

Evaluation of bus lanes in central urban areas through the use of modelling techniques

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Abstract

Within the framework of this paper, the traffic and environmental impact of bus lanes introduced in urban central areas is evaluated through the use of traffic simulation modelling techniques. The results from the examination of various parameters such as energy consumption and pollutants emitted (CO, CO₂, NO_x, HC, and Pb) through the use of the traffic simulation model Simulation and Assignment of Traffic to Urban Road Networks (SATURN) are presented. The reference area is the centre of the city of Thessaloniki, Greece, which is characterized by severe traffic and environmental problems.

1 Introduction

The promotion of Public Transport in urban areas includes a variety of measures among which bus lanes play an important role. The impact of bus lanes concerns not only traffic but also the environment since more people are supposed to use environment friendly buses instead of polluting private cars. A large number of local authorities have decided to introduce bus lanes or to expand their existing network of bus lanes in their areas in order to affect modal split in favour of Public Transport and to solve their traffic and associated environmental problems. Although bus lanes in theory are supposed to work without problems, in practice there are quite a few reasons which impose obstacles in their daily operation. Therefore, various problems can be identified through the evaluation of this measure and, as a consequence, corrective actions can be taken by the competent authorities.



Sensitivity analysis of exclusive bus lanes (among other strategies) in Taipei city centre show that a passenger's modal choice and energy consumption is not affected by this strategy in the short term and therefore the use of other strategies is recommended [1]. According to another study the effect of bus lanes to emissions is a reduction by 5-12% of NOx particulate emissions from buses and this reduction exceed 15-30% if there is a bus priority system in the traffic lights [2]. A research in the U.K. has showed that disbenefits can often occur in case where buses are subject to a pre-signal unless bus detectors are used to gain priority signalling [3].

Traffic simulation models are often used for the evaluation of bus lanes. According to the results of the QRS II (Quick Response System II) for Athens the increased use of the existing bus lanes system resulted to -7,3% CO, -6,7% HC, -4,4% NOx, -2,5 Pb and -5,8% CO₂ [4].

The use of SATURN (Simulation and Assignment of Traffic to Urban Road Networks) in the city of Komotini, Northern Greece, shows that the environmental conditions in the road network have been significantly improved after the implementation of an extensive and exclusive bus only network together with the introduction of HOV lanes [5]. More specifically CO₂ and CO emissions have been significantly decreased as well as bus fuel consumption by 3,09%. In any case it should be mentioned that "the more comprehensive the scheme the more extensive will need to be the assessment and the longer the period allowed for people to adjust to the changes before measuring the effects" according to OECD [6].

Within the framework of this paper, the traffic and environmental impact of bus lanes introduced in urban central areas is evaluated through the use of traffic simulation modelling techniques. The results of the examination of various parameters such as energy consumption and pollutants emitted (CO, CO₂, NOx, HC, and Pb) through the use of a simulation model are presented. The reference area is the centre of the city of Thessaloniki, which is characterized by severe traffic and environmental problems.

2 Characteristics of the bus lane system in Thessaloniki

Thessaloniki is a city in Northern Greece with more than one million inhabitants. According to the results of the General Transportation Study [7] for the year 1998 the number of trips daily made within the city boundaries by all transport modes is 1.600.000. A percentage of 27,5% of all trips is made by Public Transport while the respective figure ten years ago was 36,4%. That means there has been a constant decline in the use of the city Public Transport system for many years.

The Public Transport system of Thessaloniki today consists of 488 buses and 55 bus lines, all belonging to O.A.S.Th which is the bus operator. O.A.S.Th has 2.180 employees and was established in the year 1957. Every day 437 buses (out of 488) are in operation and they serve 140.000.000 passengers per year. By the end of the year 2007 the whole bus fleet will be replaced by modern, environment friendly, buses.



In order to promote the use of Public Transport and to improve the quality of services provided to the passengers, the city authorities decided to introduce bus lanes, mainly in the city centre which actually suffers from severe traffic and associated environmental problems. The geometric and functional characteristics of bus lanes in the city of Thessaloniki are presented in Table 1.

Table 1: Geometric and functional characteristics of bus lanes in Thessaloniki.

Road	Length (m)	Lanes left for the rest of the traffic	Buses during peak hour	Operation (day/time)	Servicing hours for shops (lorries & trucks)
Mitropoleos	980	1	60	Monday-Friday 10:00-22:00	08:00-10:00 & 16:00-18:00
Vas.Olgas	3.200	3	30-40	Monday-Friday 06:30-20:30	12:30-15:30
Tsimiski	1.300	3	40-50		12:30-15:30
Egnatia	1.750	2 per direction	115-185 per direction		09:30-12:30 & 16:00-17:00

Source: [8]

The increase of the average speed of buses after the implementation of bus lanes was quite substantial according to the results of a research carried out by the Civil Engineering Department of the Aristotle University of Thessaloniki in year 1997 [9].

More specifically, the average speed of buses has been increased from 7,8 km/h to 11,8 km/h in Mitropoleos bus lane and by 10%-15% in Vas.Olgas bus lane. The introduction of bus lanes also led to an overall improvement of the air quality since there was an important impact on the temporal decrease of SO₂ and TSP values in the city center [10].

Since the bus lane examined within the framework of this paper is the one of Egnatia road (central arterial road with 3 lanes per direction in total) it was considered necessary to present hereinafter data concerning the specific bus lane. The commercial speed of buses along Egnatia bus lane according to the results of the research carried out in the Department of Transportation & Hydraulic Engineering of the Aristotle University of Thessaloniki [11] is presented in Tables 2 and 3. It must be mentioned at this point that commercial speed takes



into account the delays due to bus stops, traffic lights etc. The number of buses using Egnatia bus lane is presented in Table 4.

Table 2: Commercial speed of buses along Egnatia bus lane (inbound direction).

Time Bus line	7-8	8-9	9-10	10-11	13-14	14-15	15-16	16-17
2	11,5	10,5	9,6	9,2	9,2	9,7	10,3	10,9
10	12,8	10,9	8,6	10,2	9,8	9,7	10,8	10
11	12,2	10,3	9,9	9,1	10,5	10,8	11	11,9
14	12,4	10,2	8,2	8,8	9	9,5	10,8	9,8
17	11,6	8,9	8,7	9,3	9,9	10,3	10,9	11,2
27	12,5	10,6	10,1	11,4	10,1	9,8	10,2	10,8
37	12,7	9,9	10,8	11,8	10,2	10	10,9	10,7

Table 3: Commercial speed of buses along Egnatia bus lane (outbound direction).

Time Bus line	7-8	8-9	9-10	10-11	13-14	14-15	15-16	16-17
2	13,4	10,3	10,1	13,6	9,2	9,7	10,3	10,9
10	13	10,3	10,2	11,5	9,8	9,7	10,8	10
11	11,5	11,5	11,2	11,5	10,5	10,8	11	11,9
14	12,9	10,8	10	9,6	9	9,5	10,8	9,8
17	13,5	11,2	11,2	11,8	9,9	10,3	10,9	11,2
27	12,8	10,6	11,2	12,2	10,1	9,8	10,2	10,8
37	12,2	10	11,4	10,8	10,2	10,1	10,9	10,7

Table 4: Number of buses using Egnatia bus lane (per direction).

Time Direction	7-8	8-9	9-10	10-11	13-14	14-15	15-16	16-17
Inbound direction	124	129	128	116	126	94	113	122
Outbound direction	128	146	128	133	130	124	121	129

As shown in the above tables, commercial speed is in the area of 11,5-12,8 km/h (inbound direction – morning peak/7-8) and 9,5-10,8 km/h (outbound direction – afternoon peak/14-15). It must be mentioned at this point that enforcement of bus lanes is more intense during the morning peak period.



3 Methodology of the research and model used

The objective of the research was to assess the traffic and environmental impacts of the bus lane along Egnatia road in the centre of the city of Thessaloniki. This was achieved through the examination of various indicators such as average speed, delays, travel time and travel distance as well as energy consumption and pollutants emitted (CO, CO₂, NO_x, HC, Pb).

The traffic simulation model used for the evaluation was SATURN (Simulation and Assignment of Traffic to Urban Road Networks). SATURN is a suite of flexible network analysis programs developed at the Institution for Transport Studies, University of Leeds, UK. SATURN is a combined traffic simulation and assignment model for the analysis of traffic management schemes over relatively localised networks [12,13]. SATURN is also closely linked with the ME2 Model (Matrix Estimation from Maximum Entropy), a technique that enables demand trip matrices to be estimated directly from traffic counts.

The values of the performance indicators were calculated for the city road network both “before” and “after” the implementation of the bus lane in Egnatia road. The parameters of the transport system examined include traffic volumes, speed, delays, as well as the use of the road network expressed in travel distance (pcu*kms) and in travel time (pcu*hrs), where pcu is passenger car unit. Environmental parameters examined include emissions of pollutants and fuel consumption. The city centre of Thessaloniki together with the bus lines crossing the area are presented in Figure 1.

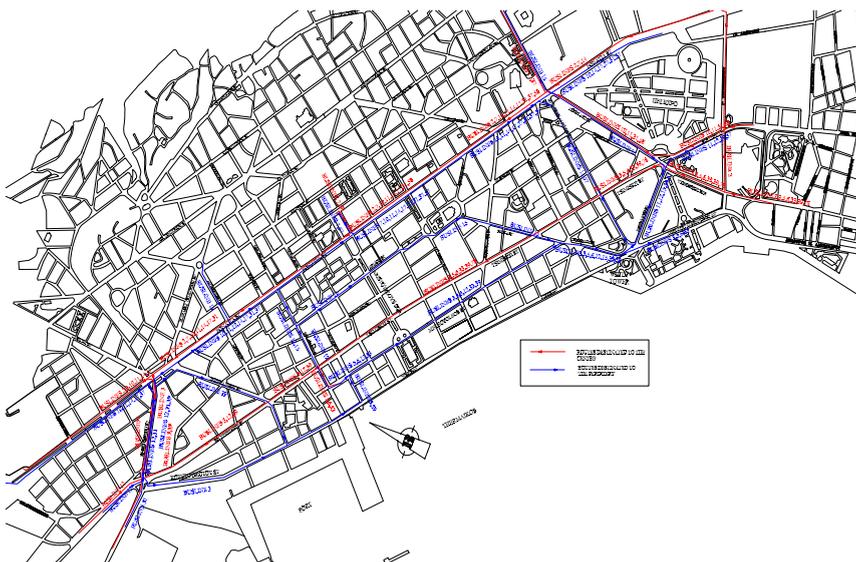


Figure 1: Thessaloniki central bus network.



4 Evaluation results

The evaluation results of the “before” and “after” situation as produced by SATURN include values for the average speed, delays, travel distance, fuel consumption and travel time. Values have been calculated separately for the morning and the afternoon peak period and refer to all types of vehicles in the city centre and to buses only. Values of the indicators examined during the morning and afternoon peak period for the “before” and “after” situation are presented in Tables 5 and 6 respectively.

Table 5: Values if indicators in the “before” and “after” situation for all types of vehicles and for buses only (morning peak period) in the city center.

	“Before” situation	“After” situation	Difference (%)
Values of indicators for all types of vehicles in the city center			
Average speed (km/h)	12,2	12,1	-0,82
Delays (pcu*hrs)	18.504,6	18.820,8	1,71
Travel distance (pcu*kms)	288.688,7	288.395,9	-0,10
Travel time (pcu*hrs)	23595,4	23903,1	1,30
Values of indicators for buses in the city center			
Average speed (km/h)	9,2	9,6	4,35
Travel distance (pcu*kms)	5.092	4.183,6	-17,84
Travel time (pcu*hrs)	550,6	433,9	-21,20
Fuel consumption (lit)	1.076,3	815,6	-24,22

Table 6: Values if indicators in the “before” and “after” situation for all types of vehicles and for buses only (afternoon peak period) in the city center.

	“Before” situation	“After” situation	Difference (%)
Values of indicators for all types of vehicles in the city center			
Average speed (km/h)	16,9	16,8	-0,59
Delays (pcu*hrs)	10.251,7	10.257,9	0,06
Travel distance (pcu*kms)	24.5014,1	24.4258,5	-0,31
Travel time (pcu*hrs)	14.559,6	14.543,8	-0,11
Values of indicators for buses in the city center			
Average speed (km/h)	12,1	13,5	11,57
Travel distance (pcu*kms)	5.092	4.183,6	-17,84
Travel time (pcu*hrs)	420,7	310,9	-26,10
Fuel consumption (lit)	949,2	680,4	-28,32

Vehicle emissions are also examined with SATURN. Values for CO, CO₂, NO_x, HC and Pb for the city centre road network concerning the “before” and “after” situation during the morning and afternoon peak period are presented in Figures 2 and 3 respectively.



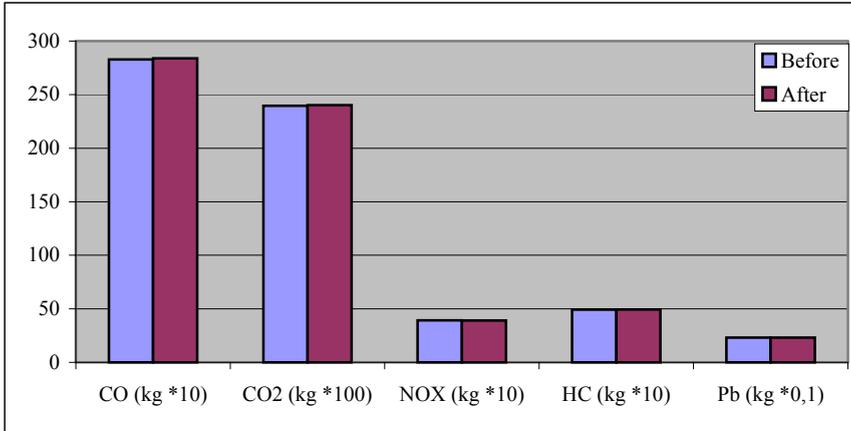


Figure 2: Values of emissions from traffic in the city centre road network for the “before” and “after” situation” (morning peak period).

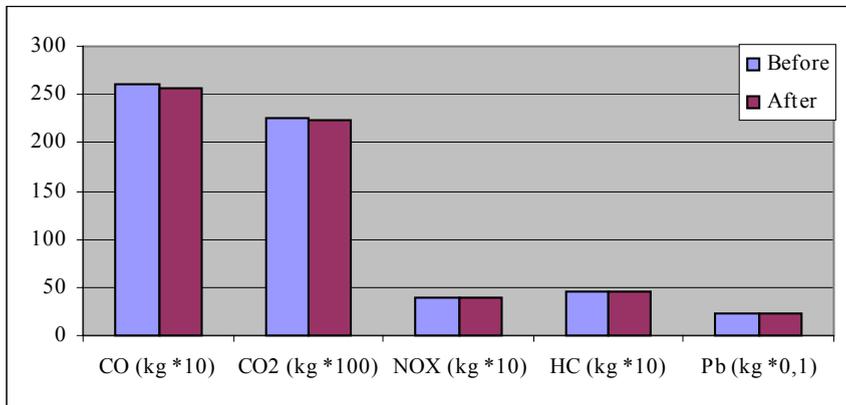


Figure 3: Values of emissions from traffic in the city centre road network for the “before” and “after” situation” (afternoon peak period).

In Figures 4 and 5 the impacts of the bus lane in its near area are presented for the morning and afternoon peak period respectively.

5 Conclusions

The benefits from the implementation of the bus lane are very significant for buses in the city centre as it was expected. Travel time of buses has been reduced by 21,2% during the morning peak period and by 26,1% during the afternoon peak period. Fuel consumption has been reduced by 24,22% during the morning peak period and by 28,32% during the afternoon peak period. The average speed of buses has been increased by 4,35% during the morning peak period and by 11,57% during the afternoon peak period. In general it seems that benefits are



higher in the case of the afternoon peak period in the city centre. When considering traffic in all types of vehicles then the average speed is reduced both in the morning and afternoon peak period (by 0,82% and 0,59% respectively). Delays of vehicles are also increased both in the morning and afternoon peak period (by 1,71% and 0,06% respectively).

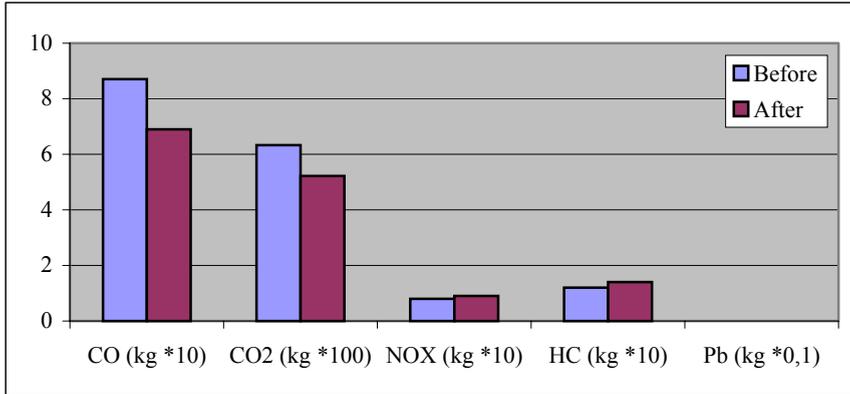


Figure 4: Values of emissions from traffic in the near area of the bus lane for the “before” and “after” situation” (morning peak period).

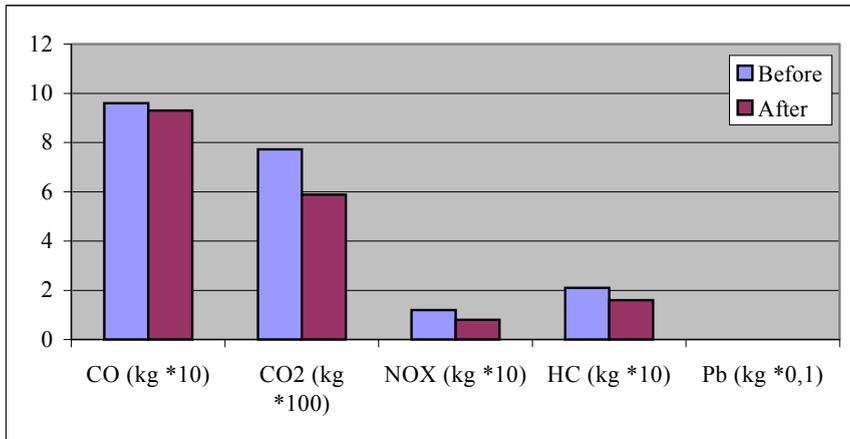


Figure 5: Values of emissions from traffic in the near area of the bus lane for the “before” and “after” situation” (afternoon peak period).

Changes in the level of emissions of CO, CO₂, NO_x, HC and Pb cannot be easily identified when considering the total area of the city centre. On the contrary, results have shown that there is a substantial decrease of CO and CO₂ emissions in the near area of the bus lane examined, for both morning and afternoon peak period. NO_x and HC emissions have been reduced only during the afternoon peak period.

Finally, the use of SATURN has been proved to be very important to the evaluation process of bus lanes and it is a powerful tool for those involved in the

process of design and implementation of bus lanes in urban areas facing severe traffic and environmental problems.

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