

An integrated model to evaluate road traffic emissions in wide-area planning

Luigi PIEMONTESE* & Francesco PISANO*

*University of Naples "Federico II", 80100 Naples, Italy

Fax +39 081 25 38 616 - email: piemonte@unina.it, fr.pisano@virgilio.it

Abstract

In this note we describe an integrated model to estimate road traffic emissions and to evaluate different scenarios in wide-area planning. The model is a part of a Decision Support System (DSS) we have designed at University of Naples as a support in defining outlines of wide-area plans and in evaluating choices taken by the planners with quantitative indicators when possible. In fact, to plan a sustainable development, new locations for socio-economic activities can be planned and great attention has to be taken over reorganization of mobility system. Considering that wide-area plans have to be submitted to Strategic Environmental Assessment, as provided for by Directive 2001/42/CE, and that road transport induces very significant environmental pressures, we have included in DSS this integrated model to simulate scenarios concerning different socio-economic system organizations and road network layouts and to estimate road traffic emissions in each scenario. Actually the model has been calibrated and it is applied to the General Provincial Territorial Plan of Province of Latina. In the note we present early results.

Key-words: *wide-area planning, simulation models, road traffic emissions, air pollution, sustainable development methodology.*

Résumé

Dans cette communication on donne une description d'un modèle intégré pour la détermination des émissions dues à la circulation routière et l'évaluation de différents scénarios pour la planification territoriale. Le modèle fait partie d'un Système de Support aux Décisions (SSD), qu'on a projeté à l'Université de Naples, pour aider les urbanistes leurs donnant des indicateurs quantitatifs pour évaluer leurs choix. Attendu que la planification territoriale doit être soumise à l'évaluation stratégique de l'environnement, selon la directive 2001/42/CE et que les véhicules provoquent un fort impact, on a prévu dans le SSD ce modèle intégré. Le modèle a été calibré et appliqué au Plan Général Territorial de la province de Latine et ici on présente les premiers résultats.

Mots-clefs: *planification territoriale, modèles de simulation, émissions due à la circulation routière, pollution de l'air, méthodologie pour un développement soutenable.*

Introduction

In developing the General Provincial Territorial Plan (GPTP) of Province of Latina, the authors have decided to specify a Decision Support System to give a useful aid to define outlines of wide-area planning and to evaluate choices taken by the planners. The Province of Latina is located in the southern side of Lazio with an area of about 2240 square kilometres. The Province is divided into 33 municipalities and in the year 2007 there was a total of 528663 residents. Two main homogeneous territorial systems can be identified with regards to historical and economic features: a) the northern pontine area, including more than 65% of industrial settlements on the total of the Province and where it is also developed intensive agriculture; b) the southern pontine area including the most important tourist centres of southern Lazio. These two areas of provincial territory are also characterized by different urban models. In fact, the results of land-use analysis show that in northern area we can find a widespread urbanization while in the southern area we have

concentrate urbanization especially along main road network. For what concerns the road network, it is based on two parallel main axes that run from South-East to North-West, and on a set of less relevance transversal roads that join the coast and inland areas. Main axes connect the Province of Latina to the Province of Caserta in the South and Rome in the North. In wide-area plans, as GPTP, outlines for socio-economic growth have to be defined. To achieve this goal, new areas for industrial compounds expansion have been marked off and new locations for public utilities have been identified. So that this plan does effective, great attention has been taken over the reorganization of mobility system and several projects about rail transport and road network have been scheduled. In particular, the results of transport studies show that in Province of Latina there are several problems, related to the mobility system, which induce poor quality of life and poor environmental quality:

- 1) Heavy exchange and crossing traffic (with origin, destination or both located outwards of Province);
- 2) Poor road network connecting coastal activity system and inland socio-economic system;
- 3) poor quality level of lengthwise links.

The consequences are that we have very high travel time both in business and entertainment travels; very high costs, both monetary and environmental, sustained by the community; very low ability in attracting tourism compared to the resources of provincial territory. To solve these problems, authors and their team have defined three courses of action:

- 1) The realization of a high quality road connection along longitudinal axis to improve on North-South relationships;
- 2) The increase and improvement of the set of transversal roads that play the role of adduction to longitudinal axes;
- 3) The decrease of travels by car with reorganization of public transport and realization of a system of rapid transit connecting main urban areas and main seaside centres.

1 - Objectives

During planning process we had two needs. On the one hand we intended to check the impacts of working hypothesis about activity localization and road network layout in terms of accessibility and travel time to reach different destinations. On the other hand GPTP had to be submitted to Strategic Environmental Assessment (SEA), being a wide-area planning tool, as provided for by Directive 2001/42/CE, recognized in Italy by Decree-Law n. 152/2006 and by Decree-Law n. 4/2008. So, our aim has been to specify a Decision Support System (DSS) to define alternative policies to plan and govern a wide-area. Then, in DSS, we have included a Land Use–Travel Demand System of Models to evaluate projects and plans provided for a wide-area plan and, in particular, to compare different choices about activity localization and road network layout. From the point of view of environmental assessment, considering that road transport induces very significant environmental pressures (available data, from European Environment Agency and referred to year 2005, show that transport –excluding international aviation and maritime transport– has contributed to about 21% of total greenhouse gas emissions in the 15 countries of the European Union before the expansion on 1 May 2004 and 56% of total NO_x), we have assumed the problem of emissions from road vehicles and energy consumption as the main concern for sustainable development of Province of Latina territory. To estimate road traffic emissions in different scenarios, concerning different socio-economic system organizations and road network layouts, we have included in the Land Use–Travel Demand System of Models this submodel the results of which we are going to talk about in next paragraphs.

2 – The method

In figure 1 it is described with a flow chart the Decision Support System for territorial planning and government where it is included the Land Use–Travel Demand System of Models consisting of some mathematical submodels that give quantitative indicators, when it is possible, to simulate and evaluate the effects of different policies. The Integrated Model to Evaluate Road Traffic Emissions

includes the assignment model of traffic to road networks and some models to calculate emissions in air of different pollutants in different network layouts. It is based on transportation engineering approaches to specify and calibrate the traffic assignment model and on the most recent revision (December 2007) of the EMEP/CORINAIR Emission Inventory Guidebook to estimate emission factors produced by road traffic. The integrated model can be expressed formally as follows:

INTEGRATED MODEL

$$E_{TOTAL,i,k,t} = E_{HOT,i,k,t} + E_{COLD,i,k,t} =$$

$$= \sum_l P_{k,l,t} \times f_{m,l,t} \times L_l \times e_{HOT,i,k,l} + \sum_l P_{k,l,t} \times f_{m,l,t} \times L_l \times \beta_{i,k} \times e_{HOT,i,k,l} \times (e_{COLD,i,k,l} / e_{HOT,i,k,l} - 1)$$

where,

$E_{TOTAL,i,k,t}$ = total emissions [g] of pollutant i for vehicle class k in period t;

$E_{HOT,i,k,t}$ = emissions [g], during stabilised (hot) engine operation, of pollutant i for vehicle class k in period t;

$E_{COLD,i,k,t}$ = emissions [g], during transient thermal engine operation (cold start), of pollutant i for vehicle class k in period t;

$P_{k,l,t}$ = percentage of vehicle class k, on link l in period t;

L_l = length [km] of link l;

$e_{HOT,i,k,l}$ = average emission factor [g/km] for pollutant i, for vehicle class k, on link l, with thermally stabilised engine and exhaust aftertreatment system in period t;

$\beta_{i,k}$ = fraction of mileage driven with cold engines or catalyst operated below the light-off temperature for pollutant i and vehicle class k;

$e_{COLD,i,k,l} / e_{HOT,i,k,l}$ = cold over hot ratio for pollutant i, vehicle class k and link l;

$f_{m,l,t}$ = vehicle flow of transport mode m, on link l, in period t got from assignment model:

ASSIGNMENT MODEL

$$f_{m,t} = A_m P_m(C_m) d_{m,t}$$

where,

$f_{m,t}$ = vector of link flows related to transport mode m (for example car or bus) and period t;

A_m = matrix of incidence, links×paths, related to transport mode m;

$P_m(C_m)$ = matrix of path's probability of choice, paths×OD pairs, related to transport mode m and depending on path costs;

$d_{m,t}$ = vector of travel demand in period t by mode m.

For what concerns transport modes and classes of vehicles, according to data provided by Italian Automobile Club, we have considered passenger cars, buses, motorcycles and commercial vehicles as transport modes; pre-Euro, Euro 1, Euro 2, Euro 3 and Euro 4 as legislation classes; gasoline powered vehicles and diesel vehicles as fuel typology. Finally, we have adopted the detailed methodology proposed by the Emission Inventory Guidebook, where emission factors are calculated by speed-dependent mathematical expressions, because the vehicle speed has a major influence on the emissions in air and our assignment model estimates an average speed for each link of road network depending on congestion of the link itself.

3 – Results and conclusions

Actually we are testing our model on provincial road network consisting of 2353 links, 1534 nodes and 67 centroids. We have built scenarios described in table 1 and in this note we present early results related to scenarios 0, 7 and 8. In particular, we have simulated scenario 0, that we have assumed as reference scenario, with actual organization of socio-economic activities and road network. Then we have simulated and compared scenarios 7 and 8. Both in scenario 7 and scenario 8 we consider a large-scale hypothesis of reorganization of main productive activities and public utilities. For what concerns road network layout, in scenario 7 we test the hypothesis of realization of a highway from Rome to Latina and the hypothesis of improvement of the other main connection axes. In scenario 8 we hypothesize the improvement of the North-South connection by realizing a highway from Rome to Formia. Also in this scenario it has been included the improvement of the main transversal roads (see fig. 2). Finally, we have assigned actual travel demand to the scenarios described (in reference to a weekday peak period t of 2.5 hours), we have estimated traffic loads and

average speed for each link, road traffic emissions and we have defined a set of performance indicators related both to mobility and environment. In table 2 the results are referred. The importance of our model depends on its power:

- a) to allow ex-ante and ex-post evaluations;
- b) to evaluate the weight of different factors that affect pollutant emissions;
- c) to estimate quantitative indicators;
- d) to estimate pollutant emissions in each transportation zone or in each municipality;

because, in Italy, both Environment Protection Agency (APAT) and New Technologies, Energy and Environment Agency (ENEA) have the task to calculate the inventory and projection of pollutant emissions for each year but their results are too much aggregate and they don't allow any evaluation as the ones above mentioned. In Italy, an approach similar to our one has been adopted only by few other local governments as, for example, Lombardia Region and the Province of Reggio Emilia. The results of these early applications confirm the importance of having some quantitative indications to evaluate the effects due to decisions often taken on the basis of one's own experience in particular planning on a wide-area where a too large number of variables play a role. Actually, at University of Naples, we are attending to simulate the other scenarios and estimate the future travel demand. In next simulations we will also consider the vehicles replacement trend from euro 0 to euro 4 and following classes.

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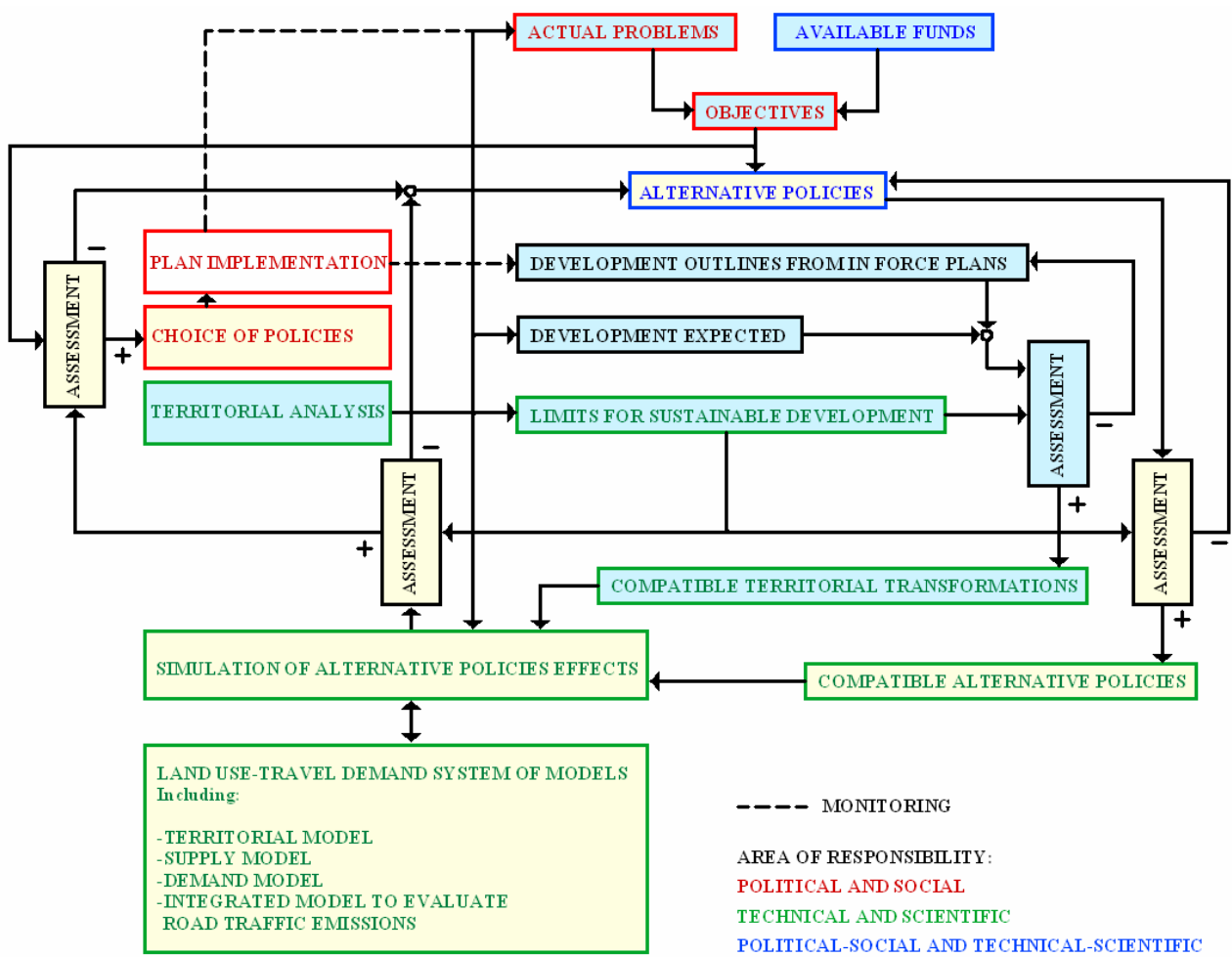


Figure 1: The Decision Support System (DSS) designed to define and evaluate alternative policies to plan and govern a wide-area.

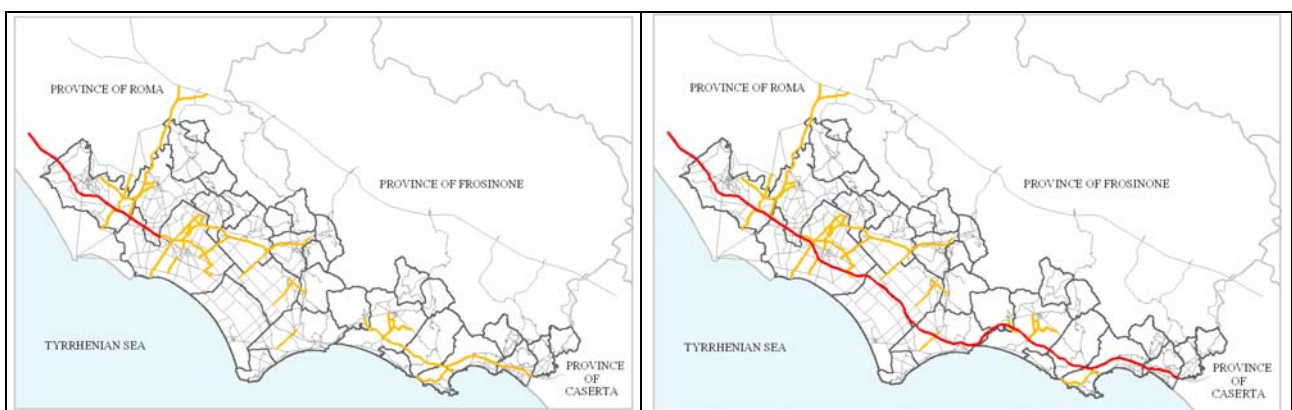


Figure 2: Representations of Scenarios 7 and 8.

Socio-economic shape of territory / Road network layout	Actual	Intermediate road network layout	Complete road network layout
Actual	Scenario 0	Scenario 1	Scenario 2
Intermediate reorganization of main economic activities and public utilities	Scenario 3	Scenario 4	Scenario 5
Complete reorganization of main economic activities and public utilities	Scenario 6	Scenario 7	Scenario 8

Table 1: Main characteristics of simulation scenarios.

Indicators / Scenarios	Scenario 0				Scenario 7				Scenario 8			
Percentage of links with saturation level > 0.9	12.4%				17.8%				9.50%			
Average speed	56.8 km/h				54.1 km/h				59.1 km/h			
Total travel time	1077205 veic×h				2506889 veic×h				1052009 veic×h			
Total distance on road network	2712360 veic×km				1472164 veic×km				2758155 veic×km			
Percentage variation of hot emissions for gasoline passenger cars (Euro 1-4)	E1	E2	E3	E4	E1	E2	E3	E4	E1	E2	E3	E4
CO	-	-	-	-	+32	+42	+49	+61	na	na	na	na
HC	-	-	-	-	+34	+20	+26	+12	na	na	na	na
NOx	-	-	-	-	+34	+9	+14	+4	na	na	na	na
PM	-	-	-	-	+6	+6	+8	+8	na	na	na	na
na = not yet available												

Table 2: Early results related to Scenarios 0, 7 and 8.