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Modelling the Adverse Health Effects of Road Traffic Noise: A Case Study in Adana, Bulent Angin Boulevard[#]

Muzaffer Yucel[1], Barış Kahveci[1], Deniz Colakkadioglu[1*]

Cukurova University, Agriculture Faculty, Department of Landscape Architecture, Adana, Turkey

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Abstract: Environmental noise is a well-known source of pollution in urban areas that can be described as an undesirable sound. According to the findings of the World Health Organization (WHO), noise is the second largest environmental cause of health problems, just after the impact of air quality. The adverse effects of noise pollution on human health have been categorized under 6 groups by WHO: hearing impairment, sleep disturbance, social behavior (annoyance, anger, depression etc.), cognitive performance, cardiovascular and psychophysiological risks and work performance. Main sources of noise in urban areas include road, rail, and air traffic, industries, construction and public work and the neighborhood. Not all noise can be called noise pollution. In the context of main sources of noise in urban areas, traffic noise has become the most serious and common type of noise pollution. Bulent Angin Boulevard, which is the subject of the research, is one of the roads with heavy traffic in Adana. The research was executed in the pilot area extending to the 1 121 m route of Bulent Angin Boulevard and 112,07 ha area covering 500 m east and 500 m west of this route. In line with the aim of the research, the first step has been to map Bulent Angin Boulevard-induced environmental noise during daytime (07:^{oo}-19:^{oo}), evening time (19:^{oo}-23:^{oo}) and night time (23:^{oo}-07:^{oo}) by employing SoundPLAN 7.3 software. After that, traffic-induced noise distribution maps were analyzed by threshold values stipulated by the Regulation on Environmental Noise Assessment and Management that is compliance with the European Union Directive on Environmental Noise (2002/49/EC) and noise limits identified by WHO. As a result of the study, the adverse health effects of the road traffic noise in the research area were determined by 11 noise distribution maps and designated the ratio of population exposed to the noise. Three of these 11 maps were created according to Regulation on Environmental Noise Assessment and Management; eight of them were created according to noise limits identified by WHO (1 map for cognitive performance, 1 map for sleep disturbance, 3 maps for social behavior (annoyance, anger, depression etc) and 3 maps for cardiovascular and psychophysiological risks).
Keywords: *Adana, Noise mapping, Noise pollution*

Introduction

Environmental noise is a well-known source of pollution in urban areas that can be described as an undesirable sound (Yücel, 2000). Main sources of noise in urban areas include road, rail, and air traffic, industries, construction and public work and the neighborhood. Not all noise can be called noise pollution. If it does not happen regularly, it may be termed as "Nuisance" (Farooqi, 2016). In the context of main sources of noise in urban areas, traffic noise which is happened regularly, has become the most serious and common type of noise pollution. With the rapid development of urban areas, the traffic noise pollution has become increasingly serious.

According to the findings of the World Health Organization (WHO), noise is the second largest environmental cause of health problems, just after the impact of air quality. Noise pollution affects both health and behavior. It is well documented that environmental noise can cause hearing impairment (Basner *et al*. 2014; Sun *et al*. 2017), annoyance and sleep disturbance (Stansfeld *et al*., 2000; de Kluizenaar *et al*., 2007; Murphy et al., 2009; Ohrstrom & Skanberg 2004; Brown et al. 2012; Halperin 2014; Douglas and Murphy 2016), increased the activation of the sympathetic nervous and endocrine systems, elevated physiological risk factors such as hypertension and myocardial infarction, and caused serious health problems such as cardiovascular disease (van Kempen *et al*., 2002; Babisch, 2003; Griefahn & Spreng, 2004; Ising & Kruppa, 2004; Babisch *et al*., 2005; Bluhm *et al*., 2007; Fyhri

**Corresponding: E-Mail: dcolakkadioglu@cu.edu.tr, Tel: +90 322 338 65 45 Fax: +90 322 338 61 89*
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& Klæboe, 2009) , and negative emotions such as anxiety, anger, disappointment, depression, *etc*. (Fields, 1998; King & Davis, 2003; Moudon, 2009; Miedema 2003; Soares *et al*. 2017).

The adverse effects of noise pollution on human health have been categorized under 6 groups by WHO (1999): hearing impairment (limit value: 140 dB (A)), sleep disturbance (limit value: 45 dB(A)), social behavior (annoyance, anger, depression etc. limit value: 55 dB(A), cognitive performance (limit value: 35dB(A)), cardiovascular and psychophysiological risks (limit value: 65-70 dB(A)), mental health and work performance.

According to WHO (1999), to avoid hearing impairment, impulse noise exposures should never exceed a peak sound pressure of 140 dB(A) peak in adults, and 120 dB(A) in children. Measurable effects on sleep start at background noise levels of about 30 dB (A). Physiological effects include changes in the pattern of sleep stages, especially a reduction in the proportion of REM sleep. Subjective effects have also been identified, such as difficulty in falling asleep, perceived sleep quality, and adverse after-effects such as headache and tiredness. At nighttime, outside sound levels about 1 meter from facades of living spaces should not exceed 45 dB(A), so that people may sleep with bedroom windows open. To protect the majority of people from being seriously annoyed during the daytime, the outdoor sound level from steady, continuous noise should not exceed 55 dB (A) on balconies, terraces, and indoor living areas. Sound level during the evening and night should be 5-10dB (A) lower than during the day. To be able to hear and understand spoken messages in classrooms, the background sound level should not exceed 35 dB (A) during teaching sessions. For outdoor playgrounds the sound level of the noise from external sources should not exceed 55 dB (A), the same value given for outdoor residential areas in daytime (WHO, 1999).

Cardiovascular effects are associated with long-term exposure to LAeq 24 h values in the range of 65-70 dB(A) or more, for both air and road traffic noise. However the associations are weak and the effect is somewhat stronger for ischemic heart disease than for hypertension. Nevertheless, such small risks are potentially important because a large number of persons are currently exposed to these noise levels, or are likely to be exposed in the future. Furthermore, only the average risk is considered and sensitive subgroups of the populations have not been sufficiently characterized. Other observed psychophysiological effects such as changes in stress hormones, magnesium levels, immunological indicators, and gastrointestinal disturbances are too inconsistent for conclusions to be drawn about the influence of noise pollution. According to WHO (1999), more research is required to estimate the long term cardiovascular and psychophysiological risks due to noise. In view of equivocal findings, no guideline values can be given by WHO. Studies that have examined the effects of noise on mental health are inconclusive and no guideline values can be given by WHO. However, in noisy areas, it has been observed by WHO that there is an increased used of prescription drugs such as tranquilizers and sleeping pills and increased frequency of psychiatric symptoms and mental hospital admission. This strongly suggests that adverse mental health effects are associated with community noise (WHO, 1999).

Much of the urban populations are vulnerable to the adverse health effects traffic noise. Taking into account the adverse effects of noise, the European Union (EU) has initiated two phases of strategic noise mapping for Communities with more than 250,000 and 10,000 inhabitants (EC, 2002). The EU initiative of noise mapping aims at reducing the number of exposed population to noise and achieving a better quality of life only in its member communities. The Directive requires Member States to develop and adopt action plans designed to manage noise issues and effects, including noise reduction if necessary (Tsai et al., 2009). Urban areas near busy road systems are usually selected for initial implementation of mapping systems needed to draft noise control schemes. On its path to EU membership process, Turkey commenced pilot studies for noise mapping as stipulated by EU 2002/49/EC Directive. These pilot studies have particularly been conducted on the roads dealing with heavy traffic.

Bulent Angın Boulevard, which is the subject of the research, is one of the roads with heavy traffic in Adana. Because Bulent Angın Boulevard is the basic transportation line connecting the northern Adana known as New Adana with the city center and providing access to Cukurova University and Balcali Research Hospital. Also the presence of densely populated settlements and also a number of educational institutions along the boulevard leads to a high and sensitive population exposed to noise. In view of the above, present research aims to model adverse health effects of road

traffic noise induced by a part of Bulent Angin Boulevard and to designate the ratio of population exposed to the noise.

Materials and Methods

The research was executed in the pilot area extending to the 1 121 m route of Bulent Angin Boulevard and 112,07 ha area covering 500 m east and 500 m west of this route (Figure 1). The research area is within the boundaries of 4 neighborhoods: Yeni Baraj, Yesil Yurt, Sumer and Beyazevler.

Figure 1. Location of the research area

In line with the aim of the research, 11 noise distribution maps of research area measured via SoundPLAN 7.3 software have been compiled by following the 5 stages explained hereinafter.

1) Forming Digital Ground Model: 1/25 000-scaled topographic maps of research area were initially digitalized upon coordinating via ArcGIS 10.0 software. Devised contour lines were transferred to SoundPLAN 7.3 software to form the digital ground model of this area.

2) Forming Structural Areas and to designate the ratio of population exposed to the noise: The other most salient factor affecting noise distribution in structural areas is the height of buildings and density. In research area 8-12 storey buildings are densely structured, there is a relatively sparsely dispersed structuring with 2-4 storey buildings. The floors of the buildings vary between 2-4. Within the scope of structural zones in study area, there are also health and educational foundations aside from residences. Sensitivity of health and educational foundations to noise may differ from structural zones hence need to be assessed individually. On that account, 9 educational foundations located in research area were modeled as independent layers in SoundPLAN software.

In this study, Facade method was used to determine the population affected by the noise. This method calculates the amount of exposure by noise levels on each floor of a building and then it estimates the exposed population using average residential area per person.

3) Defining the Emission Source: At this stage; the number of vehicles, velocity of vehicles, traffic flow, road surface features and road width features of the emission source in the research area were entered to the program as relevant data.

To identify environmental noise distribution, the total quantity of vehicles was computed with respect to the total account of vehicles in the research area during summer season in year 2017. Vehicle counting process was performed during daytime (07:$\frac{00}{}$-19:$\frac{00}{}$), evening time (19:$\frac{00}{}$-23:$\frac{00}{}$) and night time (23:$\frac{00}{}$-07:$\frac{00}{}$) zones throughout a total of 9 points defined as either heavy or light. Vehicle-counting process was bi-directional and for daytime zone 07:$\frac{30}{}$-08:$\frac{30}{}$, evening zone 19:$\frac{00}{}$-20:$\frac{00}{}$ hours and night zone (23:$\frac{00}{}$-24:$\frac{00}{}$) were measured only during weekdays on different days repeatedly. Then their mean scores were thus computed (Figure 2).

The next procedure subsequent to counting the quantity of vehicles to define the source of emission is entering the data on the velocity of vehicles and traffic flow to the program. The velocity of vehicles has been figured as the average velocity of light and heavy vehicles in different time zones of the day. Traffic flow on the other hand was defined as "constant" on the entire route of the Bulent Angin Boulevard. It was however defined as slowing down while entering traffic lights and speeding up when exiting the traffic lights.

Road surface on the complete highway has been defined to the program as plane asphalt. Next; the road width, lane and centre strip width have been entered. Within the borders of research area, the width of center strip on 3 meter-3 lane Bulent Angin Boulevard varies between 2 meters.

Hourly-average of number of vehicles passing through research area during summer season.

Point of the vehicle count	daytime (07:00-19:00)		evening time (19:00-23:00)		night time (23:00-07:00)	
	Light vehicle	Heavy vehicle	Light vehicle	Heavy vehicle	Light vehicle	Heavy vehicle
1	1476	204	1768	172	316	105
2	2440	212	2580	256	212	56
3	2358	450	2770	425	580	120
4	442	28	429	21	62	5
5	320	22	367	18	56	5
6	2384	412	2640	380	580	120
7	688	32	788	96	52	7
8	652	40	508	27	45	9
9	2384	412	2640	380	580	120

Figure 2. Hourly-average of number of vehicles passing through research area during summer season.

4) Ground Effect: Another critical factor in noise distribution is ground effect. Ground effect that is relevant of area usage can have, based on its characteristics, either a noise-absorbent quality or perfect-reflector quality. On that account, the land cover of the research area for 2017 were mapped and transferred to SounPLAN software.

Table 1. Environmental noise threshold values for Turkey (Regulation on Environmental Noise Assessment and Management -effective as of 04.06.2010 upon proclaiming on 27601 no Official Gazette)

Areas	**Current roads**		
	L-day (dBA)	**L-evening (dBA)**	**L-night (dBA)**
Areas that are densely populated with educational, cultural and health foundations and summer houses & camps which are classified as noise sensitive	65	60	55
Areas that are densely co-populated with commercial structures and noise sensitive usages	68	63	58
Areas that are densely populated with industrial zones with workplaces which are among the densely co-populated areas with commercial structures and noise sensitive usages	70	65	60
Industrial zones	72	67	62
Day: 12 hours from 07.00 till 19.00, **Evening :** 4 hours from 19.00 till 23.00, **Night:** 8 hours from 23.00 till 07.00.			

Table 2. Noise threshold values indicated by the World Health Organization (WHO, 1999)

Effects	**Sound Levels**
Cognitive performance	35dB(A)
Sleep disturbance	45 dB(A)
Social behavior (annoyance, anger, depression etc)	55 dB(A)
Cardiovascular and psychophysiological risks	65-70 dB(A)
Hearing impairment	140 dB(A) peak in adults, and 120 dB(A) in children
Mental health	-
Work performance	-

Results

Within the scope of the study, the negative impacts of the noise stemming from the traffic in Bulent Angin Boulevard on health have been mapped according to the limit values determined by WHO (1999) (Figure 3). The number of the population and buildings affected from the mentioned noise has also been specified in Table 3.

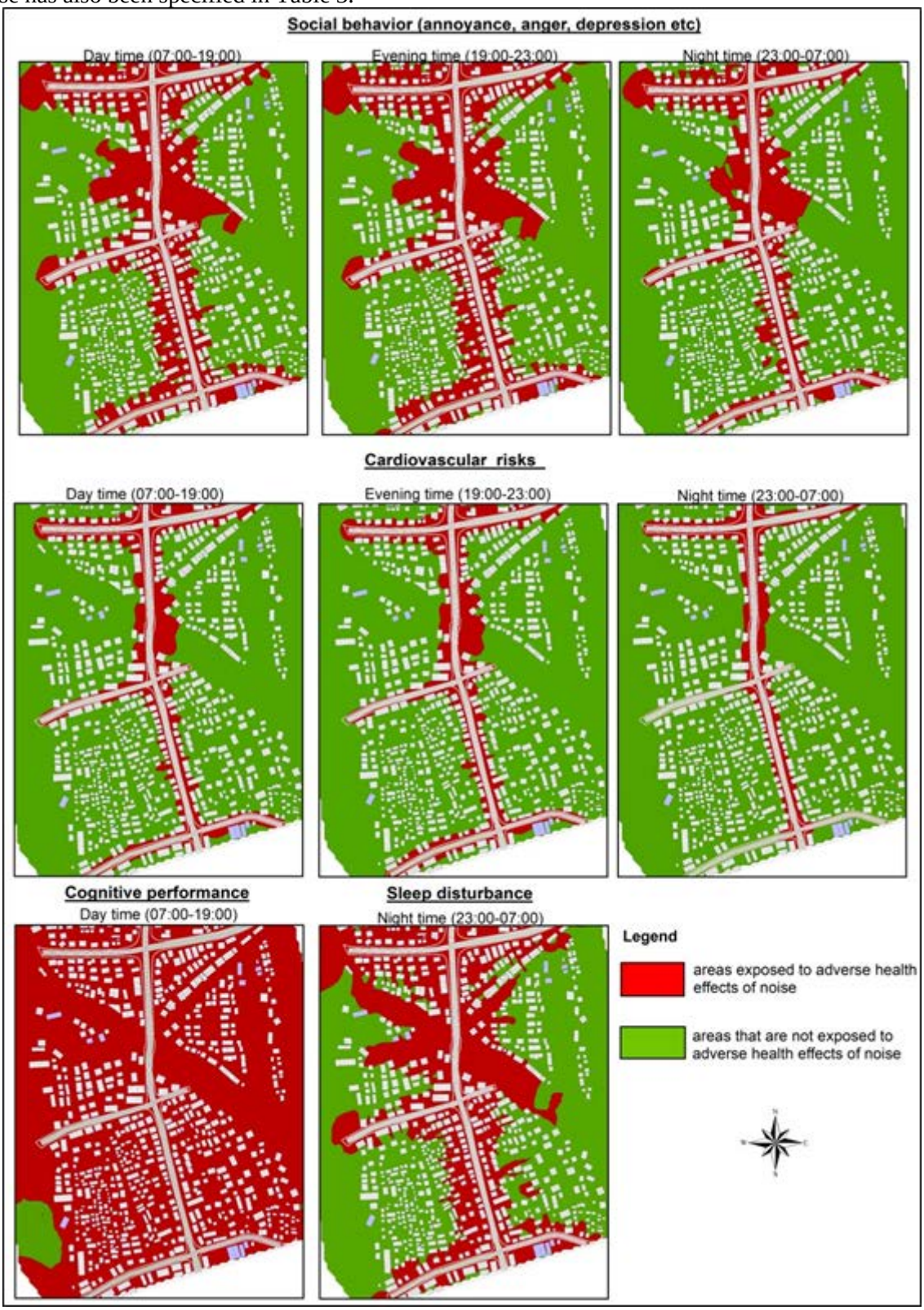

Figure 3. Noise distribution maps of Bulent Angin Boulevard according to WHO (1999) criteria

Table 3. Population affected from a noise level above threshold values of WHO (1999).

Effects	Threshold value dB(A)	Number of individuals	Percentage by total population in research area (%)	Number of buildings	Percentage by total buildings in research area (%)
Social behavior (annoyance, anger, depression *etc*.)	55	18 330	49	221	31
Cardiovascular and psychophysiological risks	65	9 012	24	191	26
Cognitive performance	35	36 881	100	712	100
Sleep disturbance	45	20 648	55	345	42
Hearing impairment	140	0	0	0	0

In the research area, almost 31% of the buildings are affected from the noise stemming from the traffic in Bulent Angin Boulevard and almost half (49%) of the population are affected from the social behavioral disorders such as anger, anxiety and depression. 24% of the population is under the risk of vardiovascular problems based on the noise.

All of the buildings in the research area; in other words, all the population are affected from the noise which is above 35dB (A) noise level in which cognitive performance is negatively affected. In the research area 9 educational institutions also take place in the area in which there is a noise level above 35 dB (A).

One of the most important negative impacts of noise on human health is the disorders stemming from the sleep disturbance. A significant ratio of the buildings such as 42% within the scope of the research area and almost 55% of the population are affected from the noise which is at a noise level causing to sleep disturbance between the time interval 23:00-07:00 being especially the night time.

Maximum noise level stemming from the noise in Bulent Angin Boulevard in the research area is 89 dB (A). For this reason; there is no risk of hearing impairment stemming from the traffic noise within the scope of the study area.

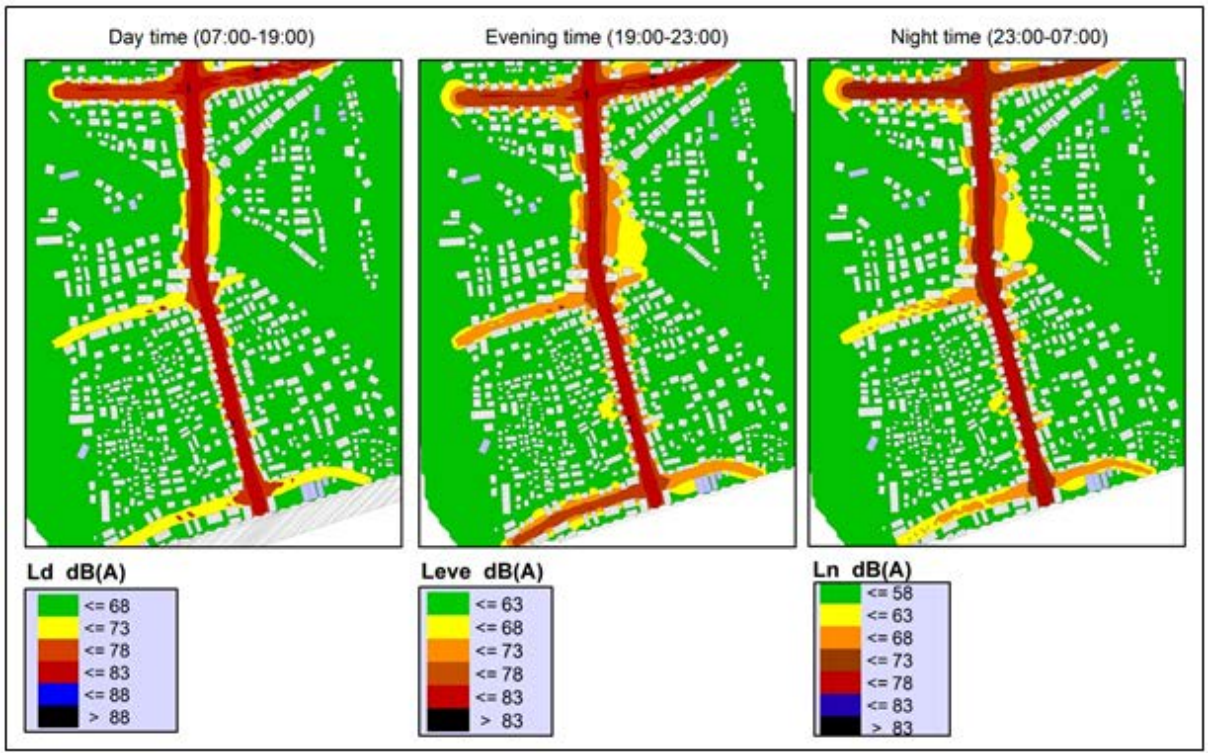

Figure 4. Noise distribution maps of Bulent Angin Boulevard according to Regulation on Environmental Noise Assessment and Management

In addition to the criteria of WHO (1999) in which the impacts of noise on human health have been studied, there are also the limit values determined as per the Regulation on Environmental Noise Assessment and Management which entered in force after publication in the Official Gazette dd. 04.06.2010 and no. 27 601 in accordance with the EU criteria in our country (Table 1). The noise distribution maps of the research area according to the mentioned legal arrangement limit values take place in Figure 4.

As it could be seen in Figure 4; when the noise distribution of the research area in day time, evening and night time periods has been examined, it could be seen that the noise in the majority of the area is under the legal limit values. Noise is only above the Regulation limit values in the first-row buildings in the eastern and western edges of Bulent Angin Boulevard which is the source of emission.

There are also educational institutions which are among the structural elements delicate to noise within the research area. Legal arrangement limit values determined for the educational institutions in our country have been determined as 65 dB(A) in day time, 60 dB(A) in the evening and 55 dB(A) at night. The educational institutions in the area give education and teaching at day time. For this reason; especially the day time noise distribution map is highly important for the educational institutions. 3 out of 9 educational institutions taking place within the scope of the research area are affected from the noise above 65 dB(A) being the day time period.

Discussion and Conclusion

One of the environmental problems negatively affecting the human health in urban areas is noise pollution. The most important one among the noise sources in urban areas is the noise of traffic due to its continuity (Kang et al., 2009; Zannin & Zwirtes, 2009; da Paz and Zannin, 2010; Cai et al., 2015). Especially the noise stemming from the highways in which there is intensive traffic negatively affects the health and life comfort of urban citizens.

There are many studies in which the negative impacts of the noise on human health have been examined (Ohrstrom and Skanberg 2000; Stansfeld et al., 2000; Kempen et al., 2002; Babisch, 2003; Griefahn & Spreng, 2004; Babisch et al., 2005; de Kluizenaar et al., 2007; Murphy et al., 2009; Brown et al. 2012; Basner et al. 2014; Halperin 2014; Douglas and Murphy 2016; Sun et al. 2017). Within the scope of the studies conducted in international level, the studies conducted by World Health Organization regarding what kind of health problems which noise levels cause on the human health have a separate significance. Within this scope; the study conducted by WHO (1999) has been adopted as a guide in this study.

The study has been carried out by selecting Bulent Angin Boulevard being one of the highways of the city of Adana with the most intensive traffic load as emission resource. The construction of structural area in the eastern and western edges of the boulevard has caused the population getting affected from the noise to be much more.

It has been determined that a significant ratio of the population in the research area is under the risk of cognitive performance, sleep disorders, cardiovascular disorders and social behavioral disorders among the negative impacts of noise on the human health. Bulent Angin Boulevard has been selected as the emission source within the scope of the study. However; there are many intermediate roads in the area and a part of Tarsus-Adana-Gaziantep Highway also takes place within the borders of the research area. In addition; vehicle census has been realized in summer period. A significant ratio of the urban population of Adana is in secondary houses known as summer house or highlands in the summer period. Therefore; the number of vehicles is less when compared to the general status of the year in summer period. For this reason, the noise level in the research area and the population affected from the noise are much more than what has been detected in this study. In this situation, it is very important that precautions be taken both for preventing the negative health impacts of the noise and increasing life quality.

It is very hard to develop precautions in the issue of preventing and/or decreasing the noise from its source. The main reason for this situation is the immediate construction of structural area in the eastern and western edges of the boulevard. For this reason, there is not sufficient area for the formation of noise obstacles with herbal materials. The building heights to be too many cause to the inefficiency of the structural noise walls to be insufficient effectiveness, in convenient costs. This situation obligates the performance of the precautions to be taken in the receiver. Taking the necessary precautions in the protection of the buildings against noise has been imposed to sanction in our

country with "the Regulation on the Prevention of Buildings Against Noise" published in the Official Gazette dd. 31.05.2017 and no. 30082 regarding this issue. It is necessary to conduct insulation works regarding the prevention of noise level especially and certainly for 3 of the educational institutions taking place in the research area.

Within the scope of this study, noise distribution maps have been formed also according to the Regulation on Environmental Noise Assessment and Management in which the limit values have been determined in the issue of the prevention and/or decrease of the noise in our country. However; it has been seen that it is too inefficient when compared to the noise limit values determined by WHO (1999). Therefore; it is highly important to re-assess the Regulation limit values by taking the human health and life comfort into consideration.

Noise is an environmental problem negatively affecting the human health and life comfort especially in urban areas. In this situation, noise distribution maps should be seen as very important data for the urban plans. The formation of noise maps before the construction of urban areas and solving the problems before they occur by using these maps as a precaution data source will provide more efficient results together with the projections of population to be conducted and the calculation of the traffic load.

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