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Simulation of the environmental efficiency of the Rome Intermodal UDS designed for the next Jubilee

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Abstract

For the demand-intensive occasion of the Jubilee of the year 2000, a new Urban Transport System (UTS) has been designed for Rome, based on several modal interchange nodes (car-train, bus-train) radially located along city belt, and on a selective pricing policy for the downtown penetration by private car. The objective is to improve the mobility-environmental efficiency in the central areas. Several possible configurations for the new intermodal UTS have been evaluated by use of case-specific models, innovative simulation methodologies and related sw tools. These models allow in particular an explicit characterisation of the inter-multi-modal network and are based on comprehensive cost-functions, encompassing perceived costs as a function of traveller category, pricing, and other cost factors. The paper focalizes on the simulation environment developed and used in order to characterise the aforementioned parameters. In particular, the MTCP system (Macroscale Transport Chain Planning) and the MIAURB system (Macroscale Integrated Analysis of Urban mobility-environmental Balance) are described. These systems have been both applied to the intermodal network model to evaluate, in sequence: a) the modal split due to the intermodal supply, b) the detailed transport times of the network links; c) the multimodal traffic volumes; d) the environmental "zonal" efficiency parameters, in terms of: space occupancy, time-space usage, pollutant emissions, social cost of mobility, etc. A discussion on the results obtained and performance of the simulation method is finally presented.

Introduction

It is probably superfluous to discuss here the many problems related to the current situation of degraded urban mobility; it is evident however that the evolution of this situation, without any efficient countermeasures, is producing a rapid and severe degeneration of the social-economic assets and liveability in larger towns. The following are distressing examples: congestion of transport networks, criticality of air pollution and traffic noise; the economic cost of transport (15% of family budget) that is beyond any acceptable limit; in addition, the indirect costs (environment, energy, etc.) suffered by the community are even more higher than the direct costs.

Recent studies of important European cities reveal that the most efficient way to solve urban mobility problems is the balanced implementation of four actions: i) improvement of public transport, ii) development of intermodal infrastructure and other integrated facilities, iii) development of area pricing and road pricing policies, iv) organisation in the distribution of the services within an urban planning.

Experience indicates that a good strategy is to implement targeted interventions to partially solve problems in the short term, provided that they are carried out within a global integrated planning scenario.

1 Methodological Approach

The correct approach to solve this problem is to take into consideration the so-called "mobility-environment balance". Mobility in congested towns strictly interacts with the environment and the sociality. The basic objective is to get UTS configurations where users' internal costs and benefits are "externalised" in order to control the modal split, reduce the impacts, and maximise the mobility efficiency of the whole society.

The design methodology requires a comprehensive planning activity of alternative scenarios, including intermodality and pricing; this can be accomplished by the combined use of two different kinds of simulation tools: the MTCP (Macroscale Transport Chain Planner, D'Appolonia [1]) and MIAURB (Macro Integrated URban Balance, D'Appolonia [2]) software systems.

The first allows to analyse the UTS with particular attention to the interaction of different transport modes and to the influences that the most important influencing factors (time, cost of travel, comfort, etc.)

have on modal choices.

The second allows to investigate in detail the public and private road traffic, which is the major cause of pollution. This analysis is performed using as input the MTCP outputs, including the configuration of the road network, which depends on the MTCP defined interchange nodes, and the reference modal OD matrices. As an example, if there is a travel with use of car and subway, the first part of this displacement will be considered in the private car OD matrix, while the second in subway OD matrix, and the MIAURB road network is accordingly defined.

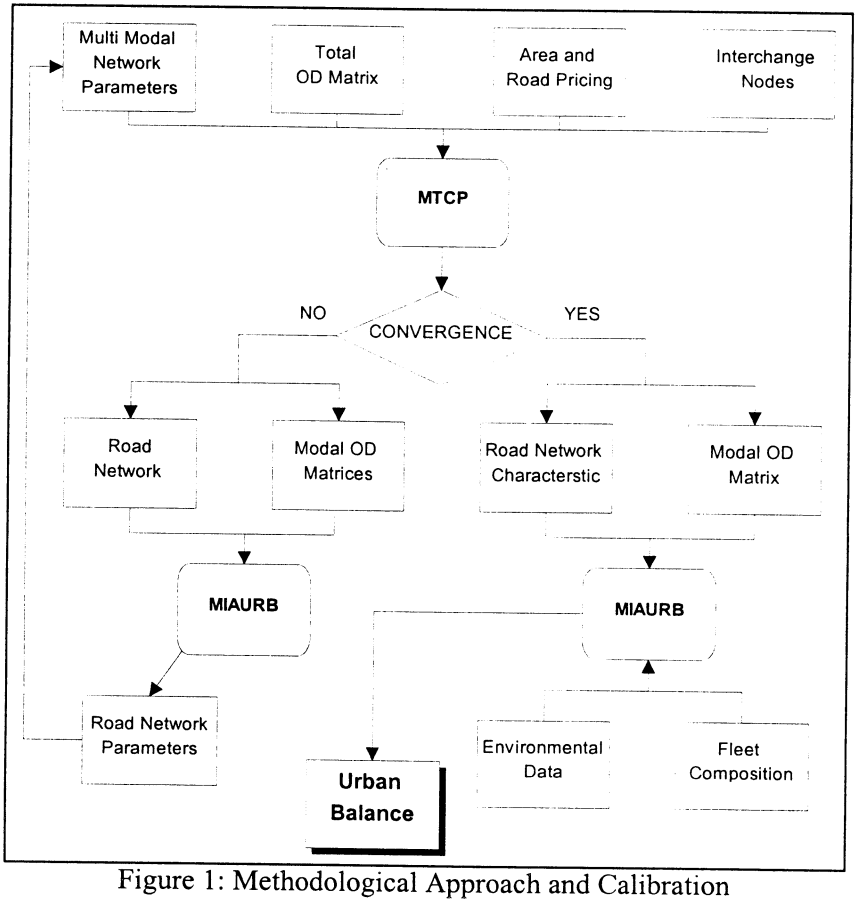

Figure 1: Methodological Approach and Calibration

The calibration of the model is achieved with an iterative use of the aforementioned code (Figure 1). The UTS configurations are implemented within MTCP, where modal displacement time are independent to each other. MIAURB allows to define dependencies between traffic

volumes and velocities of road vehicles, and can be used to modify the initial inputs to MTCP. This procedures should be repeated until convergence be achieved, in the modal split, between two MTCP runs.

More detail about the two tools are provided.

1.1 MTCP (Macroscale Transport Chain Planner)

A simulation system encompassing multi-modal and multi-users assignment, is provided by MTCP - Macroscale Transport Chain Planner- which has been employed in the "Porte di Roma" project. This product was developed on the methodological basis of previous models (Stan [3]), with specific enhancements to solve two typical problems: passenger intermodality in urban areas and freight transport planning at regional macro-scale (Righetti [4]).

The MTCP system requires 3 input data sets:

1) a multi-layered graph; each layer is composed of mono-modal and mono-directional "transfer" links; the layers can be connected at selected points by "modal interchange" links;
2) total OD matrix for each user type;
3) system data, including the definition of the transport modes and the user types, cost function parameters, bonus/malus, etc.

As in a typical aggregated assignment model (De Ortuzar [5]), the simulation procedure implemented in MTCP consists in searching all constraint-consistent and transport-efficient routes linking each OD pair, and, subsequently, subdividing the OD total flow over these routes. Traffic distribution to each route is inversely proportional to the generalised route cost. In this way, MTCP evaluates the traffic volume, for each mode and user type, both in the "transfer" and the modal "interchange" links.

The MTCP system provides a correct representation of the basic elements discussed above. In particular:

- relationships between supply and different users kinds are definable at link level;
- route flows are stochastically evaluated (Logit type functions) through a computationally efficient single-step procedure;
- specific situations can be simulated (as a variation of generalised cost) by defining conditions for bonus/malus factors applied to links;
- tariff terms in the cost function can be defined as generic functions of total travel length, for each type of users and mode, consistently with the urban transport pricing policies (road and area pricing);
- approximations inherent to macro-description of the network can be

reduced by the definition of a mean accessibility cost for each centroidal zone.

1.2 MIAURB (Macro Integrated Analysis of URban Balance)

The MIAURB system is made by a score of processing-analysis-simulation modules which pick up data, for their computation, from a wide database and/or MTCP system. The data refers to the network physical characteristics, to monitoring campaigns of traffic volumes, air pollutants and noise levels. A brief description of the four basic modules is hereby provided.

DAPTRANS provides simulation of urban traffic. Its basic functions are:

- deterministic and probabilistic evaluation of multimodal traffic parameters given a project demand (public/private origin-destination O-D matrices) and a public/private supply (road network):
- evaluation of main and alternative routes for each O-D pair (travel);
- evaluation of efficiency parameters related to mobility and spatial occupancy

In particular DAPTRANS can evaluate at micro-scale and locate the vehicle queues. For each link it is computed the maximum number of equivalent vehicles waiting in queue as a function of the real dimensions of the link. This parameter allows to determine an "effective" capacity of the link intersection; on these bases traffic volumes exceeding this value are assigned to the originator links, by a back-propagation alghoritm. The effect of this methodology is a better representation of congested situations.

DAPTRANS is able to consider other specific characteristics, such as: collective means of transport running on reserved lanes and managed by dedicated signalling, traffic limited zones, road tolls and area pricing, and results updating by traffic counts information (OD reconstruction is also allowed by use of the DAPROD module).

DAPATMOS module provides a global/local (canyon effect) evaluation of air pollution by traffic emission. Its basic functions are:

- evaluation of pollutants emissions (CO, NOx,, SOx, Pb, VOC, Particulate, etc.) and of energy consumption due to different vehicle types and traffic characteristics (as simulated by DAPTRANS). Such analysis is based on available emission factor data (EMEP/CORINAIR [6]);
- evaluation of diffusion of pollutants at global level as a function of meteorological conditions, based on the DIMULA model (ENEA

[7]);

- evaluation of local concentration of pollutants on the basis of geometric characteristics of roads (canyon effect) and local meteorological conditions (USEPA [8]).

In particular the code is able the evaluate in detail the pollutants emission due to vehicles waiting in queue, which are the major cause of impact in urban congested areas.

DAPNOISE provides an evaluation of noise emissions due to traffic. Equivalent sound levels are computed on the road axis and then propagated on the basis of attenuation laws (CETUR [9], Cannelli [10]) which consider calibration curves obtained by specific data measured for the urban configuration under consideration.

DAPCOMP computes efficiency parameters (Ott [11]) at macro level i.e. for selected zones of the city or for the entire UTS, and compare these values with the limit capacities pre-defined (on urban planning bases) for each zone.

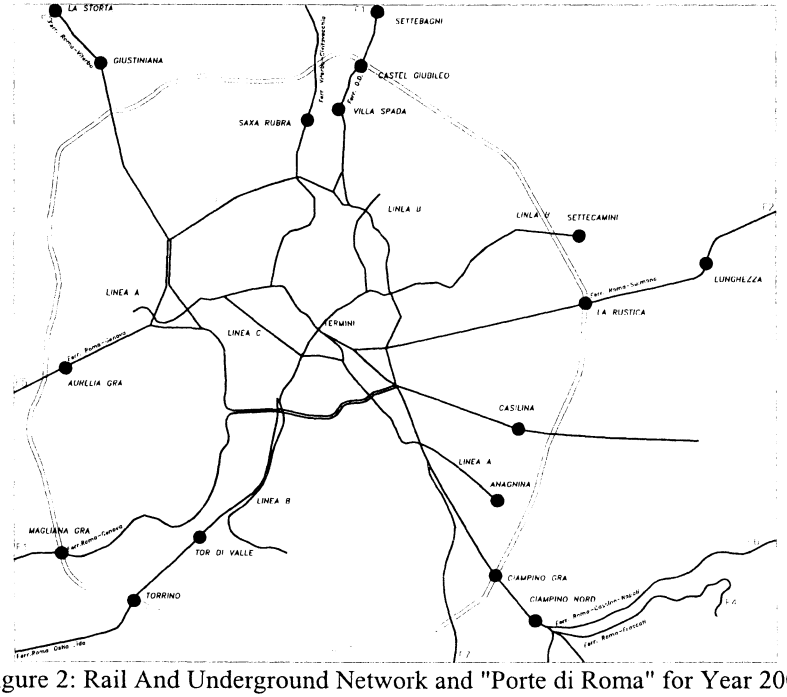

Figure 2: Rail And Underground Network and "Porte di Roma" for Year 2000

2 Rome Model

The described methodology has been used to analyse the Rome UTS of the Jubilee and the year 2000+, to assess the efficiency of possible mobility configurations. The Rome model includes a multi-modal 4-layered network (railroad, subway, public and private road transport system) represented in Figure 2, a multi-user demand (students, clerk's and workers, freelances and managers, tourist's), and road and area pricing schemes.

2.1 Multi-Modal Network

Public Transport System

The public transport system has been modelled with three different network layers (railroad, subway, and bus). These are characterised by the following parameters, specific for each mode and for each service: commercial speed, headway, accessibility (mean time spent by an user to reach the station or the bus stop), and interchange time and cost (mean time and cost spent by an user to take another line or transport system).

Private Transport System

Each link of the road network, is characterised by a commercial speed and capacity. Other parameters are related to road pricing (highway toll system) and to area pricing (mean cost to park, this value is defined for each transport zone).

Intermodal Link (Private-Public)

The Rome model is completed with the location of interchange nodes: car parkings that allows to access to the public transport system (railroad and subway). This links are characterised with a limit capacity, an accessibility (mean time spent to park the car and reach the station), and direct cost for parking.

2.2 Multi-Users Demand

The transport demand has been modelled with four OD matrix: students, clerk's and workers, freelances and managers, tourist's. This are characterised by a different time value and inclination to the use of a given transport mode. The first parameter is directly defined as a program input, the second is represented by bonus/malus coefficients.

2.3 Simulations Results

Modal Split and Mobility

In Table 1 are reported the results of four different scenarios: 1995 (base

scenario), 2000_int (year 2000 with interchange nodes and area pricing), 2000_nint (year 2000 without interchange nodes, but with area pricing) and 2010 (year 2010 with both interchange nodes and area pricing).

The number of private car users decreases notably and consequently the mean travel speed increases. This is due principally to the area pricing toll system (there is a no significant difference between the scenarios 2000_int and 2000_int). The greater use of public transportation mean involves a decrease of "out of pocket" costs.

Modal Split	1995	2000_int	2000_nint	2010
Total Users	591000	641000	641000	678000
Private Car "pc"	312000	125000	147000	119000
Railroad "r"	56000	140000	96000	171000
Subway "s"	99000	137000	167000	177000
Bus "b"	124000	105000	130000	106000
Private-Public	-	55000	-	45000
Public-Public	-	79000	101000	60000
Passengers x km "pc" [10^6]	2.9	1.4	1.3	1.2
Passengers x km "r" [10^6]	0.7	2.1	1.8	2.4
Passengers x km "s" [10^6]	0.5	1.2	1.2	1.8
Passengers x km "b" [10^6]	1.3	1.1	1.5	1.0
Mean speed [km/h]	10.6	12.0	11.5	12.8
Out Of Pocket Costs [£/km]	385	353	341	295

Table 1: Analyses Results

Environment

The effects of the mobility policy has been evaluated dividing the urban context in three concentric zones (Figure 3). The reduction of pollutant emissions increase progressively toward downtown (where the parking toll is higher): in first zone the reduction is about 60%, in the second 80% and in the third (historical centre) up to 90% with respect to the present highly critical situation of Rome centre..

Costs Benefits Analyses

The methodology adopted allowed to get the parameters required to develop a costs benefits analyses. In particular it has been possible to choose, among various possibilities, the best location of interchange nodes and their layouts, and to define an efficient implementation sequence.

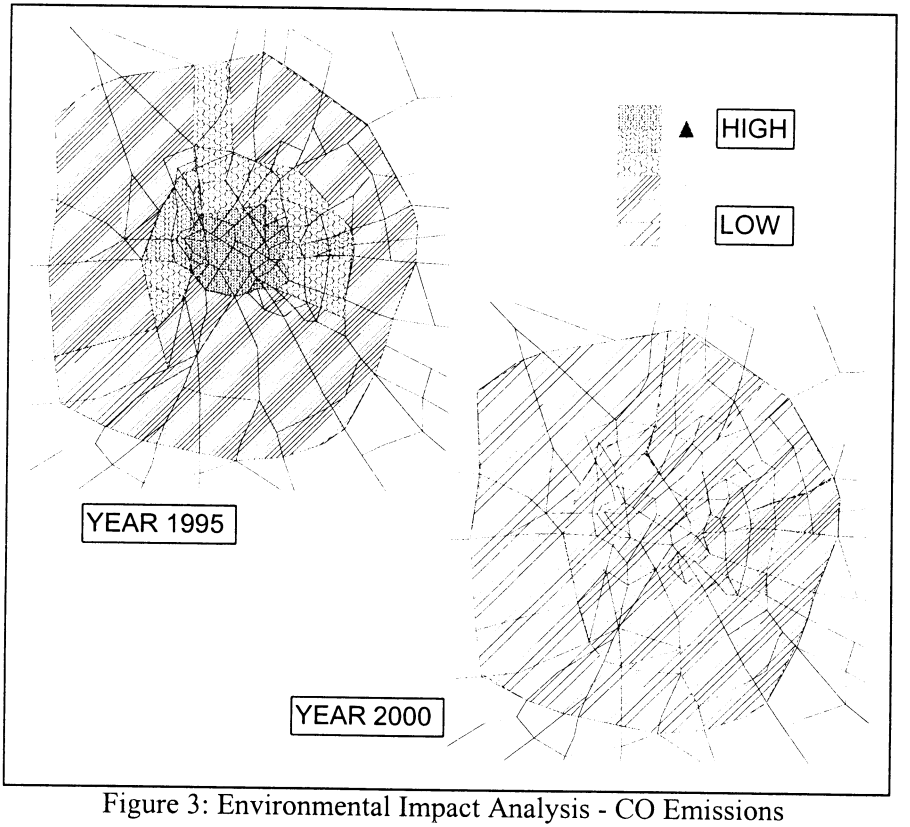

Figure 3: Environmental Impact Analysis - CO Emissions

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