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ROAD TRAFFIC NOISE MODELLING NEAR HIGHWAY STREET USING THE CNOSSOS-EU METHOD

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ABSTRACT

Environmental noise is a damaging environmental factor in the cities. Acoustic barriers are commonly used to mitigate highway traffic noise. Nevertheless, they adversely affect the visual aesthetics of the metropolitan environment. We investigated how a certain type of noise barrier application decreased the nearby traffic noise at a designated location. The CNOSSOS-EU calculation method was used to evaluate the road traffic noise. The noise mapping software IMMI facilitated the investigation. The results showed that the noise barrier effectively reduces noise levels at the receptor side where the population exposure was computed. Our findings indicate that, in the absence of a noise barrier, an additional 114 individuals were exposed to noise levels exceeding 50–55 dB(A) during the day (L_{day}), while an additional 175 individuals experienced noise levels exceeding 45–50 dB(A) at night (L_{night}), compared to the scenario where the barrier was in place. This impacts both future population exposure estimates and the execution of urban noise management plans.

Keywords: *noise pollution, road traffic noise, CNOSSOS-EU method.*

1 INTRODUCTION

The term "noise" refers to an unwanted or unpleasant sound [1]. Urban noise constitutes a global issue that has been thoroughly researched internationally [2]. Currently, noise pollution in cities is seen as a public health issue [3]. The World Health Organisation [4] defines environmental noise as noise that is released from all sources and encompasses all types of noise, including that from roads, trains, aeroplanes, factories, public works projects, and even residential areas, except for noise at the industrial workplace. The adverse health effects are usually non-auditory, as the noise levels often do not exceed 85 dB for extended durations. In terms of magnitude, road traffic, air traffic, railway, and industrial noise constitute the four principal causes of environmental noise disturbance in metropolitan settings [5]. Road traffic noise has become the most extensively studied source because of its widespread occurrence and significant level of disruption. In this regard, it is estimated that almost 50% of the European Union's population is subjected to road traffic noise levels that are deemed detrimental to their health and general well-being [6]. The population affected by road traffic noise greatly exceeds that affected by rail, aeroplane, and industrial noise. This is due to the extensive road network, which significantly surpasses all other sources of noise. The existing mitigations seem inadequate in achieving the objectives established by the zero-pollution strategy, and the effectiveness of their implementation is insufficient. Several studies have compared and analysed effective measures, all of which agree that implementing mitigation at the source produces the most favourable outcomes [7]. An effective mitigation should be proven against other potential alternatives and assessed based on cost-benefit analysis. Different approaches can be adopted for dealing with issues regarding road traffic noise, focusing on any of the following phases: source generation, environmental propagation, and reception [8]. At the initial stage, the concept is to interpose physical obstacles, such as acoustic barriers, between the sound source and the receivers. Acoustic barriers are a conventional method employed in noise reduction; by being positioned along the path of sound propagation, they have emerged as a prevalent

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approach to address the issue [9]. Research on the effectiveness of various configurations of acoustic barriers provides insight into their ability to reduce sound intensity [10]. An important factor in noise attenuation is the barrier edge's height and shape, which have been thoroughly studied. Indeed, the quantity of barriers and their distance from each other directly impact the performance of the acoustic barrier. For instance, the implementation of parallel barriers is often used to reduce noise in locations close to a road; nonetheless, their efficacy may be inferior when compared to a singular barrier [11]. The opposite acoustic barrier reduces the nearby acoustic barrier's attenuation by reflecting multiple waves [10], [11]. The CNOSSOS-EU calculating technique was approved by the European Commission in 2009 in compliance with Directive 2002/49/EC's article 6.2. The legal foundation for the implementation of future rounds of strategic noise mapping was established in 2015 with the publication of Commission Directive (EU) 2015/996, which mandates that all EU MS switch from their previous nationally based methods to the CNOSSOS-EU standardised method for the 2022 round of strategic noise mapping. Europe is the inaugural region for creating an urban noise mapping and developing the technical underpinnings for such maps [12]. The European Noise Directive advises using computational methods over in-situ measurements for the construction of noise maps whenever feasible [13],[14]. The traffic noise computation models are utilised to compute the noise map [15], which is then conjoined with GIS, and the evaluation of noise pollution relies on L_{den} and L_{night}. This study investigates the impact of road noise barriers on sound levels near a major roadway and identifies the noise levels that reach buildings and the population in the Kismacs district of Debrecen (Hungary). The evaluation focuses on a recently built noise barrier designed to reduce road traffic noise in this district, as a significant increase in traffic is forecasted for this road section due to industrial developments.

2 MATERIALS AND METHODS

2.1 Average Daily Traffic

The source of average daily traffic (ADT) data is Hungarian Public Roads, which is used to estimate the traffic volume for each road section. The road type, the road's county-specific location, the number of the studied section, and the border sections of the examined section are used to assign a specific code number to the cross-sectional traffic data so that the ADT data can be accessed. To create the comprehensive traffic data needed for the noise maps, the raw traffic count data from Hungarian Public Roads was categorised and systematised into acoustic groups. For both road directions, the hourly vehicle traffic data for each lane was added up and then combined for the specified time of day (day and night). The data analysis results were converted into information that the noise mapping software could process.

Table 1. Average hourly distribution statistics by acoustic vehicle category (unit: vehicle/hour) for the section (D: day, N: night)

Time	Cat. 1	Cat. 2	Cat. 3	Cat. 4a	Cat. 4b
2021 D	770.58	12.70	27.27	1.55	1.55
2021 N	148.71	2.73	6.47	0.34	0.34

2.2 IMMI noise mapping program

This program, which originated in Germany, provides numerous opportunities in various domains of noise mapping. The CNOSSOS-EU method was used for the calculations of noise levels within the software, depending on the provided traffic data and other parameters. For each category of acoustic vehicles, IMMI software models noise sources as road sections with a specific average speed and flow rate per hour. The average speed is subsequently computed, and the IMMI software is employed to determine the sound power level for each road section and time interval. In this work, the noise levels were computed for a grid size of 20 m x 20 m in the examined area. Performing individual model runs for every measurement point using "hourly distribution data as input" was shown to be the most appropriate approach for processing the data analysis results. The determination of category-specific average speeds was carried out considering the characteristics of different road sections and traffic lights. A precise calibration of certain parameters is necessary to calculate the transmission of sound from the source to the receivers. The meteorological conditions used in the model closely matched the characteristics observed during the measurements. The road and building network are sourced from OpenStreetMap, while the road gradient data is collected from the STRM digital elevation model [16]. In the model, the traffic flow for the research area was selected as continuous fluid flow, while the reference surface was chosen as the characteristic of the road surface, the building's height: ground level—3 metres; the roof's height—2 metres.

The base map designates road No. 33 as a line source. The source lines were positioned in the middle of each lane of the road while utilising "CNOSSOS-EU" calculating methods. The buildings near the measurement point were individually modelled based on the Debrecen urban development plan (satellite images allow for the input of additional details, like the height of the buildings).

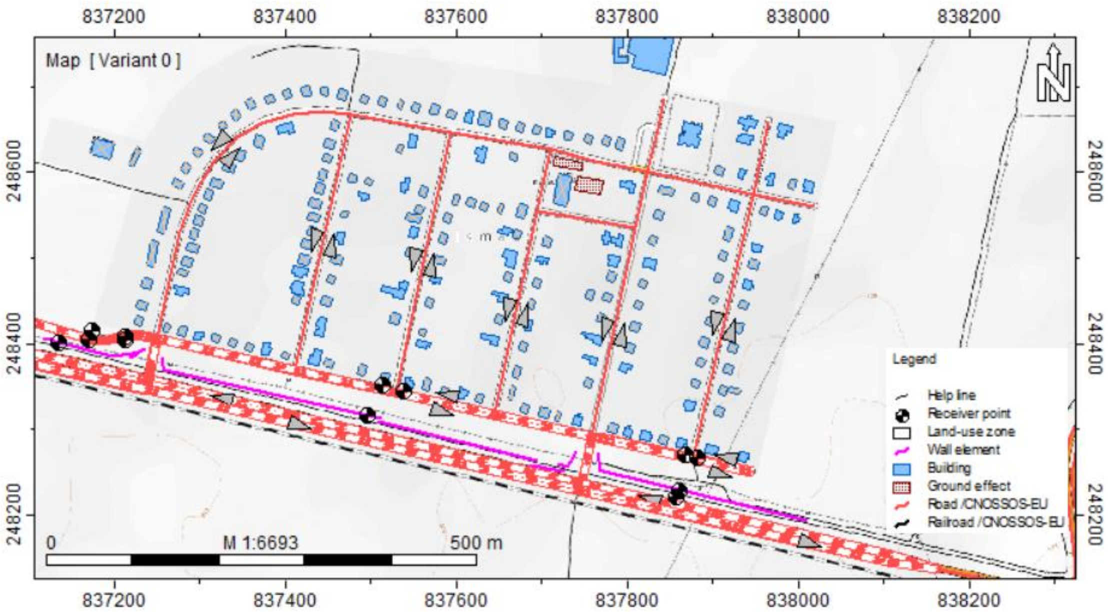


Fig. 1. Base map of the study area under investigation.

3 RESULTS AND DISCUSSION

3.1 Population exposure estimation

During the noise mapping technique, average hourly values for both day and night across the survey period were used as a percentage for each hour of the ADT data. The IMMI noise mapping tool is applicable for several parameters, allowing for the creation of thematic maps. Each of these thematic maps illustrates the population residing in certain residential structures, as ascertained by the IMMI program by examining the parameters of the buildings. This map can be used to analyse how many people are directly impacted by the noise burden that the specified road segment causes. The software can also perform intricate calculations on the involvement topic, allowing it to ascertain the number of people who are impacted by noise exposure ranges at a specific distance from the source. The program analysis determines that the noise pollution from the investigated area affects approximately 427 residents in the modelled area, which is immediately adjacent to the analysed section (Fig. 2).

For the day case (Fig. 3), most residents fall within the 45-to-50 decibel range, with approximately 216 people belonging to this category. The highest load range is 55–60 dB, affecting 14 individuals. For the night case (Fig. 5), most of the residents fall within the 35-to-40 decibel range, with approximately 183 people belonging to this category. The highest load range, which affects two individuals, is between 50 and 55 dB. It is important to observe that more people belong to smaller load categories due to the presence of condominiums that can house more residents at a distance from the roadway compared to those situated near it.

Fig. 2. Number of people living in the near vicinity of the investigated area.

3.2 The efficiency of the acoustic barrier

The efficiency of the existing barrier from the receptor side was evaluated in the investigated area in Kismacs City. The IMMI software was used to calculate the difference that would occur if the current acoustic barrier did not exist. For the noise mapping process, the average hourly distribution results from the ADT (from Hungarian Public Roads) data were used. The comparison was conducted between the simulation results at the receptor side of the barrier, based on the traffic ADT data in scenario one, and the results after the removal of the existing barrier in scenario two. The substantial associations between noise levels and the traffic volume are anticipated, given that road traffic was the primary noise source in the study area.

Fig. 3 details the results of the population exposure assessment for the Kismacs district of Debrecen using L_{day} values and the CNOSSOS-EU model. For the day case, the result indicates that the no-barrier case, as opposed to the barrier case, would expose an additional 114 people to decibel levels of road traffic that are >50-55 dB(A) L_{day}, since most residents fall into this category. For the noise level >60-65, the no-barrier case would expose an additional 62 people to this highest load range level of noise. This conclusion implies that the noise barrier could significantly decrease the population's exposure to noise levels from road traffic in the investigated area. Figure 4 provides a graphic representation of these discrepancies.

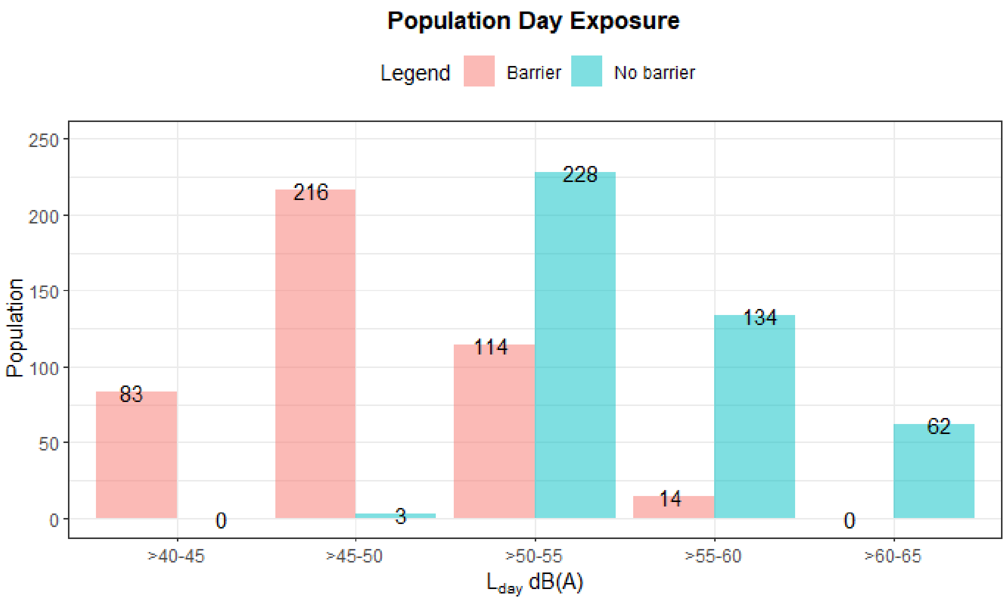
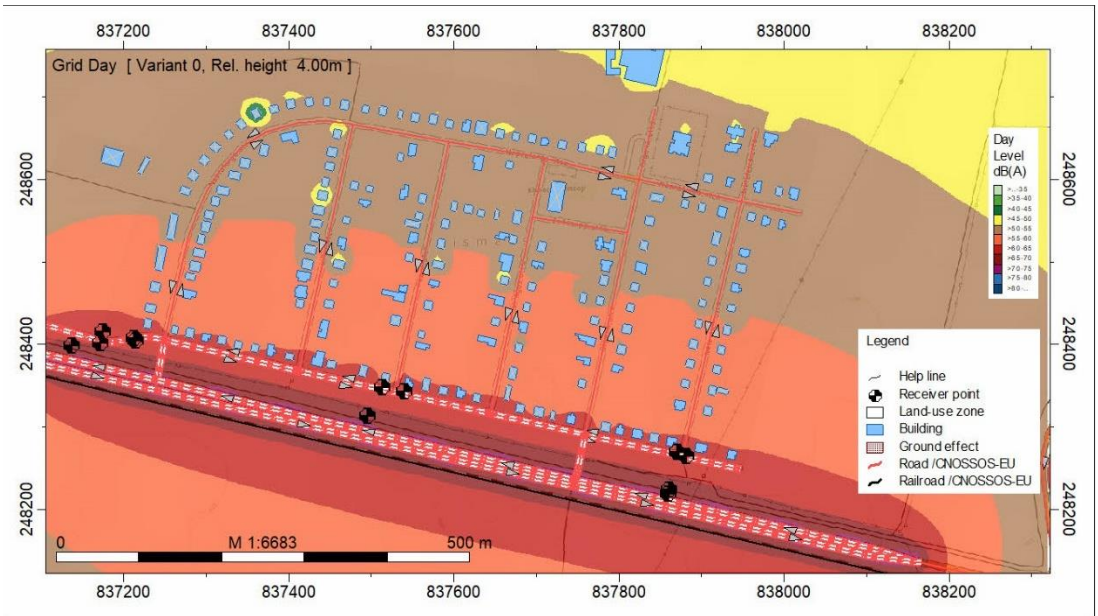


Fig. 3. Population exposure (L_{day}) in the Kismacs district of Debrecen —no barrier/barrier.



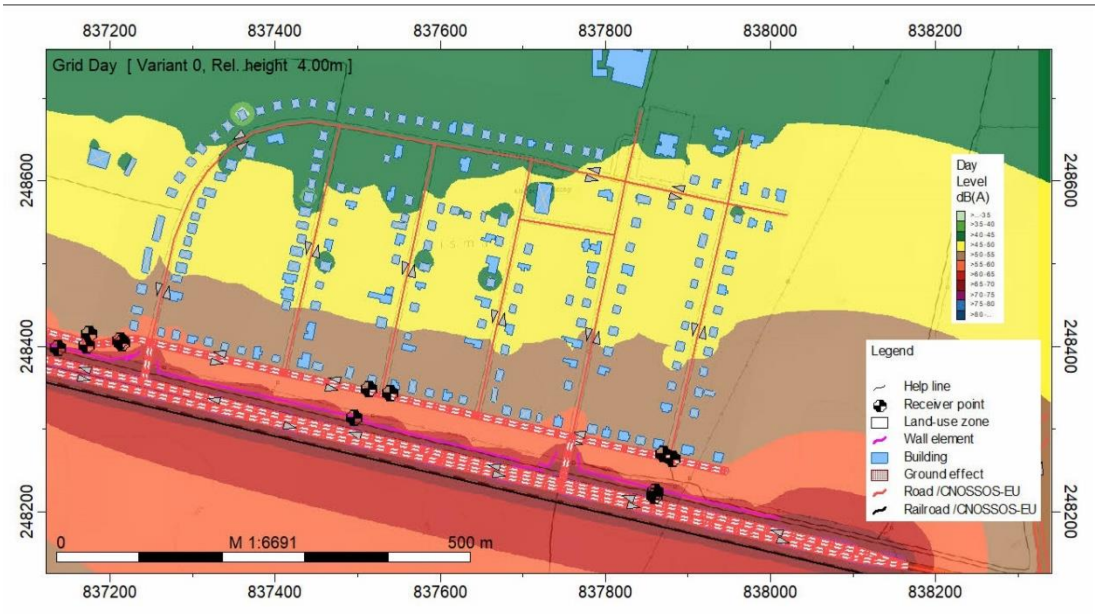


Fig. 4. A graphic representation of the daytime noise variation at the building façade in the Kismacs district of Debrecen —no barrier/barrier.

Fig. 5 details the results of the population exposure assessment for the Kismacs district of Debrecen using L_{night} values and the CNOSSOS-EU model. The result indicates that the no-barrier case, as opposed to the barrier case, would expose an additional 175 people to decibel levels of road traffic that are >45-50 dB(A) $L_{night,}$ since most residents fall into this category. For the noise level >50–55, the no-barrier case would expose an additional 119 people to this highest load range level of noise. Like the day (L_{day}) measurement, the barrier modelling case also successfully reduces the road traffic noise levels that the population experiences in the investigated area. Figure 6 provides a graphic representation of these discrepancies.

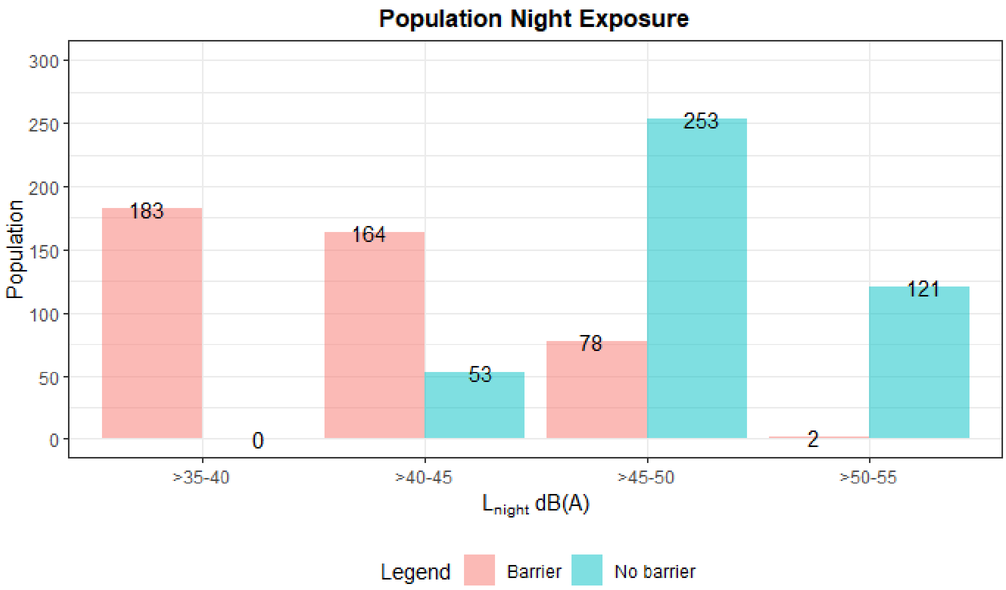
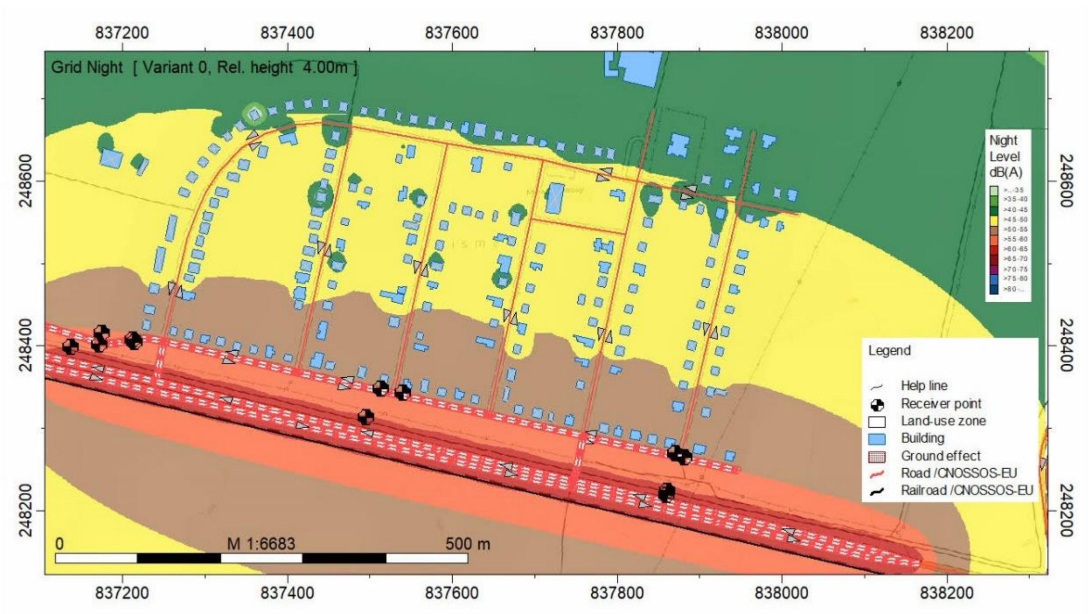


Fig. 5. Population exposure (L_{night}) in the Kismacs district of Debrecen —no barrier/barrier.



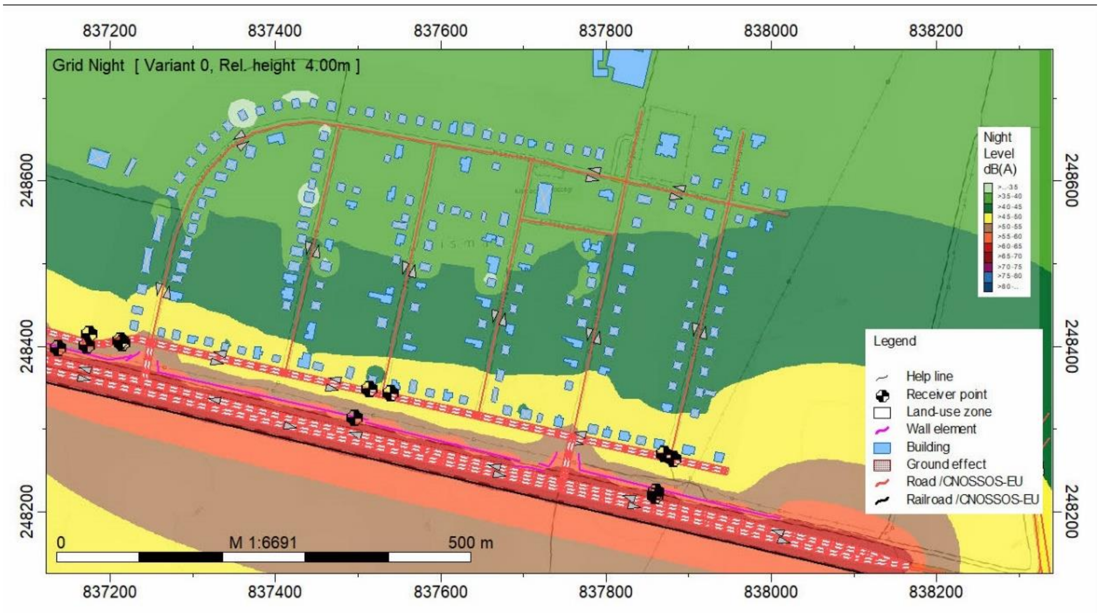


Fig. 6. A graphic representation of the nighttime noise variation at the building façade in the Kismacs district of Debrecen —no barrier/barrier.

4 CONCLUSIONS

The implementation of noise barriers as part of strategies to mitigate environmental noise is a prevalent method of controlling road noise. This study examined the concurrent impact of a particular noise barrier installation on proximal road noise at a designated location. The calculation of population exposure for the investigated area was estimated using the IMMI software tool in accordance with CNOSSOS-EU methodologies. Most populations expected to be exposed to road traffic noise levels exceeding 45-50 dB(A) L_{day} (approximately 216 persons) and 35-40 dB(A) L_{night} (approximately 183 persons) belong to this category. A comparison was performed between the simulation results at the noise barrier's receptor side, derived from the average hourly traffic data in scenario one, and the results after the removal of the existing barrier at each measurement point in scenario two. The software's elimination of the existing barrier revealed that an additional 114 people were exposed to noise levels >50-55 dB(A) $L_{day,}$ and an additional 175 people were exposed to noise levels >45-50 dB(A) L_{night} when no barrier was used, compared to the barrier case that was used. This study revealed that noise barriers can effectively diminish noise levels at the receptor sides of the barriers. With appropriate design, noise barriers can serve as effective tools for reducing noise exposure, as this study has also demonstrated. The conducting modelling could also be suitable for predicting future changes through appropriate traffic forecasting.

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