

Review

Traffic Noise and Inhabitant Health—A Comparison of Road and Rail Noise

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Abstract: The negative effect of traffic noise on human health is indisputable. The article illustrates the magnitude of this problem in selected European capitals using data made available by the European Environment Agency, collected as a part of strategic noise mapping under Directive 2002/49/EC. The purpose of the described studies is to determine the number of people suffering from noise-induced health problems, and to compare the effect of the road noise on human health with the effect of noise from rail vehicles. Studies concern noise annoyance, induced sleep disturbance, and Disability-Adjusted Life Years, or DALY index. Analyses clearly show that environmental pollution from road noise often exceeds environmental pollution from railway noise by a factor of 10. In addition, studies show that in many cities, more than half of the population is exposed to road noise exceeding the acceptable values. The worst of all selected agglomerations with regard to people exposed to road and rail noise is Paris, the capital of France. It should be noted, however, that it has the highest population density of all the analyzed cities and a very well developed transport network. Further studies are needed to characterize the effect of traffic noise on inhabitant health more accurately, using specific indicators allowing to do so.



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Keywords: road noise; railway noise; environmental noise pollution; sleep disturbance; health effects of noise

1. Introduction

Noise is one of the most adverse effects associated with moving means of transport. The amount of noise generated is affected by many factors related to the vehicle, the road, and the environment. Among the different types of noise, road noise is one of the most severe for people and has a significant effect on their health [1,2]. Together with other types of noise, it constitutes the acoustic climate. The assessment of acoustic climate involve indicators that mostly concern the effect on human health.

The assessments of road noise effect on people so far have largely consisted only of references to noise limits set in Poland by the Minister of Environment, in agreement with the Minister of Health, [3,4] without any additional assessment of the noise level values obtained. Such an approach prevents completely assessing the actual state of the threat and is merely a technical action indicating the area and magnitude of the threats.

The studies carried out for many years [5–7], determining the effects of noise on people, have led to the conclusion that, in addition to relating the values of equivalent sound level A (L_{Aeq}) and the long-term average sound level A for the whole day (L_{DWN}) and night period (L_N) to limit values, it is necessary to introduce methods which would enable the assessment of these values in terms of human health. The current END Directive [8] allows the use of dose-effect relations for the assessment of harmful effects. At the same time, beyond specifying the indicators that can be used in the assessment, there are no specific rules and formulas provided, which is foreseen in the amendment to the END Directive [9].

Noise annoyance is the term used in this case to express negative feelings such as anxiety, dissatisfaction, anger, irritation, and annoyance. Adverse effects of noise occur when interactions result in disturbing a person's intended activities. The sound level of an acoustic stimulus, its psychoacoustic characteristics, time of onset, time course, frequency range, and information content usually modify the response [10]. The rest associated with sleep is extremely important, as unconscious activation of the autonomic nervous system occurs during sleep. Having considered the foregoing, practically all regulations and recommendations involve reducing the sound level during the night-time in comparison to the daytime.

In the literature, there are publications concerning analysis of indicators describing annoyance only for road noise, without taking into account railway noise [11,12]. Many of them clearly indicate the importance of considering such indicators as a noise annoyance or sleep disturbance. Already, at the beginning of the 21st century, the authors of the above indicators emphasized that the lack of use of these indicators may lead to an underestimation of the negative impacts of noise, which may influence the prioritization of noise protection [13]. This approach has been used in subsequent years to carry out reports related to the planning and developing of effective and efficient noise mitigation measures [14].

The aim of this paper is the assessment of railway noise pollution and its comparison with road noise for selected European capital cities, as well as the use of various currently used indicators. The analyses are focused on the negative influence of noise on human health. The use of these indicators enables an assessment to be made in a much more comprehensive manner than just referring to noise limit values.

2. Methods

One of the important results associated with the effect of noise on people is annoyance (irritation), an emotional state in humans. It is often coupled with feelings of discomfort, anger, depression, and helplessness. This chapter includes commonly used formulas regarding the negative impact of noise on human health, which are recommended by WHO [6,7]. This allows a comparison of the state of noise pollution in different countries and cities—including road, rail and aircraft noise. Annoyance is one of the more significant non-auditory effects of noise. In order to assess annoyance (effect), WHO [10] recommends using L_{DWN} (dose), which is the primary indicator used in acoustic mapping to assess the amount of noise over an entire 24 h period throughout the year in a defined area. It can be calculated using the following formula [8]:

$$L_{DWN} = 10 \lg \left[\frac{12}{24} 10^{0,1L_D} + \frac{4}{24} 10^{0,1(L_W+5)} + \frac{8}{24} 10^{0,1(L_N+10)} \right] \quad (1)$$

where:

L_{DWN} —means the average long-term sound level A expressed in decibels (dB), determined for all the days of the year, taking into account the daytime (defined as the period from 7:00 a.m. to 7:00 p.m.), the evening (defined as the period from 7:00 p.m. to 11:00 p.m.) and the night-time (defined as the period from 11:00 p.m. to 7:00 a.m.),

L_D —means the long-term average sound level A expressed in decibels (dB), determined during all the daytime periods of a year,

L_W —means the long-term average sound level A expressed in decibels (dB), determined during all the evening periods of a year,

L_N —means the long-term average sound level A expressed in decibels (dB), determined during all the night periods of a year.

It is possible to determine the percentage of people affected by noise annoyance using noise annoyance (pollution) indicators (%D, %WD) [12]. The calculation formulas vary depending on the type of traffic noise being analyzed.

When discussing road noise, the percentage of people affected by irritating noise can be calculated from the formula [10,15]:

$$\%D = 1.795 \cdot 10^{-4}(L_{DWN} - 37)^3 + 2.110 \cdot 10^{-2}(L_{DWN} - 37)^2 + 0.5353(L_{DWN} - 37) [\%] \quad (2)$$

while the percentage of people affected by high noise annoyance from the formula:

$$\%WD = 9.868 \cdot 10^{-4}(L_{DWN} - 42)^3 - 1.436 \cdot 10^{-2}(L_{DWN} - 42)^2 + 0.5118(L_{DWN} - 42) [\%] \quad (3)$$

Similarly, in the case of railway noise, these formulas take the form [10,15]:

$$\%D = 4.538 \cdot 10^{-4}(L_{DWN} - 37)^3 + 9.482 \cdot 10^{-2}(L_{DWN} - 37)^2 + 0.2129(L_{DWN} - 37) [\%] \quad (4)$$

$$\%WD = 7.239 \cdot 10^{-4}(L_{DWN} - 42)^3 - 7.851 \cdot 10^{-2}(L_{DWN} - 42)^2 + 0.1695(L_{DWN} - 42) [\%] \quad (5)$$

The effect on inhabitants' sleep is another one of the most adverse noise effects [16]. The consequences of sleep deprivation or sleep disturbances can be discomforts such as malaise, irritability, as well as problems with concentration [17–19]. The sleep disturbance index measures the percentage of people with sleep disturbance and depends on the L_N index. Analogously to the previously discussed indicator, this one also depends on the traffic noise under consideration.

Based on [16], the percentage of people affected by severe sleep disturbance induced by traffic noise is described by the formula:

$$\%WZS = 20.8 - 1.05L_N + 0.01486L_N^2 [\%] \quad (6)$$

Moreover, the percentage of people affected by severe sleep disturbance induced by railway noise is shown by the formula:

$$\%WZS = 11.3 - 0.55L_N + 0.00759L_N^2 [\%] \quad (7)$$

WHO reports [7,10,13] also introduced indicators that are more complex and include more health variables. The assessment includes disease burden, which has a direct effect on people's performance status and life expectancy. The indicator that was adopted in the assessment is DALY (Disability Adjusted Live Year) [20,21]. In case of a single noise source x and a health effect y (annoyance, sleep disturbance, cardiovascular disease manifested as myocardial infarction), one should use the following formula to calculate DALY [9], [15]:

$$DALY_x = \sum_y (PAF_{x,y} \cdot DW_y + PAF_{x,y} \cdot YLL_y) \cdot P \text{ [years]} \quad (8)$$

where:

P —population in the analyzed area

$PAF_{x,y}$ —population attributable fraction, percentage of population at risk from noise source x and health effect y

DW_y —disability weight resulting from the health effect y

YLL_y —years of life lost; fixed values depending on health effect

$DALY = 1$ is understood as one lost year of healthy life

The following formula should be used to calculate the percentage of the population at risk for a given type of noise source:

$$PAF_{x,y} = \frac{\sum_{\text{exposure band } i} [p_i \cdot (RR_{i,x,y} - 1)]}{\sum_{\text{exposure band } i} [p_i \cdot (RR_{i,x,y} - 1)] + 1} \quad (9)$$

where:

p_i —the percentage of the total number of P persons in the analyzed area who are exposed to the noise exposure range i

RR_i —relative risk associated with a given noise source x and health effect y for a given range of noise exposure i

However, these indicators are very rarely used in practice in Poland to assess human exposure to traffic noise. The most common indicators used in practice are mainly those related to noise limit values, in accordance with the regulations [3].

Following the introduction of the END Directive [8], strategic noise mapping is required in all Member States once every five years. The areas which are obligatorily covered by the program include:

- Agglomerations with more than 100,000 inhabitants;
- Roads loaded with traffic of over 3 million vehicles per year;
- Main railway lines loaded with traffic of over 30,000 trains per year;
- Major airports within the country.

This results in measurements taken to verify the computational model. The analyzed data presented in the paper are from the noise level measurements taken in 2017. Unfortunately, the data made available by the European Environment Agency [22] are not complete for all cities. However, many countries collect comprehensive data that enable comparison of the state of road and rail noise pollution in individual cities in the European Union. The main research problems include the formation of the size of indicators determining the noise pollution, as well as determining their importance in the subsequent assessment of this environmental hazard. In addition, the research problem is the search for the most polluted European cities and the scale of the obtained values of indicators, which relate directly to the risks associated with the health of residents. Twelve European capitals were selected for further analysis and are listed along with demographic data in Table 1.

Table 1. Selected European agglomerations in which the acoustic maps were made.

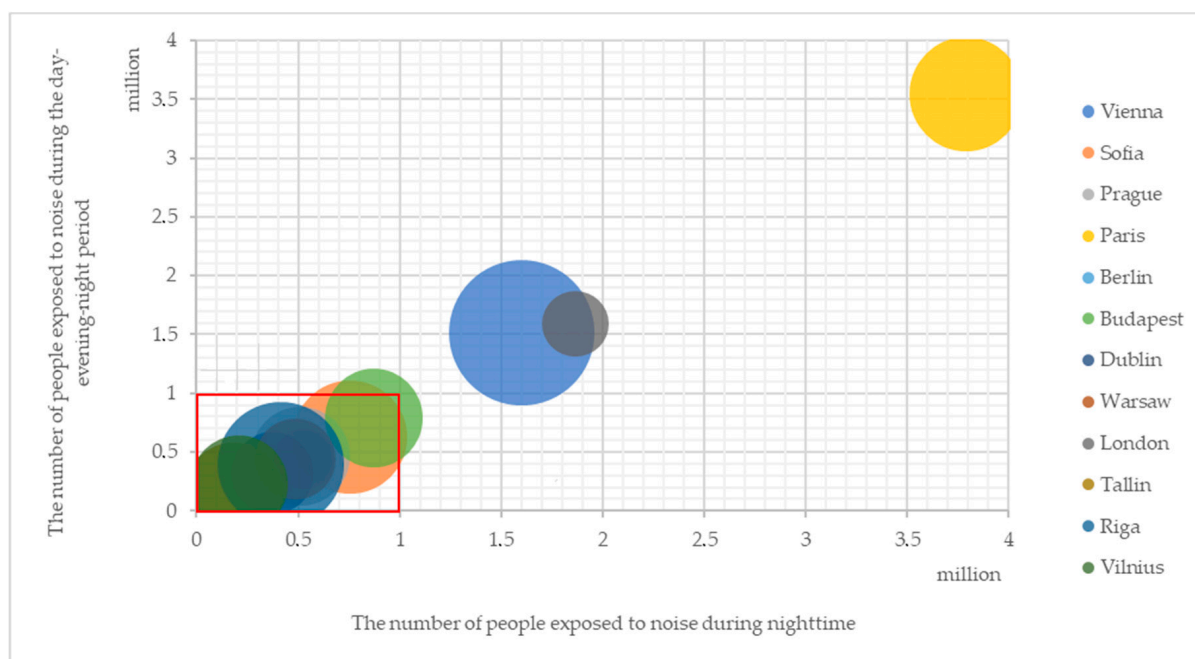
Country	City	Number of Inhabitants	Area [km ²]	Population Density [Persons/km ²]
Austria	Vienna	1,862,251	459	4058
Bulgaria	Sofia	1,332,817	492	2709
Czech Republic	Prague	1,234,005	772	1599
France	Paris	7,068,800	814	8682
Germany	Berlin	3,460,725	892	3880
Hungary	Budapest	2,158,871	1130	1911
Ireland	Dublin	1,308,900	936	1399
Poland	Warsaw	1,753,977	517	3392
United Kingdom	London	9,878,000	1623	6085
Estonia	Tallinn	435,972	159	2739
Latvia	Riga	641,007	304	2109
Lithuania	Vilnius	574,339	401	1433

The studies presented below were carried out using the formulas given in this chapter, on the basis of which a number of factors were analyzed. Firstly, the number of people exposed to road and rail noise exceeding the limit values ($L_{DWN} > 60$ dB and $L_N > 50$ dB, values recommended by the European Environment Agency) was determined based on data obtained from the realization of acoustic maps available from the European Environment Agency [22]. On this basis, and by using Formulas (2)–(7), it was possible to calculate the number of residents exposed to high annoyance and high sleep disturbance caused by road and rail noise and compare them. Furthermore, based on the obtained results, it became possible to present the percentage distribution of the number of residents exposed to noise-related annoyance depending on its level. An additional index, whose values were calculated on the basis of Formulas (8) and (9), is the DALY index, which determines the potential number of productive years of life lost due to loss of health caused by traffic noise. The analyses allowed for a comprehensive assessment of the state of noise pollution and its influence on the health of residents in selected European capitals, as well as for the formulation of conclusions.

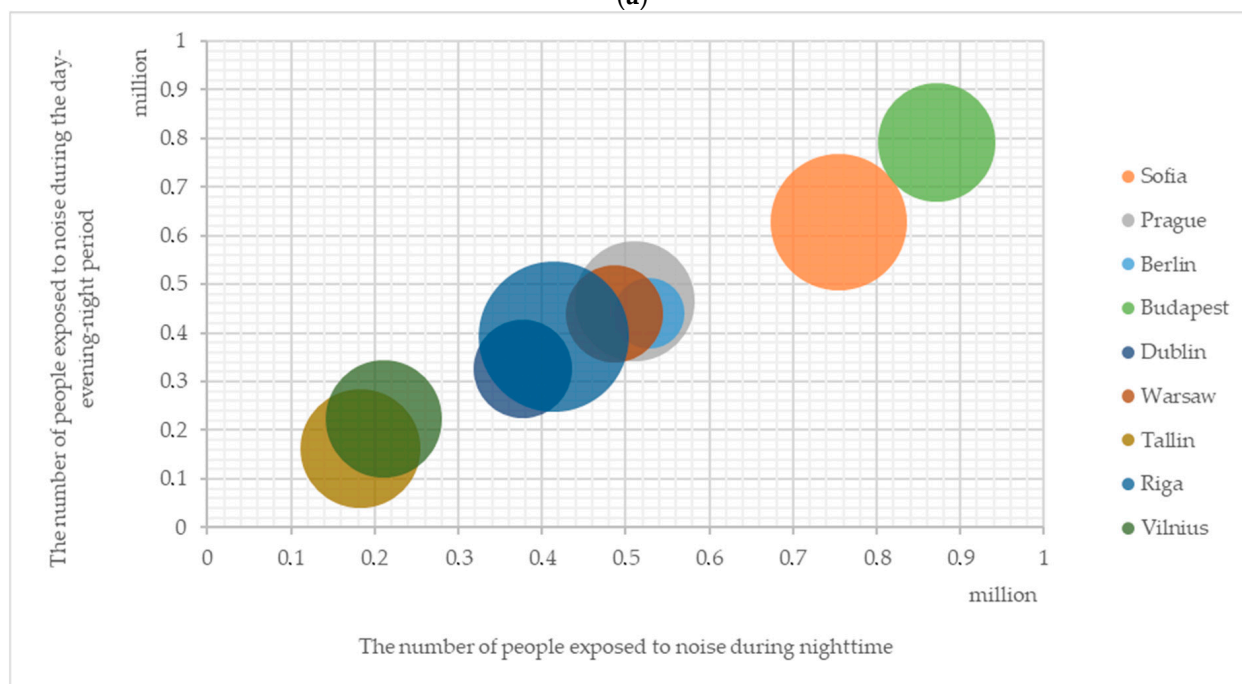
3. Results

3.1. Road Noise

Road noise is currently one of the biggest environmental issues, and Figure 1a shows the scale of the problem. This graph shows the number of people exposed to road noise ($L_{DWN} > 60$ dB and $L_N > 50$ dB) in selected European capital cities. The size of a given circle depends on the percentage share of people exposed to the aforementioned noise levels, in terms of the population of the analyzed agglomeration.



(a)



(b)

Figure 1. (a) The number of people exposed to road noise ($L_{DWN} > 60$ dB and $L_N > 50$ dB) in selected European capital cities. (b) The number of people exposed to road noise ($L_{DWN} > 60$ dB and $L_N > 50$ dB) in selected European capital cities.

When analyzing the results shown in Figure 1a, there is a large variation among the selected agglomerations. Such large differences may be affected by the development level of the city's transport network and the existing traffic volume. Paris is the capital city with the highest number of inhabitants exposed to road noise during daytime and night-time. The values reach almost 4 million people exposed to higher-than-acceptable noise levels ($L_{DWN} > 60$ dB and $L_N > 50$ dB). The next agglomerations in this list are London and Vienna. The values do not exceed 2 million people in both cases. However, it should be noted that in the case of the UK capital, the number of people exposed to road noise exceeding acceptable limits represents less than 20% of London's total population. However, when considering the situation in Vienna, which has a lower population density than London, the value is more than 80% of the total population. The reason for this may be the character of land use, especially the type of existing buildings and their location in relation to the city transport network. One of the sources of generating high level of road noise are arterial roads, whose density in the case of Vienna is 1.75 km/km², while in London it is 1.39 km/km² [23]. Another difference is the share of built-up areas occupied by roads and boulevards, which is 18% in Vienna and 10% in London. In addition, attention can be given to the share of area within walking distance of arterial roads. For the British capital, this indicator is 78%, while for the Austrian capital, it is 95% [23]. These data indicate differences in the discussed capital cities in relation to their well-developed transport networks and location of buildings in relation to them. Moreover, it is worth noting that, despite the introduction of uniform principles of acoustic mapping in the European Union, there are different approaches to the detailed analysis of data preparation. Directive [22] does not specify shape of input data, so this fact can be another reason for differences in results.

The other agglomerations form a group of cities in which the number of people exposed to the foregoing noise levels does not exceed 1 million, both for daytime and night-time. The range of the axes was reduced in order to provide better illustration of the results from these agglomerations. The data are shown in Figure 1b.

Based on Figure 1b, 3 groups of agglomerations can be distinguished. The first group of cities with the lowest environmental pollution from traffic noise includes Estonia's capital, Tallinn, and Lithuania's capital, Vilnius. The number of people exposed to road noise above the limit values does not exceed 300,000, taking into account both daytime and night-time. Moreover, the number of people analyzed in both cases does not represent more than 40% of the population of the agglomeration in question.

Another group consists of cities with exposed population ranging between 300,000 and 600,000. These include: Dublin, Riga, Warsaw, Prague, and Berlin. The percentage of people analyzed in relation to all inhabitants, however, varies widely. When analyzing the German capital, the value is less than 15%, and in the case of Dublin, it is over 60%.

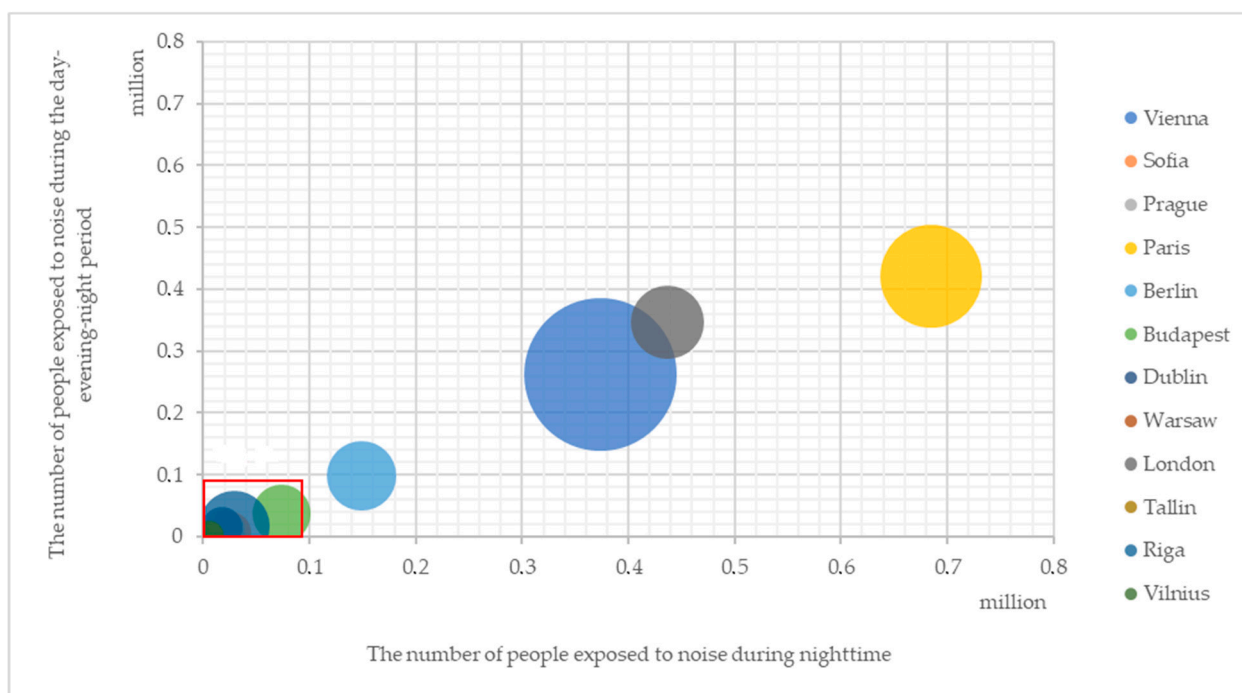
The last of the analyzed groups includes Sofia and Budapest. The number of people exposed is less than one million, but greater than 600,000. However, the percentage of these people in relation to the city population is more than 50% for the capital of Bulgaria, and less than 40% for the capital of Hungary, respectively.

It is clear that the French capital, Paris, had the worst result of all the selected agglomerations in terms of people exposed to road noise. It should be stressed, however, that it also has the highest population density of all the analyzed cities, as well as a very strongly developed transport network. Tallinn, the capital of Estonia, is the last place on this list. In terms of the proportion of inhabitants exposed to noise relative to the total population of a city, Berlin shows the best values (14%), while Vienna is characterized by the worst ones (84%).

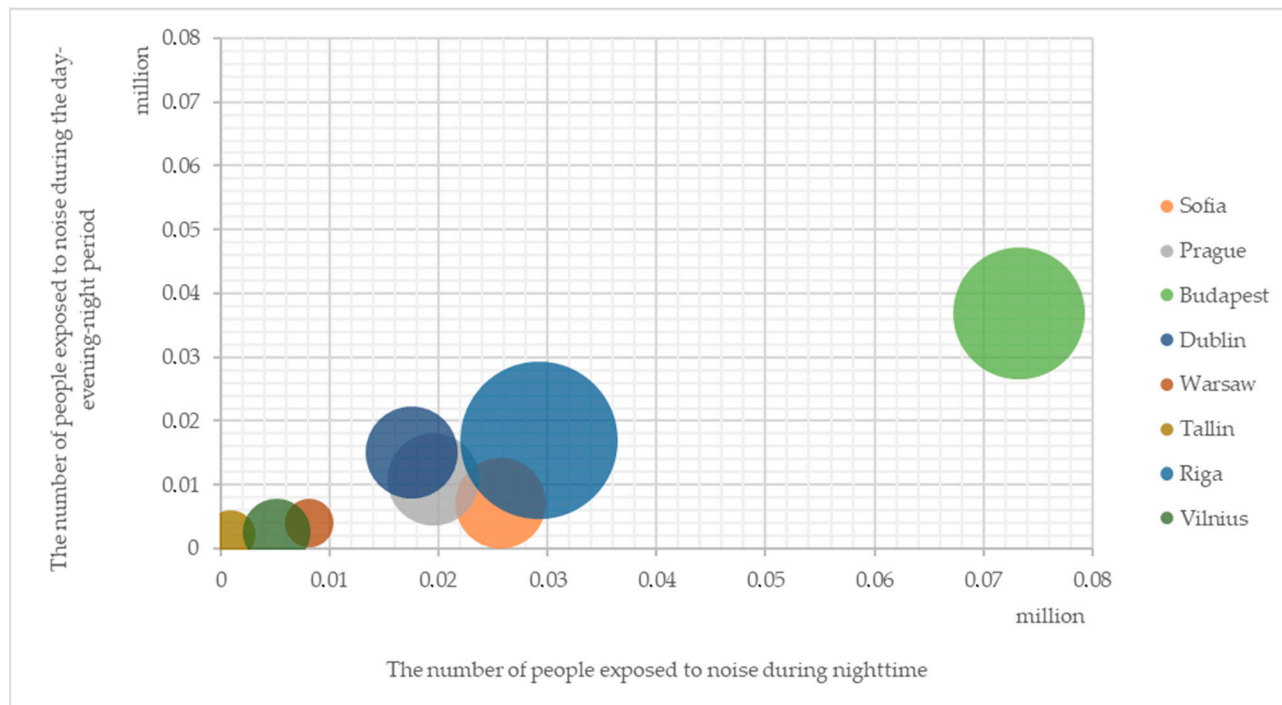
3.2. Railway Noise

Railway noise is also a major environmental problem, with hundreds of thousands of people exposed to it. However, this factor affects a much smaller percentage of inhabitants

compared with road noise. Figure 2a shows the number of people exposed to railway noise in selected European agglomerations, for $L_{DWN} > 60$ dB and $L_N > 50$ dB, analogously.



(a)



(b)

Figure 2. (a) The number of people exposed to railway noise ($L_{DWN} > 60$ dB and $L_N > 50$ dB) in selected European capital cities. (b) The number of people exposed to railway noise ($L_{DWN} > 60$ dB and $L_N > 50$ dB) in selected European capital cities.

When analyzing Figure 2a, one can notice that the railway noise is more noticeable at night in most of the analyzed cities, i.e., the number of people exposed to railway noise exceeding permissible values is higher during the night-time than during the daytime ($L_{DWN} > 60$ dB and $L_N > 50$ dB).

Similar to road noise, Paris is the European capital with the highest number of people exposed to railway noise. The values reach nearly 700,000 people exposed to noise levels exceeding acceptable limits during the night-time, constituting less than 10% of the inhabitants. The next cities in this list are London and Vienna, with values of over 430 thousand and less than 380 thousand inhabitants, respectively. Nevertheless, this represents about 20% of the population in Vienna, and only 4.5% in London. The next capital city affected by railway noise is Berlin, where almost 150,000 people have to bear with excessive railway noise during the night-time. The reason for the diversity in the presented values may be similar to that of road noise: the type of spatial development. In the case of railway noise the values are significantly lower due to a longer distance of buildings from railway tracks and the use of passenger cars as the main means of transportation. In addition, also in the case of railway noise, the differences in obtained values may be caused by the fact that countries use different ways to conduct analyses related to the number of people exposed to traffic noise. Other cities, with less than 80,000 people analyzed, are shown in Figure 2b.

Budapest is characterized by the biggest difference between the number of people exposed to excessive railway noise during daytime and night-time. When analyzing the time of daytime, the number reaches less than 40, thousand people, with more than 70 thousand during night-time. The reason for this could be freight transport, which generates mostly higher levels of railway noise than passenger trains. Additionally, there is often an increase in freight train traffic during the night compared to the daytime. On the other hand, the capital of Latvia stands out from the analyzed capitals in Figure 2b, with the highest percentage of people exposed to railway noise in relation to the entire city population, with a value of more than 4.5%. Cities such as Tallinn, Vilnius, and Warsaw are the ones least affected by railway noise. The number of people exposed does not exceed 10,000, representing no more than 1% of the total city population in any case.

3.3. Annoyance and Sleep Disturbances Caused by Traffic Noise

The effect of traffic noise on the environment, including the effect on human health, is a very significant factor. Using Formulas (2)–(7), it is possible to determine both the number of people who have problems with noise annoyance, and, by analyzing the night-time statistics, the number of people who are affected by severe sleep disturbance due to the presence of noise levels higher than acceptable values. Figure 3 shows the results obtained. The agglomerations are listed in the order of the smallest to the largest number of people affected by road and railway noise. The highest values were recorded in the case of Paris, where the number of people exposed to high levels of sleep disturbance caused by both types of noise is over 360 thousand people, and there are almost 800 thousand inhabitants suffering from noise annoyance. The best result on the list was achieved by the capital of Estonia, with the values of less than 13 thousand and over 35 thousand people, respectively. In addition, it can be noted that the difference between the percentage of people suffering from sleep disturbance caused by road noise and the percentage of people suffering from sleep disturbance caused by railway noise is the smallest in Berlin.

In addition, it is worth noting the percentage distribution of inhabitants exposed to high noise annoyance and high sleep disturbance according to noise levels. This distribution is shown in Figure 4 and concerns road noise.

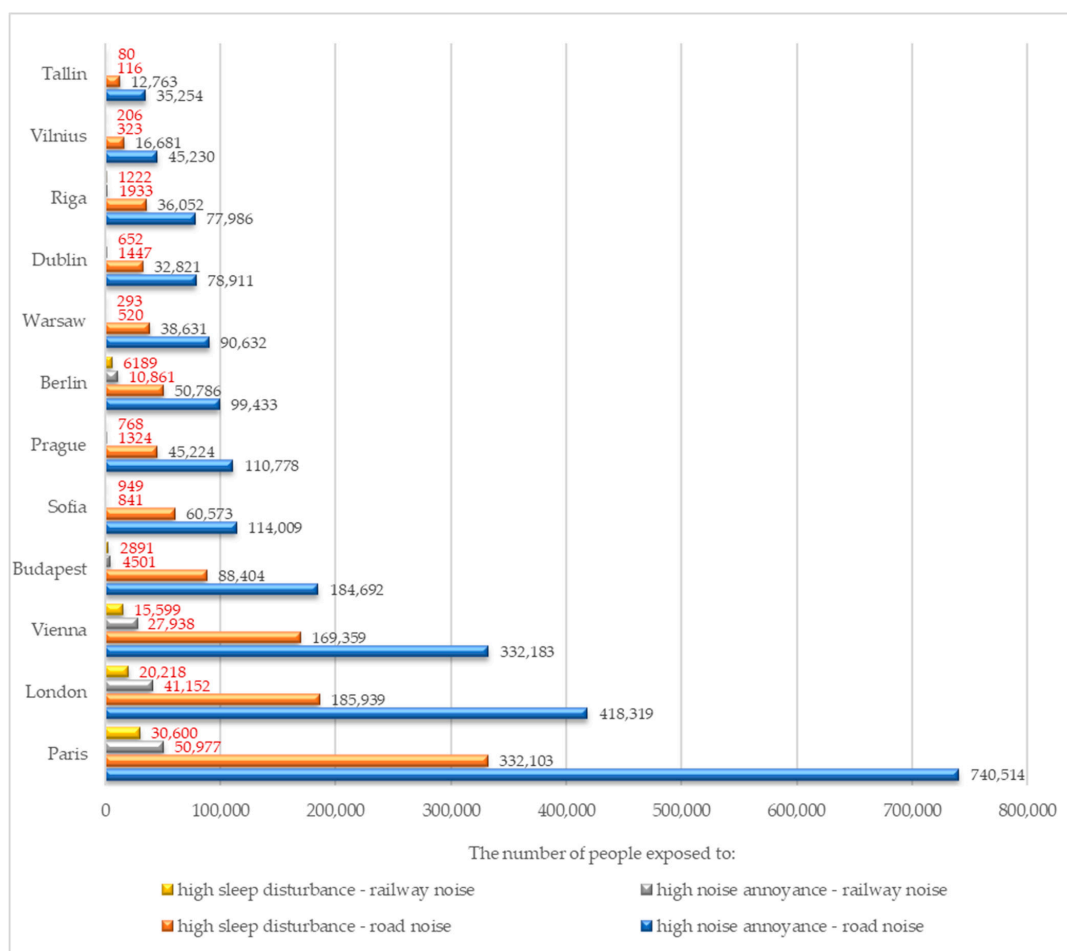


Figure 3. The number of inhabitants exposed to high levels of noise annoyance and sleep disturbance caused by road and railway noise.

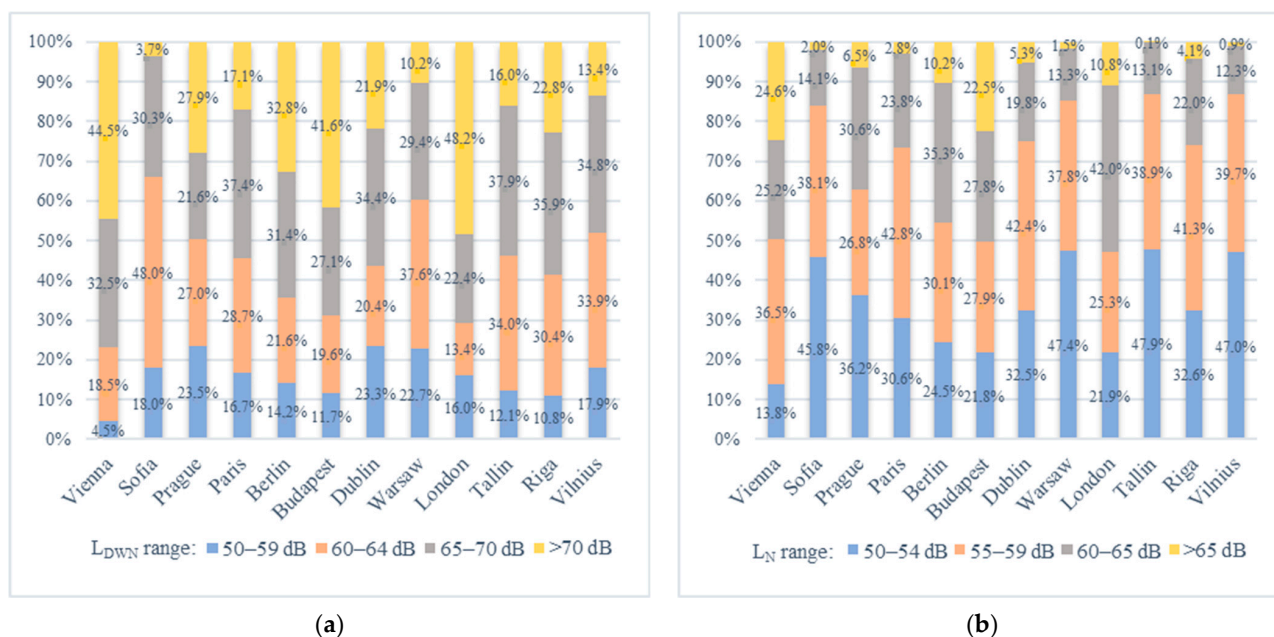


Figure 4. Percentage distribution of inhabitants exposed to: (a) high noise annoyance; (b) high sleep disturbance caused by road noise, depending on its level.

This distribution varies when analyzing individual agglomerations, however, as one can notice that in most cities, the largest percentage of inhabitants exposed to high noise annoyance concerns the ranges of 65–70 dB and over 70 dB. Only Sofia and Warsaw have the highest percentage in the 60–64 dB range. This distribution is just reversed when analyzing high levels of sleep disturbance. The lower noise level ranges, i.e., 50–54 dB and 55–59 dB, dominate in most of the capital cities analyzed. Berlin and London alone show the highest proportion of people exposed to high sleep disturbance levels in the 60–65 dB noise level range.

3.4. The DALY Indicator

Another way of identifying the traffic noise problem is to determine its effect on inhabitant health using the DALY indicator. According to the rules, it determines the potential number of productive years of life lost due to disability (loss of health) [6]. This is one of the elements to be introduced in the amendment to Annex III of the END Directive [9]. The indicator was calculated based on Equations (8) and (9) and the results are shown in Table 2.

Table 2. DALY values for noise annoyance and sleep disturbance caused by traffic noise.

Country	City	Road Noise		Railway Noise	
		DALY _D	DALY _{ZS}	DALY _D	DALY _{ZS}
		[Days/Year]			
Austria	Vienna	21.9	27.8	12.5	12.9
Bulgaria	Sofia	18.7	21.6	1.0	1.5
Czech Republic	Prague	19.0	20.0	1.6	1.4
France	Paris	19.8	22.2	8.0	8.2
Germany	Berlin	12.6	12.1	4.3	3.8
Hungary	Budapest	18.9	21.4	3.0	2.8
Ireland	Dublin	16.9	16.5	1.7	1.1
Poland	Warsaw	15.9	15.1	0.5	0.4
United Kingdom	London	15.0	14.3	5.3	4.4
Estonia	Tallinn	18.6	17.6	0.4	0.4
Latvia	Riga	20.5	23.7	4.2	4.0
Lithuania	Vilnius	18.4	17.5	0.9	0.8

DALY_D—indicator value for noise annoyance; DALY_{ZS}—indicator value for sleep disturbance.

Among the analyzed agglomerations, the DALY indicator reaches the highest values in the Austrian capital, Vienna. This applies to both noise from vehicle traffic as well as railway traffic. However, the lowest traffic noise values were obtained in Berlin, while Warsaw showed the lowest values for railway noise. When comparing the indicator values for both noise types, the greatest differences can be observed in Tallinn, in case of high noise annoyance. However, when analyzing the high level of sleep disturbances, the biggest difference is obtained for Sofia.

4. Discussion

Communication noise, which includes road and railway noise, is definitely one of the environmental factors interfering with human activity. However, the characteristics of these noises are significantly different. Train noise is characterized by periodicity, being intermittent, while road noise is continuous [24]. This is affected by the specifics of the different modes of transport and the existing traffic intensity. The study presented in this paper clearly shows that road noise is a much greater environmental hazard than railway noise. The number of people exposed to road noise exceeding the limit values is in many cases up to 10 times higher than for railway noise. The reason for this is, of course, using mainly passenger vehicles for transport. Extensive road networks allow free movement throughout the city. In addition, the existing buildings are often located very close to existing roads. A characteristic feature of roads is also the occurrence of the urban canyon

effect, which in addition to a large number of residents may be characterized by increased noise levels due to sound wave reflection effects from building facades. However, in case of railways, residential buildings are located at longer distances from the railway tracks, with the exception of the city center, comprised mostly of high-density building placement [25]. In many cities, railway networks are not developed adequately enough to use them for daily commute—this is a form of transport which, according to the authors, should be developed while simultaneously limiting private car use. It should be noted, however, that the characteristics of railroad transportation for a given city can vary significantly. In the French capital, the railway network is very well developed throughout the city, and serves mainly as passenger transport. On the other hand, freight transport is the main function of railway in many cities, and this is reflected in the results presented for the number of people exposed to this type of noise. Specifically, more people are exposed to railway noise at night-time (>50 dB) than during the entire day (>60 dB), which is due to the higher volume of railway vehicles associated with freight transport occurring at night. It should be noted that freight transport is mostly carried out at night and that the same networks as for passenger transport are usually used for this. In addition, freight transport generates higher noise levels than passenger train movements. When analyzing both types of noise, Paris is the European city with the highest number of people having to cope with everyday noise, while Tallinn has the lowest number of people suffering from noise problem among the analyzed agglomerations.

Indicators demonstrating the effect of traffic noise on the inhabitant health is another aspect presented in the article. Currently, these indicators only serve as supplementary information in environmental studies, e.g., strategic acoustic maps, and the basic criterion is exceeding the permissible values of L_{DWN} and L_N . This approach does not take into account many variables, and consequently does not provide a complete characterization of the traffic noise problem. The results presented in Figure 4b show that, for most of the analyzed cities, the largest percentage of inhabitants exposed to high noise annoyance does not concern the ranges with the highest noise level, but the lower ranges (specifically, the ranges of 50–54 dB and 55–59 dB). There are ongoing studies on further indicators with which to assess the effect of noise on specific disease occurrence (e.g., cognitive impairment in children, hearing impairment) [15]. In addition, there are ongoing works on the final formulas and coefficient values for the DALY indicator. Currently, it is treated as additional information and, due to its nature and perception, is used to estimate values only for large areas [10]. This is undoubtedly an opportunity to conduct further studies to provide more details on the effect of traffic noise on human health.

Additionally, it is worth mentioning that, after the first implementation of the Directive, an attempt was made to compare and analyze the results of acoustic mapping in many European agglomerations, but using only L_{DWN} and L_N indicators. The resulting uncertainty associated with the results, however, was too high to reach any conclusions about the effectiveness of the mitigation measures projected within the action plans [26].

5. Conclusions

This research paper presents an overview of the impact of road and rail traffic noise on the residents of selected European agglomerations. A comprehensive analysis was carried out of the results concerning the percentage of population exposed to traffic noise. In addition, using indicators of noise annoyance, sleep disturbance, and the DALY indicator, the impact of noise on human health was presented. The obtained results were highly variable, which may be affected by the characteristics of the surroundings and the different ways in which individual countries conduct analyses related to the number of people exposed to traffic noise. The study indicates incomplete assessment of noise pollution, referring only to permissible values of noise level, and is not the best comparison method between cities. It is necessary to use the additional indicators listed in the study, but apart from noise-related indicators, it is worth taking into account the character of existing

buildings and their location in relation to transport networks. This is undoubtedly an opportunity for further research.

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