# A SIMPLIFIED METHOD FOR THE ENVIRONMENTAL IMPACT OF URBAN TRANSPORTATION

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## ABSTRACT

This work is mainly aimed in supporting public administrations that have to cope with the crucial problem of comparatively assessing the environmental pressure exerted by different option policies concerning the urban transportation sector. These complex issues, in fact, deeply affect the well being of several groups of stakeholders: in doing this, local administrators should adopt simple but reliable analysis tools, in order of promptly assuming the most suitable decisions. Unfortunately, this requirement hardly conflicts with the highly complex characteristics of the pollutant phenomena that, as it is well known, do require very sophisticated analytical tools in order to be suitably approached.

In this work, authors, essentially referring to the pollutant emission factors provided within the European COPERT tool, introduce a simple methodology for a first evaluation of the environmental effects induced by different configurations of the urban transportation systems. The method only requires the knowledge of data concerning the running car fleet of the analysed sites. An application to the town of Palermo is here presented.

The changes introduced by the last released COPERT IV version are also argued.

*Keywords: urban transportation, pollutant emissions, synthetic indicators.*

# 1. INTRODUCTION

EU's greenhouse gases emissions (GHG) from transport is about 21% of the total emissions; moreover, between 1990 and 2003, it was registered an increase of 23% in emissions (CEC, 2006). It is noticeable to observe that in the context of the international traffic, maritime bunkers had increased by 40% and aviation bunkers by 80%. As a result, the whole transport growth in EU GHGs is of 28% with regards to data of 1990: this means that a continue increase with the same trend in transport GHG emissions would result in a total increase of 50% by 2020. Table 1 summarizes these trends.

**Table 1 - EU25 GHG emissions in 2003 in MT $CO_2$**

| Mode | National transport | International Bunkers | Total | Share (%) |
|---|---|---|---|---|
| **Road** | 892 | | 892 | 74 |
| **Aviation** | 23 | 112 | 135 | 11 |
| **Rail** | 7 | | 7 | 1 |
| **Navigation** | 22 | 145 | 167 | 14 |
| **Other** | 8 | | 8 | 1 |

Referring to absolute values (not to GHG per unit of transport), the highest percentage increases in GHGs was mainly affected by the rise in domestic aviation (28.9%), followed by road transport (25.1%). Rail transport has registered a dramatic decrease of 40%, but this encounters the effects of electrification of the rail lines that shifted emissions to another commercial sector (production of energy).

With reference to the different gases, the greatest increase is registered in $N_20$ (135%) mainly attributable to the increase in the number of catalytic convertors. The emissions of $CH_4$ decreased by almost 50% in the same period. Anyway, 97% of the total emissions, in volume, are given by $CO_2$, with an increase of 22.6%.

As far the energy sources are in question, it must be noted that one third of the energy use was in freight and two thirds in passenger transportations. In turn, passenger transportation accounts for 75% of petrol and 25% diesel. Moreover, passenger energy demand is stagnating while freight shows a continuous growing.

Occupancy rates for cars seem to decline, while the share of cars in overall passenger traffic was almost constant. With regard to the chosen mode of transportation, passenger traffic by aviation is currently growing while bus and rail had been decreasing.

In conclusions it can be observed that GHG emissions are growing rapidly, essentially following both the trend of GDP and the modal share that has turned toward road and aviation transportation, for both passenger traffic and freight.

Starting from these general considerations, the need rises for the availability of easy methods for assessing the environmental impact of such an important sector of the economic like of countries. Particularly, these methods should be able to capture the effects produced by pollutant emissions from the transportation sector in the urban contexts, where the larger part of the population lives and works.

## 2. THE COPERT IV AND ITS EFFECT ON THE SYNTHETIC INDICATOR

As it is well known, the European Agency for the Environment ((EEA), provides Member States with effective tools for a proper surveillance of the environmental policies. In this context, the so-called “COPERT III” (Ntziachristos *et al.*, 2000) calculation tool has been built-up: it constitutes an evolution of the previously adopted model, that is “COPERT II” (Ahlvik *et al.*, 1997).

The main features of the COPERT (**Co**mputer **P**rogramme to Calculate **E**missions from **R**oad **T**ransport) model are the following:

- it represents a statistical tool for assessing pollutant emissions from transportation at regional or urban scales;
- it easily allows comparative analysis of different scenarios concerning the transportation technologies;
- it can be utilized for the assessment of the optimal future strategies referring to the GHGs emissions from the transport sector.

The model, by means of a suitable sharing of vehicles onto proper emitting categories, essentially provides the emission factors of several pollutant substances.

COPERT IV (COPERT IV, 2006) is an MS Windows[1] software programme whose aim is to calculate air pollutant emissions from road transport. The development of COPERT has been financed by the European Environment Agency (EEA) in the framework of the activities of the “European Topic Centre on Air and Climate Change”.

The program was originally developed for estimating emissions caused by road transport to be included in official annual national inventories. However, COPERT is a free source program, so it can be utilized in any kind of applications.

COPERT IV is only a part of the CORINAIR program. CORINAIR is also sponsored and developed by EEA; it consists of a set of software tools created in order to support National Countries in compiling annual air emissions inventories. By means of CORINAIR it is possible, according to the requirements of international conventions and protocols and European Union legislation, to get a transparent and standard way for data collecting and emissions reporting procedure, in order to obtain consistent and comparable set of data for all European Countries.

The last version of the program takes its main principles from several European activities:

- the COST 319 action on the Estimation of Emissions from Transport;
- MEET (Methodologies to Estimate Emissions from Transport);
- the Inspection and Maintenance program, an European Commission (DG XI, DG VII, DG XVII) sponsored project in the framework of the 4th Framework Program in the area of Transport.

From 2005 to 2006, three versions of COPERT IV have been carried out in order to obtain the last one; these versions, with the pertinent improvements, are:

- COPERT 4 Beta Version 1.0 - Dec 2005.
- COPERT 4 Beta Version 1.4 - March 2006:
    - import from COPERT III;
    - create Excel Import File;

- mileage Degradation;
- edit/Delete Country.

- COPERT 4 Beta Version 2.0.0 - July 2006:
    - full version of COPERT III is now in this version of the software;
    - back-compatibility to previous COPERT versions and ImportER;
    - wizards to prepare inventory.

In the development of the software, new information from different projects (such as ARTEMIS and PARTICULATE) has been taken into account. As that, COPERT IV now includes:

- hot emission factors of regulated pollutants from conventional passenger cars (gasoline Euro4, diesel Euro3, Euro5 Red.fact.);
- $N_2O/NH_3$ Emission Factors for passenger cars and light duty vehicles;
- particulate matter and airborne particle emission factors;
- new corrections for emission degradation due to mileage;
- heavy duty vehicle methodology (emission factors, load factor corrections and road gradient reductions);
- emission and consumption factors for alternative fuels (CNG, hybrids, alcohols);
- two-wheelers evaporative and exhaust emissions.

This new version has been developed by Visual Basic, instead of Access, as previously done, in order of improving the compatibility with different Windows/Office operative systems. Consequently the flexibility has been improved and the running time is now shorter.

Moreover, COPERT IV is compatible with COPERT III; so data from the previous version can be easily transferred to the last one. It has a different layout and is characterized by a more friendly interaction with the operator.

The new prototype allows to better compare different scenarios, by means of a new introduced routine.

One of the most important features of this recent release of the COPERT model is the possibility, among other things, to evaluate the emissions coming from innovative vehicles, such as the so-called hybrid cars.

Figure 1 (Geivanidis S. *et al*, 2006), reports a comparison of the fuel consumption obtained with three different types of engine cars: gasoline, diesel and hybrid. The dramatic reduction of the fuel consumption performed by the last type of cars would justify taking into account these kind of private transportation means when adopting measures of traffic limitation in the historic centres of towns. This analysis is allowed by the last version of COPERT.

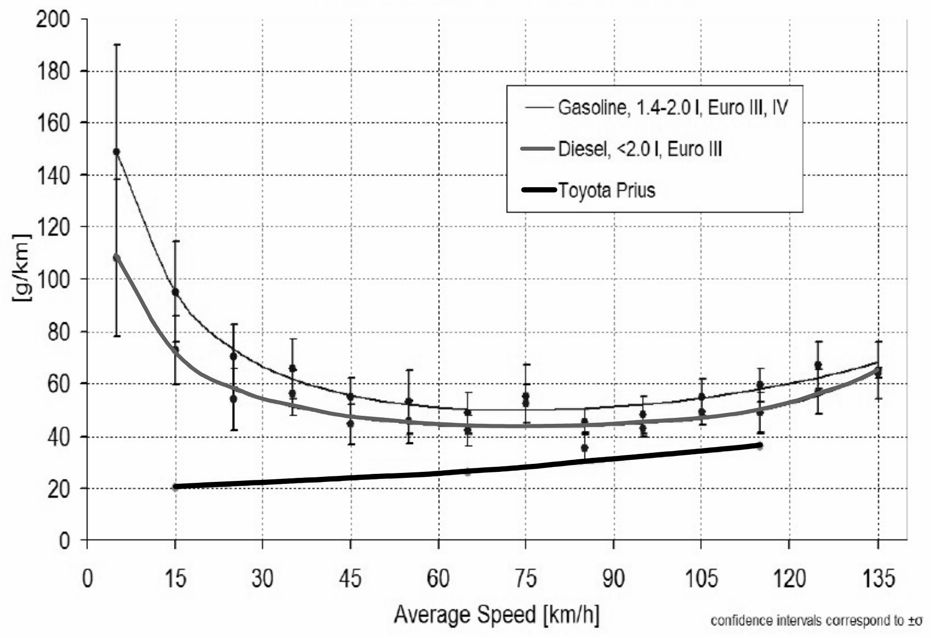


**Figure 1 - Comparison of the fuel consumption obtained with three different types of engine cars: gasoline, diesel and hybrid.**

## 2.1 A calculation tool for transportation pollutant emissions

Starting from this structure, it has been calculated (Calvino *et al.*, 2002) a synthetic parameter that can be assumed as the mean emissions released during a year in a given urban context by its vehicular running fleet characterized by an assigned composition. The whole procedure is based on the parameters indicated in Table 2 that refer to one of the classes in which the running fleet is subdivided.

**Table 2 - Main parameters constituting the synthetic indicator of the pollutant emissions from transportation**

| Parameter | Symbol | Subscript |
|---|---|---|
| **Age of the mean vehicle of the selected class** | | y |
| **Type of fuel** | | f |
| **Engine volume capacity** | | c |
| **Number of vehicles belonging to the given class** | $N_{yfc}$ | |
| **Mean speed of the vehicle (km/h)** | v | |
| **Mean trip length (km)** | t | |

| Parameter | Symbol | Subscript |
|---|---|---|
| **Transport demand** | $D_{yfc}$ | |
| **Occupation rate of the mean vehicle belonging to the class (inhabitant/vehicle)** | $t_{yfc}$ | |

On turn, the emission factors EF of a given class, that is the amount of pollutants released during a year by a given vehicle belonging to an assigned class by a unitary trip length, can be expressed as follows.

$$EF_{yfc}\Big|_{\forall class} = f(v) \tag{1}$$

While the whole emissions of the considered class can be easily computed as:

$$E\Big|_{\forall class} = EF_{yfc} \cdot N_{yfc} \cdot t \tag{2}$$

This directly leads to the definition of a synthetic indicator of the pollutant emissions of a given vehicular class, that is the Yearly Average Vehicle (YAV).

$$YAV\Big|_{\forall class} = \frac{\sum_{class} EF_{yfc} N_{yfc}}{\sum_{class} N_{yfc}} \tag{3}$$

On turn, the total pollutant emissions released by a given vehicular class are expressed by the following algorithm:

$$E\Big|_{total,\forall class} = \frac{YAV\Big|_{y,\forall class} \cdot D_{yfc}}{t_{yfc}} \tag{4}$$

## 2.2 An application to the town of Palermo

The town of Palermo, mainly due to its relevant population (one million people living and working in downtown and in the suburbs) and to the less effective system of public transportation, is responsible of a remarkable amount of pollutant emissions in the atmosphere. Table 3 reports official data referring to years 1999, 2001 and 2004. Moreover, since the town is almost lacking of industrial premises within the urban boundaries, such pollution can be essentially attributable only to the transportation system and to the buildings climatisation equipments.

In order of checking the reliability of the YAV indicator as a support for the policies devoted to the improvement of the air quality in urban areas, four transportation scenarios have been here proposed. Each of them is characterized by a different value of the mean speed of vehicles in the roads network and by the mean occupation rate. The selected values are typical of the urban areas, particularly in the Mediterranean region, where the urban layout is characterized by an old structure with narrow spaces between buildings that, not rarely belong to the country cultural heritage: this often determines a particularly low speed of the public and private means of transportation. Private (cars) and public (buses) transportation systems are supposed to contemporary operate in the town, as reported in Table 4.

YAV is here utilized for comparing emissions of several pollutant components (included particulate matter) produced by the four scenarios. Since the original data refer to years where the COPERT III was in force, we have adopted here this version of the methodology for the calculations referring to years 1999 and 2001, while the COPERT IV version has been utilized for calculations referring to the year 2004: of course this choice does not affect the generality of the proposed approach.

**Table 3 - Pollutants referring to years 1999, 2001 and 2004 in the town of Palermo**

| Type of pollutant | Releases (t/y) 1999 | Releases (t/y) 2001 | Releases (t/y) 2004 |
|---|---|---|---|
| **CO** | 41,103 | 38,413 | 25,440 |
| **$NO_x$** | 4,949 | 6,397 | 5,099 |
| **VOC** | 4,722 | 4,645 | 3,231 |
| **PM** | 233 | 264 | 288 |
| **NMVOC** | 4,414 | 8,290 | 5,218 |
| **$CH_4$** | 308 | 342 | 283 |
| **$NH_3$** | 43 | 128 | 108 |
| **$N_2O$** | 46 | 81 | 75 |
| **$CO_2$** | 808,410 | 999,220 | 877,397 |

**Table 4 - Mean speed and passenger occupation rate adopted for cars and buses in the selected scenarios**

| | v (km/h) | | | | to (pass/vehicle) | | | |
|---|---|---|---|---|---|---|---|---|
| **CARS** | 10 | 10 | 20 | 30 | 1.2 | 1.2 | 1.2 | 1.4 |
| **BUSES** | 20 | 30 | 25 | 25 | 10 | 30 | 20 | 30 |
| ***Scenario*** | ***A*** | ***B*** | ***C*** | ***D*** | ***A*** | ***B*** | ***C*** | ***D*** |

As it is possible to observe in Figure 2, scenarios can be compared in terms of four pollutants, although different combinations of the released emissions could be proposed. An analysis of the results referring to this simple application is apart the main goal of the present paper that is essentially devoted to show the feasibility of the synthetic indicator in hierarchically ranking different policy options concerning the mix of private and public transportation in urban contexts.

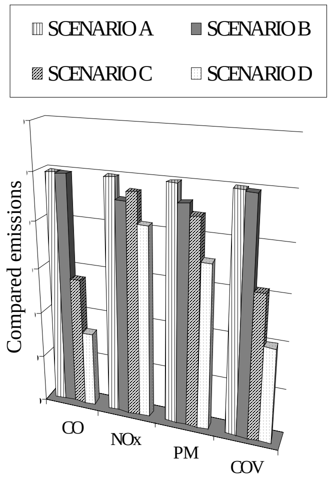


**Figure 2 - Comparing environmental performances of selected scenarios for the public/private transportation options.**

## 3. CONCLUSIONS

Through the paper a simple synthetic indicator of the pollutant emissions of a vehicular running fleet has been presented. The parameter essentially utilizes emission factors provided within the COPERT method that, in turn, requires a proper subdividing of the vehicular urban park into a suitable number of “emitting” classes. Once this statistical organization of the fleet has taken place, it is possible to build up an aggregate indicator that, by summarizing, simply represents the pollutant emissions of an average car that encompasses the main features of the vehicular park running in the urban context in a given period of time (say, a year).

This indicator can be usefully adopted by local administrations in order of hierarchically ranking different transportation policy options, by the point of view of the environmental performances.

Moreover, the changes introduced by the recent version of the COPERT (the release IV), particularly concerning the modification of the emission factors on innovative technologies, has been here discussed.

## ENDNOTES

[1] Microsoft, MS and Microsoft Access are registered trademarks of Microsoft Corporation

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