Journal of Environmental Protection and Ecology 1, No 3, 367–373 (2000)

Research and education for sustainable development

ENVIRONMENTAL IMPACTS IN THESSALONIKI FROM ALTERNATIVE TRANSPORTATION MEASURES AND POLICIES

P .PAPAIOANNOU[a], S.BASBAS[b*], C.PARATHIRA[c]

[a]*Civil Engineering Department, Aristotle University of Thessaloniki, 54006 Thessaloniki, Greece*
[b]*Aristotle University of Thessaloniki, Department of Transportation and Hydraulic Engineering, 54 006 Thessaloniki, Greece*
[c]*TRIAS S.A, 39 G.Seferi St., 54 250 Thessaloniki, Greece*
E-mail: transp@edessa.topo.auth.gr

Abstract. Thessaloniki, a major commercial, political, cultural and transport center of Northern Greece and the Balkans, faces many and severe traffic congestion problems. For this reason, a number of significant transport infrastructure projects are either under study or being implemented, while at the same time different traffic management measures and policies are being examined or tested. This paper focuses on the traffic and environmental impacts of such measures and policies in the Thessaloniki Metropolitan Area (TMA). The following measures and/or policies are examined within this paper: traffic signal optimizations, traffic signal progressive coordination, toll pricing with elastic assignment. A traffic simulation model, called SATURN and developed in the UK, was used for this purpose. The results obtained indicate that significant improvements can be achieved through an integrated approach, provided that a rational behaviour — with respect to travel cost changes – on behalf of the trip makers is assumed.

Keywords: model, environment, optimization, coordination, traffic, toll.

AIMS AND BACKGROUND

Traffic and associated environmental problems in metropolitan areas, and especially in city centers, have been increasing during the last two decades. These problems result from the need to fulfill the demand for accessibility and accommodate the traffic without at the same time taking into account the issues of the environment, quality of life and traffic safety. Therefore appropriate measures have to be designed and implemented in urban areas, which will contribute to the improvement of the overall transportation system and the land use system. Concerning the transport management level, action has been undertaken to develop models which show how to influence modal-split in favour of public transport and make on line modification of traffic control measures as well as making a contribution to the analysis and evaluation of the interaction of the land use – transport situation.

In the pursuit of strategies to bring about changes in the modal split, and improvements in the urban environment, various measures have been developed,

* For correspondence.

implemented and evaluated e.g. pricing policies, prioritization of modes, high occupancy vehicles (HOV). This paper focuses on the traffic and environmental impacts of such measures and policies in the Thessaloniki Metropolitan Area (TMA). Thessaloniki, a major commercial, political, cultural and transport center of Northern Greece and the Balkans, faces many and severe traffic congestion problems. For this reason, a number of significant transport infrastructure projects are either under study or being implemented, while at the same time different traffic management measures and policies are being examined or tested. The following measures and/or policies are examined within this paper: traffic signal optimizations, traffic signal progressive coordination and, toll pricing with elastic assignment.

THE USE OF SATURN MODEL FOR ENVIRONMENTAL EVALUATION

In the pursuit for improving traffic and environmental conditions in the highly congested modern urban cities a number of different transport management schemes is considered as already mentioned above. However, their short and long-term effects are very difficult to be estimated since the consequences of the various components of urban transport strategies are quite a lot and possibly are in conflict. In addition, many urban transport schemes take a number of years to seriously impact on the transportation system and quite often their elements are also costly. Thus, there is a necessity to adopt a method for predicting the impacts of various strategy components both separately and in combination.

Predictions on the expected traffic and environmental impacts are attained by computer based transport models. These models take into account a number of different factors of the transport system to give reliable and useful information that can be utilized for different purposes, such as planning, evaluation, etc. They can also be used for traffic forecasting and provide decision-makers with indications about the extent to which strategy objectives are met, the expected consequences of its implementation, and the magnitude of the expenditure needed.

It is common in models to include the "supply" and the "demand" side of an urban transport system. Supply side represents the infrastructure of the system such as roads, junctions, public transport networks and it is rigidly associated with characteristics like road capacity, speed, public transport fleet and headway. Demand side deals with the amount of travel at a particular point in time and space and is rigorously related to socio-demographic features such as land-use, income, and car ownership. The point at which, a given transport system with a certain operating capacity, satisfies a certain demand for person and vehicle movements with different trip purposes and using different modes is where the equilibration of supply and demand is achieved.

In modelling terms, the aforementioned procedure requires a travel demand matrix which shows the demand for travel from each geographical zone to all

368

other geographical zones of the area; it also requires a representation of the network by employing links and nodes for roads and junctions, respectively, as well as characteristics of the network like link and junction capacity and link distance. The travel demand matrix is assigned to the network on the principle that decision-makers will choose the minimum cost route and at the end all routes will have equal and minimum cost[1].

The model used in TMA is the SATURN (Simulation and Assignment of Traffic to Urban Road Networks) which is a suite of network analysis programs developed at the Institute for Transport Studies, University of Leeds. SATURN is a combined simulation and assignment model for the analysis of traffic management schemes over relatively localised networks. It allows for the analysis of the implementation of management schemes such as one-way streets, tolls imposition, changes to traffic signals, etc. SATURN is also closely linked to the ME2 Model (Matrix Estimation from Maximum Entropy), a technique that enables the estimation of the travel demand matrix from traffic counts and reduces the survey costs required to run an assignment model like SATURN as well as increases its accuracy[2]. The model was developed in 1995 and represents the TMA at a highly detailed level. The demand matrix employed is deduced using the aforementioned ME2 procedure combining the older estimated demand matrix that was calibrated for the newly attained traffic counts.

In addition, SATURN provides a model for estimating the pollutant emissions for the various scenarios tested. Many of the SATURN outputs such as speeds, flows, stops at the intersections are employed to predict the pollutant emissions. Clearly many other factors that influence the production as well as the dispersion of emissions, like meteorological data, are ignored. The pollutants that are taken into account are the following: carbon monoxide, carbon dioxide, hydrocarbons, nitrogen oxides and lead. The following equation refers to each pollutant emitted from a link:

$$E^i = (a^i_1 d + a^i_2 t_c + a^i_3 t_q + a^i_4 s_1 + a^i_5 s_2)V \quad (1)$$

where V – vehicle flow, d — total travel distance in veh/km; s_1 — total number of primary stops at an intersection (where the vehicle arrives at the end of the queue); s_2 — total number of secondary stops at an intersection (stop-starts while a vehicle moves up in a queue); t_c — average free flow travel time (cruise time); t_q – time spent in queues; a^i_1-a^i_5 — the coefficients of equation (1). The values adopted for the current study are shown in Table 1.

It should be mentioned that the coefficients given above were calibrated from the data obtained from Leeds in 1988 and are the default values assumed within SATURN. These coefficients may need to be calibrated from local data and estimated based on local environmental conditions.

Table 1. Coefficients used for the estimation of the different pollutants

Pollutants (g/PCU*)	km	Cruise hour	Queue time	Primary stops	Secondary stops
CO_2	70	0	1200	16	5
CO	0	304.8	180	2.22	0.444
NO_x	0	102.6	1.80	0.42	0.084
HCO	0	57	30	0.39	0.078
Pb	0	0.36	0.09	0.0024	0.0005

*PCU represents a private car unit.

In the case of TMA the default values of the coefficients were used and therefore the values of the pollutant emissions in absolute terms should be considered with some caution. However, the proportionate improvement in the above environmental indicators is of great value.

A string of three traffic management schemes was employed which include signal optimization, signal coordination, and toll imposition. Each of these aimed at reducing the emission pollutants by improving the overall performance of the transport system.

Optimization. Signal optimization procedure lays on the principle of calculating the green splits, given that cycle length and amber are set, that would be most effective in terms of vehicle progression in the junction. The methodology employed in SATURN is the equi-saturation algorithm that follows the Webster approach of seeking to minimize the maximum/capacity ratio by turn by adjusting the green splits. It was proved that under certain circumstances this approach can lead to considerable reductions in total travel time by up to 20% compared to the initial settings[3].

It should be noted that optimized signal setting attracts more traffic that in turn influences the signal settings as green splits are calculated in conjunction to traffic flow patterns. Hence, an iterative procedure is established till both signal settings and traffic flows are fairly stable.

Co-ordination. Signal coordination involves calculation of appropriate offsets so that vehicles progress freely through a string of signals in case they travel at a given speed. The hypothesis behind the optimum off-sets estimation is that optimum off-sets are independent to any changes in flow patterns. This assumes the selection of an offset that minimizes the total vehicle delay through an intersection.

Tolling using elastic assignment. The issue of urban road pricing is of increasing interest in the early years since, from a theoretical and economical point of view, it ensures the efficiency of the transport system, assuming that in case of toll introduction only users whose benefits exceed their costs will still travel. However, costs not only include internal costs (fuels, time spent travelling) but also the external

370

costs like environmental, congestion and accident costs imposed on the transport system by the marginal user. It is recommended that tolls levied should primarily aimed at reducing or preventing environmental damage and secondly the emphasis should be on reducing and mitigating damaging environmental effects[4].

Tolls should represent the actual cost the marginal user imposes. Hence they should vary with respect to the vehicle type, time of the day (peak, off-peak), route chosen, etc. This, of course, is impossible due to the current technological barriers. In the tests conducted in Thessaloniki network, tolls were introduced in all the entry roads of a cordon line that surrounds the historical city center.

The toll imposed was 160 drachmas and it is introduced only in the entries and not in the exits. It should be clearly stressed that toll imposition was combined with elastic assignment technique that implies that any change to the travel cost, for instance due to the toll imposed, should reduce the demand for travel.

RESULTS AND DISCUSSION

In Table 2 the absolute values of the various pollutants (kg/30 min) produced according to the implementation of each traffic management scheme (scenario) and combinations of scenarios for the a.m. peak period (08:30-09:00) and the p.m. peak period (14:30-15:00) are presented. The do nothing scenario (basic scenario) for the same periods is also presented.

Table 2. Absolute values of pollutants for the various scenarios

Scenarios	Pollutants (kg/30 min)				
	CO	CO_2	NO_x	HC	Pb
Signal optimization (a.m.)	2993.79	25366.61	427.32	522.22	2.47
Signal optimization (p.m.)	2948.45	25040.14	420.67	514.34	2.43
Tolls (a.m.)	2915.11	24576.22	394.73	507.26	2.35
Tolls (p.m.)	2543.55	22025.74	386.94	445.17	2.15
Signal coordination (a.m.)	2953.85	24827.99	402.20	514.11	2.39
Signal coordination (p.m.)	2608.58	22493.23	399.40	456.65	2.22
Signal optimization together with tolls (a.m.)	2829.45	23944.21	388.79	492.69	2.30
Signal optimization together with tolls (p.m.)	24 72.34	21497.14	380.69	433.00	2.10
Signal coordination together with tolls (a.m.)	2844.34	24048.38	389.97	495.23	2.31
Signal coordination together with tolls (p.m.)	2492.70	21642.89	382.82	436.82	2.12
Do nothing scenario (a.m.)	2939.98	24728.70	400.85	511.73	2.38
Do nothing scenario (p.m.)	2612.12	22525.99	399.13	457.24	2.22

In Table 3 the percentage (%) of the values of the various pollutants (kg/30 min) produced according to the implementation of each traffic management scheme (scenario) and combinations of scenarios for the a.m. peak period and the p.m. peak period are presented.

371

Table 3. Percentage reduction (%) of pollutants for the various scenarios

Scenarios	Pollutants (kg/30 min)				
	CO	CO_2	NO_x	HC	Pb
a.m. period					
Signal optimization	1.8	2.6	6.6	2.0	3.8
Tolls	-0.8	-0.6	-1.5	-0.9	-1.3
Signal coordination	0.5	0.4	0.3	0.5	0.4
Signal optimization together with tolls	-3.8	-3.2	-3.0	-3.7	-3.4
Signal coordination together with tolls	-3	-3	-3	-3	-3
p.m. period					
Signal optimization	12.9	11.2	5.4	12.5	9.5
Tolls	-2.6	-2.2	-3.1	-2.6	-3.2
Signal coordination	-0.1	-0.1	0.1	-0.1	0.0
Signal optimization together with tolls	-5.4	-4.6	-4.6	-5.3	-5.4
Signal coordination together with tolls	-5	-4	-4	-4	-5

(-) Represents reduction in the pollutants.

From the above data it is clear that for both a.m. and p.m. periods, signal optimization results to an increase of the values of pollutants. This can be partially explained by the fact that the specific road segments of the road network, where the delays at the junctions are minimized, become more "attractive" to the drivers. The increase in the values of pollutants is smaller during the a.m. period because the road network is heavily congested, and therefore there is not enough room for new traffic even if the overall situation is improved. Tolls reduce the values of all pollutants especially during a.m. and p.m. period. The impact of tolls mainly occurs because drivers change their routes or use alternative modes (e.g. public transport). Signal coordination results to slight increase in the values of all pollutants during a.m. period whilst the situation remains almost unchangeable (compared to the basic scenario) during the p.m. period.

What is more important is the fact that the implementation of combined measures/policies (e.g. signal optimization or signal coordination together with tolls) is more effective in terms of traffic and environmental benefits than the implementation of a measure alone. Furthermore, it is considered quite beneficial to complement these measures with other measures and/or policies such as introduction of flexible hours for shops and public organizations, car pooling and car sharing, HOV lanes, on-street parking control, replacement of old-technology cars with cars equipped with 3-way catalytic converters, etc. It is therefore necessary to set up in fact an integrated strategy — for each urban area — addressing all the above issues, that will enable the sustainable improvement of the environmental and traffic conditions.

372

REFERENCES

1. F.V. WEBSTER, P.H. BLY, N.J. PAULLEY: Urban Land Use and Transport Interaction: Policies and Models. Gower, Aldeshot, 1988.
2. SATURN User Manual, 1998.
3. T. VAN VUREN, D. VAN VLIET: Route Choice and Signal Control, Leeds, Avebury Press, 1989.
4. High Level Group on Transport Infrastructure Charging. Final Report on Estimating Transport Costs. Commission of the European Communities, 1999.

Received 19 November 1999
Revised 14 June 2000

373