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THE THIRD DIMENSION (3D) IN THE PRESENTATION OF NOISE DISTRIBUTION ON BUILDING FACADES – AS SHOWN BY THE EXAMPLE OF A FRAGMENT OF A RESIDENTIAL ESTATE IN POZNAŃ

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Abstract: The work attempts to visualise the distribution of the acoustic wave in an urban area using a 3D model. The primary objective was to present the level of noise on facades of buildings. The studied area was a fragment of a residential estate in Poznań. The geometry of the topographical objects was obtained from the GBDOT. A three dimensional model of the building development of the area was made using the Google SketchUp program. The input data for the interpolation of isophones were taken from direct field measurements. Attempts were made to obtain measurement data from road sources. The obtained values were averaged for 16 hours of the daytime. Ranges of the individual noise levels determined by the isophones were marked in colours. The applied software enables displaying the noise distribution on building facades, viewing it at various angles and making animations. The work presents the use of a 3D model for an urban area. The model is expected to improve the information database regarding noise hazards in a built-up area.

Keywords: noise mapping, 3D model, environmental information, sound visualization, public participation, thematic cartography

INTRODUCTION

Sound phenomena are gaining an increasing significance in the natural environment. The World Health Organization Report (2009) unequivocally points to the medical aspects of increased sound levels in the environment and their impact on human life. It sets the human health hazard at 65 dB(A) for daytime and at 55 dB(A) for night time. The negative impacts of that phenomenon are particularly perceived in urbanised areas. Therefore, increasing the awareness of urban inhabitants regarding the negative impact of noise pollution and its influence on human health seems to be of paramount importance.

The development of noise maps is mandatory in Europe: they must be prepared every five years. They are made by acoustics experts and are considered to be an important data storage tool (Schiewe, Weninger 2013). They provide the basis for the drawing up of action plans aimed at reducing the negative impact of noise on the human living environments.

The Environmental Noise Directive 2002/49/EC requires that acoustic maps should be drawn up also to inform and consult the public about noise exposure and its effects. Pursuant to the provisions of the Directive, the respective knowledge should not only be available to experts: it should be provided to the general public in a clear and comprehensible way. Thus, acoustic maps may become the main source of informing the public about noise hazards.

The Minister of the Environment Regulation of 1 October 2007 (Official Journal of 2007, No. 187, clause 1340), implementing the provisions of Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise (Official Journal of the European Communities L 189 of 18 July 2002, page 12; Official Journal of the European Communities, Special edition in Polish, chapter 15, volume 7, page 101) sets out the scope of data to be included in an acoustic map and the layout and presentation method, in order that they could be used for the purposes of:

– state monitoring of the environment,
– development and updating of environmental noise protection programmes,
– informing the public about noise exposure.

This paper focuses on the third theme, that is producing analyses aimed at informing the public. The studies of Schiewe and Weninger (2013) indicate that the isophones commonly used in noise maps are usually difficult to read and interpret for an 'average' public user. An alternative method of presenting acoustic wave propagation is by using colours. The cartographic presentation of noise indicators and selection of colours was regulated pursuant to ISO standard 1996-2 ('Acoustics − Description and measurement of environmental noise'). The amended ISO 1996-2:2007 standard, however, does not include information on cartographic presentation anymore. Nevertheless, in practice, the layout (and in particular the colours) recommended in the older version of the standard is still commonly used.

Therefore, there is a clear need to improve the efficiency of noise maps in terms of their comprehensibility and to increase the participation of the public in the process of their development and subsequent use. In order to improve and facilitate the process of communication between the public and spatial planning and environmental management professionals it is necessary to increase the degree of user interaction. This may be done by providing users with the possibility to 'move around' in an urban space (Hanzel 2007). This may be achieved, for example, by using three dimensional imaging, which has a long tradition in urban planning. However, it is most commonly used for the purpose of visualisation and not for spatial analyses. The 2.5D data structures currently used in GIS have certain limitations which make complete and accurate spatial analyses difficult or even impossible. This in particular refers to urban areas, where various phenomena occur with greater intensity and are mutually interactive (as far as noise distribution is concerned, the acoustic wave is modified due to the phenomena of refraction, absorption or reflection of the wave from an obstacle). The problems of modelling and mapping of acoustic wave propagation in an urban environment have, among others, been analysed by Kang (2007), Kurkula and Kuffer (2008) as well as by Kang-Ting and Min-Der et al. (2009).

A majority of the currently available acoustic maps are two dimensional (2D). They present the value of a noise level at a specific altitude (4 m above ground level). In reality, however, the sound spreads in all directions. 2D maps make it impossible to differentiate between the noise level occurring at different altitudes (this, for example, refers to multi-storey residential buildings). With regard to the presentation of acoustic wave propagation, the advantage of 3D maps is the fact that they reflect the noise in all directions. In this way, they can help better understand the phenomenon and the related hazards. A two-dimensional presentation method is less obvious to the reader than a three-dimensional (3D) model, which represents the human perception of reality (Olszewski, Gotlib 2013).

Since 2012, it has been required that the method of presentation of acoustic maps should enable three-dimensional imaging of the building development layout and the values of sound levels on the facade of a selected building at a scale not higher than 1:1,000 (Minister of the Environment Regulation 2007a). As a result, the necessity to present noise on a 3D model was legitimised. Currently, along with the typical, two-dimensional acoustic maps, 3D images are developed for selected fragments of urban areas. These take the form of static or animated images.

Nevertheless, further research and trials are required to ensure that 3D images of noise propagation are comprehensible to non-professional readers.

STUDY AREA AND WORK METHODS

The selected area of the study was a fragment of the Osiedle Stefana Batorego residential estate in Poznań (Poland). The prevailing development is four- and five-storey, with a residential function.

According to the research carried out by Butler (2004), Zannin et al. (2013) and by Kubiak, Ławniczak (2015), vehicle noise currently accounts for the largest share of noise emissions. This is also confirmed by the acoustic map drawn up in 2012, commissioned by the Municipal Authorities of the City of Poznań (Makarewicz et al. 2012).

Due to the high cost of obtaining the data, acoustic maps are made on the basis of a calculation model using the L_{DWN} indicator. It represents the long-term average level of noise determined during all days of the year, including daytime (06:00–18:00), evening (18:00–22:00) and nighttime (22:00–06:00). Making an acoustic map using field measurements is not common practice. The results of field measurements are, however, used to:

– obtain input data regarding noise source parameters,
– calibrate the calculation model,
– partially validate the calculation results obtained (conformity of the results with the actual situation).

The basis for this work was the results of direct field measurements of noise levels. In order to present the obtained results in graphic form, the L_{Aeq16} indicator for vehicle noise was calculated. This is used to determine and monitor the conditions of using the environment with reference to a single day.

Ranges of individual isophones from the acoustic map were verified by direct survey field measurements. The task was carried out using calibrated measurement instruments, namely the sound level meters SONOPAN DSA-50, IM-02/m and Brüel & Kjær 2236A, installed at an altitude of 1.5 and 4.0 m above ground level. During the measurements, we tried to include only traffic (vehicle) noise, however in the built-up parts of the residential estate located further from the roads it was difficult to ensure unambiguity in that respect (problems with unequivocal identification of the source of noise, reflection of noise waves from buildings, interference, etc.).

On the basis of the existing data and survey measurements, the pattern of isophones was drawn up (a vehicle noise immissions map) – Figure 1. Pursuant to the provisions of the Minister of the Environment Regulation of 1 October 2007, 5 dB sound level intervals were adopted. The isoline method was used for presentation purposes. In order to emphasise the general trend of changeability of the phenomenon, the spaces between the isolines were coloured. Taking the amended ISO standard into account, which does not anymore include information on the colours to be used in the cartographic presentation, different colours, other than those commonly used on acoustic maps, were applied. We also purposefully located the buildings in such a way that they covered the isophones. This was done in order to avoid the impression that these data refer to the inside parts of the buildings.

The geometry of the topographic objects of the studied fragment of the residential estate was obtained from the Topographical Objects Database (BDOT). The BDOT is a very useful tool and a source of input data for various types of planning and environmental management studies. The possibilities offered by the BDOT have been described, among others, by Medyńska-Gulij (2013), Olszewski and Gotlib (2013). The data available in the BDOT were also used to develop the three-dimensional model of the building development. For the purpose of 3D imaging, we used the free Google SketchUp software (Fig. 2). The applied Level of Details (LOD) model was based on the international 3D city model for city modelling, 3D-CityGML (OGC Specifications 2012). At the LOD1 level of detail, buildings are presented as simple blocks with generalised geometry and flat roofs.

The work was an attempt at the visualisation of acoustic wave distribution in an urban area using a 3D model. The primary objective was to find a good way to

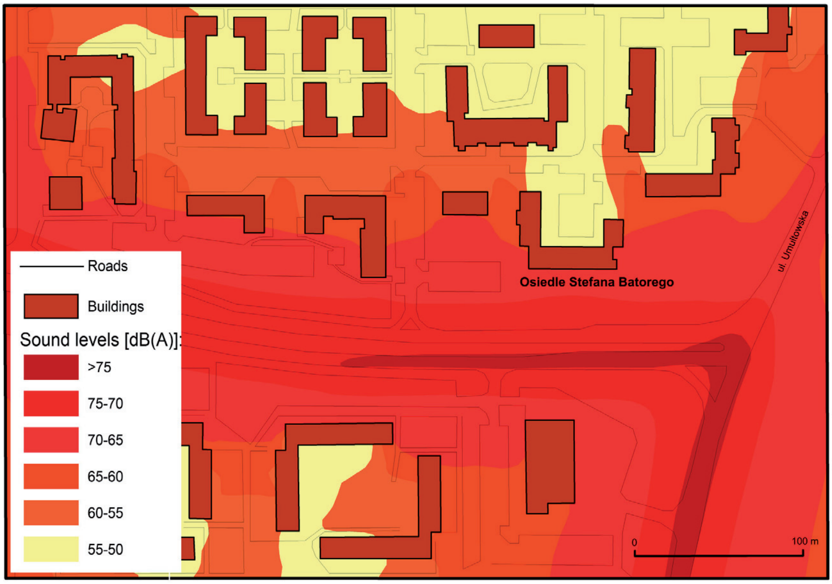

Fig. 1. Vehicle noise immissions map

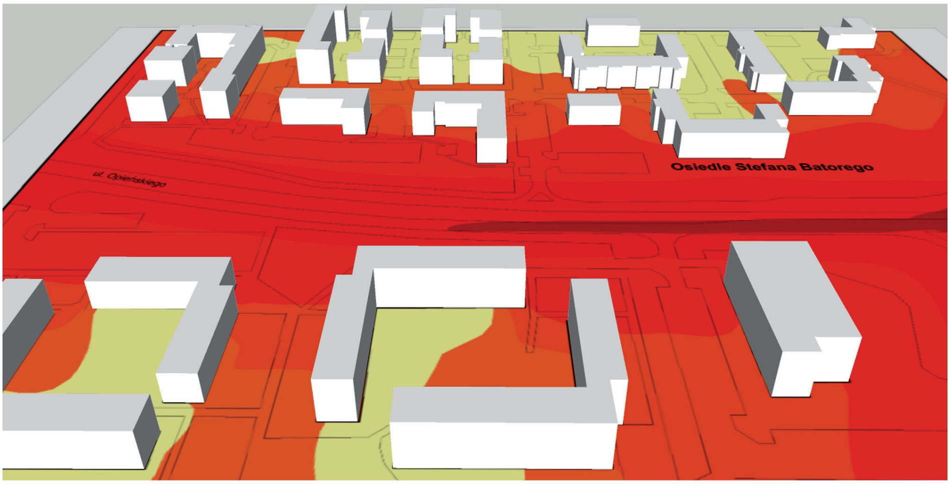

Fig. 2. The 3D model for a fragment of the os. Batorego residential estate in Poznań superimposed on the vehicle noise immissions map

present the noise level on building facades. In the presented 3D model, in order to visualise the distribution of noise on building facades and to improve the readability of the image, the vertical scale applied was twice as large as the horizontal scale.

The obtained results showing the spatial distribution of noise originate from direct field measurements. For the purpose of the research it was important to determine the dimensions of the measurement grid, as its density is closely related to the time required to carry out the measurements. The dimensions of the measurement (calculation) grid impact the accuracy of identification of the acoustic state of the environment (spatial distribution of noise). In order to evaluate noise distribution on the building facade, Kucharski (2011) recommends a grid of 10 × 10 m.

The measurement points along the individual buildings were located every 10 m. In the vertical section, the measurements were carried out at a distance from 1 to 2 m from the external wall (in order to minimise the impact of wave reflection on the sound level value), at an altitude of 1.5 and 4.0 m above ground level and, wherever possible, on the last storey of the buildings. Such location of the measurement points was considered sufficient, since the height of the buildings in the study area is 12–15 m. In the course of the research work, the method of direct noise measurements with a sampling scheme was used (Minister of the Environment Regulation 2007b), therefore three 10-minute observations (samples) were carried out at the measurement points. The research works were conducted on working, rain-free days, in the period between May and October. Due to the failure of attempts at developing a model yielding a calculation accuracy of 1 dB, an uncertainty level of environmental noise measurements up to ±3 dB is generally accepted (Kucharski 2011). In the course of the measurements, the difference between individual readings amounting to approx. 2 dB was considered satisfactory. On the basis of the obtained data, the following indicator for the entire daytime (16 hours – from 6:00 to 22:00) was calculated:

$$L_{AeqT} = 10\log\left(\frac{1}{T}\sum_{i=1}^{n} t_i 10^{0,1L_{Ai}}\right)$$

where:

L_{AeqT} – equivalent level of sound A in dB referred to the time T,
L_{Ai} – average level of sound A in dB in the following signal sample (time t_i),
t_i – time for which L_{Ai} was determined in minutes or seconds,
T – evaluation time in minutes or seconds (T = 16 hours of the daytime, i.e. from 6:00 to 22:00).

Evaluation of noise in urbanised areas is very difficult. In the field of waves reflected many times from building facades, the obtained data may be characterised by relatively low accuracy (Kucharski 2011). For the purpose of the graphic presentation of the spatial distribution of noise on building facades (3D), we assumed the same noise intervals as in the case of the immissions map, i.e. every 5 dB (50–55, 55–60, 60–65, 65–70, 70–75 and > 75 dB).

We also applied the same method of cartographic presentation, using the same set of colours as in the case of 2D imaging.

Figure 3 shows the graphic presentation of the obtained data. The 3D presentation was made using free Google SketchUp software. This enables it to be viewed from various angles through the rotation of the image. The software also enables animations to be created.

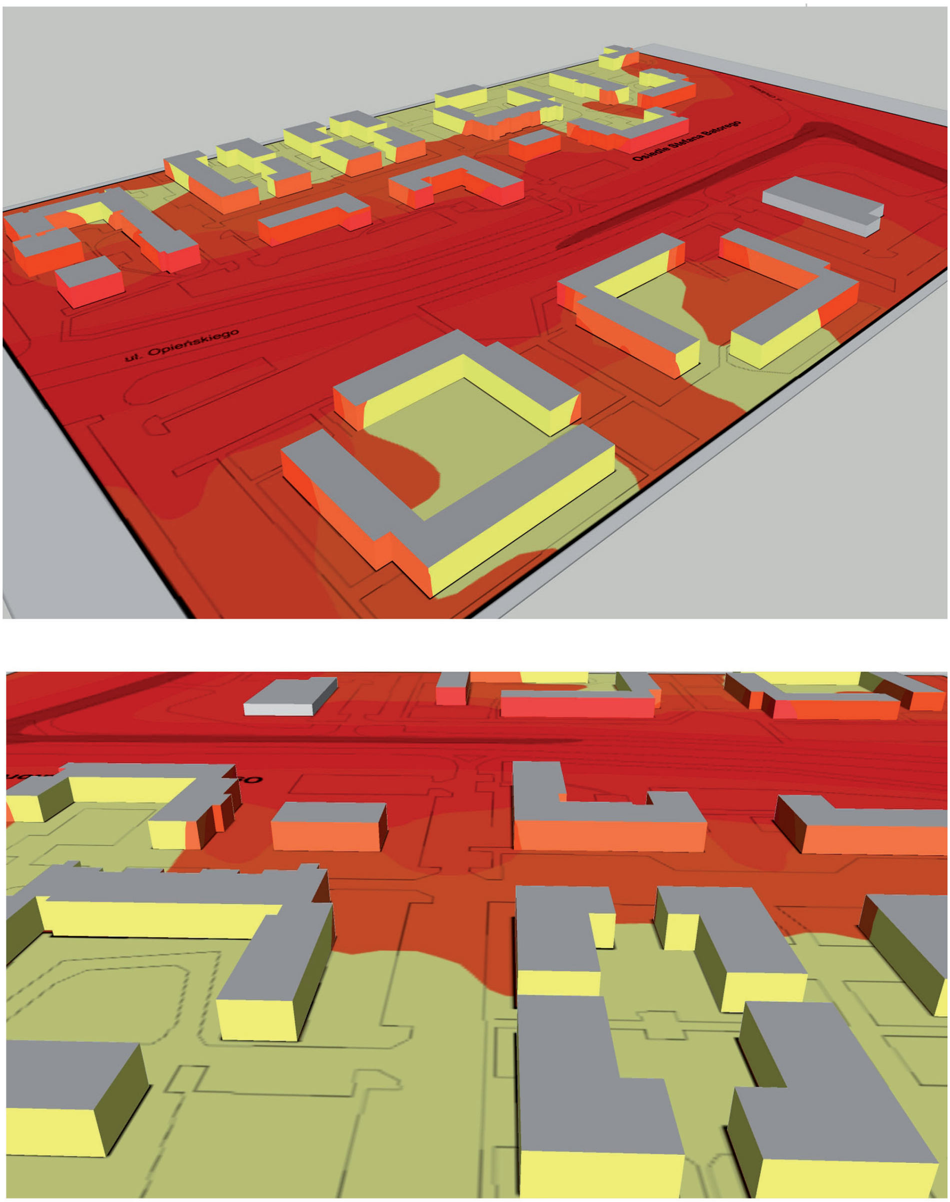

Fig. 3. Noise distribution on building facades (os. Batorego residential estate, Poznań − fragment)

CONCLUSIONS

The mapping of phenomena occurring in the natural environment should not only be used by a small group of professionals: its purpose is to also provide information in a format comprehensible to a non-professional reader. In order to increase public participation in the process of development and use of spatial data, it is necessary to continue the search for new means to make the message more comprehensible and attractive.

Three-dimensional imaging is a good solution, as it reflects the actual picture in a more easily readable way, in line with human perception. The advantages of using the third dimension can be seen not only in the visualisation but also in the spatial analyses made using GIS systems. 3D visualisation may support decision-making processes related to spatial planning and environmental management. It may also improve the accuracy of conducted analyses.

Noise maps are generated on the basis of calculated long-term indicators (L_{DWN}), referring to the whole year. From the point of view of a prospective user, it would be best to have access to information on noise distribution during the individual hours of the day. However, this is not possible without establishing permanent monitoring points, which is rather expensive.

In this study we used an indicator referring to the time of the day (16 hours). The indicator was calculated on the basis of direct field measurements. Hence, the graphic presentation represents the distribution of sounds on building facades for the calculated L_{Aeq16} index for an average work day.

For graphic purposes, use was made of the free Google SketchUp software. It enables the image to be rotated, viewed from different angles and for attractive animations to be made. An indisputable disadvantage of such a visualisation method is the noticeable change of the applied colours. Along with image rotation, the lighting of objects changes, which may result in a different perception, thus making proper interpretation of the presented data more difficult.

While presenting phenomena which are hazardous to human health, attention should also be paid to the adequate generalisation of the image. Current 3D programs (including free ones) offer the possibility of accurate reflection of the reality. Using them to present negative phenomena may contribute to increased public participation, which may result in an increasing number of complaints being filed. These may often be unjustified, since acoustic maps present averaged values. For this reason, we decided to use the LOD1 model in the present work.

With no doubt, 3D images make the message more attractive, however, in order for them to fully perform their role regarding the provision of spatial information, further trials and experiments are required.

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kartograficzna propagacji fali akustycznej w obszarze zabudowanym/The cartographic visualisation of the propagation of acoustic waves in a built-up area).

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REFERENCES

Butler D., 2004: *Noise management: Sound and vision*, Nature 427(6974), 480−482, DOI: 10.1038/427480a.

Hanzel M., 2007: *Information technology as a tool for public participation in urban planning: a review of experiments and potentials*, Design Stud. 28, 289−307.

Kang J., 2007: *Urban Sound Environment*, Taylor & Francis, Oxford.

Kang-Ting T., Min-Der L., Yen-Hua C., 2009: *Noise mapping in urban environments: a Taiwan study*, Appl. Acoustics 70, 64−72, DOI: 10.1016/j.apacoust.2008.11.001.

Kucharski R.J., 2011: *Wytyczne opracowania map akustycznych*, Główny Inspektorat Ochrony Środowiska, Departament Monitoringu i Informacji o Środowisku, Warszawa.

Kubiak J., Ławniczak R., 2015 [published online]: *The propagation of noise in a built-up area (on the example of a housing estate in Poznań)*, Journ. of Maps, DOI: 10.1080/17445647.2014.1001801.

Kurkula V.K., Kuffer M., 2008: *3D Noise Modeling for Urban Environmental Planning and Management*, Real Corp, Vienna.

Makarewicz R., Kokowski P., Gołębiewski R., Kaczmarek T., Pękala P., Kowalczuk M., Dzierża B., Gałuszka M., Pakuła T., Nowakowski T., Pajewski P., Kaszyńska D., Olejniczak J., Berezowska-Apolinarska K., Lisek P., 2012: *Mapa akustyczna miasta Poznania 2012*, Urząd Miasta w Poznaniu, AkustiX Sp. z o.o., Poznań.

Medyńska-Gulij B., 2013: *Database of Topographic Objects as a Ground for Creation the Spatial Development study in Polish Communes*, Geoinf. Polon. 12, 45−52, DOI: 10 2478/v.10300-012-0012-3.

OGC Specifications, 2012: *OGC City Geography Markup Language (CityGML) Encoding Standard*, Open Geospatial Consortium.

Olszewski R., Gotlib D., 2013: *Rola bazy danych obiektów topograficznych w tworzeniu infrastruktury informacji przestrzennej w Polsce*, GUGiK, Warszawa.

Minister of the Environment Regulation, 2007a: Rozporządzenie Ministra Środowiska z dnia 1 października 2007 r. w sprawie szczegółowego zakresu danych ujętych na mapach akustycznych oraz ich układu i sposobu prezentacji (Dz.U. 2007 Nr 187, poz. 1340).

Minister of the Environment Regulation, 2007b: Rozporządzenie Ministra Środowiska z dnia 2 października 2007 r. w sprawie wymagań w zakresie prowadzenia pomiarów poziomów w środowisku substancji lub energii przez zarządzającego drogą, linią kolejową, linią tramwajową, lotniskiem, portem (Dz.U. 2007 Nr 192, poz. 1392).

Schiewe J., Weninger B., 2013: *Visual Encoding of Acoustic Parameters − Framework and Application to Noise Mapping*, The Cartographic Journ. 50, 4, 332−344, DOI: http://dx.doi.org/10.1179/ 1743277412Y.0000000026.

World Health Organization, 2009: *Night Noise Guidelines for Europe*, WHO, Copenhagen.

Zannin P.H.T., Engel M.S., Fiedler P.E.K., Bunn F., 2013: *Characterization of environmental noise based on noise measurements, noise mapping and interviews: A case study at a university campus in Brazil*, Cities 31, 317−327, DOI: 10.1016/j.cities.2012.09.008.