A modeling framework for impact assessment of urban transport systems

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Abstract

An integrated software tool environment is presented, and a methodology is proposed for the operational support of the local authority, for analysis of the impact of transport measures in terms of network energy consumption and pollutant emissions. It is based on work done by the European Union within the save program (specific actions for vigorous energy efficiency)—Slam project (supporting local authorities methodology). As background, the Slam project is described, with the principal aspects and needs of environmental and traffic network management. The central section defines a methodology able to support technicians in recognizing the traffic asset and decision makers in evaluating interventions on urban transport infrastructures or technological systems. The role of the different models and their interactions with the transport telematics services currently active on the Florence (Italy) network is discussed. Finally, the procedure for calculating the traffic impacts on energy consumption is described with the help of a test case, the evaluation of a dedicated bus corridor in Florence. © 1999 Published by Elsevier Science Ltd. All rights reserved.

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1. Introduction

Sustainable mobility in an urban context requires a set of coordinated interventions aimed at improving the energy efficiency of the transport network. This involves a reduction of the total energy used by transport systems, and this can be achieved through the shift of a significant portion of the demand from private to public means and the continuous monitoring of the
environment. Local authorities must also be provided with the methods and decision-making tools they need to handle such complex problems as improving the energy balance of the transport network through environment control of traffic flows. A particular problem for the technical staffs of local administrations managing pollution monitoring networks concerns reliable estimates from monitoring stations of the real contribution of traffic flows to total pollution levels.

This paper presents an impact-evaluation approach for urban transport interventions and outlines the research carried out by the Florence transit company, ATAF, in the framework of the SLAM project, supported by the SAVE program of DGXVII of the European Union.

The aim of the project is to define and implement a methodology to support decision makers in the evaluation of energy and environment impacts relative to some candidate interventions on urban transport infrastructures or on technological systems.

The decision support system (DSS) paradigm (Bielli, 1992) is used. A DSS architecture, based on a blackboard model, permits the integration of different optimization, simulation and evaluation modules and the use of specialized numerical algorithms and artificial intelligence techniques (Bielli and Reverberi, 1996) to solve defined subproblems.

The methodology developed integrates models and software tools related to the estimation of arc flows on the network for a given transport demand, traffic simulation and the evaluation of energy consumption and pollutant emissions (Anderson et al., 1994).

The modeling framework consists of a database covering data relative to the transport network and the territorial and environmental context. The architecture of the models and the logical interactions among models utilized in SLAM methodological approach are diagrammed in Fig. 1.

To evaluate the performances of the transport system, the energy consumption and the environment compatibility relative to the implementation of an intervention, indicators have been selected with reference to a particular scheme of the urban site (zones, itineraries, etc.) in order to effectively characterize the impacts on mobility, energy and environment.

The ‘man in loop simulation’ approach taken by SLAM consists of an interactive and iterative process. Results of the modeling computation and evaluation are presented to decision-makers for modifications of some parameters and system elements, thus creating a new scenario, which represents feedback providing new inputs to the simulation chain. The process is repeated until a satisfactory solution has been obtained.

Simulation models were first calibrated on the current situation of the urban transport area of Florence city (with reference to the time period 7.15–8.15 a.m.), using transport demand data from the population census of 1991. A first experimentation of the integrated modeling software was carried out on a reserved bus itinerary along a main corridor of the transport network. In conclusion, a review of the developed methodology and software tools used is presented in Section 2, then indicators for traffic impact evaluation are discussed in Section 3. Finally, case studies evaluated are illustrated in Section 4.

2. The SLAM approach

The SLAM project aimed at developing a methodology and an integrated software environment (models, database and territorial representation) for estimating the energy consumption and emission effects of monitored network traffic situations and/or of transport interventions. In the
short term the realized software prototype provides support to the local authority for analysis of traffic, starting from the data acquired (traffic congestion and user behavior, pollutants, travel times, traffic loads, etc.) by the different transport telematics services active on the Florence network, both public and private (urban traffic control/utc, automatic vehicle monitoring/avm, emission pollution monitoring/epm, variable message signs/vms, etc.) (Ambrosino et al., 1994).

In the medium term, the local authority technicians can use the SLAM methodology and tools for the urban area transport planning process. They can identify which zones are most promising to any proposed intervention in terms of energy consumption and emissions, as well as estimate the overall network effects. Different types of transport interventions can be evaluated, including traffic management schemes, signal control policies and new transport infrastructures.

The defined ‘models chain’ is composed of the following main models or software modules:

(a) the traffic data acquisition module, providing traffic data input collected from field services (mainly via UTC system). These data, which represent the traffic loads on the links equipped with detectors, can be completed at network level by the identified data completion module (included in the KITS software package);
(b) the simulation models, for calculating the traffic link flows (EMME2 assignment model) and the related system performances (trip time, average speed, etc.) or representing the behavior of traffic on the network (AIMSUN2 traffic microsimulator);
On the basis of each model’s characteristics, a set of indicators was analyzed in order to synthesize the overall impacts on the three main environment sectors: mobility, energy and pollution. SLAM thus permits the analysis and evaluation of different transport scenarios, comparing the results obtained with the reality (comparison among the computed quality indicators and the defined threshold values), with the possibility of revising the intervention hypothesis if the results fail to comply with the reference quality standards of the mobility-environment system.

It is possible to update the information base on which the ‘model chain’ works and to support the calibration and validation of the chain itself. In fact, the kernel of the developed support software tool is the integrated data base (IDB), a database for collecting and managing transport network, energy, territorial and environmental data, acting as a blackboard for all the different models, where each model can read and write input and output data respectively. The IDB includes a high level of interfacing with existing monitoring and control systems (Ambrosino and Turrini, 1995). The logical database structure is composed of five different groups of data, relative to the transport network, the O–D matrices, the macrozones and corridors, the technological sensors, the estimated and measured data.

Several software packages are currently operated by ATAF, in the ‘models chain.’

(a) The traffic data acquisition module provides data input collected from field control and monitoring systems. In particular, the data collected (via transfer file) by the UTC system active on a large part of the Firenze network, represent the monitored traffic flows on each link equipped with loop detectors. These data can be completed at network level by the data completion module of KITS software and used for describing the overall traffic situation on the network.

(b) KITS is a knowledge-based environment for traffic analysis and management operations developed and tested under the EU ATT/DRIVE program (Bielli et al., 1994). Traffic flow behavior modeling and completion capabilities are the features of KITS that have been most important for the SLAM operational tool. Based on such functionalities, a KITS model of the application area, linked to the flows data collected in real-time by the network sensors, allows a complete representation of traffic evolution over a given time period. This picture is continuously updated and can be used to obtain new estimations of traffic energy consumption and emissions (Ambrosino et al., 1993).

(c) EMME2 is a transport assignment model using a representation of network supply (in the form of ‘flow-delay’ functions) and transport demand (in the form of origin–destination matrices) to make an estimate of traffic flows and speeds for each link in the network (INRO, 1994).

(d) AIMSUN2 microsimulator (Advanced Interactive Microscopic Simulator for Urban and Non-Urban Networks) is a model able to reproduce the real traffic conditions of the urban network. The behavior of each vehicle on the network is continuously simulated, and traffic conditions are identified by the composition of network flows in the access points and in the links. These data could be obtained as results of EMME2 model run or from UTC data acquisition system (integrated by KITS) or from experimental data collection. AIMSUN2 was developed by the Universidad de Catalunya, Spain (1995).
(e) TEE (traffic emission and energetic) developed by ENEA, the Italian Alternative Energy Agency, in Rome, is a model for calculating the amount of energy consumption and emissions in a particular time period, starting from link or area traffic flows, taking into account such factors as the age and the conditions of the different vehicles and the slope of the road (Negrenti, 1994).

(f) UADM (urban area dispersion model), developed by the FMA Company (Applied Meteorology Foundation) in Florence, is a model for the estimation of the pollutant diffusion produced by vehicular traffic and the resulting pollutant concentration levels in a defined application area. The model takes into account the morphological area characteristics, such as the street ‘canyons’, intersections and parking (SLAM/SAVE, 1996).

3. Traffic impact evaluation

In this section are described the main steps followed in the SLAM project for the evaluation of major impacts of both planned interventions and the reference network traffic states. The term ‘reference state’ is used for the picture of the mobility–environment system, made up of all data and parameters, in a specific daytime period.

The evaluation procedure contains two different phases, related both to data acquisition and the estimation of suitable indicators which quantitatively express the quality value of the three examined sectors (mobility, energy and pollution). The computation procedure is carried out by means of the above models interacting with the integrated database (IDB). As basic indicators of mobility performance, the number of users per km and the average speed have been considered, because they represent respectively the quantity and the quality of the transport network.

The most significant indicator of energy efficiency selected is the ratio between the total fuel quantity consumed and the number of users per km, while for air pollution, emissions levels and CO, NOx concentrations were selected, that is the emissions density (kg/h/km²), the maximum and minimum traffic emission intensity (kg/h/km) and maximum and minimum pollutant concentration (mg/m³).

The different indicators are calculated on the basis of:

(a) ‘Macrozones’: the total urban area is divided up into a number of different macrozones. The indicators relative to each macrozone are obtained from the values of indicators on each link passing through the macrozone. If a link runs along the edge of two macrozones, the contribution of this link is divided between the two macrozones affected.

(b) ‘Corridors’: transport corridors represent important streams of mobility in a city; the value of a performance indicator for a corridor is calculated by aggregating relative values for the set of links which compose this corridor.

Each performance indicator can be provided by a single macrozone and there is a correspondence with the traffic zones used in EMME2. The purpose of defining macrozones and corridors is to identify areas with similar characteristics or regulated by the same administrative acts as regards threshold values for particular indicators (e.g. pollutant concentration). In this way it is possible to give a quick, synthetic picture of the functioning conditions of the mobility–environment system...
and to indicate the efficiency of single zones in dependence with the level of service supplied by traffic itineraries that are supposed to provide access to specific urban zones, such as the city center.

Once the indicators are calculated, the results are compared with the current state and/or threshold values in order to verify whether the proposed scenario or intervention represents an improvement, matching the targets defined by the local authority. The procedure for calculating performance indicators has been incorporated within the IDB, which contains the output data from the relevant models.

4. The case study

The methodology and models chain were calibrated for the current traffic situation in Florence of the year 1996, with particular emphasis on the hour between 7:15 and 8:15 a.m. The EMME2 model, which produces input for the emissions and dispersion models, was calibrated with 1991 Census data and data collected for specific links by the urban traffic control system.

A similar approach was taken with regard to the calibration of the other models. The overall simulation included the calculation of performance indicators for 53 macrozones and corridors.

In particular, the scenario considered has been utilized for the implementation of a dedicated bus corridor with priority measures at traffic lights ('Clean Busway') from the Scandicci, an industrial and residential suburb area, to Florence city center. The first results show a significant modal shift from private to public transport (30–50%), and a reduction of energy consumption and emissions (1.6–2.25%).

Another application concerned the simulation of a new light train infrastructure with park and ride facilities. The assignment model and the hypershortest path algorithm have been calibrated with estimated O/D matrices and new performance parameters of the transport networks.

5. Conclusions

The methodology and support tools pursued in Florence city by the SAVE/SLAM project have been described. From the experience of this project, the importance of the local authority’s commitment is clear, including that of its operational and decision-making teams, in order to provide real benefits to the city. From the information point of view, benefits concerned the integration of the data and parameters coming from the traffic and monitoring services, allowing an updated analysis of the mobility, energy and environment situation in the city.

References


