Quest Journals
Journal of Research in Mechanical Engineering
Volume 9 ~ Issue 12 (2023) pp: 01-10
ISSN(Online):2321-8185
www.questjournals.org

Research Paper

Noise Pollution Effect from Engine Vehicles and Solution Suggestions

Murat ÇETİN[1], Asım AYDIN[2]
[1]*Department of Mechanical Engineering, Erzincan Binali Yıldırım University Erzincan 24109, Turkey*
ORCID: 0000-0003-0076-9648
[2]*Student of Institute of Science and Technolog, Erzincan Binali Yıldırım University Erzincan 24109, Turkey*
ORCID: 0000-0002-6739-5540

Abstract
Noise have identified as major environmental health problems in recent years. The aim of these study noise pollution problems from the vehicles in transportation sector. Today, improving engine performance, limiting fuel economy, exhaust gas emissions and noise levels is at the center of engine research. Due to the increase of vehicles, noise pollution has a negative impact on human health. It is important to minimize this vehicle-related noise pollution and to develop environmental awareness. Necessary precautions in vehicle design and additional measures in traffic will reduce the negative impact on people. The study defines noise in general terms. In the study, noise defined in general and suggestions made to reduce the noise level in vehicles and roads.
Keywords: *Environment, Noise, Pollution, Motor Vehicles, Highways*

***R**eceived 05 Dec., 2023; **R**evised 16 Dec., 2023; **A**ccepted 18 Dec., 2023 © The author(s) 2023.*
P**ublished with open access at **www.questjournals.org

I. Introduction

Currently, vehicles have become an indispensable mean of transportation where people spend most of their time. Vehicle-centered harmful exhaust gas compounds and vehicle noise draw attention in transportation and environmental pollution. With the effect of the rapid increase in the number of vehicles, motor vehicle-based noise pollution shows itself as a problem in all over the world. Noise pollution, which is a problem in big cities with the increase in vehicles in road traffic, has recently started to be a problem in small cities as well. Motor vehicles produce noise both inside the vehicle and on the environment outside the vehicle. Vehicles mainly produce engine noise, transmission noise, and intake and exhaust noise, road noise and high-speed wind noise. These types of noise seriously affect driving comfort and can harm people's physical and mental health. The cost of preventing and reducing the harmful effects of transportation activities is also important in evaluating emissions and noise pollution. In general, the costs of effectively achieving the main objectives in terms of environmental efficiency and preventing the negative impacts of their operations are a mix of this factor. While the level of success in implementing the targets is defined as the effects of the system, the inputs correspond to the resources required to achieve the targets, including reducing the negative impact of transportation on the environment. Nowadays noise pollution is the focus of various studies and research due to its proven significant impact on human health and work efficiency. Research shows that traffic noise in urban areas has tremendously increased since the beginning of the century, primarily due to increased transportation of people and goods[Linyuan Liang et al., 2020; Wang, 2010; Jacyna et al., 2017; Çerçevik et al., 2018 ; Sanja Grubesa et al., 2020; Dobson, M., et al. 2000].

The World Health Organization (WHO) defines that the impact of noise pollution on health is second only to air pollution. Noise pollution causes hearing loss, heart disease, learning problems and sleep disorders in children. Noise pollution can be reduced to lower levels by using the necessary technological techniques in vehicle use and road applications, with the meticulousness and strict rules shown against noise in production facilities**[**Wang, 2010**].** It is known that physical and psychological disturbances in humans occur as a result of leaving the sound at a level that will produce high noise to the open air. It is absolutely necessary to control because the increase in noise and the release of noise will cause mental tensions and negative effects on general public health. Due to the increase in the number of vehicles, noise pollution, which is primarily felt in big cities

along with the density of vehicles in road traffic, has started to be a problem in small cities in recent years[Yüksel et al., 2002]. Sound is a type of energy that comes out with the vibration of objects, and vibration is the name given to very fast movements made by the object. Sound occurs as a result of the vibration of the molecules that make up the substances for any reason. As a result of these vibrations, the periodic pressure changes in the atmosphere that can be perceived by our ears and carried from the source to the environment in the form of sound waves are defined as noise. Noise is an undesirable and unwanted disturbing sound. The main source of noise in and around the city is transportation activities. Noisy, it is produced by the effects between the vehicle engine, vehicle exhaust systems and other vehicle systems (for example, tire-road, suspension, brake systems, etc.). Noise levels and human perception is given in Fig.1. The values given in Fig.1 show that values above 60 dB turn into an uncomfortable environment for people[Papacostas and Prevedouros, 1993; Yüksel et al., 2002].

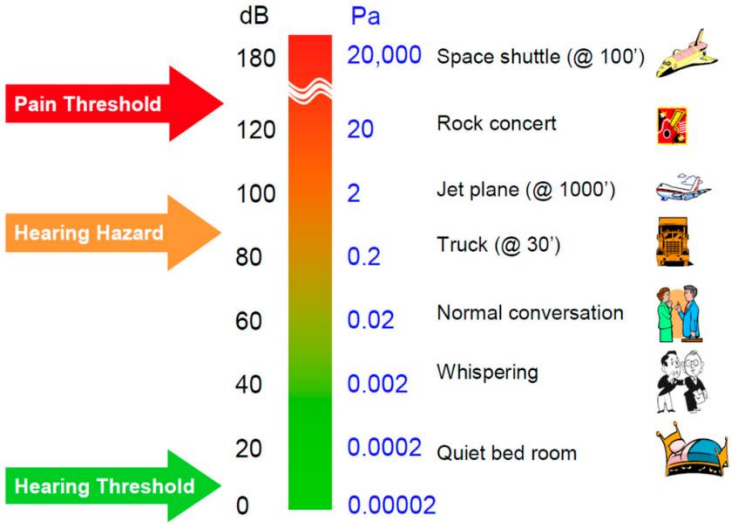

Figure 1. Comparison of sound pressure and sound levels and some common examples [Shatnawi et all, 2009]

Sound measured in units defined as decibels (dB), and the higher the noise level, the higher the decibel (dB) value. On the decibel scale, a level increase of 10 indicates that the noise is 10 times more intense or powerful. In 2011, the European Commission adopted a new regulatory proposal to implement noise emission standards in road transport. This proposal also envisages a 4 dB reduction in noise emissions from automobiles and a 3 dB reduction from heavy vehicles. These standards (Environmental Noise Directive 2002/49/EC) came into force five years after the final approval of the regulation, that is, after 2017. It is recommended in decibels (dB) as a noise indicator for general discomfort and is defined by the formula below [Jacyna et al:, 2017].

$$L_{den} = 10\lg\frac{1}{24}\left(12\cdot 10^{\frac{L_{day}}{10}} + 4\cdot 10^{\frac{L_{evening}+5}{10}} + 8\cdot 10^{\frac{L_{night}+10}{10}}\right), \quad [1]$$

Here; L_{day}, $L_{evening}$ and L_{night} are the weighted long-term average sound levels determined respectively over all day, evening and night periods of a year as defined in ISO 1996-2: 1987 regulations.

Table 1. Noise levels and human perception [Anonymous]

Noise Levels and Human Response		
Common sounds	Noise level (dB)	Effects
Jet response, carrier equipment, air sirens	140 and up	Annoying, painful noise
Jet lift (200 ft), Thunderclap, discotheque	130	Annoying, painful noise
Automobile horn, metal bridge pillar crashing	120-110	Maximum regional impact
Garbage truck (grinder)	100	Maximum regional impact
Heavy tractor (50 ft), City traffic	90	Quite irritating, in danger of hearing (8 hours)
Alarm clock (2 ft), hair dryer	80	Disturbing
Noisy restaurant, free traffic road, human voice	70	Phone becomes difficult to use
Air conditioning unit (29 ft)	60	Unsolicited, Unwanted
Light automobile traffic (10 ft)	50	quite calm

Living room, bedroom, quiet office	40	-
Library, quiet whisper (15 ft)	30	Quite calm
radio broadcasting station	20	-
	10	It can only heard.
	0	Hearing onset.

It is known that environments where the noise level is above the limit values cause temporary latent hearing impairment in terms of health. Instantaneous shock noise value above 140 dB causes permanent health problems. Noise is a problem in all modes of transport and controlled with different designs, especially in transport corridors (highway, railway and air transport) or main transport centers (airport and transit terminals). In terms of road safety and personal health, the values of time to withstand noise intensity given in Table 2.

Table 2. Noise criteria for road safety and personal health [Anonymous]

Tolerable time(hour/day)	Noise level dB(A)
8	85-90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0,25 and less time	115

In a study conducted by Seiff in 1970, the fatigue and hearing problems of drivers in commercial vehicles were compared with the noise level. In 1972, vehicle-centered noise pollution first introduced at the official level. It has come to the fore in the USA (United States of America). Noise committees related to motor vehicle noise standards established in various states of the USA and many countries around the world have recognized vehicle noise as the most fundamental problem, especially in big cities. In the USA, the Federal Highway Consortium (FHWA) encouraged the approaches used in project development related to noise standards and the noise standard values organized under different headings[Papacostas and Prevedouros., 1993]. In addition to the harmful effects of noise pollution on health, noise control methods are expensive applications and the examination of noise sources and noise prevention researches maintain their importance.

Table 3. The Federal Highway Consortium (FHWA) noise standards

Noise Level Design / Space Use Relationship		
Land Use Classification	**Noise Level Determination L10**	**Usage Area Identification**
A	60 dBA in outside	Quiet, tranquility and service are of great importance in these areas.
B	70 dBA in outside	Residences, hotels, meeting rooms, schools, mosques, churches, outdoor libraries, hospitals, picnic areas, entertainment places, playgrounds.
C	75 dBA in outside	Excludes advanced locations, featured activities, A and B outside classes.
E	55 60 dBA in inside	Hotels, mosques, churches, meeting rooms, libraries, hospitals, residences.

2. Noise Values from Transportation Activities

From the noise source; when there is no protective barrier or shield, it spreads around in the form of circular rings. Noise propagates from the center of its source to the air and the noise effect decreases as the sound intensity moves away from the source. Due to the growth in the motor vehicle industry and the increase in the number of individual vehicles, the traffic density on our roads is constantly increasing. As a result of the improvement in living conditions, significant increases are observed in air traffic due to the increase in international tourism, not only the vehicles used on the road, but also the number of aircraft and aviation flights are increasing rapidly. As a result, the amount of noise caused by vehicles used in air transportation is constantly increasing. The main factors of noise generation in transportation; It can be summarized as engine and exhaust system, moving parts on the vehicle, road geometry and surface coating, vehicle and road relationship and traffic structure.

In noise pollution, It is aimed to determine the limit values, to protect the settlements from excessive density and to make the determined limit values applicable. Road traffic noise in and around urban areas remains the dominant source of nuisance and influencing at levels above 55 dBL as defined by the European

Environmental Noise Directive (END). Approximately 100 million people in 33 countries of the European Environment Agency (EEA), of which Turkey is a member, exposed to road traffic noise over 55 dB Lden.32 million of them exposed to very high noise levels above 65 dB L. Table 4. The estimated number of people exposed to high annual average noise levels in the EU is given. The values given in Table 4 based on data officially reported by countries under the EU Environmental Noise Directive (2002/49/EC). Due to gaps in the reported data, a fill-in-the-blank routine used to estimate the exposure of the total population to high noise levels. Urban areas defined in the Environmental Noise Directive as urban agglomerations constituting this part of the region, delimited by the member state, with a population of more than 100,000 and a population density taken into account by the member state. The number of people exposed aggregated only for the same resource inside and outside urban areas, not across resources. 55 dB Lden, defined in the Environmental Noise Directive, is the EU indicator threshold for exposure to high noise. It shows an annual average level during the day, evening and night. The values in Table 4 based on data officially reported by countries under the EU Environmental Noise Directive (2002/49/EC) [EEA., 2020]

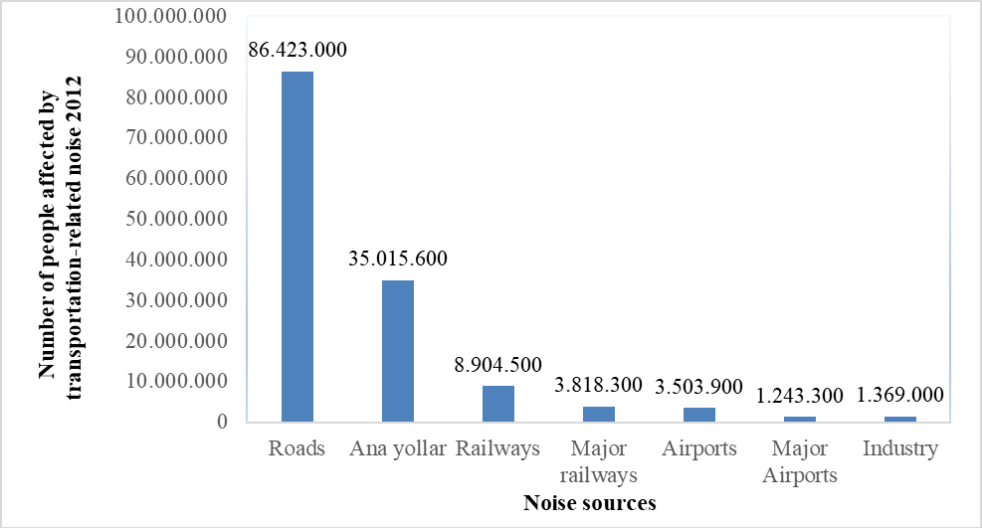

Table 4. Noise pollution in the EU and average number of people affected annually, 2012 [Licitra G, 2018]

In a free space, sound propagates equally from a source into space in all directions. The sound pressure produced by the source is the same in all directions, equidistant from the point source. As a principle of physics, the sound pressure level decreases by 6 dB on a Z-weighted (i.e. unweighted) scale every time the distance from the point is doubled. The inverse square law states that a given physical quantity or intensity is inversely proportional to the square of the distance from the source of that physical quantity and is defined as the inverse square law in acoustics and is shown in Figure 2.

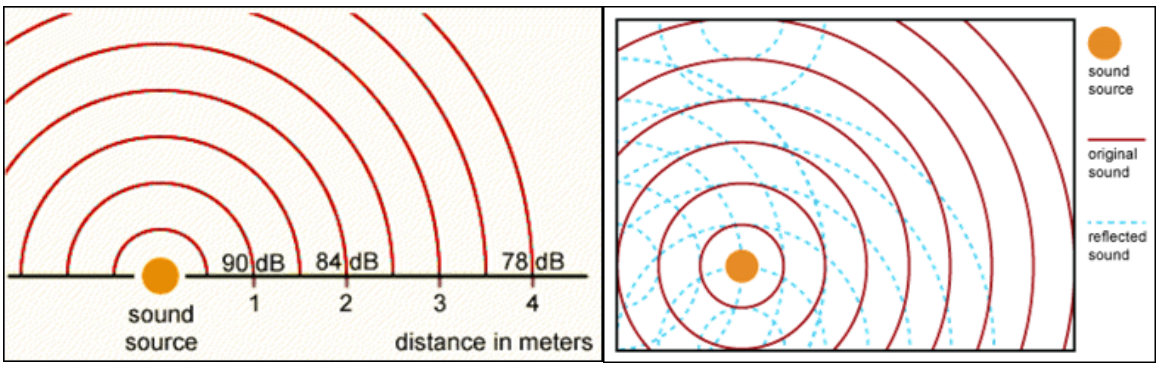

Figure 2 a Figure 2 b

Figure 2. Sound Pressure Levels in Free Space, Original and Reflected Sound Waves OSHA, 2022.]

If a point noise source in free space produces a sound pressure level of 90 dB at a distance of 1 meter, the sound pressure level will be 84 dB at 2 meters, 78 dB at 4 meters, etc. falls. This principle applies regardless of the units used to measure distance. However, sound fields are more complex in areas defined by walls. When objects that reflect sound, such as walls or machines, are inserted into the sound field, the wave structure changes completely. Sound cannot continue to propagate away from the source and echoes back to the medium. Figure 2

b shows sound emitted from a sound source and shows how reflected sound (dashed lines) complicates the situation. If the boundaries away from the noise source are not very absorbent, the reflected sound dominates and the sound waves propagate dispersedly in all directions with equal probability. The emission limit values required for taking measures against noise that adversely affect people's health are shown in Table 5. It is desirable that the noise from the vehicles does not exceed these values. Different limit values can be seen according to the countries. While it varies from state to state in the USA, In Japan, it is required not to exceed 55-70 dB during the day, 45-60 dB at night, 50 dB in important residential areas in Russia, 60 dB during the day and 40 dB at night in France[Zhang X and Zhou S., 2023].

Table 5. Zone and noise values determined for traffic noise[Anonymous]

Zone Definition	Night (22-06)dB	Day (06-19)dB	Evening (19-22)dB
Out of town residential area	35-45	30-40	25-35
City side residences	40-50	35-45	30-40
City residential area(100 m distance to traffic)	45-55	40-50	35-45
Highways, businesses.(60m distance to traffic)	50-60	45-55	40-50
City center residential area (20 m to traffic)	55-65	50-60	45-55
Industrial areas, Roads heavy vehicles	60-70	55-65	50-60

3. Noise reduction methods in road transport

Ways to protect and reduce noise;

- Precautions to be taken on the vehicle
- Measures to be taken on the road superstructure
- Measures to be taken with traffic regulation
- Prevention of noise with surrounding structures
- Planning of residential areas
- It can be listed as roadside measures.

3.1. Noise reduction Precautions on the vehicle

In motor vehicles, besides the noise caused by the engine operation, the exhaust system and the moving elements of the vehicle, the tire air pressure, the aerodynamic structure of the vehicle are the main factors causing wind noise. In addition to the noise generated by the exhaust, the noise and noise during the operation of the engine, which is at a negligible level, are insulated around the engine block and the noise generated in the engine is prevented from reaching the driver. Material selection and regular lubrication are necessary to prevent noise from moving parts. Attention should be paid to the selection of vehicle tires, old, worn and unbalanced tires should not be used in terms of noise and safety. Since deformed tires have a noise-increasing effect, if the vehicle tires are deformed, they should be replaced. Worn tires produce 14 db(A) higher noise on the road surface than new tires. Tire pressure should be at the standards specified by the manufacturer. Silencers used to control noise are usually located in the exhaust system. After combustion, high-density gas pressure is discharged through the silencer chamber. Exhaust gases thrown into the atmosphere from the vehicle engine produce high noise levels due to the cross-section change and gas velocity. This noise is reduced to a lower level by the silencer system. Different wavelengths are given to the exhaust gases in the exhaust muffler and pipes, and they are damped with sound frequencies. At this stage, some of the gases, which are reflected from the exhaust system internal pressure and defined as back pressure, want to pass into the combustion chamber and reduce the engine performance by creating vacuum pressure in the combustion chamber. By increasing the noise absorption capacity from the muffler with minimum back pressure, the effect on the performance of the engine is reduced. In order to prevent noise in exhaust systems, different applications are used according to engine specifications[Kim, 1998; Linyuan L. et al., 2020; Furgal S.et al, 2023].

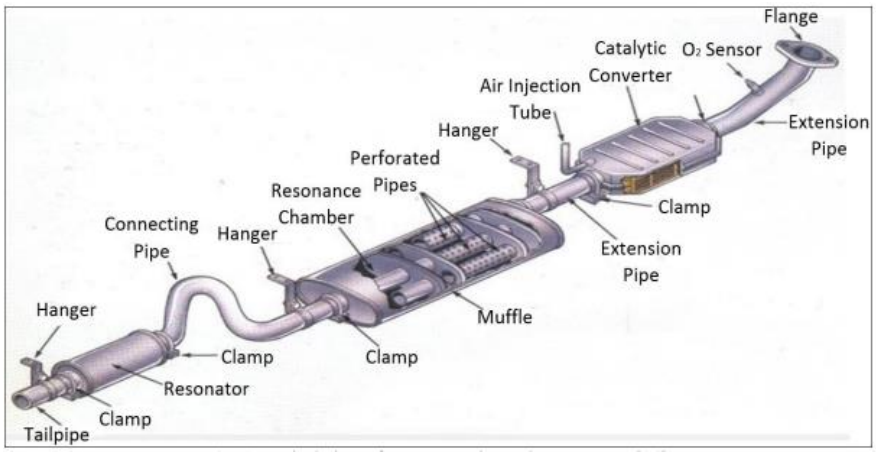

Figure 3. Typical view of an Automotive Exhaust System element structures [Anonymous]

3.2. Noise Formation from Wheel Road and Precautions to be Taken on the Road Superstructure

As the rubber wheels vibrate as they rotate on the roadway, sound is produced and these sounds produce noise. The noise caused by the interaction of the vehicle wheel and the road depends on the type of vehicle road and the way it is built. Highways consist of three layers, the carrier substrate, the binder, and the top layer. It can be concluded that in urban areas the largest source of noise is traffic-induced noise, which accounts for 80% of all communal noise sources. Traffic noise caused by road traffic is the most common type of noise in urban areas and as such poses a serious problem. Figure 1 shows the distribution of human noise annoyance according to the type of noise source. The top layer determines the surface properties such as road levelness, roughness and road holding, and the relationship between vehicle wheel and road has a significant effect on noise generation. The vibration feature of the wheel is in the development and production planning phase of the wheel; The wheel's axle load and tire pressure are determined by the tire's design, material selection, wheel structure (carcass), tire geometry and final profile. In the sound propagation during the wheel-road relationship, the way and intensity of the excitation of the wheel has a significant effect on the noise production. In this stimulation, the surface roughness that provides the adhesion between the vehicle tire and the road is an important feature. The vehicle road surface or roughness is likened to an undulating section profile in the form of peaks and valleys, similar to a three-dimensional earth surface formation. This road surface profile varies according to the workmanship used in the construction of the road surface, the construction method and the properties of the materials used. Depending on these factors, the noise level between the tire and the road can be reduced by reducing their height on the road surface. The particle size and profile depth used in road construction determine the wavelength-length distribution of the asphalt. Compared to automobile type vehicle tires, large road vehicle tires respond less to road roughness differences due to their design, material composition, high tire pressures and large dimensions. In order to reduce the noise level of the paved roads, the road surface can be concrete asphalt or concrete pavement. Although this method is more expensive than a regular flooring, it is a cost-effective alternative to other noise suppression systems. Due to the effect on the normal working order of the vehicle, the road slope should be at the lowest level considering the road and driving safety. One of the most effective solutions to prevent noise in road areas with high noise levels is to reduce the noise level with the tunnel system. Noise can be partially prevented by making road edges above the road level and reducing the distribution of sound by making road levels different at overpasses and intersections [Linyuan L., 2022; Grubesa S. and Suhanek M., 2020]

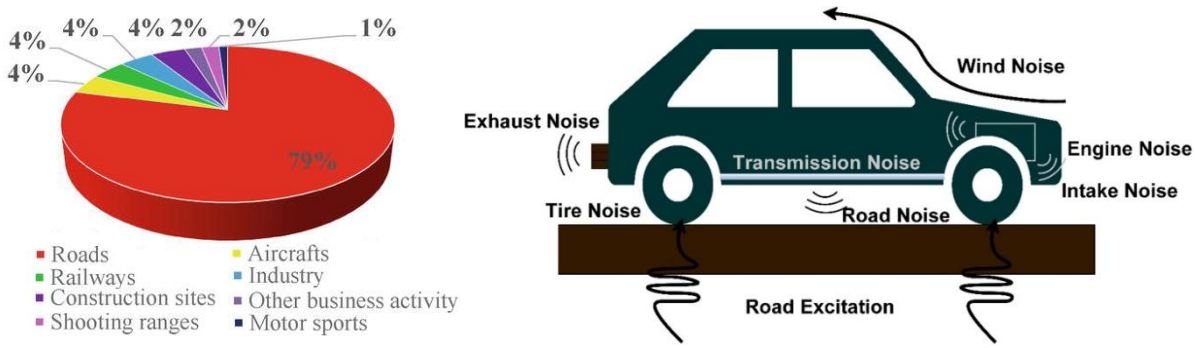

Figure 3 Automotive and road noise sources and their % values[Linyuan L. 2022]

3.3. Precautions to be taken in traffic regulation

As a result of the increase in the number of vehicles, the intensification of road transportation has made the streets a source of noise. The dense presence of people around the streets and residential areas are under the influence of this noise pollution. All motor vehicle users are the main source of noise in road traffic, and different behaviors of users have a significant impact on the increase and decrease of noise. Since it is not possible to limit or prohibit the use of motor vehicles in traffic, individual sensitivity and the way vehicles drive can contribute to reducing noise production. Here, noise pollution and environmental awareness are of great importance for the driver. (Hintzsche et al., 2008). Measures to be taken to reduce vehicle noise pollution;

• Controlling the traffic flow
• Controlling the type of vehicle in traffic
• Speed control
• Removal of heavy vehicles from resting and sitting areas at night
• Providing free flow by adjusting the lights at the intersection according to the green wave.
• In cities, the traffic noise level can be measured depending on time, a noise map can be prepared and the traffic can be arranged accordingly.

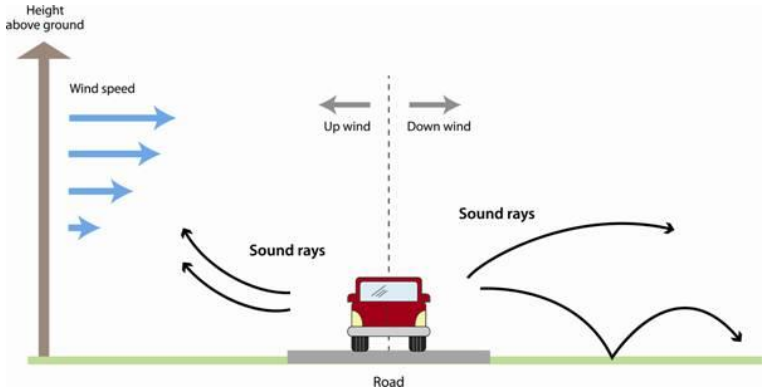

Figure 4. Distribution of vehicle noise by wind direction [Ovenden et al., 2011]

3.4. Prevention of noise with surrounding structures

In case the noise pollution level exceeds the limit values specified in the regulations, construction-related and workplace protection measures are implemented. The problem of noise pollution is also taken into account in city planning and in the selection of industrial settlements, and as with all environmental pollution factors, the most appropriate solution is to control the noise at its source. However, it is not always economically and technically possible to control the noise at its source. The technical applications and measures that can be applied to reduce and control the noise are listed below;

• Topographic and appropriate land use in urban planning,
• Regulation of minimum distances to the road in construction,
• Establishing airports, industry and industrial zones in places far from residential areas,
• Providing noise insulation in residential areas and newly constructed buildings.

Joint efforts of public and non-governmental organizations are required in the efforts to reduce the negative effects of noise pollution. Authorized institutions are required to carry out the necessary practices completely in order to comply with the restrictions and prohibitions introduced in the regulation. In communication and information activities between public institutions and the public, NGOs (non-governmental organizations) and local administrations should ensure that more regular zoning plans are made in the newly formed urban areas. In order to reduce traffic noise, residential/road distances and greening works for noise prevention should be a priority. Screening and sound barrier walls should be built on roads with visual pollution as well as noise pollution due to heavy road traffic (highway, ring road). In order to reduce the noise caused by transportation, the distance of 30-40 m between the road and residences or workplaces significantly reduces the noise pollution effect.

3.5. Preventing traffic noise with surrounding structures

According to the results of the relevant study, it is recommended that intercity traffic routes should be passed outside the city, chosen in places less sensitive to noise such as trade and industry, and green areas should be preferred. Especially in urban areas, it is necessary to leave a green area by reducing noise between residential areas and traffic roads, airport, railway and industrial facilities. If the elevation of this buffer area is changed, the noise level will be greatly reduced by greening work. If the noise source and the area to be affected are very close

to each other, the noise level can be reduced with walls made of materials such as concrete corrugated sheet or transparent acrylic plastic [Yılmaz and Özer, 1997; EEA, 2020].
The use of sound-absorbing materials in pavements of roads near residential areas;
• Planning of roadside structures according to traffic flow,
• Prevention of mutual reflections,
• Leaving buffer areas,
• Constructing buildings that should be away from noise by choosing the appropriate place,
• Designing the location and directions of the functional volumes in the building,
• The use of different materials within the structure can also significantly reduce the noise level.

3.6. Roadside noise precautions in traffic

Since sound waves occur naturally and are produced by solid objects, they show changes such as folding, reflection or echo depending on the properties of the objects. Sound waves do not propagate at the same speed in all environments and there are factors that affect the speed of sound propagation. The increase in the ambient temperature causes the internal energy, that is, the mobility of the particles in the environment to increase, and allows the sound to spread more quickly in the environment. Sound propagation is faster in solids than in liquids and gases. The reason for this is that the particles of solids are closer to each other than liquids and liquids than gases. For example, trees and other plants are considered to be a good noise canceller, in order to spread sound waves regularly, tend to reflect and cut off noise. As roadside noise canceling elements; afforestation, wall, embankment, slope and tunnel can be applied. One of the best ways to dampen sound is to reduce noise through afforestation and planting. Sound absorbing dwarf plants grown on slopes are very suitable for noise suppression as they do not grow rapidly in the transverse direction, do not obscure the viewing angle and do not require much maintenance. If noise cannot be prevented by vegetation, noise-cancelling bend walls are recommended. If the topographic structure of the land is suitable, noise prevention is done with natural slopes[EEA, 2020].

Figure 5. Noise canceling slopes and walls [Anonymous from Türkiye 2023]

Figure 6. Road section with noise barrier [Anonymous from Türkiye 2023]

Figure 7. Noise canceling trees **[**Anonymous from Türkiye 2023**]**

4. Discussion and Suggestions

Noise pollution caused by motor vehicles has been greatly reduced by improvements made in the production stages. But noise pollution caused by vehicle users continues. Reducing the noise pollution level in the transportation lines is a problem of the local administrations in the residential areas, but also a problem that concerns the society. Reducing this pollution, which can also be defined as vehicle user induced noise pollution, is directly related to legal practices, education, culture, environmental awareness and economic level.

Efforts to reduce noise pollution by using sustainable and new technologies should be supported by local and central administrations, and non-governmental organizations should organize activities to raise awareness of the problem and solve the problem. The most effective method for this is to ensure that the main roads connecting the highway and similar cities pass outside the residential area.
Newly launched vehicles have been significantly improved in terms of noise and exhaust emissions compared to previous vehicles. In addition, vehicles that are found to be harmful to the environment during road controls should be allowed to exit to traffic after the necessary procedures are taken.

If noise cannot be prevented by afforestation and planting in residential areas, noise-reducing curtains and barriers should be built, and if possible, highways should be moved out of residential areas.

Cost and economy analyzes are important in the implementation of noise reduction measures. In these applications, it is very important to detect economical and long-lasting noise canceling applications without bringing additional financial burden. By making comparisons between noise reduction systems, economical parameters should be determined, and in this context, short, medium and long-term actions should be determined.

Since the noise effect decreases depending on the increase in the distance between the noise source and the environment, the noise environment and the residential areas on the transportation routes should be planned considering the noise impact factor.

Resources

[1]. Çerçevik A.E, Kandemir Y., Yıldız S., Çelik M., (2018). Bilecik ili şehir içi yollardan kaynaklı gürültü kirliliğinin ölçülmesi ve değerlendirilmesi. Afyon Kocatepe Üniversitesi Fen ve Mühendislik Bilimleri Dergisi, 18 (1).
[2]. Dobson M., & Rya, J., (2000). Trees and shrubs for noise control. Arboricultural Advisory and Information Service, England.
[3]. European Environment Agency(EEA)., Report No 18/2019 The first and last mile- the key to sustainable urban transport Transport and environment report 2019, 2020.
[4]. Furgal S., Kałaczyński T., Łukasiewicz M., Martinod R., Analysis of the changes impact in the construction of the vehicle exhaust silencer on the noise emission level,. 21st International Conference Diagnostics of Machines and Vehicles., 2023.
[5]. Grubesa S., Suhanek M., Traffic Noise,. 10.5772/intechopen.92892 Published 2020.
[6]. Hintzsche M, Jäcker-Cüppers M, Kühne R, Heinz-Dieter Marohn, Dr. Lars Schade., (2008). *Gürültü Azaltım Önlemleri El Kitabı*. T.C Çevre ve Orman Bakanlığı, Ankara.
[7]. Jacyna, M., Wasiak, M., Lewczuk, K., Karoń, G. (2017). Noise and environmental pollution from transport: decisive problems in developing ecologically efficient transport systems. Journal of Vibroengineering, 19(7).
[8]. Kim S. H., Lee J. M., A Practical Method for Noise Reduction in a Vehicle Passenger Compartment *J. Vib. Acoust*. Jan 1998, 120(1).
[9]. Licitra G., Ascari E., Noise Mapping in the EU: State of Art and 2018 Challenges, Internoise September 2018 Conference: Chicago.
[10]. Linyuan L., Shuming C. Peiran L., The evaluation of vehicle interior impact noise inducing by speed bumps based on multi-features combination and support vector machine., Applied Acoustics Volume 163, June 2020.
[11]. OSHA technical manual, Doubling of Distance Noise Reduction, Section III, Chapter 5. Updated: July 6, 2022.
[12]. Ovenden N, Shaffer S, Fernando H., (2011). How the weather affects the scale of urban noise pollution., 161 st Acoustical Society of America Meeting, Seattle.
[13]. Papacostas C.S., Prevedouros P.D., (1993). *Transportation Engineering and Planning* (2nd edition), New Jersey: Prentice-Hall International Editions.

[14]. Shatnawi S, Gardiner M. S, Stubstad R., California's Perspective on Concrete Pavement Preservation., National Conference on Preservation, Repair, and Rehabilitation of Concrete Pavements, Missouri., 2009.
[15]. Wang X,. (2010). Vehicle noise and vibration refinement (1st edition). England:Woodhead publishing in Mechanical Engineering.
[16]. Yılmaz H., Özer S., (1997). Gürültü Kirliliğinin Peyzaj Planlama Yönünden Değerlendirilmesi ve Çözüm Önerileri. Atatürk Üniversitesi Ziraat Fakültesi Dergisi., *28*(3).
[17]. Yüksel, F., Gökdağ, M., Çetin, M., (2002). Ulaşımda araçlardan kaynaklanan gürültü kirliliği ve önleme yöntemler. Standart Ekonomik ve Teknik Dergi(TSE), 41(483).
[18]. Zhang X., Zhou S., Building a City with Low Noise Pollution: Exploring the Mental Health Effect Thresholds of Spatiotemporal Environmental Noise Exposure and Urban Planning Solution., International Journal of Environmental Research and Public *20*(5) 2023.