ENVIRONMENTAL NOISE AND AIR POLUTION IMPACT STUDY

PROJECT: ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA) FOR SECTION MATEŠEVO - ANDRIJEVICA OF BAR BOLJARE HIGHWAY

REVISION V1 : NEW ALLIGNMENT

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1 INTRODUCTION

1.1 Purpose

The purpose of this study is to identify and assess the potential impacts that may arise from the noise and air pollution emitted during the construction and the operation of the section "Matesevo – Andrijevica" of Montenegro's Bar-Boljare Highway (SEETO Route 4), on nearby dwellings and population (community and workforce). The proposal for the new highway alignment is approximately 21 km long. The start point is after the Mateševo IC and the 555m long tunnel, which is already under construction (Smokovac – Mateševo section). The end of the exploration area is the area of the Krsitica River, tributary of Lim River, near Andrijevica.

Highway section "Matesevo – Andrijevica" is part of the Bar - Boljare Highway linking the Port of Bar on the Adriatic Coast to Boljare near to the border with Serbia. The construction of the Bar - Boljare highway is included in the Spatial Plan of Montenegro (2008).

The road traffic noise will be assessed, considering the environmental and social baseline conditions analysed for the study area, and, where necessary and appropriate, mitigation measures are suggested.

1.2 Scope of Works

The study includes:

Chapter 2. *Regulatory framework:* Description of the main environmental regulatory framework in Montenegro, of Relevant European Directives and of additional project requirements concerning road traffic noise and air pollution

Chapter 3. *Existing conditions:* A brief review of the existing conditions regarding environmental noise and air quality in the vicinity of the project, based on data collected from available relevant studies

Chapter 4. *Methodology of evaluation:* Presentation of the methodology that will be followed, using computer models, to assess the noise and air pollution impact from the operation of the new highway

Chapter 5. *Evaluation of environmental impact:* Presentation of the results from the computer models and comparison of the estimated impact values to the legislation and to the existing conditions

Chapter 6. *Mitigation measures:* Indicative mitigation measures related to the impacts mentioned in the Chapter 4

All the available project data that are needed for the calculation of the noise nuisance and air pollution dissipation will be collected, such as the traffic flow of the existing road network and it's forecasts for launch year and year 2057, the detailed designs of the new highway, the topographical data at the vicinity of the project etc.

The area of study includes dwelling and settlements near the alignment between Matesevo (Ch.0+000) and Andrijevica (Ch.23+483).

1.3 Environmental Impact of Noise

Over recent years, acoustic pollution has become a common problem for developing countries and its treatment one of the new challenges in environmental policy. Furthermore, noise diminishes the quality of life in a more general perspective. Half of the EU citizens (EU 15) are estimated to live in areas which do not ensure acoustical comfort for residents:

- 40% of the population is exposed to road traffic noise with an equivalent sound pressure level exceeding 55 dB(A) during daytime
- 20% to levels exceeding 65 dB(A)
- At night, more than 30% are exposed to sleep-disturbing sound levels (>55 dB(A))

Often neglected, noise induces a severe impact on humans and on living organisms. Some of the adverse effects are summarized below:

- **Annoyance:** Noise creates annoyance to the receptors due to sound level fluctuations. The aperiodic sound due to its irregular occurrences causes displeasure to hearing and causes annoyance.
- **Physiological effects:** The physiological features like breathing amplitude, blood pressure, heart-beat rate, pulse rate, blood cholesterol are effected by noise.
- **Loss of hearing:** Long exposure to high sound levels cause loss of hearing. This is mostly unnoticed, but it has an adverse impact on hearing function.
- **Human performance:** The working performance of workers will be affected in noisy environments as they'll be losing their concentration.
- **Nervous system:** Exposure to high sound levels causes pain, ringing in the ears, feeling of tiredness, thereby effecting the functioning of human system.
- **Sleeplessness:** Noise affects the sleeping there by inducing the people to become restless and loose concentration and presence of mind during their activities.

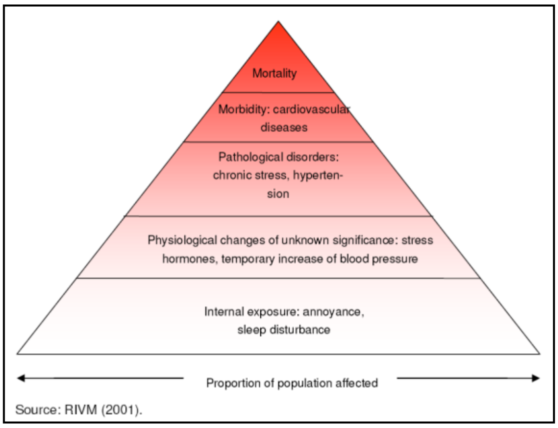


Figure 1, Effects of long-term excessive noise exposure

1.4 Environmental Impact from air pollution

Air pollution is accounted not only of its impact on climate change but also on its impact on public and individual health due to increasing morbidity and mortality. There are many pollutants that are major factors in disease in humans:

- Particulate Matter (PM), particles of variable but very small diameter, penetrate the respiratory system via inhalation, causing among others respiratory and cardiovascular diseases, reproductive and central nervous system dysfunctions, cancer.
- Ozone, even though in the stratosphere plays a protective role against ultraviolet irradiation, it is harmful when in high concentration at ground level, also affectes the respiratory and cardiovascular system.
- Nitrogen Oxide, Sulfur Dioxide, Volatile Organic Compounds (VOCs), Dioxins, and Polycyclic Aromatic Hydrocarbons (PAHs) are all considered air pollutants that are harmful to humans.
- Carbon monoxide is also a harmful air pollutant and it can even provoke direct poisoning when breathed in at high levels.

Fresh air and clean water are regarded as the key ingredients to a long and healthy life. Air and water are two elements that actually enter easily into living cells and represent their important structural elements that keep their metabolism going. Sadly enough, with the rise of the industrial development, water and especially air quality is severely deteriorated. Air pollutants can travel long distances and do not respect any boundaries or regions of a special ecological significance. Harmful particles emitted from power plants, cars or mining sites are easily carried hundreds of miles away from their original source.

Air quality standards are designed to protect human health and the environment in general. The existing air quality limits are variant from country to country and sometime even in the country itself, setting long-term and short-term objectives.

2 REGULATORY FRAMEWORK

2.1 Noise

According to project's requirements, the exposure of residents to noise from road traffic and its impact should be investigated corresponding to the national requirements for noise and to the World Bank and WHO guidelines.

2.1.1 National requirements according to Regulation 27/2015

Regulation 27/2015, published in Official Gazette of Montenegro of 05.08.2015, provides noise limits for residential acoustic zones, mixed-use acoustic zones or acoustic zones under the influence of traffic noises

The Assembly of the Capital City of Podgorica adopted the "Decision on determination of acoustic zones on the territory of the Capital City - Podgorica", no. 02-030 / 15-1101 of 31.07-2015 ("Official Gazette of Montenegro - Municipal Regulations", no. 27/2015 of 05.08.2015), which defined the acoustic zoning of the territory of Podgorica.

The limit values of the daily, evening and night noise level are 55, 55 and 45 dB respectively for the residential acoustic zone; 60, 60 and 50 dB respectively for a mixed-use acoustic zone; 60, 60 and 55 dB respectively for acoustic zone under the influence of traffic noise, according to Regulations and the Rulebook on limit values for environmental noise, methods of determining noise indicators and acoustic zones and methods for assessing the harmful effects of noise ("Official Gazette of Montenegro", No.060/11).

The Project area lies in the category 'under the influence of traffic noise, due to the presence of R-19 motorway.

2.1.2 World Bank Noise Level Guidelines

The World Bank General EHS Guidelines provide limit values for ambient noise levels as presented in the following Table:

Receptor	Daytime $L_{eq,T}$ 07:00 - 22:00 [dB(A)]	Night-time $L_{eq,T}$ 22:00-07:00 [dB(A)]
Residential; institutional; Educational	55	45
Industrial; Commercial	70	70

Table 1, World Bank EHS Noise Level Guidelines

2.1.3 World Health Organization (WHO) guidelines

The WHO Guidelines provide limit values for ambient noise levels as presented in the following table:

Designation	Day $L_{eq,T}$ [dB(A)]	Evening $L_{eq,T}$ [dB(A)]	Night $L_{eq,T}$ [dB(A)]
A	50	45	40
B	55	50	45
C	60	55	50

Table 2, Permissible Noise Levels in Areas with Different Sensitivity Scales

Where the designation means:

- A = Sensitive – These areas are designated quiet areas as they hold value in terms of them being places of worship, important tourist attractions, recreational park land and those areas surrounding hospitals, schools and noise sensitive natural habitats.
- B = Mixed – Areas designated in this category will typically be dominated by Residential Properties and may range from sparse population densities to suburban districts of cities.
- C = Non-sensitive – This designation applies to mixed areas, often within cities where there is a mix of residential and commercial activities. This designation will also apply to retail and financial districts.

The Project area lies in Designation B.

2.2 Air pollution

The exposure of residents to air pollution from road traffic and its impact should be investigated corresponding to the national requirements for air quality and to the World Bank and WHO guidelines.

2.2.1 National requirements according to Regulation OG 25/12

The Regulation on determining the types of pollutants, threshold limit values and other air quality standards (OG 25/12) defines the limit values and tolerance limits, as well as other air quality standards for polluting substances, which are included in Annex I of the Directive 96/62/EC as well as in the Framework Directive 2008/50/EC on ambient air quality and cleaner air for Europe. The European limits are discussed in the next paragraph.

2.2.2 European Directives

The European Directive 2008/50/EC on ambient air quality and cleaner air for Europe entered into force on 11 June 2008. The directive sets legally binding limits for concentrations of major air pollutants. It merges and replaces nearly all the previous EU air quality legislation. New air quality objectives for PM2.5 (fine particles) are set, including the limit value and exposure related objectives – exposure concentration obligation and exposure reduction target.

Generally, this Directive aims to protect human health and sets limit values for lead (Pb), nitrogen dioxide (NO2), particulate matter (PM10 and PM2.5), sulphur dioxide (SO2), benzene, carbon monoxide (CO), certain toxic heavy metals (arsenic, cadmium, nickel and benzo(a)pyrene) and polycyclic aromatic hydrocarbons (PaH) and ozone (O3). The long-term objective for ozone intends to provide protection for vegetation.

In all zones and agglomerations where the level of pollutants exceeds the upper assessment threshold established for those pollutants, fixed measurements shall be used to assess the ambient air quality. Those fixed measurements may be supplemented by modelling techniques and/or indicative measurements to provide adequate information on the spatial distribution of the ambient air quality.

According to the Directive, limit values are defined in the following Table:

Pollutant	Averaging Period	EU Limit Value ($\mu g/m^3$)
Sulphur dioxide (SO_2)	1 hour	350 Not to be exceeded more than 24 times in a calendar year
	1 hour To be measured over 3 consecutive hours	500 Alert threshold at locations representative of air quality over at least 100 km^2 or an entire zone or agglomeration, whichever is the smaller
	24 hour	125 Not to be exceeded more than 3 times in a calendar year
	Calendar year and winter	20 Critical level for the protection of vegetation
Nitrogen dioxide (NO_2)	1 hour	200 Not to be exceeded more than 18 times in a calendar year
	1 hour To be measured over 3 consecutive hours	400 Alert threshold at locations representative of air quality over at least 100 km^2 or an entire zone or agglomeration, whichever is the smaller

Pollutant	Averaging Period	EU Limit Value ($\mu g/m^3$)
	Calendar year	40
	Calendar year	30 Critical level for the protection of vegetation
Particulate matter (PM_{10})	24 hours	50 Not to be exceeded more than 35 times in a calendar year
	Calendar year	40
Particulate matter ($PM_{2.5}$)	Calendar year	20
Carbon monoxide (CO)	Maximum daily 8 hour running average	10,000
Benzene (C_6H_6)	Calendar year	5
Lead (Pb)	Calendar year	0.5
Ozone (O_3)	1 hour	180 Information threshold
	1 hour To be measured or predicted for three consecutive hours	240 Alert threshold

Table 3, Limit values for the protection of human health

2.2.3 World Health Organization (WHO) guidelines

Projects that have significant sources of air emissions, and potential for significant impacts to ambient air quality, should prevent or minimize impacts. WHO suggests in the document 'Air Quality Guidelines', published at 1999, that emissions do not result in pollutant concentrations that reach or exceed the values in the following table:

Pollutant	Averaging Period	Guideline value in $\mu g/m^3$
Sulphur dioxide (SO_2)	24-hour 10 minute	125 (Interim target-1) 50 (Interim target-2) 20 (guideline) 500 (guideline)
Nitrogen dioxide (NO_2)	1 -year 1-hour	40 (guideline) 200 (guideline)
Particulate Matter PM_{10}	1 -year	70 (Interim target-1) 50 (Interim target-2) 30 (Interim target-3) 20 (guideline)
	24-hour	150 (Interim target-1) 100 (Interim target2) 75 (Interim target-3) 50 (guideline)

Pollutant	Averaging Period	Guideline value in µg/m³
Particulate Matter $PM_{2.5}$	1 -year	35 (Interim target-1) 25 (Interim target-2) 15 (Interim target-3) 10 (guideline)
	24-hour	75 (Interim target-1) 50 (Interim target-2) 37.5 (Interim target-3) 25 (guideline)
Ozone	8-hour daily maximum	160 (Interim target-1) 100 (guideline)

Table 4, WHO Ambient Air Quality Guidelines

3 EXISTING CONDITIONS

Environmental Noise measurements were performed along the proposed alignment at five (5) locations during 2019. The laboratory that carried out the noise and vibration measurements is the accredited laboratory "Center for ecotoxicological research Podgorica LLC". The Noise level measurements were conducted with Class 1 Sound Level Meter / Data Logger type Svan 977A. The measurement method used was based on international standard ISO 1996 and the measurement period was 23.09-28.09.2019.

The locations for the measurements have been selected with the criteria to be along the new highway alignment and in locations where houses or buildings are close to the new highway i.e. in a distance less than 150 m. More specifically, the measurement points which were selected are shown in the following map:

Figure 2, Environmental Noise Measurement locations and alignment of future highway

The results from the measurements are given in the table below (Table 5), grouped in three time periods: day, evening and night. In the next page the noise level time-history of each location is presented.

Location	L_{day}	$L_{evening}$	L_{night}	L_{DEN}
M01	50	45	41	50.4
M02	55	54	53	59.8
M03	60	50	44	58.0
M04	61	60	53	62.6
M05	61	59	54	62.8

Table 5, measured noise levels [dB(A)]

Air pollution measurements were conducted by "Center for ecotoxicological research Podgorica LLC", according to "Regulation on the manner and conditions in Air Quality Monitoring" (Off.gazette of Montenegro, No: 21/11, 32/16) – standards: MEST EN 1412:2014 (SO_2), MEST EN 1411:2014 (NO, NO_2), MEST EN 14626:2014 (CO) and MEST EN 12341:2016 (PM_{10}, $PM_{2.5}$).

The results are shown in report "00-1744/2" – "Ambient air quality measurement on the highway route Mateseco-Andrijevica, baseline state" issued at 22.10.2019.

The measurements were made to 4 locations, coinciding with points M02 – M05 of the noise measurements (Figure 2). The summary of the results is shown in the following table:

	PM_{10}	$PM_{2.5}$	SO_2	NO	NO_2	CO
	μg/m³	*μg/m³*	*μg/m³*	*μg/m³*	*μg/m³*	*mg/m³*
M02	13.82	7.44	2.35	3.35	4.00	0.21
M03	21.61	8.80	2.71	7.76	6.13	0.21
M04	11.34	6.83	2.44	4.52	5.58	0.10
M05	10.70	6.44	2.25	2.83	1.35	0.16

All measured values were below the appointed limit values of:

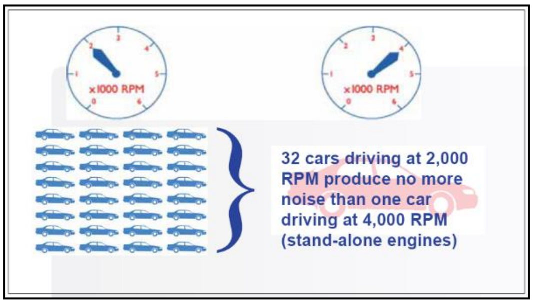
- sulfur dioxide: hourly mean value of 350 g/m³ and daily limit value of 125 μg/m³,
- nitrogen dioxide: hourly mean value of 200 μg/m³ and annual mean value of 40 μg/m³,
- carbon monoxide: daily 8-hour mean value of 10 mg/m³,
- Particulate matter PM10: daily mean value of 50 μg/m³, annual mean value of 40 μg/m³,
- Particulate matter PM2.5: annual mean value of 25 μg/m³.

4 METHODOLOGY OF EVALUATION

4.1 Road traffic noise sources

Road traffic has an impact on environmental noise that is immediately obvious. Transit noise is generated by vehicles in motion.

Vehicle propulsion units generate a) diesel-engine or petrol-engine exhaust noise; see figure on the right, b) air-turbulence noise generated by cooling fans and c) gear noise.



Rolling noise is generated by the interaction of wheels with their running surfaces. The noise level of the rolling noise is significantly more affected by the vehicle's speed than propulsion noise (Figure 3). In highways, tire noise from rubber-tired vehicles is the most significant noise source.

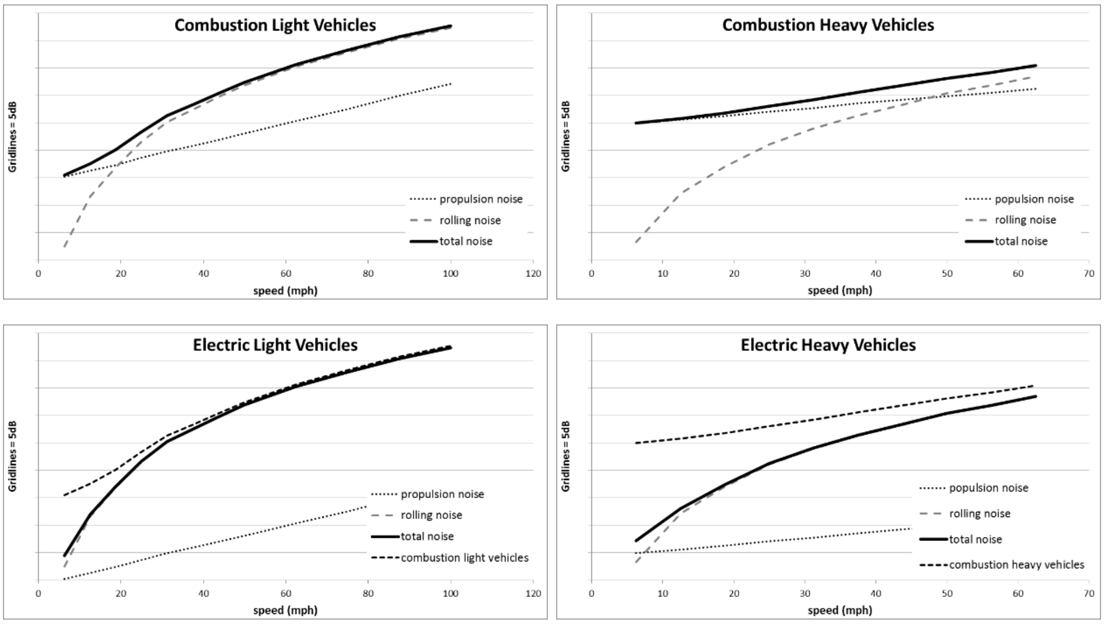


Figure 3, Key road traffic noise sources and their overall contribution

4.2 Definitions, Properties and Measuring Units of Sound

Sound is defined as the mechanical disturbance that propagates with certain speed in a medium that can develop internal forces and has such a character that can stimulate the ear (the auditory transducer) and cause auditory sense.

The frequency of the sound, f, is the oscillation frequency of the particles of the elastic medium due to the dissipation of the sound wave, which corresponds to the number of repetitions per second and is measured in Hertz (Hz).

In acoustics the units that are used are usually logarithmic. The main unit of measurement is the decibel (dB). It is a logarithmic unit of measurement of acoustic pressure, intensity and power emitted by a sound source. Instant sound level (Sound Pressure Level) is defined thus as:

$$\mathrm{SPL} = 20 \log \frac{p(t)}{p_{ref}},$$

where $p(t)$ is the sound pressure and $p_{ref} = 2 \times 10^{-5}\ N/m^2$ is the reference value.

The dynamic range that can be perceived by a young person is 0 - 120 dB, which in linear units corresponds to the range from $20\ \mu\mathrm{Pa}$ to $20{,}000{,}000\ \mu\mathrm{Pa}$. Exposure to sounds above 120 dB is harmful, even if it is short-term.

The human ear works in the frequency range from 16 Hz up to 20 kHz, but its sensitivity is not the same at all frequencies. Specifically, the human ear is more sensitive to frequencies in the range of 1000-6000 Hz. For this reason, and in order to adjust the measured noise in the way of the human ear canal, frequency-weighting filters are used. The most common filter is the A-weighting filter.

The sound level resulting from measurements with A-weighting filter is called the A-weighted sound level and is measured in dB(A). In most cases, the noise measurements (acoustic pressure levels) are made using this filter, by using certified portable devices called sound level meters. These instruments are fitted with A-weighting filter and the calculation in dB(A) is done automatically.

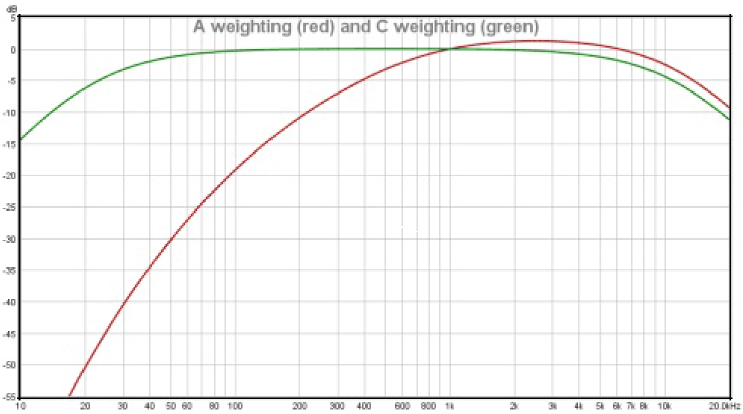


Figure 4, A-weighting and C-weighting curves

4.3 Indicators for the Assessment of Environmental Noise

All noise sources cause a time-varying sound pressure level. Therefore, the noise cannot be described and evaluated with the use of instant sound level. For this reason, in order to sensibly quantify noise, we use certain single-value indexes/descriptors. Indexes commonly used for the assessment of environmental noise are:

L_{eq}: the equivalent continuous sound level or equivalent noise level, which expresses the level of a constant sound source that encompasses the same acoustic energy with the actual sound:

$$L_{eq} = 10\log\frac{\frac{1}{T}\int_0^T p(t)^2 dt}{p_{ref}^2},$$ where T is the time of observation

$L_{F,max}/L_{F,min}$: the maximum/minimum of all the exponential moving average levels recorded during a measurement using the time constant ‘Fast’ ($T = 125$ ms)

$L_{S,max}/L_{S,min}$: the maximum/minimum of all the exponential moving average levels recorded during a measurement using the time constant ‘Slow’ ($T = 1$ s).

The ‘Slow’ filter dampens the reaction to sudden changes in noise level more than the ‘Fast’ filter, thus $L_{S,max}$ always has lower value than $L_{F,max}$ and $L_{S,min}$ always has higher values than $L_{F,min}$.

$L_{F,5\%}/L_{F,10\%}$: the level at which $5\%/10\%$ of the exponential moving average levels recorded during a measurement using time constant ‘Fast’ ($T = 1$ ms) is below it.

They are useful for isolating transient noise incidents from background noise, i.e. vehicle pass-by, and they are often used in transport noise analysis

$L_{F,90\%}/L_{F,95\%}/L_{F,99\%}$: the level at which $90\%/95\%/99\%$ of the exponential moving average levels recorded during a measurement using time constant ‘Fast’ ($T = 1$ ms) is below it.

They are effective in excluding transient noise incidents from the results; hence they provide an estimate of the ambient background noise of an area whenever no characteristic noise source is dominant.

SEL: the Sound Exposure Level is the sound level of a transient sound source that emits constant sound for one second and encompasses the same acoustic energy with the actual sound:

$$SEL = L_{eq} + 10\log T,$$ where T is the time of observation

It can be used to compare noise events which have different time durations.

$L_{day}/L_{evening}/L_{night}$: the A-weighted long-term average sound level as defined in ISO 1996-2:2007, determined over all respective periods of a year (day: $T = 07\text{h}00 - 19\text{h}00$, evening: $T = 19h00 - 23h00$, night: $T = 23h00 - 07h00$)

L_{DEN}: weighted 24h noise level index defined by L_{day}, $L_{evening}$ and L_{night} using the formula:

$$L_{DEN} = 10\log\left(\frac{12}{24}10^{\frac{L_{day}}{10}} + \frac{4}{24}10^{\frac{L_{evening}+5}{10}} + \frac{8}{24}10^{\frac{L_{night}+10}{10}}\right)$$

4.4 European Environmental Noise Assessment method

The Environmental Noise Directive (END) is the main EU instrument through which land-based noise emissions are monitored and actions developed. It defines environmental noise as ‘unwanted or harmful outdoor sound created by human activities, including noise emitted by means of transport, road traffic, rail traffic, air traffic, and from sites of industrial activity’ (2002/49/EC Directive). It places an obligation on EU Member States to assess noise levels by producing strategic noise maps for all major roads, railways, airports and urban areas. Based on these noise-mapping results, Member States must prepare action plans containing measures that address noise issues and their effects for those areas where the specific END indicator thresholds have been surpassed. The Directive neither sets limit values for noise exposure, nor prescribes measures for inclusion in the action plans.

The END was revised by the EU Directive 2015/996 of 19 May 2015 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council. The amendment suggests that the Member States will apply the new European Commission developed Common NOise aSSessment methOdS (CNOSSOS-EU) for calculating environmental noise starting 31st December 2018. CNOSSOS-EU aims at improving the consistency and comparability of noise assessment results across the EU Member States which are performed on the basis of the data becoming available through the consecutive rounds of strategic noise mapping in Europe.

To evaluate the noise nuisance from a new highway, as in the case of this project, the procedures defined in CNOSSOS-EU road computation method are applied. The method calculates the sound power of the road vehicles based on their type, their frequency and the road surface type and condition. Then the dissipation of the noise level from the highway to the sensitive receiver is calculated considering the distance, the topology and the sound absorption of the terrain, the environment (temperature, relative moisture, wind) and any obstacle (i.e. noise barrier, other buildings) that comes between the source and the receiver.

The calculated estimate of the noise level at the receiver is then compared with the noise limits applicable to the area under study. If there are areas where the level is over the limits, mitigation measures should be designed.

4.5 Road traffic air pollution sources and dissipation

Traffic fumes contain harmful chemicals that pollute the atmosphere. Road traffic emissions produce greenhouse gases that contribute to global warming.

The emissions from the road vehicles will be calculated from COPERT software tool, following the methodology defined in EMEP/CORINAIR Emission Inventory Guidebook, developed by the UNECE Task Force on Emissions Inventories and Projections.

4.6 Construction noise & air pollution sources

Construction activity is inherently noisy due to the following:

- Vehicle traffic in/out from site and borrow pits
- Construction work (e.g.concrete, excavation, machinery, crane operation)

Construction activity is also producing air pollutants, mainly from the internal combustion engines of construction machinery, which mainly run on diesel.

The assessment of the impact is done using the type of machines and vehicles to be used in a "representative" project (see §5.5 - Construction site machinery composition).

4.7 Sound and Air Pollutants Propagation simulation software

Under the scope of the Environmental Impact Study of the project, in order to quantitatively assess the emitted noise levels by the operation of the Highway, a noise simulation model was developed using specialised computer software. The calculations and the resulting noise maps were performed using the specialized noise prediction and noise assessment software IMMI Premium 2021 by Woelfel MebSysteme GmbH. The software fully covers the requirements of European Noise Directive including its 2015 amendment, while it provides -through the QSI data Structure (DIN 44687)- the possibility of transferring projects and data to and from other noise prediction and evaluation software. In this way, full compatibility with other relevant software is achieved and the data is usable over time.

All input data information was gathered and classified in GIS layers for data management and quality assurance purposes. IMMI provides great interconnectivity between its data structures and GIS software (Figure 5).

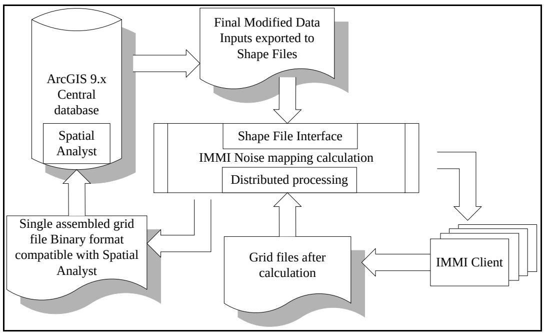


Figure 5, IMMI interconnectivity with GIS software

Other IMMI Premium 2021 features that are valuable for the current study include:

- Completeness of the software as to the needs arising from the Environmental Noise Directive (2002/49 EC) and its amendment (EC 2015/996)
- Possibility to perform the calculations as a whole 3D model area of the project by distributing the intensive calculations required to a computer network (Figure 6)
- Provides elements as sound screens (straight or cantilevered), green belts, porous asphalt etc. to investigate the efficiency of noise abating measures
- Automated algorithm for optimal calculation of sound barrier height
- Acceleration mechanisms to increase the speed of noise mapping calculations
- Interconnectivity (data input/output) with geographic information Systems (GIS) and design software like Autocad
- Connection to WMS servers for acquiring georeferenced satellite imagery
- Usability in model changes after importing directly from the software
- Quality assurance mechanisms and automatic checks of the data quality before starting calculations
- Simultaneous calculation in each receiver position of all 4 noise indicators (L_{day}, $L_{evening}$, L_{night}, L_{den}) and registration in separate layers
- Ability to display results in thematic maps (with different sets of receivers or sources or combination of sources/receivers)
- Ability to perform different scenarios for the identification of noise measures with different policies (policy tests) but also with different meteorological and spatial planning data

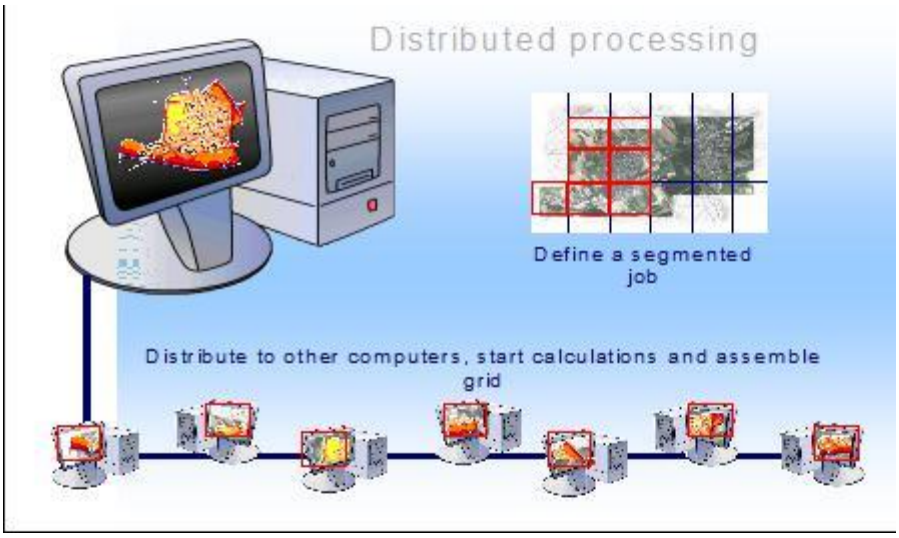


Figure 6, IMMI distributed processing schematic

For calculating road transportation noise, the model uses the European Commission developed Common NOise aSSessment methOdS (CNOSSOS-EU). The method calculates the sound power of the vehicles based on their type, their speed, their frequency and the pavement type and condition. Then the dissipation of the noise level from the highway to the sensitive receiver is calculated considering the distance, the topology and the sound absorption of the terrain, the environment (temperature, relative moisture, wind) and any obstacle (i.e. noise barrier, other buildings) that comes between the source and the receiver.

The new European Commission developed COmmon NOise aSSessment methOdS (CNOSSOS-EU) for calculating environmental noise requires a substantial amount of input parameters in order to produce a 3D model of the area of the project, such as meteorological parameters, terrain model, screening obstacles, road network geometry and traffic flows distributed over different vehicle types (light vehicles, medium heavy vehicles, heavy vehicles) and over three time periods during one 24h day ('day': 07h00 - 19h00, 'evening': 19h00 - 23h00, 'night': 23h00 - 07h00).

Air pollution is estimated using a suitable Atmospheric Dispersion Model. Atmospheric dispersion modelling is the mathematical simulation of how air pollutants disperse in the ambient atmosphere. It is performed with computer programs that solve the mathematical equations and algorithms which simulate the pollutant dispersion. The dispersion models are used to estimate or to predict the downwind concentration of air pollutants or toxins emitted from sources such as industrial plants, vehicular traffic or accidental chemical releases.

All the calculations of the dispersion of gas and dust are made with the following software: IMMI Premium 2021, licence number S72/354, according to the Gaussian model (TA Luft 1986 [6]), using the emissions defined from §4.5 - Road traffic air pollution sources and dissipation.

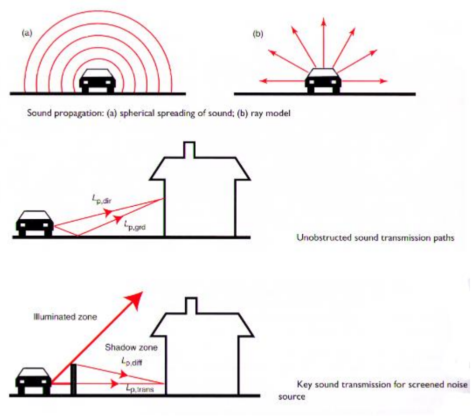
4.8 Calculating efficiency of Road Traffic Noise Mitigation Measures

Noise reduction can be achieved at-source using low noise road surfaces. Low-noise road surfaces, such as thin-layer, double-layer, porous and poroelastic pavements, offer considerable potential to cut road noise dramatically, since tyre-road interaction is the main noise source at high vehicle speeds. Such surface measures have the advantage of bringing immediate benefits, particularly for use in noise hotspots. CNOSSOS-EU models low-noise road surfaces by applying a weighting factor to the sound power of the individual vehicle noise emissions. The weighting factors are given in 1/3-octave bands and they depend on the type of the road surface and the vehicle category. Generic weighting factors for low-noise road surfaces are provided (1-layer ZOAB, 2-layer ZOAB, 2-layer ZOAB (fine), thin layer A, thin layer B).

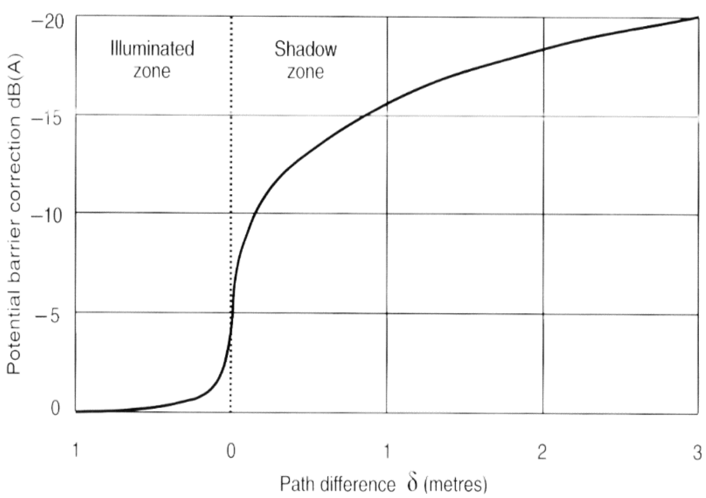
If the desired degree of noise reduction cannot be achieved by at-source measures, noise barriers will be helpful in reducing propagation of the noise. The primary function of noise barriers is to shield receivers from excessive noise generated by road traffic. Many factors need to be considered in the detailed design of noise barriers. A proper design of noise barriers would be needed to take into consideration both acoustic and non-acoustic aspects. Acoustical design considerations include barrier material, barrier locations, dimensions and shapes. Non-acoustical design considerations are equally important, such as maintainability, structural integrity, safety and aesthetics.

When introducing a barrier, the critical ‘acoustic ray’ is the ones diffracted above the top edge of the barrier

The length difference δ (diffracted path length minus direct path length) is the most important parameter on the attenuation the barrier can provide. There is mathematical formula to predict accurately the sound insulation (Figure 7).



CNOSSOS-EU models geometrically the attenuation from screening, based on the increase of distance the sound wave has to travel among other factors. Each road lane is divided in several equivalent point sources and the attenuation factor is calculated by tracing rays, in generated vertical and horizontal cross sections, from the discretised point sources to the receiver. The model is also taking into account the negative effects on the actual attenuation from noise barriers that can be caused by downwind propagation and reflections. Reflections reduce the acoustic performance and can be prevented by using sound absorptive barriers (Figure 9). The formula is semi-empirical and has a cut-off at 25 dB maximum attenuation in any scenario.



0..-5 dB
minimal mitigation of noise to receivers, the barrier might not be efficient cost wise

-5..-10 dB
receivers will understand a noticeable decrease of noise exposure

-10..-15 dB
the screening of the noise barrier is very noticeable

-15..-20 dB
very difficult to reach in practice – too high barriers are needed

Figure 7, Noise barrier Insertion Loss

The effective height of a barrier can be improved by locating the barrier as close to the source as possible and by angling or curving a cantilevered barrier towards the road (Figure 8).

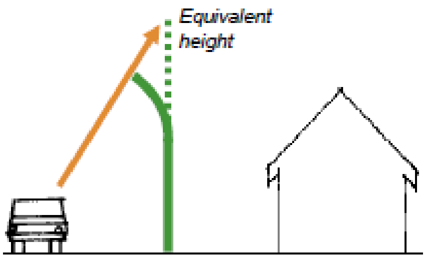


Figure 8, A cantilevered barrier angled across the road can increase the noise mitigation achieved by a barrier

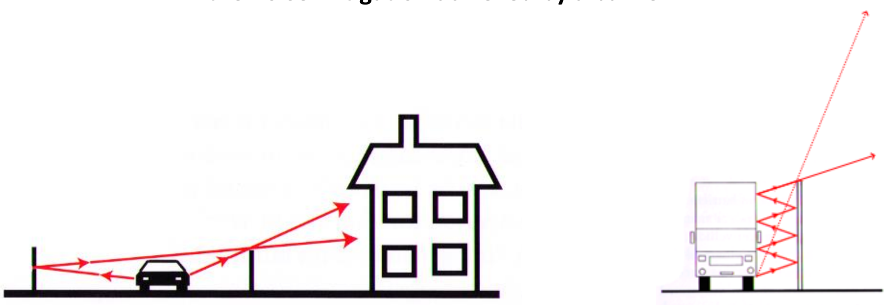


Figure 9, Influence of reflections in road traffic noise propagation

5 INPUT DATA

5.1 Meteorological Data

The monthly average temperature in the region variates from -1°C to 23°C and the average air humidity from 50% to 78%. The dominant wind is shown in Figure 10:

The air temperature was implemented in the models to an average of 10°C and the humidity as an average of 65%RH. The wind rose used is displayed below:

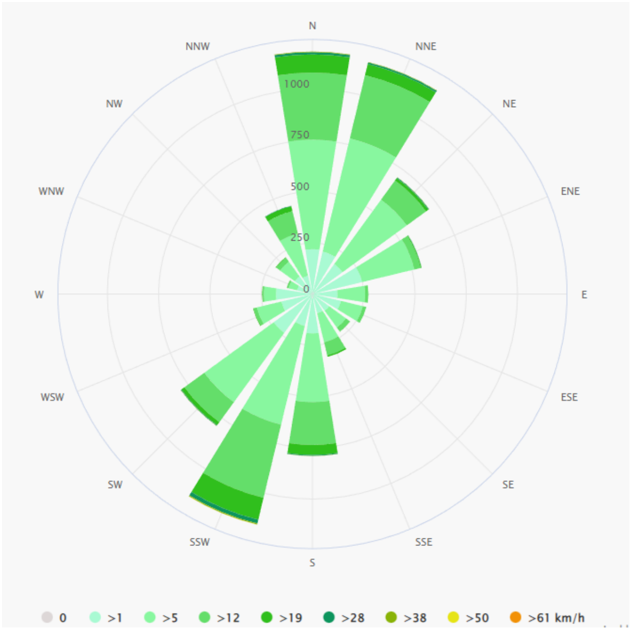


Figure 10, Wind roses from historical data in the region

5.2 Terrain model

The characteristics of the topography have been defined in the model by importing elevation data from various sources, thus shaping the digital terrain model of the study area. The digital elevation of the noise model is composed of:

- the broader area in a grid resolution of 1’’ arc was taken from the USGS SRTM database,
- the contours inside an area of approximately ±50-100m from the alignment’s axis from the project’s topographic survey of existing conditions,
- the area that will be modified by the project from the TIN model of the design

The model includes land uses of the area regarding housing areas (villages) and areas covered by vegetation, as they are determined in project’s ESIA report. In general, the overall absorption coefficient value was taken as 0.5 in the model*, which is a conservative value for rural environments.

5.3 Alignment

The geometry of the proposed Project was taken from the final design documents and it follows the longitudinal section shown below:

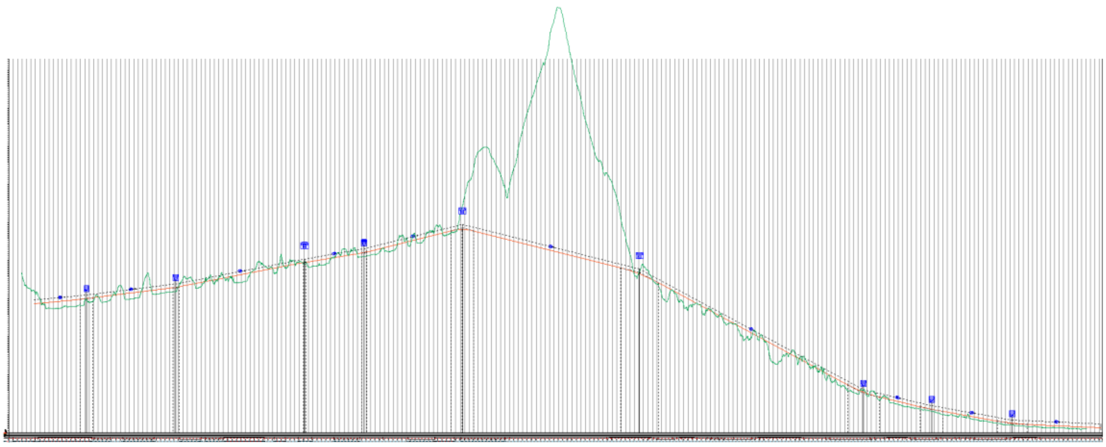


Figure 11, Longitudinal section of the alignment

5.4 Traffic flows

For this study, the estimates of the traffic flows that are proposed in project's Traffic Study were used (Traffic Analysis Report BB-D-00-0-SS-0-00-PD-01, April 2021).

AADT veh/day						
From	**To**	**2022**	**2027**	**2032**	**2037**	**2057**
Matesevo	Andrijevica	2 688	3 558	4 585	6 009	7 906
Andrijevica	Matesevo	2 786	3 688	4 753	6 228	8 195

Heavy veh/day						
From	**To**	**2022**	**2027**	**2032**	**2037**	**2057**
Matesevo	Andrijevica	101	113	126	140	198
Andrijevica	Matesevo	104	117	131	145	205

* minimum value of 0.0 represents hard reflecting ground and maximum value of 1.0 represents absorbing soft ground

Table 6, Traffic flows under various scenarios for the new highway

The average operating speed that has been considered in the models is 100 km/h for light and medium heavy vehicles and 80 km/h for heavy vehicles.

The distribution to day/evening/night intervals is estimated from 'Appendix 1 ATC – Counts from Traffic Study', which results to 82%-14%-4% respectively.

5.5 Construction site machinery composition

To assess noise and air emission levels from the construction worksite, an estimation of the composition of an indicative construction site is presented in the following table, i.e. the type and number of machinery and vehicles to be used during the construction phase of the Project (Table 7). The table also includes the type of fuel used by each machine and the daily fuel consumption per machine / vehicle. Worksite operation of approx. 10 hrs/day is assumed.

Equipment	No of machinery / vehicles	Fuel	Fuel consumption (lt/h)
Tracked Excavator (20 t)	2	Diesel	19.0
Compressor / Pneumatic breaker	2	Diesel	3.5
Dozer (200 KW)	2	Diesel	17.0
Tracked loader (60 KW)	1	Diesel	19.0
Road surfacing (asphalt spreader, chip spreader, road roller, lorry)	1	Diesel	35.0
Road roller	1	Diesel	7.0
Truck mixer	1	Diesel	20.0
Truck 20 t	4	Diesel	8.0

Table 7, Typical synthesis of worksite equipment & fuel consumption

<u>Noise emissions</u>

The L_{eq} noise from the operation of the equipment to be used during the construction of the project, based on the directive of Defra (UK Department for Environment, Food and Rural Affairs) "Noise database for prediction of noise on construction and open sites" is presented in the following table:

A/A	Μηχάνημα	Average noise level in 10m distance from source, L_{eq} [dB(A)]	Site clearance	Topsoil strip	Earth-works	Pavement & surfacing	Structures	Piling
1	Excavator	70	✓	✓		✓		
2	Excavator loader	76	✓	✓	✓	✓		✓
3	Grader	86	✓	✓	✓	✓		
4	Tractor - compressor	80	✓	✓	✓	✓	✓	✓

5	Compressor	65	✓	✓	✓	✓	✓	
6	Cylinder	73	✓	✓	✓	✓	✓	
7	Dump truck	86	✓	✓	✓	✓		✓
8	Crane	76			✓	✓	✓	✓
9	Fixed-base crane or mobile crane	68				✓	✓	
10	Concrete pump	66				✓	✓	✓
11	Concrete mixer	79				✓	✓	✓
12	Ground compressor	78	✓		✓	✓	✓	✓
13	Telescopic loader	71	✓		✓	✓	✓	✓
14	Drilling rig	89						✓

Table 8, Noise emissions from worksite equipment

<u>Dust emissions from aggregate storage piles</u>

Dust is a major air quality problem at and around construction sites. Dust is problematic for a variety of reasons, as outlined below:

- Inconvenience to local people. For example, people may have to re-wash laundry that has been put outdoors to dry, and wash windows, curtains and vehicles. Dust can contaminate meat hanging up in open-air butchers and other food that is exposed to it in homes, shops and open-air restaurants, giving food a gritty texture.
- Health and safety problems. Dust might affect health by irritating eyes and worsening the health of people with asthma. Dust can reduce visibility for drivers on roads. It can also be blown for long distances by the wind.
- Crop damage. Even low concentrations of dust can affect plant and fruit growth as far away as one kilometer from a construction site. Plant growth is particularly susceptible to dusts that are highly alkaline, for example limestone and cement dust. Dust deposited during light rainfall can cause the soil surface to form a crust increasing run-off. These constitute social/economic impacts. One of the mitigation measures implemented by the Contractor will be a grievance mechanism with potential compensation for crop damage.
- Impact on ecology. Dust blowing onto watercourses may damage the ecological conditions by increasing sedimentation, reducing sunlight and suffocating fish. It may also affect plant growth and change the species of plants growing in an area. Dust may also damage trees and other vegetation planted as part of the construction contract.
- Damage to batching and asphal plants and equipment. Within the construction site, dust can cause mechanical or electrical problems in sensitive equipment such as computers. It can also increase abrasion of moving parts in equipment and clogging of air filters.
- The demolition of objects (buildings, Residential Properties, fences, etc.) located on the path of the highway route. In the case of buildings and Residential Properties, their demolition implies the risk of finding asbestos containing materials that might have been used for their construction. If this happened a highly dangerous asbestos air contamination could occur. At the construction site, the possible impacts are expected across the axis of the highway (at a distance of ± 100 m).

According to US EPA (AP-42; 13.2.4), the quantity of particulate emissions generated by either type of drop operation, per kilogram (kg) (ton) of material transferred, may be estimated using the following empirical expression:

E = k × 0.0016 × $\frac{(U/_{2,2})^{1,3}}{(M/_{2})^{1,4}}$ (kg/t)

where:

E = emission factor k: particle size multiplier (for particles < 30 μm, k= 0.74)

U: wind speed (assumed 5 m/s) M: material moisture content (assumed 10%)

Particulate emissions are calculated as E= 0.36 g particulates/ t material.

Particulate emissions from movement of construction vehicles (paved roads)

Particulate emissions occur whenever vehicles travel over a paved surface such as a road. In general terms, re-suspended particulate emissions from paved roads originate from, and result in the depletion of, the loose material present on the surface (i.e., the surface loading). In turn, that surface loading is continuously replenished by other sources. The movement of vehicles is associated with construction worksite operations, such as transfer of materials and equipment.

According to US EPA (AP-42; 13.2.1), the quantity of particulate emissions from resuspension of loose material on the road surface due to vehicle travel on a dry paved road may be estimated using the following empirical expression:

E = k × $(sL)^{0,91}$ × $(W)^{1,02}$

where k: particle size multiplier depending on particle size range (g/ Vehicle Kilometer Travelled)

sL: Silt loading, (0.06 g/m^2 for paved roads).

W: average weight (tons) of the vehicles traveling the road (5 t)

Particulate emissions (PM 2.5 and PM 10) are calculated in the following table taking into account the aforementioned

	k (g/VKT)	sL (g/m2)	W (t)	E (g/VKT)
PM 2,5	0,15	0,06	5	0,06
PM 10	0,62	0,06	5	0,25

Table 9, Particulate emissions from movement of construction vehicles (paved roads)

It can be concluded from the table above that the particulate emissions from the movement of construction vehicles on paved roads is 0,06 g/Vehicle Kilometer Travelled for PM 2,5 and 0,25 g/Vehicle Kilometer Travelled for PM 10.

Consequently, the impacts will be moderate, negative, direct / cumulative since dust and combustion gases are generated by the construction activities, reversible, of local character and short-term since at each location air pollution will last the time the construction activity takes place.

Locations for borrow pits, rock crushing facilities, concrete batching yards and asphalt plants will require approvals. Efforts will be made to ensure that these facilities are located as near to the Project Road as practical to avoid unnecessary journeys and potential dust issues from vehicle movements during construction works on unpaved roads in urban areas. Haul routes will be prepared and submitted to the Engineer as part of his Traffic Management Plan (TMP) which is analyzed in more details in the Environmental Management Plan of this ESIA.

5.6 Sensitive Receivers

For the assessment of the sensitive areas regarding noise and air pollution, the following criteria were taken into account:

- The distance of schools, health institutions, religions institutions and other relevant institutions
- The distance of residential houses, population density and recreation places
- The distance of agricultural farms and plantations with proposed alignment
- The distance of industrial activates with the study area

Based on the above, the sensitive receivers are clustered in five main locations along the alignment, (1) at 1+300 - 1+700, (2) Bare Kraljske settlement at 5+400 - 8+000, (3) Gnjili Potok settlement at 13+850 - 17+140, (4) Kralje village at 17+350 - 18+750 and (5) Andrijevica (north) at 20+200 - 23+100.

From document “Tresnjevik-Andrijevica Design Change v2.0.dwg” which displays the design change for the section Tresnjevik tunnel – Andrijevica, 333 buildings were extracted, distributed to the above clusters as follows:

Gnjili Potok	84 buildings
Kralje village	89 buildings
Andrijevica	160 buildings

6 EVALUATION OF ENVIRONMENTAL IMPACT

6.1 Noise

6.1.1 Construction Phase

In the model for the effect of noise on the construction phase it is taken into account that special attention will be given to the delivery of materials, especially when falling from a height. Building materials should be properly managed so as to produce minimal noise. During the various phases of construction corresponds the equipment in Table 7. Within these phases, of course, only part of the equipment mentioned will be used simultaneously.

The noise emissions of the machines that have been introduced in the software are in accordance with the directive of Defra (UK Department for Environment, Food and Rural Affairs) "Noise database for prediction of noise on construction and open sites", as presented in chapter §5.5. Construction activities investigated include Site clearance works, Topsoil strip works, Earthworks, Pavement and surfacing works, Construction works and Piling works. The worst-case scenario investigates simultaneous operation of the work machinery and the construction trucks, assuming a L_w. = 98 dB noise source distributed within the site at a height of 2m from the ground and a L_w = 91 dB point power noise source at a height of 20 m from the ground.

In the absence of detailed information regarding uses of individual buildings along the proposed development, the construction assessment has been carried out based on distance from the earthwork of the proposed development (assumed to be the nearest location to the receptors in which construction activities would take place).

Predicted construction noise levels at noise sensitive receptors for each construction activity are shown in Table 9:

Distance band	Predicted construction noise level L_{Aeq} (dB) at the façade, per activity						
	Site clearance	Topsoil strip	Earth-works	Pavement and surfacing	Structures	Piling	Worst-case scenario
20m	71	70	70	67	70	71	74
40m	65	64	64	61	64	65	68
80m	59	58	58	55	58	59	62
160m	53	52	52	49	52	53	56
320m	47	46	46	43	46	47	50

Table 10, Particulate emissions from movement of construction vehicles (paved roads)

Within a buffer zone of 40m, the impact of the construction noise is considered debatable for the nearby sensitive acoustic receivers, where more than 65 dB(A) is expected. When sensitive receivers lie in this buffer zone from the noise sources, then the contractor should monitor for any noise nuisance incidents and apply the mitigation measures proposed in §7.1 (page 34). As a first estimate, such candidate areas include all locations presented in §5.6 Sensitive Receivers (page 28).

6.1.2 Operation Phase

All the calculations of the sound dissipation were made with the following software: IMMI Premium 2023, licence number S72/354.

A 3D model of the area of the project was produced for the calculations based on the input parameters as described in Chapter 5: Input Data (meteorological parameters, terrain model, screening obstacles, road network geometry and traffic flows distributed over different vehicle types and over three time periods during one 24h day (‘day’: 07h00 - 19h00, ‘evening’: 19h00 - 23h00, ‘night’: 23h00 - 07h00).

The following tables present maximum noise levels generated in each identified sensitive receiver cluster from the calculation of road operation for the launch year and year 2057:

Sensitive Receivers	L_{day} (12h) [dB(A)]	$L_{evening}$ (4h) [dB(A)]	L_{night} (8h) [dB(A)]	L_{DEN} [dB(A)]
1+300 - 1+700	58.7	51.0	45.6	57.5
Bare Kraljske	66.7	59.0	53.6	65.5
Gnjili Potok	66.5	58.8	53.4	65.3
Kralje	67.5	59.8	54.3	66.2
Andrijevica (north)	68.1	60.4	55.0	66.9

Table 11, Estimated Noise levels during Project’s operation: launch year

Sensitive Receivers	L_{day} (12h) [dB(A)]	$L_{evening}$ (4h) [dB(A)]	L_{night} (8h) [dB(A)]	L_{DEN} [dB(A)]
1+300 - 1+700	63.6	55.9	50.4	62.3
Bare Kraljske	71.5	63.9	58.4	70.3
Gnjili Potok	71.4	63.7	58.3	70.2
Kralje	72.4	64.7	59.2	71.1
Andrijevica (north)	73.0	65.3	59.9	71.8

Table 12, Estimated Noise levels during Project’s operation: 2057

The noise levels contours (indicators L_{day}, $L_{evening}$, L_{night} and L_{DEN}) in the project area for the launch year and year 2057 are presented at the maps of Appendix C.

The calculated noise levels results have been evaluated against the noise limit values set by the regulation presented in Chapter 2 of this report. As expected, the results of the model indicate that noise levels in the study area are quite elevated close to the road, and in some cases above the limits (60 dB(A) for L_{day} & $L_{evening}$ and 55 dB(A) for L_{night}). Consequently, the impacts may be characterized as negative, permanent, of local scale, high, probable and although they are reversible, the retrofit includes partial service down-time and the cost is significantly higher than if the mitigation measures are executed during construction.

6.2 Air pollution

6.2.1 Construction phase

During the construction phase the main source of air pollutants comes from the internal combustion engines of construction machinery, which mainly run on diesel, from concrete batching and asphalt plants. There is the possibility of impacts to local air quality due to dust and exhaust gas emissions (NOx, CO, SO2, VOCs) from some site equipment with diesel internal combustion engines (trucks, excavators, loaders etc.) and from concrete batching and asphalt plants.

The construction phase will comprise a series of different operations including land clearing, topsoil removal, material loading and hauling, stockpiling, grading, bulldozing, compaction, heavy vehicles movement on paved and unpaved roads, concrete and asphalt plants etc. Each of these operations has its own duration and potential for generation of dust and exhaust gases. It is therefore anticipated that the extent of dust emissions will vary substantially from day to day depending on the level of activity, the specific operations, and the prevailing meteorological conditions.

Exhaust gases emitted from the operation of worksite machinery are mainly carbon monoxide (CO), hydrocarbons (VOC), nitrogen oxides (NOx) and sulphur oxides (SOx). The emission factors for the construction equipment and fuels shown in Table 13 have been derived from EMEP/EEA emission inventory guidebook 2013 (1.A.4 Non-road mobile sources – machinery GB2013, Tier 1 emission factors). Total air emissions from the worksite are calculated by the fuel consumption of each equipment type multiplied by its emission factor according to Table 13.

Fuel type	CO	NO_X	PM_{10}	SO_x	CO_2
	g/kg	g/kg	g/kg	g/kg	kg/kg
Diesel	10.7	32.79	2.09	6.0	3160

Table 13 , Emission factors for off-road machinery

Based on the above emission factors and the construction machinery composition as presented in Table 7 (page 25), the total air pollutants emissions for the worst-case scenario of simultaneous operation of all equipment are shown in the Table below:

Pollutant	Emission (g/h)	(μg/m³)	Limit (μg/m³)
CO	1636,90	0.05	10
NO_X	5036,85	8.34	30
PM_{10}	320,41	0.50	40
SO_x	307,20	0.24	20
CO_2	485k	16.40	

Table 14, Emissions from worksite operation

As it can be concluded from the above calculations, air emissions from the operation of the worksite equipment are low and therefore their distribution in the surrounding area will concern negligible concentrations. Therefore, the operation of the construction machinery may have a minor effect on air quality and it is not expected that any nuisance will occur.

6.2.2 Operation phase

The impairment of air quality due to emission of pollutants from the traffic on the highway is based on the results from gas dispersion models calculated with the special computer software IMMI 2021. Calculations are made for the launch year and year 2057. The quantitative estimation is accomplished by focusing on the main pollutants from road transport, SO_2, NO_x, CO and particulates (PM_{10} + $PM_{2,5}$). The following tables demonstrate the results.

SO_2 concentration	launch year	2057
	concentration results [μg/m³]	
1+300 - 1+700	0.91	2.69
Bare Kraljske	1.65	4.84
Gnjili Potok	1.71	5.04
Kralje	3.66	10.77
Andrijevica (north)	3.12	9.19

Table 15 - Area exposure for SO_2 concentration

NO_x concentration	launch year	2057
	concentration results [μg/m³]	
1+300 - 1+700	32.98	97.01
Bare Kraljske	59.40	174.72
Gnjili Potok	61.85	181.91
Kralje	132.15	388.70
Andrijevica (north)	112.84	331.89

Table 16 - Area exposure for NO_x concentration

CO concentration	launch year	2057
	concentration results [μg/m³]	
1+300 - 1+700	113.85	334.88
Bare Kraljske	205.06	603.15
Gnjili Potok	213.49	627.96
Kralje	456.20	1341.85
Andrijevica (north)	389.52	1145.73

Table 17 - Area exposure for CO concentration

$PM_{10} + PM_{2,5}$ concentration	launch year	2057
	concentration results [μg/m³]	
1+300 - 1+700	1.74	5.12
Bare Kraljske	3.13	9.21
Gnjili Potok	3.26	9.59
Kralje	6.97	20.50
Andrijevica (north)	5.95	17.50

Table 18 - Area exposure for particle mater concentration

In all scenarios the emissions are below the acceptable limits. An increment is noted for the scenarios of the future projections due to the increase of road traffic.

7 MITIGATION MEASURES

7.1 During Construction

Estimates of gas pollution levels during the construction of the project are low and temporary, so there is no need to take action. However, regarding the nuisance from dusting during the construction period of the project, a number of measures are proposed to limit emissions and reduce dust concentrations in the following receivers.

Dust emission control is carried out by simple management methods and the level of nuisance depends significantly on the control measures at source. With regard to the production of dust due to the movement of construction vehicles and in particular on non-paved surfaces, a management code for dust limitation during construction shall include:

- humidification of traffic routes
- intervention on bare surfaces where necessary
- setting maximum speed limits on all un paved surfaces
- the exhausts of all machinery should be facing away from the ground
- the mains and the traffic corridors should be clean and moist

Also, deposits or postings of materials in / from piles should be minimized, and the deposition of materials in piles should be done from the minimum possible height. Fencing or covering unused piles reduce their corrosion by the wind. Piles of materials can be protected either by man-made fences or by placing them near dams or rows of trees, bushes, or near fences.

More general measures for the management of the site to limit dust include:

- Trucks carrying loose materials should be covered.
- Raining during the movement and deposition of sand and gravel, as well as washing the wheels of all vehicles leaving the work area, may reduce the dust emitted. Vehicles leaving the field of work must be clean.
- All machinery and equipment used in construction should be in good condition, and meet the manufacturer's specifications, in order to minimise dust emissions.
- Mixing and preparing the concrete blend is preferable to liquid rather than dry concrete. This work should be carried out in a closed or fenced area.
- Cement and inert storage silos shall be closed by installing dust filters.

With regard to powders that are expected to be created during the transport of bulk materials from quarries or excavation sites to the construction site, the following measures are proposed which are also related to driving safety:

- Special marking along the entire transport route of materials that works are being carried out
- Marking at the exits of quarries and construction sites
- Avoid overfilling bulk transport trucks

- Covering materials with cover
- Maintenance of the road transport network
- If the route is through residential areas, consider the possibility of bypassing them. If not, then seek to wetting the roads.
- Hard surfaces will be required in construction areas with regular movements of vehicles.
- Effective use of water sprays will be implemented (e.g., carry out watering for dust control at least 3 times a day: in the morning, at noon, and in the afternoon during dry weather with temperatures of over 25 °C, or in windy weather. Avoid overwatering as this may make the surrounding muddy). All water used for controlling dust will be free of odour and pollution.

Before the construction stage, the contractor will develop an Air Quality and Dust Management Plan as well as a Construction Traffic Management Plan to ensure that the Project will not introduce people into an area of poor air quality where previously there had been no relevant exposure. The Contractor will be responsible, through compliance with this EMP, for the following:

- Exhaust emissions: No furnaces, boilers or other similar plant or equipment using any fuel that may produce air pollutants will be installed without prior written consent of the Engineer. Construction equipment will be maintained to a good standard and fitted with pollution control devices regularly monitored by the Contractor and Engineer.
- Open burning of waste materials: No burning of debris or other materials will occur on the Site without permission of the Engineer.
- The Contractor will ensure and that material stockpiles will be located in sheltered areas and be covered with tarpaulins or other such suitable covering to prevent material becoming airborne.
- Earthwork operation to be suspended when the wind speed exceeds 20 km/h in areas within 500 m of any community.

In addition, borrow pits, concrete batching plant, rock crushing facility and asphalt mixing plant will be the subject of separate environmental application under the responsibility of the Contractor. The Engineer will ensure that no such facility becomes operational without the required permits.

Regarding noise nuisance and the expected mild increment of the noise levels during construction that may affect residential areas near construction sites, the anti-noise measures proposed during construction are summarised in three levels of intervention:

- Use of machinery on the site equipped with an EEC type noise certificate.
- Taking into account noise in the definition of the work programme and construction methodology for reducing noise emissions, in particular for work near residential areas.
- Application of technical solutions with the construction of sound curtains around the site and the use of mobile noise-cancelling systems at high noise emission points.

The project contractor should choose the layout of the sites and the planning of the works in order to cause the least possible harassment in the urban man-made environment of the immediate and wider area of the project. The arrangement of accumulated materials on site should be done in such a way that they act as sound curtains to reduce noise.

Finally, the design and construction of the sound curtains on site should be done carefully to provide the necessary protection. For greater efficiency, the sound curtains will be placed as close as possible to the source of the noise.

Figure 12, Indicative form of temporary noise barrier

In cases where sound insulation of the equipment will be required for a few months, sandbags will be used. Also excavation products and/or construction materials can offer soundproofing during their temporary deposition before use. For example, piles of armaments, pipes, etc., concrete bags, piles of vegetable land, etc. with appropriate installation are sufficient to reduce noise from the work area. A practical rule in the creation of similar temporary sound barriers is that the length of the barrier is at least ten times the height. If barriers with a shorter length are used, they should be directed around the source of the noise.

In order to reduce the nuisance of vehicle traffic, the following guidelines are proposed:

- Adjust the speed limit of vehicles within the temporary roads of the site to 10 km/h or less, as appropriate.
- Stabilization of dirt roads with gravel (or similar) immediately after their formation

- Vehicles shall be loaded and unloaded in such a way as to minimise noise production and, where possible, to be carried out away from noise-sensitive areas.
- The roads within the site will be constructed with as little slope as possible. Eliminating sharp gradients helps to reduce traffic noise, because vehicle engines, especially those at multiple speeds such as trucks, do not have to operate as intensively.
- Avoid unnecessary use of horns when exiting/entering nearby roads, unnecessary revving of engines and switch off equipment when not required.
- Use rubber linings in, for example, chutes and dumpers to reduce impact noise and minimise drop height of materials
- Start-up plant and vehicles sequentially rather than all together.

All equipment must be maintained at high operational levels and placed where possible in positions that maximise the effect of any noise barriers, such as temporary construction site buildings or inactive equipment. Machinery and operational equipment (including excavators, crushers, loading/unloading, generators, etc.) will be placed as far away from noise-sensitive areas as possible and physical barriers such as warehouses, piles or buildings shall be used to reduce noise wherever possible.

At the same time, the planning of noise production activities will be designed to avoid the effects, e.g. avoiding the simultaneous use/operation of noisy equipment, use of piles of excavation materials as a noise barrier for sensitive acoustic receivers during excavation, maintenance of temporary structures that act as a noise barrier (e.g. construction site offices, warehouses, etc.) until the last phase of the project, etc.

Plant should always be used in accordance with manufacturers' instructions. Care should be taken to site equipment away from noise-sensitive areas. Where possible, loading and unloading should also be carried out away from such areas. Special care is necessary when work has to be carried out at night but it might be possible to carry out quiet activities during that time.

Machines such as cranes that might be in intermittent use should be shut down between work periods or should be throttled down to a minimum. Machines should not be left running unnecessarily, as this can be noisy and wastes energy.

Plant from which the noise generated is known to be particularly directional should, wherever practicable, be orientated so that the noise is directed away from noise-sensitive areas. Acoustic covers to engines should be kept closed when the engines are in use and idling. If compressors are used, they should have effective acoustic enclosures and be designed to operate when their access panels are closed.

The choice of equipment will take into account the noise level. Instead of equipment with diesel or petrol engines and be mandatory in compliance with European Directive 2000/14/EC regarding noise emission of work machinery. In case there will be pile-driving works in bridge foundations, impact noise when piling is being driven can be reduced by introducing a non-metallic dolly between the hammer and the driving helmet or by enclosing the driving system in an acoustic shroud, or an enclosure that encloses the hammer and the complete length of pile being driven.

In the event of any complaint, the source of the excessive noise will be identified and measures such as the location of the equipment and the opening hours will be assessed. For this reason, sensitive audio receivers should be detected before work begins.

It goes without saying that all installations, machinery and other vehicles will be regularly checked that they operate efficiently and in accordance with manufacturers' specifications by trained and qualified operators. In addition to increased safety, this process affects both the proper maintenance and the quiet operation of the machinery as possible.

It is also very important to avoid complaints to communicate properly with those affected, before carrying out any inevitable noisy activities near noise-sensitive receivers, they should be informed in advance or of the work to be carried out, and of the expected duration.

The working hours should be planned and account should be taken of the effects of noise upon residents in areas surrounding site operations and the likely consequence of any lengthening of work periods. Where reasonably practicable, quiet working methods should be employed, including use of the most suitable plant, reasonable hours of working for noisy operations, and economy and speed of operations. Haulage vehicles should not arrive at or leave the site between 19.00 h and 07.00 h. On tunnel sites, for example, it is common practice to provide night-time storage areas for soil and debris.

In any case, the noise emitted during the construction stage will not cause permanent nuisance conditions. The conditions that will be created will be short-term and reversible.

7.2 During Operation

Within the framework of the project's ESIA study, a preliminary estimation implementing selected noise abatement measures was conducted. Calculations were made with the use of software IMMI Premium 2023, using the same noise simulation model and input data and assumptions described in previous chapter. It must be noted that optimization and detailed design of noise barriers should be the outcome of a detailed acoustic study.

For this preliminary calculation of noise reduction, national and international guidelines were taken into account. Based on the results of the model, for the launch year, levels up to 14 dB above the limits have been spotted in four areas along the alignment: Bare Kraljske, Gnjili Potok, Kralje and Andrijevica (north) (Table 19 - Table 20). Column 'Bar-Boljare highway' displays the noise level that is emitted from the proposed Project WITHOUT any noise protection measures, column 'Background Noise' the noise level that is emitted from all other environmental noise sources based on the noise measurement survey (mainly the remaining roads of the area under study) and column 'Overall' displays the cumulative noise.

Sensitive Receivers	Bar-Boljare highway [dB(A)]	Background noise [dB(A)]	Cumulative Noise [dB(A)]	Limit [dB(A)]
Bare Kraljske	66.7	55.0	67.0	60.0
Gnjili Potok	66.5	57.5	67.0	60.0
Kralje	67.5	60.0	68.2	60.0
Andrijevica (north)	68.1	61.0	68.9	60.0

Table 19, Areas requiring noise protection – day results

Sensitive Receivers	Bar-Boljare highway [dB(A)]	Background noise [dB(A)]	Cumulative Noise [dB(A)]	Limit [dB(A)]
Bare Kraljske	53.6	53.0	56.3	55.0
Gnjili Potok	52.3	48.5	54.6	55.0
Kralje	53.7	44.0	54.7	55.0
Andrijevica (north)	52.3	53.5	57.3	55.0

Table 20, Areas requiring noise protection – night results

For these areas the introduction of noise barriers at the roadside was investigated. The height of the barriers was gradually increased in order to achieve the target values in both L_{day} and L_{night} indices, up to a height of 4.5 meters, since above 4.5m structural limitations render the noise barrier installation incompetent. Where there are residential areas on both sides of the road, absorptive type noise barriers are assumed, to avoid causing reflection of noise to receivers on the opposite side.

The noise limits are 60 dB(A) for daytime and 55 dB(A) for nighttime. However, when the cumulative noise is higher than the above values, the noise emissions are still acceptable if the impact to the background noise from noise emissions of the new project is equal or less than 3 dB.

The resulting noise levels after the proposed mitigation measures are applied, are presented in Table 21 and Table 22. From the results, it can be seen that the noise levels from the new highway can be restricted in all control points to project's target values set by national regulation.

Sensitive Receivers	Bar-Boljare highway [dB(A)] (1)	Background noise [dB(A)] (2)	Cumulative Noise [dB(A)] (3)	Impact on background noise [dB] {(3) – (2)}
Bare Kraljske	59.8	55.0	61.1	6.1
Gnjili Potok	57.3	57.5	60.4	2.9
Kralje	59.7	60.0	62.9	2.9
Andrijevica (north)	60.4	61.0	63.7	2.7

Table 21, Noise modelling barrier optimisation results – day

Sensitive Receivers	Bar-Boljare highway [dB(A)] (1)	Background noise [dB(A)] (2)	Cumulative Noise [dB(A)] (3)	Impact on background noise [dB] {(3) – (2)}
Bare Kraljske	46.7	53.0	53.9	0.9
Gnjili Potok	43.1	48.5	49.6	1.1
Kralje	45.9	44.0	48.1	4.1
Andrijevica (north)	44.6	53.5	54.0	0.5

Table 22, Noise modelling barrier optimisation results – night

Therefore, it is believed that no extra noise mitigation measures, such as porous asphalt, speed-limit restrictions, etc. will be needed in order for the highway to reside within the noise limits and no general public annoyance is expected when the project will start to operate.

The proposed mitigation measures consist of the following noise barriers:

Location	NB length (m)	NB area (m^2)	NB avg height (m)
7+000 - 8+100/ left side	1 100	3 300	3.0
14+050 - 14+800/ left side	750	2 250	3.0
14+930 - 15+650/ left side	720	2 160	3.0
16+000 - 16+600/ left side	600	1 800	3.0
17+300 - 17+500/ left side	200	600	3.0
18+500 - 19+250/ left side	750	2 250	3.0
19+450 - 19+750/ left side	300	900	3.0
20+450 – 22+500/ left side	2 050	6 150	3.0
20+200 - 20+600/ right side	400	1 200	3.0
20+950 - 22+100/ right side	1 150	3 450	3.0
21+300 - 22+000/ right side	700	2 100	3.0

Table 23, Noise barrier length and area per segment

Appendix A – Baseline Measurements

Appendix B – Contour Maps