N1-II	CNG	4
63	2	N1-II	Euro 1	1
64	2	N1-II	Euro 2	1
65	2	N1-II	Euro 3 (PFI)	1
66	2	N1-II	Euro 4 (PFI)	1
67	2	N1-II	Euro 5 (PFI)	1
68	2	N1-II	Euro 6 up to 2017 (GDI)	1
69	2	N1-II	Euro 6 up to 2017 (PFI)	1
70	2	N1-II	Euro 6 up to 2017 (GDI+GPF)	1

71	2	N1-II	Euro 6 2018-2020 (GDI)	1
72	2	N1-II	Euro 6 2018-2020 (PFI)	1
73	2	N1-II	Euro 6 2018-2020 (GDI+GPF)	1
74	2	N1-II	Euro 6 2021+ (GDI)	1
75	2	N1-II	Euro 6 2021+ (PFI)	1
76	2	N1-II	Euro 6 2021+ (GDI+GPF)	1
77	2	N1-III	CNG	4
78	2	N1-III	Euro 1	1
79	2	N1-III	Euro 2	1
80	2	N1-III	Euro 3 (PFI)	1
81	2	N1-III	Euro 4 (PFI)	1
82	2	N1-III	Euro 5 (PFI)	1
83	2	N1-III	Euro 6 up to 2017 (GDI)	1
84	2	N1-III	Euro 6 up to 2017 (PFI)	1
85	2	N1-III	Euro 6 up to 2017 (GDI+GPF)	1
86	2	N1-III	Euro 6 2018-2020 (GDI)	1
87	2	N1-III	Euro 6 2018-2020 (PFI)	1
88	2	N1-III	Euro 6 2018-2020 (GDI+GPF)	1
89	2	N1-III	Euro 6 2021+ (GDI)	1
90	2	N1-III	Euro 6 2021+ (PFI)	1
91	2	N1-III	Euro 6 2021+ (GDI+GPF)	1
92	2	N1-I	LPG	5
93	2	N1-I	Euro 1	2
94	2	N1-I	Euro 2	2
95	2	N1-I	Euro 3 (DPF)	2
96	2	N1-I	Euro 4 (DPF)	2
97	2	N1-I	Euro 5 (DPF)	2
98	2	N1-I	Euro 6 up to 2016 (DPF)	2

99	2	N1-I	Euro 6 up to 2016 (DPF+SCR)	2
100	2	N1-I	Euro 6 up to 2016 (LNT+DPF)	2
101	2	N1-I	Euro 6 2017-2019 (DPF)	2
102	2	N1-I	Euro 6 2017-2019 (DPF+SCR)	2
103	2	N1-I	Euro 6 2017-2019 (LNT+DPF)	2
104	2	N1-I	Euro 6 2020+ (DPF)	2
105	2	N1-I	Euro 6 2020+ (DPF+SCR)	2
106	2	N1-I	Euro 6 2020+ (LNT+DPF)	2
107	2	N1-II	LPG	5
108	2	N1-II	Euro 1	2
109	2	N1-II	Euro 2	2
110	2	N1-II	Euro 3 (DPF)	2
111	2	N1-II	Euro 4 (DPF)	2
112	2	N1-II	Euro 5 (DPF)	2
113	2	N1-II	Euro 6 up to 2017 (DPF)	2
114	2	N1-II	Euro 6 up to 2017 (DPF+SCR)	2
115	2	N1-II	Euro 6 up to 2017 (LNT+DPF)	2
116	2	N1-II	Euro 6 2018-2020 (DPF)	2
117	2	N1-II	Euro 6 2018-2020 (DPF+SCR)	2
118	2	N1-II	Euro 6 2018-2020 (LNT+DPF)	2
119	2	N1-II	Euro 6 2021+ (DPF)	2
120	2	N1-II	Euro 6 2021+ (DPF+SCR)	2
121	2	N1-II	Euro 6 2021+ (LNT+DPF)	2

122	2	N1-III	LPG	5
123	2	N1-III	Euro 1	2
124	2	N1-III	Euro 2	2
125	2	N1-III	Euro 3 (DPF)	2
126	2	N1-III	Euro 4 (DPF)	2
127	2	N1-III	Euro 5 (DPF)	2
128	2	N1-III	Euro 6 up to 2017 (DPF)	2
129	2	N1-III	Euro 6 up to 2017 (DPF+SCR)	2
130	2	N1-III	Euro 6 up to 2017 (LNT+DPF)	2
131	2	N1-III	Euro 6 2018-2020 (DPF)	2
132	2	N1-III	Euro 6 2018-2020 (DPF+SCR)	2
133	2	N1-III	Euro 6 2018-2020 (LNT+DPF)	2
134	2	N1-III	Euro 6 2021+ (DPF)	2
135	2	N1-III	Euro 6 2021+ (DPF+SCR)	2
136	2	N1-III	Euro 6 2021+ (LNT+DPF)	2
137	3	>3,5 t	Conventional	1
138	3	>3,5 t	CNG	4
139	3	>3,5 t	LPG	5
140	3	Rigid <=7,5 t	Conventional	2
141	3	Rigid <=7,5 t	Euro I	2
142	3	Rigid <=7,5 t	Euro II	2
143	3	Rigid <=7,5 t	Euro III	2
144	3	Rigid <=7,5 t	Euro IV (SCR)	2
145	3	Rigid <=7,5 t	Euro IV (EGR)	2
146	3	Rigid <=7,5 t	Euro V (SCR)	2
147	3	Rigid <=7,5 t	Euro V (EGR)	2
148	3	Rigid <=7,5 t	Euro VI (DPF+SCR)	2
149	3	LCV (general)	Electrical	3
150	3	LCV (general)	CNG	4
151	3	LCV (general)	LPG	5
152	3	Rigid 7,5 - 12 t	Conventional	2
153	3	Rigid 7,5 - 12 t	Euro I	2
154	3	Rigid 7,5 - 12 t	Euro II	2
155	3	Rigid 7,5 - 12 t	Euro III	2

156	3	Rigid 7,5 - 12 t	Euro IV (SCR)	2
157	3	Rigid 7,5 - 12 t	Euro IV (EGR)	2
158	3	Rigid 7,5 - 12 t	Euro V (SCR)	2
159	3	Rigid 7,5 - 12 t	Euro V (EGR)	2
160	3	Rigid 7,5 - 12 t	Euro VI (DPF+SCR)	2
161	3	Rigid 12 - 14 t	Conventional	2
162	3	Rigid 12 - 14 t	Euro I	2
163	3	Rigid 12 - 14 t	Euro II	2
164	3	Rigid 12 - 14 t	Euro III	2
165	3	Rigid 12 - 14 t	Euro IV (SCR)	2
166	3	Rigid 12 - 14 t	Euro IV (EGR)	2
167	3	Rigid 12 - 14 t	Euro V (SCR)	2
168	3	Rigid 12 - 14 t	Euro V (EGR)	2
169	3	Rigid 12 - 14 t	Euro VI (DPF+SCR)	2
170	4	Rigid 14 - 20 t	Conventional	2
171	4	Rigid 14 - 20 t	Euro I	2
172	4	Rigid 14 - 20 t	Euro II	2
173	4	Rigid 14 - 20 t	Euro III	2
174	4	Rigid 14 - 20 t	Euro IV (SCR)	2
175	4	Rigid 14 - 20 t	Euro IV (EGR)	2
176	4	Rigid 14 - 20 t	Euro V (SCR)	2
177	4	Rigid 14 - 20 t	Euro V (EGR)	2
178	4	Rigid 14 - 20 t	Euro VI (DPF+SCR)	2
179	4	Rigid 20 - 26 t	Conventional	2
180	4	Rigid 20 - 26 t	Euro I	2
181	4	Rigid 20 - 26 t	Euro II	2
182	4	Rigid 20 - 26 t	Euro III	2
183	4	Rigid 20 - 26 t	Euro IV (SCR)	2
184	4	Rigid 20 - 26 t	Euro IV (EGR)	2
185	4	Rigid 20 - 26 t	Euro V (SCR)	2
186	4	Rigid 20 - 26 t	Euro V (EGR)	2
187	4	Rigid 20 - 26 t	Euro VI (DPF+SCR)	2
188	4	Rigid 26 - 28 t	Conventional	2
189	4	Rigid 26 - 28 t	Euro I	2
190	4	Rigid 26 - 28 t	Euro II	2
191	4	Rigid 26 - 28 t	Euro III	2
192	4	Rigid 26 - 28 t	Euro IV (SCR)	2
193	4	Rigid 26 - 28 t	Euro IV (EGR)	2
194	4	Rigid 26 - 28 t	Euro V (SCR)	2
195	4	Rigid 26 - 28 t	Euro V (EGR)	2
196	4	Rigid 26 - 28 t	Euro VI (DPF+SCR)	2
197	4	Articulated 14 - 20 t	Conventional	2
198	4	Articulated 14 - 20 t	Euro I	2

199	4	Articulated 14 - 20 t	Euro II	2
200	4	Articulated 14 - 20 t	Euro III	2
201	4	Articulated 14 - 20 t	Euro IV (SCR)	2
202	4	Articulated 14 - 20 t	Euro IV (EGR)	2
203	4	Articulated 14 - 20 t	Euro V (SCR)	2
204	4	Articulated 14 - 20 t	Euro V (EGR)	2
205	4	Articulated 14 - 20 t	Euro VI (DPF+SCR)	2
206	4	Articulated 20 - 28 t	Conventional	2
207	4	Articulated 20 - 28 t	Euro I	2
208	4	Articulated 20 - 28 t	Euro II	2
209	4	Articulated 20 - 28 t	Euro III	2
210	4	Articulated 20 - 28 t	Euro IV (SCR)	2
211	4	Articulated 20 - 28 t	Euro IV (EGR)	2
212	4	Articulated 20 - 28 t	Euro V (SCR)	2
213	4	Articulated 20 - 28 t	Euro V (EGR)	2
214	4	Articulated 20 - 28 t	Euro VI (DPF+SCR)	2
215	5	Rigid 28 - 32 t	Euro II	2
216	5	Rigid 28 - 32 t	Euro III	2
217	5	Rigid 28 - 32 t	Euro IV (SCR)	2
218	5	Rigid 28 - 32 t	Euro IV (EGR)	2
219	5	Rigid 28 - 32 t	Euro V (SCR)	2
220	5	Rigid 28 - 32 t	Euro V (EGR)	2
221	5	Rigid 28 - 32 t	Euro VI (DPF+SCR)	2
222	5	Rigid >32 t	Euro I	2
223	5	Rigid >32 t	Euro II	2
224	5	Rigid >32 t	Euro III	2
225	5	Rigid >32 t	Euro IV (SCR)	2
226	5	Rigid >32 t	Euro IV (EGR)	2
227	5	Rigid >32 t	Euro V (SCR)	2
228	5	Rigid >32 t	Euro V (EGR)	2
229	5	Rigid >32 t	Euro VI (DPF+SCR)	2
230	5	Articulated 28 - 34 t	Euro II	2
231	5	Articulated 28 - 34 t	Euro III	2
232	5	Articulated 28 - 34 t	Euro IV (SCR)	2
233	5	Articulated 28 - 34 t	Euro IV (EGR)	2
234	5	Articulated 28 - 34 t	Euro V (SCR)	2
235	5	Articulated 28 - 34 t	Euro V (EGR)	2
236	5	Articulated 28 - 34 t	Euro VI (DPF+SCR)	2
237	5	Articulated 34 - 40 t	Euro II	2
238	5	Articulated 34 - 40 t	Euro III	2
239	5	Articulated 34 - 40 t	Euro IV (SCR)	2
240	5	Articulated 34 - 40 t	Euro IV (EGR)	2
241	5	Articulated 34 - 40 t	Euro V (SCR)	2

242	5	Articulated 34 - 40 t	Euro V (EGR)	2
243	5	Articulated 34 - 40 t	Euro VI (DPF+SCR)	2
244	5	Articulated 40 - 50 t	Euro II	2
245	5	Articulated 40 - 50 t	Euro III	2
246	5	Articulated 40 - 50 t	Euro IV (SCR)	2
247	5	Articulated 40 - 50 t	Euro IV (EGR)	2
248	5	Articulated 40 - 50 t	Euro V (SCR)	2
249	5	Articulated 40 - 50 t	Euro V (EGR)	2
250	5	Articulated 40 - 50 t	Euro VI (DPF+SCR)	2
251	5	Articulated 50 - 60 t	Euro II	2
252	5	Articulated 50 - 60 t	Euro III	2
253	5	Articulated 50 - 60 t	Euro IV (SCR)	2
254	5	Articulated 50 - 60 t	Euro IV (EGR)	2
255	5	Articulated 50 - 60 t	Euro V (SCR)	2
256	5	Articulated 50 - 60 t	Euro V (EGR)	2
257	5	Articulated 50 - 60 t	Euro VI (DPF+SCR)	2

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