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# A GIS-based decision support system for planning urban transportation policies

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**Abstract**

A decision support system (DSS) integrated in a geographical information system (GIS) for the analysis and evaluation of different transport policies is presented. The objective of the tool is to assist transport administrators enhance the efficiency of the transportation supply while improving environmental and energy indicators. The DDS works on three levels. The first performs the transport network analysis, the second assesses the energy consumption and pollutant emissions and the third evaluates the several policies selected. Road traffic is simulated using a deterministic, multi-modal traffic assignment model with capacity constraints. The model allows the estimation of traffic flow patterns within each link of the road network starting from the knowledge of the network characteristics and traffic demand. Energy consumption and pollutant emission calculations are based on the methodology developed by the CORINAIR working group. The evaluation of each policy scenario is based on a number of traffic, environmental and energy indicators. A multi-criteria analysis, where decision is based upon judging over appropriate weighted criteria, is adopted. Models are integrated in a GIS environment, which serves as the repository of the data as well as the user interface of the tool. The use of the tool is demonstrated through characteristic case studies on the Greater Athens Area in Greece. Two policy measures, one concerning the extension of the region where half of the private cars are prohibited from entering to the Municipality of Athens and the other the reduction of parking places in the same region by 50% are evaluated.


*Keywords:* Decision support systems; Geographical information systems; Transport policies; Traffic modeling

## 1. Introduction

Within the general framework of a multi-modal transport system both private and public transport modes are managed by a planning authority that has control of traffic decision variables. In this scheme, urban transport management seeks for policies that would enhance the efficiency of transportation supply with particular concern in improving environmental, social and budget indicators. In all cases, the satisfaction of total travel demand must be balanced with the provision of reliable transportation services and with minimizing the costs of externalities associated with road

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traffic [1]. The implementation of a traffic management strategy would involve a set of mathematical models to perform transport network analysis and estimate the corresponding impact on environmental and energy indicators, an interactive procedure for providing alternative scenarios for the transportation infrastructure as well as rational automated procedures for comparing the results [2].

Transport modeling, given a transport network and a set of data representing the spatial distribution of urban activities and their intensities, assesses the four basic components of the travel pattern in a study area, i.e. trip generation, trip distribution, modal share, and traffic assignment. This type of modeling can provide valuable insights into the effectiveness of a transportation policy on the performance of the transportation infrastructure. Of even greatest significance is the ability for planners and analysts to tackle decision-making problems of "what–if" nature regarding policy and infrastructure changes and estimate the resulting impacts on travel patterns and environmental or energy indicators [3].

Despite the obvious importance of using transport models for evaluating urban transportation policies, their development and application in empirical settings often face critical obstacles. A first difficulty is related to the fact that conventional strategies apply sequential modeling of the four transport model components. A sequential approach can generate computationally tedious, inconsistent and non-convergent results among the individual components, even when using feedback loops and re-estimation [4]. A more efficient and consistent strategy involves simultaneous estimation of all components, a procedure that due to its apparent computational complexity has been prohibitive for application on a large urban scale [5,6]. A second difficulty is a result of the need to manage the spatial data required for an urban scale transport modeling. Data required include an origin–destination zoning system, aggregate travel demand for each zone, and the transport network for each travel mode [7]. The need to evaluate "what–if" scenarios as well as the dynamic nature of urban environments dictate the necessity for the analyst to update the database frequently. Consequently, it is critical that the computational platform for the transport model should provide effective database management and ensure database integrity after updates without sacrificing data realism.

Geographical information system (GIS) technology offers extremely significant power in transport modeling. The spread of GIS use facilitates the efficient and portable spatial data storage, updating and processing. In addition, a GIS system facilitates model accessibility, database maintenance and updating, and cartographic display of model results. This can greatly enhance the role of the transport model as a decision support system (DSS) in transportation planning and policy development. The interface of network-based equilibrium models with a GIS platform offers substantial potential of modeling transportation planning, analysis and control. GIS systems can greatly improve the realistic representation of the multi-modal transportation network, increased likelihood of database integrity relative to the traditional multi-modal network data model, effective user-interfaces and efficient visualization of network equilibrium solutions [8].

In this work, a computer-integrated tool for evaluating urban transportation policies is presented. The tool provides estimates of road traffic and evaluates the implications of urban traffic policies. The tool is a prototype GIS-based DSS that involves realistic representation of the multi-modal transportation network. The uniqueness of the tool lies in combining transport network and travel demand database management, GIS utilization for policy definition and result presentation, traffic simulation and analysis, energy consumption and pollutant emission modeling, evaluation of environmental impacts and scenario comparison into a seamlessly integrated package. While neither of these elements is new, it is the tight integration that provides the new approach and qualifies the tool as a user-friendly decision support tool. In the following sections of the paper the basic structure of the tool is presented, its operation is outlined and characteristic case studies for the Greater Athens Area in Greece demonstrate the effectiveness of the proposed approach.

## 2. Tool architecture

The decision support tool was setup according to the structure presented in Fig. 1. It was implemented within the operating environment of MapInfo GIS that serves as a central repository for the basic data, as an intermediate storage space for each scenario parameters, as well as for providing the user interface. The tool was implemented according to a three-step schema that involves (a) the database, (b) a number of mathematical models for traffic assignment as well as for emission and energy consumption estimation, and (c) the presentation of model results through appropriate thematic maps, figures and diagrams. Scenarios can be planned, simulated and compared and the decision-maker, analyst or planner can undertake rational actions to control traffic conditions with respect to his objectives. The user of the tool should not be necessarily a transportation expert, however such expert help would be needed during the setup stage, while installing the tool in a new urban area.

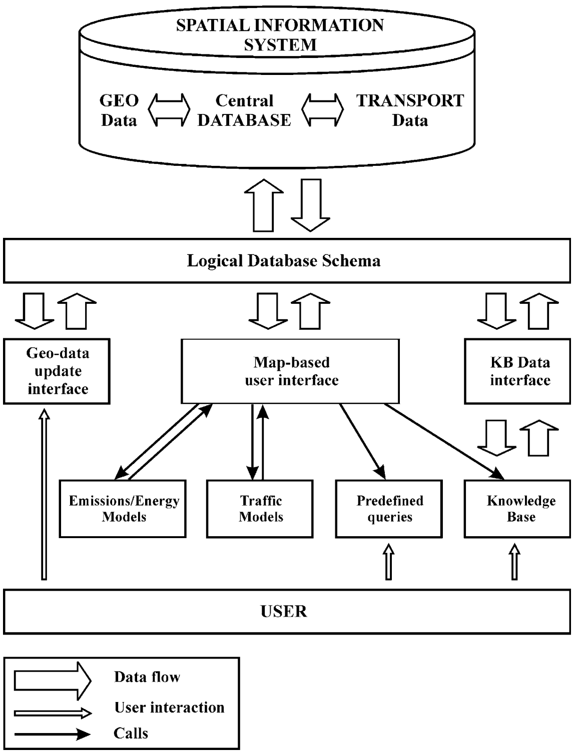



Fig. 1. Architecture of the decision support system.

In this work, the tool is applied to the Greater Athens Area of Greece. However, due to its generic form and structure it can easily be extended to work with other regions. All the region specific data are stored in the GIS database, which is described in Section 2.1. Special attention has been given to the portability of the tool. The GIS functions used are generic and the tool can easily be ported in any GIS environment. The mathematical models have been implemented in computer programs written in the C++ programming language and are portable between many computers platforms that support ANSI standard C++. An additional interface layer has been developed, which allows the mathematical models to be called by any programming platform that supports the use of dynamic link libraries (DLLs).

### 2.1. GIS database

The GIS database is the heart of spatial and operational information system and provides the central storage system that allows communication and intermediate storage between the various submodels. Within the object and data relational tables of MapInfo, network territorial data, traffic demand characteristics, transit line networks and road attributes are stored. GIS-integrated models use these data to estimate and reproduce traffic behavior and characteristics, and calculate pollutant emissions and energy consumption. The GIS database is organized on the basis of the road network map. Each link has as attributes topographic (e.g. nodes, UTM coordinates, total length), toponomastic (street names), physical (traffic directions, number of lanes), transport (road typology by means of speed-flow curves) and transit (description of public transport lines and corresponding frequencies) information.

Traffic demand characteristics are expressed in terms of origin destination matrices of person trips and corresponding demand function for each transportation mode involved. This requires the definition of a suitable zoning of the entire urban context. Once travel demand data are provided, it is possible to reproduce traffic behavior on each link of the network, and once traffic flows on each link have been assigned by the traffic model, it is possible to evaluate speeds using the available speed-flow curves. Vehicle flows and speeds along each link, together with traffic composition, will produce estimations of all the environmental and energy indicators required. These may be aggregated over the whole area or broken down into sub-areas (e.g. municipal boundaries, zones), or even a spatial grid for reference and comparison.

### 2.2. Traffic modeling

Road traffic is simulated using a deterministic model that solves the user equilibrium auto assignment problem with capacity constraints [9]. According to such modeling schemes, a transportation system consists of two elements, transport supply and travel demand. The transport supply is the set of facilities and modes available to the users of the transportation network. Travel demand is expressed by the number of users using the network for a specific reason, with a specific mode, at a given time of day. The equilibrium between transport supply and travel demand produces a flow pattern on network links. A set of traffic assignment models are built to simulate the interaction between these two elements and compute the network flows.

The mathematical representation of the multimodal transport problem is based on the simultaneous elastic demand–traffic assignment concepts [10]. This is an extension to the traditional, sequential travel demand modeling. It achieves consistent estimates by embedding the components within a market equilibrium framework where the task is to predict the equilibrium between supply and demand. An alternative approach to the above network equilibrium model is the use of a microsimulation model. Despite its appeal from a behavioral perspective, this approach soon becomes computationally intractable for modeling any traffic system of a realistic size.

Elastic demand was modeled by appropriate decaying exponential relations involving transportation cost as a measure of the level of service offered by the transportation system:

$$T_{ij} = T_0 \exp(-\lambda C_{ij}) \tag{1}$$

where $T_{ij}$ is the number of person trips made from origin $i$ to destination $j$, $T_0$ is the free cost travel demand, $C_{ij}$ is the cost for traveling from origin $i$ to destination $j$ expressed in time units, and $\lambda$ is a parameter for calibration.

In-route transportation cost was modeled as a function of vehicle flow on each network link given by well-known BPR functions involving free link costs and road capacities [11]:

$$C_a = t_{a,0}\left(1 + \sigma\left(\frac{V_a}{Q_a}\right)^{\gamma}\right) + t_{a,c} \tag{2}$$

where $C_a$ is the generalized link travel cost, $t_{a,0}$ is the free flow travel time, $V_a$ is the link flow, $Q_a$ is the link capacity, and $\sigma$, $\gamma$ are parameters for calibration. The term $t_{a,c}$ is a fixed cost, which accounts for any extra cost (for example a toll expressed in time units) applied on the link.

Simultaneous inelastic demand assignment for all transportation modes was modeled according to the concept of diagonalization, where flows and minimal travel cost are fixed for all but one mode to create separable cost and demand functions that are used to formulate an equivalent optimization problem for one user class, introducing in this way an iterative computational procedure until convergence [12]. The solution of the elastic demand assignment problem, mentioned above, was implemented through the appropriate modification of the well-known Frank–Wolfe algorithm suggested in [6]. The objective function of the optimization problem is

$$\min Z(V) = \sum_a \int_0^{V_a} C_a(v)\,\mathrm{d}v - \sum_{ij} \int_0^{T_{ij}} C_{ij}(t)\,\mathrm{d}t \tag{3}$$

where $C_{ij} = C_{ij}(T_{ij})$ is the inverse of the demand function (1), providing the travel cost as a function of the number of person trips.

When the flow pattern of private vehicles is estimated, modeling of route choice on the transit network is performed. Transit assignment is a problem tackled by many authors and still attracts much attention due to its inherent difficulties related to the appropriate formulation of congestion effects and the representation of passenger decisions made at stops served by multiple transit lines [13–15]. In the present work, the behavior of transit users is modeled by using the concept of transit hyper-paths on a generalized network combining the road network (acting as walk links) and the transit lines. A non-linear version of the optimal strategy model is adopted where the generalized cost of travel is an increasing function of the passengers riding on a segment of the transit line (discomfort function). It is assumed that the waiting times at bus stops are not affected by the congestion effects, and the decision of a passenger to walk, board on a passing bus or alight at a certain stop depends on the weighted criterion of the bus frequency and comfort cost of passing buses [14]. The problem is formulated as a variant of the classical traffic assignment model and solved by methods typical of this methodology [6]. As a result, the flow pattern of passengers at each transit line including walking is estimated.

### 2.3. Modeling of emissions and energy consumption

Air pollutants' emission rates are calculated by an appropriate emission model that uses the estimated flow pattern of road traffic and proportional emission factors for each vehicle type in vehicle fleet involved. The air pollutants currently analyzed are carbon monoxide (CO), nitrogen oxides ($NO_X$), carbon dioxide ($CO_2$), volatile organic compounds (VOC) and particulate material (PM). Accordingly, energy consumption due to traffic is estimated by using an appropriate energy consumption model that takes into consideration traffic volumes and link travel speed levels provided from the traffic demand model.

Both models are based on the methodology developed by the CORINAIR working group for calculating emission/consumption factors from road traffic [16]. However, other methodologies, based on emission/consumption factors [17], can be easily adopted by the tool. According to the CORINAIR methodology, the emission/consumption factors per vehicle and per unit driving distance depend on the vehicle category and the average travel speed. Vehicles are classified into different categories according to vehicle type (passenger car, bus, track, etc.), engine type, engine size and fuel type. The relevant emission/consumption formulas and the percentage of each vehicle category compared to all vehicles (extracted from statistical surveys) are stored in the GIS database. These data, along with the mean vehicle speeds and the traffic flow patterns supplied by the traffic demand model, are used as inputs to the air pollutants' emissions and energy consumption prediction models. Results include not only the total emission level of each pollutant and the total consumption of each fuel type in the study area, but also averages by vehicle category and by link.

Emission rate $E_{p,g}$ (g/hour) calculated for pollutant $p$ and vehicle category $g$ can be expressed as

$$E_{p,g} = \sum_a EF_{g,p}(u_a) \cdot V_a \cdot L_a \quad (4)$$

where $EF_{p,g}$ is the emission factor (g/km vehicle) for pollutant $p$ and vehicle class $g$, which is a function of travel speed $u_a$, $V_a$ is the link flow (vehicles/hour) and $L_a$ is the link length (km). Total emission $E_p$ (g/hour) for pollutant $p$ produced by all vehicle categories is computed using the formula

$$E_p = \sum_g \frac{c_g}{100} E_{g,p} \quad (5)$$

where $c_g$ is the percentage of vehicle category $g$ with respect to the vehicle fleet. A similar approach is followed for the calculation of energy consumption rates.

## 3. Policies to encourage the use of public transport

The energy demand of transportation sector and corresponding pollutant emissions, that are both direct results of the immense use of motorized transportation, make desirable the analysis of alternative policies through a quick-response DSS.

A characteristic of the decision support tool is that it pre-defines a number of "abstract" policies and incorporates them as "methods" into the system. These "methods" are algorithms and procedures for estimating impacts for each predefined policy type. An "abstract" policy becomes "application specific" by the user-definition of its parameter set and its geographic domain. An initial

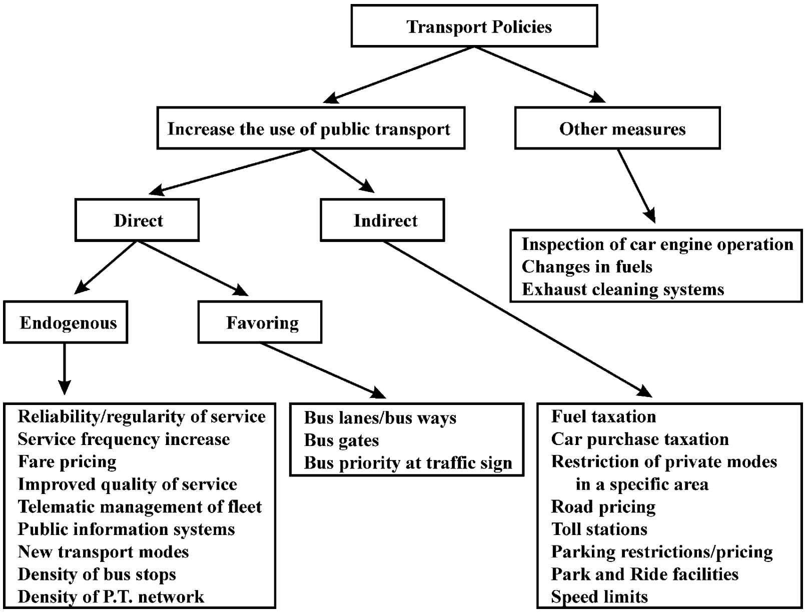



Fig. 2. Hierarchy of policies handled by the DSS tool.

set of policies that can be taken into consideration is given in Fig. 2. The policies incorporated within the framework of the developed tool are mainly focused to the shift from private to public transport as a means of reducing fuel consumption and improving urban environment. In this case, the main aim is either to improve efficiency of the public transport and increase its competitiveness to private modes or to discourage the use of the private modes.

The transport models mentioned above were suitably enhanced by a set of additional procedures for all policies discussed here. Modeling of the policies can be done by modifying on-the-fly the cost and demand functions of all transport modes affected. For example, restriction of traffic in a specific area can be simulated by imposing an artificial infinite cost to links entering the area, so that they are effectively excluded from the minimal paths calculated by the Frank–Wolfe procedure. The same goes in the case of road pricing where toll fare can be directly added to travel cost. Bus lanes bus ways will directly affect travel cost functions by affecting road capacity and speed. In the same sense, bus priority at traffic lights will impose an extra time cost for private cars at the affected nodes. Parking restriction can be modeled by directly fixing inelastic demand functions for private cars to the zones affected by the policy. Public transport service improvement and introduction of new public transport modes can be modeled by modifying demand functions, based on the elasticity concept. Changes of private car fleet will directly affect economic and environmental indices that can be computed accordingly through emissions and energy consumption models.

## 4. Operational aspects of the decision support system

The operation of the DSS tool is based on the concept of scenarios. A scenario is defined in terms of an appropriate database that represents the transportation infrastructure of the study area at the starting point as well as a set of user-defined policies whose impacts will modify the database. User interaction with the DSS environment falls into three different functional groups, accessed via a hierarchical menu system; namely scenario

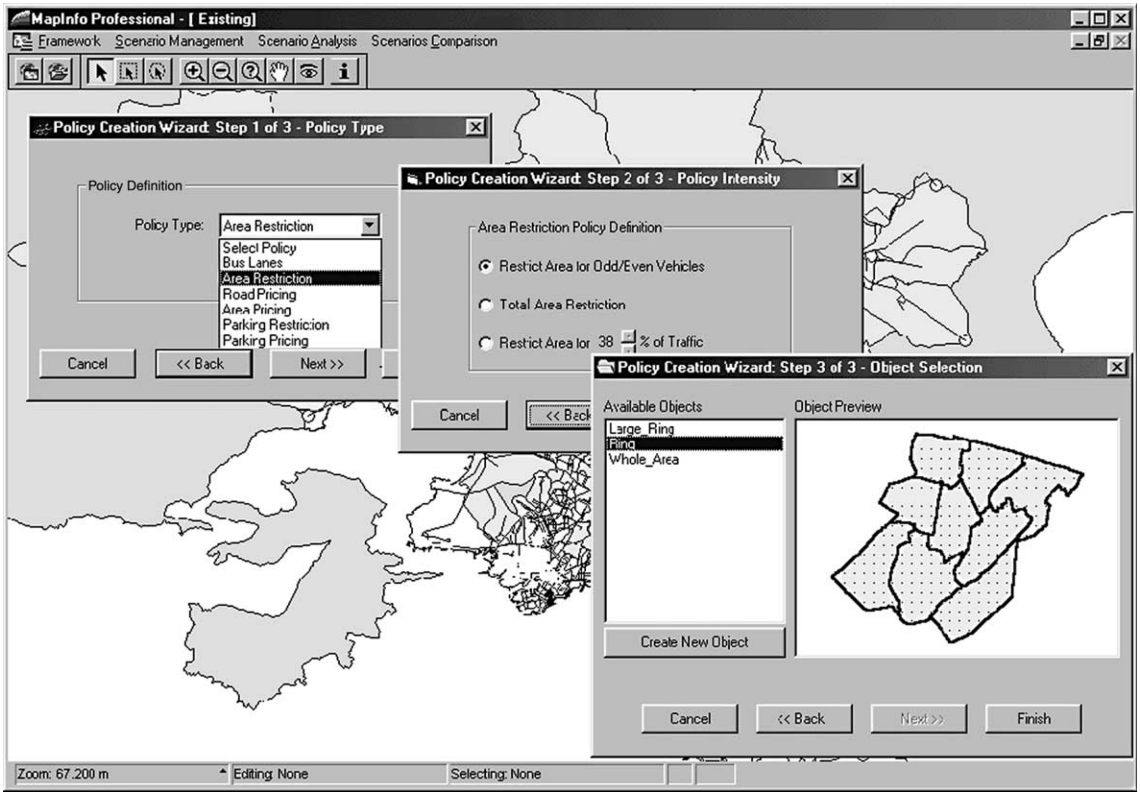



Fig. 3. Using the DSS tool to define policies.

management, scenario analysis and scenario comparison.

Scenario management provides the user with capabilities to create a new or to retrieve a previously stored scenario and to define a set of some policy measures to be examined. A "reference" or "zero-state" scenario is always present, serving as the basis for the creation of new scenarios. The definition of a new policy measure is carried out through interactive procedures based on sets of hierarchical popup dialog boxes which allow the user to specify the policy type, the geographical objects (road sections or sub-areas) upon which it is to be applied and policy-specific parameters. Alternatively, an automatic selection procedure is able to propose the objects, which fulfill a set of user-defined criteria. Safeguards have been incorporated into the policy definition module to ensure that user responses are valid. This form of user-interface is very flexible and is easily mastered by users even if they have little previous experience. A screenshot of a typical user interaction of this kind is presented in Fig. 3.

Scenario analysis corresponds to the analysis and presentation of computational results through appropriate thematic maps, diagrams and reports. The user can estimate the impacts of the set of policy measures included in the current scenario either by examining a summary report (on-screen or in hard copy) or via an interactive report which utilizes the capabilities of the GIS to produce diagrams, tables and thematic maps. Part of this detailed report can been seen in Fig. 4 where a screenshot of CO emission rates is presented. It should be noted that these report elements are dynamic in the sense that drill-down, zooming and output configuration is possible.

Finally, scenario comparison permits the evaluation and comparison of alternative scenarios. The evaluation of each scenario is based on a number of

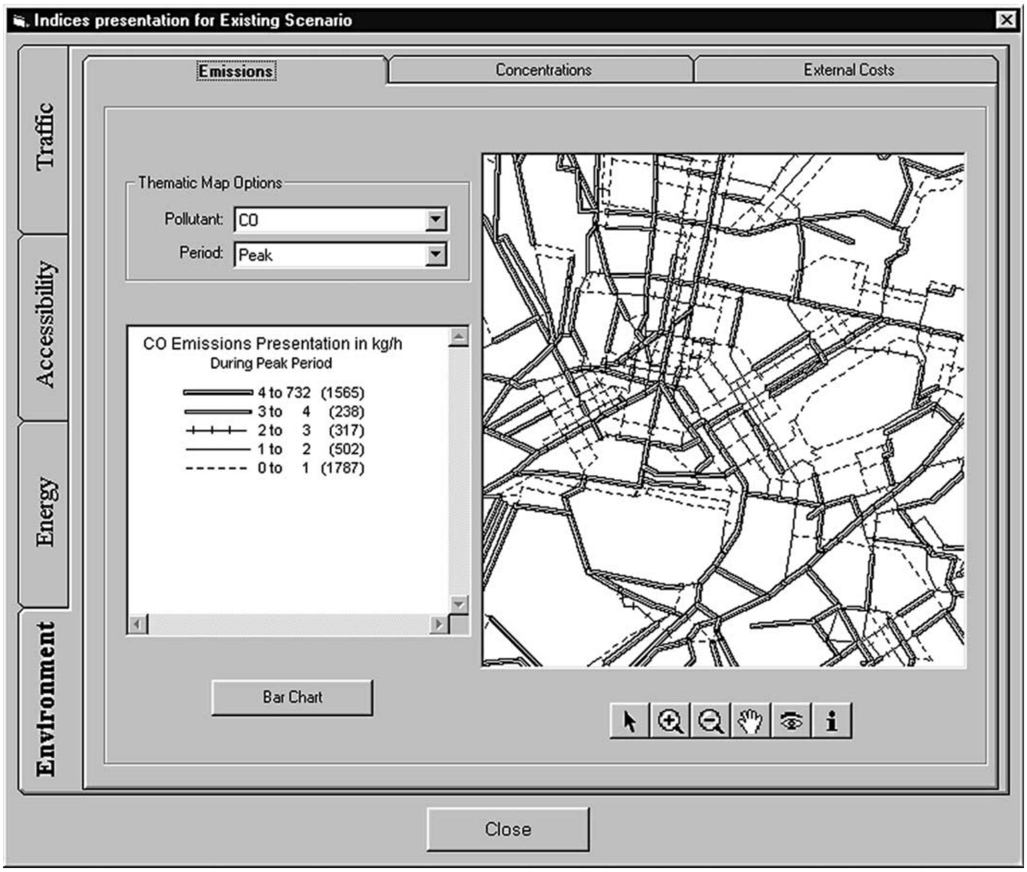


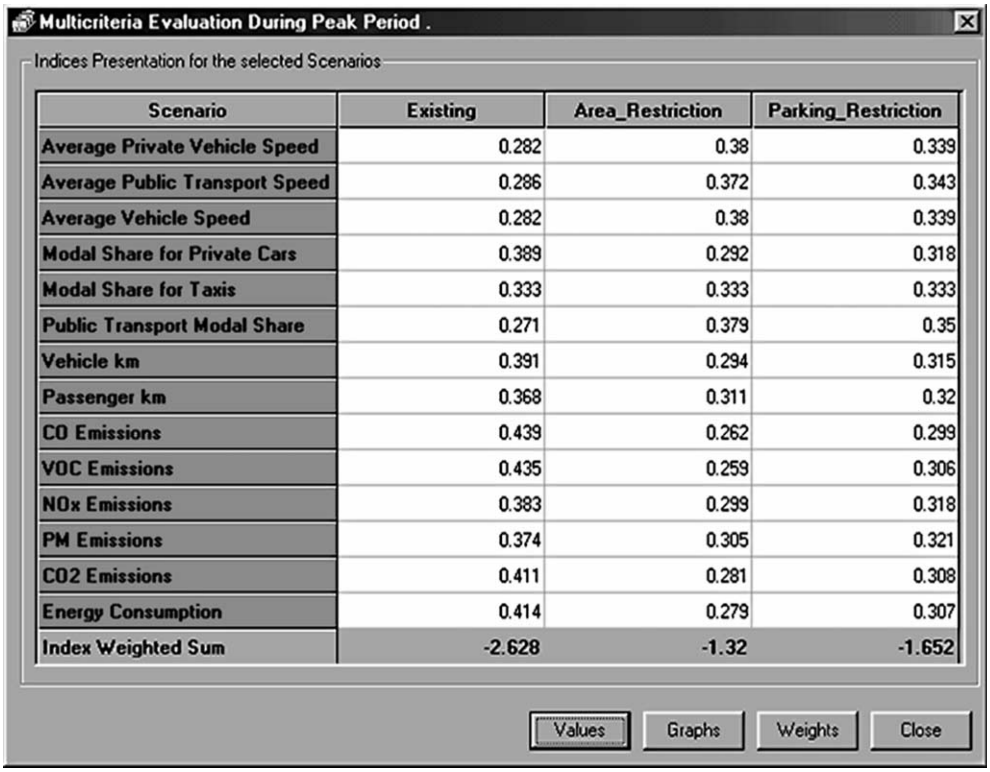

Fig. 4. Interactive thematic map of emission estimations.

traffic, environmental and energy indicators. A multi-criteria analysis, where each decision is based upon judging over appropriate weighed criteria is adapted for comparing user-selected scenarios. The user is allowed to define the number of indicators and weighting factors assigned to each one through appropriate dialogs (Fig. 5).

## 5. Case studies

The Greater Athens Area is the target region used in case studies of the DSS tool described. This area consists of 83 local authority areas, while the integrated urban character of the region is ensured by the existence of a common/shared infrastructure (public transport system, road network, etc.) connecting all its parts as well as a common administrative framework. The urban activities of this region gravitate towards the centers of the cities of Athens and Piraeus, as well as in the centers of a small number of regional centers clustering the two main centers. The Municipality of Athens is the central part of the region.

All road traffic in Athens encounters significant delays and small traffic speeds, which lead to large travel times. As a result of the increase in travel demand and the rapid increase in the use of private cars, during the last 25 years, there is currently a 2.6% average annual increase of traffic within the central areas, 3.5% increase within the rest of the main urban area (Athens Basin) and 7% increase within the suburban and semi-rural areas. Traffic congestion and delays are not helped by the fact that a significant percentage of roads are either of small width or at large grade. It has been estimated




| Scenario | Existing | Area_Restriction | Parking_Restriction |
|---|---|---|---|
| Average Private Vehicle Speed | 0.282 | 0.38 | 0.339 |
| Average Public Transport Speed | 0.286 | 0.372 | 0.343 |
| Average Vehicle Speed | 0.282 | 0.38 | 0.339 |
| Modal Share for Private Cars | 0.389 | 0.292 | 0.318 |
| Modal Share for Taxis | 0.333 | 0.333 | 0.333 |
| Public Transport Modal Share | 0.271 | 0.379 | 0.35 |
| Vehicle km | 0.391 | 0.294 | 0.315 |
| Passenger km | 0.368 | 0.311 | 0.32 |
| CO Emissions | 0.439 | 0.262 | 0.299 |
| VOC Emissions | 0.435 | 0.259 | 0.306 |
| NOx Emissions | 0.383 | 0.299 | 0.318 |
| PM Emissions | 0.374 | 0.305 | 0.321 |
| CO2 Emissions | 0.411 | 0.281 | 0.308 |
| Energy Consumption | 0.414 | 0.279 | 0.307 |
| Index Weighted Sum | -2.628 | -1.32 | -1.652 |

Fig. 5. Multi-criteria evaluation of multiple scenarios.

that the overall daily average traffic speed throughout the main urban areas about 23 km/hour, while the average speed in the remote suburbs is 35 km/hour and in the semi-rural areas 52 km/hour. Speeds during the peak hours and on the central region are much lower, though in many cases less than 10 km/hour. Data on transport demand and public transport for the city of Athens were mainly provided by the Athens Urban Transport Organisation, which is the public organisation responsible for planning, coordinating and providing financing for all public transport networks within the Greater Athens Area.

The analysis that follows takes into account the influence of partial restriction of private modes in the central area of Athens enforced in 1983 (establishment by the government of an internal ring where half of the private vehicles are prohibited from entering). Origin destination matrices, as well as the results presented, correspond to the morning peak hours of a typical day.

### 5.1. Policy analysis

Four scenarios are considered as case studies to examine the extent to which two different transport policy measures can affect traffic flows, travel speed and modal split, and reduce total energy consumption and air pollutant emissions. These scenarios are defined below:

*Scenario 0:* Reference scenario. This scenario assumes that the status of the transportation system remains unchanged. The results obtained under these conditions serve for comparison purposes to assess the effectiveness of the policy measures implemented under the other two scenarios.

*Scenario 1:* Area traffic restriction. This scenario examines the impacts of extending the region where half of the private cars are prohibited from entering, to the zones comprising the Municipality of Athens. At the same time, full restriction of private cars in the central area of Athens (internal ring) is enforced.

*Scenario 2:* Parking restriction. This scenario examines the impacts of reducing the number of parking places in the Municipality of Athens by 50%, thus restricting indirectly traffic and allowing more road space for it.

*Scenario 3:* Area and parking restriction. This scenario combines the policy measures of scenarios 1 and 2. It is used to examine the total impacts of the two policies (extension of prohibited region and restriction of parking places).

A summary of some results comparing the effectiveness of scenarios 1, 2 and 3 in enhancing the traffic efficiency and reducing fuel consumption and air pollution levels are presented in Tables 1–4. It can be seen than both measures force a shift from private to public transport modes (Table 1). Increasing the fraction of travel demand served by public modes will increase overall traffic efficiency (Table 2) while reducing fuel consumption and pollutant emissions. However, the percentage shift

Table 1
Estimated travel demand (passengers/peak hour) under different scenarios and its distribution by different modes

| | Scenario 0 | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|---|---|
| | | Estimate | Change (%) | Estimate | Change (%) | Estimate | Change (%) |
| Private modes | 307,845 | 232,368 | −24.52 | 263,924 | −14.27 | 197,585 | −35.82 |
| Taxi | 34,101 | 34,101 | 0.00 | 34,101 | 0.00 | 34,101 | 0.00 |
| Public transport | 169,281 | 244,757 | 44.59 | 213,202 | 25.95 | 279,541 | 65.13 |

Table 2
Estimated average travel speed (km/hour), vehicle kilometers and vehicle hours (per peak hour) under different scenarios

| | Scenario 0 | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|---|---|
| | | Estimate | Change (%) | Estimate | Change (%) | Estimate | Change (%) |
| Speed | 16 | 32 | 100.00 | 22 | 37.50 | 43 | 168.75 |
| Vehicle kilometers | 2,471,560 | 2,498,916 | 1.11 | 2,153,553 | −12.87 | 2,095,190 | −15.23 |
| Vehicle hours | 154,473 | 78,091 | −49.45 | 97,885 | −36.63 | 49,305 | −68.08 |

Table 3
Estimated fuel consumption level (tons/peak hour) under different scenarios

| | Scenario 0 | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|---|---|
| | | Estimate | Change (%) | Estimate | Change (%) | Estimate | Change (%) |
| Gasoline | 97.57 | 60.96 | −37.52 | 72.07 | −26.14 | 44.64 | −54.25 |
| Unleaded gasoline | 68.82 | 47.04 | −31.65 | 54.54 | −20.75 | 37.07 | −46.13 |
| Diesel | 17.68 | 14.08 | −20.36 | 15.44 | −12.67 | 12.19 | −31.03 |
| LPG | 1.99 | 1.83 | −8.04 | 1.88 | −5.53 | 1.72 | −13.72 |

Table 4
Estimated air pollutant emission levels (tons/peak hour) under different scenarios

| | Scenario 0 | Scenario 1 | | Scenario 2 | | Scenario 3 | |
|---|---|---|---|---|---|---|---|
| | | Estimate | Change (%) | Estimate | Change (%) | Estimate | Change (%) |
| CO | 35,663 | 20,462 | −42.62 | 24,880 | −30.24 | 14,242 | −60.07 |
| $CO_2$ | 521,580 | 353,250 | −32.27 | 408,259 | −21.73 | 275,147 | −47.25 |
| VOC | 3955 | 2292 | −42.05 | 2818 | −28.75 | 1625 | −58.90 |
| $NO_X$ | 3199 | 2587 | −19.13 | 2816 | −11.97 | 2265 | −29.19 |
| PM | 52 | 39 | −25.00 | 44 | −15.38 | 33 | −36.54 |

to public modes predicted under the conditions of scenario 2 is less than that predicted for scenario 1. Significant fuel savings (Table 3) and emission reductions (Table 4) are estimated for all scenarios. The limited reduction of LPG consumption is due to the fact that taxis, which account for the entire LPG consumption, remains unaffected by the policies implemented in scenarios 1, 2 and 3. The maximum reduction in emissions is achieved for CO and VOC. This change is due to the fact that the modal share of private cars, which account for most of CO and VOC emissions, is reduced (see Table 1).

## 6. Conclusions

Computer-based tools that perform travel demand analyses are extremely useful for transportation planning and policy development in a study area. Apart from predicting reasonable estimates for the extent of pollutant emissions and energy consumption caused by road traffic, efficient methodologies can be extracted for promoting and quantifying the penetration of public transport within a unified traffic management framework. A computer-integrated tool for planning urban transportation policies has been developed and can provide estimates of consequences of road traffic and account for the application of urban traffic policies that would facilitate the actions of authorities involved. The tool is a GIS-based DSS that involves realistic representation of the multimodal transportation network and efficient implementation of network equilibrium solutions for problems related to the application of urban transportation policies. The tool was tested for characteristic case studies that demonstrated the effectiveness of the proposed approach for the study area of Greater Athens.

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