SPENET - Software package for environmental regulatory assessment of noise and atmospheric emissions from urban traffic: application in Italian areas

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Abstract

An useful tool for environmental assessment from urban motor vehicle traffic was implemented on a Personal Computer. The package (model) consists of four modules (input data, noise and emissions levels calculations, graphic interface), and it allows the comparaison of real and future scenarios to evaluate the impact of urban transportation plans. The results of an Italian town in the surroundings of Milan are presented. A data structure for a GIS interface is designed.

1 Introduction

According to some new provisions introduced in 1991 about traffic impact in urban areas [1], Italian local authorities must evaluate noise levels to prepare new urban regulatory plans; as a consequence, there is a renewed necessity of impact assessment of urban traffic. Tha aim of this work is to provide an useful tool, that could be able to correctly analyse environmental problems of traffic and reduce the importance and the number of measures. Furthermore it is not so important to analyse only main effects (noise and emissions), than put them in relation with their causes (topography of road network, speed and composition fleet of vehicles, and so on).
The first part of this work focuses main characteristics of four modules of SPENET, summarily describing models' algorithms and its peculiarities. The second part contains main remarks of an application in a middle dimensions Italian town, that presents several characteristics of the most part of Italian urban areas. Some results about noise and emission levels are presented.

The last part deals with the attempt to interface SPENET with a GIS (Geographic Information System), and it describes the main functions to be implemented and some significative aspects of the data-structure, necessary to resolve problems to link a GIS with a mathematical model.

2 The model

SPENET is implemented in Fortran 77 language and runs on a Personal Computer in MS-DOS environment.
The software package SPENET include four modules:
- UDA: Urban Data Acquisition
- NIP: Noise Impact Processor
- EIP: Emission Impact Processor
- IGA: Interface, Graphic and Animation.

UDA: Urban Data Acquisition
This module loads the input data for the two following mathematical models, informations about urbanistic regulatory plan and urban topography, and includes building and street structural characteristics, traffic flows, drive cycles, vehicles category spleet, type of fuel and some environmental variables, as reference temperature (fig.1). It provides the two structured data sets, necessary to the calculation algorithms.

NIP: Noise Impact Processor
The model calculates the noise equivalent level LAeq,t. It evaluates the hourly average LAeq,1h on each road arc along the pavement's edge at different heights, according to the following algorithm [2,3,4]:

$$Leq(A) = Tf + a + W + S + P + F + R \qquad (1)$$

with:
Tf: function of weighted normalized traffic flow
a: experimental fitting parameter
W: variable depending from the rate of the width of the real and reference line
S: contribution due to the vehicle speed in each arc
P: function of road slope
F: parameter, dependent from kind of feather edge
R: correction term to refer simulated values to the receptor position.

The width of the respect zone of each road arc (further of this area there is a reduction of noise level of a selected value) is calculated according to an algorithm of linear propagation in open country.

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EIP: Emission Impact Processor
The model calculates the time emission rate (hourly; daily; period) of five conventional pollutants (NOx, SO2, CO, PTS, VOC) and benzene for each road arc. The algorithm considers warm and cold emissions, dependent from environmental temperature; it uses kinds of fuel, drive cycles and composition fleet of vehicles, that are considered in the model according to CORINAIR methodology [5].
The previous terms are considerd in the following formula [6]:

$$E_t = u * K * p_j * f_{jl}(s_i,t_i) * a_i \qquad (2)$$

with:
E_t: period emission caused by traffic
u: conversion term for measurement unit
K: kilometers covered by urban traffic during the period
pj: kilometer portion covered by vehicle class j
$f_{jl}(s_i,t_i)$: specific emission factor of the pollutant l at the environmental temperature t_i, to the medium speed v_i in the hour i for the vehicle class j; this term is calculated with a further algorithm, based on CORINAIR indications.
a_j: fraction of kilometers covered by traffic in the hour i

In Italy the most part of vehicles use the leaded gasoline that contains about 40 % weigth of aromatic compounds [7,8]. As a result of this the benzene emissions are estimated as a fraction (about 1/15 .. 1/20) of VOC emissions.

IGA: Interface, Graphic and Animation.
The results of the two models are represented in a CAD environment: it receives as input the ASCII file of road network topography, of emissions and noise levels for each road arc, and it plots various output thematic maps.

3 Application example

The package was applied on Valmadrera, a typical Italian town of about 10,000 inhabitants in the neighborough of the city of Lecco (about 40 km north of Milan). The area is characterized by an ancient metropolitan zone with complex urbanistic structure, and by the presence of a surrounding zone with industrial activity and highway; moreover, there is a residential area in the near hilly zone. So, there is three kinds of traffic: a metropolitan one in the ancient area, characterized by low speed and frequent jams; an industrial one, in the surrounding zone, composed prevalently by vans and trucks; a periodic flow towards the city of Lecco.

The road network was modeled by fifty arcs (fig.2), structured in three road classes, according to the previous consideration; in relation, a set of measurements of traffic flows were obtained in fifteen significative spots, and a set of measurements of noise levels during five days from 7.00 a.m. to 7.00 p.m..
Emission levels were calculated for each road, vehicle and speed category, and then the global emissions rate for each pollutant were obtained (fig.3).
The comparaison between simulated and measured noise levels are quite satisfactory (fig.4); the model overestimates the LAeq values in the daily period, and in the night period underestimates, according the increased importance of sporadic noise.
Other SPENET applications are carrying out in towns situated in the neighborought of Milano, using a widest set of field measures.

4 A data-structure for a GIS interface

To improve the use of SPENET as a planning tool a GIS (Geographic Information System) interface was created. This module allows the user to interact with the models. Operating into the GIS environment, the user can configurate an appropriate input data set, runs the models and obtains the representation of the new scenario.
In order to provide the GIS interface to SPENET, the following software functions had to be implemented:
- two representation levels: a global one, to paint a complete picture of study site and its characteristics, and a local one, to zoom a particular portion and to approach to specifical analysis functions;
- the search functions are even structured on these two definition levels and provide thematic maps of road network about vehicles category split, speed and output noise and emissions levels (1st level) and respect zones (2nd level);
- some analysis functions provides graphic interpolation of hour values of selected input and output parameters;
- the cartographic functions, able to integrate raster and vectorial data formats of input topography;
- the planning functions: the user can modify some significative input parameters, like vehicle speed, fleet composition and traffic flows, related to some arcs of the road network; so he can analyse models' outputs, represented by the GIS interface.
- the plotting and saving utilities of the simulated scenarios.

According to the previous analysis phase, the GIS data-structure was designed. The GIS interface deals only with data sets that the user selects, and it loads them from external data-bases (DOS or UNIX environment). The only objetcs included in the data model are the ones necessary to the grafic representation or the ones that must be loaded in the GIS data-base itself; informations are structured in fixed data (topography, road network,

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measurement spot positions, etc.) and variable data (measurments, vehicle category split and speed, simulated emissons and noise levels, etc.).

5 Conclusions

The software package SPENET is implemented to run on a Personal Computer, and contains input data acquisition, models simulation and graphic output data interface on a CAD environment.
The simulation results, obtained in the test real case, put in evidence the traffic and urbanistic problems of a typical Italian middle town, characterized by a complex topography, a different vehicles flows and a little frequency of catalytic cars.
The aim of this work is to reach a global approach to the planning activities related to impact of traffic in urban areas, both for noise and pollutant emissions; in order to properly face questions related to mobility needs, traffic management, pollutant control and its impact on human health, a territorial tool is linked to mathematical simulation model.
In order to include in the system urbanistic considerations, a further module will be designed to compair graphic and numerical output with the urban traffic plan, provided by local authorities.
The GIS interface will be developed and some test cases will be used as validation of the module. Furthermore in the next future the data-structure will be updated and two other modules will be added, to develop the planning functions; the user will be able to interact even with some topografic elements of road networks, and to choose the simulation model and its parameters into a models' data base.

References

1. Decreto del Presidente del Consiglio dei Ministri del 1 Marzo 1991. Limiti massimi di esposizione al rumore nell'ambiente abitativo e nell'ambiente esterno. G.U. Serie Generale n. 57, 8 Marzo 1991, 4-7.
2. Castagna E., Invernizzi S., Bassanino M., Pozzi A., Un modello matematico di supporto alla zonizzazione acustica del territorio, pp. 222-227, in Atti della Giornata di studio sull'inquinamento atmosferico, Milano, 17 Giugno 1994.
3. Bassanino M., Bazzoni P., Buzzi F., Castagna E., Invernizzi S., Ledda S., Tamponi M., Un modello matematico di supporto alla zonizzazione acustica del territorio. Analisi di sensibilità, pp. 179-185, in Atti del XXII Convegno Nazionale Associazione Italiana di Acustica, Lecce, 13 -15 Aprile 1994.
4. Brambilla G., Cannelli G. B., Santoboni S., Valutazione e previsione dell'inquinamento acustico urbano; mappa del rumore di Roma, Rapporto scientifico n. 56, Istituto di Acustica O. M. Corbino, CNR, Roma.

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5.COPERT90, CORINAIR Working Group on Emission Factors for Calculating 1990 Emission from Road Traffic, Vol. 1: Methodology and Emission Factors, Environmental Consultancy, Brussels, 1991.
6.Gagliano F., Tamponi M., Inventario delle emissioni: un ssistema di modelli per gestire le emissioni provenienti dagli impianti industriali dal traffico autoveicolare e dagli impianti di riscaldamento, pp. 270-276, in Atti della Giornata di studio sull'inquinamento atmosferico, Milano, 17 Giugno 1994.
7.Stazione sperimentale per i Combustibili, La Rivista dei Combustibili, Fascicolo 7-8 , Vol. 47 , Milano, Luglio-Agosto 1993 .
8.Volkswagen AG Research and Development, Unregulated Motor Vehicle Exhaust Gas Components, Wolfsburg, 1989.

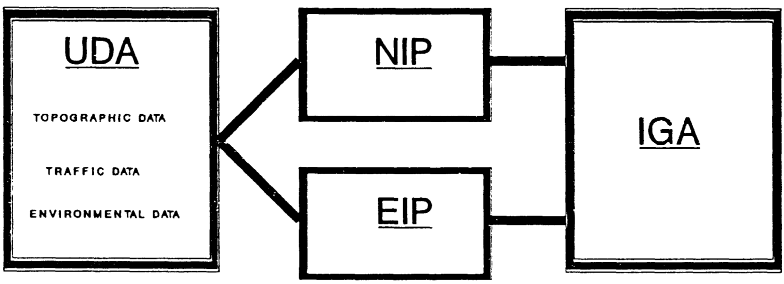

Figure 1

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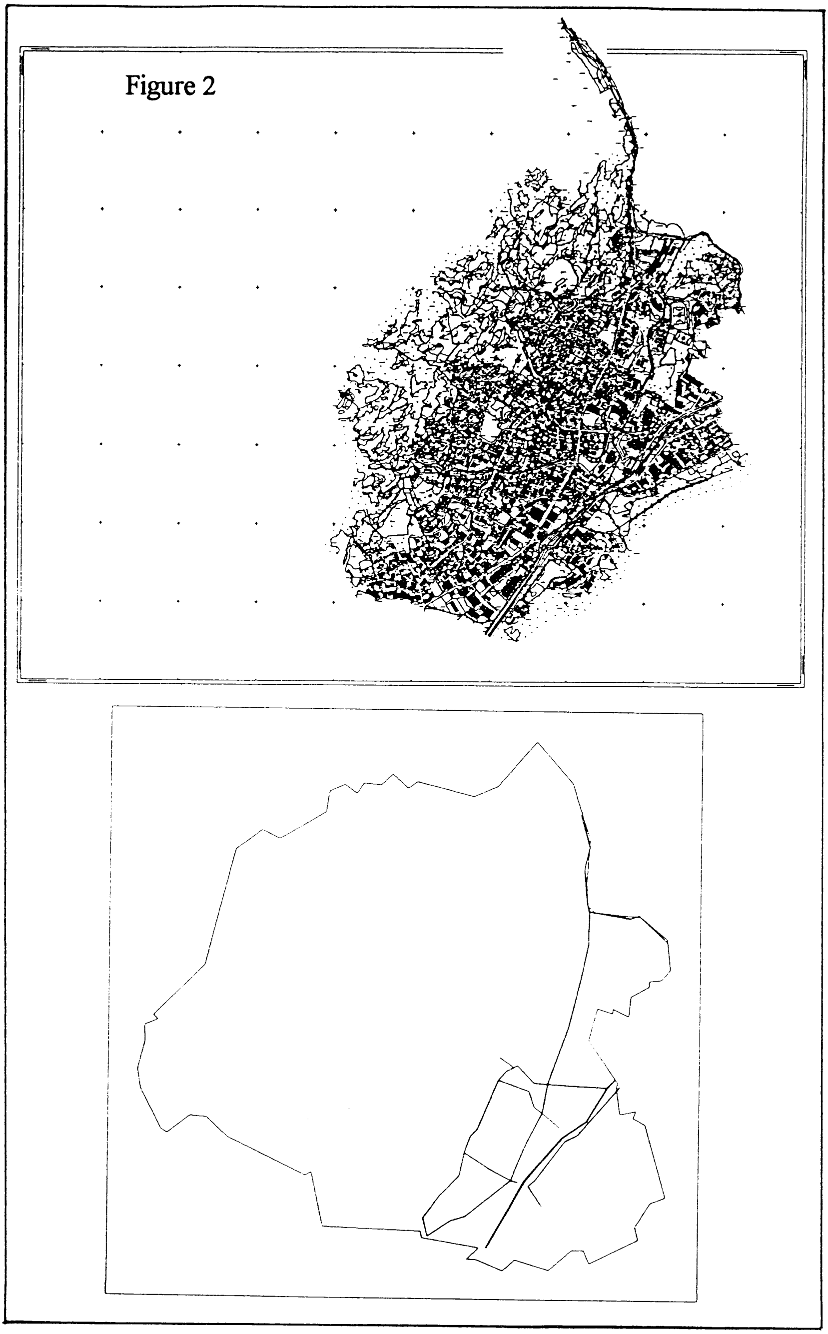
Figure 2



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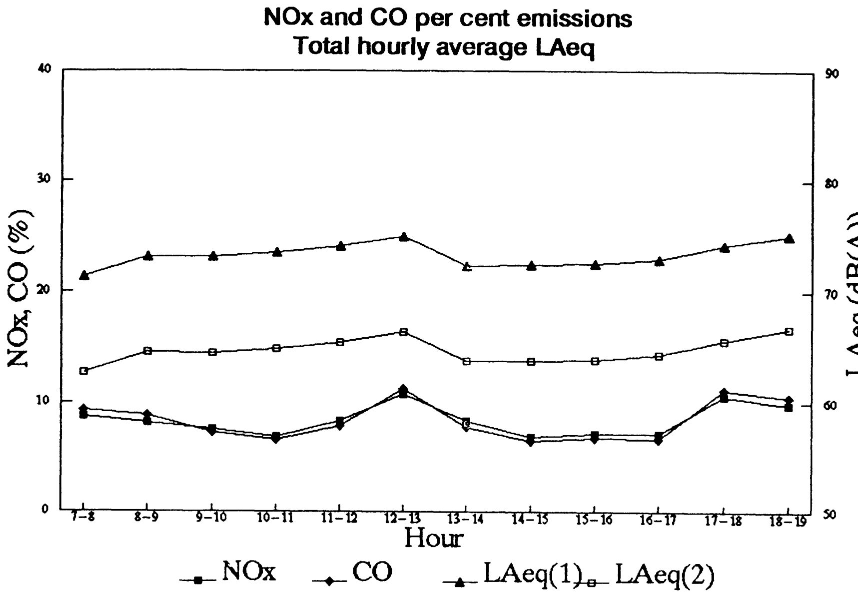

NOx total period emission 431.95 kg
CO total period emission 1581.33 kg
(1) Road arc n.11 Leq(A) distribution
(2) Road arc n.14 Leq(A) distribution

Figure 3

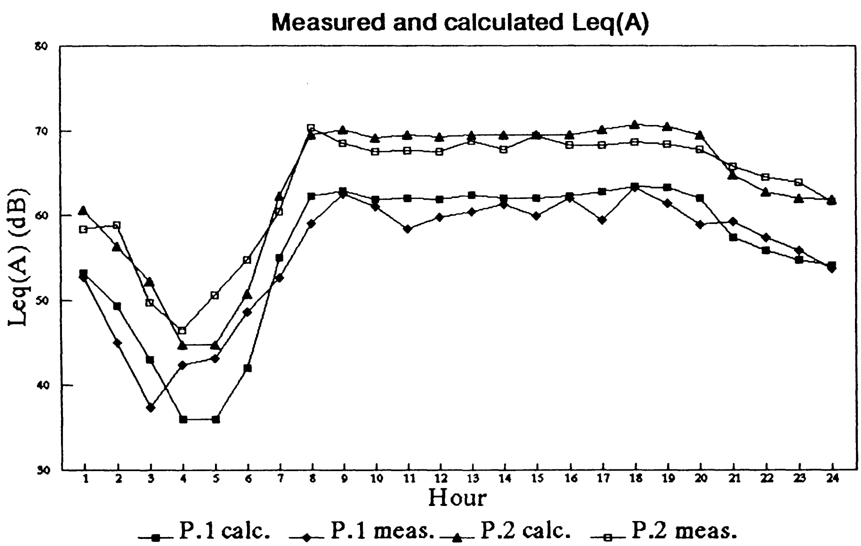

Figure 4