Development and Comparison of Statistical Procedures for the Estimation of Road Transport Atmospheric Emissions in Italy at Local Level

Sviluppo e Confronto di Metodologie Statistiche per la Stima delle Emissioni Atmosferiche da Trasporto Stradale in Italia a Livello Locale

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Riassunto
Questo studio analizza le stime delle emissioni da trasporto stradale a livello provinciale e confronta i risultati ottenuti da differenti metodologie top-down. In assenza di dati a livello locale, le emissioni sono adattate dal livello nazionale a quello locale attraverso l'utilizzo di variabili *proxy*, come previsto nella metodologia europea CORINAIR. Sono evidenziati i risultati prodotti dal modello MEDITRoad (APAT-CITEPA) a differenti livelli di disaggregazione spaziale mediante la scelta di opportuni indicatori e funzioni di allocazione. Un ulteriore confronto viene effettuato con i risultati di un'allocazione spaziale delle emissioni nazionali basata sulla *cluster analysis* relativa ad un analogo set di indicatori.

Keywords: air emissions; national emission inventories; local estimates; road transport; spatial disaggregation; statistical analysis; comparative evaluation.

1. EEA methodology for road emission estimations

Emissions from road traffic show an increase in trends from 1990 onwards, due to an increase in fuel consumption and a growth in passenger car traffic and in car ownership per inhabitant. Road transport is one of the major contributors to air pollution in Italy. Estimates at national level show that, in recent years, transport has been the main source of pollution in urban areas with regard to different pollutants and greenhouse gases (Saija et al., 2000).
The methodology used in Italy to estimate national emissions from road transport is COPERT III (Ntziachristos, Samaras, 2000) which is recommended by the European Environment Agency to compile national emission inventories according to the CORINAIR methodology (CORe INventory AIR). This mathematical model is based on large data requirements including information on the national automotive fleet and several related parameters such as speed-dependent emission functions, fuel consumption, average speed and mileage for each category vehicle and driving mode.
A bottom-up approach, even though desiderable in certain circumstances, would involve compiling activity data, e.g. vehicle flows, fleet composition and speeds, in a very accurate and updated way which is not often feasible (Crabbe et al., 2000).

In alternative to the CORINAIR standard top down approach based on proxy variables, two new methodologies are proposed in this study: the first, based on cluster analysis, takes into account local particularities and information (Saija, Romano, 2001); the second one, using MEDITRoad software, applies the COPERT model to two different levels of spatial disaggregation.

2. Cluster Analysis

A set of indicators related to transport activities is used to identify homogeneous areas in the Italian territory with regards to transport activities. Both vehicle categories and socio-economic information are considered simultaneously in order to classify homogeneous areas. The base data for the analysis are the values of seventeen variables for each of the 103 provinces into which Italy is divided, and which refer to the year 2001. The same analysis was carried out for the year 1996.
A description of indicators used to classify Italian provinces is the following list:

1. Employees in manufacturing and construction industry / Labour forces;
2. Employees in electricity, gas, steam and hot water supply / Labour forces;
3. Employees in trade, hotels, restaurants, transport and communication /Labour forces;
4. Employees in financial intermediation, real estate, renting and business activities / Labour forces;
5. Employees in public administration and defence, social security / Labour forces;
6. Urban road length / Surface;
7. Rural road length / Surface;
8. Highways road length / Surface;
9. Gasoline Passenger cars per capita;
10. Diesel Passenger cars per capita;
11. LPG Passenger cars per capita;
12. Light duty vehicles / Vehicle fleet;
13. Heavy duty vehicles / Vehicle fleet;
14. Mopeds per capita;
15. Motorcycles per capita;
16. Gasoline sales / Gasoline Passenger cars;
17. Diesel fuel sales / Heavy duty vehicles;

The choice of the variables is justified by easy availability of the relative data and relevance to traffic flows. Data relating to employees, labour forces and road lengths are provided by ISTAT (Industry and services census 1996 and 2001), vehicle fleet data by the Italian Automotive Association (ACI), fuel sales data by the Italian Oil Companies Association (Unione Petrolifera). A cluster analysis has been applied to find similarities between units and to identify groups in the data.
Provinces have been classified hierarchically and then aggregated by the Ward method using SPAD5 (DECISIA). Four groups have been individuated. For each cluster, COPERT methodology has been applied to estimate road transport emissions of five pollutants (NO_X, NMVOC, CO, CO_2, PM). For each pollutant, standard emissions e_i^k, by vehicle category k and province i, obtained by disaggregating national totals by simple proxy variables (population of the municipalities and road length) are compared with the estimated emissions $\tilde{e}_c^k$, by vehicle category k and for each cluster c, and then corrected by the following variation index:

$$V_c^k = \frac{\tilde{e}_c^k - \sum_{i=1}^{m} e_i^k}{\sum_{i=1}^{m} e_i^k}$$ where m is the dimension of cluster c

The corrected emission $\hat{e}_i^k$ for province i included in cluster c and vehicle sector k is:

$$\hat{e}_i^k = e_i^k (1 + V_c^k)$$ for each category k.

The deviation observed at national level is under the 1% threshold.

3. The MEDITRoad model

The MEDITRoad model is based on a top-down technique to be applied on two different spatial scales using multi-scale constraints: in the first step, COPERT national parameters are assigned to an intermediate (*meso*) scale, then COPERT model is applied on every meso-level and a normalisation process with the national level is carried out; the second step, from the meso scale level to the finest expected level (*local*), is based on spatial allocation of COPERT output data (activity and emissions factors), which ensures harmonisation of the emissions between both different scales. The identification of the meso scale is a free choice, according to the user preferences, national specificities, available data and the objectives of the emission inventory (Chang and Gaborit, 2004). In this study, the clusters previously identified have been chosen to define the mesoscale spatial level. The local level has been identified with provinces. All the indicators at provincial level, related with each cluster, have been used to perform the second step.

4. Conclusion

A comparative evaluation between CORINAIR standard top down methodology and the cluster analysis disaggregation shows an increasing performance to explain the emissions behaviour per macro area or per vehicle category. On the other hand, MEDITRoad methodology provides better results than CORINAIR standard, which performance is comparable with the cluster methodology. The best results have been achieved applying the data set indicators related to each selected cluster at MEDITRoad meso scale level. To compare estimates subdivided by province or by vehicle categories, the index of quadratic dissimilarity of Gini has been used in order to obtain a synthetic information on the dissimilarity between the distributions estimated by CORINAIR standard top-down procedure versus MEDITRoad or cluster procedure, over the national area and all vehicle categories.

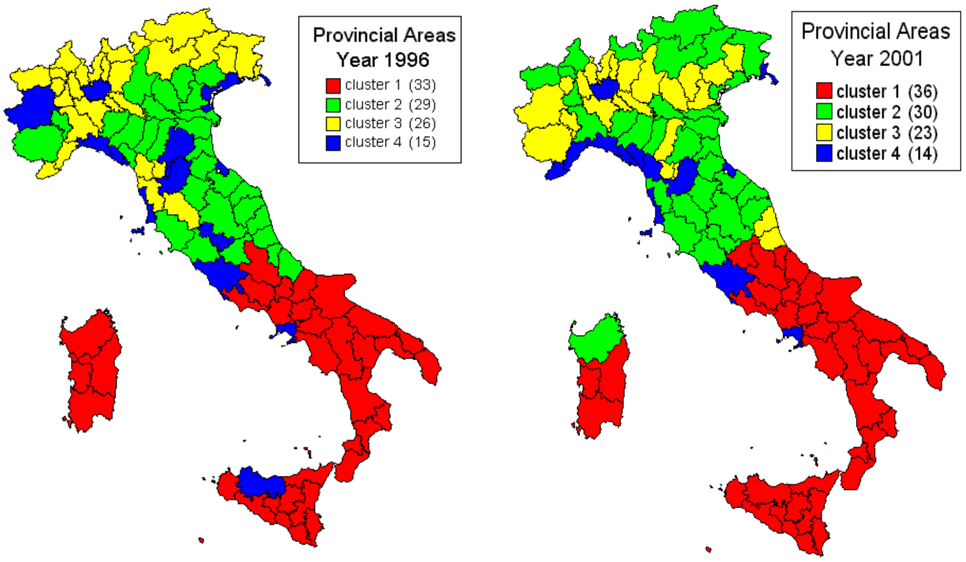
All these analysis have been carried out for the year 1996. Estimations for year 2001 are in progress.

Table 1: *Gini index per estimation methodology.*

Typology of data aggregation	MeditRoad vs CORINAIR standard	Cluster vs CORINAIR standard
Areal emissions	0,052	0,011
Vehicle categories	0,036	0,002

The index values range between 0 (identical distribution of the estimates) and 1 (maximum dissimilarity).

Figure 1: *Cluster aggregations at provincial level in year 1996 and 2001.*



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