INVESTIGATING THE ENVIRONMENTAL IMPACTS OF PEDESTRIANIZATION AND TRAFFIC MANAGEMENT STRATEGIES IN THE CITY CENTER OF THESSALONIKI WITH AIMSUN

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ABSTRACT

Traffic congestion in urban areas results in increased energy consumption and vehicle emissions. Traffic management plans that alleviate traffic congestion also mitigate the environmental impacts of vehicular traffic. This study evaluates the environmental effect of a set of traffic management schemes and pedestrianization schemes with the use of the microscopic simulation model AIMSUN. Pedestrianization of specific road sections along with traffic regulating measures such as conversion of a two-way road to one-way road, change of direction of a one-way road have been simulated in different areas of Thessaloniki's city centre network. The assessment of the environmental effect is conducted in terms of fuel consumption, GHG and air pollutants estimation. Fuel consumption and the environmental indicators are quantified directly through AIMSUN's internal fuel consumption and emissions model. The morning peak period of a typical weekday between 09:00am-10:00am has been simulated and the demand data have been obtained through a macroscopic traffic assignment model that had been previously developed for the wider area of Thessaloniki. The results presented in this paper refer to network-wide, and section simulation statistics (i.e. fuel consumed carbon dioxide (CO_2), nitrogen oxides (NO_x) and particulate matter (PM)).

Keywords: environment, pedestrianization, traffic management, microscopic simulation, emissions model, AIMSUN

1. Introduction

Pedestrianization is defined as the restriction of traffic from specific road segments, which is followed by paving works, street furniture and other details (Hall and Hass-Klau, 1985). The implementation of pedestrianization schemes aims to promote awareness of the historic environment of cities, and increase the values of properties located within the traffic-free areas (Chiquetto, 1997). However, restricting traffic flow from specific portions of a road network can have substantial implications regarding local and network-wide environmental conditions. Since traffic flow and speed are the principal explanatory variables for the levels of air pollution, changes imposed on the patterns of traffic flow inevitably induce changes on the patterns of traffic emissions and fuel consumption (Chiquetto, 1997).

A study has been conducted with the use of a mesoscopic traffic simulation model to evaluate the effects of pedestrianization in the city of Chester, UK (Chiquetto, 1997). Simulation outputs from SATURN (i.e. vehicle queues, traffic flow and travel times) have been used to feed environmental predictive models for the estimation of traffic emissions. Concurrently, an assessment of travellers' response to changes imposed on traffic conditions with respect to mode choice has been also performed. Results indicated that total fuel consumption slightly decreased, and emissions decreased around the pedestrianized area but increased in the network as a whole.

Another study evaluated the impacts of pedestrianization schemes on traffic and the environment in the cities of Katerini and Rhodes, Greece (Pitsiava-Latinopoulou & Basbas, 2000). This study examined the operation of junctions located near to the greater area of the pedestrianization schemes using the program SIDRA (Signalized Intersection Designs and Research Aid). The results of the analysis indicated that NO_x, HC and CO emissions decreased significantly along with fuel consumption and average delay per vehicle. Moreover, a reduction of road accidents was also observed in the near area of the pedestrianization schemes.

Relatively few studies have been also conducted for the assessment of the traffic and environmental impacts of other traffic management schemes such as conversion of a two-way road to one-way road, change of direction of a one-way road and traffic calming measures. Specifically, a study set in Montreal, Canada investigated the effects of isolated traffic calming measures both at corridor and network level (Ghafghazi and Hatzopoulou, 2014). This study was based on the development of a microscopic simulation model of a dense urban neighbourhood. Traffic calming is the combination of physical changes in road design and speed management in order to improve road safety especially for users of non-motorized transportation sharing the road with drivers (Lockwood, 1997). Traffic calming measures eliminate conflicting movements, improve visibility and reduce exposure, as well as sharpen driver's attention (Ewing, 1999). The results of the aforementioned study indicated that on average, isolated calming measures increase carbon dioxide (CO_2), carbon monoxide (CO), and nitrogen oxides (NO_x) emissions by 1.5, 0.3 and 1.5 % respectively across the entire network. Area-wide schemes result in a percentage increase of 3.8 % for CO_2, 1.2 % for CO, and 2.2 % for NO_x across the entire network.

This study evaluates the environmental impacts of pedestrianization schemes in the city centre of Thessaloniki with the use microscopic traffic simulation. The road network of Thessaloniki's central business district area has been simulated in AIMSUN. Aggregate and disaggregate simulation output statistics have been obtained through the simulation experiments and are presented in this study.

2. Microscopic traffic and emissions simulation modelling

Microscopic traffic simulators can imitate the longitudinal and lateral movement of individual vehicles as they occur in real-life. Their ability to dictate these movements is based on a set of sub-models which replicate driver's car-following, lane changing and gap acceptance behavior. Thus, the simulators estimate each vehicle's position, speed and acceleration for every simulation step. The trajectories of the vehicles are then utilized for the estimation of fuel consumption and emissions by the corresponding models that are integrated with the microscopic traffic simulation models. A microscopic emission model has been integrated with AIMSUN (Panis *et al.*, 2006). This model is based on empirical measurements which relate vehicle emissions with the instantaneous speed and acceleration of the vehicle. The importance of using microscopic emission models for the assessment of the environmental impacts of traffic management and control policies has been stresses explicitly, since this is a complex issue that requires detailed analysis of not only their impact on average speed but also on other aspects of vehicle operation such as acceleration and deceleration (Rakha and Kamalanathsharma, 2011).

3. The study site – aimsun model

A detailed microscopic simulation model has been developed, covering the central business district area of the city of Thessaloniki. The model development has been implemented with the Aimsun microscopic traffic simulator. The simulated network is comprised of 401 sections and 290 junctions; its total length is 42-km and it is depicted in Figure 1. Among the 290 junctions, 62 are controlled by signals. Forty public transport lines have been also simulated along with their corresponding time plans.

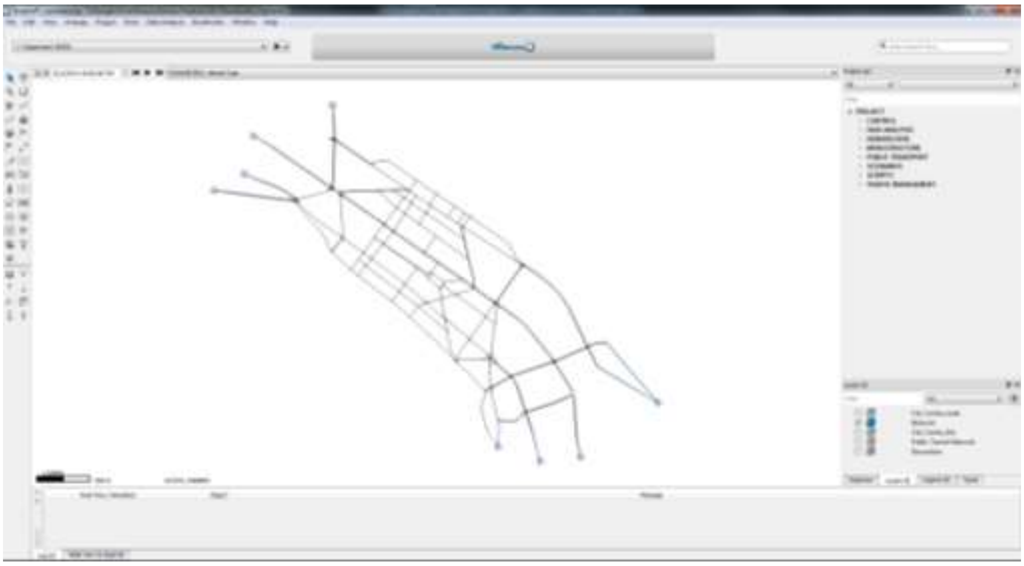

Figure 1: Simulated network in AIMSUN.

Demand has been obtained through a macroscopic traffic assignment model developed in VISUM for the wider area of Thessaloniki (Stamos *et al.*, 2013). Field traffic flow data collected from traffic sensors located throughout the road network of Thessaloniki from an one-hour morning peak period (i.e. 09:00-10:00am) of a typical weekday (i.e. Wednesday 15th October 2014) have been input to the macroscopic model, which executed the traffic assignment and produced the necessary demand info for the "loading" of the microscopic model. Traffic composition information has been also obtained through a previous study (Mitsakis *et al.*, 2013). According to this study the fleet in this portion of Thessaloniki's road network is comprised 90% by private vehicles, 5% by taxis, 4% by trucks and 1% by buses.

The operation and performance of the network has been assessed for five different pedestrianization schemes. A total of 6 scenarios have been simulated, 1 pertaining to the base case scenario and 5 to the simulated pedestrian areas. The exact measures involved in each pedestrianization scheme are presented in Table 1.

Table 1: Description of scenarios.

Scenarios	Descriptions
Scenario 1	Entails the pedestrianization of A.Sofias St. from Egnatia St. to Nikis Ave., of Keramopoulou St. from P.Ioakim St. to A.Sofias St., of Makenzi King St., of Ermou St. from K.Ntil St. to A.Sofias St., and the conversion of Ermou St. to a two lane one-way street from K.Ntil St. to E.Venizelou St.
Scenario 2	Entails the measures of Scenario 1, plus the conversion of Tsimiski St. to a three lane street, with two general purpose lanes and one exclusive bus lane.
Scenario 3	Entails the pedestrianization of A.Sofias St. from Egnatia St. to Nikis Ave., of Keramopoulou St. from P.Ioakim St. to A.Sofias St., of Makenzi King St., of Ermou St. from A.Sofias St. to E.Venizelou St., and the conversion of Ermou St. to a two lane one-way street from K.Ntil St. to E.Venizelou St.
Scenario 4	Entails the measures of Scenario 1, plus the pedestrianization of Nikis Ave. from E.Venizelou St. to E.Aminis St.
Scenario 5	Entails the pedestrianization of Nikis Ave. from E.Venizelou St. to E.Aminis St. and the conversion of Tsimiski St. from a four lane street to a three lane street, with two general purpose lanes and one exclusive bus lane.

Due to the stochastic nature of AIMSUN multiple runs of each simulated scenario are necessary, so that the simulation output is statistically significant. Therefore, five simulations of the base case scenario were initially run, each with a different random seed generated by AIMSUN's internal random number generator, and statistics (i.e. standard deviation and mean value) regarding the average network speed were collected for this sample of runs. The significance level was selected to be 95%, the tolerable error equal to 0.5km/h, and given the standard deviation of the average network speed of the initial sample, the required number of runs was determined to be five.

4. Results and discussion

The output of the simulation experiments pertains to traffic performance measures and environmental indicators. Simulation output statistics have been estimated both at section level (i.e. disaggregate level) and network level (i.e. aggregates). The estimated traffic performance measures are average section traffic flow and average network speed. The environmental indicators are fuel consumption, CO_2, NO_x, and PM emissions.

4.1. Disaggregate simulation output statistics

The local impacts of the pedestrianization schemes have been evaluated on three specific road sections that are located in the proximity of the pedestrianized areas. The implementation of the pedestrianization schemes results in the redistribution of traffic in the nearby road network. It becomes apparent from the simulation results that traffic flow on these specific road sections increases significantly (Table 2) compared to the base case scenario. Consequently, fuel consumption and CO_2 emissions also increase substantially (Table 3 and 4).

Table 2: % Difference in average traffic flow against the base case scenario.

Demand Level	Tsimiski St. (upstream of K.Ntil St.)	Mitropoleos St. (downstream of & A.Sofias St.)	E.Venizelou St. (upstream of Ermou St.)
Scenario 1	76,20	11,57	62,14
Scenario 2	72,02	11,10	59,44
Scenario 3	74,05	17,07	77,27
Scenario 4	72,74	74,63	85,53
Scenario 5	64,74	39,93	105,64

Table 3: % Difference in average fuel consumption against the base case scenario.

Demand Level	Tsimiski St. (upstream of K.Ntil St.)	Mitropoleos St. (downstream of & A.Sofias St.)	E.Venizelou St. (upstream of Ermou St.)
Scenario 1	45,37	12,91	70,45
Scenario 2	38,02	16,96	70,89
Scenario 3	34,93	25,32	89,52
Scenario 4	41,22	48,71	127,55
Scenario 5	41,49	34,09	112,31

Table 4: % Difference in average CO_2 emissions against the base case scenario.

Demand Level	Tsimiski St. (upstream of K.Ntil St.)	Mitropoleos St. (downstream of & A.Sofias St.)	E.Venizelou St. (upstream of Ermou St.)
Scenario 1	60,51	13,34	69,77
Scenario 2	53,25	16,30	70,62
Scenario 3	56,12	24,33	87,78
Scenario 4	56,70	58,41	117,48
Scenario 5	56,38	37,36	117,94

4.2. Aggregate simulation output statistics

The impacts of the pedestrianization schemes have been also assessed network-wide. Since traffic is banned from several road sections, which are converted to pedestrian areas, demand has to be accommodated by the rest of the network. Thus more traffic corresponds to lesser network capacity and consequently traffic conditions on the whole network deteriorate. Apparently, the average network speed decreases compared to the base case scenario after the implementation of the traffic-free areas (Table 5). Since the average network speed regarding the base case scenario is 28,23 km/h, it becomes obvious that the average network speed after the implementation of the pedestrianization schemes is less fuel efficient and environmentally friendly. Network-wide traffic emissions rise significantly as a result of pedestrianization (Table 5).

Table 5: % Difference in average network statistics against the base case scenario.

Demand Level	Speed	CO_2	NO_x	PM
Scenario 1	-10,99	35,54	26,05	76,70
Scenario 2	-12,44	36,54	27,09	79,58
Scenario 3	-10,87	34,35	24,89	73,81
Scenario 4	-18,31	41,08	31,14	86,65
Scenario 5	-20,57	39,64	31,20	80,87

5. Conclusions

The environmental impacts of pedestrianization schemes in the city centre of Thessaloniki have been evaluated with the use of microscopic traffic simulation modelling. Results have indicated that significant increase in fuel consumption and emissions occur with the implementation of pedestrianized areas both locally (i.e. isolated road sections) and network-wide. However, no assessment has been conducted to evaluate the potential impacts of pedestrianization on travel demand reduction and mode choice shift that could possibly incur different changes to energy consumption and environmental conditions. Moreover, it has to be mentioned that emissions within the pedestrianized areas cannot be estimated through microscopic traffic modelling.

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