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EVALUATION OF TRAFFIC NOISE LEVELS AS A RESULT OF URBAN TRANSPORT MEASURES, APPLYING A GIS-BASED TECHNOLOGY

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Abstract. *Traffic noise is a significant effect of transport in urban areas and a priority issue in the EU. Noise as an environmental factor needs to be considered more closely when transport policies and relevant measures are examined and planned to tackle transport related problems. There is a need for including impacts on noise both at the macro and the micro level. Existing official traffic noise calculation methods mainly focus on the former. By using suitable methods for both these levels in combination with transport simulation models and GIS technology, it is possible to approach the whole issue in a more comprehensive way. Visualisation of problem areas and spots with extreme effects as well as other traffic parameters is easily achieved with the use of GIS functionality.*

1 TRAFFIC, NOISE AND THE ENVIRONMENT

Traffic and associated environmental problems have emerged in the majority of modern cities all over the world, in the last decades, as a result of increased car ownership and mobility. Among the environmental problems, noise pollution along with air pollution is considered to be the most important ones.

Noise is quite unlike other atmospheric pollutants to which we are exposed. The insidious nature of other pollutants is not experienced immediately and it seems that no dialogue or vernacular terms exist to attempt to describe the phenomena at the citizens' level. Most of us use a wide range of terms to describe noise and many would agree about using terms that suggest reduction of quality of life.[1]

According to a Commission Green Paper, Environmental noise caused by traffic, industry and recreation is identified as one of the main local environmental problems in Europe.[2] It has been also stated that around 20 percent of the EU citizens are exposed to noise levels that scientists and health experts consider to be unacceptable, where most people become annoyed, where sleep is disturbed and where adverse health effects are to be feared. In addition, approximately 170 million EU citizens are living in areas where the noise levels are high enough to generate serious annoyance. In the industrial world, more than 110 million people are exposed to noise levels over 65 dB, due to road transportation services.[3]

Regarding the external costs of noise -especially transport noise- to society, the Green Paper states that according to a wide variety of studies, these estimates range from 0.2% to 2% of GDP across Europe. The external unitary cost of noise for various transport means as estimated from Cotana et al,[4] is presented in the following Table 1

Transport means	Costs (10^{-3} Euro/vehicle km)		
	Urban	Extra-urban	Global average value
Motorcycle	69,4	15,2	38,4
Car	16,8	3,4	7,7
Bus	69,4	15,2	42,3
Diesel train	442,0	221,0	285,2
Electric train	566,0	283,0	339,6
Airplane	n.a	n.a	105,0

Table 1: External unitary costs of noise – passenger vehicles – different means

The road noise problem is considered to be one of the major priority areas for action at EU level and proposals of DGIII foresee a 25% cut in emissions from this source.[5] According to the results of a research study about traffic noise, in Turin, it was found that people living in buildings lining roads with tramway line and more than 3000 vehicles per hour perceive a similar disturb of the people living in roads with tramway line and 600-800 vehicle per hour, characterized by canyon sections.[6]

Noise measurements were made, and proposals were formatted, in the framework of various environmental impact assessment studies concerning transport infrastructure in Greece. Such a case is the study for the environmental impacts from the construction of six multilevel junctions in Thessaloniki which was carried out by the research team of the Laboratory of Transportation Engineering of A.U.Th.[7] The case of N.Philadelphia in Athens, where the National Road No1 crosses the area and is responsible for the production of traffic noise problems, is also such an example. L_{10} exceeded the limit of 70 dBA and the annual average daily traffic was in the area of 90000 PCUs (15% heavy vehicles). The construction of a noise barrier was decided as an effective solution to the problem.[8] Reducing the effects of noise to people requires extended investments in noise protection measures. The cost concerning the measures (i.e. noise barriers) for the reduction of traffic noise was presented in the framework of various scientific publications in Greece.[9] The prediction Swiss model EMPA was evaluated after a comparison with field measurements in two major streets of Thessaloniki, V. Olgas and Mitropoleos [10] Traffic noise impacts were also estimated for the main entry and exit areas of the under study New Arterial Tunnel Bypass of the city center of Thessaloniki [11] A methodology for the assessment of environmental impacts from noise traffic due to the operation of parking stations in urban areas was applied in Athens (Protomagia Sq) in the framework of a pilot study [12] Mathematical models were also used in the calculation of the expected noise levels along parts of the road network of the city of Rhodes, in order to evaluate alternative traffic management schemes [13] Traffic noise maps were produced for five major urban agglomerations in Greece: Piraeus, Patras, Larissa, Heraklion and Ioannina. The relatively important variation in the values of typical deviation, together with the differences found between maximum and minimum values in all cities, was explained by the fact of that these cities include quite areas and areas closed to road axes which were heavily congested [14]

Especially for the noise barriers, the construction cost depends on their dimensions, materials, way of foundation etc., (i.e for a 30 ft noise barrier the cost in U.S.A is 394.83 ft/$ in case of concrete, 434.16 ft/$ in case of steel, and 388.07 ft/$ in case of wood, 1988 prices) [15]

In Japan, 4135 out of 4772 roadside observatory stations failed to keep environmental quality standards for noise in the year 1997. With the aid of two models (traffic assignment model and traffic noise model) and the use of the GIS technology, several policy measures for reducing the level of traffic noise were tested in Sendai city. The installation of drainage asphalt pavement proved to be an efficient way to reduce traffic noise levels. Cordon pricing was effective too but it also worsened the situation outside the codon line.[16] A research project for traffic noise impact assessment using vector-based GIS package was carried out in Denmark. The noise calculations follow the Nordic Traffic Noise Model which has been developed to describe traffic conditions in the Nordic countries. The results of the project indicate that the utilization of digital technical maps and central register information in connection with environmental traffic impact assessment, can provide essential improvements relative to more traditional methods [17] Within the study of the Marsh area of Huddersfield in U.K, twenty two roads were identified as having a significant traffic flow for the purpose of noise assessment. These were individually isolated within the GIS from a file of all roads in Kirklees Metropolitan, which had been digitized at 1:10000 scale. Basic noise levels for each of the 22 road links were calculated and digital files were input to the GIS package IDRISI for Windows. The final process in creating the noise map was to combine the basic noise map and the noise reduction coverage in a single overlay and the reclass it to a meaningful sound level categories [18] Regarding the relational data base structure of traffic noise, a conceptual design for GIS based modelling has been recently proposed [19]

The above references show that traffic noise impacts are a considerable factor for most transport related projects and measures. However, these impacts are usually studied when a new infrastructure project is to be made. The high cost of new infrastructure in urban areas usually leads decision makers to other solutions such as transport demand management (TDM) measures for dealing with traffic problems. In these cases normally no specific studies for estimation of noise impacts is made. Depending on the selected strategy of a regional or local authority, TDM measures may or may not alter existing noise levels in inhabited areas or in areas with mixed land uses.

The objective of this paper is a) to point out the need for examining the various transport related strategies and measures from the traffic noise point of view and b) to demonstrate a new approach taking into account traffic simulation and noise calculation models along with GIS application capabilities. Transport measures – real and future – in the city of Thessaloniki, Greece, are examined for this purpose.

The ultimate target of this work is to pinpoint areas of interest for transport and environment professionals and to indicate the need for enhancement to existing noise prediction methods of additional components pertaining to micro level noise impacts (such as vehicle decelerating and accelerating, stopping of vehicles, flow variation among lanes, etc.) A way to approach this issue is shown in Figure 1.

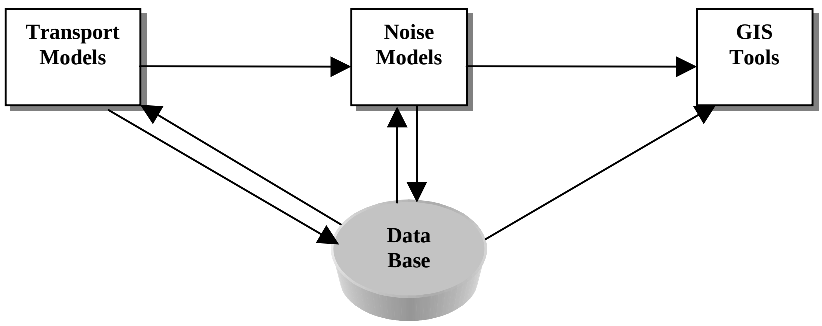

Figure 1: Tools for approaching traffic noise issue

2 TRANSPORT POLICIES AND MEASURES IN URBAN AREAS

Local, regional and state authorities face severe traffic and transport problems in urban areas due to the rapid increase of both car ownership and mobility of persons and goods. Impacts of traffic to the environment are a common phenomenon, and almost all involved look for effective ways to deal with this. Overall the main problems related to the transport system can be identified under the following headings[20]:

- Accessibility
- Mobility
- Safety
- Environment
- Energy

The necessity for planning principles, which take better account of social and environmental issues, has led to considerable research in recent years. Two main categories of impact can be considered:

- The first comprises those factors attributable to traffic such as noise, air pollution and vibration.
- The second relates to factors associated with transport infrastructure (roads, rail tracks, etc.) and which are to a large extent independent of traffic volumes.

Noise and air pollution may easily be related to traffic volumes, speeds and distances, but vibration levels are more difficult to predict. The main problem for all these factors is to relate the levels of disturbance to defined standards of acceptability so that their effects can be assessed non-subjectively.

Concerning the factors in the second category, severance and barrier effects as well as changes in land access can be measured and demonstrated using isochrone technique, whereas visual intrusion usually has to be subjectively assessed.

Traffic management offers considerable scope for improving the urban environment, mainly by limiting the amount of traffic, improving regulating and re-distributing traffic flow, or changing the composition of the traffic. Traffic re-planning schemes are especially important in identifying and treating environmentally areas within towns.

Table 2 presents an overall overview of the various transport strategies and measures and the respective impacts on the above mentioned headings. Noise is incorporated in the environmental factors.

Evaluation techniques that compare and rank projects prior to implementation do, however, suffer from the difficulty of comparing unlike environmental factors (i.e. noise, pollution, and vibration) estimated using different measurement scales. There is a further problem in the overall evaluation when these diverse environmental factors must be compared with other quite dissimilar criteria, such as safety, mobility etc.

Performance of Land-Use Measures	Env	Performance of Infrastructure Measures	Env	Performance of Management Measures	Env	Performance of Information Measures	Env	Performance of Pricing Measures	Env
Flexible working hours	0	New roads	√ / X	Conventional traffic management	√ / X	Direction signing	0	Ownership taxes	X
Development densities	?	Parking supply	√	UTC systems	√	Variable message signs	0	Fuel taxes	√√
Development within transport corridors	√ ?	New conventional rail services	√√	Advanced Transport Telematics (ATT)	?	Driver information	0	Company car tax changes	√√
Development mix	?	Light rail	√√ / X	Accident remedial measures	0	Parking information	?	Parking charges	√ ?
Developer contributions	0	Guided bus	√ ?	Traffic calming	√√ / X	Telecommunications	√√	Congestion charges	√√
Commuted payments	0	Park-and-ride	√	Physical restrictions on car use	X?	Public awareness	?	Fare levels	√
Travel reduction ordinances	?	Terminals and interchanges	√	Regulatory restrictions on car use	√√	Timetables	?	Fare structures	√
Parking standards	√	Cycle routes	0	Parking controls	√	Passenger information	?	Concessionary fares	0
		Pedestrian areas	√√ / X	Car sharing	0	Operation information	0		
		Lorry parks	√	Bus priorities	?	Fleet management	0		
		Transshipment	?	HOV lanes	?				
		Other freight modes	?	Service levels	√				
				Service management	0				
				Cycle lanes priorities	0				
				Cycle parking	√?				
				Pedestrian crossings	?				
				Lorry routes, bans	√ / X				

Table 2: Transport strategies and measures and the respective impacts[21]

Key:

√	√√	√√√	Positive impact of increasing scale	X	XX	XXX	Negative impact of increasing scale
√/X			Both positive and negative impacts	?			Uncertain impact
0			No significant impact				

As mentioned already, traffic management is currently the prevailing method for dealing with traffic and environmental problems. The so called Transport Demand Management (TDM) measures comprise different types of interventions, mainly in urban areas, that aim at reducing transport demand during the day or during a specific time period. The idea in any case is that TDM measures discourage people from excessive and irrational use of private cars, they cause mode shift to environmentally friendly modes and thus they result in better traffic and environmental conditions. In this respect many research efforts have been undertaken recently in several urban areas from different countries around the world to study the impacts and the effectiveness of such measures.

Since transport demand is created from the people who travel to satisfy a need (the same applies to goods as well), certain TDM measures target at the reduction of these needs. Other measures again focus on the time differentiation of travel needs so that better exploitation of existing capacity can be achieved.

In principle TDM measures have the following goals:

- to reduce traffic congestion
- to improve road safety
- to reduce environmental pollution
- to reduce energy consumption

According to the European Research project AIUTO[22] TDM measures can be classified in the following categories:

Pricing Measures	**Innovative measures**
Road use charges	Park & ride
Parking charges	Car pooling
Public Transport fare structure	Dial & ride
	Card operated car
Regulatory measures	**Supplementary measures**
Access control	HOV lanes
Parking Management	Urban traffic control
Traffic calming zones	VMS
Pedestrianisation	Ramp metering
Cycling	
PT promotion (publicity campaigns, information systems, through ticketing etc.)	

Table 3: Classification of TDM measures

No specific reference to traffic noise impacts is made in the above mentioned bibliography. The term “environmental impacts” apparently includes noise impacts but, in most research efforts environmental impacts pertain to local pollution and global warming. Again, when considering the measures of Table 3, only some of them have a direct impact on traffic noise levels. The rest have only indirect impacts; for example campaigns aiming at reducing car usage result indirectly to noise level reduction if they are successful. On the other hand physical measures restraining car available space result directly to noise levels since less traffic is allowed to pass through a certain area or point. Similarly, introduction of cycling or pedestrianisation in urban areas has obviously a direct and significant reduction of traffic noise levels.

3 TRANSPORT MEASURES IMPACTS ON NOISE LEVELS

3.1 Noise and TDM measures

Transport Demand Management (TDM) Measures, as previously mentioned, aim at achieving certain traffic related goals such as, reduction of speed, reduction of traffic flows along arterial or collector streets, discouraging traffic from passing through inhabited neighbourhoods and local roads, facilitating public transport vehicles and offering a better and safer environment for pedestrians. These goals can be achieved by single measures or by mixes of measures, including physical, regulatory, pricing and other technologically related measures. Often, the desired goal is reached through car restraint and suitable parking policy and/or proper traffic signal management (changes of time settings, progression, phase sequence changes etc.).

However, though the set goals in terms of traffic are met, it is questionable if the resulting situation is equally acceptable in terms of environmental conditions and most particularly in terms of noise levels. Discouraging for example traffic along a city centre arterial street by changing the traffic signal time settings so that progression is not possible, will result in lower speeds, continuous acceleration and breaking between successive intersections, and as a consequence higher pollutants' emissions. In addition, when it comes to noise, it is most likely that changes at noise levels will take place.

The changes are twofold; Firstly, there will be a reduction in noise levels due to lower traffic levels or due to a change in the number of heavy vehicles. This is measured at a **macro level** according to a traffic noise calculation technique such as the British CRTN[23] method, by calculating the $L_{10(1h)}$. In case that more buses than before use the road as a consequence of public transport prioritisation measure, then a reverse effect should be expected to take place if the total traffic volume remains the same. Secondly, there will be an increase in the noise produced as a result of vehicle acceleration and deceleration (breaking). This additional noise depends on several factors such as traffic composition, maximum speed reached between successive junctions, gradient of street etc. The noise is produced and should be considered at a **micro level** and apparently is not easy to be calculated. The fact however is that, after the implementation of all the selected TDM measures, a negative outcome may be the result of the whole effort.

Table 4 shows the expected noise consequences at the micro and at the macro level as well as the expected impact on speed and flow.

Measure / Changes	**Targeted Traffic Impact 1 (Speed)**	**Targeted Traffic Impact 2 (Traffic volume)**	**Noise Impact Macro level**	**Noise Impact Micro level**
Traffic signal settings	Reduction	Reduction	Decrease	Increase
Car space restraint	Reduction	Reduction	Decrease	Variable
Bus priority (bus lanes, separate signalling, etc)	Increase	Variable	Increase	Variable
HOV lanes	Increase	Increase	Increase	Decrease
Traffic calming	Decrease	Decrease	Decrease	Variable
New infrastructure	Increase	Increase	Increase	Decrease

Table 4: Expected traffic and Noise Impacts from TDM measures

3.2 Factors to consider in noise measurement

It is well known from the existing bibliography that the following factors have to be considered for the calculation of the noise derived from traffic:

- Traffic flow
- Condition of roads and adjacent areas
- Weather
- Time of measurement
- Place of measurement

The basic noise level is obtained as a function of the flow rate, the speed of the traffic, the composition of the traffic, the gradient of the road and, where appropriate, the road surface. On any given road the flow rate, mean speed and composition are interdependent. For example increasing the flow rate may cause a reduction in the mean speed so that the net increase in noise level may be comparatively small. The basic noise level at a reference point of 10m away from the nearside carriageway edge is given by the following equation:

$$L_{10_{(1h)}} = -27.60 + 10\log(q) + 33\log\left(v + 40 + \frac{500}{v}\right) + 10\log\left(1 - \frac{5p}{v}\right) + \lambda G + \mu(4 - 0.03p)\,dB(A) \quad (1)$$

where:
q = total traffic flow during one hour period
v = total mean traffic speed in kilometres per hour
p = heavy vehicles percentage
G = road gradient
λ = numerical factor equal to 0.3 when the real mean traffic speed is used, or to 0.3 when the predicted mean traffic speed is used
μ = numerical factor equal to 0 for pavement without grooving or 1 in case of deep random grooving (of 5mm or more)

With n component noise levels L_1, L_2,…L_n the combined noise level due to all n components is given by:

$$L = 10\log\{\sum_{1}^{n} 10^{(L_n/10)}\} \quad (2)$$

The above mathematical relationship caters for the calculation of traffic noise at the macro level as this was previously defined. The official British and other European methods have incorporated all the information and research results obtained in the past years for this purpose. However at the micro level, and especially from the TDM point of view, there is still room for further investigation and research. For example in several cases, installation of speed humps have been correlated with increase noise level and annoyance, though in others this is presented as an excuse for removing them because humps cause discomfort to drivers. In Pylea Thessaloniki, a relevant survey[24] indicated that inhabitants are quite happy with the installation of speed humps along a collector road because they have diverted through traffic to other roads.

Again the change of route effect of TDM measures and the possible noise consequences onto other inhabited areas is an interesting topic for investigation. Interfacing traffic simulation models that calculate traffic related parameters at the micro level (links and nodes) as well at the macro level (areas, zones) with traffic noise levels could lead to calculation of traffic noise as a result of TDM measures under examination.

4 THE CASE STUDY

4.1 Description of the area and the measures examined

The case study, which is presented in this paper, concerns the Thessaloniki city centre and in particular two main arterial roads in the area shown in Figure 2. Thessaloniki as it is the case for Athens faces severe and increasing traffic problems. Various traffic-related measures are examined and often taken from the responsible authorities, to relieve drivers and trip makers in general. However, noise impacts from these measures rarely considered at a sufficient detail, meaning that no traffic models are employed to estimate new values of traffic parameters and thus input data for calculation of traffic noise levels.

In the city of Thessaloniki a new infrastructure project has been recently studied as a major means for improving traffic problems as well as improving environment and quality of life. It is the New Arterial Tunnel bypass of the city centre, which has also combined with several other interventions and measures. Some of these measures include:

- Narrowing of Tsimiski Street road pavement, so that three lanes are available for traffic instead of four that exist today.
- Pedestrianisation of the old seacoast road - from the Harbour area to the White Tower.
- Introductions of a new bus lane along Egnatia Street at both directions - combined with bus restructuring; this measure has been already implemented.
- Optimisation of traffic signals and harmonisation of signal cycles.

The expected changes of traffic and environmental related parameters – traffic volume, speed, journey times, number of stops, pollutants' emissions etc.- for the new conditions have been estimated from traffic simulation models especially developed for this study. All necessary values of these parameters were used as input data in the noise model applied for the purposes of this paper.

The formula (1) was used for the calculation of the noise levels. The before and after data, used for the calculation of traffic noise levels along the arterial streets of Tsimiski and Egnatia according to the British CRTN method, are shown in Table 5 and 6. Traffic volume and speed figures are given per lane and thus noise levels before and after the implementation of the examined measures are derived per lane, per direction and per street.

Egnatia Before Bus lane implementation								
Lane	**Function**	**q (veh/hour)**	**V (Km/h)**	**p%**	**$L_{10(1h)}$ 4m**	**$L_{10(1h)}$ 10m**	**$L_{10(1h)}$ 15m**	**$L_{10(1h)}$ 20m**
1.1	Mix traffic	300	8	25	69,1	65,1	63,4	62,1
1.2	Mix traffic	700	12	5	71,1	67,1	65,3	64,1
1.3	Mix traffic	1000	20	2	71,3	67,3	65,5	64,3
2.1	Mix traffic	300	10	20	67,9	64	62,2	61
2.2	Mix traffic	350	15	5	67,2	63,2	61,5	60,2
2.3	Mix traffic	450	20	2	67,8	63,8	62,1	60,8
Direction								
1					75,4	71,4	69,6	68,4
2					72,4	68,5	66,7	65,5
Street								
Egnatia					77,1	73,2	71,4	70,2
Egnatia After Bus lane implementation								
Lane	**Function**	**q (veh/hour)**	**V (Km/h)**	**p%**	**$L_{10(1h)}$ 4m**	**$L_{10(1h)}$ 10m**	**$L_{10(1h)}$ 15m**	**$L_{10(1h)}$ 20m**
1.1	Bus Lane	95	12	100	60,1	56,1	54,4	53,1
1.2	Mixed traffic	1165	20	2	71,9	68	66,2	65
1.3	Mixed traffic	1165	20	2	71,9	68	66,2	65
2.1	Bus Lane	90	15	100	59,6	55,7	53,9	52,7
2.2	Mixed traffic	350	40	2	67,9	64	62,2	61
2.3	Mixed traffic	350	40	2	67,9	64	62,2	61
Direction								
1					75,1	71,1	69,4	68,1
2					71,3	67,3	65,5	64,3
Street								
Egnatia					76,6	72,6	70,9	69,6

Table 5: Noise levels per lane, direction and street for Egnatia before and after Bus lane introduction

Traffic volumes refer to a typical morning peek hour.

Tsimiski (Current Situation)								
Lane	**Function**	**q (veh/hour)**	**V (Km/h)**	**p%**	**$L_{10(1h)}$ 4m**	**$L_{10(1h)}$ 10m**	**$L_{10(1h)}$ 15m**	**$L_{10(1h)}$ 20m**
1	Bus Lane	90	20	100	59,6	55,6	53,9	52,6
2	Mixed traffic	1450	14,5	2,5	73,5	69,6	67,8	66,6
3	Mixed traffic	1450	14,5	3	73,5	69,5	67,8	66,5
4	Mixed traffic	1100	14,5	2	72,3	68,4	66,6	65,4
Street								
Tsimiski					78	74	72,3	71
Tsimiski (Future Situation)								
Lane		**q (veh/hour)**	**V (Km/h)**	**p%**	**$L_{10(1h)}$ 4m**	**$L_{10(1h)}$ 10m**	**$L_{10(1h)}$ 15m**	**$L_{10(1h)}$ 20m**
1	Bus Lane	90	20	100	59,6	55,6	53,9	52,6
2	Mix traffic	1500	14	4	73,8	69,8	68	66,8
3	Mix traffic	1300	14	2	73,2	69,2	67,5	66,2
Street								
Tsimiski					76,6	72,6	70,9	69,6

Table 6: Noise levels per lane and street for Tsimiski before and after Tunnel construction

Traffic volumes refer to a typical morning peek hour

4.2 Results

The application of the CRTN method provided the expected noise levels per lane and per street for the periods before and after the implementation of the transport measures described above. These results were derived for four different height levels, namely 4, 10, 15 and 20 metres above the pavement surface level. The numerical figures of the traffic noise levels are shown in Tables 5 and 6. Figure 3 and 6 present graphically the noise levels per lane for Egnatia and Tsimiski streets respectively for height level of four metres. GIS APPLICATION

Geographical Information Systems is a technology that enables the concurrent use of geo-spatial and descriptive data in an efficient and effective way. Furthermore GIS enables the integration of different components used in a scientific area and the better organisation of data and information coming from different origins and often serving different goals. This technology was chosen for the elaboration and presentation of geo-referenced data in the study area such as traffic flow, speed, noise etc. The use of GIS technology in this paper is rather simple but it shows that it can be used as the means for integrating transport and noise data and information along with traffic and noise models that already exist or that will emerge in the future.

The presentation of the above mentioned information was made by using the standard features of the ARC/INFO and ARC.VIEW GIS products. Existing maps of the are containing the building blocks and other information were used as background maps. For the traffic noise presentation purposes the thematic layers (coverages) containing all the factors that simulate traffic noise were prepared. These include:

- the inhabited blocks (polygon features) that reflect the sound waves
- the linear sources of sound waves that simulate the traffic lanes (line features)
- the reception points placed on the corners of the blocks (point features)

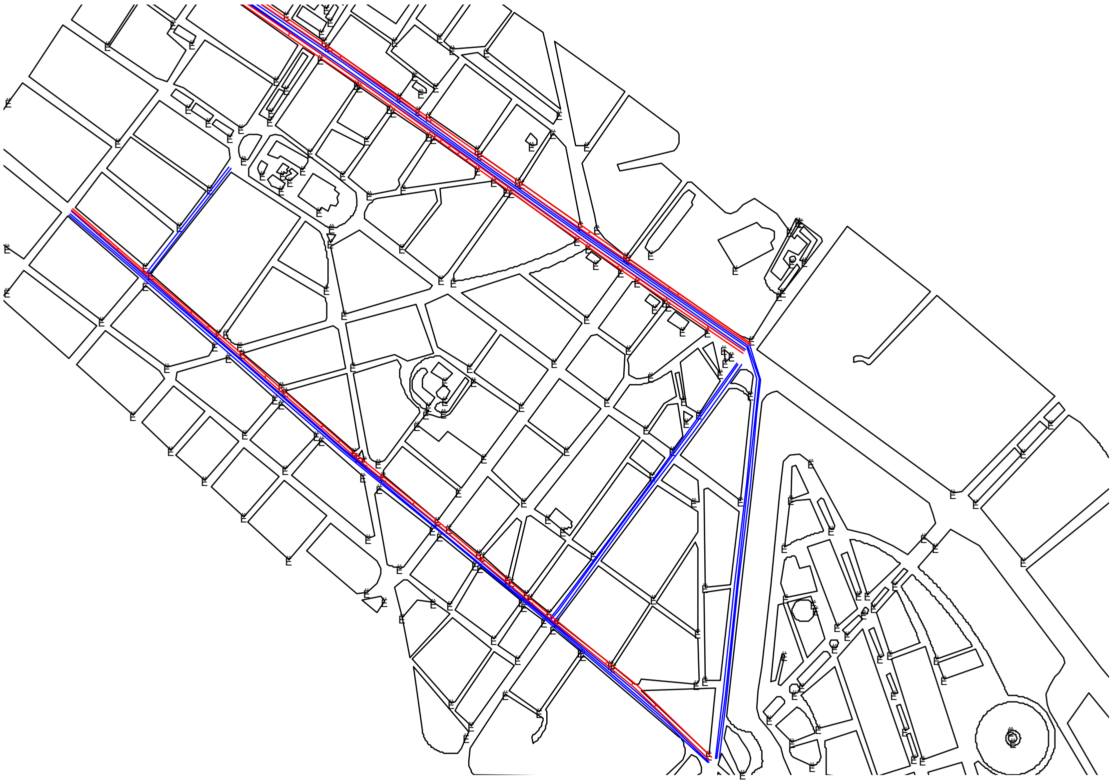

Figure 2: Digital map of the area under study (city centre of Thessaloniki)

The line features simulate the traffic lanes, which act as linear noise sources. The blue lines represent the car lanes and the red ones the bus lanes

These coverages containing the descriptive and spatial information were converted to shapefiles in order to be processed by ARCVIEW/GIS. The data connected to any layer of the final shapefile were imported to the relational database which was finally processed by the visual modelling application built according to the CRTN method considerations. The results were represented back through ARCVIEW/GIS producing the noise maps. Different colours are used for different traffic noise groups, according to the map legend. The noise levels were calculated for four distinct height levels. The maps produced for height levels of 4 and 15 meters are presented in Figures 4-5 and 7-8.

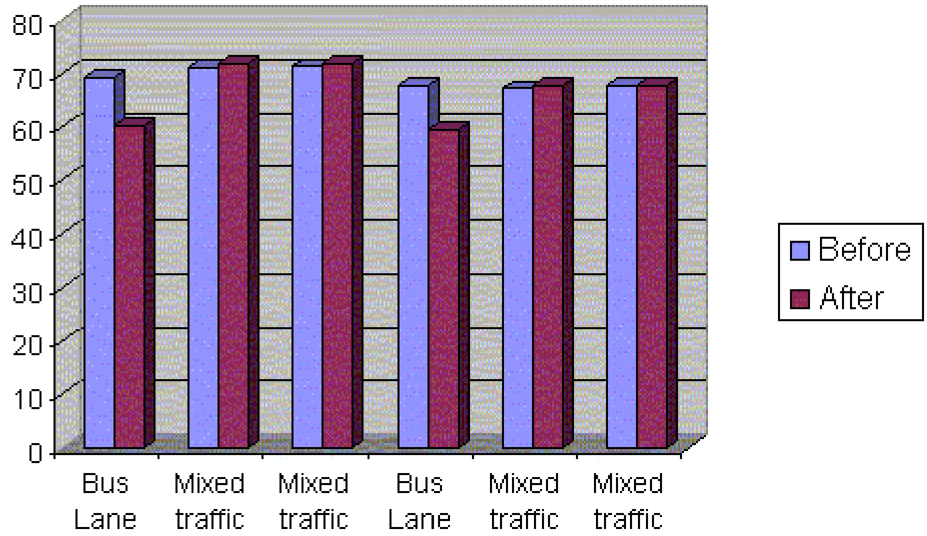

Figure 3: Noise levels per lane for Egnatia before and after bus lane introduction for height level of 4 metres

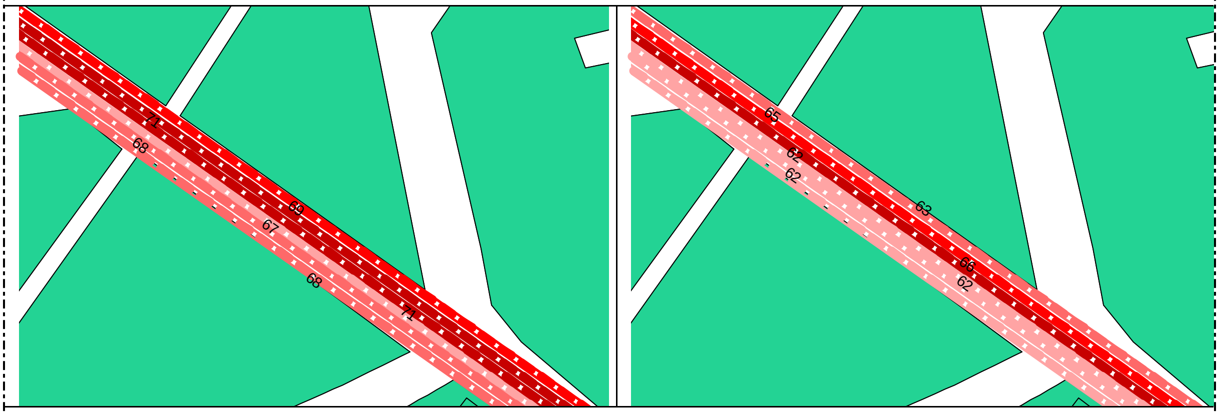

Figure 4: Noise levels at the height of 4 and 15 meters, on Egnatia street before the introduction of bus lanes

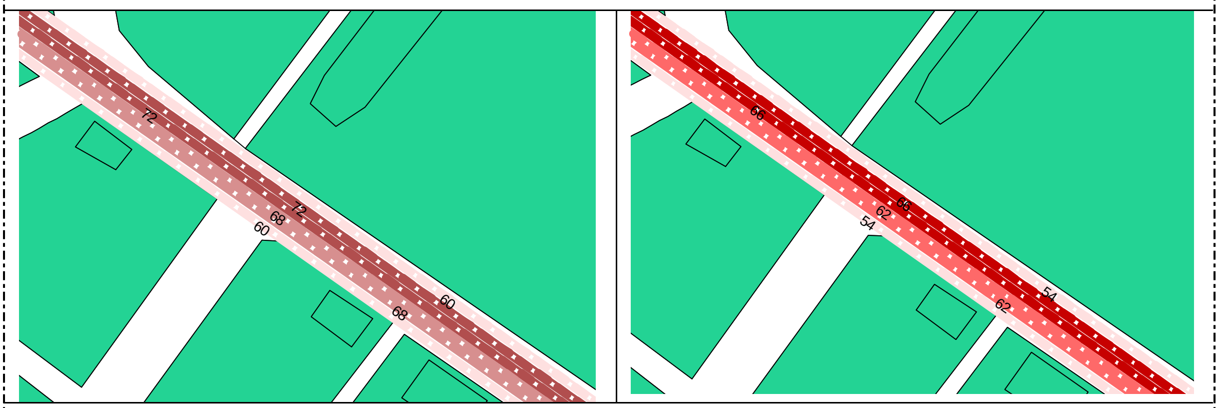

Figure 5: Noise levels at the height of 4 and 15 meters, on Egnatia street after the introduction of bus lanes

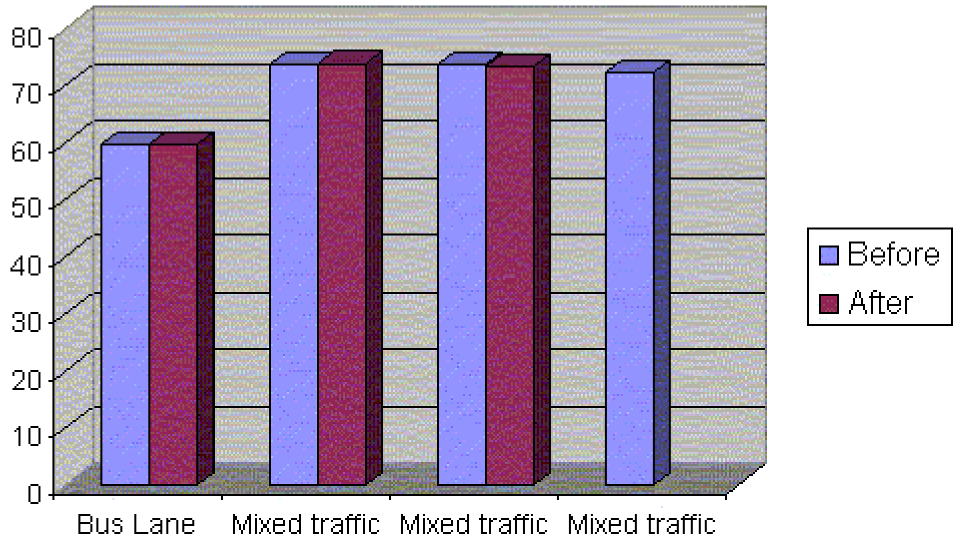

Figure 6: Noise levels per lane for Tsimiski before and after tunnel construction

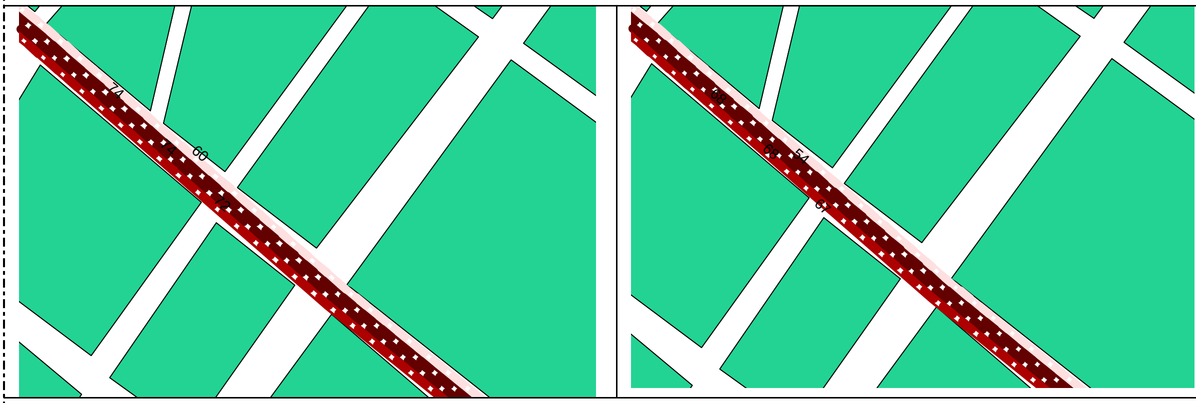

Figure 7: Current noise levels at the height of 4 and 15 meters, on Tsimiski street

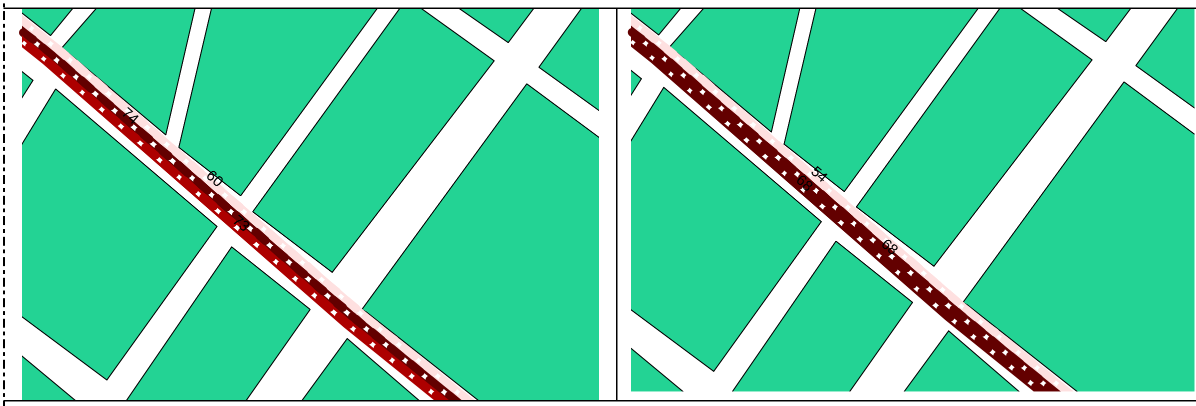

Figure 8: Expected noise levels at the height of 4 and 15 meters, on Tsimiski street after the implementation of the proposed infrastructure of the arterial by pass tunnel

5 CONCLUSIONS

Traffic noise impacts at the urban areas need to be examined at two levels, the macro and the micro level. The existing official Noise Calculation methods mainly address the macro level and they normally used for examining the expected impacts of traffic from new infrastructure projects rather than from transport demand management measures. The latter are considered today as the only perhaps way to deal with the increasing traffic problems in urban areas of developed countries. In examining such measures, new traffic noise levels are rarely calculated and thus evaluation of the proposed transport measures cannot be considered as comprehensive.

The adoption of traffic simulation models, together with the existing Noise Calculation methods can enable researchers and professionals to estimate future noise levels resulting from traffic at the macro level. The impacts on traffic noise resulting from TDM measures cannot be estimated at the micro level according to the existing official methods. It is believed that in several cases these impacts may counterbalance the initial expected benefits in traffic noise. Further research involving field data collection in cases of TDM measures implementation is necessary to reach to more concrete conclusions.

Finally, the adoption of GIS technology and its functionalities, can facilitate the manipulation of traffic noise related data and information. GIS is a useful analysis and presentation tool and can definitely assist researchers for achieving their goals. By integrating transport and noise models along with geographical referenced data, GIS can offer the solutions required for a comprehensive approach to noise calculation. This is also true for calculating noise levels at the micro scale, since such data can be handled by GIS equally successfully.

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