Electric Vehicle and Conventional Vehicle. Urban Air Pollution Assessment

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Abstract: Road traffic is the main source of air pollutant emissions in urban areas. Pollutant emissions can be evaluated and calculated using mathematical models based on the characteristics of traffic flowing in roads. This article aims to assess the air pollution produced by a fleet of vehicles with conventional (diesel and petrol) and electrical (hybrid and electric) motorization, in the city centre of Braga. The scientific toolbox adopted to develop the studies includes emission models to estimate emission data and a GIS platform.

Key-Words: Electric vehicle, air pollution, urban environment, NOx, CO, emission factors.

1 Introduction

Urban air pollution has become a major factor in degradation of the population's quality of life. It is a problem that tends to deteriorate, mainly due to the unbalanced development of urban spaces and to the significant increase in population's mobility, with consequently increase of road traffic levels [1].

The air quality in urban areas has caused an increasing concern of the authorities which led to a growing development of electric vehicles (EV's). This has placed them in front of the debate on strategies for reducing environmental impacts, such as the health of the population caused by the automobile sector, because it is a major factor that contributes to air pollution in urban areas and emissions of greenhouse gases to the atmosphere.

The compounds released into the air from the exhaust gases from cars give rise to a variety of environmental impacts with different geographic scales and time [2]. Certain compounds have an immediate and localized effect. For example, a plume of black smoke is instantly unpleasant to whoever sees it, while in a longer time scale, repeated exposure to fumes from vehicles exhaust can cause the darkening of buildings facades, by deposition of particles on its surface.

The main products of hydrocarbon combustion reaction are carbon dioxide (CO2) and water (H2O). However, the combustion is not always one hundred percent efficient; sometimes part of the fuel is not burned or is only partially burned. In this process the product of combustion is more complex and may consist of hydrocarbons and other organic compounds (VOC), carbon monoxide (CO) and particulate matter that contains carbon and other contaminants. Moreover, the combustion conditions - high pressures and temperatures - originate from an oxidation of the nitrogen present in air and fuel, forming nitrogen oxides (mainly NO and some NO2), conventionally referred to as NOx.

In Portugal, as in other EU countries, emission limits for air pollutants are regulated by publication of specific legislation. The Law No. 111/2002 [3] (Transposition of Directives 1999/30/EC and 2000/69/EC [4, 5]) fixes the values - limit and alert thresholds for pollutants like carbon monoxide, sulfur dioxide, nitrogen oxides, particulates, benzene and lead.

This article aims to evaluate emissions of air pollutants generated in the city centre of Braga, by varying the percentage of electric / hybrids vehicles in the traffic stream, and by the creation of various scenarios. Each scenario was prepared according to the criterion of percentage increase in electric vehicle powertrain in relation to the internal combustion vehicles.

The methodology includes the mathematical model that CORINAIR [6] proposed, based on traffic data, followed by the calculation of emission factors and related emissions for the pollutants CO and NOx. Later, it was possible from the data obtained, to create emission maps using a GIS (Geographic Information System) platform.

2 Calculation of emissions of air pollutants in the central zone of Braga

Braga is located at the Northwest of Portugal and is one of the largest cities in the country with 176,154 inhabitants [7]. This study aims to evaluate emissions of air pollutants (CO and NOx) produced by a fleet of vehicles with conventional (diesel and petrol) and electrical (hybrid and electric) motorization, in a central zone in the city of Braga (Fig.1).

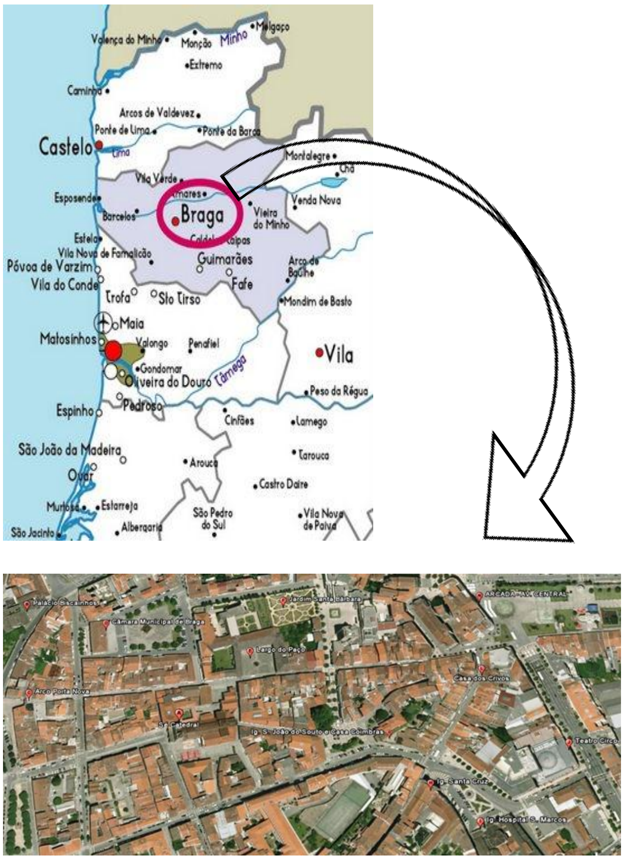


Fig.1 – Location of the study area

2.1 Methodology

As mentioned earlier in this article, in order to assess emissions of air pollutants, several scenarios were conceived by varying the percentage of electric / hybrid vehicles in the traffic stream. Each created scenario was prepared according to the criterion of percentage increase in electric vehicle powertrain with regard to internal combustion vehicles. In the last scenario, only electric vehicles were used , because in the previous scenarios the vehicles powertrain used were electric hybrid vehicles, in order to make up a realistic analysis of the concentrations of pollutants emitted by the flow of traffic in the study area. Table 1 presents the percentage increase adopted for each scenario.

The scenarios created are purely hypothetical, which is not an impediment to its implementation in practice; it is only necessary that the hybrid and electric vehicles are a reality in the short term, in our day-to-day. For each scenario created, the calculation of emission factors according to the CORINAIR methodology was made, referring to cars with petrol, diesel and hybrid vehicles, as well, as heavy vehicles. As this study takes place in urban areas, heavy vehicles are considered in their entirety as buses.

Table 1 – Increase percentages adopted for the different scenarios

		Curr. sit.	**Scen. 1**	**Scen. 2**	**Scen. 3**	**Scen. 4**
Conventional	Light	100%	80%	50%	20%	20%
	Heavy	100%	100%	100%	100%	100%
Hybrid	Light	0%	20%	50%	80%	70%
	Heavy	0%	0%	0%	0%	0%
Electric	Light	0%	0%	0%	0%	10%
	Heavy	0%	0%	0%	0%	0%

Using data relating to the composition of the Portuguese fleet, it was possible to determine the equivalent amount of diesel cars, petrol and even the associated European standard.

In the table 2 are listed the emission factors corresponding to each class of vehicles and the corresponding European standard.

Table 2 – Emission factors for each class of vehicles and for the different scenarios

		Curr. sit.	**Scen. 1**	**Scen. 2**	**Scen. 3**	**Scen. 4**
EF equivalent (g/km.veicles)						
CO	Light	0.7269	0.5905	0.3858	0.181	0.177
	Heavy	3.2283	3.2283	3.2283	3.2283	3.2283
NOx	Light	0.2664	0.2151	0.1382	0.0614	0.0604
	Heavy	6.7407	6.7407	6.7407	6.7407	6.7407

After determination of emission factors (EF) it is possible to proceed to the calculation of the equivalent emissions to each class and for each European standard by Equation 1:

$$Emission = EF \times \%vehicles \qquad \text{(Eq.1)}$$

Subsequently, to the sum was computed in order to obtain the total emission equivalent to a vehicle, related to the different types discussed (conventional, hybrid and bus). Then, the equivalent emission per vehicle was determined, by multiplying the number of vehicles in the various courses of study area per hour, both for light and heavy vehicles (bus), having as final result the total emissions caused by traffic in each track in the study area.
In this study, only the "hot emissions” were calculated.

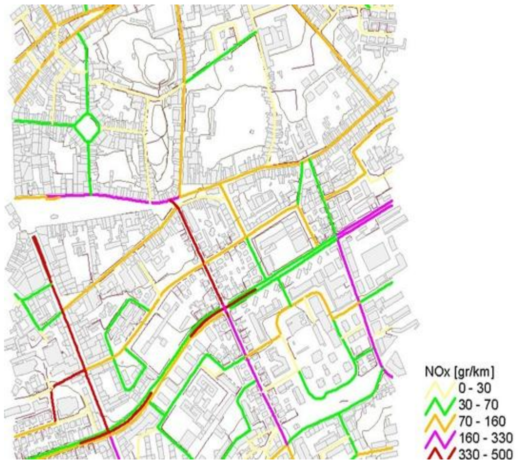
2.2 Achievements

After performing the calculations of CO and NOx emission factors related to the values presented in the previous table, it was possible to obtain emission maps presented below for the different situations studied.
From the concentrations of pollutants, classes of pollutants were defined; a specific colour was assigned to each different class, according to the degree of danger for the population. This process was conducted in a GIS platform.

2.2.1 Current situation

The current situation illustrates the reality of the emission of air pollutants in the city centre of Braga. Figures 2a) and 2b) illustrate maps of emissions for the pollutants CO and NOx respectively.

a) CO emissions



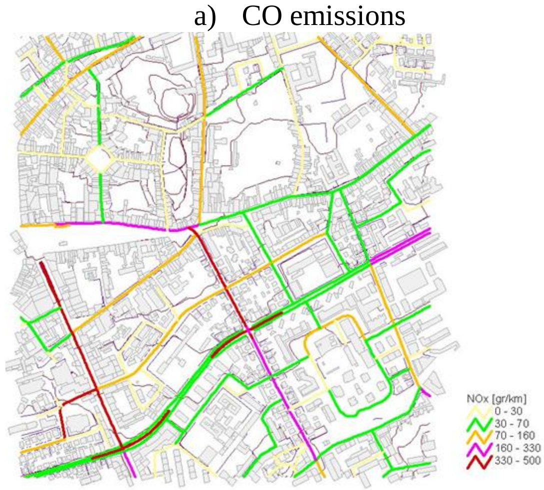
b) NOx emissions

Figure 2 – Emission maps, current situation

2.2.2 Scenario 1

This scenario would be, in the short term, the most realistic scenario, since the percentage of vehicles with engine power present in the composition of traffic is still reduced. Figures 3a) and 3b) are showing maps of emissions for the pollutants CO and NOx respectively.

a) CO emissions



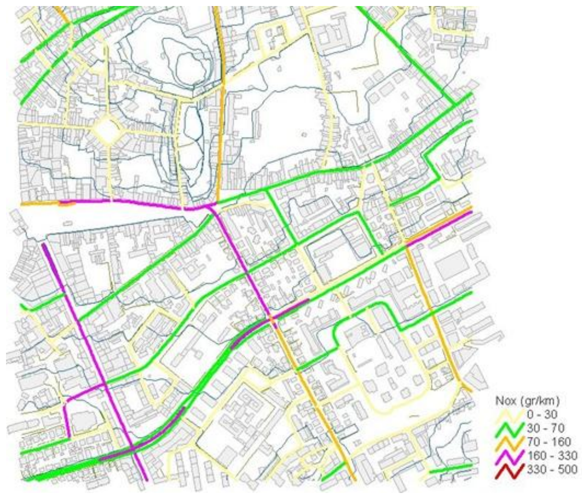
b) NOx emissions

Figure 3 – Emission maps, scenario 1

2.2.3 Scenario 2

This scenario presents a percentage of hybrid vehicles equal to the vehicles with internal combustion engine. Figures 4a) and 4b) show the maps of emissions for the pollutants CO and NOx respectively.

a) CO emissions



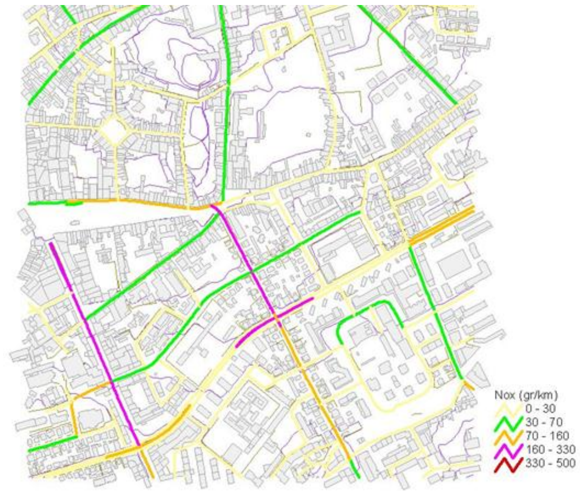
b) NOx emissions

Figure 4 – Emission maps, scenario 2

2.2.4 Scenario 3

In this scenario, the traffic consists of only 20% of vehicles with internal combustion engine, the remainder being composed of hybrid vehicles. Figures 5a) and 5b) show the maps of emissions for the pollutants CO and NOx respectively.

a) CO emissions



b) NOx emissions

Figure 5 – Emission maps, scenario 3

2.2.5 Scenario 4

For the fourth scenario, it can be noted that this is similar to the previous scenario, the only difference is that a 10% fully electric vehicles has been introduced in the traffic mix. Figures 6a) and 6b) show the maps of emissions for the pollutants CO and NOx respectively.

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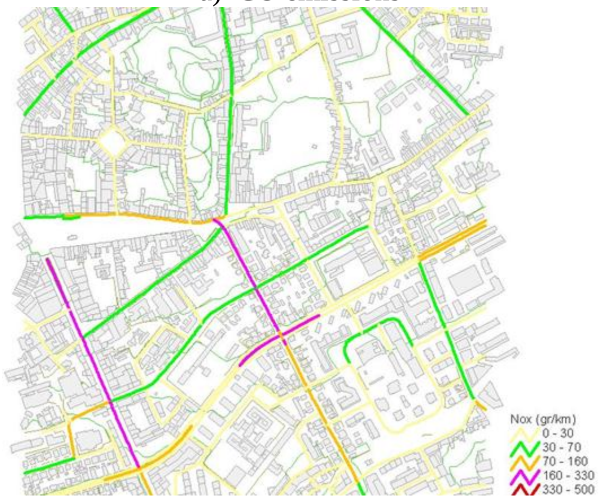
a) CO emissions



b) NOx emissions

Figure 6 – Emission maps, scenario 4

2.3 Analysis

Summary tables 3 and 4 allow undertaking a comparative analysis between the various scenarios and the current situation, in order to assess which scenarios best contribute to reduce the emission levels in urban centre of Braga.

Table 3 – NOx total emissions of each scenario

	Emission (g)	Reduction compared to previous scenario (%)	Reduction in relation to current situat. (%)
Curr. Sit.	2,560.03	0%	0%
Scenario 1	2,155.05	15.8%	15.8%
Scenario 2	1,547.60	28.2%	39.6%
Scenario 3	940.12	39.3%	63.3%
Scenario 4	932.09	0.9%	63.6%

Table 4 – CO total emissions of each scenario

	Emission (g)	Reduction compared to the previous scenario (%)	Reduction in relation to current situat. (%)
Curr.Sit.	5,962.65	0%	0%
Scenario I	4,884.63	18.1%	18.1%
Scenario II	3,267.29	33.1%	45.2%
Scenario III	1,650.06	49.5%	72.3%
Scenario IV	1,614.65	2.2%	72.9%

The results concerning the current situation demonstrate the necessity of introducing in the traffic flow vehicles using new technologies, so that there is an reduction in air pollution from urban centres regarding the emission of pollutants. From this, emerges the use of vehicles with engine power (hybrid and electric), being introduced with different percentages in the traffic flow in the various scenarios created. It can be seen that the inclusion of these vehicles in traffic flow led to a reduction in emissions, resulting in an improvement in pollution levels.

Comparing scenario 1 and 2, it was found that the latter produces better results. The emissions of the pollutant NOx were decreased by 15.8% while for CO the reduction is around 18.1%. The results obtained for scenario 1 were less pervasive. However, realistically this seems the most plausible scenario in practical terms as stated above.

In scenario 3 with the introduction of 80% of hybrid vehicles in the composition of traffic, it represents an increase of 60% compared to the first scenario. Comparing these two scenarios, there is immediately a reduction in emissions. For the pollutant NOx, reduction reaches 47.5% while for the CO pollutant emissions there is a decrease of 54.3%. Comparing now the scenario 3 with the current situation, the reduction of emission values is even more striking. It appears that the emissions decrease significantly for both pollutants, reaching 47.5% for NOx and 54.3% for the CO. This scenario thus leads to more favourable results with regard to the reduction in emissions for the scenario 1.

The fourth scenario is the one that can best contribute to an improvement of the quality of air in urban centres. Scenario 4 includes 10% of electric vehicles in the traffic mix, leading to further reduction of pollutant emissions, and so this is the one that contributes most significantly to the improvement of pollution levels in urban centres. Comparing scenario 4 with the current situation, reducing emissions are significant, reaching 63.6% to 72.9% for NOx and CO respectively.

Overall, the scenarios created contributed to a reduction in emissions, although with different results, as expected.

3 Conclusions

The results presented in the maps of emissions, shows that vehicles with engine power reduce emissions of greenhouse gases, and if they are fully electric it could even reach the zero value, significantly improving the quality of life for people in urban areas.

In this work, the objective was to evaluate the emissions caused by vehicle flow in the area being studied with the introduction of the electric vehicle in the traffic mix through the creation of scenarios. After analysing the results related to each scenario created, it was found that in the current situation there were a higher percentage of high volumes of emissions. This proved the necessity of introducing electric vehicles in the traffic flow.

Scenarios 3 and 4, although unrealistic, proved to be the most effective in reducing levels of emissions, therefore contributing to an improved environmental quality.

After analysing the results for each scenario, it was found that the scenario 1 was the one that least contributes to reduce emissions. This was expected, since this is the scenario with lower incorporation of vehicles with engine power (hybrid or electric) in the traffic flow.

To conclude the results confirmed the expected, i.e. a decrease in the concentration of emissions with the introduction of electric vehicles with engine traffic flow. However, these results can further be improved, since the desire would be to extinguish all types of emissions.

The use of electric and hybrid vehicles and its impact on urban air quality was the subject of this article. In the future this aspect will be combined with other dimensions to study the overall quality of urban environment applied to a city, applying a multi-dimensional evaluation model methodology [8].

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