STUDIA UBB GEOGRAPHIA, LXX, 2, 2025 (p. 87-125)
(RECOMMENDED CITATION)
DOI:10.24193/subbgeogr.2025.2.06

TYPOLOGICAL ANALYSIS OF THE ROAD TRANSPORT SYSTEM AND URBAN SPATIAL ORGANISATION USING CADMAPPER AND OPENSTREETMAP (OSM). CASE STUDY: BISTRIȚA-BECLEAN-NĂSĂUD-SÂNGEORZ-BĂI URBAN AXIS

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ABSTRACT. – Typological Analysis of the Road Transport System and Urban Spatial Organisation Using Cadmapper and OpenStreetMap (OSM). Case Study: Bistrița-Beclean-Năsăud-Sângeorz-Băi Urban Axis. This research presents an analysis of typological aspects of the road stacking system and their impact on the spatial organisation of urban functions along the Bistrița–Beclean–Năsăud–Sângeorz-Băi urban axis, following the structure and definitions of the analytical study in *The Role of Streetscape* (Tătar, A.M., Pop, C.C., 2025). The study emphasises how types of roads create organisational structures and affect the distribution of commercial, economic, tourist, and cultural locations, as well as the functioning of urban industries in a medium-sized urban area. The study used Cadmapper and OpenStreetMap (OSM), which are freely accessible geospatial datasets, to assign types of roads and map the spatial logic and configuration of urban functions. By employing typological mapping and spatial analysis, this research identified various transport types and functional types, as well as their relationships. In doing so, this enables the role of urban land utilisation. The results revealed how road slab structures and hierarchies affected the location of urban functions differently. While specific types of roads produced the most effective spatial organisation in transport models, certain kinds of roads influenced urban structure and efficiency less than others. The study highlights the significance of transport system typology in urban planning as a crucial element of

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sustainable development and functional zoning. The paper provides the basis for developing better urban diagnostics and urban contrasts, as well as strategies that take into consideration development scenarios specific to Bistrița-Năsăud area.

Keywords: *road transport system, urban spatial organisation, Bistrița-Beclean-Năsăud-Sângeorz Băi urban axis, Cadmapper, OpenStreetMap (OSM).*

1. INTRODUCTION

The geographical axis is defined as a "line of spatio-temporal shape, a line that allows, in a temporal-spatial way, the diagnosis and geographical forecasting of a territory. This territory can take different geometric conformations and dimensions according to the capacity of component polarisation" (Pop, C.C., 2003).

The geographical axis operates through the integration of its constituent elements, and every point, place, level, order of organisation, secondary axis, central axis, local mesh, and so on, has its organisational laws (C.C. Pop, 2016, p. 287). A geographical axis comprises elements, and how these elements manifest reflects the status of its functioning (Pop, C.C., 2016, p. 289).

The spatial distribution of urban functions and the structure of road transport systems are universally accepted as related yet distinct elements of sustainable urban development, especially in medium-sized cities (Rodrigue, J.-P., 2023). In this case, a structured road network not only enables mobility but also plays a proactive role in distributing economic, cultural, and tourist functions across space and time. Our analysis will focus on the Bistrița–Beclean–Năsăud–Sângeorz-Băi axis, where urban form and transport networks co-evolve and spatially influence land use and functional zoning.

Various forms of urban roads (i.e., arterial roads, collector roads, and pedestrian streets) contribute significantly to city orientation and, in practice, shape the placement and manifestation of urban functions. The existence and nature of street types, in essence, dictate the quality and liveability of urban environments (Tătar A.M., Pop, C.C., 2025). For example, arterial roads bring commercial and logistical activity due to their speed and mobility space (Baker Institute, 2023), and cultural and tourism activity, on the other hand, clings to pedestrian streets and historic streetscapes near high-value spaces with aesthetic features and close spatial relationships (Bhalla, K., 2023). The location of cultural institutions and leisure facilities in Bistrița and Beclean, for example, complements the secondary road networks, where access and environmental benefit provide opportunities for enhancing mobility patterns and behaviours.

The establishment of economic places is directly associated with transport access, as clusters of high accessibility (indicative of geographic analysis of locations such as Eindhoven; Qin, J., et al. 2022) often feel an attraction for retail, services, and mixed-use developments; likewise, cultural and tourist zones are frequently discovered within 'walkable' environments, in spatial proximity to multimodal nodes, adding to their experiential benefit as well as pedestrian flows (Wang M., et al. 2025). The orientation and distance, as measured in walking and cycling time, demonstrate that these zones are 'designed' patterns, indicative of the road networks and where people can navigate, including implications for visibility and their intended use of urban space.

This study employs open geospatial data from Cadmapper and OpenStreetMap (OSM) – viewing & treating the road types as a typological mapping approach – seeking to clarify open road types and the geographic considerations, transport relationships with urban function using an integrated accessibility approach for overlaying land use using metrics, and hierarchical networks for establishing convenience of transport planning within their urban formations. The applied framework enables the identification of spatial mismatches, underutilised spaces of inactivity, and the potential for densifying functional spaces in situ (Lu P., et al. 2025).

Recent work has investigated the new open geospatial technology (UGT) capabilities offered by tools such as Cadmapper and OpenStreetMap (OSM) and how they reinvigorate urban diagnostics and spatial modelling (Ou, J., et al., 2025).

With these tools, we can classify road networks and integrate them with land-use data to map typologies and conduct spatial analyses at scales ranging from local to global (Kuncheria et al., 2025; Gil, 2015). Further, with volunteered geographic information (VGI), spatial data has become more accessible, enabling urban studies that are more inclusive and replicable (Capineri et al., 2024).

The importance of urban traffic network studies to urban economic and social development is self-evident. The most far-reaching impact on the modern urban form has been the development of traffic technologies such as the automobile, highway, metro and subway (Ding R. et al., 2019, p. 3). The expansion of these urban traffic networks has shaped the morphology of modern cities, while changes in urban forms will, in turn, affect urban traffic network structures. Here, we define an "urban traffic network" as an urban land-based traffic network, with emphasis on road and rail networks, and it is both related to the traffic flow and infrastructure (Ding R. et al., 2019, p. 3).

Typological studies of transportation systems have evolved, progressing from typological characterisations based solely on geometry to studies that consider the interplay between transport and land use, encompassing traffic dynamics, trip demand, and multimodal connectivity (Rode, P., et al., 2015; Gao, Y., & Zhu, J., 2022).

Recent literature has moved beyond theoretical models to embrace data-driven, context-sensitive planning strategies.

Street networks may be planned according to clear organising principles, or they may evolve organically through accretion, but their configurations and orientations help define a city's spatial logic and order (Boeing, G., 2019). The street network is considered the skeleton of a town, as it links geographical units in urban space. To some extent, the morphological structure of streets determines the breadth and intensity of interconnections between different functional areas in urban settings. Accordingly, it affects the flows and operational efficiencies of various resource elements within the city and its urban spatial structure (Lobsang, T., Zhen, F., & Zhang, S., 2020).

Debates persist regarding the most effective way to integrate transport planning and land-use planning. Some contend that dense, transit-oriented development is the solution (World Bank, 2023), compared with the provision of zoning flexibility that allows real estate development to be responsive to demands for transport modes that reflect emerging travel patterns and changing socio-economic forces (HelloLandMark, 2025).

In Eastern European contexts, including Romania, the legacy of mono-functional planning and fragmented infrastructure poses challenges to coherent spatial organisation (Chung, Y., et al., 2025). Building on the analytical framework established in "*The Role of Streetscape*" (Tătar, A.M., & Pop, C.C., 2025), this study extends the typological analysis to a regional scale.

The results show that road hierarchy and configuration are essential for the location and accessibility of vital urban functions. Specific typologies—for instance, radial arterial networks and grid-based secondary streets—promote greater spatial coherence and efficiency of development, supporting sustainable urban planning and functional area zoning consistent with the Bistrița-Năsăud area.

2. MATERIALS AND METHODS

This research utilises a mixed-methods geospatial framework to examine the typology of road transport systems and their impact on urban spatial organisation within the Bistrița–Beclean–Năsăud–Sângeorz-Băi geographical axis.

The method uses open-source geospatial tools, typological mapping, and spatial analysis techniques to ensure that the results can be replicated and are transparent.

To facilitate this analysis, a typological classification of the road transport system was employed. It was based on five primary factors: functionality, network structure, accessibility level, infrastructure type, and usage purpose.

We used these categories to break down and make sense of road network data from Cadmapper and OpenStreetMap (OSM). This helped us get a better picture of how people move around in cities and suburbs.

The classification made it easier to find transport corridors, differences in infrastructure, and spatial dynamics that are important for sustainable urban planning and territorial cohesion.

The method includes:

A. Data Sources

The primary datasets were obtained from:

- Cadmapper: Used to extract topographic and infrastructural data, including road networks, building footprints, and elevation models.
- OpenStreetMap (OSM): Provided volunteered geographic information (VGI) on road classifications and land-use types.

These datasets were selected for their accessibility, frequency of updates, and compatibility with GIS platforms. All data used are publicly available and can be accessed via cadmapper.com and openstreetmap.org.

B. Spatial Analysis Techniques

The following spatial analysis methods were applied:

- Network hierarchy analysis: To determine the structural role of each road type in urban connectivity.
- Land-use overlays: Urban functions (commercial, cultural, tourist, and economic) were mapped and overlaid with road typologies to identify spatial correlations.
- Accessibility metrics: Calculated using isochrone maps and proximity buffers to assess how road types influence access to urban functions.
- 15-minute city concept application and ANOVA analysis.

C. Study Area Delimitation and Replicability – Data Availabilitys

The geographical axis was segmented into four urban nodes: Bistrița, Beclean, Năsăud, and Sângeorz-Băi. Each node was analysed individually and comparatively to identify typological patterns and spatial mismatches. (Figure 1)

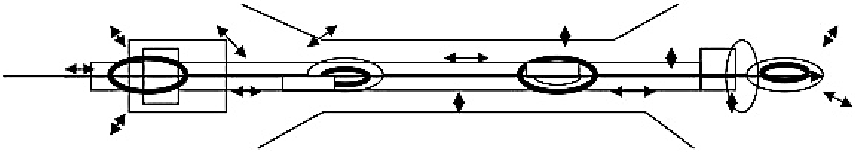

Fig. 1. The composite model for spatial structures in the form of a geographic axis is used in the study.
Source: (Pop, C.C., 2016, pp. 286-287)

All datasets and scripts used in this study are available upon request. The use of open-source tools and public data ensures that the methodology can be replicated and adapted for use in other urban contexts.

3. RESULTS AND DISCUSSIONS

3.1. Geographical Context

The Urban Axis Bistrița–Beclean–Năsăud–Sângeorz-Băi developed along a natural geographical corridor composed of:

- Ø Bistrița Basin
- Ø Someșul Mare Corridor
- Ø Sângeorz-Băi Basin

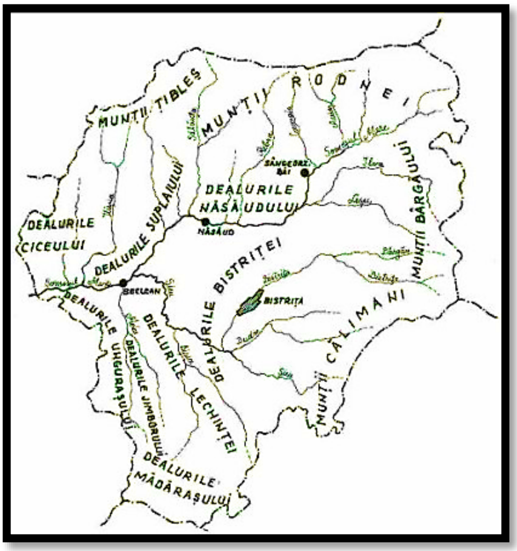

Fig. 2. Location of the Urban Axis Bistrița–Beclean–Năsăud–Sângeorz-Băi
Source: Bîca, I., Onofreiu, A., 2014, p. 13

This succession of landform units provided favourable conditions for:

- The development of the road transport system, particularly through national roads DN17 and DN17D, follows these natural corridors.
- The organisation of urban space, with towns arranged linearly and efficiently connected, according to the characteristics of the terrain (floodplains, terraces, mountain basins) (fig. 2).

From a geographical point of view, the axis follows an East-West direction, primarily following the route of the national road DN17 and the Someșul Mare River.

Component towns have a linear arrangement, promoting the establishment of a corridor of development with urban-rural linkage possibilities.

Bistrița-Beclean-Năsăud-Sângeorz-Băi is a polycentric spatial pattern connecting four major urban hubs in the northern region of Bistrița-Năsăud County. The correlation is characterised by a homogenous territorial area and a varied set of functional characteristics, including those of an administrative, economic, tourist, and regional transportation nature.

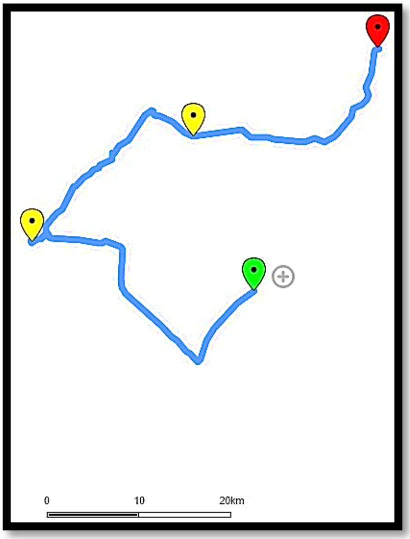

Fig. 3. Geographical axis model: Bistrița-Beclean-Năsăud-Sângeorz-Băi
Source: https://www.openstreetmap.org/

The colored markers indicate the component cities of the axis, and the blue route represents the geographical connection between them. It is a functional model of a geographical axis (fig. 3).

For better organisation and clarity, the research results are structured into two subchapters:

I. Analysis of Road Transport System

II. Points of interest (POIs) and Urban spatial organisation

3.2. Analysis of the Road Transport System

In the urban municipalities of Bistrița-Năsăud County, such as Bistrița, Beclean, Năsăud, and Sângeorz-Băi, the road transportation system follows a common base construction, which is organised along a road network, which constitutes the fundamental physical infrastructure, including national routes, city streets, and principal boulevards.

The network connects city quarters and settlements in the vicinity, as well as other settlements in Bistrița-Năsăud County.

Public transportation is primarily provided by a network of suburban and urban buses owned and operated by private enterprises, with notable routes established to benefit the central district and nearby suburban regions.

Alternative transportation infrastructure includes cycle-specific routes, pedestrian precincts, upgraded pavement, and electric vehicle charging stations. The city has a program on sustainable transportation, in line with the principles of green urbanism.

The highway system of transportation plays an essential role by connecting urban spaces, rationalising the movement of vehicles, and enhancing the overall quality of urban life in these three aspects.

Despite the general structural similarities, the degree of development, network density, and urban integration level vary significantly due to differences in town size, geographical position, and resource availability. For these reasons, it is fitting to discuss a common typology with local adaptations that are peculiar to each city.

3.2.1. Bistrița

a. Typology of the Road Transport System in the City of Bistrița

- Model: Axial and Central

Classification:

- Axial – Linear development along Bistrița Valley and DN17, with predominantly East-West urban expansion.
- Central – Presence of a well-defined historical core, with a radial street network converging toward the medieval centre.
- Justification:

The municipality of Bistrița has developed along the natural axis formed by the Bistrița River and the DN17 road layout, giving the town an overall axial structure. The medieval historical centre, with its central square, defined the organisation of streets that connect the present town centre radially with George Coșbuc and Dornei, thereby defining the urban core. The main axial routes, connecting to the human and environmental geography, are Calea Moldovei and Drumul Cetății, radially branching off this historic and contemporary urban core, and have a primarily axial urban character.

Example:

- Ø Central core: Central Square, George Coșbuc Street, and Dornei Street.
- Ø Axial expansion: Calea Moldovei (to the East) and Drumul Cetății (to the West), running parallel to the Bistrița River and DN17.

b. Road transport system

National and County roads crossing Bistrița

These roads ensure the city's connection with surrounding villages and peripheral neighbourhoods:

- Ø DN17 (E58) – crosses the city from East to West. It connects the neighbourhoods of Unirea, Viișoara, Independenței, and Calea Moldovei. It is the main transit route toward Beclean, Dej, and Vatra Dornei.
- Ø DN17C – route is Bistrița – Dumitra – Năsăud – Salva – Coșbuc – Moisei. It is essential for connecting with the northern part of the county.
- Ø DN17D starts in Beclean and heads northeast, connecting the town of Năsăud and the communes along the Upper Someș Valley.
- Ø DJ173 connecting the localities of: Bistrița (DN 17) – Jelna – Orheiu Bistriței – Budacu de Sus – Șoimuș – Șieu – Posmuș – Teaca – Ocnița – Milaș – the border with Mureș County.

Typology of neighbourhoods in Bistrița (table 1)

1. Central neighbourhoods

- Ø Historic Centre – pedestrian area, with streets such as Gheorghe Șincai and Piața Centrală (Central Square).
- Ø Andrei Mureșanu – residential and commercial area, connected via Decebal Boulevard and Andrei Mureșanu Street.
- Ø Subcetate – a developing area, accessible via Năsăudului Street.

2. Peripheral and Extended neighbourhoods

- Ø Unirea – connected via Calea Moldovei (DN17), an area with heavy traffic and commercial development.
- Ø DJ172B connects the Unirea district with the component locality of Slătinița.

- Ø Viișoara – accessible via Independenței Boulevard and Libertății Street.
- Ø Access route to Sigmir. The main access is from the western part of the city, using the extension of National Road DN17 (Calea Clujului), followed by Sigmirului Street.
- Ø The main access to the component locality of Slătinița is from the north-eastern area of the municipality of Bistrița, using National Road DN17, followed by County Road DJ172B.
- Ø Ghinda – accessible via modernised secondary roads, with proposed links to DN17 and Jelna.
- Ø The road that starts in the municipality of Bistrița on Tărpiului Street and crosses the Industrial Area (passing by facilities such as Leoni) is County Road 173B (DJ 173B).

Table 1. Main Boulevards and Streets in Bistrița
Connected Roads and Served Areas

Boulevard / Street	Served Neighbourhoods / Zones	Connected / Crossed Roads
Independenței Boulevard	Viișoara, industrial area, Petru Rareș Square	DN17
Calea Moldovei	Unirea, Viișoara, commercial area (Selgros, Kaufland)	DN17
Decebal Boulevard	Andrei Mureșanu, central area	DN 17
Andrei Mureșanu Street	Andrei Mureșanu, Năsăudului, train station area	DN17
Năsăudului Street	Subcetate neighbourhood, exit toward Năsăud	DN17C
Gheorghe Șincai Street	Unirii Square, the central area	DN 17, DJ 173C
Gării Street	Bistrița Nord Train Station, industrial area	DN 17, DJ 173 B
Libertății Street	Viișoara, southern area	DN17
Tărpiului Street	Tărpiului neighbourhood, connection to DN17C	DJ 173B, Gării Street

Source: the authors

3. Expanding Neighbourhoods

- Ø ANL Subcetate – new housing developments, accessible via Năsăudului Street.
- Ø Zona Electrica – streets such as Lt. Călin, Minulescu, and Cerbului – are currently under modernisation.

Road Connections Between Neighbourhoods

- Ø Urban streets – Decebal, Andrei Mureșanu, Gheorghe Șincai, Năsăudului.

Proposed or modernised roads: Sigmir – Valea Căstăilor (for traffic decongestion), Ghinda – Jelna / DN17 (for faster access), Slătinița – Nepos / Livezile (for network expansion), Tărpiului Road – DN17C (for industrial area access).

The public transportation network in Bistrița, operated by Transmixt, consists of a total of 221 stations (fig. 4). The local public transport system in Bistrița follows the spatial organisation of the city, which we have structured into:

Ø Main Routes **-** Bus routes with a strategic role in urban mobility

1. Routes linking urban centres and peripheral areas

Ø Calea Moldovei – Unirea. Main stops: Calea Moldovei (Selgros, Kaufland), Unirea (Avicola, Lacrima School, Unirea Church, Agronomist's House).

Ø Calea Clujului - Calea Moldovei. Main stations: Independenței Nord, Decebal, Petre Ispirescu, Ștefan cel Mare, Calea Moldovei (Cibela).

Role: Crosses the city from West to East, connecting two major arteries and natural areas (Codrișor).

Fig. 4. Road infrastructure and Urban landscape on DN 17
Calea Moldovei towards Unirea, Bistrița.
Source: the authors

2. Routes connecting the civic centre with administrative and educational areas:

Ø Republicii - Calea Moldovei (fig. 5). Main stations: Republicii, Gării, General Grigore Bălan, 1 Decembrie, CNLR, CNAM.

Role: Connects the administrative Centre with the commercial area and DN17.

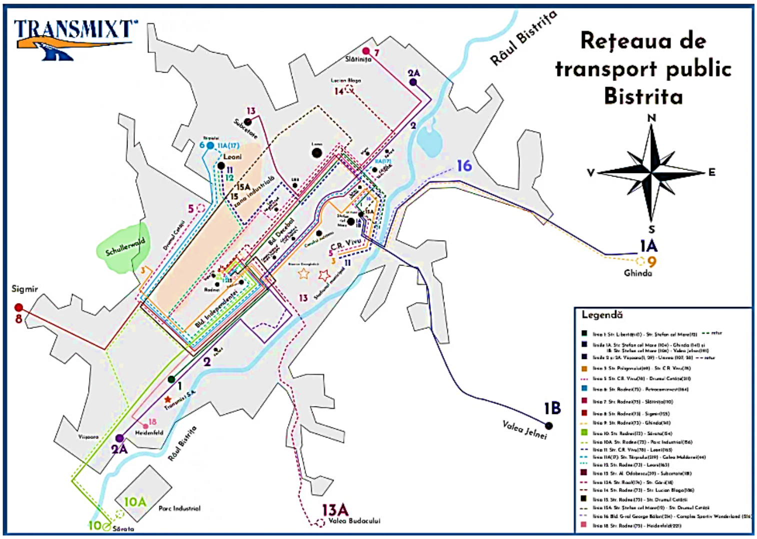

Fig. 5. Bistrița's public transport network
Source: https://tmxbn.ro/transport-local/

- Secondary Routes - Complementary and Local Routes

  1. Distribution routes in neighbourhoods and residential areas

- Libertății – Independenței. Main stations: Libertății, Petru Maior, Eroilor, Independenței (Kindergarten No. 10, Mat).
  Role: Short route between administrative and commercial areas.
- Petre Ispirescu - Andrei Mureșanu - Ștefan cel Mare. Main stations: Petre Ispirescu, Andrei Mureșanu, Ștefan cel Mare.
  Role: Internal routes in mixed-function neighbourhoods (housing, education, services).

  2. Routes with a tourist and ecological role

- Calea Moldovei - Capușele - Cocoșul Forest - MHC Lake. Main stations: Calea Moldovei, Ioan Slavici.

Access to Capușele and Cocoșul Forest

- Role: Trail with ecotouristic potential, linked to bicycle infrastructure and green spaces.

Fig. 6. Public Transport Infrastructure – Bus Stop on Calea Moldovei, Bistrița
Source: the authors

Infrastructure for Alternative Mobility – Bicycle Lanes

Approximately 30 km of bicycle lanes have already been developed on 29 streets in the city (primary route): 1 Decembrie, Năsăud (Han zone), Avram Iancu, Grănicerilor, Ghinzii, C.R. Vivu, Vasile Lupu, Tudor Vladimirescu, Cimitirului, Crinilor, Ioan Slavici, Subcetate, Drumul Cetății, Drumul Dumitrei Vechi, Dimitrie Cantemir, Eroilor, Împăratul Traian, Valeriu Braniște, Aleea Sălciilor, Petru Maior, Alexandru Odobescu, Ioan Rațiu, Codrișor/Victor Onișor, Alba Iulia, Aleea Șieu, Panait Cerna, Gheorghe Pop de Băsești, Axente Sever, Garoafei (fig. 7).

Elements highlighted in Fig. 7:

- Road lane marked "BUS" – indicates priority for public transportation.
- Red-coloured bicycle lane – with directional markings.
- Pedestrian sidewalk – paved and clearly delineated.
- Traffic signalling – visible in the pedestrian area, contributing to traffic safety.

Fig. 7. Integration of Road, Bicycle, and Pedestrian Infrastructure on Năsăudului Street, Bistrița
Source: the authors

Bike-Sharing System (fig. 8)

The bike-sharing system in Bistrița, operated by means of the GLOBIKES app, includes:

- Ø 165 mechanical bicycles
- Ø 10 electric bicycles
- Ø 7 rental terminals located throughout the city

Fig. 8. Bike Rental Station – Alternative Mobility Infrastructure in Mihai Eminescu Park, Bistrița
Source: the authors

The image shows a bike rental station located on a paved sidewalk in Mihai Eminescu Park, Bistrița. Five blue and white bicycles are neatly aligned, each equipped with a front basket and a rear locking device.

In the background, trees and parked cars are visible, indicating the facility's integration into the urban landscape.

Bus stops on the route between Libertății Street and Independenței Street in Bistrița:

- Ø Stop 1 – near the starting point (Libertății Street)
- Ø Stop 2 – at the intersection with Petru Maior Street
- Ø Stop 3 – at the intersection with Eroilor Street
- Ø Stop 4 – near the endpoint (Independenței Street)

The bus route encompasses DN17, a national route that connects users with other parts of the county as well as neighbouring villages and the north-eastern part of Romania (fig. 9). The bus route connects two major streets in the city, allowing users to move between residential areas, commercial, and institutional destinations. Libertății Street is associated with the administrative and residential areas of the town, while Independenței Street serves the same commercial and transit purposes.

Bus stops on the route Between Decebal Street and Năsăudului Street (Bistrița):

- Ø Stop 1 – located on Decebal Street, near the intersection with Republicii Street
- Ø Stop 2 – on Crinilor Street
- Ø Stop 3 – on Andrei Mureșanu Street
- Ø Stop 4 – on Năsăudului Street, near the intersection with Gârleanu Street

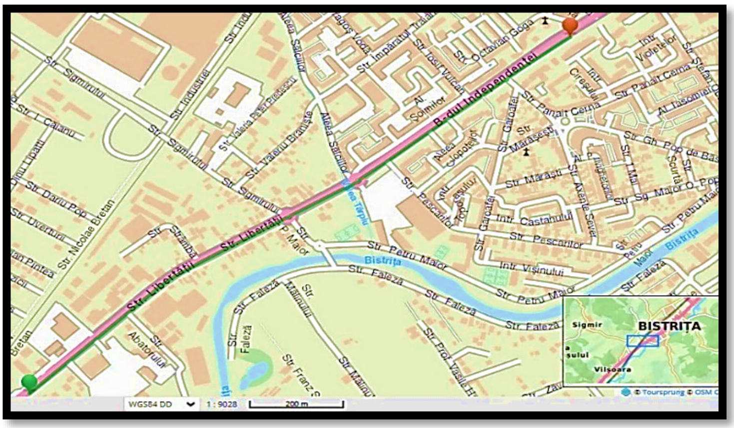

Fig. 9. Route Libertății Street - Independenței Street
Source: https://www.openstreetmap.org/

The bus route is marked on the map with a green line, connecting two key areas of the city: the central zone (Decebal–Republicii) and the northern zone (Năsăudului–Gârleanu). It follows essential urban streets and is part of the public transportation network in Bistrița. The route also intersects DN17, a major national road that enhances regional connectivity (fig. 10).

Fig. 10. Route: Decebal Boulevard - Năsăudului Street
Source: https://www.openstreetmap.org/

Bus stops on the route between Republicii Boulevard and Calea Moldovei Street (Bistrița):

- Ø Stop 1 – near Bulevardul Republicii (starting point, marked with green)
- Ø Stop 2 – on Gării Street
- Ø Stop 3 – on General Grigore Bălan Street
- Ø Stop 4 – on 1 December Street
- Ø Stop 5 – near Calea Moldovei (endpoint, marked with red)

This bus route connects Bulevardul Republicii, a central boulevard with administrative and commercial functions, to Calea Moldovei, a major eastern exit of the city aligned with DN17, a national road of strategic importance. The route passes through key urban streets such as Strada Gării, which links to the train station, and Strada General Grigore Bălan, a segment of DN17 that supports regional traffic (fig. 11).

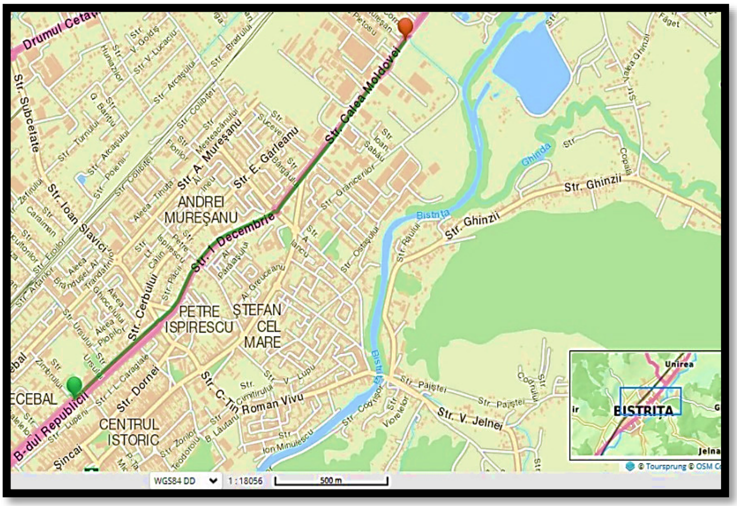

Fig. 11. Route Between Republicii Boulevard and Calea Moldovei Street
Source: https://www.openstreetmap.org/

Neighbourhoods along the route:

- Historical Centre – the cultural and civic core of Bistrița
- Ștefan cel Mare Street – mixed-use area with residential blocks and public institutions
- Petre Ispirescu – residential neighbourhood with proximity to green areas
- Andrei Mureșanu – dense urban zone with educational and service infrastructure

Bus stops on the route between Calea Clujului and Calea Moldovei (Bistrița):

- Stop 1 – in the Independenței Nord area (near Calea Clujului)
- Stop 2 – in Independenței Sud
- Stop 3 – near Decebal Street
- Stop 4 – on Petre Ispirescu Street
- Stop 5 – in the Andrei Mureșanu neighbourhood
- Stop 6 – near Ștefan cel Mare Street, close to Calea Moldovei

This bus route connects two major entry/exit arteries of Bistrița: Calea Clujului (western access) and Calea Moldovei (eastern access). It passes through central and residential neighbourhoods, such as Decebal, Andrei Mureșanu, and Ștefan cel Mare, and intersects key urban zones, including the Historic Centre, as well as natural areas like Codrișor Forest.

The route is part of the city's public transport network and follows segments of DN17, enhancing both local and regional mobility (fig. 12).

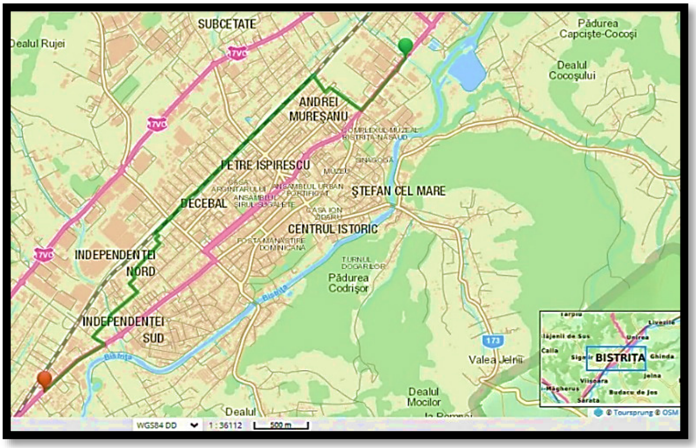

Fig. 12. Route Calea Clujului - Calea Moldovei
Source: https://www.openstreetmap.org/

The bus route connects Calea Moldovei (a major commercial artery) with Unirea, a rapidly expanding residential area (fig. 13).

Passes through several key streets:

- Ø Calea Moldovei Street – a main road with heavy traffic and access to commercial centres.
- Ø Ioan Slavici Street – a connector between residential neighbourhoods.
- Ø Andrei Mureşanu Street – a mixed-use area with housing and services.
- Ø DN17C – a national road facilitating access to peri-urban and rural areas.

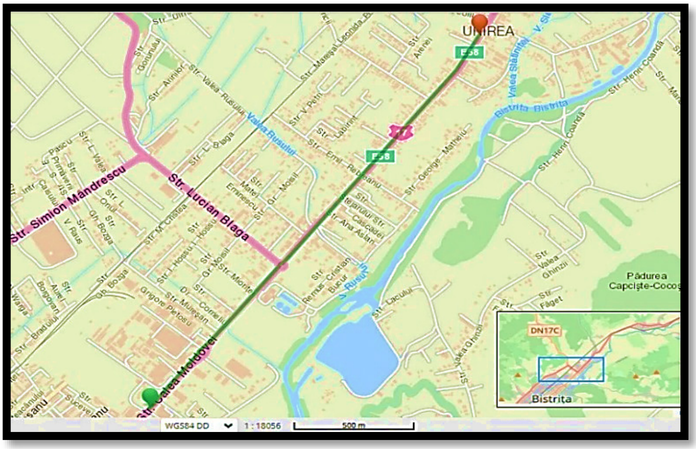

Fig. 13. Bus route Calea Moldovei-Unirea
Source: https://www.openstreetmap.org/

Importance of the Route

- Access to commercial centres:

The route serves areas with supermarkets, DIY stores, and other commercial facilities along Calea Moldovei. It facilitates transportation for both employees and customers.

- Expanding residential area – Unirea:

Population growth and real estate development in Unirea require efficient connectivity with the city centre. The route supports daily mobility for residents to schools, workplaces, and public institutions.

- Links to natural attractions and tourist infrastructure:

Proximity to Capușele-Cocoșul Forest, Bistrița River and the MHC Lake offers opportunities for the development of leisure and ecotourism routes.

- Key roads on the route:

Calea Moldovei – a commercial and industrial artery, Ioan Slavici – a transit street between neighbourhoods, and Andrei Mureșanu – a residential and educational area.

DN17C – a strategic road connecting to the northern parts of the county.

3.2.2. Beclean

a. Typology of the Road Transport System in the Town of Beclean

- Model: Linear

Classification:

- Linear – Urban development along the DN17 road axis, with an elongated structure and urban functions concentrated along this main direction.
- Justification:

The town of Beclean has predominantly developed along the national road DN17, which gives the settlement a linear morphology. The urban structure is elongated, with commercial, administrative, and transport functions concentrated along the central axis. Lateral branches are limited, which emphasises the linear character of the road transport network.

Example:

- Central axis: 1 Decembrie 1918 Street, which crosses the town from East to West.
- Nodal point: Beclean Train Station area, situated on the DN17 axis, serves as a regional mobility hub.

Recent infrastructure projects (road overpasses, connections between DN17 and DJ172) aim to improve traffic flow along the central axis, highlighting the importance and centrality of this linear structure in the town's spatial organisation.

b. Road transport system

Bicycle Route in Beclean:

- Aleea Gării – a central pedestrian area, an important starting point.
- 1 Decembrie 1918 Street – connects the city centre to the Someșul Mare River area.
- Someșul Mare River Promenade – a bike lane separated from the roadway, located on the embankment.
- Codrului Street leads toward the forest and recreational area.
- Băile Figa Area – the route circles the spa complex and the nearby forest.
- Gării Street – part of the "Drumul Gării din Beclean" project.
- Coldău and Podirei neighbourhoods – connected through extended bike lanes.

These bike lanes are part of a 15–17 km infrastructure project that connects the city's neighbourhoods and recreational areas (fig. 14 and 15).

Fig. 14. Integration of bicycle lanes into the urban landscape of Beclean
Source: the authors

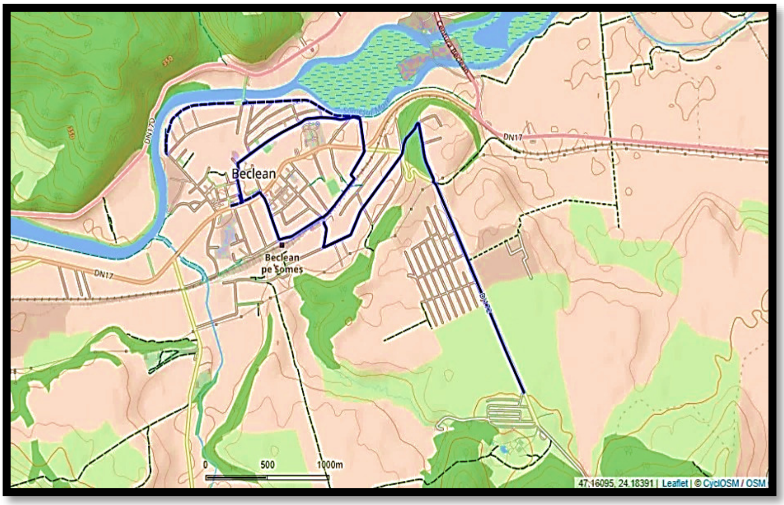

Fig. 15. Spatial Distribution of Bicycle Lanes in Beclean
Source: https://www.openstreetmap.org/

Public transport operator

- Official name: Urban Public Transport Company Beclean SRL
- Fleet type: exclusively electric buses
- Number of bus stops and routes: there is a total number of 55 bus stops in the town of Beclean, 5 routes and itineraries: Băile Figa – Coldău, Băile Figa – Beclenuț, Podirei – Rusu de Jos, Băile Figa – Rusu de Jos, Figa – Town Centre – S-D Figa – Coldău.

Descriptive analysis of two public transport routes in Beclean – “Băile Figa – Coldău” and “Figa – Town Centre – S-D Figa – Coldău” – from an economic, tourist, and social perspective.

Route: Băile Figa – Coldău

- Economic importance: it connects the tourist area of Băile Figa with Coldău, a neighbourhood with residential and commercial functions. It facilitates access for employees and suppliers to the spa complex and commercial units in Coldău (fig. 16). It supports local economic development through connectivity between service and production areas.
- Tourist importance: Băile Figa represents one of the most important tourist attractions in Bistrița-Năsăud County. The route offers easy access for tourists staying in Coldău or neighbouring regions. It promotes ecological mobility in a city that supports sustainable tourism.

- Social importance: it provides public transportation for Coldău residents to commute to work or for recreation at Băile Figa. The bus service promotes less dependence on private transport by offering Coldău residents their own accessible and environmentally friendly mode of transportation.

It connects two communities and encourages social inclusivity and municipal response, including all ratepayers' access to a public facility.

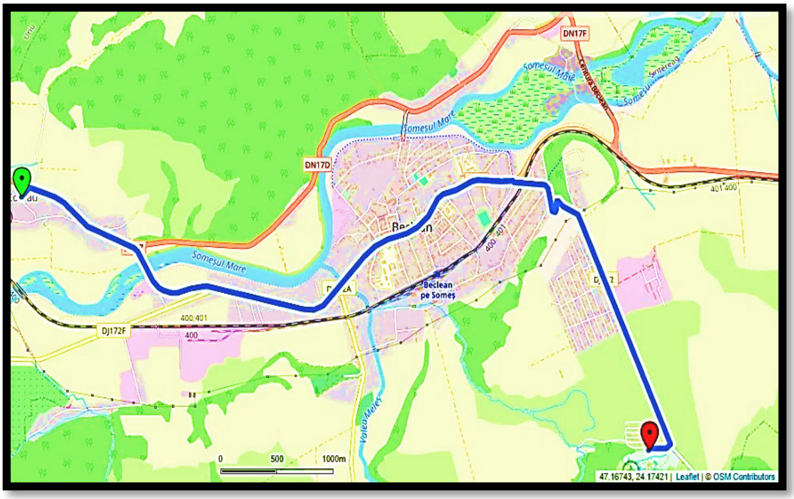

Fig. 16. Route: Băile Figa – Coldău, Beclean
Source: https://www.openstreetmap.org/

Figa – Town Centre – S-D Figa – Coldău

- Economic importance: it passes through the town centre of Beclean, a commercial and administrative hub. It links the tourist area with the development zone S-D Figa, where residential and infrastructure projects are located. It supports economic activity by connecting residential areas with service and commercial zones (fig. 17).
- Tourist importance: it provides direct access between Băile Figa, the town centre, and Coldău, facilitating tourist movement between key points of interest. It is ideal for tourists who wish to visit both the spa area and the historic or commercial centre of the city.

It can be integrated into "urban ecotourism" routes, considering the bicycle infrastructure and electric buses. Figa Resort is located in Bistriţa-Năsăud County, 3 km from Beclean, and was opened in 2010 with the assistance of PHARE funds, making it one of the most modern locations with thermal baths in Romania. Băile Figa resort is located in a basin between the hills of Beclean, and is famous for its salty waters and mud with properties similar to those of Techirghiol. The recreational area is composed of an outdoor saltwater pool, an indoor heated freshwater pool, a sauna, a jacuzzi, massage, fitness, sports fields with synthetic surfaces.

The resort features an indoor heated freshwater pool, alongside a sauna, a jacuzzi, and a doctor's office. Upstairs, guests can enjoy massage rooms, table tennis, and a fitness room. Terraces also surround an outdoor saltwater pool. Near the saltwater pool is a mini sandy beach with sun loungers.

The mud is similar to the one in Techirghiol and is suitable for the treatment of rheumatic diseases, musculoskeletal disorders, nervous system conditions, and even gynaecological diseases (https://www.hartaturistului.com/).

- Social importance: it is a multifunctional route serving residents from multiple neighbourhoods and areas of interest. It connects new residential zones (S-D Figa) with the town centre and educational, cultural, and medical facilities. It contributes to urban cohesion by reducing peripheral isolation and promoting equitable mobility.

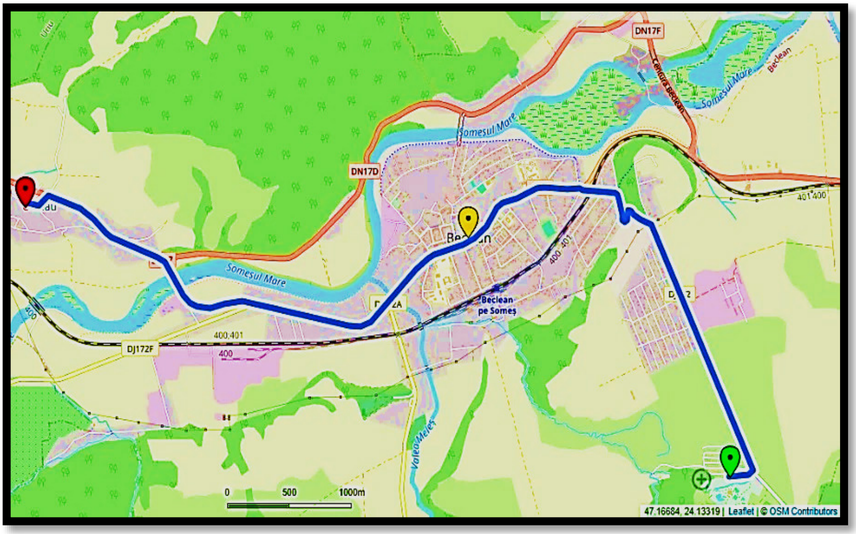

Fig. 17. Route: Figa – Town Centre – S-D Figa – Coldău
Source: https://www.openstreetmap.org/

These two routes are strategic for the town of Beclean. They integrate tourist, economic, and social functions, support sustainable mobility through the use of electric buses, and connect urban development zones with the town centre and existing infrastructure.

3.2.3. Năsăud

a. Typology of the Road Transport System in Năsăud

Central and radial model

- Central model: Năsăud has a well-defined civic centre, located around the Town Hall and the Central Park, which functions as the urban core.
- Radial model: Several major streets radiate from this core and extend towards the outskirts, which is characteristic of a radial layout.
- Spatial justification

A mix of administrative, commercial, and recreational functions characterises the central area. Streets such as Mihai Eminescu, Piața Unirii, and Bulevardul Grănicerilor converge towards this area, supporting the idea of a radial organisation.

- Examples

Bulevardul Grănicerilor is a main artery connecting the central area to the southern part of the town.

Mihai Eminescu Street links the central area to the eastern part. Piața Unirii serves as an intersection node and a point of convergence.

b. Road transport system

DN17C connects Năsăud with Bistrița (to the south) and with Moisei/ Maramureș (to the north).

DN17D connects Năsăud with Sângeorz-Băi (to the northeast) and with Beclean (to the west).

In Năsăud, the local public transportation system is undergoing significant development through the urban mobility project, which is financed with 5 million euros from European funds. The road infrastructure has been modernised, specifically the carriageway used jointly by public passenger transport vehicles, to reduce CO_2 equivalent emissions from transport.

A total of 3.8 km of road has been upgraded, including Crișan, Avram Iancu, Andrei Mureșanu, Vasile Nașcu, Tudor Vladimirescu, Comoarei, and Dumitru Vârtic streets. Additionally, pedestrian routes (sidewalks) have been laid out over a distance of 2.8 km.

Electric buses have been purchased, a depot has been built and charging stations have been installed. Furthermore, a traffic management system will be created, including video monitoring and an intelligent transport system (ITS) (fig. 18).

Description of the local road transport system:

The system comprises five electric buses, of which three are small electric buses with approximately 10–15 seats, and two are large electric buses with approximately 25–30 seats, designed for public road transport.

The project also involves the construction of a depot for local public passenger transport, including the associated technical infrastructure, and the installation of 32 public transport (electric bus) stops. An integrated ticketing system for passengers will be created ("e-tickets" or "e-ticketing").

Fig. 18. Bus Stop "Năsăud 2025" model: urban light – EcoTransit – transparent shelter – SmartStop
Source: the authors

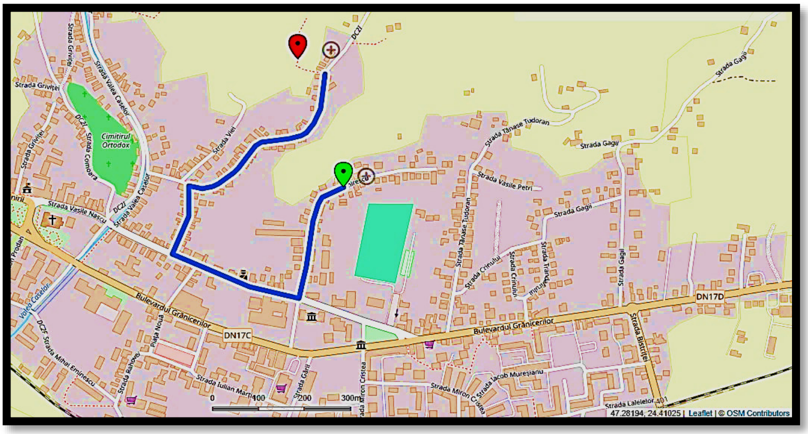

Fig. 19. Route: Tudor Vladimirescu-Avram Iancu
Source: https://www.openstreetmap.org

3.2.4. Sângeorz-Băi

a. Typology of the Road Transport System in Sângeorz-Băi

Grouped and axial model

- Justification:

The town of Sângeorz-Băi has a dispersed structure, with residential areas and tourist zones (the spa resort) separated spatially but connected through axial roads. This spatial organisation reflects a functional distribution of the urban space, where areas are grouped according to their purpose (residential, tourism, nature) and linked via an axial transport network.

Example:

- DN17D is the main road artery connecting the central area with the spa districts and surrounding natural zones.
- Urban areas are grouped based on their functions: administrative centres, residential neighbourhoods, and tourist facilities.

This layout ensures efficient accessibility between the town's key functions without causing excessive congestion in the central core.

b. Road transport system

In the town of Sângeorz-Băi, local public transport is provided by Sângeorz-Băi Town Hall, in collaboration with local operators, through a modern system of electric minibuses.

Operator and infrastructure:

Local authorities manage the transport system, and routes are available in the Moovit app, which provides real-time information.

Number of stops: the public transport network includes 36 bus stops, distributed across two main lines.

Transport lines:

- Line 1: Depot – Valea Borcutului; Length: 5 km; Number of stops: 9.
- Line 2: Depot – Cormaia School; Length: over 8 km; Number of stops: 18.

These lines cover the central neighbourhoods and points of interest in the town, including the wastewater treatment area, Cormaia, Valea Borcutului, and the town centre (fig. 20).

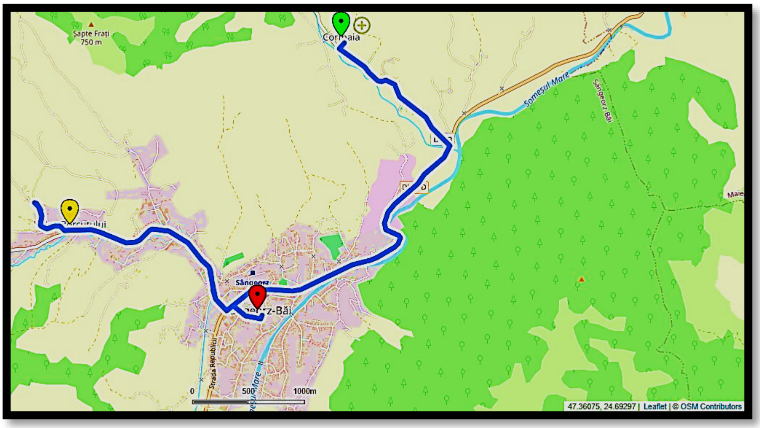

Fig. 20. Transport route: Cormaia-Sângeorz-Băi-Valea Borcutului
Source: https://www.openstreetmap.org

Bicycle lanes and bike-sharing system in Sângeorz-Băi

Length of bicycle lanes

- Ø A total of 6.334 km of bicycle lanes were built as part of the urban mobility project.
- Ø The lanes are equipped with public lighting, pedestrian railings, and waste bins.

The route largely follows the banks of the Someșul Mare River, connecting the central area with the spa districts and promenade zones.

- Ø Additional cycling routes

There are also cycling trails in the Valea Borcutului–Parva area, measuring 3,704 m in length, suitable for cyclists with intermediate experience. These routes offer spectacular views and are integrated into the natural landscape of the Rodna Mountains.

Bike-sharing system

- Ø A total of 60 bicycles were purchased through European funding.
- Ø The bikes are available at four bike-sharing stations located throughout the town.
- Ø Usage is free for the first hour, after which a fee of 10 lei/hour is charged.

Access is granted via a card issued by the Town Hall, with online registration available at sangeorzbike. ro.

3.2.5. Typology of the Road Transport System in Bistrița–Beclean–Năsăud–Sângeorz-Băi urban axis

- Dominant model: axial

Reasoning: The DN17 and DN17D arteries ensure urban connectivity by following the natural axis formed by the Bistrița and Someșul Mare valleys, being configured in accordance with the specific relief of the depressions they cross.

Key characteristics:

- The towns are aligned along a regional transport axis.
- The primary road network dictates the direction of urban development.
- Connections between cities are direct, with few major branches.

Secondary influences:

- Central: it is important in towns such as Bistrița and Năsăud, where a well-defined urban core exists.
- Linear: in Beclean, where development is closely tied to the road axis.
- Grouped: in Sângeorz-Băi, where urban functions (residential, tourism) are dispersed but connected axially.

Examples:

- DN17 links Bistrița to Beclean and further towards Cluj-Napoca.
- DN17D continues towards Năsăud and Sângeorz-Băi, following the valley of the Someșul Mare River.

Table 2. Total length of bicycle lanes – bike-sharing systems

City	Length of bicycle lanes (km)	Number of bicycles	Number of stations	Notes
Bistrița	30 km	175 (165 regular + 10 electric)	7 stations	GLOBIKES system, mobile app available
Beclean	17 km	-	-	-
Năsăud	0 km (functional)	-	-	-
Sângeorz-Băi	6.3-6.4 km	60	4 stations	Access via Town Hall-issued card, registration at sangeorzbike. ro

Source: the authors

Analysis of bicycle infrastructure and bike-sharing systems in Bistrița–Beclean–Năsăud–Sângeorz-Băi urban axis (table 2):

- Estimated total length: ~49.3-50 km of bicycle lanes across the urban axis.
- Number of bicycles: 235; stations: 11.

The data regarding cycling infrastructure within the urban axis Bistrița–Beclean–Năsăud–Sângeorz-Băi reflects the situation as of 2025, with prospects for future expansion.

In the studied urban axis, the bus stop models for 2025 include the following functional and stylistic subtypes:

- Urban light – featuring an airy design with a lightweight metal structure, suitable for modern urban spaces.
- EcoTransit – adapted for ecological transport using electric buses.
- Transparent shelter – equipped with transparent panels for enhanced visibility and safety.
- SmartStop – integrated with an e-ticketing system and video monitoring for a digital and secure passenger experience.

3.3. Urban spatial organisation

3.3.1. Analysis of the degree of implementation of the 15-minute city principle

The 15-minute city concept aims to create self-sufficient neighbourhoods with the essential functions of living, working, commerce, healthcare, education, and entertainment by decentralising urban functions and services (Khavarian-Garmsir et al., 2023). Seven dimensions constitute the 15-minute city: (1) proximity, (2) density, (3) diversity, (4) digitalisation, (5) human scale, urban design, (6) flexibility, and (7) connectivity.

These are briefly discussed (Khavarian-Garmsir et al., 2023) (table 3).

Table 3. Percentage of urban residential areas covered by the 15-minute city principle

City	Percentage of Urban Residential Areas
Bistrița	75%-80%
Beclean	90%
Năsăud	90%
Sângeorz-Băi	70%

Source: the authors

The differences in coverage percentages within the 15-minute city principle for the four cities along the Bistrița–Beclean–Năsăud–Sângeorz-Băi axis can be explained by urban typology, street network structure, and the distribution of essential functions.

- *Beclean*

A small town with essential functions (schools, markets, parks, public transport) concentrated in the centre. Distances are short, and access is easy from almost any residential point.

- *Năsăud*

A transparent and efficient urban structure, with a predominantly orthogonal street network. Urban functions are evenly distributed, and the town's size favours proximity.

- *Bistrița*

A larger city with a mixed street network: historical areas with narrow and winding streets, and modern zones that are better organised. Functions are well distributed in the centre, but peripheral regions may have limited access to certain services. Distances increase in new neighbourhoods or industrial zones. Good accessibility is available in the centre, but it decreases towards the periphery.

- *Sângeorz-Băi*

A resort town with mountainous terrain, which negatively affects pedestrian accessibility. It has an organic street network, with winding roads and a dispersed distribution of buildings. Urban functions are concentrated in the central tourist area, while peripheral residential zones are less connected.

The more compact a city is, with an orthogonal street network and evenly distributed functions, the more likely it is to align with the 15-minute city principle.

The analysis was conducted using Cadmapper.

Analysis of variance ANOVA is a statistical method developed by Sir Ronald A. Fisher. Anova works by dividing the total variation into two components variation between groups sum of squares between groups, indicated as SS_Between and variation within the group sum of squares within the groups, indicated as SS_Within. Fisher, in the 1920s, used to compare the averages of various groups and determine whether the differences observed between them are statistically significant or attributed to chance variation. Then we calculate the mean squares MS and the statistic F, which is the ratio between MS_Between and MS_Within.

The resulting p-value indicates whether the differences are significant ($p < 0.05$) or not (Cochran, W. G., 1980; Janczyk, M., & Pfister, R., 2023).

In this study, ANOVA analysis was applied to compare the coverage of the 15-minute city principle in four cities in the urban axis Bistrița-Beclean-Năsăud-Sângeorz-Băi. The percentage values examined were Bistrița (75-80%), Beclean (90%), Năsăud (90%), and Sângeorz-Băi (70%).

The result obtained was an F-statistic of 8.20 and a p-value of 0.2500, indicating that there are no statistically significant differences between cities in terms of coverage of the 15-minute city principle.

This finding has important implications for the study of the urban axis. It suggests a functional coherence among the analysed cities, which validates the polycentric model and supports the idea of a balanced territorial organisation. Secondly, it demonstrates that the morphological diversity of cities (axial, central, and clustered) does not hinder the application of sustainable urbanism principles but rather allows for efficient local adaptations.

3.3.2. Spatial Analysis with Cadmapper

3.3.2.1. Bistrița

The axial-central urban layout model relies on the existence of an axis - usually a boulevard or major thoroughfare - that crosses the urban landscape, and on which the complete metropolitan morphogenesis is based.

This axis is a unifying spatial element that links urban morphologies adjoining it, serving to connect areas of civic importance, public utilities, commercial zones, and residential areas within the city (fig. 21, fig. 22).

The balanced or symmetrical disposition of buildings, roads, and green spaces with respect to an axis suggests a systematic effort toward efficient and aesthetic urban planning, as the axis appears to represent the systematic arrangement of spatial objects.

The symmetrical green space along the axis suggests a concern for the quality of the urban environment and the formation of ecological corridors and recreational spaces.

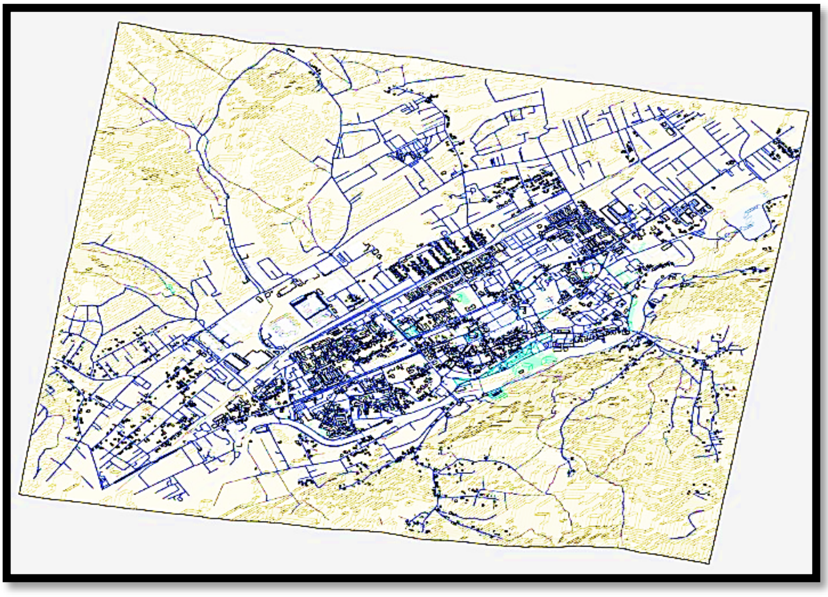

Fig. 21. Spatial structure of Bistrița municipality - cartographic representation
Source: https://cadmapper.com/pro

- File Type: AutoCAD DXF
- Area: 24.429 km^2
- Buildings: 4285 total, 66 with height value (2%)

- Topography: included, 337.00 m above sea level
- Settings: Road meshes (highways 8.0, major 8.0, minor 8.0, paths 5.0), 3D buildings (no value = 3.0 m), 10 m contours
- Spatial Reference System: Meters; UTM Zone: 35, Easting: 306875.44, Northing: 5220790.12. 3D Axonometric View
- 1:20.000

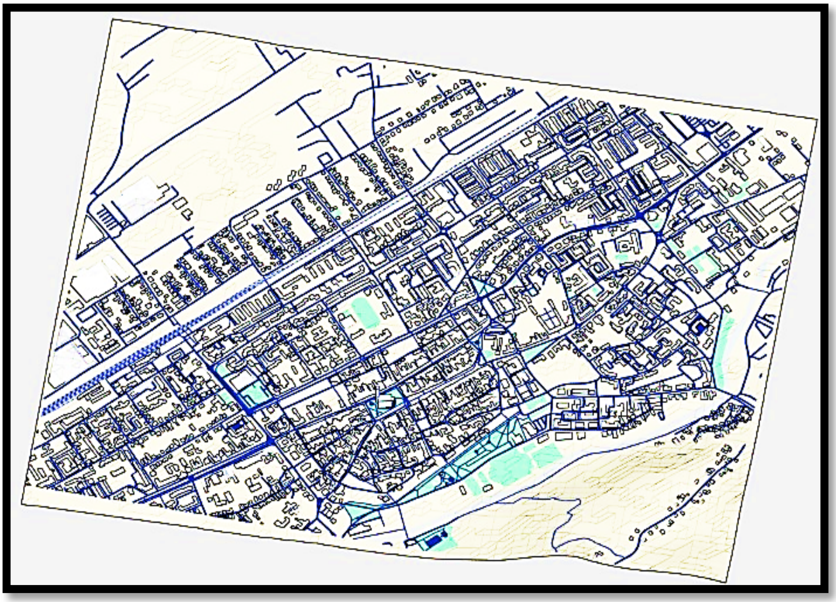

Fig. 22. Bistrița - spatial organisation and road network
Source: https://cadmapper.com/pro

- File Type: AutoCAD DXF
- Area: 5.149 km^2
- Buildings: 2117 total, 62 with height value (3%)
- Topography: included, 352.00 m above sea level
- Settings: Road meshes (highways 8.0, major 8.0, minor 8.0, paths 5.0), 3D buildings (no value = 3.0 m), 10 m contours
- Spatial Reference System: Meters; UTM zone: 35, easting: 308852.33, northing: 5222285.43.3D Axonometric View
- 1:10.000

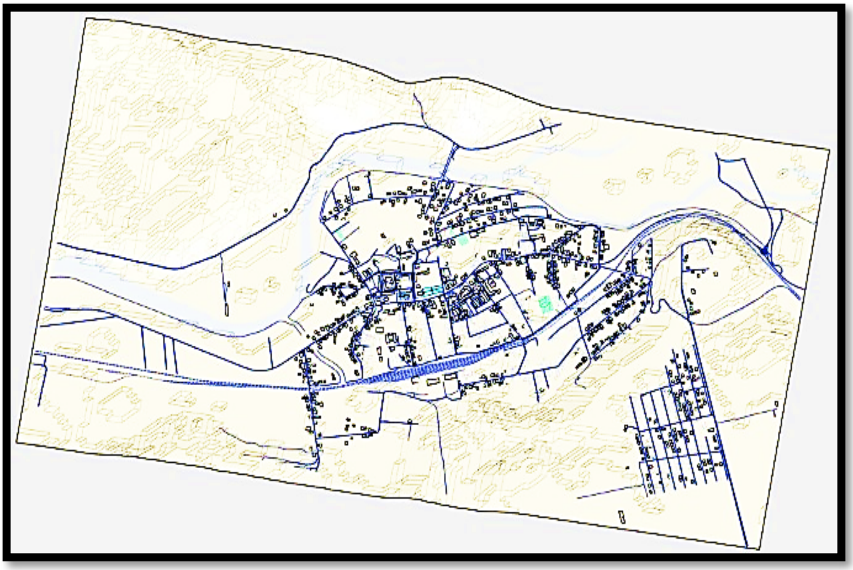

Fig. 23. Urban structure and hydrographic network in Beclean
Source: https://cadmapper.com/pro

- File Type: AutoCAD DXF (fig. 23)
- Area: 9.607 km^2
- Buildings: 1424 total, 0 with height value (0%)
- Topography: Included, 246.00 m above sea level
- Settings: Road meshes (highways 8.0, major 8.0, minor 8.0, paths 5.0), 3D buildings (no value = 3.0 m), 10 m contours
- Spatial Reference System: Meters; UTM Zone: 35, Easting: 284086.25, Northing: 5227786.39. 3D Axonometric View.
- 1:10.000

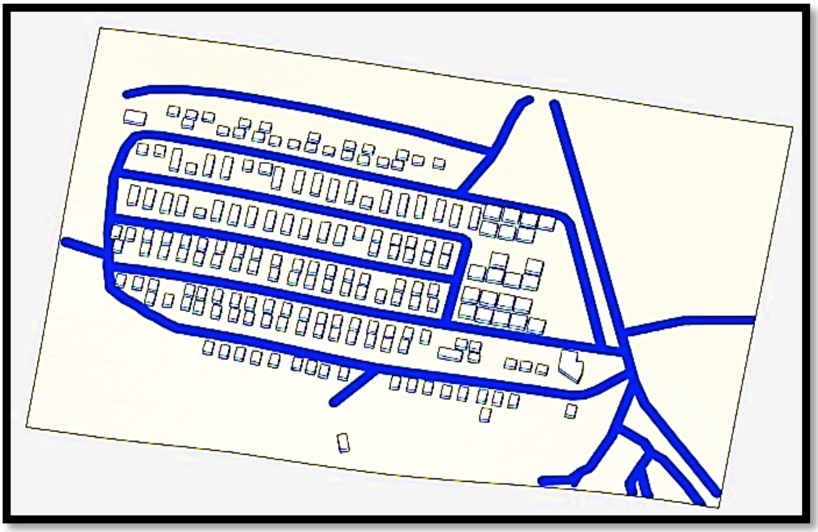

Fig. 24. Organisation model of the Tourist Resort Băile Figa
Source: https://cadmapper.com/pro

- Ø File Type: AutoCAD DXF
- Ø Area: 0.117 km^2
- Ø Buildings: 187 total, 0 with height value (0%)
- Ø Topography: Included, 290.00 m above sea level
- Ø Settings: Road meshes (highways 8.0, major 8.0, minor 8.0, paths 5.0), 3D buildings (no value = 3.0 m), 10 m contours
- Ø Spatial Reference System: Meters; UTM Zone: 35, Easting: 288076.23, Northing: 5227208.93. 3D Axonometric View.
- Ø 1:5.000

The tourist resort Băile Figa is organised in a coherent spatial system, with a well-defined road network, characterised by parallel and perpendicular roads that facilitate access to the main areas of interest: accommodation, leisure and tourist infrastructure. The layout of buildings in a rectangular pattern suggests urban planning oriented towards functional efficiency and accessibility to the city, located on County Road DJ 172 (fig. 24).

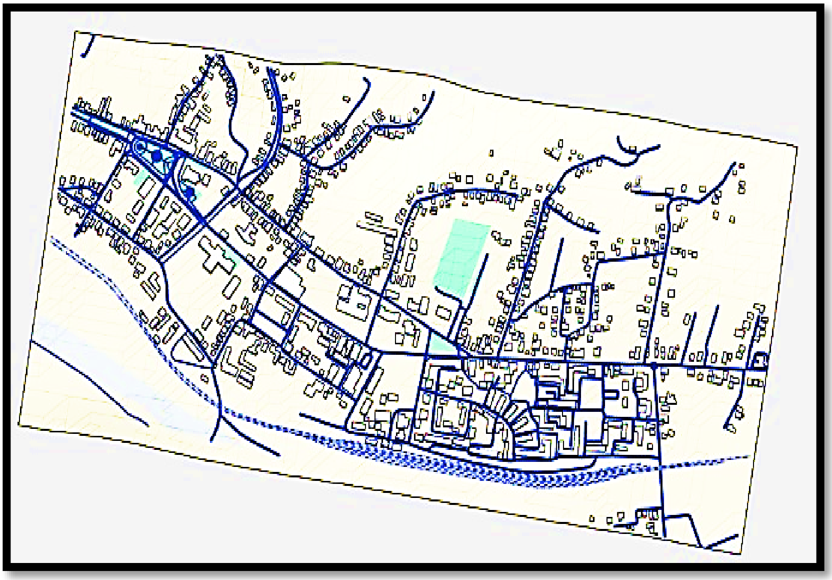

Fig. 25. Road network and spatial organisation in Năsăud
Source: https://cadmapper.com/pro

- File Type: AutoCAD DXF (fig. 25)
- Area: 1.57 km²
- Buildings: 758 total, 1 with height value (0%)
- Topography: Included, 311.00 m above sea level
- Settings: Road meshes (highways 8.0, major 8.0, minor 8.0, paths 5.0), 3D buildings (no value = 3.0 m), 10 m contours
- Spatial Reference System: Meters; UTM Zone: 35, Easting: 303243.99, Northing: 5239585.92. 3D Axonometric View
- 1:10.000

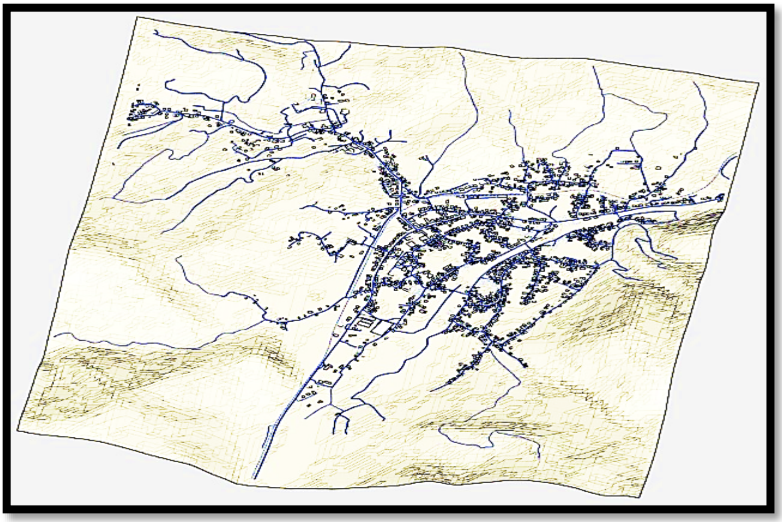

Fig. 26. Urban structure and land features of Sângeorz-Băi
Source: https://cadmapper.com/pro

- File Type: AutoCAD DXF (fig. 26)
- Area: 10.907 km^2
- Buildings: 2312 total, 0 with height value (0%)
- Topography: Included, 417.00 m above sea level
- Settings: Road meshes (highways 8.0, major 8.0, minor 8.0, paths 5.0), 3D buildings (no value = 3.0 m), 10 m contours
- Spatial Reference System: Meters; UTM Zone: 35, Easting: 322467.10, Northing: 5246501.33. 3D Axonometric View.
- 1:20.000

4. CONCLUSION

This research emphasises the essentially interdependent nature of road transport system typologies and the spatial organisation of the urban settlement types along the Bistrița–Beclean–Năsăud–Sângeorz-Băi geography axis. The typological mapping and geospatial analysis of all the road networks (using open-source tools such as Cadmapper and OSM) was one of the typological spatial contextualisation of essential urban functions: commercial, cultural, tourist, and economic.

The results concluded that road typologies and hierarchies along urban road networks modulate patterns of accessibility and the structural distribution of metropolitan functions, contributing to spatial coherence. The relevant urban organisation types identified were axial, central, linear, and grouped, suggesting local responses to geography and the short histories of existing infrastructure-based urban development, with responses related to spatial aspirations towards sustainability. The application of the '15-minute city' concept was closely associated with urban geography, morphology and connectivity, and was most evident in the less dispersed forms (Beclean, Năsăud). In contrast, daily activity connectivity was inhibited in more hilly/mountainous forms (Sângeorz-Băi).

Alternative mobility infrastructure (commonly bike lanes, bike-sharing programs, and electric transport modes) radically improves the quality of life (urbanity), reduces emissions, and relieves pressure on urban space.

The ANOVA supports the study's general conclusions and reports reliable population measures that are viable in the context of addressing urban and regional planning policy recommendations.

A typological analysis, such as the one proposed here, provides a replicable methodological basis for making sense of urban diagnostics and sustainable territorial planning, which can be applied in comparable areas. The analysis underscores the significance of open geospatial data in urban decision-making and highlights the crucial need for polycentric and ecologically sustainable development of transport infrastructure.

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