Wiadomości Statystyczne. The Polish Statistician, 2023, *68*(12), 83–92 https://doi.org/10.59139/ws.2023.12.5
Dyskusje. Recenzje. Informacje / Discussions. Reviews. Information

Improving research on environmental noise pollution and its impact on the population in the context of sustainable development

Doskonalenie badań nad zanieczyszczaniem środowiska hałasem i jego oddziaływaniem na ludność w kontekście zrównoważonego rozwoju

1. Introduction

In the early decades of the 21st century, environmental statistics became one of the main pillars of information resources which describe the world we live in, prepared by official statistics services for individual, corporate and institutional users. Data sources are also being enhanced, which not only widens the scope of the presented information and statistical analyses, but also reduces the labour intensity experienced by producers of official statistics. One of these extensions involves the study of population exposure to noise in cities with more than 100,000 inhabitants in Poland, planned to be carried out in 2024 by Statistics Poland. The undertaking evolved from an experimental project into a target solution. Strategic noise maps prepared by cities with a population exceeding 100,000 constitute the source of data, as does the number of people living in a specific building to which a spatial location can be assigned based on data collected in the 2021 Census. These two administrative records enable the preparation, conduct and publication of survey results without the additional involvement of respondents, which is consistent with the direction of development that official statistics is set to follow (Allin, 2021).

In the context of the study of the population's exposure to noise, the direction of development of official statistics related to the spatial reference of the observed phenomena is significant, as it enables the recorded measures to be combined with the precise geographical location of the surveyed units, e.g. the population. The hitherto method of referring the measures to spatial location has been implemented by apportioning the population among the administrative divisions. The current state of research in the field of census taking and noise assessment offers the possibility of combining them and relating them to a wide range of population, ensuring precise mutual reference. This article explores the new directions of development in this area. Its purpose is to discuss the process of improving statistical research on population exposure to noise pollution in the context of sustainable development with the application of new trends in data acquisition.

2. The progress of research on noise pollution in the EU

The discourse on the need to harmonise various activities aiming to reduce population exposure to noise could be traced back to as early as 1993 in an official document of the European Union, titled *Towards sustainability: A European Community programme of policy and action in relation to the environment and sustainable development*). 'To maintain the overall quality of life' was one of the five actions described in the environmental programme, which included a commitment to measures reducing population exposure to noise. It was formulated as follows: 'No person should be exposed to noise level which endangers health and quality of life' (*Towards sustainability*, p. 56). It can be therefore clearly stated that the documents defining the concept of sustainable development included a clear goal: to reduce noise pollution, which poses a threat to health and quality of life until its complete elimination.

A comprehensive programme for limiting the exposure of the population to excessive noise emissions in the EU was presented in a follow-up document, published in 1996, referring entirely to the issues of noise pollution (Commission of the European Communities, 1996). It quoted the results of the conducted surveys which indicated that 20% of the population of Western Europe experienced negative effects of noise (Commission of the European Communities, 1996, p. 1). The standardisation of the assessment of noise levels relating to its classification, methods of measurement and territorial distribution was soon introduced, as was the obligation of the member states to take clearly defined measures to reduce the level of noise affecting the population. Based on this document, the Environmental Noise Directive (END; 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, further referred to as Directive 2002/49/EC) was prepared and adopted in 2002. The following expectations were formulated: 'Achieving a high level of health and environmental protection is part of the Community policy, and protection against noise is among the adopted goals'. In addition to indicating the need to take measures to minimise the impact of noise, the END also imposed an obligation on member states to prepare strategic noise maps, also referred to as acoustic maps, every five years. By 2022, four editions were prepared: in 2007, 2012, 2017 and 2021. Progress in the measurement methodology can be seen in each successive edition, eliminating any emerging discrepancies in the interpretation of a complex and self-perceived phenomenon. During these two decades, the mandatory territorial scope of strategic noise maps was extended. The minimum population ceiling for towns was lowered from 250,000 to 100,000, thus increasing the population covered by the study and (i) for major roads, the level of over

3 million vehicle passages per year was defined, (ii) for railway lines above 300,000 train passages per year, and (iii) for major airports over 50,000 take-offs and landings per year (Directive 2002/49/EC). The methods of noise level assessment were successively clarified in the subsequent editions of the END. In 2015, a directive was passed specifying the method of measuring and preparing strategic noise maps (Commission Directive (EU) 2015/996 of 19 May 2015 establishing common noise assessment methods according to Directive 2002/49/EC of the European Parliament and of the Council, further referred to as Commission Directive (EU) 2015/996). The document consists of over 800 pages, which is indicative of the complexity of the subject matter and the difficulties in coordinating activities enabling the harmonisation and comparability of the presented results. Moreover, this complexity is multidimensional, where, apart from the technical area related to the measurement methods, the estimation of the number of people exposed to noise is the problematic issue. This topic will be discussed in the next chapter.

3. Contribution of official statistics to research on noise pollution

The key issue in preparing strategic noise maps is the identification of the population affected by excessive noise emissions. In the directives (Directive 2002/49/EC; Commission Directive (EU) 2015/996; Commission Directive (EU) 2020/367 of 4 March 2020 amending Annex III to Directive 2002/49/EC of the European Parliament and of the Council as regards the establishment of assessment methods for harmful effects of environmental noise, further referred to as Commission Directive (EU) 2020/367) and guidelines relating to the methods of developing noise maps (Główny Inspektorat Ochrony Środowiska [GIOŚ], 2021), the focus is laid on acoustic issues that enable the determination of accurate immission maps of road, rail and industrial noise and showing the spatial distribution of pollution in the studied area. However, a reasonable confidence estimation of the population exposed to precisely defined noise levels requires an equally precise allocation of the number of people living in dwellings subject to spatial analysis. This task was entrusted to local governments obliged under the END regulation to prepare strategic noise maps. However, they do not have datasets to accurately determine the number of people living in particular buildings. The information available to local governments on registered residents, based on which the number of residents is estimated, or resulting from detailed records (e.g. for the purposes of waste management) shows significant biases.

The solution proposed in the recommendations (GIOŚ, 2021, pp. 208–210) refers to the information published by Statistics Poland, which in annual cycles provides

the size and structure of the population in territorial breakdown, at the level of gminas (Polish equivalent to communes – NUTS 5). This number should be then distributed in proportion to the number of residential units, considering single-unit, two-unit and other buildings. The estimates prepared in this way are used to determine the number of people exposed to noise in buildings using one of the two methods specified in the END. The first one considers the location of the building together with the directions of exposure of the façade towards the source of the noise, while the other one assigns the population to an address point located within the building.

The above-mentioned methods of estimating the number of people living in specific buildings reveal significant limitations which should be considered when assessing the phenomenon of noise pollution.

To reduce the identified barriers, it becomes necessary to include information provided by official statistics in the process of estimating the number of people exposed to noise according to the location of buildings. The new methods of the 2021 population and housing census, taking into account the location of the residential building, make meeting the requirements for publishing data in a 1 km^2 grid possible, and help develop strategic noise maps with greater accuracy. Another advantageous phenomenon is the synchronisation of the dates of the preparation of both datasets, i.e. five-year periods for the preparation of strategic noise maps (e.g. 2021, 2026, 2031...), with ten-year deadlines for the implementation of censuses (e.g. 2021, 2031...). Acoustic maps can be therefore fed with population data from the most up-to-date census data.

The set of 244 indicators illustrating the 17 Sustainable Development Goals (SDGs) does not directly refer to noise reduction, which can be recognised as a shortcoming. The need to eliminate this type of pollution is clearly indicated in the documents constituting the sustainable development initiative (Towards sustainability), which encourages a precise reference to it in the implementation process. References to noise pollution can also be found in research works presenting composite indicators of sustainable development (Lafortune et al., 2022; Sachs et al., 2022), but only as a supplement to the categories of pollution listed in the objectives (3.9, 6.3, 14.1), i.e. air and water, or housing conditions, e.g. urban sprawl and overcrowded settlements (Lafortune et al., 2022, pp. 53, 96). The lack of noise indicators in UN documents can be explained by the complexity of the issue of measuring this phenomenon and the difficulties in implementing them on a global scale.

However, the services of official statistics have taken steps to fill the existing gap. As part of the project entitled *On the 2030 Agenda and SDGs*, they present an

indicator called *Population living in households considering that they suffer from noise*. This indicator shows that the share of people experiencing inconvenience due to this reason was constantly decreasing: from 16.2% in 2010 to 12.5% in 2019 (Główny Urząd Statystyczny, 2022). The source of these data is a survey coordinated within the EU called EU-SILC (European Union statistics on income and living conditions; Eurostat, n.d.). The selection of the research sample is representative, so we can legitimately apply its results to the entire population. It should be noted here that they reflect the subjective perception of the surveyed community whose representatives are selected irrespectively of the noise indicators. The scope of this study covers many social areas defined by the European Pillar of Social Rights initiative. Therefore, the postulate of transposing the subjective assessment of noise pollution to the entire population becomes of significant importance in this study. It is also worth adding that strategic noise maps encompass only 27.8% of the population of Poland covered by the fifth edition of the survey carried out in cities with more than 100,000 inhabitants in 2021.

The next chapter discusses the prospects of integrating the trends in the development of official statistics and research on noise pollution, thus enabling a wider exploration of its impact on the population from the health, economic and environmental perspectives.

4. Research project on exposure of the population to noise in cities exceeding 100,000 inhabitants, carried out by Statistics Poland

The guiding idea behind the research project entitled *Exposure of the population to noise in cities of more than 100,000 inhabitants*, launched by Statistics Poland was to extend the scope of reliable statistics describing the impact of selected pollutants on humans using sources of data that do not impose much burden on the respondents. The aim was to indicate the number of people exposed to selected categories of noise in cities with more than 100,000 inhabitants in a uniform and comparable for the country way. The study combined strategic noise maps based on a well-established methodology, presenting the excess levels of permissible road, tram, railway, aviation and industrial noise with reliable data on the number of people living in individual buildings with assigned geographical locations (X, Y).

The study was carried out in accordance with the assumptions formulated for research projects: from experimental statistics to statistical production. In 2020, an experimental project was launched in cooperation with three cities – Gdańsk, Gdynia and Bydgoszcz, which provided a strategic noise map from the 2017 edition for analytical purposes. These maps were compared with the results of an

experimental project entitled *Development of a method for estimating the size and structure of the population* according to the actual place of stay, considering the criterion of staying and absence of 12 months or more according to the territorial division and a 1 km^2 grid. It identified sources of data that could be used in estimating the population size in relation to a 1 km^2 grid in accordance with the requirements set out by the European Commission (Commission Implementing Regulation (EU) 2018/1799 of 21 November 2018 on the establishment of a temporary direct statistical action for the dissemination of selected topics of the 2021 population and housing census geocoded to a 1 km^2 grid, further referred to as Commission Implementing Regulation (EU) 2018/1799). The results of the conducted analyses were presented to the Methodological Commission of Statistics Poland, who acknowledged the need to include the proposed experimental study in statistical production starting from 2024. The administrative collections will be used as the source material. Qualitatively verified acoustic maps prepared as of 31 December 2021 will be provided to Chief Inspectorate of Environmental Protection by local governments and infrastructure operators obliged to prepare strategic noise maps. The database of address points with assigned geographic coordinates (X, Y) and the estimated population, calculated using the 2021 census data, will be obtained from official statistics resources. Such a list will be used to prepare many comparative analyses in a unified and coherent manner. Breakdowns by noise pollution category and by territory will be available.

The experience gained will be subject to further research in this area and new solutions will be proposed or existing ones will be strengthened with the use of new data sources, which is considered in the next chapter.

5. Further research development

The integration of two datasets, i.e. the size and structure of the population related to address points with acoustic measurements from strategic noise maps, conducted by official statistics services, creates a synergistic potential for obtaining additional results otherwise unattainable from separate surveys. It should be emphasised here that the current state of their maturity resulted from the development of methodological works as well as from technological progress. The methodological development of strategic noise maps, manifested by a precise description of noise intensity assessment methods (Commission Directive (EU) 2015/996) enables the comparison of the results provided by different producers of noise maps. Statistics Poland, following the EU requirement to map the population in a 1 km^2 grid in the 2021 census (Commission Implementing Regulation (EU) 2018/1799), used spatially

located references to buildings. These two trends combined into one research bundle create new cognitive opportunities absolutely necessary to reduce environmental noise pollution. This issue will be dicussed from an environmental, health and economic perspective.

The environmental perspective of the development of noise research refers to two matters: the precise addressing of the studied phenomena, in which population estimates can be related to the spatial location of residence with greater accuracy, and to the expansion of the scope of research. Local governments in cities with more than 100,000 inhabitants used official statistics estimates showing the number of people assigned to a broad administrative division. Moreover, the administrators of the main roads, railway lines and airports, who are obliged to prepare strategic noise maps, encounter difficulties in preparing precise estimates for the number of people exposed to noise generated by the respective means of transport. The new formula of integrated research overcomes these limitations. The precise assessment of the effectiveness and efficiency of the measures taken to reduce the impact of noise is also an interesting research topic. Another area of application of the new indicators may be the unification of the method of measuring noise pollution in terms of two sustainable development goals: 3 – *Ensure healthy lives and promote well-being for all at all ages* and 11 – *Make cities and human settlements inclusive, safe, resilient, and sustainable*.

The health perspective in the development of research on noise is related to the possibility of launching many studies examining the impact of noise on the health of a population throughout the whole country. The initiated studies pertaining to selected locations where data on the degree of noise intensity were available (Argys et al., 2020) can be extended to a wider sample of the population. An opportunity arises to precisely study the incidences of the already recognised disorders (Basner et al., 2014), such as ischemic heart disease (IDH), high annoyance (HA) or significant sleep disorders, and the resulting consequences. Discovering correlations between morbidity and residential locations exposed to nuisance noise of various categories (road, rail, tram, air and industrial) will also allow the identification of the potential hidden associations between noise and morbidity (Hammer et al., 2014).

The economic perspective of the development of noise research is also promising. The above-mentioned possibilities of carrying out research on the effectiveness of the preventive measures aimed at minimising or eliminating the impact of noise on the environment make it possible to select the most effective ones. Another aspect of economics-based research is the attempt to determine the costs of the effects of noise pollution and compare them with the measure of the value of goods and services produced by a specific community of a country or region, i.e. with the Gross

Domestic Product (GDP). Such attempts have already been made and certain approximations were even quoted (King et al., 2011, p. 756). However, after reaching the indicated sources (Cvetković & Praščević, 2006, p. 22), it turns out that the calculation of the share of 'the costs caused by noise pollution' in GDP was difficult to find. This issue is cognitively interesting and important for determining further directions for the undertaken activities. Nevertheless, it requires data collection from numerous sources, which should be available to official statistics. Based on such calculations, an attempt may be made to approximate the health costs, the value reduction of real estate due to the exposure of residents to noise, or the expenses incurred to reduce the effects of noise. Thus, the analysis of the economic aspect of noise pollution may become an important direction in further research.

6. Conclusions

Research on environmental noise pollution has a long tradition. The knowledge about its negative impact on the health and the environmental and economic aspects of human life is constantly being extended. The subject of noise reduction has even become a component of the framework constituting the Sustainable Development Goals (*Towards sustainability*). However, a question arises whether the previously expressed expectations regarding environmental noise have been forgotten or ignored (King & Murphy, 2016). Such conclusions may be prompted by the lack of a reference to noise pollution on the list of indicators of the United Nations Sustainable Development Goals (United Nations, n.d.). In the European circle, on the other hand, the consistent development of this study is visible, manifested by the adoption of the END and the preparation of five editions of strategic noise maps for selected areas. Each of them was accompanied by an extension of the territorial scope, as well as a specification of the noise measurement methodology (Commission Directive (EU) 2015/996). The last edition was supplemented with the requirement to prepare an assessment of the harmful effects of environmental noise (Commission Directive (EU) 2020/367). The European experience can therefore be used to include the aspect of the area affected by noise pollution in the existing sustainable development goals and indicators.

However, the European way is characterised by serious barriers associated with the costly process of the cyclical development of strategic noise maps, which may prove unbearable for many countries. Official statistics presented a medium option, applicable to those countries that could not initially undertake the task of a unified method of noise measurement for key urban (cities) and linear (roads, railways) spaces. It is a sample survey where one of the research areas would involve the

subjective perception of noise. Official statistics studies also offer tools for the further exploration of noise impact by using sets of the number of people living in specific buildings with an assigned XY spatial location. In the area of health, there is research capacity for population studies on a representative sample of people exposed to specific categories of noise and its intensity, compared to a control group. In the environmental area, an interesting issue would be a comparative analysis of the activities undertaken by individual local government units to eliminate noise pollution. In the economic field of study, there are many research directions relating to the effectiveness and efficiency of the implemented protection from noise. All these threads should support the system of monitoring the achievement of sustainable development goals.

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