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A method for developing an information base for planning volunteer rescue units based on open geospatial data

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ABSTRACT

The article develops a method for forming an information base for planning volunteer rescue formations using open geospatial data. The relevance of the study is determined by the need to provide decision-support systems with structured, spatially consistent, and analytically suitable data on settlements, road networks, buildings, and infrastructure objects within territorial communities. The study aims to develop a method that enables automated collection, verification, preprocessing, integration, aggregation, and structuring of open geospatial data for further use in planning volunteer rescue formations. The proposed method includes identification of the study area, acquisition of data from an open mapping environment, selection of target spatial objects, data quality checking and cleaning, spatial integration, aggregation of territorial characteristics, and formation of a structured feature matrix with associated metadata. To implement the method, software code was developed in Python in a cloud-based computing environment using specialized libraries for geospatial data processing, tabular data management, and visualization. The method was experimentally tested using a territorial community in Volyn Oblast as a case study. As a result, an information base was formed containing spatially consistent characteristics of settlements, road networks, buildings, and infrastructure objects. Experimental verification confirmed the operability of the proposed method according to spatial, structural, and logical criteria. The practical value of the study lies in creating a reproducible information basis for further assessment and prediction of rescue-service accessibility and for decision support in planning volunteer rescue formations. Further research should focus on integrating additional official and departmental data sources and using the formed information base in models for accessibility prediction and rational location of rescue formations.

Keywords: Method; rescue formations; information base; open geospatial data; OpenStreetMap; data processing; territorial communities

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Introduction. Ensuring a timely response to emergencies in local communities depends to a large extent on the spatial accessibility of emergency response units, the condition of the transportation infrastructure, and the ability to rationally deploy available human and logistical resources. This problem is particularly acute in rural communities, which are characterized by vast territorial expanses, scattered settlements, an uneven road network density, and significant distances to professional fire and rescue units. Under such conditions, volunteer rescue units complement the existing emergency response system by reducing the time it takes for rescuers to arrive at the scene and increasing the accessibility of rescue services for remote settlements [12], [13].

The experience of volunteer fire and rescue units in various countries confirms the importance of involving local communities in ensuring civil protection. Volunteer units serve not only as an additional operational resource but also as a component of the local resilience system, capable of providing an initial response before professional services arrive [12], [13], [14]. At the same time, establishing such units requires a well-founded selection of deployment locations, an assessment of

territorial coverage, transportation accessibility, population density, and the location of potentially hazardous and socially significant facilities. To this end, tools are needed to create an information base for planning volunteer rescue units based on open geospatial data.

Analysis of literature. The development of geoinformation technologies has significantly expanded the capabilities for providing information to support such tasks. Modern GIS solutions are used to model service areas, plan routes, analyze response times, and optimize the placement of fire and emergency rescue units [7], [8], [9], [10], [11]. In particular, combining spatial data with network analysis makes it possible to move from a simplified assessment of accessibility based on radii to an analysis of actual movement through the road network. Studies by S. Shahparvari et al. [8], K. Mao et al. [9], and D. Coles et al. [10] demonstrate that the structure of the transportation network, the spatial distribution of units, and the condition of individual road segments directly influence the actual accessibility of emergency services. GIS is also used for comprehensive spatial assessments of fire risk and the accessibility of relevant infrastructure [11].

To perform such an analysis, detailed and up-to-date data on the road network, buildings, settlements, and social, industrial, and critical infrastructure facilities are required. One of the most accessible sources of such data is OpenStreetMap. Its advantages include its open-source nature, extensive geographic coverage, continuous updates, and the ability to automatically retrieve data for a specified area. The development of software tools, notably OSMnx, has significantly simplified the automated generation of road network graphs, the extraction of object geometry, and the performance of subsequent network analysis [1].

At the same time, the direct use of raw OpenStreetMap data in emergency response infrastructure planning tasks has certain limitations. OSM data is generated by a large number of users; therefore, its completeness, positional accuracy, semantic consistency, and timeliness vary across different areas and categories of emergency response units' objects [2], [3], [4], [5], [6]. In some settlements, objects with the same functional purpose have different sets of tags, some attributes are missing, and geometric objects are duplicated or represented in different forms. This requires verification, filtering, standardization of data into a unified structure, and the generation of derived spatial indicators before their use in models that employ management decision-support systems.

In previous studies, the authors established the scientific and methodological foundation for the use of spatial data in the development of safety systems for local communities. Approaches to planning the territorial deployment of fire and rescue units were proposed [16], intelligent models for selecting the locations of volunteer rescue units were developed [15], and the possibilities of using OpenStreetMap open data to obtain information about the transportation infrastructure of settlements were investigated [17]. This confirmed the feasibility of using open geospatial sources as an information basis for spatial planning tasks.

Further research focused on using geospatial characteristics to predict the availability of volunteer rescue teams. To this end, a set of features was developed to characterize the road network, building density, the location of educational and healthcare facilities, industrial sites, places where large numbers of people gather, and access to major highways [18]. Based on these data, the potential for applying deep learning models to predict the accessibility of facilities in spatially distributed systems was investigated. Separately, the use of modern geographic information systems for optimizing community safety infrastructure was justified [21], and software tools for implementing planning models for rural rescue units were examined [19]. The issue of deriving value from the development of territorial safety systems and portfolios of related projects was addressed in [20].

The results presented here lay the groundwork for the development of information technology to plan the establishment and development of volunteer rescue units. At the same time, the task of creating an information database that would facilitate the transition from heterogeneous, unprocessed geospatial data to a structured set of indicators suitable for further spatial analysis, mathematical modeling, machine learning, and decision support requires a separate solution.

The specificity of this task lies in the need to simultaneously account for several data groups: spatial characteristics of settlements; road network parameters; the location of social and critical infrastructure facilities; building characteristics; potentially hazardous and industrial facilities; existing fire and rescue units; and indicators of transportation accessibility. For further use, this data is collected within a single territorial region, verified for completeness and accuracy, cleaned of duplicates, semantically harmonized, spatially aggregated, and transformed into quantitative and categorical features.

Thus, there is a need to develop a method that will define the sequence for acquiring, verifying, cleaning, integrating, and transforming open geospatial data into a unified information database for planning volunteer rescue units. Unlike existing approaches, which focus primarily on the final determination of unit locations or the assessment of their spatial accessibility [8], [9], [11], [15], [16], this method aims to formalize the informational component of the process – from selecting sources and acquiring raw data to constructing a structured set of features suitable for subsequent computational procedures.

The purpose and objectives of the research. Planning the establishment of volunteer rescue units requires the use of up-to-date data on populated areas, the road network, social and industrial infrastructure facilities, as well as the spatial characteristics of local communities. Existing approaches are primarily focused on using individual datasets and do not ensure their systematic collection, verification, harmonization, and structuring, which limits their potential for further use in management decision-support systems.

The purpose of this study is to develop a method for creating an information database for planning volunteer rescue units based on open geospatial data, which ensures the automated collection, verification, preprocessing, integration, and structuring of spatial and infrastructure characteristics of local communities.

To achieve this goal, the following tasks must be addressed:

- define the structure of information needs and identify appropriate sources of open geospatial data for planning volunteer rescue units;
- develop a method for creating an information database based on the collection, verification, preprocessing, integration, and structuring of geospatial data;
- create an information base and experimentally verify the effectiveness of the proposed method.

Research methods. Planning the establishment of volunteer rescue units for rural communities requires analyzing data on the service area, settlements, the road network, and infrastructure facilities. To further assess the availability of rescue services and use the data in forecasting models, a standardized description of the territory must be developed. The practical challenge of this process lies in the fact that the required data comes from various sources. In particular, in OpenStreetMap, roads, buildings, settlements, and other features are represented by different geometric types and sets of attributes, so they require verification, spatial harmonization, and conversion to a unified format.

For a formal description of the source data, let's introduce the set:

$$D^0 = \{D^S, D^R, D^I, D^G\}, \quad (1)$$

where D^S is data characterizing populated areas; D^R is road network data; D^I is data characterizing infrastructure objects; D^G is geometric and spatial data required to align these objects within the boundaries of a given rural community.

The primary open-source spatial data source for generating components D^R , D^I and part of D^S is OpenStreetMap. In the proposed method, these components are considered separately not by their source of origin but by their functional purpose in subsequent analysis. For the road network, the geometry and connectivity of its segments are important; for infrastructure objects, the type, number, and spatial location are important; and for settlements, their identification and territorial affiliation are important.

Data processing begins with defining the spatial area under study. This is necessary to distinguish objects belonging to a specific community from those in neighboring territories and to establish a unique spatial reference.

We will represent the territory of the community under study as the region:

$$\Omega \subset R^2, \quad (2)$$

The community boundaries define the spatial area from which geoinformation objects are selected. The set of objects used to derive the community's characteristics is then defined as:

$$O_\Omega = \{o_i \in O : g(o_i) \cap \Omega \neq \emptyset\}, \quad (3)$$

where O is the initial set of geospatial objects; o_i is an individual object; $g(o_i)$ is the geometric representation of an object; O_Ω – objects that are spatially associated with the studied territory.

Condition (3) is fundamental to the territorial selection of objects. Its practical application helps avoid situations where roads or infrastructure objects belonging to a neighboring administrative territory are included in a community's informational description.

After defining the study area, primary data is collected. In this process, OpenStreetMap features are not treated as ready-made attributes. At this stage, they are merely initial spatial entities from which the characteristics of settlements are derived during further processing.

For the i -th settlement, its primary descriptive information is represented by the set:

$$Z_i^0 = \{S_i, R_i, I_i\}, \quad (4)$$

where S_i is characterizes the settlement itself; R_i is contains the associated road network objects; I_i is infrastructure objects that spatially belong to the corresponding territory.

Method for Building an Information Base. In the proposed method for building an information base – based on the collection, verification, preprocessing, integration, and structuring of geospatial data – the object of analysis is not an individual road or building, but rather a settlement along with the set of characteristics spatially associated with it. The sequence for implementing this method is shown in Figure 1.

The next component of the method involves verifying the obtained data. This stage is particularly important for open geospatial data, as the level of detail varies across different territories. Not every object has the same set of attributes, and individual records may be incomplete.

For each value that characterizes the j -th property of the i -th object, its state is determined:

$$q_{ij} = \begin{cases} 1, & x_{ij} \text{ is available and suitable for use,} \\ 0, & x_{ij} \text{ is absent or requires verification.} \end{cases} \quad (5)$$

Based on this, the completeness of the informational description of an individual object is determined:

$$K_i^{com} = \frac{1}{m} \sum_{j=1}^m q_{ij}, \quad (6)$$

where m is the number of characteristics being examined.

A value K_i^{com} close to one indicates a complete description of the object according to the selected system of characteristics. A decrease in this indicator points to the presence of omissions or values that require further clarification.

During data cleaning, a fundamental distinction is made between missing information and a zero value. For characteristics describing the number of objects in a given category, zero is a valid value and signifies the actual absence of such objects. A missing value, on the other hand, indicates that the corresponding value has not been established.

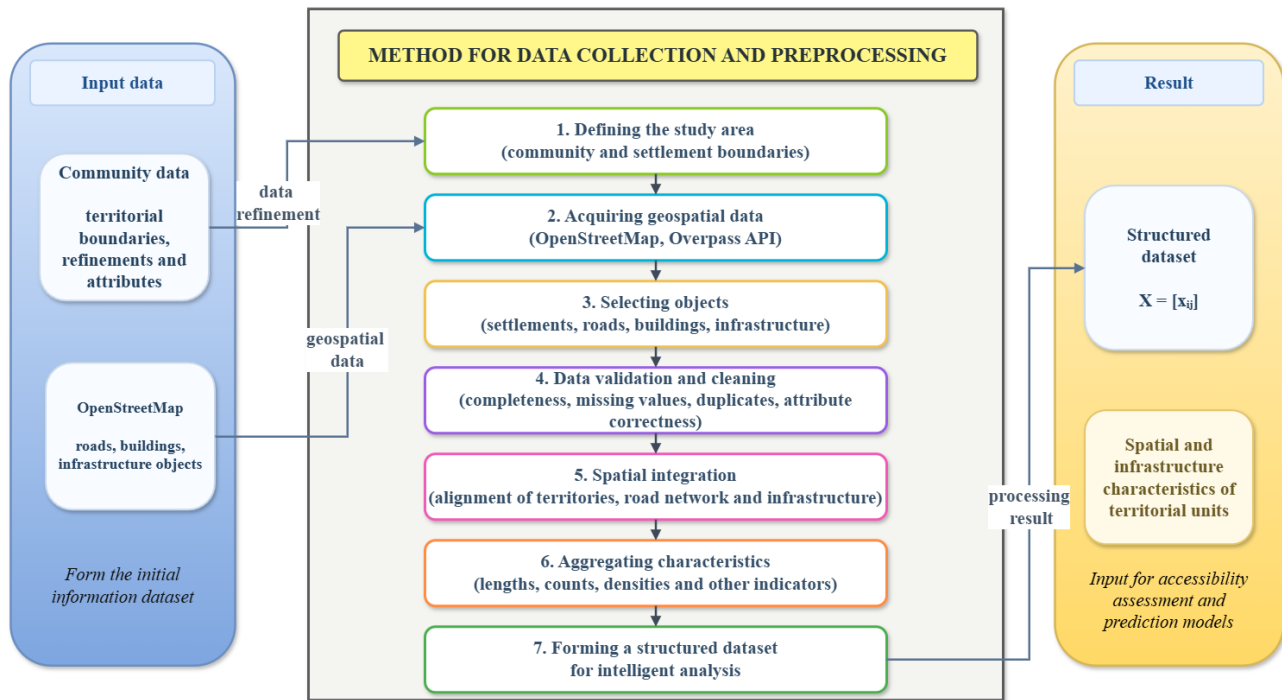


Fig.1. Stages in Implementing the Method for Developing an Information Base

Source: compiled by the authors

Therefore, within the framework of this method, the following condition is adopted:

$$x_{ij} = 0 \neq x_{ij} = NA, \quad (7)$$

This distinction is necessary to ensure that the incompleteness of the source data does not result in an artificially constructed characteristic of the territory. For subsequent intelligent analysis, this distinction is essential, since erroneously replacing missing values with zeros alters the structure of the resulting sample.

Another problem is related to the duplication of spatial objects. In conventional tabular data, duplicates are identified by matching records; however, for geospatial data, completely identical coordinate values are not a prerequisite. Therefore, during verification, both spatial proximity and the type of object should be taken into account.

For two objects o_i and o_j , the following condition is checked:

$$d(o_i, o_j) \leq \varepsilon, \quad (8)$$

where $d(o_i, o_j)$ is the spatial distance between the objects; ε is a specified threshold value.

Satisfaction of condition (8) alone is not sufficient grounds for removing one of the records. Additionally, the type and available attributes of the objects are compared. This ensures that objects that are geographically close but functionally different are not erroneously merged.

After verification and pruning, spatial integration is performed. This involves establishing relationships between settlements, the road network, and infrastructure objects. For each settlement, a unique set of related objects is formed, allowing a transition from OpenStreetMap's fragmented representation to an informational description of the territorial unit.

If Ω_i denotes the territory of the i -th settlement, the set of infrastructure objects associated with it is defined by the expression:

$$I_i = \{o_j \in I : g(o_j) \cap \Omega_i \neq \emptyset\}, \quad (9)$$

The set of road network elements is formed similarly:

$$R_i = \{r_j \in R: g(r_j) \cap \Omega_i \neq \emptyset\}, \quad (10)$$

where R is the initial set of road objects.

As a result, each settlement receives its own spatially consistent dataset:

$$Z_i = \{S_i, R_i, I_i\}, \quad (11)$$

Afterward, aggregation operations are performed. Their purpose is to obtain numerical characteristics of the territory instead of a large number of primary geospatial objects. For example, if the road network of the i -th settlement contains n_i segments, its total length is determined by the following equation:

$$L_i^{road} = \sum_{j=1}^{n_i} l_{ij}, \quad (12)$$

where l_{ij} is the length of the j -th segment.

For territories that differ significantly in area, the absolute value L_i^{road} is not always sufficiently informative. Therefore, a relative measure has been developed alongside it:

$$\rho_i^{road} = \frac{L_i^{road}}{S_i}, \quad (13)$$

where S_i is the area of the corresponding settlement.

For infrastructure objects, aggregation is performed based on their classification into specific functional categories. The number of objects in category k within the i -th territory is defined as:

$$N_{ik} = \sum_{j=1}^{m_i} \delta(c_j, k), \quad (14)$$

where m_i is the total number of selected infrastructure facilities; c_i is the category of the j -th facility; $\delta(c_j, k)$ is an indicator function that takes the value 1 if the facility belongs to category k and 0 otherwise.

After performing the specified operations, each i -th settlement is described by a vector:

$$x_i = [x_{i1}, x_{i2}, \dots, x_{im}], \quad (15)$$

where m – is the number of features generated after preprocessing.

For N territorial units, we obtain a structured array:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ x_{N1} & x_{N2} & \dots & x_{Nm} \end{bmatrix}, \quad (16)$$

In this case, the matrix X is not the original OpenStreetMap dataset, but rather the result of sequential integration and preprocessing of various data groups. Each row corresponds to a separate territorial unit, and each column corresponds to the generated characteristics. At the same time, it is advisable to store geographic identifiers and coordinates separately as part of the metadata:

$$M_i = \{id_i, lat_i, lon_i, src_i, t_i\}, \quad (17)$$

where id_i is the identifier of the territorial object; lat_i are the spatial coordinates of the territorial object; src_i is information about the source; t_i is the time the data was obtained or updated.

This approach ensures that the connection between numerical characteristics and their spatial origin is not lost. Once the results of the assessment or forecast are obtained, they are linked back to a specific settlement and presented in a geoinformation environment.

We formally represent the proposed method as follows:

$$M_D = \langle D^0, F_{col}, F_{val}, F_{sp}, F_{agg}, X \rangle, \quad (18)$$

Unlike existing approaches, which focus primarily on collecting and storing information about infrastructure objects, the proposed method culminates in the formation of a structured information array that is directly used in subsequent stages of intelligent analysis.

The differences between the basic approach and the one proposed in this dissertation are presented in Table 1.

Table 1. Differences between the proposed data collection and preprocessing method and the baseline approach

Feature	Baseline approach	Improved method
Main purpose	Accumulation of data on infrastructure objects	Preparation of data for planning the establishment of volunteer rescue formations
Source of spatial data	OpenStreetMap	OpenStreetMap combined with characteristics of settlements and the territorial community
Territorial selection	Processing of individual infrastructure objects	Targeted selection of objects within the study area
Preprocessing	Preparation of information for storage	Data verification, cleaning, and spatial integration
Result structure	Information on individual objects	Consistent description of settlements
Aggregation	Not considered a final objective	Formation of quantitative territorial characteristics
Further use	Information support for infrastructure projects	Intelligent analysis, assessment, and prediction of rescue service accessibility

Source: compiled by the authors

The proposed method for collecting and preprocessing data to plan projects for establishing volunteer rescue units involves defining the community's territory, obtaining geospatial data, selecting objects within the territory, verifying and cleaning records, spatially aligning the characteristics of settlements, the road network, and infrastructure, aggregating them, and converting them into a single structured representation.

Results of the information database development. To implement the proposed method, program code was developed in the Google Colab environment using Python. The software implementation relies on the use of the OSMnx, GeoPandas, Shapely, Pandas, NumPy, Matplotlib, and Folium libraries, which enable the retrieval of OpenStreetMap data, its spatial processing, validation, aggregation, visualization, and the creation of a structured database. The developed code automates the main stages of the method and ensures the reproducibility of experimental studies.

Experimental validation of the proposed method was conducted for the Ratnivska territorial community in Volyn Oblast. During the automated delineation of the study area using OpenStreetMap, a polygon with an area of 480.24 km² was obtained. The reference value for the community's area is 481.20 km², so the relative deviation is only 0.20%. The result confirms the accuracy of the spatial identification of the study area and provides a basis for using the generated polygon for the further selection of geospatial objects.

Within the defined territory, 49 OpenStreetMap features initially identified as settlements were obtained. After comparing names, verifying spatial affiliation, and removing features that did not

belong to the specified community, a list of 24 settlements was compiled. Thus, all settlements specified in the initial information requirements framework were identified.

At the same time, a road network graph was generated, containing 949 nodes and 2,381 road segments. To ensure a unified spatial representation around the centers of settlements, technical aggregation zones were established, bounded by the outer boundary of the community. These zones are not considered administrative boundaries of settlements but are used to unambiguously assign road segments, buildings, and infrastructure objects to the corresponding territorial units.

Fig. 2 illustrates the spatial heterogeneity of the community's territory. Settlements are distributed unevenly, and the most developed road network is concentrated in the central and southern parts of the territory, particularly near Ratne. At the same time, certain northern and peripheral territorial units are characterized by a significantly lower density of road connections. This spatial structure confirms the advisability of developing characteristics not only for the community as a whole but also separately for each territorial unit.

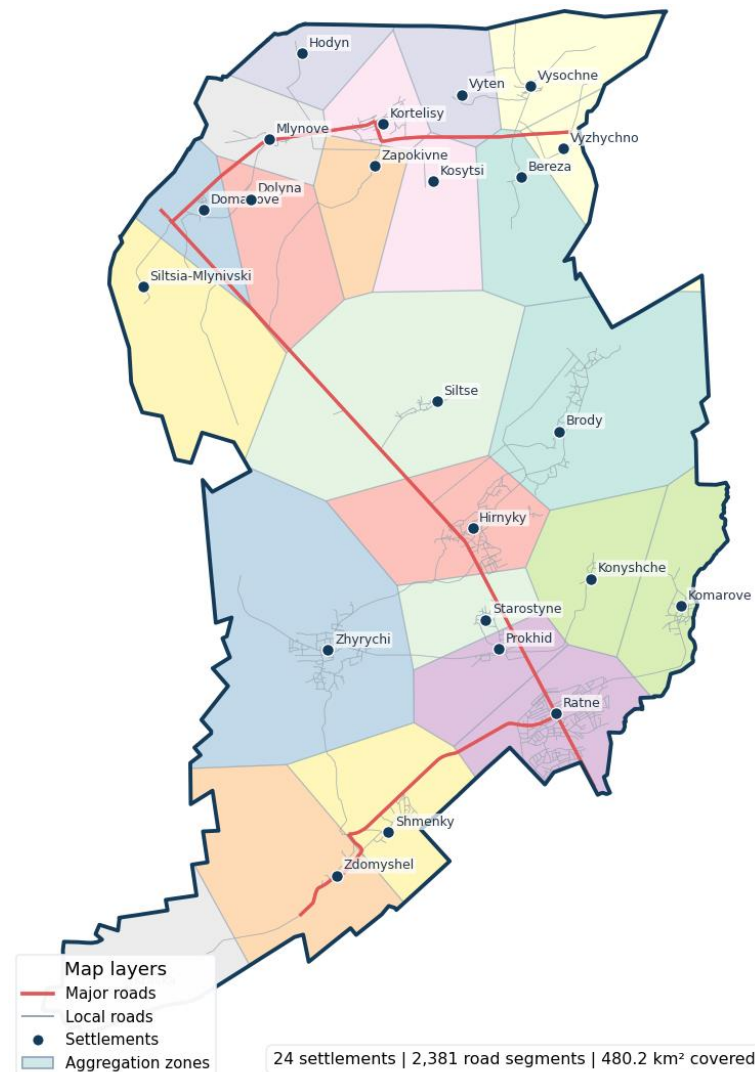


Fig.2. Settlement network, roads and spatial aggregation zones of the Ratnivska Territorial Community

Source: compiled by the authors

The next step was to verify the completeness and validity of the data obtained. The results are presented in Table 2.

For settlements and buildings, the completeness coefficient based on the set of verified characteristics used in the method was 1.000. For infrastructure objects, the average value was 0.861. No spatial duplicates were found among the selected infrastructure objects.

Table 2. Results of source data verification and cleaning

Data layer	Raw objects	Selected/clean objects	Mean completeness coefficient
Settlements	49	24	1.000
Roads	2381	2381	0.518
Infrastructure	12	12	0.861
Buildings	1249	1249	1.000

Source: compiled by the authors

The lowest completeness coefficient was obtained for road segments – 0.518. This is due to the absence of additional semantic attributes in some OpenStreetMap objects, specifically road names, pavement types, or speed limits. At the same time, all 2,381 segments had geometry and basic attributes sufficient to form a road graph, calculate length, and perform spatial integration. Therefore, the obtained value primarily characterizes the completeness of the attribute description, rather than the absence of the road network itself.

Based on the results of spatial integration and aggregation, the total length of the road network within the defined zones was 755.6 km. The values differed significantly among territorial units.

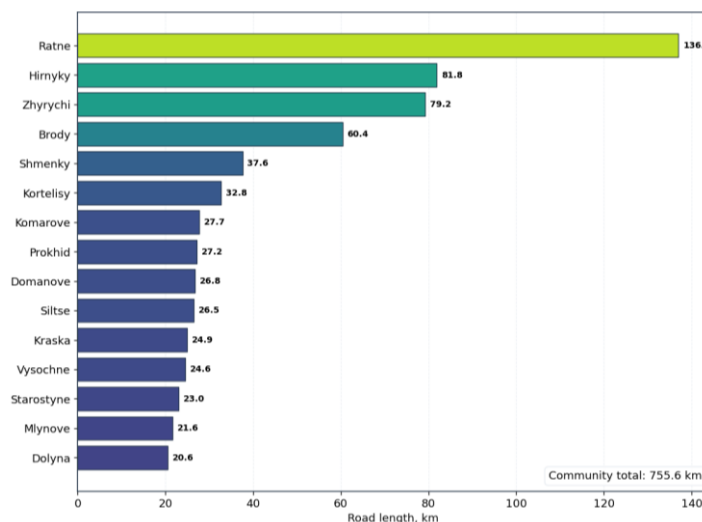


Fig.3. Road network length by settlement aggregation zone

Source: compiled by the authors

The longest total road network lengths were recorded in the Ratne area – 136.9 km, Hirnyky – 81.8 km, Zhorychiv – 79.2 km, and Brody – 60.4 km. For most other territorial units, this figure did not exceed 40 km. Thus, using only the total length of roads for the entire community would obscure significant local differences, whereas the proposed aggregation allows for their quantitative representation.

In addition to the absolute length, the density of the road network was determined. For example, for Hirnyky it was 3.74 km/km², for Domanove – 2.61 km/km², and for Vyzhychne – 1.90 km/km², while for certain peripheral areas the value was significantly lower. This is precisely why it is advisable to include both absolute and relative characteristics of the road infrastructure in the database.

Based on the identified OSM tags, 12 infrastructure objects were also identified: 6 religious sites, 3 industrial facilities, 2 educational institutions, and 1 healthcare facility. The identified facilities are distributed unevenly. The largest number was recorded for Ratne, while for a significant portion of other settlements; the corresponding facilities were not marked in the open data. The relationship between road network density and the number of identified infrastructure facilities is shown in Fig. 4.

Ratne differs significantly from other administrative units in terms of both the density of its road network and the number of identified infrastructure facilities. For most other settlements, the

number of such facilities ranged from zero to two. At the same time, no direct correlation was observed between the presence of a major-class road and the number of infrastructure facilities. This confirms the need to use several groups of spatial characteristics simultaneously, rather than a single indicator of transportation accessibility.

After aggregation was completed, a separate row in the structured database was generated for each settlement. An excerpt from the resulting matrix is presented in Table 3.

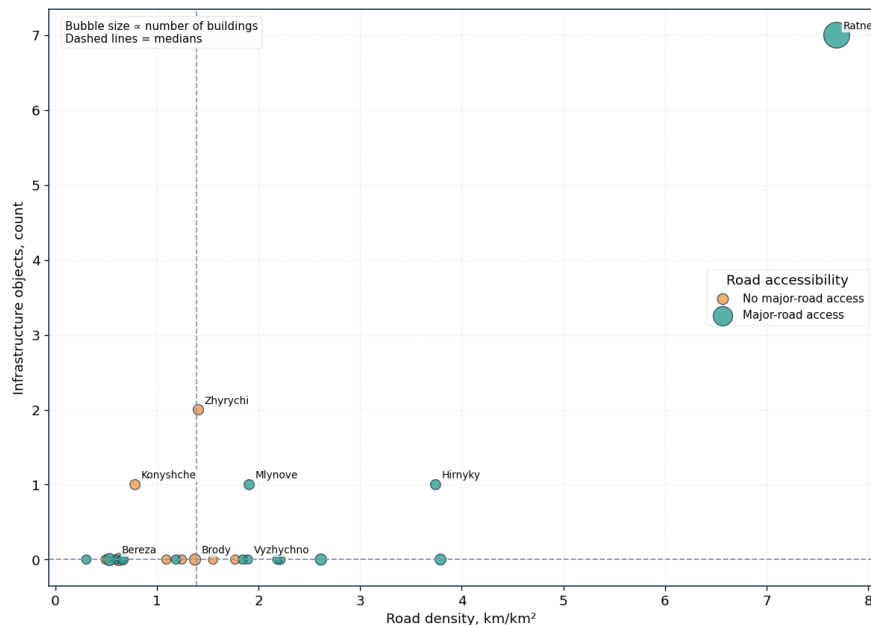


Fig.4. Road density and infrastructure intensity in settlement aggregation zones

Source: compiled by the authors

Table 3. Fragment of the formed information base

Settlement	Road length, km	Schools	Healthcare	Worship	Industrial	Buildings	Major-road access
Bereza	10.12	0	0	0	0	0	1
Brody	60.39	0	0	0	0	6	0
Hirnyky	81.84	0	0	1	0	1	1
Zhyrychi	79.23	1	0	1	0	2	0
Kortelisy	32.76	0	0	0	0	4	1
Ratne	136.95	1	1	2	3	1196	1

Source: compiled by the authors

Thus, for each territorial unit, a vector comprising seven key characteristics was obtained: the length of the road network; the number of educational, healthcare, religious, and industrial facilities; the number of buildings; and the level of access to major-class highways. In addition, the expanded dataset includes the area of the zone, geographic coordinates, road density, the KATOTTG identifier (Codifier of Administrative-Territorial Units and Territories of Territorial Communities), the data source, and the date the data was obtained.

At the same time, the obtained values highlight a characteristic of using open geospatial sources. Of the 1,249 buildings identified, 1,196 are located in Ratne, while buildings are missing from the sample in many other settlements. A similar situation is observed for some infrastructure objects. Therefore, a zero value in the generated database should be interpreted as the absence of an object in the results of the OSM query, rather than an unconditional confirmation of its actual absence on the ground. This is precisely what justifies the inclusion of a separate stage for verifying the quality of the source data in the proposed method.

Results of the experimental validation of the proposed method's performance. The method's performance was evaluated based on a set of spatial, structural, and logical criteria. The validation focused on the ability of the algorithmic sequence to correctly transform heterogeneous open geospatial data into a structured information base. It was not intended as an assessment of the absolute accuracy or completeness of OpenStreetMap itself.

The results of the validation procedures are presented in Table 4.

Table 4. Experimental verification of method operability

Criterion	Obtained value	Requirement	Result
Community polygon area agreement	0.20 % error	≤ 10 %	PASS
Official settlement coverage	24/24 (100.0 %)	100 %	PASS
Unique settlement rows	24/24	All unique	PASS
Infrastructure spatial assignment	100.00 %	≥ 99 %	PASS
No missing values in core XX	True	True	PASS
Non-negative numerical characteristics	True	True	PASS
Binary major-road access	[0, 1]	{0,1}	PASS
Complete metadata MM	100.0 %	100 %	PASS

Source: compiled by the authors

All 8 validation criteria were met. Specifically, 100% coverage of the specified list of settlements was achieved, all entries in the generated matrix are unique, and all selected infrastructure objects are unambiguously linked to their corresponding spatial zones. No missing values were found in the base matrix XX; quantitative characteristics are non-negative; and the attribute indicating access to the main road network takes only valid values of 0 or 1. A complete set of service metadata has also been generated for all territorial units.

The resulting 100% completion rate for the checks does not imply 100% accuracy of the source OpenStreetMap data. It indicates that all procedures for building the information base, as specified by the algorithm, were completed correctly and produced a structurally consistent dataset suitable for subsequent computational procedures.

The duration of the main stages of the method was evaluated separately.

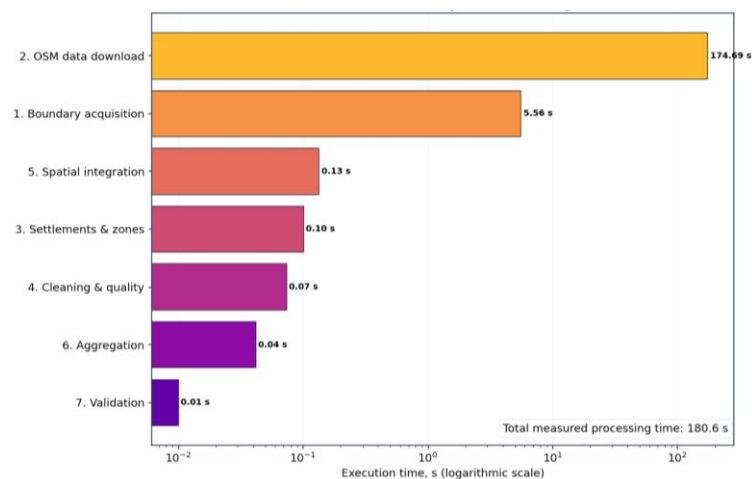


Fig.5. Execution time by method stage

Source: compiled by the authors

The total recorded execution time was 180.6 seconds. The majority of this time was spent retrieving OpenStreetMap data – 174.69 seconds, or approximately 96.7% of the total time. Defining the community boundaries took 5.56 seconds. However, once the source data was obtained, the actual computational operations were performed quickly: spatial integration – 0.13 seconds, zone formation – 0.10 seconds, cleaning and quality checking – 0.07 seconds, aggregation – 0.04 seconds, and a final check – 0.01 seconds.

Thus, the main time constraint of the proposed approach is not the processing of geospatial data, but rather its retrieval from an external service. After loading the source objects, the sequence of validation, spatial integration, and aggregation takes less than one second for the dataset under study. This confirms the practical applicability of the method for creating an information database for a local community and updating it as updated data becomes available.

Thus, the experiment ensured a complete transition from open geospatial objects to a structured information database in which 24 territorial units are associated with harmonized numerical characteristics and metadata. The resulting dataset can be used in subsequent stages of information technology to assess and forecast the availability of rescue services and to support management decisions regarding the planning of volunteer rescue units.

Conclusions. This paper develops a method for creating an information database for planning volunteer rescue units based on open geospatial data. The method involves sequentially defining the study area, obtaining OpenStreetMap data, selecting target objects, verifying and cleaning records, performing spatial alignment, aggregating characteristics, and creating a structured dataset for further use in management decision-support systems.

An experimental validation was conducted for the Ratne Territorial Community in Volyn Oblast. The area of the study territory obtained from OpenStreetMap was 480.24 km², which differs from the reference value of 481.20 km² by 0.20%. All 24 settlements within the community were identified; a road network consisting of 2,381 segments and 949 nodes was formed; and 1,249 buildings and 12 infrastructure objects were selected based on specified OSM tags. The total length of the road network in the defined spatial zones was 755.6 km.

As a result, a structured vector of characteristics was generated for each settlement, containing the length of the road network, the number of educational, healthcare, religious, and industrial facilities, the number of buildings, and an indicator of access to major highways. Additionally, spatial coordinates, area, road network density, data source, and date of collection were recorded. This establishes a link between numerical characteristics and their spatial origin and enables the use of the resulting database for further assessment and forecasting of emergency service accessibility.

Experimental validation demonstrated the effectiveness of the proposed method according to all defined structural and logical criteria. The method ensures 100% coverage of populated areas, unambiguous spatial assignment of infrastructure objects, the absence of gaps in the base attribute matrix, the correctness of numerical and binary characteristics, and the completeness of service metadata. The total execution time was 180.6 seconds, with 174.69 seconds spent on retrieving OpenStreetMap data, while the subsequent procedures of cleaning, integration, aggregation, and verification were completed in a fraction of a second.

The results confirmed that the quality of the resulting information base depends on the completeness of OpenStreetMap's attribute data. Therefore, the quantitative characteristics obtained should be viewed as a representation of the objects recorded in the open geospatial source at the time the query was executed, rather than as an exhaustive registry of objects in the territorial community.

Further research should focus on integrating OpenStreetMap with other open and agency-specific data sources, improving procedures for automatically verifying their completeness and timeliness, and taking into account the actual condition of the road network and traffic patterns. A separate area of focus is the use of the established information base in models for assessing and forecasting the availability of volunteer rescue units, as well as in tasks related to justifying their rational deployment and further development.

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Метод формування інформаційної бази для планування добровільних рятувальних формувань на основі відкритих геопросторових даних

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АНОТАЦІЯ

У статті розроблено метод формування інформаційної бази для планування добровільних рятувальних формувань на основі відкритих геопросторових даних. Актуальність дослідження зумовлена необхідністю забезпечення систем підтримки прийняття рішень структурованими, просторово узгодженими та придатними до подальшого аналізу даними про населені пункти, дорожню мережу, будівлі та об'єкти інфраструктури територіальних громад. Метою роботи є розроблення методу, який забезпечує автоматизований збір, перевірку, попередню обробку, інтеграцію, агрегування та структурування відкритих геопросторових даних для подальшого використання під час планування добровільних рятувальних формувань. Запропонований метод передбачає визначення території дослідження, отримання даних із відкритого картографічного середовища, відбір цільових просторових об'єктів, перевірку якості та очищення даних, їх просторову інтеграцію, агрегування територіальних характеристик і формування структурованої матриці ознак із відповідними метаданими. Для реалізації методу розроблено програмний код мовою Python у хмарному обчислювальному середовищі з використанням спеціалізованих бібліотек для роботи з геопросторовими даними, табличними структурами та візуалізацією. Експериментальну апробацію виконано на прикладі територіальної громади Волинської області. У результаті сформовано інформаційну базу, яка містить узгоджені характеристики населених пунктів, дорожньої мережі, забудови та інфраструктурних об'єктів. Експериментальна перевірка підтвердила працездатність запропонованого методу за просторовими, структурними та логічними критеріями. Практична цінність дослідження полягає у створенні відтворюваної інформаційної основи для подальшого оцінювання і прогнозування доступності рятувального обслуговування та підтримки прийняття рішень щодо планування добровільних рятувальних формувань. Подальші дослідження доцільно спрямувати на інтеграцію додаткових офіційних і відомчих джерел даних та використання сформованої інформаційної бази у моделях прогнозування і раціонального розміщення рятувальних формувань.

Ключові слова: метод; рятувальні формування; інформаційна база; відкриті геопросторові дані; OpenStreetMap; обробка даних; територіальні громади

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