The economic crisis in Greece, resulted a dramatic reduction in GDP, over 25% during last 5 years, and also a significant increase of unemployment which reached the rate of 28% in 2014. As a result a significant reduction in traffic volumes, vehicle-kilometers travelled and changes in driving behaviour, mainly in speed, are recorded. This paper presents the effect of traffic characteristics changes in environmental traffic noise. Traffic and speed data as well as noise measurements are compared in a before-after analysis. The results show differences in Lden and Light indicators and interesting changes in peak-hours and night hours values, as well. More specifically, there is an overall reduction of total traffic noise level. The measurements over the limits of L_{den} (>70 dB (A)) and L_{night} (>60dB (A)) are less, comparing with periods before crisis. On the other hand, traffic reduction resulted and increase of average speed in peak-hours when congestions last less hours. In some of these cases noise measurements have higher values than before. This analysis conclude that in current conditions environmental effects of road infrastructures have decreased but the necessary protection measures must be considered and implemented, preventing the difficulties which road operators will face again when, in the near future, the recession will end.

1. Introduction

Economic crisis in Greece resulted a decline of GDP by 25-30% between 2009 and 2015, while unemployment increased by 132%, from 11.9% in the 1st quarter of 2010 to 27.6% in 1st quarter of 2013. At the same period, gasoline price raised by 50% on average, mostly due to a “new” tax in the start of 2010 as a fiscal measure while a decline in the average monthly household expenditure, from 2,203.55 € in 2009 to 1,509.39 € in 2013, which corresponds to a 31.5% decrease (2013 constant prices) is recorded by Hellenic Statistical Authority (ELSTAT) [1]. Economic recession officially started in 2008 but the consequences in the everyday life start to be obvious in 2010. From 2010 a significant reduction in traffic volumes and total Vehicle Kilometre Travelled was recorded. Also, different travel demand patterns are follower due to user’s adjustment in crisis contest and a significant reduction in fuel sales occurred. Specifically, a sharp decrease of 20.2% in sales of motor fuels, 65.4% in sales of heating oil and 34.1% in total fuel sales was recorded, according to the ELSTAT [2]. Traffic data from Egnatia Odos motorway (in Northern Greece) and in Atica Tollway (Athens Metropolitan area) show a total traffic reduction over 30% from 2009 [3, 4].
The relationship of economy conditions and traffic has been covered by many studies while several studies correlate urban and economy development with environmental impacts [5, 6]. Traffic volume and environmental noise have a strong relationship, also, and many characteristics of traffic, such as speed and heavy vehicles have significant impacts on the noise level [7, 8, 9]. This paper analyses traffic and speed characteristics in 2 major freeways in Athens Metropolitan Area, Greece and compares noise measurements and traffic conditions before and after economic crisis in the country. The scope of this work is to identify whether this “new” situation with lower traffic volumes in arterial roads of an urban area resulted better environmental conditions and improve sustainability. The focus is on the differences of noise level before and after recession start.

2. Methodology and sites

For this study we analysed 65 sites in 2 major freeways in Attica Metropolitan Area, in Athens, Greece. The capital city of Greece has a population of about 4.5 mil inhabitants and served by 2 major freeways: Attica Tollway and Athens – Lamia National Road. National road is separated in 2 sectors. The northern sector is a Concession Project where acoustic legislation is monitoring and evaluating by an operation company, Nea Odos SA. Attica Tollway is the first Road Concession Project in Greece and is operating by Attikes Diadromes S.A.

Attica Tollway (AT) is an urban freeway of about 70 km, which serves as the ring road of the Athens (Greece) metropolitan area. The freeway has two separated directional carriageways, each consisting of 373.6 lane-km, of which 71.8% is on 3-lane sections, 24.5% is in 2-lane sections and 3.7% is in 4-lane sections. The 15.4 km spur of AT leading to the center of Athens through mountainous terrain has 56 tunnels and cut and-cover sections, which comprise 12% of its length. The freeway’s operator (Attikes Diadromes S.A.) focuses on providing rapid detection and clearance of incidents, toll collection, and planning and monitoring of routine and major maintenance projects. In-field ITS equipment includes color CCTV cameras, closely spaced emergency roadside telephones, variable message signs (VMS), lane control signals, and variable speed limit signs. The Attica Tollway Patrol Service (ATPS) consists of 50 employees and a fleet of 20 small trucks fully equipped with road signs, cones, traffic lights and other emergency equipment. Patrols are supervised and constantly supervised by the freeway’s Traffic Management Centre (TMC) [10, 4].

Nea Odos S.A. is operating the project of Ionia Odos (IO) with a total length of 380 km, including two motorways, one in western and the other in eastern Greece. The eastern part has approximate length of 172.5 km including 8 bridges, 30 ICs and semi-I/Cs and 84 under & overpasses. Services of Nea Odos include a 4-digit emergency telephone number, 24 hour Patrol & Intervention units, Traffic Management Centre and Tunnel Traffic Management Centre equipped with cutting-edge control systems which ensure safe circulation and address all incidents in a timely and effective manner, emergency phones located along the motorway and free road assistance to immobilized vehicles [11].

Both freeways, are under a Full Environmental Noise and Atmospheric Pollution Monitoring program based on fixed stations and/or mobile 24 hours monitoring grid for environmental noise monitoring according to the European Directive 2002/49/EC [12, 13].

For the analysis we used volume, speed and acoustic noise measurement for 5 or more years period before and 5 years after 2009 based on what available were provided by operators of the freeways. We also focused our analysis in the urban areas and the sections with high traffic. In both cases the sections with high volume is about 10 km in urban areas in northern Attica.

Finally, noise level measurements are analysed for these 65 sites using $L_{den}$ and $L_{eight}$ indicators. Environmental noise in defined by the following equation (Eq.1)

$$L_{den} = 10 \log \left( \frac{1}{24} \left[ \frac{L_{day}}{10} + \frac{L_{evening} + 5}{10} + \frac{L_{night} + 10}{10} \right] \right)$$

(1)
where,
- $L_{\text{day}}$ is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987 (e.g. ISO [14]), determined over all-the-day periods of a year, Levening is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all-the-evening periods of a year,
- $L_{\text{night}}$ is the A-weighted long-term average sound level as defined in ISO 1996-2: 1987, determined over all-the-night periods of a year.

The new maximum values for the relevant European noise indices introduced by the Ministry of the Environment for Strategic Noise Mapping purposes [15] measured at a height of 3.8–4.0 m and within a minimum distance of 2 m from the closest – to the road noise source – façade are as follows:
- Environmental Noise Index $L_{\text{den}} \leq 70$ dB(A),
- Environmental Noise Index $L_{\text{night}} \leq 60$ dB(A).

3. **Results**

3.1 **Traffic Volume changes**

Traffic volumes differences for a period of 10 years in AT and 5 years in IO are shown in Table 1. Traffic demand in AT were continually increased up to the year 2009 when the highest number of average daily entries, was recorded. This number reached 307.300 vehicles per day on average. After this year, a significant reduction took place and after only two years, the number of entries was back at the 2005 level. The fifth year of the recession in Greece, 2014, daily entries decreased to 196,960. That means a total reduction of 36% in daily traffic between 2009 and 2014.

Available data from Nea Odos (NO) show the same trend during the period of crisis. Daily Entries in Afidnes Toll Station (located at the entry in Athens Area) have a reduction of about 11.4% per year. In 2014, was recorded the lowest number of vehicles in Afidnes Toll station, 39968 vehicle on both ways, which 16.4% lower than the previous year and -38.5% compared with traffic in 2010.

Table 1: Traffic Volumes Evolution, Freeways in Athens, 2005-2014.

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
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<td>270002</td>
<td>295140</td>
<td>300993</td>
<td>307300</td>
<td>281324</td>
<td>250491</td>
<td>215644</td>
<td>200473</td>
<td>196960</td>
</tr>
<tr>
<td>Ionia Odos - Afidnes Toll Station daily entries change</td>
<td>65010</td>
<td>60029</td>
<td>52691</td>
<td>47837</td>
<td>39968</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*2010: assumption- not officially provided; Av Daily entries in both ways; values refer to June of each year.

3.2 **Speed changes**

A recent study resulted some interesting findings about average speed changes during the first years of the crisis. Specifically, Vogiatzis and Kopelias [9] found that, there is an overall reduction of speed as a result of the of driver’s behavior adaptation to lower speed due to fuel expenses. But this trend is not occurred all areas and all hours. Studying over 40 sites in AT, they resulted that the 24-hour average speed shows a minimum value in 2008 and in 2012 reaches the 9-years peak.

In this paper we focused on the urban area of the motorway and we found that this situation is also obvious. After 2009 there is a remarkable stability while in some cases the speed increase due to the fact that the high traffic volume sections show high growth of speed during peak hours after the year of 2010. At the areas of low traffic there are not significant differences and speed is close to free-flow..
speed for a 3-lanes motorway section that is over 100 km/h. In contrast, when traffic volume reaches higher values, speed in 2008 and 2009 decrease, in most of the cases below 80 km/h, while in 2012 and 2013 it remains in higher values and almost all measurements are over 90km/h [9]. In Fig. 1 is shown over 15 sites average speed for 2 years period before and after 2010. The speed – flow chart shows that before crisis, during the years with the higher traffic in the motorway, higher values of traffic resulted lower speed in the morning peak hour than in the years with lower values of traffic after 2010.

![Figure 1: Speed-Flow values for before-after period in morning peak hours (8-10 p.m.).](image)

**3.3 Changes in Noise Indicators**

Due to dramatic decrease of traffic flow, noise indicators have also a reduction. In both freeways there is a reduction of $L_{den}$ (dB) and $L_{night}$ (dB) after 2009 which was the year with the highest traffic volumes of the last decade. For example in Fig. 2 and 3 is shown the noise indicators for Ionia Odos from 2010 to 2014, in 13 sites. There is a reduction of 4.3% in $L_{den}$ (dB) between 2010 and 2014 and 4.8% in $L_{night}$ (dB). In AT in 42 sites the change is 2.8% for $L_{den}$ and 4.8% for $L_{night}$.

Another effect of the traffic volume change in noise level, is the decrease of the number of positions with noise over the limits. In Fig. 4 is presented the number of locations in AT urban part, where $L_{den}$ was measured over 70 dB(A) and $L_{night}$ over 60 dB in a before-after comparison (3 years period before and 3 years after 2009). Before, the sites over the limits were in total 93 and after 65. There is a reduction of 37.5% in $L_{den}$ indicator (40 sites before compared with 25 after) and 24.5% in $L_{night}$ (53 sites before and 40 after).
Figure 2: $L_{\text{den}}$ reduction, 2010-2014.

Figure 3: $L_{\text{night}}$ reduction, 2010-2014.

Figure 4: Number of over-limited measurements of noise level before and after.
Looking in details the 24-hour measurements, we found that sections with higher traffic volumes have significant greater reduction than the sections with low traffic. In Fig. 5 and 6 is presented the change (years of comparisons 2010 and 2013) of hourly noise measurements in positions with high and low traffic in IO. The reduction of $L_{den}$ in low traffic sections is -2.1% and -2.6% for $L_{night}$. On the other hand in high traffic section, $L_{den}$ is changed by 5.7% and $L_{night}$ by 7.6%.

Probably, the impact of the enormous reduction in traffic has a significant impact in sections with high traffic where compared with the low traffic section where low traffic has lower noise level in both periods. This result is similar with the previous one about sites over the limits since low traffic is also a situation in night hours where the reduction of sites over the limits is less ($L_{night}$) than the changes in high volumes sites ($L_{den}$).

![Figures 5: Before-after changes in $L_{den}$ and $L_{night}$ indicators in low traffic sections.](image)

![Figures 6: Before-after changes in $L_{den}$ and $L_{night}$ indicators in high traffic sections.](image)
4. Conclusions

In the present study, over 60 locations in the major freeways of the Athens Metropolitan Area were studied. Noise measurement, traffic flow and speed are analysed for about 20 km of Attica Tollway and Ionia Odos (the urban part of the Athens –Lamia National Road) for periods before and after 2009 the year which was the first of a continued economic crisis in Greece.

Overall we found that there is a significant reduction in traffic flows that is over 35% for both freeways. At the same time average speed is also decreased but there are periods and section that speed is stable or increased for some hours of the day. These sections are the high volume parts of the freeways where the reduction of volume resulted less congestion hours and an overall increase of travel time speed.

This trend was clear during the first years of the crisis, while after 2013 speed decreased.

Regarding noise level, volume reduction resulted the change of L_{den} by -3.4% and of L_{night} by -4.8% on average for all sites. Sections with low traffic before 2009 have lower reductions than sections with high traffic. High traffic sections have a change in L_{night} of -7.6% and L_{den} of -5.7%, 2 to 3 times more than the sections with low traffic. Also, noise level measurements over 70 dB(A) for L_{den} and 60 dB for L_{night} (limit values) has significantly decreased during the last years. The change is between 25 to 38%.

Obviously, traffic volume is the most important variable for noise level and since the traffic has this dramatic reduction during the last years, noise has also a negative trend. But what we found in this study is that the noise level change is not so significant than the traffic reduction is. For example, 3 to 5% in a level of 70 dB(A) is 2,1 to 3,5 dB (A). Also the expected stabilization and growth of Greek economy will probably be followed by a higher noise levels so the necessary protection measures and monitoring programs must be considered and implemented, preventing the difficulties which road operators will face again when, in the near future, the recession will end.

REFERENCES

1 Hellenic Statistical Authority (ELSTAT), online reports at http://www.statistics.gr


