

UDC 628.3:539.1

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## Assessing the reliability of noise simulation models in a built-up area

**Abstract.** In modern environments, noise is a dominant factor negatively impacting the urban ecosystem and, consequently, the health of city residents. Noise exposure reduces labor productivity and the efficiency of rest, serves as a primary cause of nervous disorders, and significantly diminishes the quality and safety of life.

The aim of the study is to determine the reliability of developing simulation models for sound propagation in urban built-up areas. Research methods include field instrumental measurements, a cartographic method for predicting noise pollution from sources with the construction of 3D sound field models, and statistical methods for processing and evaluating research results. The results demonstrate a strong relationship between the outcomes of field instrumental measurements and the cartographic prediction of the noise regime in the studied residential area. The calculated correlation coefficient amounted to  $r = 0.889$ , indicating a high level of agreement between the compared datasets. In addition, the required number of observations to determine the degree of correlation between the two groups of compared sound level values was established as 12 observations

**Keywords:** modeling, noise propagation, correlation analysis.

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Received: 05.12.2025

Accepted: 18.12.2025

Published: 26.12.2025

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### Introduction.

Under contemporary conditions, noise is one of the dominant factors negatively affecting the urban ecosystem and the health of the urban population. Noise exposure lowers labor productivity, affects the quality of rest, and is a major cause of neurological disorders [1-14].

Computer simulation modeling is employed to account for, evaluate, and provide reliable forecasts of the noise regime in urban environments when designing new developments or reconstructing existing ones [15]. This method accounts for the acoustic characteristics and location of sound sources relative to protected objects, the configuration and height of buildings, and other physical parameters. In modern urban planning practice, this is perhaps the simplest and most reliable way to forecast the state of the acoustic

environment before and after implementing noise-mitigation measures. Using this method allows for the selection of noise protection means on an invariant basis, enabling the correct prioritization and determination of expected acoustic efficiency. Without computer modeling, solving such tasks is practically impossible, making this work highly relevant.

At the same time, designers who have sound field maps have the opportunity to competently and reasonably conduct economic calculations of the cost of noise protection [16].

**Problem statement.** The practical application of this method requires sufficient reliability for forecasting urban noise regimes. To determine the reliability of the applied simulation modeling method, field instrumental measurements of sound levels

generated by a single point source were conducted in the "Peremoha" residential district of Dnipro. The field data were compared with the results of computer simulation. Measurements were taken in the block comprising residential buildings No. 8, 11, 15, 17, and 17A on Hetmana Petra Doroshenka St..

This study aims to determine the reliability of the simulation model for sound propagation in urban areas and evaluate the suitability of a specifically developed software product for cartographic forecasting of urban noise pollution.

### Main material and results.

To achieve the goal, we formulated and solved the following tasks:

1. The existing noise levels spreading from the applied single source (dodecahedron) DSh1 in the adjacent territory of the residential block No. 8, 11, 15,

17 and 17A on Hetmana Petro Doroshenko Street were determined by the method of field instrumental research (Fig. 1).

2. A cartographic forecast of noise pollution from DSh1 was compiled for the adjacent territory of the residential block on Hetmana Petro Doroshenko Street - the territory of the residential development located near the surveyed enterprise.

3. The results of the forecast of noise pollution of the residential development on Hetmana Petro Doroshenko Street were compared with the results of field instrumental measurements.

4. The degree of correspondence of the results of the calculation of sound fields obtained using the simulation model to the instrumentally measured values of sound levels was determined. The comparison of the obtained results was performed using well-known methods of regression and correlation analysis.



Figure 1 Layout of sound level measurement points in a residential area of Dnipro.

**Research methodology used:** the sound (sound pressure) levels of the omnidirectional single point emitter (dodecahedron) DSh1 were determined by the method of full-scale instrumental measurements at the calculated points on the territory of the residential block on Hetmana Petra Doroshenko Street (Fig. 1). The omni directional sound source DL 301 (Dodecahedron Loudspeaker, by amplifier D 301) manufactured by "LOOK-LINE" (Italy) was used as the noise source (DSh1). Acoustic measurements were carried out using integrating sound level meters "OKTAVA - 101".

Using a special computer program, a forecast of the noise regime of the studied territory was made (Fig. 2).

The configuration of the residential development of the surveyed territory was taken according to the data of space photography of the area (Fig. 1). The dimensions and mutual location of DSh1, as well as adjacent buildings, were specified using a laser rangefinder "LEICA - A8".

The initial data for calculating the correlation coefficient between the obtained results of field instrumental measurements and the data of the compiled cartographic forecast (simulation model) of

the noise regime of the surveyed residential area are given in Table 1 below. Fig. 3 and Fig. 4 present the results of the analysis of variance of the studies and

compare the results of field instrumental measurements and the cartographic forecast of noise pollution of the residential area.

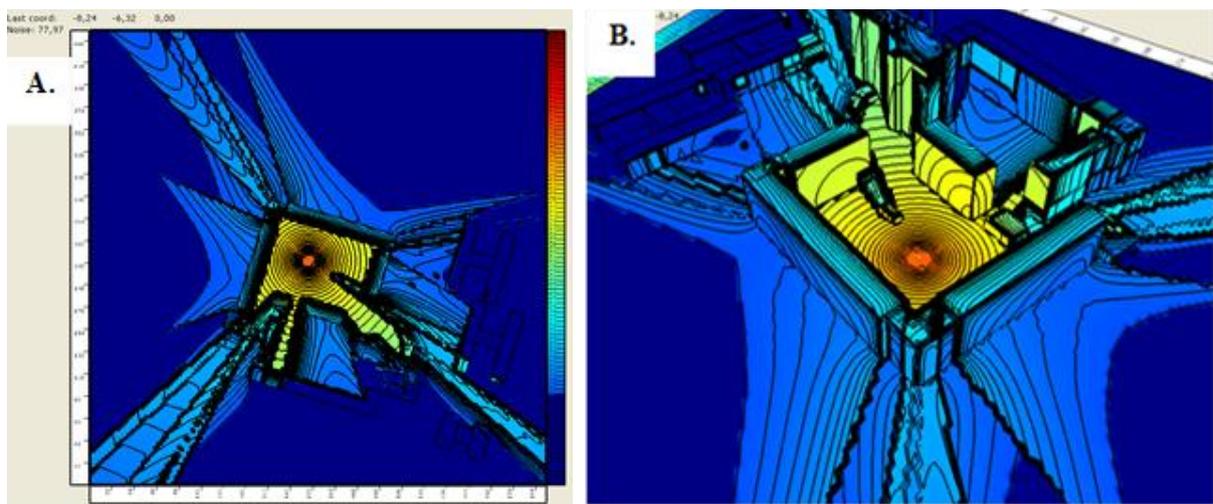


Figure 2 - Cartographic forecast of the noise regime of the territory of the surveyed residential building:  
A - top view, B - axonometric projection

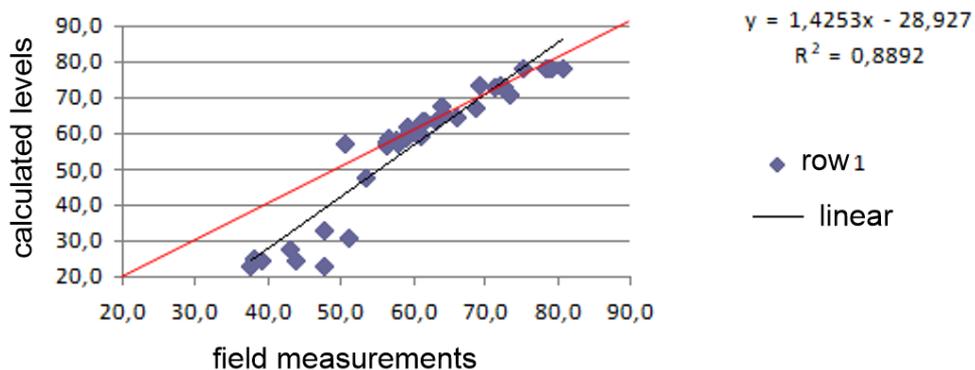


Figure 3 - Analysis of variance research

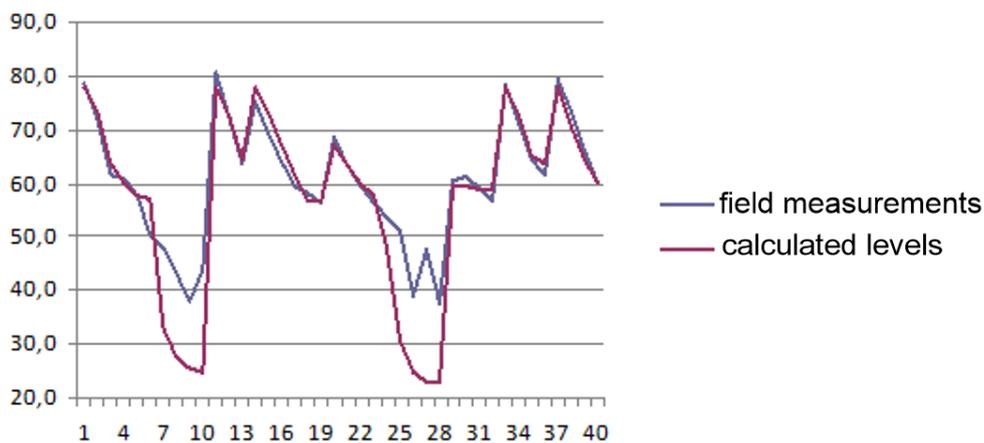


Figure 4 - Comparison of the results of field instrumental measurements and cartographic forecast of noise pollution in the territory

**Table 1 Calculating the correlation coefficient**

Measurement point	Natural levels, dBA, X	Design levels, dBA, Y	X x Y	X <sup>2</sup>	Y <sup>2</sup>
2	78,5	78,0	6121,8	6159,9	6084,0
3	72,0	73,2	5272,9	5188,9	5358,2
4	61,5	63,5	3905,6	3782,8	4032,3
5	60,9	60,2	3666,9	3710,3	3624,0
6	57,7	57,9	3338,5	3324,7	3352,4
7	50,6	57,1	2892,1	2565,4	3260,4
8	48,0	33,1	1587,3	2299,5	1095,6
9	43,1	27,6	1188,8	1855,1	761,8
10	38,1	25,4	968,4	1453,7	645,2
11	44,1	24,8	1092,6	1940,9	615,0
12	80,7	78,0	6294,5	6512,2	6084,0
13	72,5	72,6	5263,0	5255,3	5270,8
14	63,6	64,5	4101,7	4044,0	4160,3
15	75,1	78,0	5857,4	5639,2	6084,0
16	69,3	73,1	5064,2	4799,5	5343,6
17	63,9	67,3	4303,7	4089,3	4529,3
18	59,4	61,6	3656,4	3523,3	3794,6
19	58,0	56,9	3302,6	3368,9	3237,6
20	56,4	56,7	3195,9	3177,1	3214,9
21	68,7	67,0	4601,7	4717,3	4489,0
22	63,2	63,3	4002,4	3997,9	4006,9
23	59,6	60,0	3578,4	3557,0	3600,0
24	56,5	57,7	3261,2	3194,5	3329,3
25	53,6	47,6	2550,0	2869,8	2265,8
26	51,1	30,8	1574,6	2613,5	948,6
27	39,1	24,8	970,4	1531,0	615,0
28	47,8	23,0	1099,0	2283,2	529,0
29	37,7	23,2	874,8	1421,8	538,2
30	60,6	59,6	3612,9	3674,7	3552,2
31	61,2	59,4	3635,1	3745,1	3528,4
32	59,1	58,9	3480,5	3491,9	3469,2
33	56,8	58,7	3334,4	3226,8	3445,7
34	78,3	78,0	6107,0	6130,1	6084,0
35	71,4	72,7	5188,7	5093,9	5285,3
36	64,3	65,2	4195,2	4140,1	4251,0
37	61,7	63,5	3918,2	3807,4	4032,3
38	79,2	78,0	6177,4	6272,3	6084,0
39	73,3	70,6	5174,6	5372,1	4984,4
40	66,0	64,4	4247,7	4350,5	4147,4
41	60,2	60,1	3616,3	3620,6	3612,0
Average	60,6	57,4	3656,9	3795,0	3583,6

**Conclusions.**

The correlation coefficient  $r = 0.889$  indicates a fairly high feedback between the results of field instrumental measurements and the cartographic forecast of the noise regime of the territory of the surveyed residential development. The required number of observations to determine the degree of connection between two groups of comparable sound level values can be determined by the following formula:

$$N = \frac{9 - 18r^2 + 9r^4}{\Delta^2}$$

where  $r$  is the correlation coefficient;  $\Delta$  is the marginal error that the researcher considers possible to allow.

$$N = \frac{9 - 18 \cdot 0,886^2 + 9 \cdot 0,889^4}{0,095^2}$$

Therefore, in order to obtain the required accuracy, 12 observations are required.

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## Оцінювання надійності моделей імітаційного розповсюдження шуму на території забудови

**Анотація.** У сучасних умовах шум є одним із домінуючих факторів, що негативно впливають на міську екосистему і, як наслідок, на здоров'я міського населення. Дія шуму знижує продуктивність праці та ефективність відпочинку людей, є однією з основних причин нервових розладів, суттєво знижує рівень якості та безпеки їхньої життєдіяльності. Метою визначення надійності складання імітаційної моделі розповсюдження звуку в міській забудові. Методи дослідження: метод натурних інструментальних вимірювань; картографічний метод прогнозування шумового забруднення від джерел шуму з побудовою 3D моделі звукових полів та статистичні методи обробки і оцінки результатів дослідження. Результати дослідження свідчать про наявність тісного зв'язку між результатами польових інструментальних вимірювань та картографічним прогнозуванням шумового режиму на досліджуваній житловій території. Розрахований коефіцієнт кореляції становив  $r = 0,889$ , що вказує на високий рівень узгодженості між порівнюваними масивами даних. Крім того, встановлено, що необхідна кількість спостережень для визначення ступеня кореляції між двома групами порівнюваних значень рівнів звуку становить 12 спостережень.

**Ключові слова:** моделювання, розповсюдження шуму, кореляційний аналіз.

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Надіслано до редакції:	05.12.2025	Прийнято до друку після рецензування:	18.12.2025	Опубліковано (оприлюднено):	26.12.2025
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Suggested Citation:

APA style

Sankov, P., Zakharov, Y., Zakharov, V., & Tkach N. (2025). Assessing the reliability of noise simulation models in a built-up area. *Academic Journal Industrial Machine Building Civil Engineering*, 2(65), 91-96. <https://doi.org/10.26906/znp.2025.65.4216>

DSTU style

Assessing the reliability of noise simulation models in a built-up area / P. Sankov et al. *Academic journal. Industrial Machine Building, Civil Engineering*. 2025. Vol. 65, iss. 2. P. 91-96. URL: <https://doi.org/10.26906/znp.2025.65.4216>.