International Scientific-Methodical Conference

BALTIC SURVEYING'25

Assessment of spatial consistency of the bdot10k road network for the localization of renewable energy installations

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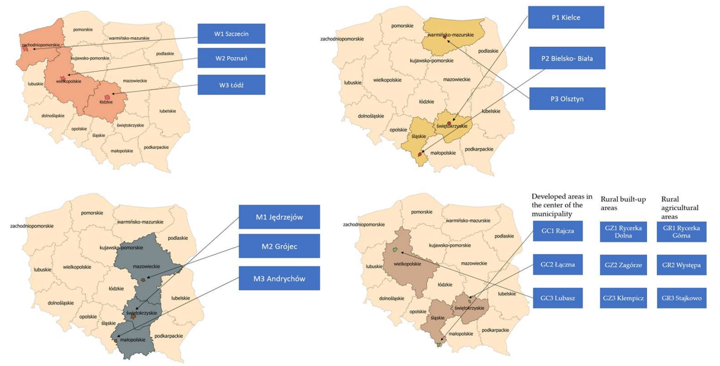
Abstract

The increase in energy production from renewable energy sources (RES) has remained a key issue for many years, both in Poland and worldwide. The selection of locations for planned renewable energy installations involves the use of various spatial datasets, particularly geodetic databases. The analyses performed in the preliminary design stage use GIS tools that allow the identification of optimal investment areas, the exclusion of inappropriate locations, and the definition of factors that influence the economic feasibility of the investment. One of the crucial factors is direct access to the road network, the presence of a paved access road, and the ability to determine the distance from the road axes. The purpose of this study was to estimate the spatial consistency of the publicly available BDOT10k geodetic database concerning the road network. Analyses carried out in representative test areas allowed the identification of gaps in BDOT10k through comparison with reference data from the BDOT500 database. The research was carried out in a GIS environment, focusing on surface data analysis and the road surface attribute.

Introduction

Analyses of road network data from BDOT10k were carried out for the presented elements shown in the table below by comparing the data with objects from the BDOT500 reference database. The study focused on two geodetic databases: Databases of Topographic Objects at a scale of 1:10 000 (BDOT10k) and BDOT500 databases which contain information on the road network, among other things. Like the other geodetic databases, they are part of the National Geodetic and Cartographic Resource (in Polish: PZGiK).

- The **BDOT10k** geodetic database is characterized by the best accessibility, as they cover the entire country, is available online for free and for any use, and use a uniform data format nationwide. BDOT10k provides a detailed topographic objects database with a scale equivalent to 1:10,000 topographic maps. The geometry of objects for the BDOT10k is recorded with an accuracy of at least 1.5 m, and for objects with challenging field identification, the accuracy is no less than 5 m.
- The most detailed and accurate spatial data in Poland are collected in three main geodetic databases: the land and buildings register (EGiB), the utilities network (GESUT),and the topographic objects database (**BDOT500**). These databases are used as reference databases for many studies and less detailed databases. Most of the objects in these databases are identified based on direct field surveying. According to the standard, surveying must determine a point's location relative to the nearest horizontal geodetic control points and measurement control network with a minimum accuracy of 0.10 m—in the case of field details of group I (e.g., buildings, construction equipment); 0.30 m—in the case of field details of group II (e.g., covered construction objects); 0.50 m—in the case of field details of group III. Coverage of complete object-oriented EGiB, GESUT, and BDOT500 databases in Poland is not comprehensive. In many regions of Poland, spatial data related to the thematic scope of BDOT500, GESUT, and EGiB databases are often available as vector maps, though raster data are sometimes still needed. In several poviats, the data are hybrid, meaning that while some data are digitized in the database, older data have not yet been transferred and remain in vector and/or raster format. Reference database information is provided to users as a base map (Polish name: mapa zasadnicza).



Materials and methods

The next phase of the work involved creating a method to estimate the completeness of data within the BDOT10k database. It was determined that completeness is the most critical quality aspect for users of spatial data. A database is deemed useful if it includes the data that users are looking for. The completeness of the data in BDOT10k was examined separately for spatial data and attribute data (for a selected primary attribute recorded in the database). The measure used to determine the **attribute completeness** (K_a) was the ratio of the number of data entries in the research database to the number of data entries that should be present according to the theoretical model. Given that the analysis compared the research database with a reference database, the attribute completeness coefficient was determined as the ratio of the number of attribute values in the research database to the number of distinct attribute values in the reference database the analysed study area.

Spatial completeness or geometric completeness was determined as the degree of similarity between two spatial sets by calculating the **spatial completeness coefficient** (K_p). For a comprehensive completeness analysis, both the completeness coefficient K_p and a **spatial redundancy coefficient** (N_p) were calculated. Formulas for calculating the degree of completeness and redundancy were used earlier in the literature. The spatial redundancy coefficient is an additional metric that complements the completeness coefficient and should be considered alongside it.

The completeness degree was calculated using the formula:

$$K_p = \frac{2 * \sum P_i}{\sum P_{bad} + \sum P_{ref}} \times 100\%$$

$$N_p = \frac{2 * (\sum P_{ref} - \sum P_i)}{\sum P_{bad} + \sum P_{ref}} \times 100\%$$

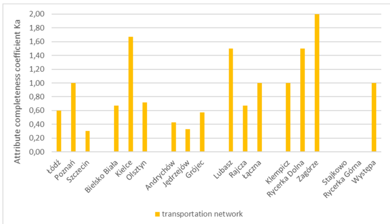
where:

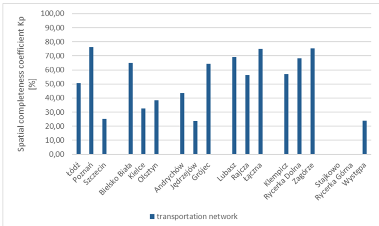
P_i—the product of the intersecting (overlapping) surfaces of the selected layer(s) in the research and reference databases within the research area; P_{bad}—the area of the examined layer within the analysis area; P_{ref}—the area of the reference layer within the research area.

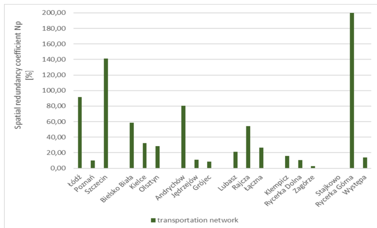
Research area

The developed methodology for assessing the suitability of databases was applied to eighteen research areas across Poland, located in eight provinces. The research areas were differentiated by the size of the locality and the level of urbanization. Four groups of areas were selected: province capitals (W), poviat capitals (P), towns (M), and rural municipalities (G). Three research areas were selected for each group. For urban areas (W, P, and M groups), the research areas were located outside city centres, on city outskirts, and in investment areas. Partially undeveloped areas adjacent to existing buildings were selected. The siting selection was random, but efforts were made to ensure that land cover objects, such as the road network and buildings related to factors important for renewable energy investment siting, were included within the research area. For the group of rural municipalities (G), the number of areas was increased to three per municipality. This group was further divided into areas near the centres of cities/towns being the seat of the municipality (group GC), areas around developed zones but located in rural outskirts of the municipality (group GZ), and areas in rural outskirts of the municipality in undeveloped agricultural areas (group GR). Three locations were selected for each of the research groups: GC, GZ, GR.

Results







A high value of the spatial completeness coefficient was obtained for most urban areas and rural settlements (GC and GZ groups). Only in four test areas did the coefficient fall below 40%. These areas were Szczecin, Kielce, and Jędrzejów. In the Szczecin research area, where a complete BDOT500 (reference) database exists, it was found that the BDOT10k database contains significantly fewer road network objects than the reference database. This is evidenced by a low spatial completeness index of 25% and the high level of redundancy at 141%. The lowest spatial completeness was recorded for typically agricultural areas, where unpaved dirt roads prevail (GR group areas). In these sites, the reference database often lacks data from updating measurements, which would reveal objects in the BDOT500 database or the base map. Conversely, the absence of dirt roads in the BDOT10k database in some test areas may result from interpretive difficulties or visibility on the orthophotomap. It is worth mentioning that while the geometry of dirt roads is recorded in BDOT10k, the surface width attribute is NULL. In places where spatial data on road objects are missing from both BDOT10k and the reference database, the only road-related information is the parcel boundary and the land use designation "dr" in EGiB. In the agricultural area of Stajkowo, there were no spatial data available in either the BDOT10k or the reference databases. In the Rycerka Górna area, there were no objects in the research database, while the reference database (fundamental base vector map, as there was no BDOT500 database in the area) included layers of the edges of dirt roads (Fig). As a result, the data redundancy coefficient was 200% (completeness: 0%), which is the highest among all values in the tested areas. It is noteworthy that outside the test area, there is a dirt road with a similar layout and appearance on the orthophotomap, which was identified in the BDOT10k database (Fig).

Conclusions

- road objects have a linear representation in the BDOT10k database, while road width is only found as an attribute of the database. This causes difficulties in spatial analyses performed for the location of RES facilities. Efforts should be made to disclose roads as polygons in the BDOT10k database;
- performed analyses showed a relationship between the degree of land investment and the spatial correspondence of the BDOT10k database to the BDOT500 database;
- there is a need to look for tools for automatic updating of the BDOT10k database. This will make it possible to objectivize the updating process, automate it and eliminate errors that depend on the interpretation of the person entering the data into the database;
- efforts should be made to simplify the designations of the pavement type attribute in BDOT10k and to unify the designations with the BDOT500 reference database.

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7-9 May 2025, Olsztyn, Poland