THE PAPER PRESENTS AN ANALYSIS OF THE NOISE RECORDED BY THE TWO ROAD TRAFFIC NOISE-MONITORING STATIONS. THE STATIONS WERE LOCATED IN KIELCE, POLAND, AT THE ROAD NO. 74: ON THE OUTSKIRTS OF THE CITY AND NEAR THE CENTER. BASED ON THE EXPERIMENTALLY RECORDED DATA, AN EQUIVALENT SOUND LEVEL AND ACOUSTIC PRESSURE WERE DETERMINED FOR THREE SUB-INTERVALS OF THE DAY: NIGHTS, DAYS AND EVENINGS. THE CONDUCTED ANALYSES SHOWED THAT THE AVERAGE ANNUAL VALUES (DEPENDING ONLY ON THE TIME SUB-INTERVALS) OF THE MEDIAN DO NOT DIFFER SIGNIFICANTLY BETWEEN STATIONS. A SIMILAR CONCLUSION CAN BE DRAWN BASED ON SIMULATIONS OF THE MEDIAN AND THE C90 PERCENTILE OF THE SOUND PRESSURE. HOWEVER, THE MAXIMUM RELATIVE DIFFERENCES IN THE C99 PERCENTILE OF THE ACOUSTIC PRESSURE BETWEEN STATIONS ARE AROUND 13%. THE MAXIMUM RELATIVE DIFFERENCES IN MEDIAN PRESSURE BETWEEN STATIONS ARE AROUND 15% (FOR THE TIME SUB-INTERVAL NIGHTS).

reason, the authors decided to conduct a detailed analysis of the road noise generated during this period.

2 Noise monitoring stations

The subject of research, presented in this work, are results of the equivalent sound level measurements recorded by stationary, automatic stations for monitoring noise and vehicle traffic located at Lodzka Rd. (marked as S1 station) and Jesionowa Rd. (marked as S2 station) in Kielce. The location of these stations in the urban layout of Kielce is shown in Figure 1. The distance between these stations is about 2 km. Streets Lodzka and Jesionowa form one communication route constituting a section of national road No. 74 from the western to eastern borders of the city. Lodzka Street consists of four lanes separated by a 3m wide green belt. It is the main part of the exit route from the center of Kielce towards Lodz, Warsaw and Krakow. This road is mainly used for transit and suburban traffic. Jesionowa Street consists of five lanes separated by a 5m wide green belt. It connects Lodzka street with the express road S74. It is intended for the urban and suburban traffic, as well as for transit traffic. These streets are at flat ground level and the technical condition of the bituminous surface is good. There are two large intersections with city roads between the measuring stations. The average daily traffic for S1 station is 20200 vehicles, including 2050 heavy and for S2 station 29500 vehicles, including 1900 heavy.

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Results analysis methods

The most commonly used measure for noise assessment is the equivalent sound level \( L_{Aeq,T} \) expressed in dB(A), defined as follows:

\[
L_{Aeq,T} = 10 \cdot \log \left[ \int_0^T \left( \frac{p_A(t)}{p_0} \right)^2 \, dt \right] = 10 \cdot \log \left[ \left( \frac{p_{\text{rms}}}{p_0} \right)^2 \right] \quad (1)
\]

where:
- \( T \) - measurement time, s,
- \( p_A(t) \) - sound pressure corrected by frequency characteristics, Pa,
- \( p_0 \) - the standardized reference acoustic pressure of \( 20 \cdot 10^{-6} \) Pa.

Expanded uncertainty of measurements is determined from [12]:

\[
u(t_{a,N-1}) = u = \pm \sqrt{\frac{\sigma^2}{N} + 0.026\sigma^2} \cdot t_{a,N-1}, \quad (2)
\]

where \( t_{a,N-1} \) is the quantile of the \( t \) - distribution at the confidence level \( a \), standardized at 0.05. Equation (2) can be applied, assuming that the null hypothesis about normal unimodal distributions \( H_0 \) of the measured sound level, independent variables, adequately large quantity of data and low standard deviations, can be accepted. In the case of the traffic noise, those conditions are not always met.

The logarithm function used to represent \( L_{Aeq,T} \), determined according to Equation (1), may impede comparative analysis and affect results of the statistical tests. For that reason, the authors decided to additionally determine the RMS value of sound pressure (denoted \( p_{\text{rms}} \)), from Equation (3), in the analyzed time interval \( T \) and use this parameter expressed in mPa for further analysis.
Data that can be considered atypical have less impact on values of this coefficient. The relative differences between the positional statistical parameters, such as the $CX$ and $CY$ percentiles, can be calculated according to the following relationship:

$$V_{Q_p} = 0.5 \left[ Q_0(p_{\text{Aeq,T}}) - Q_0(p_{\text{Aeq,T}}) \right] \cdot 100\%,$$

Data that can be considered atypical have less impact on values of this coefficient. The relative differences between the positional statistical parameters, such as the $C_X$ and $C_Y$ percentiles, can be calculated according to the following relationship:

$$\varepsilon_{X-Y} = \frac{C_X - C_Y}{C_Y} \cdot 100\%,$$

where:

$C_{X'}, C_{Y'}$ - percentiles of order X and Y, respectively.

This indicator can be used to analyze values of the noise parameters recorded by one measuring station. When analyzing data recorded by several measuring stations, the ratio of relative difference between the X-percentiles can be calculated as follows:

$$\varepsilon_X = \frac{C(S2)_{X} - C(S1)_{X}}{C(S1)_{X}} \cdot 100\%,$$

where:

$C(S2)_{X}, C(S1)_{X}$ - percentiles of order X of the tested parameter determined for the stations S1 and S2, respectively.

4 Measurements results

Examples of diagrams showing recorded $L_{\text{Aeq,T}}$ for all the measurement days in 2013 split into time sub-intervals, are shown in Figure 2a for station S1 and in Figure 2b for station S2.

Table 1 shows basic average annual statistics of the parameter $L_{\text{Aeq,T}}$ for the 24 h periods and three time sub-intervals determined from station S1 measurement data, expressed in dB(A). The Lilliefors and Shapiro-Wilk tests were performed on each dataset, with the Lilliefors test used to check the normality of the data.

![Figure 2 Equivalent sound levels $L_{\text{Aeq,T}}$ for all the measurement days in 2013 split into time sub-intervals; a) station S1, b) station S2 [10]

\begin{align*}
\mu_{\text{Aeq}} &= \mu_A = \sqrt[10]{10^{[10 \cdot (\mu_{\text{Aeq,T}})]} \cdot \mu_A^*}, \\
\varepsilon_{X-Y} &= \frac{C_X - C_Y}{C_Y} \cdot 100\%, \\
\varepsilon_X &= \frac{C(S2)_{X} - C(S1)_{X}}{C(S1)_{X}} \cdot 100\%, \\
V_{\text{Q_p}} &= 0.5 \left[ Q_0(p_{\text{Aeq,T}}) - Q_0(p_{\text{Aeq,T}}) \right] \cdot 100\%. 
\end{align*}
respectively, which confirms the validity of rejection of the $H_0$ hypothesis. Quantile charts are graphic illustrations of the fact that distributions of the analyzed data deviate from the normal distribution and that these distributions are left-skewed.

Statistical tests of the $L_{Aeq,T}$, determined from station S1 measurement data rejected the hypothesis $H_0$ for all the average annual time intervals given in Table 1, as in the case of analyzes for S2 stations. Values of the medians of $L_{Aeq,T}$ for each time sub-interval, presented in Table 1, exceed values applicable in Poland in accordance with the law, especially for the time sub-interval night, i.e. by about 11 dB.

Type A uncertainty of measurements of the traffic noise, calculated according to Equation (2), is about 0.2 dB(A).

Examples of diagrams, showing calculated according to Equation (3), split into 24-hour period sub-intervals, are

Table 1 Average annual values of basic statistical noise measures determined by the station S1 and S2, for all the measurement days in 2013

| period of the day | median $L_{Aeq,T}$ (dB(A)) | $\mu$ (dB(A)) | median $P_{Aeq}$ (mPa) | $\mu$ (mPa) | $\sigma_{P_{Aeq}}$ (mPa) | COV (%) | $V_{Q91}$ (%) | $C_{90}$ (mPa) | $C_{99}$ (mPa) |
|------------------|------------------|----------------|------------------|----------------|------------------|-------|----------------|----------------|----------------|
| station S1       |                  |                |                  |                |                  |       |                |                |                |
| 24 h             | 70.50            | 0.24           | 66.99            | 0.73           | 64.68            | 19.93 | 30.82          | 24.72          | 91.42          | 104.50         |
| night            | 67.10            | 0.25           | 45.29            | 0.53           | 43.03            | 8.35  | 19.41          | 10.78          | 52.00          | 59.02          |
| day              | 72.70            | 0.20           | 86.50            | 0.84           | 83.77            | 13.18 | 15.73          | 9.53           | 98.41          | 107.51         |
| evening          | 70.70            | 0.20           | 68.55            | 0.66           | 67.24            | 10.30 | 15.32          | 9.02           | 79.26          | 88.89          |
| station S2       |                  |                |                  |                |                  |       |                |                |                |
| 24 h             | 70.68            | 0.20           | 68.40            | 0.67           | 66.48            | 18.28 | 27.50          | 21.28          | 88.11          | 105.31         |
| night            | 67.43            | 0.22           | 47.05            | 0.54           | 46.34            | 8.56  | 18.47          | 12.17          | 56.43          | 64.89          |
| day              | 72.29            | 0.17           | 82.32            | 0.77           | 82.74            | 11.67 | 14.10          | 7.86           | 96.39          | 112.50         |
| evening          | 71.03            | 0.16           | 71.21            | 0.63           | 71.90            | 10.02 | 13.94          | 8.83           | 84.06          | 100.78         |

Wilk statistical tests rejected hypothesis $H_0$, because the calculated significance levels were lower than the required level of 0.05. In the cases where the normal distribution of given data was doubtful, the Jarque-Bera test was additionally used. Results of those tests are not included in Table 1, but one can conclude that in the case of data expressed in dB(A) for the S1 and S2 station, in each of the four considered periods of the day, there are grounds to reject the $H_0$ hypothesis. Figure 3 shows (for comparison) examples of histograms with the probability density function plotted and Q-Q quantile charts for standardized values of analyzed measurement data, expressed in dB(A) or mPa.

Analysis of Figure 3 shows that, depending on the units used (i.e. dB(A) or mPa in which noise is expressed) one can notice differences in the shape of both histograms, probability density functions and Q-Q charts for standardized values of the analyzed data. The calculated values of kurtosis and skewness for data (expressed in dB(A)) recorded by station S1 are 2.93 and -0.65, respectively, which confirms the validity of rejection of the $H_0$ hypothesis. Quantile charts are graphic illustrations of the fact that distributions of the analyzed data deviate from the normal distribution and that these distributions are left-skewed.

Statistical tests of the $L_{Aeq,T}$, determined from station S1 measurement data rejected the hypothesis $H_0$ for all the average annual time intervals given in Table 1, as in the case of analyzes for S2 stations. Values of the medians of the $L_{Aeq,T}$ expressed in dB(A) for each time sub-interval presented in Table 1 are similar for both stations. The values of the medians of $L_{Aeq,T}$ for each time sub-interval, presented in Table 1, exceed values applicable in Poland in accordance with the law, especially for the time sub-interval night, i.e. by about 11 dB.

Type A uncertainty of measurements of the traffic noise, calculated according to Equation (2), is about 0.2 dB(A).

Examples of diagrams, showing calculated according to Equation (3), split into 24-hour period sub-intervals, are...
The calculated values of the $C_{90}$ and $C_{99}$ parameters of the noise pressure, determined for the 24 h periods, are similar for both stations and are approximately 90 mPa and 105 mPa, respectively. The average annual coefficients of relative percentile differences of the order $X = 99$ and $Y = 90$, calculated according to Equation (6), are always greater for the S2 station and their maximum value is about $S_{299 - 90} = 112$ mPa. The minimum value of the $C_{99}$ parameter is for the S1 station and is about 59 mPa. Figure 5 presents the average annual values of the coefficient $\varepsilon_X$ of the relative difference in the sound pressure percentiles between the S1 and S2 stations, determined for the time sub-interval a) days, b) nights.
The coefficient $\varepsilon_X$ takes both positive and negative values. A change in the sign of this factor indicates that some pressure percentiles for station S1 have higher values than for station S2 - this occurs especially for the time sub-interval days. Figure 5 shows that the minimum values occur near the 50th percentile. The variation range from minimum to maximum is around 10%. The maximum value is around $\varepsilon_0 = 13\%$ for the time sub-interval evenings. The analyzed relationships can be described by a second-degree polynomial. Values of the coefficients of this polynomial depend on the time sub-interval. Values of the correlation coefficients $R$ are high and amount to about 0.80. The analyzes conducted so far have not revealed significant large differences between the average annual values of a median and $C_{90}$ noise pressure, determined for stations S1 and S2. However, for parameter $C_{90}$ (for the evenings) the maximum relative pressure differences are around: $\varepsilon_{90} = 13\%$ (between stations S1 and S2), $\varepsilon_{90-95}(S1) = 12\%, \varepsilon_{90-95}(S2) = 20\%$. For any time sub-interval, regardless of the station, the noise parameter values are higher than the normative ones. For the time sub-interval day - these differences are around 11dB(A).

In order to conduct further more detailed comparative analyzes of the two stations, it was decided to calculate the average annual values of the sound pressure parameters for individual days of the week [1]. Figure 6 presents box plots prepared for average annual pressures $p_{A_{24h}}$ calculated for individual days of the week and for time sub-intervals: nights, days, and evenings. These plots show how the median and the interval between the first and third quartiles change during the week. They also show that the set of data analyzed contains values that can be considered atypical. The only period when there is no unusual data is time sub-interval - nights - on Saturdays. Since no causes were identified for occurrence of the atypical data, these data were taken into account in further analysis of the recorded samples of the traffic noise. This phenomenon is thus characterized by high randomness, which is consistent with the findings reported in the literature [12].

These graphs show that changes in the median value on weekdays are different in nature depending on the economic function of the section of road being studied, i.e. location of the measuring station. At station S1, the median value increases gradually from Mondays to Fridays. At station S2, the median value increases slightly or decreases from Mondays to Fridays. However, on weekend days, for both stations, the nature of changes in median $p_{A_{24h}}$ is similar. On Saturdays and Sundays, the median value of $p_{A_{24h}}$ for time sub-interval nights and days decreases and for the evenings the differences are insignificant - even then, the permissible noise values are exceeded. The statistical tests for data expressed in mPa showed that for some of the weekdays and for certain time sub-intervals within a 24-hour period there was not enough evidence to reject the hypothesis $H_0$. For the S1 and S2 stations, such days are Fridays, Saturdays and Sundays. Saturdays and Sundays are the weekend days and the traffic parameter values of road vehicles are different from on the business days.

As previous analyzes have shown, the largest exceedances of permissible noise occur for the time sub-

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure6.png}
\caption{Box plots of average annual sound pressure $p_{A_{24h}}$ for individual days of the week and for time sub-intervals: nights, days, evenings: a) S1 station, b) S2 station}
\end{figure}
The maximum relative differences between the values of parameters $C_{90}$ and $C_{99}$ for S1 station are \( \%1399\) and for S2 station \( \%1999\). The maximum relative differences in the $C_{50}$, $C_{90}$ or $C_{99}$ parameter values between stations, regardless of the day of the week for the nights, are approximately: \( \%1550\), \( \%2590\), \( \%1799\). Figure 7 shows the mutual relations between values of the coefficients of relative changes in the median pressure $p_{ARM}$ on individual days of the week, for the nights for the stations S1 and S2. The COV coefficient values are several percent higher than the $V_{Q31}$ coefficient. The nature of changes in their value during the week is varied for each station. For the S1 station, values of these coefficients increase from Mondays to Tuesdays and decrease from intervals - nights, which is particularly burdensome for residents [13]. Therefore, the authors decided to conduct further analysis for nights and on individual days of the week. Some values of the noise parameters at night and for individual days of the week are given in Table 2.

### Table 2 Average annual values of the statistical measures $p_{ARM}$ determined for individual days of the week for stations S1 and S2, time sub-interval - nights

| days of the week | median $p_{ARM}$ mPa | $\sigma_{p_{ARM}}$ mPa | COV | $V_{Q31}$ | $C_{90}$ mPa | $C_{99}$ mPa | $u$ mPa |
|------------------|-----------------------|------------------------|-----|----------|--------------|--------------|--------|
| **station S1**   |                       |                        |     |          |              |              |        |
| 
| mondays          | 43.25                 | 41.84                  | 6.28 | 15.00    | 7.41         | 46.88        | 52.00  | 1.06   |
| tuesdays         | 46.35                 | 44.81                  | 8.26 | 18.43    | 8.48         | 53.34        | 57.46  | 1.40   |
| wednesdays       | 46.88                 | 45.33                  | 7.80 | 17.20    | 4.03         | 51.41        | 58.14  | 1.32   |
| thursdays        | 47.70                 | 46.28                  | 6.69 | 14.46    | 6.50         | 52.30        | 56.78  | 1.12   |
| fridays          | 49.38                 | 48.51                  | 6.02 | 12.41    | 6.35         | 54.47        | 61.30  | 1.00   |
| sundays          | 44.26                 | 42.87                  | 5.80 | 13.53    | 9.47         | 48.87        | 51.80  | 0.98   |
| **station S2**   |                       |                        |     |          |              |              |        |
| 
| mondays          | 49.78                 | 48.24                  | 7.94 | 16.46    | 11.98        | 58.00        | 61.00  | 1.34   |
| tuesdays         | 46.94                 | 48.30                  | 7.47 | 15.46    | 8.05         | 50.39        | 65.70  | 1.23   |
| wednesdays       | 48.98                 | 48.33                  | 8.08 | 16.71    | 7.04         | 56.74        | 63.48  | 1.35   |
| thursdays        | 49.70                 | 49.11                  | 7.88 | 16.04    | 7.92         | 56.89        | 63.63  | 1.31   |
| fridays          | 51.13                 | 50.65                  | 6.95 | 13.72    | 7.47         | 56.90        | 67.86  | 1.13   |
| sundays          | 43.30                 | 43.34                  | 5.95 | 13.73    | 8.32         | 50.50        | 55.79  | 0.99   |

#### Figure 7 Changes in the coefficient of variation of the sound pressure on particular days of the week for the time sub-interval - nights a) S1 station, b) S2 station (designations; 1 - 7 - consecutive days of the week, from Monday to Sunday)

The maximum relative differences between the values of parameters $C_{90}$ and $C_{99}$ for S1 station are \( \epsilon_{90} = 13\% \) (on Wednesdays) and for S2 station \( \epsilon_{90} = 19\% \) (on Fridays). The maximum relative differences in the $C_{90}$, $C_{99}$ or $C_{99}$ parameter values between stations, regardless of the day of the week for the nights, are approximately: \( \epsilon_{90} = 15\% \), \( \epsilon_{90} = 25\% \), \( \epsilon_{90} = 17\% \).

Figure 7 shows the mutual relations between values of the coefficients of relative changes in the median pressure $p_{ARM}$ on individual days of the week, for the nights for the stations S1 and S2. The COV coefficient values are several percent higher than the $V_{Q31}$ coefficient. The nature of changes in their value during the week is varied for each station. For the S1 station, values of these coefficients increase from Mondays to Tuesdays and decrease from
Tuesdays to Fridays, after which from Fridays to Sundays they increase again. On the other hand, for the S2 station, values of these ratios decrease from Mondays to Tuesdays, from Tuesdays to Fridays they decrease or increase, after which from Fridays to Sundays they increase again.

Analysis of Figure 7 shows that nature of changes in the COV values from Monday to Wednesday for each station is different. However, from Wednesday to Sunday, the nature of the changes is similar. In the case of the $V_{90}$ coefficient values, the qualitative differences occur from Monday to Tuesday and from Tuesday to Sunday the nature of the changes is similar.

5 Conclusions

The study evaluated and compared results of measurements recorded by the two stationary road noise-monitoring stations, located on one road. For this purpose, the arithmetic mean and median, as well as the variable components of the signals tested were calculated. For analysis of these signals, the acoustic pressure $\mathcal{P}_{\text{ARMAS}}$ and the classical COV and positional $V_{90}$ coefficients of variation were used. Use of the relative difference coefficients between pressure percentiles $\mathcal{P}_{\text{ARMAS}}$ has been proposed.

Annual average median and $C_{90}$ percentile of the sound pressure $\mathcal{P}_{\text{ARMAS}}$ (depending only on 24-hour sub-periods) showed no significant differences between the S1 or S2 stations. For the 24h periods the median, $C_{90}$ and $C_{95}$ percentile of the sound pressure $\mathcal{P}_{\text{ARMAS}}$ for both stations S1 and S2 are similar and are about 67 mPa, 90 mPa and 105 mPa, respectively. However, for both stations, depending on the time sub-interval, the median pressure $\mathcal{P}_{\text{ARMAS}}$ assume similar values, which are around: for nights 46 mPa, for days from 84 mPa and for evenings 70 mPa. The maximum values of the $C_{90}$ parameter are always present for the S2 station and for the time sub-interval days are about 112 mPa. The minimum value of the $C_{95}$ parameter is for the S1 station and is about 59 mPa. At any time sub-interval, regardless of the monitoring station, values of the noise parameters are higher than normative. For the night, these differences are the largest and amount to about 11dBA. The relative differences between the $C_{90}$ and $C_{95}$ parameter values are always greater for the S2 stations and their maximum value is approximately $e_{X-Y}(S2) = 20\%$ - for the evenings. However, for the S1 station and for the evenings $e_{X-Y}(S1) = 12\%$. The maximum relative differences in $C_{90}$ percentile pressure between the stations S1 and S2 are approximately 13% for the evenings. Pressure variation coefficients for the 24h periods and for both stations are in the range: for the COV from 27.50% to 31% and for $V_{90}$ from 21% to 25%. Whereas the coefficients of pressure variation for: nights, days, evenings are in the range: for COV from 13% to 19%, for $V_{90}$ from 8% to 12%.

In order to conduct more detailed comparative noise analyzes for the stations tested, the average annual values of the sound pressure parameters on particular days of the week were calculated. At station S1, the median values increase gradually from Mondays to Fridays. At S2, the median value increases slightly or decreases from Mondays to Fridays. This nature of the median value changes on weekdays is due to location of the measuring stations. However, at weekends, the nature of changes in median $\mathcal{P}_{\text{ARMAS}}$ is similar for both stations.

As previous analyzes for the time sub-interval night have shown: the structure of vehicle traffic for both stations is similar and the largest exceedances of permissible noise occur. It has been shown that at nights for stations S1 and S2: the minimum median $\mathcal{P}_{\text{ARMAS}}$ occur on Sundays and the maximum on Fridays. Percentile $C_{90}$ and $C_{95}$ for station S1 have the lowest values on Sundays and the highest on Fridays. Whereas for S2 station - $C_{90}$ and $C_{95}$ percentiles have the smallest values on Sundays and the highest ones on Tuesdays and Fridays, respectively. The maximum relative differences between the $C_{90}$ and $C_{95}$ percentiles for the S1 station are $e_{90-95} = 13\%$ (on Wednesdays, nights) and for the S2 station $e_{90-95} = 19\%$ (on Fridays, nights). The maximum relative differences in the $C_{90}$ $C_{95}$ percentiles between stations, regardless of the day for the nights, are approximately: $e_{90} = 15\%$, $e_{95} = 25\%$, $e_{95} = 17\%$. It should be noted that the median values of $\mathcal{P}_{\text{ARMAS}}$ for both stations are in ranges with similar boundaries and a span of about 16 mPa. On the other hand, for parameter $C_{90}$ the differences between the lower boundaries of the ranges are 7 mPa and the values of the lower and upper boundaries for each station differ by 19 mPa (for nights).

Minimal values of the coefficients of variation for the time sub-interval night occur on different days: for $V_{90}$ on Wednesdays and for COV on Fridays. The nature of the change in COV value from Mondays to Wednesdays for each station is different. However, from Wednesdays to Sundays, the nature of the changes is similar. In the case of the $V_{90}$ coefficient value, qualitative differences occur from Mondays to Tuesdays and from Tuesdays to Saturdays, the nature of the changes is similar.

References

[1] GERAGHTY, D., O’MAHONY, M. Investigating the temporal variability of noise in an urban environment. *International Journal of Sustainable Built Environment* [online]. 2016, 5(1), p. 34-45. ISSN 2212-6090. Available from: https://doi.org/10.1016/j.ijsebe.2016.01.002
[2] KHAIWAL, R., SINGH, T., TRIPATHY, J. P., MOR, S., MUNJAL, S., PATRO, B., PANDA, N. Assessment of noise pollution in and around a sensitive zone in North India and its non-auditory impacts. *Science of the Total Environment* [online]. 2016, 566-567, p. 981-987. ISSN 0048-9697. Available from: https://doi.org/10.1016/j.scitotenv.2016.05.070

[3] VOGIATZIS, K., REMY, N. Environmental noise mapping as a smart urban tool development. In: *Smart Urban Development* [online]. IntechOpen, 2019. Available from: https://doi.org/10.5772/intechopen.88449

[4] CZYZEWSKI, A., KOTUS, J., SZCZODRAK, M. Online urban acoustic noise monitoring system. *Noise Control Engineering Journal* [online]. 2012, 60(1), p. 69-84. ISSN 0736-2501. Available from: https://doi.org/10.3397/1.3670102

[5] MIHAILOV, D. I., PRASCEVIC, M. R. Permanent and semi-permanent road traffic noise monitoring in the city of Nis (Serbia). *Journal of Low Frequency Noise, Vibration and Active Control* [online]. 2015, 34(3), p. 251-268. ISSN 1461-3484, eISSN 2048-4046. Available from: https://doi.org/10.1260/0263-0923.34.3.251

[6] PETROVA, M., NENKO, A. Urban emptiness as a resource for sustainable urban development. *Management of Environmental Quality: An International Journal* [online]. 2018, 29(3), p. 388-405. ISSN 1477-7835. Available from: https://doi.org/10.1108/MEQ-01-2018-0004

[7] FIGLUS, T., GNAP, J., SKRUCANY, T., SZAFRINGIEC, P. Analysis of the influence of different means of transport on the level of traffic noise. *Scientific Journal of Silesian University of Technology. Series Transport* [online]. 2017, 97, p. 27-38. ISSN 0209-3324, eISSN 2450-1549. Available from: https://doi.org/10.20858/sjsutst.2017.97.3

[8] BASNER, M., MCGUIRE, S. WHO environmental noise guidelines for the European region: a systematic review on environmental noise and effects on sleep. *International Journal of Environmental Research and Public Health* [online]. 2018, 15(3), p. 519. eISSN 1660-4601. Available from: https://doi.org/10.3390/ijerph15030519

[9] JANDACKA, D., DECKY, M., DURCANSKA, D. Traffic related pollutants and noise emissions in the vicinity of different types of urban crossroads. In: IOP Conference Series: Materials Science and Engineering: proceedings. IOP Publishing, 2019. p. 012152.

[10] BAKOWSKI, A., RADZISZEWSKI, L., DEKYS, V. Urban noise recorded by stationary monitoring stations. In: IOP Conference Series: Materials Science and Engineering: proceedings. Vol. 245. Iss. 4. IOP Publishing, 2017. p. 042045. Available from: https://doi.org/10.1088/1757-899X/245/4/042045

[11] BOCHATKIEWICZ, J. Acoustic maps of the city of Kielce - updated 2013 / Mapy akustyczne miasta Kielce - aktualizacja 2013 (in Polish) [online]. Available from: http://www.um.kielce.pl/gfx/kielce2/userfiles/files/srodowisko/opracowania/mapa_akustyczna_aktualizacja_2013.pdf

[12] PRZYSUCHA, B., BATKO, W., SZELAG, A. Analysis of the accuracy of uncertainty noise measurement. *Archives of Acoustics* [online]. 2015, 40(2), p. 183-189. ISSN 0137-5075, eISSN 2300-262X. Available from: https://doi.org/10.1515/aoa-2015-0020

[13] SLAVIK, R., GNAP, J. Selected problems of night-time distribution of goods within city logistics. *Transportation Research Procedia* [online]. 2019, 40, p. 497-504. ISSN 2352-1465. Available from: https://doi.org/10.1016/j.trpro.2019.07.072