A graphical software interface for traffic emissions analysis

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Abstract

To assure a satisfactory air quality in congested urban areas traffic managers have to consider vehicle emissions among the effects of traffic planning and management. In this paper the general structure of an information system capable to support traffic management with traffic and emissions analysis is presented. The information system is made of two modules: TRANSNET and EMISSION. TRANSNET implements a programming tool for the modelling of traffic flows in the transportation network of a city. EMISSION links the modelling of traffic with the evaluation of vehicle emissions corresponding to vehicle operating conditions determined by traffic. In particular, in this paper the current implemented version of EMISSION is presented, which represent information relative to an individual vehicle in the traffic flow of Naples city. EMISSION uses driving cycles to characterise vehicle operating conditions and traffic image to characterise traffic conditions relative to determined driving cycles. It displays fuel consumption and emissions measured in the laboratory using determined driving cycles. This application is useful to compare traffic conditions, driving cycles, fuel consumption and exhaust emissions connected with different streets and traffic levels in the urban network.

1 Introduction

In highly congested urban areas, traffic planners have to consider vehicle exhaust emissions among the effects of traffic plan and traffic management policy. This is more emphasised in Italy, where a specific law obliges City
Major to stop vehicle circulation in the case pollution level exceeds limits established by law.

Thus, since the first phase of traffic plan conception, planner should evaluate expected pollution levels related to predictable critical traffic conditions for different zones. Pollution levels depend on a number of factors, traffic emissions are one of them, which can be up to a certain extent controlled.

Traffic emissions are a function of flow vehicle composition and of individual vehicle exhaust emissions. Vehicle composition can be assumed on the basis of statistical surveys. Thus the problem is solved by the determination of vehicle operating conditions and related exhaust emissions for different traffic conditions.

In this paper, the structure of a decision support system for traffic planners capable to support traffic management with traffic and pollutant analysis is presented. The development of DSS is in progress with the co-operation of Institute for System Analysis of the Academy of Science of Moscow and Istituto Motori of Research Council of Naples. The information system is made of two modules: TRANSNET and EMISSION. TRANSNET implements a programming tool for the modelling of traffic flows in the transportation network of a city. EMISSION links the modelling of traffic with the evaluation of vehicle emissions corresponding to vehicle operating conditions determined by traffic.

TRANSNET is based on some well known models and algorithms [1] [2] and some specific methods developed [3] [4] for the evaluation of traffic flows. EMISSION input information is based on the experimental information detected on road, on results of a complex procedure of data analysis and classification founded on multivariate statistical analysis [5], on emission laboratory measurements [6]. An experimental approach was followed to determine vehicle operating conditions representative of different traffic condition for each road. Vehicle operating conditions are determined by driving cycles performed by each vehicle through the traffic. Typical driving cycles are determined by statistical analysis of vehicle kinematics recorded on the road by instrumented vehicles. Cluster analysis is used to determine driving cycles by velocity profile detected on the road and to classify them into groups of driving cycles representative of different traffic conditions [5]. Driving cycles determined by this way are used to measure emissions in the laboratory.

EMISSION is intended to evaluate emissions of the vehicle flow on the basis of a given vehicle composition of flow. Vehicle emissions are measured in laboratory using driving cycles determined for each vehicle category. At the current status of research, experimental results achieved so far are relative to just one medium size vehicle. Actually EMISSION uses driving cycle to characterise vehicle operating conditions, an image of traffic recorded while that cycle was detected to characterise traffic conditions, on-road and laboratory measured fuel consumption to compare the two different situations,
exhaust emissions measured in the laboratory with the medium size gasoline car.

Further developments will be the extension of emission data base to many different vehicle category to allow the emission analysis to consider different traffic vehicle composition for emission evaluation.

2 General structure of DSS.

In fig. 1 the general structure of the information system is presented. The shaded area refers to Emission module. Transportation Network and Traffic Flows is common information of the two modules. In fig.2 the structure of graphical interface for emission analysis is shown.

![Figure 1: The general structure of the information system](image-url)
3 Program TRANSNET.

The program TRANSNET implements a programming tool for the modelling of traffic flows in the transportation network of a real city. The program is designed as a Windows application for IBM-compatible PC with the self-explanatory "user-kind" interface, which provides the following functionality:

- Input and edit an information about the transportation network. This information includes both the geographical data (coordinates of nodes and arcs) and the traffic characteristics, i.e. the set of characteristics, that are necessary to perform the modelling of traffic flows in the network
- Modelling of traffic in the network: evaluation of an origin-destination flows, assignment of OD flows on the network, evaluation of shortest paths etc.

3.1 General structure of information

From the perspective of modelling traffic flows, transportation network is considered as an oriented graph, which consists of nodes (intersections) and arcs (links). Each node and arc has a set of characteristics, that define the conditions and the cost of moving along the arc, and the cost of any manoeuvre at the intersection.

3.1.1 Hierarchical structure

The following hierarchical structure of information is used:

- Basic element of information is a "line", as an ordered sequence of "points". Two neighbour points in a line are connected by a pair of arcs (namely, the "forward" and the "backward" arc). Points on a line correspond to an intersections (in a case of streets) or stations of the "railway-like" lines (see below).
Lines of the transportation network are combined into "sets of lines". It is preferable to combine lines with similar characteristics in a single set (highways, main streets, small streets etc.). This allows the use of the "default" arc characteristics for each line and simplifies the description of the network.

On the top of hierarchy we distinguish two main "categories" of lines: "street" and "railway-like" lines. The latter include the lines of transport types, that use their own separate way, and do not occupy street space in the city (railway, underground, subway lines etc.).

### 3.1.2 Traffic characteristics of arcs
The traffic characteristics of arcs are the following:

- Class of the arc. This characteristic defines the cost (the travel time)-flow function of an arc.
- Number of lanes and the parking permission flag.
- Length of the arc
- Flags, which define the permission of tracks and the presence of public facilities (bus, trolley-bus etc.) in the arc.

### 3.1.3 Traffic characteristics of intersections
The complete description of an intersection is given by a matrix of costs of manoeuvres at intersection. The specification of the individual matrix for each intersection in large networks seems to be rather difficult task for the user. However the majority of intersections in real networks can be described with the use of predefined "standard" cost characteristics.

The program distinguish following standard manoeuvres at intersections:

- forward move - move along the current line (it is not necessary a geometrical straight line);
- overturn - move back along the same line;
- right turn and left turn - relative to the direction of the forward move.

The additional information, that can be specified for the standard intersection, is the "scheme of permitted turns", i.e. matrix of flags, which define the permission of each manoeuvre at intersection.

If an intersection has non-standard characteristics (costs or geometry) it is declared as "user-defined", and the matrices of costs is inputted by user.

### 3.1.4 Structure of information
The structure of information provided for the system of "default setting" of traffic characteristics of network objects. Namely, the default arc characteristics, specified for a set of line (single line), are automatically applied to each line in this set (each arc of this line). These defaults can be overridden for the individual lines (arcs), if necessary. Similarly the default scheme of turns, specified for both directions of moving along a line, is automatically applied to each point in this line.

This principle of "default setting" provides the essential decrease of user input.
3.1.5 Classes of arcs
The main characteristic of an arc is a cost-flow function, which defines the dependence of cost of moving along the arc on the current flow through the arc. The structure of information contains a database of predefined cost-flow functions, which are applied to arcs of different classes. The specification of class in the description of arc referred this arc to a particular function from this database.

Cost-flow function can be defined either in the analytical (polynomial or exponential approximation) or in the table form. In a first case the coefficient of an analytical functions are inputted, otherwise the name of the file, that contains a table is specified.

3.1.6 Origin-destination zones
The origin-destination zones are presented by a set of points of special category. These points are linked to the normal points with the so called "virtual" arcs. Main characteristics of OD-points are:
- total out-flow;
- total in-flow;
- cost-characteristics of virtual arcs, which link OD-point to the normal points of the network.

3.2 Models and algorithms
The main modelling tasks, performed by the program are:
- Finding the shortest paths (i.e. paths with a minimal cost). The effective shortest paths algorithm [1] was adopted to take into account the costs of manoeuvres at intersections (turn penalties).
- Evaluation of an origin-destination flows. Evaluation of an origin-destination flows is based on the entropy maximising procedure. The "weighted" entropy function is constructed with the use of the empirical "travel cost distribution" function [3] [4].
- Solving the traffic assignment problem. The linear approximation method of the solution of equilibrium (capacity constrained) traffic assignment problem was implemented. The classical Frank and Wolfe algorithm [2] was adopted to incorporate several classes of travellers (those using the public facilities, private cars and tracks).

3.3 The interface of the program
Main elements of the user interface are:
- Menu and a control bar for selecting the appropriate functions and commands.
- "Map window", which contains a graphical representation of the network.
- Specialised dialogs and pop up windows, that are created at a run-time for input of data, specification of parameters, choosing different options, visualisation of requested information etc.

4 Program EMISSION

Program EMISSION is designed on the base of the program TRANSNET and is intended (as a perspective goal) to link the modelling of traffic with the evaluation of the emissions and pollution in the city. The current version of a program serves as a programming tool for the visualisation of an empirical data on the emissions and pollution, and, in particular, the graphical representation of data for the transportation network under issue.

4.1 General structure of emissions data

4.1.1 Traffic level data
The empirical study shows that the variety of different traffic conditions in the city can be divided into groups with similar characteristics with respect to emissions and a fuel consumption the so called" traffic levels". Each traffic level is characterised by the following set of data:
- emissions of different types (CO2, CO, HC, NOX, and particulate)(g/km);
- fuel consumption (g/km);
- reference to a typical "traffic cycle";

Traffic cycle describes the typical travel rate of a vehicle: the dependence of the velocity and gear on time. Traffic cycle data is stored in a file and is linked to the traffic level data via reference to a file.

An additional visual characteristic of traffic level is an image of the typical traffic conditions in a street. These images (if available) are stored in files and linked to the traffic level data via reference to file.

4.1.2 Emissions data
The traffic level data sets for all basic traffic levels are combined in a container; this container constitutes the complete description of emissions data. The program handles the general emissions data (i.e. the emissions data, which characterise the average emissions for the whole city), as well as the individual emissions data sets, which can be specified for each street (or arc) in the city.

The special database contains the description of routes, for which the measured emissions data is available.

4.2 The program interface

4.2.1 Main menu
Main menu of the program consists of the basic command groups (see the description of the program TRANSNET) and an additional group Emissions. Group Emissions include 2 command items:
4.2.2 Main window

Main window contains:
- the Map window;
- the "Route view" dialog.

Map window contains the graphical representation of the network. The routes, for which the measured data is available, are shown on the map. "Route View" dialog is used to select an appropriate route, and to track route street-by-street or point-by-point. The selected route/point on a route is highlighted on the map. (fig. 3)

![Main window](image)

Figure 3: Main window

4.2.3 Emissions data

The general emissions data and the individual emissions data for the currently selected street is displayed and edited via the "Emissions" dialog. The "Emissions" dialog contains:
- a list of traffic levels;
- histogram of emissions and fuel consumption for the traffic level, currently selected in the list;
- histogram of the traffic cycle;
- image of typical traffic conditions.

Edit button calls the special "Edit" dialog for editing the data of the selected traffic level.

This dialog is used for changing the values of emission/consumption, and setting the references to the traffic cycle data file (fig. 4), and image file (fig.5).
Figure 5: Emission window representing traffic image.

**Key Words:** Traffic management - information system - emissions

**References**