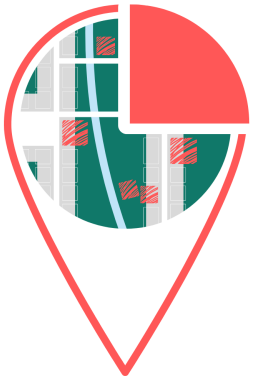


ECO_RET

-a Tool for the ecological retrofitting of existing suburban areas

User Manual

Purpose of the tool

ECO_RET (Ecological Retrofitting of Existing Suburbs Tool) was developed in QGIS to diagnose and assess existing suburban areas and identify possible directions for their ecological transformation. It supports the [1]transformation of monofunctional suburbs into more self-sufficient, accessible and environmentally friendly structures consistent with the 15-minute city concept, using existing spatial resources and development potential.

ECO_RET is an automated analytical model developed in a GIS environment. Here, the tool is understood as a set of procedures, algorithms and spatial operations that enable the processing of geographic data, the analysis of urban and environmental indicators, and the generation of results that support planning decisions. The tool integrates various spatial data, such as land use, the transport network, the distribution of services, buildings and green spaces, and then converts them into a set of measurable parameters used to assess the sustainability of the study area.

ECO_RET is based on the QGIS Graphical Modeler, a *module that* enables complex analytical processes to be created without programming. The Graphical Modeler combines multiple geoprocessing tools in a clear flowchart in which individual operations and their dependencies are shown graphically. This enables spatial-analysis sequences to run automatically, research procedures to be standardised, and analyses to be repeated easily for different locations and datasets.

In ECO_RET, the Graphical Modeler serves as the environment integrating the successive stages of suburban-area assessment. This approach makes the analytical process more transparent, reduces the risk of errors and allows the tool to be adapted easily to the conditions of different cities and regions.

[1]Here, suburbs are understood as areas that emerged with the development and spatial expansion of a city. Depending on the course of urbanisation processes, some were eventually incorporated into the city's administrative boundaries, while others remain outside them. A characteristic feature of suburbs is their initially non-urban functional character, reflected in the dominance of residential ('dormitory') functions and incompletely developed urban functions such as services, retail and workplaces.

Tool structure

The model has a multilayered structure and was designed as a coherent research process that moves from identifying the existing condition of suburbs, through analysing their development, to assessing their functionality and potential transformation towards more sustainable urban forms. Its logic is based on gradually narrowing and deepening the analysis—from general conditions, through dynamic processes, to detailed aspects of accessibility and transformation potential.

The analysis was built as a sequence of interpretive layers, from the basic spatial structure, through the transport system and planning regulations, to service functions and investment potential. Each element contributes a different but complementary dimension of knowledge about the suburbs.

Each part of the model requires appropriately prepared input data in the form of geodatabases saved in GeoPackage (GPKG) format. Each **geodatabase is an organised set of spatial information required for subsequent stages of the analysis. The** data come from different sources (described later in this manual), but before use they must be standardised in terms of coordinate reference system, attribute structure and spatial extent so that they can be compared and combined within a single research model.

A separate database is created for each model component and contains layers corresponding to specific analytical topics. Depending on the stage being analysed, these may include vector data representing administrative boundaries, road networks, service facilities, cadastral plots, land-use types, protected areas or social infrastructure. Each layer contains descriptive attributes that enable further processing and spatial analysis.

Preparing data for comparative and multicriteria analyses is particularly important. This requires not only collecting the relevant thematic layers, but also standardising them and verifying their quality. The data must be cleaned of topological errors, deduplicated and enriched with the additional information required to calculate indicators and perform spatial analyses. As a result, each geodatabase forms a complete, ready-to-use input dataset for a specific model component.

The results of each analytical stage are also saved in GeoPackage format, ensuring consistency throughout the research process. Each analysis generates new spatial layers containing calculation, classification or assessment results. Keeping the same data structure allows the results of one stage to be used as inputs for subsequent analyses.

This organised data flow creates a uniform analytical environment in which all model stages are interconnected. Input geodatabases provide the information

needed to perform the analyses, while output geodatabases document the results of successive operations and provide the basis for further calculations. Consequently, the entire model functions as a sequence of interconnected spatial processes, leading from source data to the final identification of ecological urbanisation potential in the analysed suburbs.

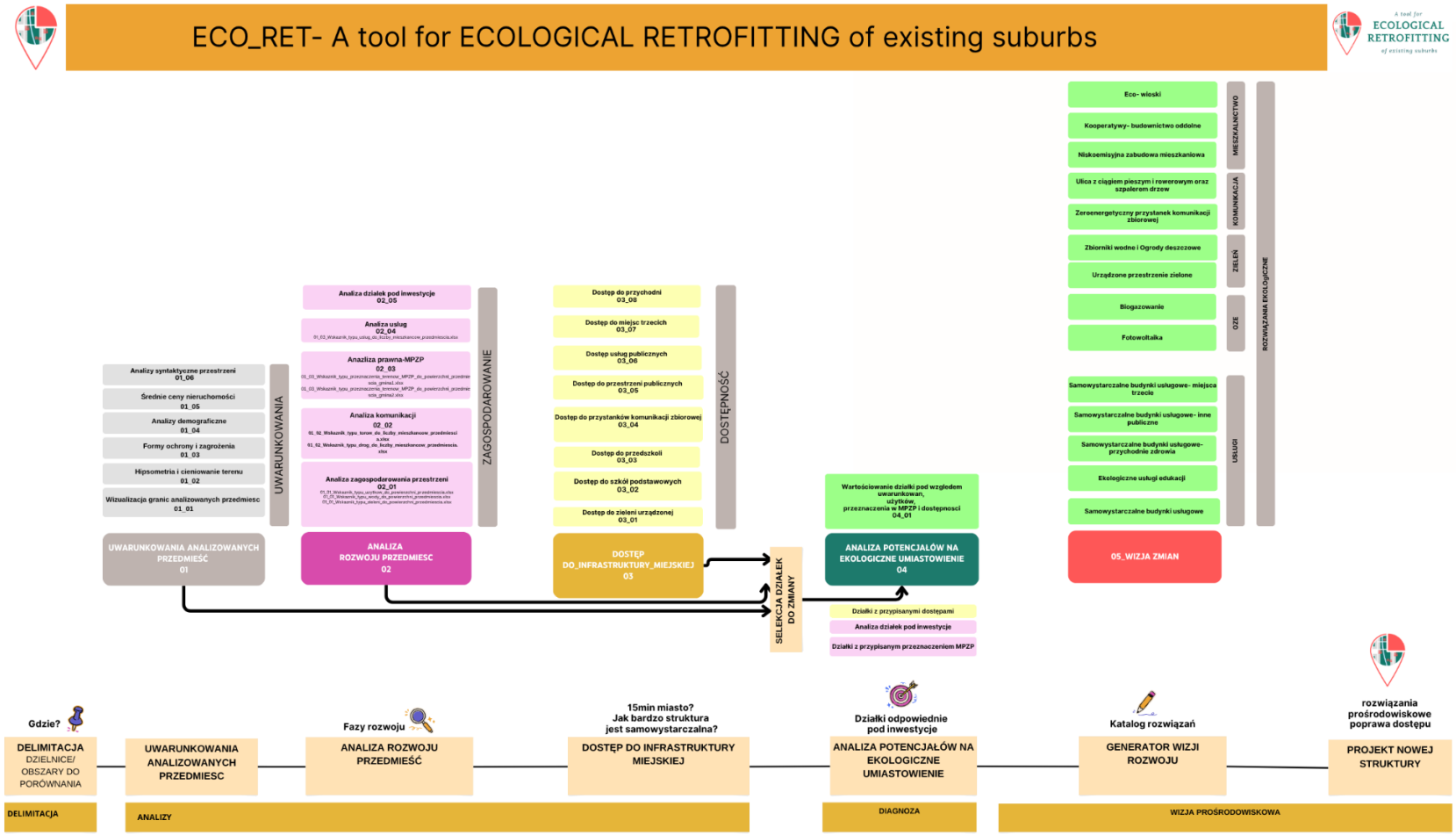


Figure 1. ECO_RET tool diagram.

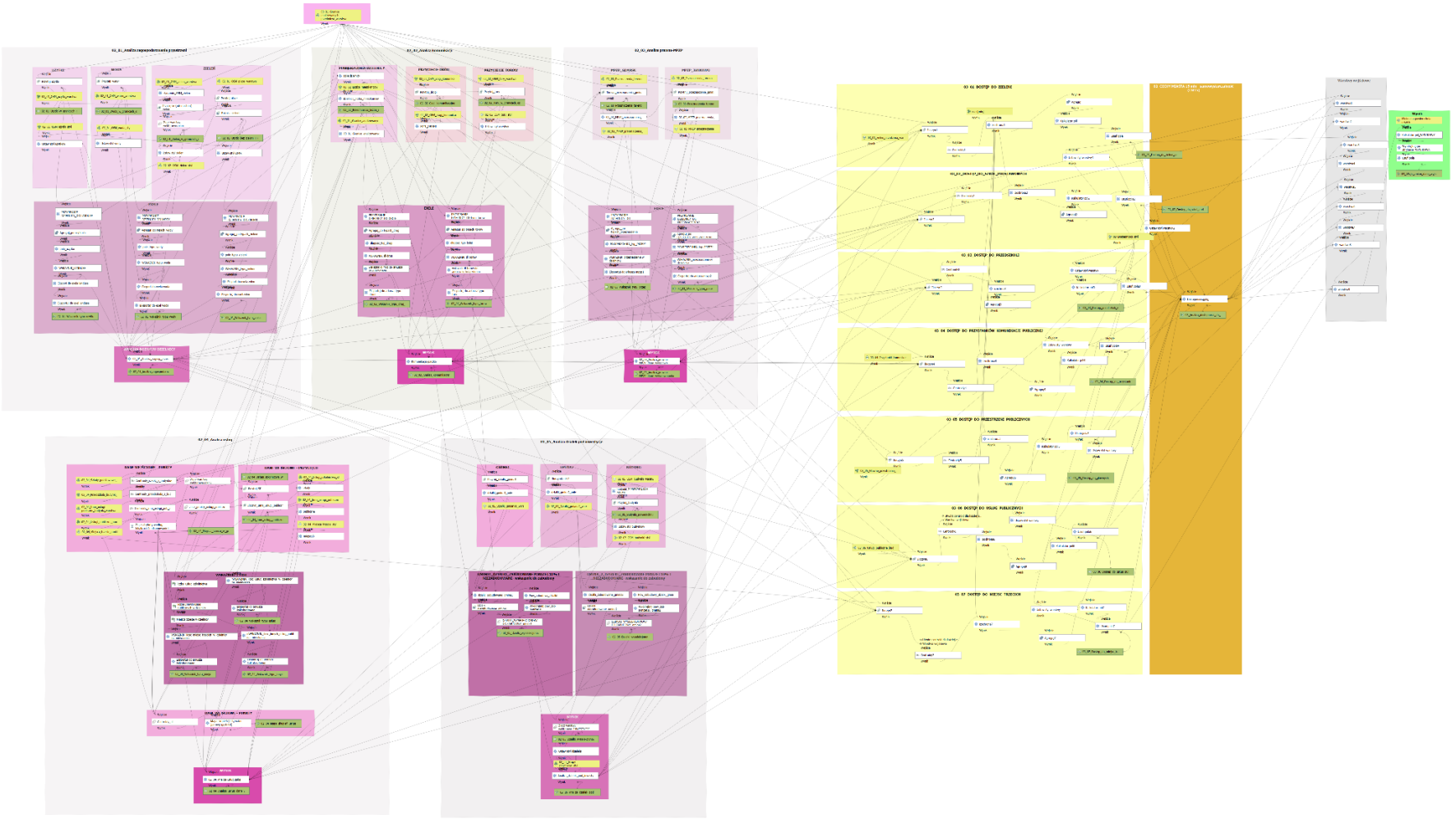
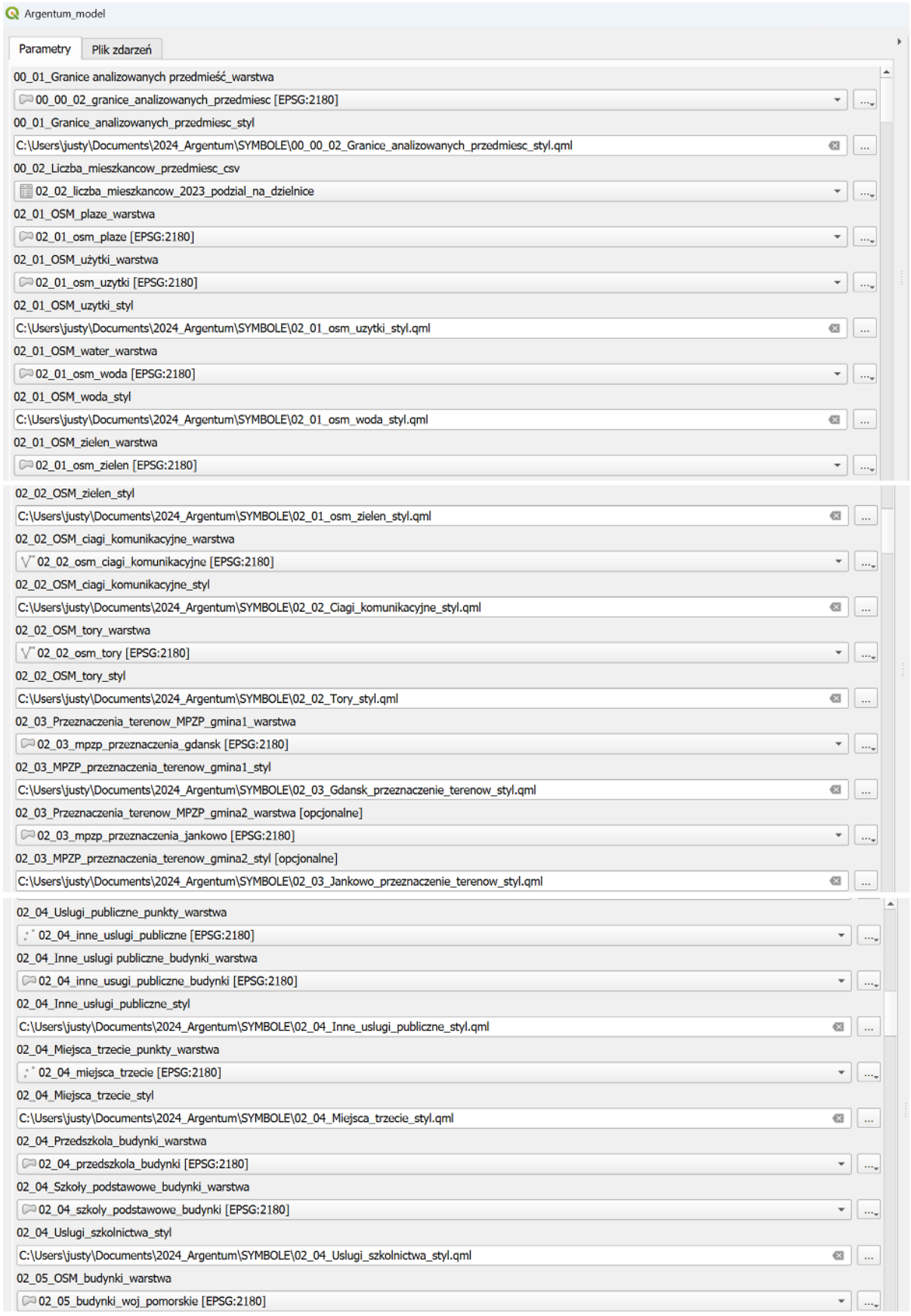
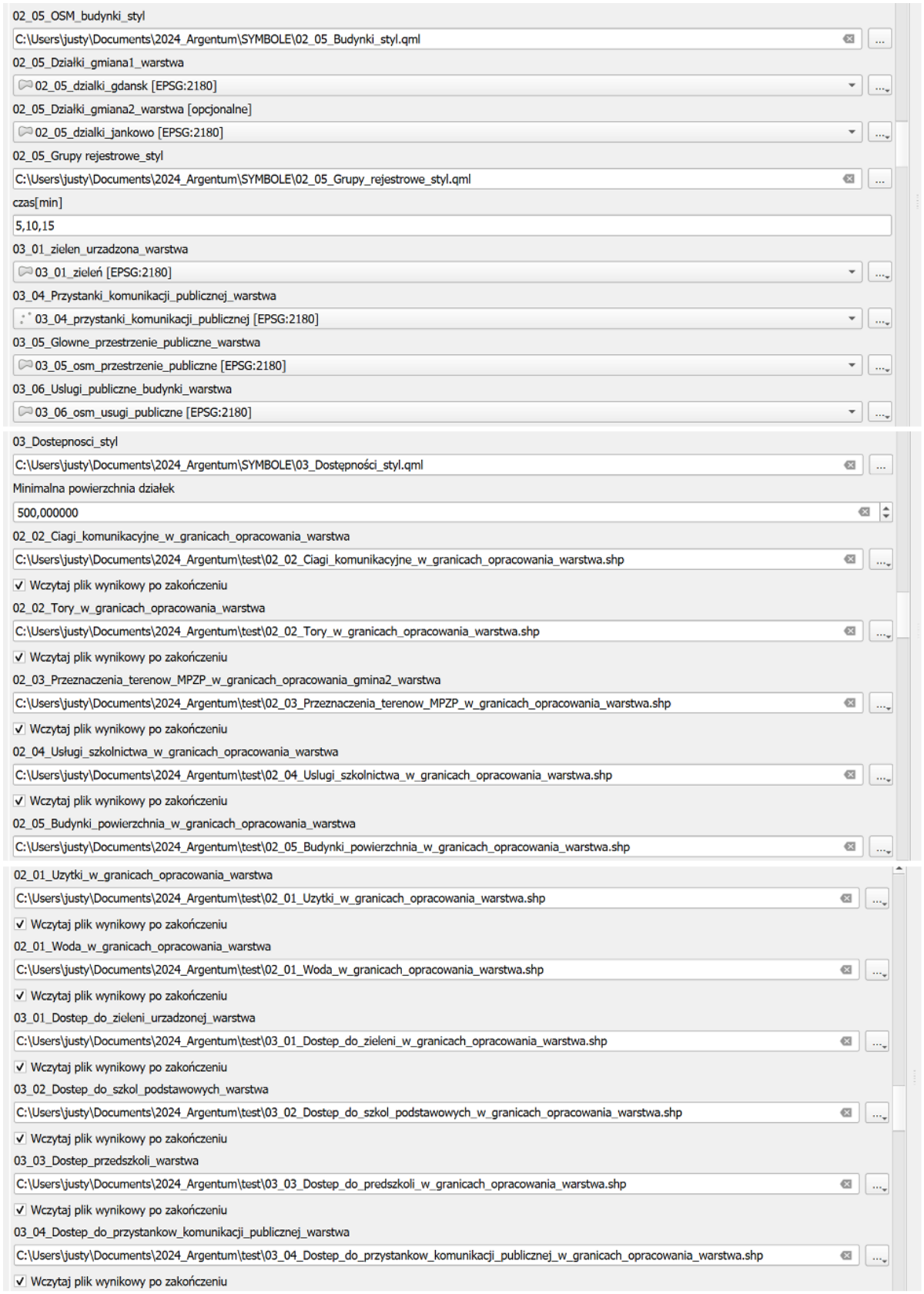
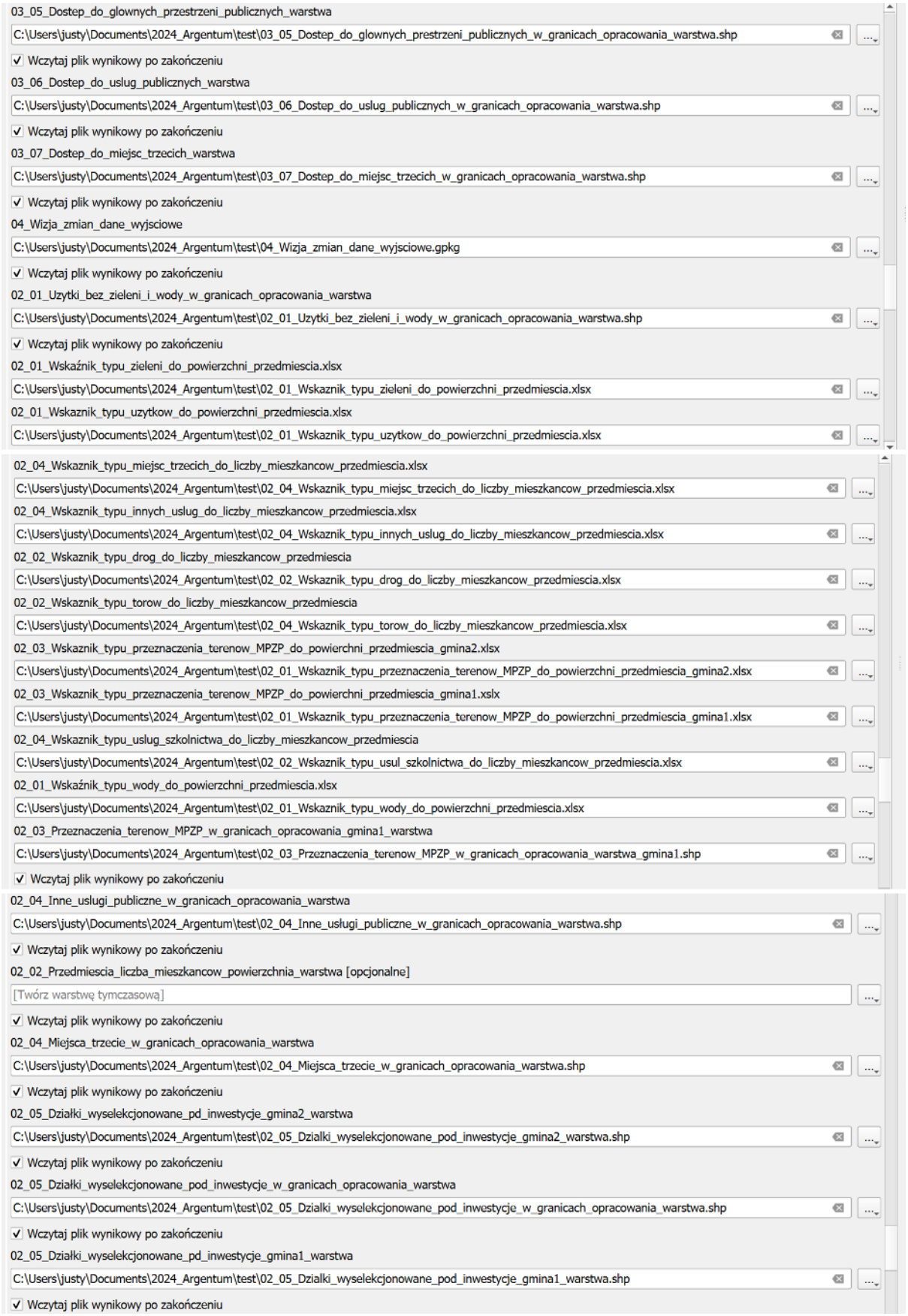


Figure 2. Diagram of the model created in the QGIS Graphical Modeler.


Argentum_model
Parametry
Plik zdarzeń
00_01_Granice analizowanych przedmieść_warstwa
00_00_02_granice_analizowanych_przedmiesc [EPSG:2180]
00_01_Granice_analizowanych_przedmiesc_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\00_00_02_Granice_analizowanych_przedmiesc_styl.qml
00_02_Liczba_mieszkancow_przedmiesc_csv
02_02_liczba_mieszkancow_2023_podzial_na_dzielnice
02_01_OSM_plaze_warstwa
02_01_osm_plaze [EPSG:2180]
02_01_OSM_użytki_warstwa
02_01_osm_uzytki [EPSG:2180]
02_01_OSM_uzytki_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_01_osm_uzytki_styl.qml
02_01_OSM_water_warstwa
02_01_osm_woda [EPSG:2180]
02_01_OSM_woda_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_01_osm_woda_styl.qml
02_01_OSM_zielen_warstwa
02_01_osm_zielen [EPSG:2180]
02_02_OSM_zielen_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_01_osm_zielen_styl.qml
02_02_OSM_ciagi_komunikacyjne_warstwa
02_02_osm_ciagi_komunikacyjne [EPSG:2180]
02_02_OSM_ciagi_komunikacyjne_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_02_Ciagi_komunikacyjne_styl.qml
02_02_OSM_tory_warstwa
02_02_osm_tory [EPSG:2180]
02_02_OSM_tory_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_02_Tory_styl.qml
02_03_Przeznaczenia_terenow_MPZP_gmina1_warstwa
02_03_mpzp_przeznaczenia_gdansk [EPSG:2180]
02_03_MPZP_przeznaczenia_terenow_gmina1_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_03_Gdansk_przeznaczenie_terenow_styl.qml
02_03_Przeznaczenia_terenow_MPZP_gmina2_warstwa [opcjonalne]
02_03_mpzp_przeznaczenia_jankowo [EPSG:2180]
02_03_MPZP_przeznaczenia_terenow_gmina2_styl [opcjonalne]
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_03_Jankowo_przeznaczenie_terenow_styl.qml
02_04_Uslugi_publiczne_punkty_warstwa
02_04_inne_uslugi_publiczne [EPSG:2180]
02_04_Inne_uslugi publiczne_budynki_warstwa
02_04_inne_usugi_publiczne_budynki [EPSG:2180]
02_04_Inne_usługi_publiczne_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_04_Inne_uslugi_publiczne_styl.qml
02_04_Miejsca_trzecie_punkty_warstwa
02_04_miejsca_trzecie [EPSG:2180]
02_04_Miejsca_trzecie_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_04_Miejsca_trzecie_styl.qml
02_04_Przedszkola_budynki_warstwa
02_04_przedszkola_budynki [EPSG:2180]
02_04_Szkoły_podstawowe_budynki_warstwa
02_04_szkoly_podstawowe_budynki [EPSG:2180]
02_04_Uslugi_szkolnictwa_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_04_Uslugi_szkolnictwa_styl.qml
02_05_OSM_budynki_warstwa
02_05_budynki_woj_pomorskie [EPSG:2180]


02_05_OSM_budynki_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_05_Budynki_styl.qml
02_05_Działki_gmiana1_warstwa
02_05_dzialki_gdansk [EPSG:2180]
02_05_Działki_gmiana2_warstwa [opcjonalne]
02_05_dzialki_jankowo [EPSG:2180]
02_05_Grupy rejestrowe_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\02_05_Grupy_rejestrowe_styl.qml
czas[min]
5,10,15
03_01_zielen_urzadzona_warstwa
03_01_zieleń [EPSG:2180]
03_04_Przystanki_komunikacji_publicznej_warstwa
03_04_przystanki_komunikacji_publicznej [EPSG:2180]
03_05_Glowne_przestrzenie_publiczne_warstwa
03_05_osm_przestrzenie_publiczne [EPSG:2180]
03_06_Uslugi_publiczne_budynki_warstwa
03_06_osm_usugi_publiczne [EPSG:2180]
03_Dostepnosci_styl
C:\Users\justy\Documents\2024_Argentum\SYMBOLE\03_Dostępności_styl.qml
Minimalna powierzchnia działek
500,000000
02_02_Ciagi_komunikacyjne_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_02_Ciagi_komunikacyjne_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_02_Tory_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_02_Tory_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_03_Przeznaczenia_terenow_MPZP_w_granicach_opracowania_gmina2_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_03_Przeznaczenia_terenow_MPZP_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_04_Usługi_szkolnictwa_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_04_Uslugi_szkolnictwa_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_05_Budynki_powierzchnia_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_05_Budynki_powierzchnia_w_granicach_opracowania_warstwa.shp
02_01_Uzytki_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_01_Uzytki_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_01_Woda_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_01_Woda_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
03_01_Dostep_do_zieleni_urzadzonej_warstwa
C:\Users\justy\Documents\2024_Argentum\test\03_01_Dostep_do_zieleni_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
03_02_Dostep_do_szkol_podstawowych_warstwa
C:\Users\justy\Documents\2024_Argentum\test\03_02_Dostep_do_szkol_podstawowych_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
03_03_Dostep_przedszkoli_warstwa
C:\Users\justy\Documents\2024_Argentum\test\03_03_Dostep_do_predszkoli_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
03_04_Dostep_do_przystankow_komunikacji_publicznej_warstwa
C:\Users\justy\Documents\2024_Argentum\test\03_04_Dostep_do_przystankow_komunikacji_publicznej_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu


03_05_Dostep_do_glownych_przestrzeni_publicznych_warstwa
C:\Users\justy\Documents\2024_Argentum\test\03_05_Dostep_do_glownych_prestrzeni_publicznych_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
03_06_Dostep_do_uslug_publicznych_warstwa
C:\Users\justy\Documents\2024_Argentum\test\03_06_Dostep_do_uslug_publicznych_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
03_07_Dostep_do_miejsc_trzecich_warstwa
C:\Users\justy\Documents\2024_Argentum\test\03_07_Dostep_do_miejsc_trzecich_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
04_Wizja_zmian_dane_wyjsciowe
C:\Users\justy\Documents\2024_Argentum\test\04_Wizja_zmian_dane_wyjsciowe.gpkg
Wczytaj plik wynikowy po zakończeniu
02_01_Uzytki_bez_zieleni_i_wody_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_01_Uzytki_bez_zieleni_i_wody_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_01_Wskaźnik_typu_zieleni_do_powierzchni_przedmiescia.xlsx
C:\Users\justy\Documents\2024_Argentum\test\02_01_Wskaznik_typu_zieleni_do_powierzchni_przedmiescia.xlsx
02_01_Wskaznik_typu_uzytkow_do_powierzchni_przedmiescia.xlsx
C:\Users\justy\Documents\2024_Argentum\test\02_01_Wskaznik_typu_uzytkow_do_powierzchni_przedmiescia.xlsx
02_04_Wskaznik_typu_miejsc_trzecich_do_liczby_mieszkancow_przedmiescia.xlsx
C:\Users\justy\Documents\2024_Argentum\test\02_04_Wskaznik_typu_miejsc_trzecich_do_liczby_mieszkancow_przedmiescia.xlsx
02_04_Wskaznik_typu_innych_uslug_do_liczby_mieszkancow_przedmiescia.xlsx
C:\Users\justy\Documents\2024_Argentum\test\02_04_Wskaznik_typu_innych_uslug_do_liczby_mieszkancow_przedmiescia.xlsx
02_02_Wskaznik_typu_drog_do_liczby_mieszkancow_przedmiescia
C:\Users\justy\Documents\2024_Argentum\test\02_02_Wskaznik_typu_drog_do_liczby_mieszkancow_przedmiescia.xlsx
02_02_Wskaznik_typu_torow_do_liczby_mieszkancow_przedmiescia
C:\Users\justy\Documents\2024_Argentum\test\02_04_Wskaznik_typu_torow_do_liczby_mieszkancow_przedmiescia.xlsx
02_03_Wskaznik_typu_przeznaczenia_terenow_MPZP_do_powierchni_przedmiescia_gmina2.xlsx
C:\Users\justy\Documents\2024_Argentum\test\02_01_Wskaznik_typu_przeznaczenia_terenow_MPZP_do_powierzchni_przedmiescia_gmina2.xlsx
02_03_Wskaznik_typu_przeznaczenia_terenow_MPZP_do_powierchni_przedmiescia_gmina1.xslx
C:\Users\justy\Documents\2024_Argentum\test\02_01_Wskaznik_typu_przeznaczenia_terenow_MPZP_do_powierzchni_przedmiescia_gmina1.xlsx
02_04_Wskaznik_typu_uslug_szkolnictwa_do_liczby_mieszkancow_przedmiescia
C:\Users\justy\Documents\2024_Argentum\test\02_02_Wskaznik_typu_usul_szkolnictwa_do_liczby_mieszkancow_przedmiescia.xlsx
02_01_Wskaźnik_typu_wody_do_powierzchni_przedmiescia.xlsx
C:\Users\justy\Documents\2024_Argentum\test\02_01_Wskaznik_typu_wody_do_powierzchni_przedmiescia.xlsx
02_03_Przeznaczenia_terenow_MPZP_w_granicach_opracowania_gmina1_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_03_Przeznaczenia_terenow_MPZP_w_granicach_opracowania_warstwa_gmina1.shp
Wczytaj plik wynikowy po zakończeniu
02_04_Inne_uslugi_publiczne_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_04_Inne_usługi_publiczne_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_02_Przedmiescia_liczba_mieszkancow_powierzchnia_warstwa [opcjonalne]
[Twórz warstwę tymczasową]
Wczytaj plik wynikowy po zakończeniu
02_04_Miejsca_trzecie_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_04_Miejsca_trzecie_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_05_Działki_wyselekcjonowane_pd_inwestycje_gmina2_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_05_Dzialki_wyselekcjonowane_pod_inwestycje_gmina2_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_05_Działki_wyselekcjonowane_pod_inwestycje_w_granicach_opracowania_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_05_Dzialki_wyselekcjonowane_pod_inwestycje_w_granicach_opracowania_warstwa.shp
Wczytaj plik wynikowy po zakończeniu
02_05_Działki_wyselekcjonowane_pd_inwestycje_gmina1_warstwa
C:\Users\justy\Documents\2024_Argentum\test\02_05_Dzialki_wyselekcjonowane_pod_inwestycje_gmina1_warstwa.shp
Wczytaj plik wynikowy po zakończeniu

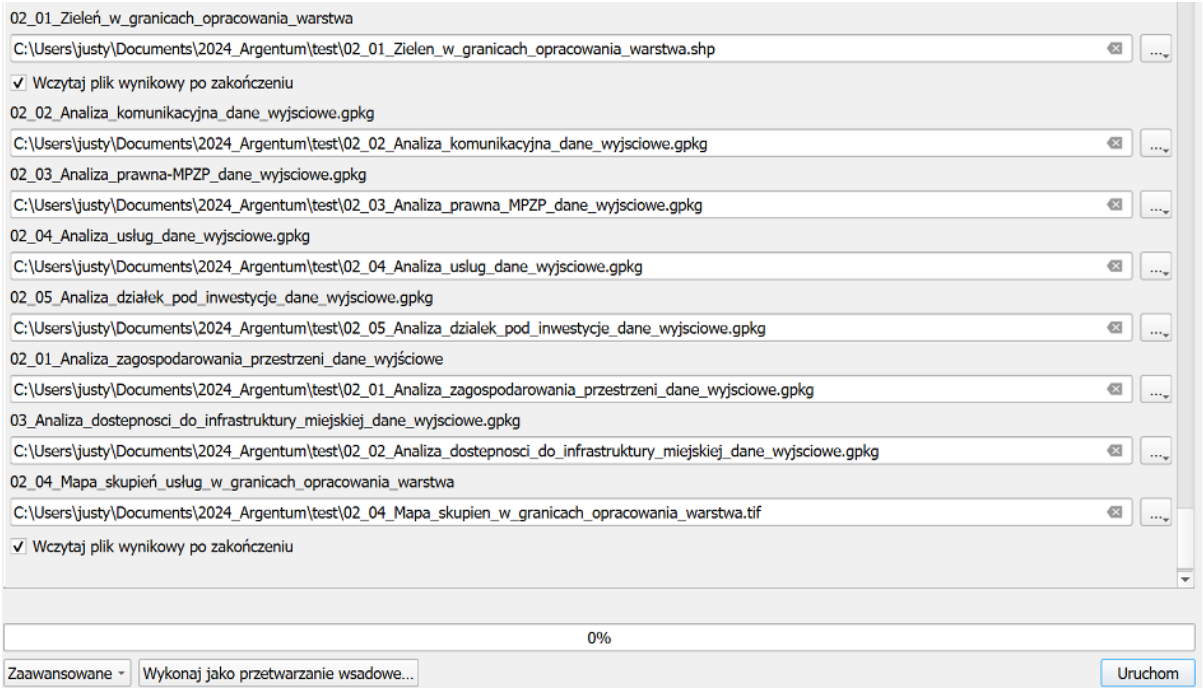


Figure 3. Tool interface visible to the user.

COMPONENT 01. Conditions of the analysed suburbs

The purpose of this part of the model is to identify the spatial conditions of the selected suburbs as comprehensively as possible before assessing their development. The components in this section follow a logical sequence—from identifying the study area to examining its physical and environmental characteristics.

Together, Module **01, Conditions of the analysed suburbs,** creates a multidimensional picture of the area, combining:

- physical factors (terrain),
- environmental factors (protection and hazards),
- social factors (demographics),
- and structural factors (spatial relationships).

Table 1 presents a detailed specification of the first module of the research model: 01 Conditions of the analysed suburbs. It organises all the elements required to perform the analyses, from input data and visualisation methods to the expected results saved in the output geodatabases. The table structure reflects the logic of the models, in which each component functions as a separate submodel with its own set of source data, cartographic styles and analytical results. Particular attention should be paid to the fact that the first part of the study is carried out outside the main model environment because the analyses of suburban conditions have different requirements.

The module includes several independent analyses: visualisation of the boundaries of the analysed suburbs, analysis of hypsometry and terrain relief, analysis of protected areas and hazards, demographic analyses, and space syntax analyses (described below).

Visualisation styles (.qml) assigned to individual layers are also an important part of the data. They ensure a uniform method of data presentation in the GIS environment, enabling automatic layer symbology and maintaining visual consistency throughout the model.

The module concludes with the generation of six output layers/geodatabases corresponding to the individual analyses. These geodatabases are also the final products of the first stage of the study.

The data required by the model come from publicly available spatial databases, public-administration resources and original studies prepared for the research. They were selected to meet the requirements of individual analyses while maintaining the greatest possible spatial accuracy.

Basic administrative data—including the boundaries of cities, municipalities, districts, statistical areas, cadastral districts and other territorial units—were obtained primarily from the National Register of Boundaries (PRG), maintained by the Head Office of Geodesy and Cartography, and from local databases maintained by local government units.

Terrain-relief data come from the Digital Terrain Model (DTM) made available by the Head Office of Geodesy and Cartography as part of the national geodetic and cartographic resource. These data are used to generate contour lines, hillshade models and hypsometric visualisations for assessing the physiographic conditions of the analysed suburbs.

Information on nature-protection forms was obtained from the Central Register of Nature Protection Forms and data from the General Directorate for Environmental Protection. It includes, among other things, nature reserves, Natura 2000 sites, landscape parks and protected landscape areas.

Demographic data were obtained from Statistics Poland (GUS), particularly its Local Data Bank and statistical data aggregated for spatial units. They make it possible to determine the population size, structure and spatial distribution within the analysed areas.

Space syntax analyses use street- and transport-network data, most commonly obtained from OpenStreetMap and BDOT10k databases. The data are **then processed in** DepthmapX (outside QGIS), which calculates space syntax parameters such as *integration* and choice, *used* to assess the accessibility and spatial connectivity of the study area.

Before the analyses begin, all source data must be standardised by harmonising coordinate reference systems, file formats and attribute structures. This enables joint processing in the GIS environment and the creation of consistent input and output geodatabases for the individual model stages.

Table 1. Model 01_01_Conditions of the analysed suburbs. Input and output databases for the ECO_RET tool

MODEL_01	**01_CONTEXT OF THE ANALYSED SUBURBS**					
DATA/ANALYSES	01_01_Visualisation_of_analysed_suburb_boundaries	01_02 Hypsometry and terrain hillshading	01_03_Protected areas and hazards	01_04_Demographic analyses	01_05_Average property prices	01_06_Space syntax analyses *requires additional software depthmap.x
Individual Models						
Input data	01_01_Visualisation_of_analysed_suburb_boundaries_input_data.gpkg	01_02_Hypsometry_and_terrain_hillshading_input_data.gpkg	01_03_Protected_areas_and_hazards_input_data.gpkg	01_04_Demographic_analyses_input_data.gpkg	01_05_Average_property_prices_input_data.gpkg	01_06_Space_syntax_analyses_input_data.gpkg
	01_01_City_boundaries_layer.shp	01_02_Digital_terrain_model.tiff	01_01_Analysed_suburb_boundaries_layer.shp	01_04_Municipality1_and_municipality2_districts_with_assigned_population_layer.shp	01_01_Analysed_suburb_boundaries_layer.shp	01_01_Analysed_suburb_boundaries_layer.shp
	01_01_City_district_boundaries_layer.shp	01_01_Analysed_suburb_boundaries_layer.shp	01_03_Protected areas_1_layer.shp (e.g. nature reserves)	01_01_Analysed_suburb_boundaries_layer.shp	01_05_Municipality1_and_municipality2_districts_with_assigned_prices_layer.shp	01_06_Axial_map_space_syntax_analysis_layer.shp
	01_01_Boundaries_of_peripheral_city_districts_layer.shp		01_03_Protected_areas_2_layer.shp (e.g.Special_areas_of_conservation)			
	01_01_City_area_boundaries_layer.shp		01_03_Protected_areas_3 _layer.shp(e.g. Protected_landscape_areas)			
	01_01_Boundaries_of_all_neighbouring_municipalities_layer.shp		01_03_Protected_areas_4_layer.shp (e.g.Landscape_parks)			
	01_01_Boundaries_of_the_selected_neighbouring_municipality_layer.shp		01_03_Protected_areas_5_layer.shp (e.g.Heritage protection)			
	01_01_Boundaries_of_the_cadastral_district_in_the_selected_neighbouring_municipality_layer.shp		01_03_Hazards_1_layer.shp (e.g. one-metre_coastal_flood_hazard)			
	01_01_Analysed_suburb_boundaries_layer.shp		01_03_Hazards_2 _layer.shp(e.g. landslide_hazard)			

			01_03_Hazards_3_layer.shp(e.g. river_flood_hazard)			
			01_03_Hazards_4_layer.shp (e.g. high_groundwater_hazard)			
			01_03_Hazards_5_layer.shp(e.g. other_hazards)			
Styles	01_01_City_boundaries_style.qml	01_01_Analysed_suburb_boundaries_style.qml	01_01_Analysed_suburb_boundaries_style.qml	01_04_Analysed_suburb_boundaries_style.qml	01_01_Analysed_suburb_boundaries_style.qml	01_01_Analysed_suburb_boundaries_style.qml
	01_01_City_district_boundaries_style.qml	01_02_Contour lines_style.qml	01_03_Protected_areas_style.qml	01_04_Population_choropleth_and_proportional-symbol_map_by_sex_style.qml	01_05_Average_asking_property_prices_style	01_06_space_syntax_analysis_integration_metric_style.qml
	01_01_Boundaries_of_peripheral_city_districts_style.qml		01_03_Hazards_style.qml			
	01_01_City_area_boundaries_style.qml					
	01_01_Boundaries_of_all_neighbouring_municipalities_style.qml					
	01_01_Boundaries_of_the_selected_neighbouring_municipality_style.qml					
	01_01_Boundaries_of_the_cadastral_district_in_the_selected_neighbouring_municipality_style.qml					
	01_01_Analysed_suburb_boundaries_style.qml					
Output data	01_01_Visualisation_of_analysed_suburb_boundaries_output_data.gpkg	01_02_Hypsometry_and_terrain_hillshading_output_data.gpkg	01_03_Protected_areas_and_hazards_output_data.gpkg	01_04_Demographic_analyses_output_data.gpkg	01_05_Average_property_prices_output_data.gpkg	01_06_Space_syntax_analyses_output_data.gpkg
	01_01_City_boundaries_layer.shp	01_02_Clipped_digital_terrain_model.tif	01_03_Merged_hazards_layer.shp	01_04_Municipality1_and_municipality2_districts_with_assigned_population_layer.shp	01_05_Municipality1_and_municipality2_districts_with_assigned_prices_layer.shp	01_06_Integration_metric_within_the_analysed_suburbs_layer.shp

01_01_City_district_boundaries_layer.shp	01_02_Terrain relief.tif	01_03_Merged_protected_areas_layer.shp	01_01_Analysed_suburb_boundaries_layer.shp	01_01_Analysed_suburb_boundaries_layer.shp	01_01_Analysed_suburb_boundaries_layer.shp
01_01_City_area_boundaries_layer.shp	01_02_Contour lines_layer.shp	01_03_Clipped_protected_areas_and_hazards_layer.shp			
01_01_Boundaries_of_all_neighbouring_municipalities_layer.shp					
01_01_Boundaries_of_the_selected_neighbouring_municipality_layer.shp					
01_01_Boundaries_of_the_cadastral_district_in_the_selected_neighbouring_municipality_layer.shp					
01_01_Analysed_suburb_boundaries_layer.shp					

01_01. Visualisation of the boundaries of the analysed suburbs

The model begins by clearly defining the spatial extent of the analysis. At this stage, the suburban area is defined as the study unit, enabling subsequent comparisons and data aggregation.

Figure 4. Model 01_01. Visualisation of the boundaries of the analysed suburbs.

The boundaries may be based on administrative, functional or morphological divisions, but they must be applied consistently in all subsequent model steps. This provides a uniform analytical basis and avoids errors caused by inconsistent data.

01_02. Hypsometry and terrain hillshading

The next step is a physiographic analysis, with particular emphasis on terrain relief. Hypsometry provides information on absolute and relative elevations, slopes and landforms, while terrain hillshading depicts the shape of the surface (relief) by simulating light and shade. This highlights convex and concave forms, such as ridges and valleys. Terrain affects the possibilities for locating development as well as technical and transport infrastructure.

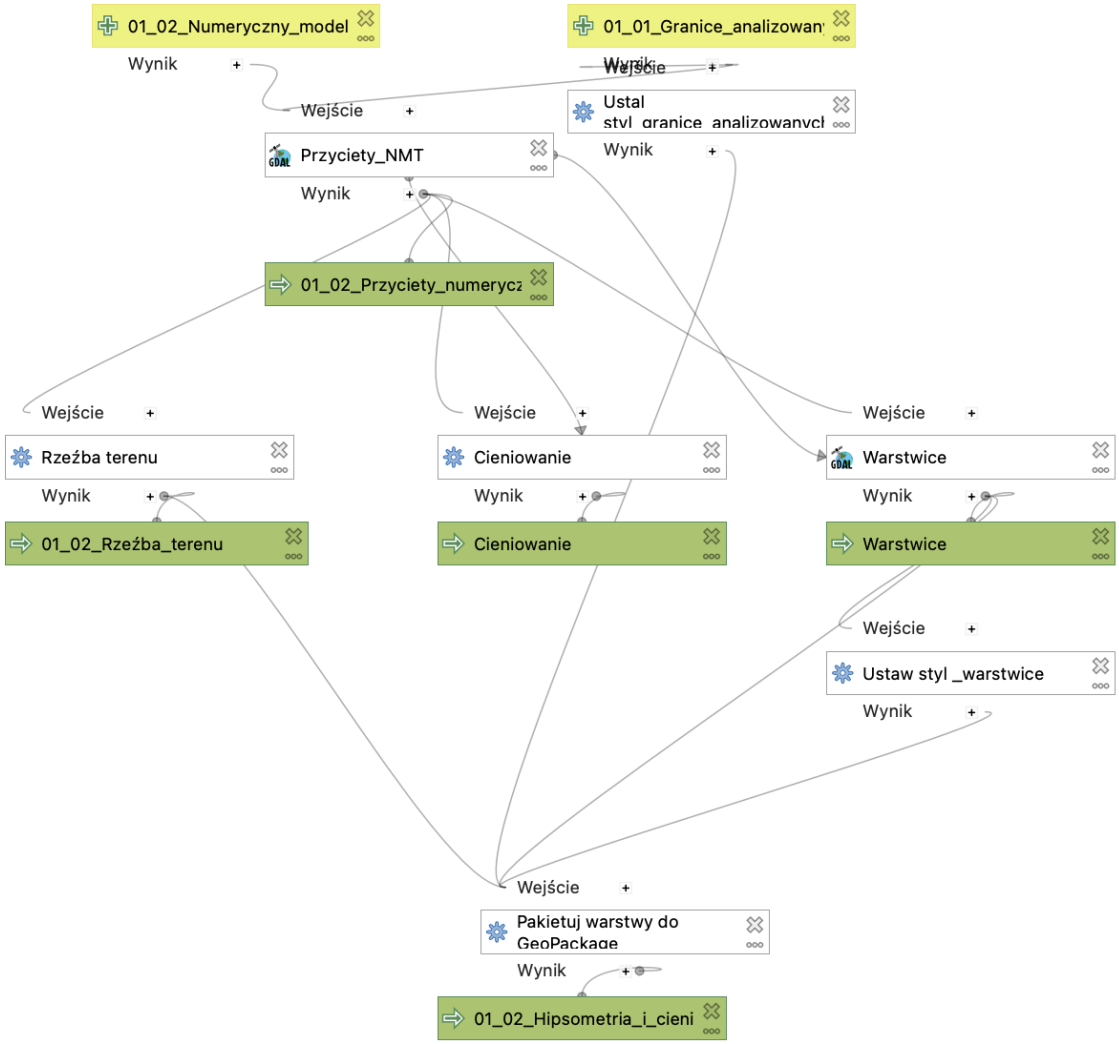


Figure 5. Model 01_02. Hypsometry and terrain hillshading.

01_03. Protected areas and hazards

In the next step, the model considers environmental and formal constraints that determine how space may be developed. The analysis covers both existing nature-protection forms and hazard areas. The first group includes protected areas that restrict intensive urbanisation or impose specific spatial-management rules. Hazards, in turn, may arise from natural factors such as flood risk, landslides or other geodynamic processes.

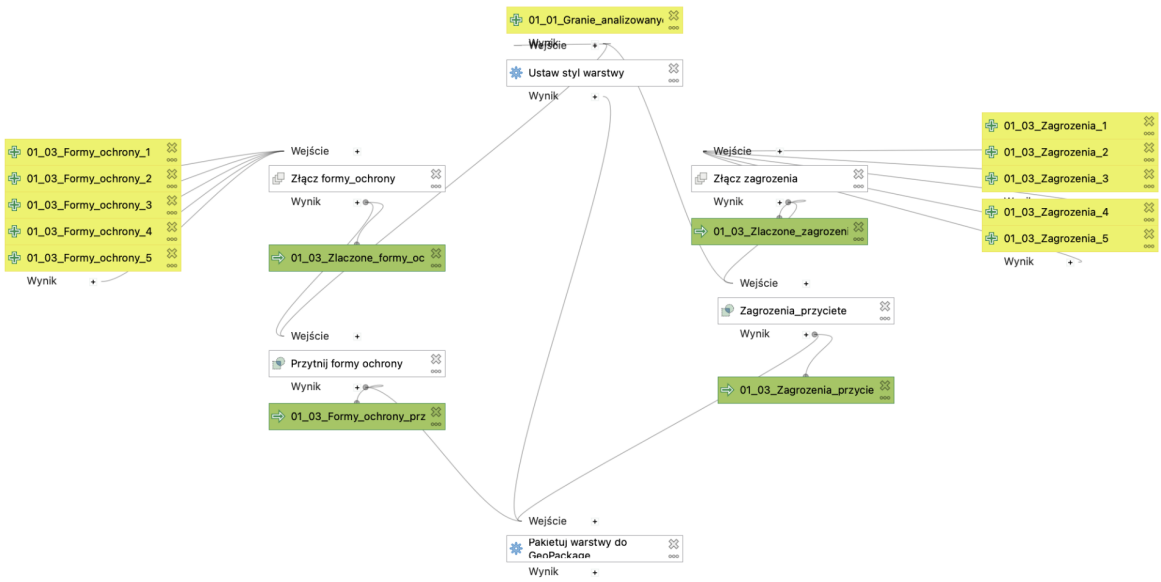


Figure 6. Model 01_03. Protected areas and hazards.

Including this component not only identifies barriers to development but also highlights particularly sensitive areas that require special planning approaches.

01_04. Demographic analyses

After identifying the physical and environmental conditions, the model moves to the social dimension. Demographic analyses—limited here to population size—capture population dynamics, one of the main factors shaping suburban space.

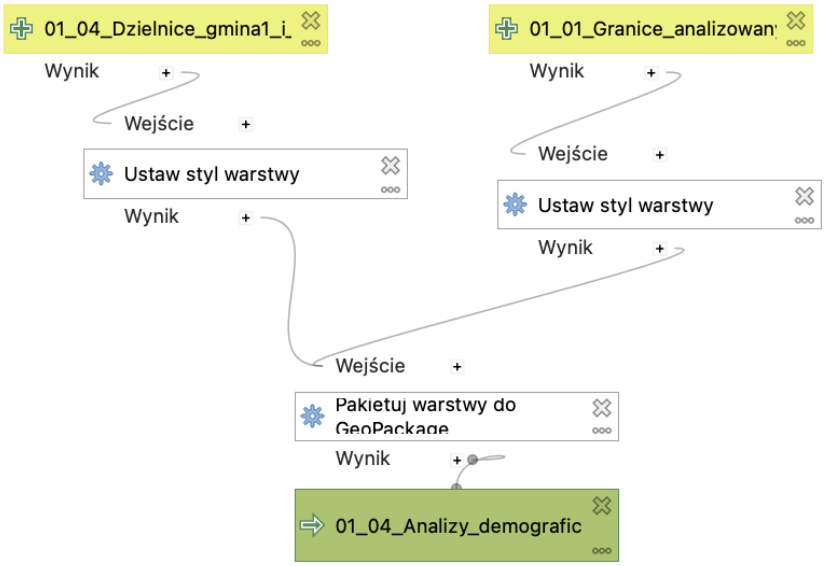


Figure 7. Model 01_04. Demographic analyses.

This analysis helps explain pressure for new development and the demand for social and technical infrastructure.

01_05. Average property prices

The next element is an economic analysis represented by property-price levels. It introduces a market dimension into the model and enables the attractiveness of individual areas to be assessed.

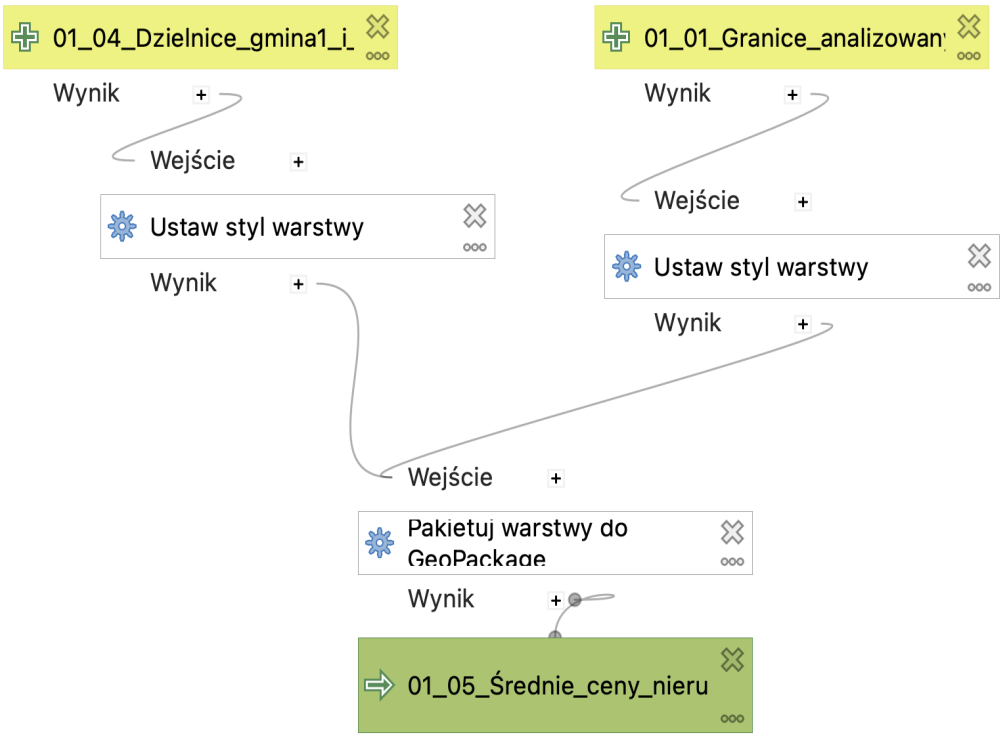


Figure 8. Model 01_05. Average property prices.

At the same time, price analysis identifies areas under investment pressure that may undergo intensive transformation in the future.

01_06. Space syntax analyses

The final component of this part of the model is space syntax analysis, which introduces a relational and structural perspective on space. Unlike earlier analyses, which focus on point or area characteristics, space syntax analysis examines the pattern of spatial connections.

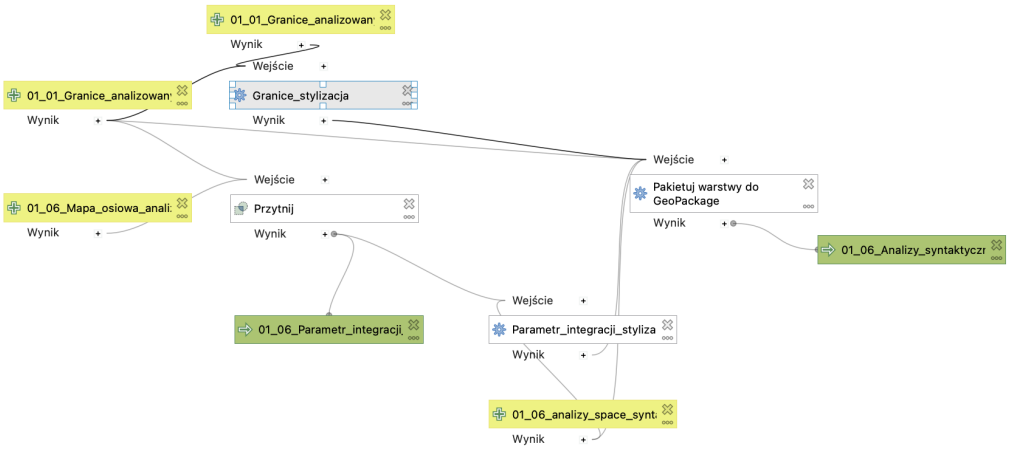


Figure 9. Model 01_06. Space syntax analyses.

Axial-line maps were generated using the standard space syntax methodology, based on representing the longest and smallest possible number of lines of sight and movement. The indicators provide supplementary information about the accessibility structure of suburban street networks. Space syntax measures were calculated using DepthmapX software. This makes it possible to determine the degree of integration of individual areas, identify central and peripheral parts, and assess movement potential and accessibility.

COMPONENT 02. Analysis of suburban development

The analysis was built as a sequence of interpretive layers, from the basic spatial structure, through the transport system and planning regulations, to service functions and investment potential. Each element contributes a different but complementary dimension of knowledge about the suburbs (see Figure *2. Diagram of the model created in the QGIS Graphical* Modeler).

Module **02, Analysis of suburban** development, is a key link in the model because it moves from describing conditions to interpreting spatial processes. It integrates the physical, transport, legal, functional and investment dimensions of development to create a coherent picture of development dynamics.

Table 2 presents the second module of the research model, which assesses the degree of development and land use in the analysed suburbs. Unlike the first module, which focuses on spatial, environmental and social conditions, this stage examines actual urbanisation processes and the functional characteristics of the study areas.

The module consists of five submodels: land-use analysis (02_01), transport analysis (02_02), legal analysis concerning local spatial development plans (02_03), service analysis (02_04), and analysis of plots designated for development (02_05). Each submodel has its own input geodatabase, set of source layers and output geodatabase containing the analysis results.

The results of all analyses are saved in separate output geodatabases and as numerical indicators that provide the basis for the next model module.

The data required for Model 02, Analysis of suburban development, come mainly from OpenStreetMap (OSM), which provides information on land use, green spaces, surface water, buildings, the road network and railway infrastructure.

Population data should be obtained from the Local Data Bank of Statistics Poland (GUS) or from original studies prepared using statistical data assigned to the analysed spatial units.

Information on land-use designations should be obtained from local spatial development plans (MPZP) made available by municipal offices and local spatial-information systems.

The locations of schools, kindergartens, public services and third places should be obtained from local-government databases, public registers and OpenStreetMap data.

Cadastral-plot data should be downloaded from the register of datasets and services available through the national geoportal. These data come from the land and building register (EGiB) maintained by the relevant public-administration bodies.

Table 2. Model 02_02_Analysis of suburban development. Input and output databases for the ECO_RET tool

MODEL_02 02_ANALYSIS_OF_SUBURBAN_DEVELOPMENT

DATA/ANALYSES	02_01_Land-use analysis	02_02_Transport analysis	02_03_MPZP planning-law analysis	02_04_Services analysis	02_05_Analysis of plots for development
Individual Models	02_01_Land-use analysis.model3	02_02_Transport_analysis.model3	02_03_MPZP_planning-law_analysis.model3	02_04_Services_analysis.model3	02_05_Analysis_of_plots_for_development.model3
Input data	01_01_Analysed_suburb_boundaries_layer.shp	01_01_Analysed_suburb_boundaries_layer.shp	01_01_Analysed_suburb_boundaries_layer.shp	02_01_Analysed_suburb_boundaries_layer.shp	01_01_Analysed_suburb_boundaries_layer.shp
	02_01_Land-use_analysis_input_data.gpkg	02_02_Transport_analysis_input_data.gpkg	02_03_MPZP_planning-law_analysis_input_data.gpkg	02_04_Services_analysis_input_data.gpkg	02_05_Selection_of_plots_for_development_input_data.gpkg
	02_01_OSM_beaches_layer.shp (gis_natural_tree_2180)	02_02_OSM_railway_tracks_layer.shp (gis_osm_transport_free_1)	02_03_MPZP_land-use_designations_municipality1_layer.shp	02_04_Third_places_layer.shp	02_05_Plots_municipality1_layer
	02_01_OSM_green_spaces_layer.shp (gis_osm_natural_a_free_1)	02_02_OSM_transport_routes_layer.shp (e.g. gis_osm_roads_free_1)	02_03_MPZP_land-use_designations_municipality2_layer.shp	02_04_Primary_school_buildings_layer.shp	02_05_Plots_municipality2_layer
	02_01_OSM_land_use_layer.shp (gis_osm_landuse_a_free_1)	01_02_suburb_population.csv		02_04_Kindergarten_buildings_layer.shp	02_05_OSM_buildings_layer (gis_osm_buildings_a_free_1)
	02_01_OSM_water_layer.shp (gis_osm_water_a_free_1)			02_04_Other_public_service_buildings_layer.shp	
	02_01_Buildings_layer.shp			01_02_suburb_population.csv	
Styles	02_01_OSM_green_spaces_style.qml	02_02_OSM_railway_tracks_style.qml	02_03_MPZP_land-use_designations_municipality1_style.qml	02_04_Third_places_style.qml	02_05_cadastral_ownership_groups_style.qml
	02_01_OSM_land_use_style.qml	02_02_OSM_transport_routes_style.qml	02_03_MPZP_land-use_designations_municipality2_style.qml	02_04_Education_services_style.qml	02_05_OSM_buildings_style.qml
	02_01_OSM_water_style.qml	01_01_Analysed_suburb_boundaries_style.qml	01_01_Analysed_suburb_boundaries_style.qml	02_04_Other_public_services_style.qml	01_01_Analysed_suburb_boundaries_style.qml
	01_01_Analysed_suburb_boundaries_style.qml			01_01_Analysed_suburb_boundaries_style.qml	
Output data	02_01_Land-use analysis_output_data.gpkg	02_02_Transport_analysis_output_data.gpkg	02_03_MPZP_planning-law_analysis_output_data.gpkg	02_04_Services_analysis_output_data.gpkg	02_05_Analysis_of_plots_for_development_output_data.gpkg

02_01_Green_spaces_within_the_study_area_layer.shp	02_02_Suburbs_population_and_area_layer.shp	02_03_MPZP_land-use_designations_within_the_study_area_municipality1_layer.shp	02_04_Third_places_within_the_study_area_layer.shp	02_05_Building_footprints_within_the_study_area_layer.shp
02_01_Water_within_the_study_area_layer.shp	02_02_Transport_routes_within_the_study_area_layer.shp	02_03_MPZP_land-use_designations_within_the_study_area_municipality2_layer.shp	02_04_Education_services_within_the_study_area_layer.shp	02_05_Plots_selected_for_development_within_the_study_area_layer.shp
02_01_Land_use_excluding_green_spaces_and_water_within_the_study_area_layer.shp	02_02_Railway_tracks_within_the_study_area_layer.shp	02_03_MPZP_land-use_designation_type_indicator_per_suburb_area_municipality1	02_04_Other_public_services_within_the_study_area_layer.shp	
02_01_Land-use_type_indicator	02_02_Railway-track_type_indicator_per_population	02_03_MPZP_land-use_designation_type_indicator_per_suburb_area_municipality2	02_04_Service_cluster_map_within_the_study_area_layer.tiff	
02_01_Water_type_indicator	02_02_Road-type_indicator_per_population			
02_01_Green-space_type_indicator				
02_01_Land-use_type_indicator_per_suburb_area.xlsx	02_02_Railway-track_type_indicator_per_suburb_population.xlsx	02_03_MPZP_land-use_designation_type_indicator_per_suburb_area_municipality1.xlsx	02_04_Service-type_indicator_per_suburb_population.xlsx	
02_01_Water_type_indicator_per_suburb_area.xlsx	02_02_Road-type_indicator_per_suburb_population.xlsx	02_03_MPZP_land-use_designation_type_indicator_per_suburb_area_municipality2.xlsx		
02_01_Green-space_type_indicator_per_suburb_area.xlsx				

02_01. Land-use analysis

This analysis builds on the earlier identification of land-use forms, but adopts a more synthetic approach here: it assesses the proportions of individual land types and their importance within the structure of the entire area.

Particular attention is paid to the relationships between built-up areas, green spaces and elements of the water system. This makes it possible to determine whether the suburbs are more urbanised or still retain the characteristics of an open landscape. The analysis also reveals the degree of spatial fragmentation and discontinuities in the development structure that are typical of suburbanisation processes.

In practice, it provides a basis for assessing spatial order and shows whether development is occurring in an organised manner or is dispersed and uncontrolled.

02_02. Transport analysis

The transport system plays a key role in how suburbs function. Here, both the parameters of the road network and its relationship to population size are examined.

The analysis considers not only the density of the road network, but also its character—whether it enables efficient movement or instead creates dependence on private transport. It also covers the hierarchical structure and accessibility of roads.

This component helps determine the extent to which suburban development is linked to transport infrastructure and the extent to which it outpaces that infrastructure. In many cases, it reveals a fundamental contradiction of suburbanisation: rapid building development accompanied by an inadequately developed transport network.

02_03. Legal analysis – MPZP

The model considers the formal dimension, namely the provisions of local spatial development plans. This analysis compares the existing structure with planning intentions, which is crucial for assessing development directions.

The main subjects of analysis are the land-use designations set out in the plans and their share of the total suburban area. This determines whether planning policy promotes sustainable development or perpetuates monofunctionality and dispersed development.

Identifying discrepancies between the plan and reality is particularly important. These are the areas where spatial tensions and development-management problems most often arise.

02_04. Service analysis

The next step analyses service functions, one of the basic indicators of the suburbs' 'urbanity'. The number and structure of services are examined in relation to population size.

This answers whether suburbs are developing as self-sufficient places or remain dependent on the central city. A shortage of services is one of the most common characteristics of suburban areas and leads to more intensive daily commuting.

The analysis also has a qualitative dimension: it indicates which types of services dominate and which are underrepresented. This makes it possible to determine how well the area meets residents' needs and where the greatest functional deficits occur.

02_05. Analysis of plots for development

This part of the model focuses on the area's development potential as **reflected in the land available for investment.** Plot analysis determines where and how further urbanisation may take place.

The aim is not merely to identify vacant land, but also to assess its accessibility, size and compliance with planning provisions. In this sense, the analysis bridges the current situation and future development directions.

It is particularly important to understand whether the available land encourages continued dispersed development or enables more compact and orderly forms of urbanisation. This component therefore helps assess potential scenarios for the further transformation of suburbs.

COMPONENT 03. Access to urban infrastructure

The third model component develops the earlier analyses and focuses on one of the most important aspects of suburban functioning: actual access to basic services and urban infrastructure. While the previous module examined the structure and directions of spatial development, this stage shifts attention to residents' everyday experience and their ability to use the city's resources.

The entire section is based on the assumption that the degree of suburban 'urbanisation' results not only from the presence of buildings, but primarily from the quality and accessibility of urban functions. Accessibility measurement therefore becomes the key analytical instrument, understood not only as physical distance but as the ability to reach specific services effectively (see *Figure 2. Diagram of the model created in the QGIS Graphical* Modeler).

This part of the model follows a progression from basic elements of the living environment (green spaces), through educational and transport infrastructure, to more complex social functions.

Module **03, Access to urban infrastructure,** shifts the focus of analysis from the structural level to the perspective of the user of the space. It assesses the extent to which suburbs function as genuinely ‘urban’ living environments rather than merely residential areas.

By integrating different forms of accessibility—from environmental, educational and transport access to social access—the model creates a multidimensional picture of spatial functionality. The results provide a direct basis for identifying areas of deficiency. The module also examines whether the spatial structure is consistent with the 15-minute city concept.

The following are analysed:

- access to managed green spaces,
- access to schools,
- access to kindergartens,
- access to healthcare clinics,
- access to public services,
- access to public spaces,
- access to third places,
- access to public transport.

The results are presented as accessibility maps and indicators.

Data on managed green spaces should be obtained primarily from OpenStreetMap databases, local spatial-information systems and municipal studies of recreational areas and urban parks. The layer includes parks, squares, small green spaces and other managed green areas intended for residents’ everyday use.

Information on primary schools and kindergartens can be obtained from local-government registers, data published by the Ministry of Education and Science, local education databases and OpenStreetMap. The data should be recorded as building locations, enabling their spatial accessibility to be determined accurately.

The layer showing public-transport stops should be prepared using OpenStreetMap data and data published by local public-transport organisers. It includes bus, tram and trolleybus stops and other public-transport service points within the study area.

Data on major public spaces come from municipal spatial-information systems, local spatial development plans and OpenStreetMap databases. They include city squares, market squares, major small squares and other spaces that perform integrative and social functions.

The layer of other public services was developed from administrative data and OpenStreetMap resources. It includes public-administration facilities, libraries, cultural centres, healthcare facilities, social-welfare centres and other institutions providing public services to residents.

Data on third places are available mainly from OpenStreetMap. This category includes places that foster everyday social contact, such as cafés, local activity centres, community centres, libraries and other social spaces between home and work.

The collected data are used to conduct accessibility analyses for individual infrastructure categories. Isochrones of 5, 10 and 15 minutes are applied by default. These values can be changed when completing the model's input data. The results are saved in the output geodatabase as separate layers showing the level of access to managed green spaces, primary schools, kindergartens, public-transport stops, public spaces, public services and third places. The results provide a basis for assessing the provision of urban infrastructure in the suburbs and are used in the next module, which analyses ecological urbanisation potential.

Table 3. Model 03_Analysis of access to urban infrastructure. Input and output databases for the ECO_RET tool

DATA/ANALYSES	**03_ANALYSIS_OF_ACCESS_TO_URBAN_INFRASTRUCTURE**
MODEL_03	**03_ANALYSIS_OF_ACCESS_TO_URBAN_INFRASTRUCTURE**
Input data	01_01_Analysed_suburb_boundaries_layer.shp
	03_Analysis_of_access_to_urban_infrastructure_input_data.gpkg
	03_01_Managed_green_spaces_layer.shp
	03_02_Primary_school_buildings_layer.shp
	03_03_Kindergarten_buildings_layer.shp
	03_04_Public_transport_stops_layer.shp
	03_05_Main_public_spaces_layer.shp
	03_06_Other_public_service_buildings_layer.shp
	03_07_Third_places_layer.shp
Styles	03_Accessibility_style.qml
Output data	**03_Analysis_of_access_to_urban_infrastructure_output_data.gpkg**
	03_01_Access_to_managed_green_spaces_layer.shp
	03_02_Access_to_primary_schools_layer.shp
	03_03_Access_to_kindergartens_layer.shp
	03_04_Access_to_public_transport_stops_layer.shp
	03_05_Access_to_main_public_spaces_layer.shp
	03_06_Access_to_other_public_services_layer.shp
	03_06_Access_to_third_places_layer.shp

03_01 Access to managed green spaces

The first element analysed is access to managed green spaces, a basic indicator of the quality of the living environment. Unlike earlier analyses, which identified the presence of green areas, the key issue here is their functional accessibility to residents.

Managed green spaces—parks, squares and organised recreational areas—play an important role in the urban structure, influencing health, quality of life and social integration. This analysis captures the actual quality of recreational space and its distribution in relation to residential development.

03_02 Access to primary schools

Access to primary education is fundamental to the functioning of local communities. The analysis examines whether children living in the suburbs can reach schools conveniently and safely.

School accessibility is one of the key criteria for assessing quality of life in residential areas. A lack of access leads to longer journeys, more car traffic and greater dependence on private transport. Good access to education also helps build local communities and reduces the need for daily travel to the central city.

03_03 Access to kindergartens

The educational analysis is supplemented by access to kindergartens, which reflects the local character of social infrastructure even more strongly. Kindergartens are closely linked to place of residence and require a high degree of spatial accessibility.

This analysis identifies areas where infrastructure development has failed to keep pace with demographic change, resulting in overloaded facilities or the need to use services in other parts of the city.

03_04 Access to public-transport stops

The next element concerns access to public transport, which is crucial to reducing car dependence. The analysis examines the distance to stops and the possibility of using public transport as an alternative to private modes of travel.

Public-transport accessibility is one of the most important indicators of suburban sustainability. High-quality access promotes integration with the central city, increases social mobility and limits the adverse effects of suburbanisation, such as congestion and pollutant emissions.

03_05 Access to public spaces

Access to public spaces—understood as shared places such as plazas, squares and other areas that encourage social interaction—is also analysed. This component goes beyond functionality in the narrow sense and addresses quality of life and the building of social relationships.

Public spaces are one of the basic elements of the urban structure, and their absence is characteristic of many suburban areas with dispersed development. The analysis therefore assesses whether the suburbs provide conditions for social life or remain merely residential spaces with limited community functions.

03_06 Access to public services

This component covers public services in the broad sense, such as administration, primary healthcare and other public-utility institutions. It analyses the extent to which suburbs are provided with basic institutional infrastructure.

Access to these services directly affects residents' quality of life and the degree of functional self-sufficiency of suburban areas. Their absence requires frequent trips to

the city centre, increasing pressure on the transport system and deepening suburban dependence on the central city.

03_07 Access to third places

A distinctive element of the analysis is access to so-called third places—spaces between home and work, such as cafés, libraries and meeting places. They introduce a more qualitative dimension of how space functions into the model.

The presence and accessibility of such places indicate the maturity of the urban structure and its capacity to support social life. In suburban contexts, their absence is a clear sign of functional underdevelopment.

COMPONENT 04. Analysis of ecological urbanisation potential

The final model component synthesises and interprets all the preceding analyses. The accumulated knowledge of conditions, development structure and infrastructure accessibility is transformed into an assessment of the potential for further, more sustainable suburban transformation. Unlike the preceding parts, which are largely diagnostic, this module has a distinctly practical and design-oriented character.

The central element of this part of the model is plot valuation (04_01), which integrates different types of data and allows them to be used simultaneously in assessing spatial potential. Each plot is analysed as a unit in which three key dimensions intersect: environmental and spatial conditions, current development, and the formal land-use designation arising from planning documents. The accessibility dimension developed in the previous module is added **to this set. The model selects undeveloped plots and plots on which buildings cover less than 10% of the plot area.**

The valuation process treats plots not merely as empty elements of space, but as carriers of specific characteristics and constraints.

Of particular importance in this part of the model is the integration of this information with the results of the urban-infrastructure accessibility analysis. This determines not only where development may occur, but also whether it can function sustainably. Plots with good transport connections and access to services and public spaces have greater potential for urbanisation than isolated plots that require infrastructure to be created from scratch.

This process produces a complex picture of the area in which each plot is assigned a specific level of transformation potential. It identifies groups of plots with similar characteristics that are particularly suitable for development intensification, as well

as plots that should remain undeveloped because of their environmental value or limited accessibility.

Another important step in this model phase is to link the valuation results to the earlier analysis of plots for development and their designation in planning documents. This enables actual potential to be compared with formal potential.

The final result of this part of the model answers a key question: which plots are genuinely suitable for investment in the context of sustainable suburban development? The answer is not binary, but is based on a differentiated assessment of potential that enables areas to be ranked.

This forms the basis for determining each plot's potential for change, understood as the capacity of an area to be transformed into a more 'urban' structure while preserving the principles of ecological urbanisation. This approach to development is not limited to further expansion of the built environment, but consciously shapes it in accessible locations that are provided with infrastructure and do not conflict with natural systems.

The final model module performs an integrative and decision-support function. It combines all previous analyses into a single interpretive tool that enables the transition from diagnosis to the identification of specific courses of action.

With this design, the model goes beyond describing reality and supports practical conclusions. It indicates where development should be intensified, where it should be limited and where it should be excluded altogether. It therefore provides a basis for spatial planning aimed at more sustainable, efficient and ecological forms of suburban urbanisation. Based on the preceding analyses, the tool identifies the plots with the greatest transformation potential.

The following are taken into account:

- plot area (the size threshold can be changed directly in the model),
- designation in the MPZP,
- development potential,
- infrastructure accessibility,
- land ownership.

The result is a map of plots recommended for change (intervention).

COMPONENT 05. Development vision generator

The final stage of ECO_RET marks the transition from the analytical phase to the design phase. All preceding modules—covering the analysis of suburban conditions, spatial development, access to urban infrastructure and ecological urbanisation potential—provide the information needed to **identify areas that may become sites**

for future spatial interventions. The development vision generator supports the design and planning process by assigning suitable ecological urbanisation solutions to selected areas (see Figure 2. Diagram *of the model created in the QGIS Graphical* Modeler).

The generator uses the results of Component **04: plot valuation, access to urban infrastructure, land-use designations in the MPZP and investment potential. On** this basis, it selects areas recommended for transformation and assigns possible design measures to them in the text field 'INTERWENCJA'.

Selection of plots for specific environmentally friendly solutions

The tool's results are saved in a GeoPackage file. The output layer contains plots together with attributes describing their characteristics, accessibility and potential for implementing environmentally friendly solutions.

The rule catalogue presents the conditions for assigning individual interventions. **The full Field Calculator expression checks all rules simultaneously and populates the 'INTERWENCJA' field for the entire layer.**

If a plot meets several sets of criteria, several proposals separated by semicolons are stored in the field. Existing values are retained, while array_distinct() prevents duplication when the expression is run again.

Threshold values and criteria can be modified to reflect the characteristics of the study area. Field names and text values, however, must exactly match those in the layer's attribute table.

Intervention-assignment mechanism

Based on the results of earlier analyses, ECO_RET processes spatial data and creates output layers describing the conditions of **individual plots. Undeveloped plots and plots on which buildings cover less than 10% of the plot area qualify for final selection.**

Among other things, the tool analyses:

- plot area;
- access to green spaces;
- access to primary schools and kindergartens;
- access to public-transport stops;
- access to public spaces;
- access to services;
- access to third places;
- land-use designation in planning documents;

- ownership form or registration group.

After checking the conditions recorded in the catalogue of ecological solutions, ECO_RET identifies plots that meet the requirements for individual interventions. The names of the recommended solutions are entered automatically in the INTERWENCJA `text field in` the attribute table of the output layer.

If a plot meets the conditions for several solutions, multiple `proposals are` stored in the INTERWENCJA field. The tool does not prepare a design for a specific development; it indicates which ecological urban functions could complement the structure of the area.

Automatic population of the INTERWENCJA field

Before running the rules, make sure that the layer contains the fields used in the expression: ‘pole’, ‘GRUPA_REJE’, ‘PRZEZNACZE’, ‘PRZEZNACZE2Legenda’, [2]‘Dostep’, ‘Dostep_2’–‘Dostep_7’, and the text field ‘INTERWENCJA’.

Procedure in QGIS

1. Open the attribute table of the plot layer and enable editing mode.
2. Open the Field Calculator.
3. Select ‘Update existing field’ and choose the ‘INTERWENCJA’ field. If the field does not yet exist, create a text field with a length of at least 2,048 characters.
4. Do not select the option that limits the calculation to selected features only.
5. Paste the expression provided later in this manual, run the calculation and save the changes.

Important: the ‘INTERWENCJA’ field must be a text field. The expression retains previous entries, appends new proposals after a semicolon and removes duplicates.

Catalogue of assignment rules

The table below presents abbreviated criteria. The full logic is stored in the Field Calculator expression.

No.	Group	Intervention	Summary criteria

[2]The ‘PRZEZNACZE’ and ‘PRZEZNACZE2Legenda’ fields appear in the table when the analysis includes local spatial development plans (MPZP) prepared using different designation systems or when the study area lies within two municipalities. In such cases, land-use designations may differ between planning documents, resulting in two different categories being assigned to the same area. It should be noted that rules standardising the designations used in MPZP documents have applied since 2021; however, plans prepared before that date remain in force, so different designation systems may still operate in parallel. Field names depend on
the MPZP land-use designation layers entered in Component 02, Analysis of suburban development. This must be taken into account when entering the supplied SQL code in QGIS.

1	Services	**Self-sufficient service buildings**	GRUPA_REJE outside groups 1–4; area ≥ 500 m²; service designation.
2	Services	**Ecological education services – kindergarten**	Area ≥ 2,000 m²; access to public-transport stops; service designation.
3	Services	**Ecological education services – schools**	Area ≥ 4,000 m²; access to public-transport stops; service designation.
4	Services	**Self-sufficient service buildings – healthcare clinics**	Area ≥ 1,000 m²; access to public-transport stops and public spaces; service designation.
5	Services	**Self-sufficient service buildings – other public services**	Area ≥ 1,000 m²; access to public-transport stops and public spaces; service designation.
6	Services	**Self-sufficient service buildings – third places**	GRUPA_REJE outside groups 1–4; area ≥ 1,000 m²; access to green spaces, public-transport stops and public spaces; service designation.
7	Services	**Eco-markets**	Area ≥ 1,000 m²; access to public-transport stops and public spaces; service designation.
8	Renewable energy	**Large-scale photovoltaic power generation**	Area ≥ 2,000 m².
9	Renewable energy	**Large-scale biogas production**	Area ≥ 2,000 m².
10	Green spaces	**Public managed green spaces**	GRUPA_REJE in groups 1–4; area ≥ 500 m²; access to green spaces.
11	Green spaces	**Water reservoirs and rain gardens**	Area ≥ 500 m²; access to green spaces.
12	Transport	**Zero-energy public-transport interchange**	Area ≥ 2,000 m²; GRUPA_REJE outside groups 5–9; access to public spaces.
13	Transport	**Street with a pedestrian and cycle route and an avenue of trees**	GRUPA_REJE outside groups 5–9; access to public spaces.
14	Housing	**Low-emission housing**	Area ≥ 1,000 m²; access to green spaces, schools, kindergartens, public-transport stops, public spaces, services and third places.
15	Housing	**Housing cooperatives – bottom-up development**	Area ≥ 2,000 m²; full set of seven accessibility criteria.
16	Housing	**Ecovillages**	Area ≥ 10,000 m²; full set of seven accessibility criteria.

Interpretive note: healthcare clinics, other public services and marketplaces currently have identical criteria. The same applies to photovoltaics and biogas production. Plots meeting these conditions will receive all corresponding proposals.

Field Calculator expression

Paste the entire expression below when updating the ‘INTERWENCJA’ field.

```
with_variable(
        'uslugi_mpzp',
        (
        "PRZEZNACZE" IN (
        'teren usług',
        'teren zabudowy mieszkaniowej jednorodzinnej lub usług',
        'tereny zabudowy mieszkaniowo-usługowej',
        'Tereny zabudowy mieszkaniowo-usługowej',
        'Tereny zabudowy usługowej',
        'Tereny zabudowy usługowej z zielenią towarzyszącą',
```

```
'usługi',
'zabudowa mieszkaniowo-usługowa',
'zabudowa produkcyjno - usługowo-składowa',
'zabudowa usługowa komercyjna i publiczna',
'zabudowa usługowa użyteczności publicznej',
'zabudowa usługowa z zielenią towarzyszącą'
)
OR
"PRZEZNACZE2Legenda" IN (
'zabudowa mieszkaniowa jednorodzinna z usługami',
'zabudowa usługowa',
'zabudowa usługowa, rzemiosło oraz składy i magazyny'
)
),

with_variable(
'pelne_dostepy',
(
"Dostep" = 'dostep do zieleni'
AND "Dostep_2" = 'dostep do SP'
AND "Dostep_3" = 'dostep do przedszkoli'
AND "Dostep_4" = 'dostep do przystanków'
AND "Dostep_5" = 'dostep do przestrzeni publicznych'
AND "Dostep_6" = 'dostep do uslug'
AND "Dostep_7" = 'dostep do miejsc trzecich'
),

array_to_string(
array_distinct(
        array_filter(
        array_cat(
        string_to_array(
              coalesce("INTERWENCJA", ''),
                ';'
        ),

        array(
                CASE
                WHEN
                   "GRUPA_REJE" NOT IN ('1','2','3','4')
                        AND "pole" >= 500
                        AND @uslugi_mpzp
                THEN 'Samowystarczalne budynki usługowe'
                ELSE NULL
                END,

             CASE
                WHEN
                   "pole" >= 2000
                        AND "Dostep_4" = 'dostep do przystanków'
                        AND @uslugi_mpzp
                THEN 'Ekologiczne usługi edukacji - przedszkole'
                ELSE NULL
                END,
```

```
                    CASE
                    WHEN
                        "pole" >= 4000
                            AND "Dostep_4" = 'dostep do przystanków'
                            AND @uslugi_mpzp
                    THEN 'Ekologiczne usługi edukacji - szkoły'
                    ELSE NULL
                    END,

                    CASE
                    WHEN
                        "pole" >= 1000
                            AND "Dostep_4" = 'dostep do przystanków'
                          AND "Dostep_5" = 'dostep do przestrzeni publicznych'
                            AND @uslugi_mpzp
                    THEN 'Samowystarczalne budynki usługowe- przychodnie
zdrowia'
                    ELSE NULL
                    END,

                    CASE
                    WHEN
                        "pole" >= 1000
                            AND "Dostep_4" = 'dostep do przystanków'
                         AND "Dostep_5" = 'dostep do przestrzeni publicznych'
                            AND @uslugi_mpzp
                    THEN 'Samowystarczalne budynki usługowe- inne publiczne'
                    ELSE NULL
                    END,

                    CASE
                    WHEN
                        "GRUPA_REJE" NOT IN ('1','2','3','4')
                            AND "pole" >= 1000
                            AND "Dostep" = 'dostep do zieleni'
                            AND "Dostep_4" = 'dostep do przystanków'
                            AND "Dostep_5" = 'dostep do przestrzeni publicznych'
                            AND @uslugi_mpzp
                    THEN 'Samowystarczalne budynki usługowe- miejsca trzecie'
                    ELSE NULL
                    END,

                    CASE
                    WHEN
                      "pole" >= 1000
                            AND "Dostep_4" = 'dostep do przystanków'
                            AND "Dostep_5" = 'dostep do przestrzeni publicznych'
                            AND @uslugi_mpzp
                    THEN 'Eko- targowiska'
```

```
                    ELSE NULL
                    END,

                    CASE
                    WHEN "pole" >= 2000
                    THEN 'Fotowoltaika o dużej mocy- produkcja'
                    ELSE NULL
                    END,

                    CASE
                    WHEN "pole" >= 2000
                    THEN 'Biogazowanie o dużej mocy'
                    ELSE NULL
                    END,

                    CASE
                    WHEN
                       "GRUPA_REJE" IN ('1','2','3','4')
                            AND "pole" >= 500
                            AND "Dostep" = 'dostep do zieleni'
                    THEN 'Publiczne, urządzone przestrzenie zielone'
                    ELSE NULL
                    END,

                    CASE
                    WHEN
                       "pole" >= 500
                            AND "Dostep" = 'dostep do zieleni'
                    THEN 'Zbiorniki wodne i Ogrody deszczowe'
                      ELSE NULL
                    END,

                    CASE
                    WHEN
                       "pole" >= 2000
                            AND "GRUPA_REJE" NOT IN ('5','6','7','8','9')
                            AND "Dostep_5" = 'dostep do przestrzeni publicznych'
                    THEN 'Zeroenergetyczny węzeł przesiadkowy komunikacji
zbiorowej'
                    ELSE NULL
                END,

                    CASE
                    WHEN
                       "GRUPA_REJE" NOT IN ('5','6','7','8','9')
                            AND "Dostep_5" = 'dostep do przestrzeni publicznych'
                    THEN 'Ulica z ciągiem pieszym i rowerowym oraz szpalerem
drzew'
                    ELSE NULL
                    END,
```

```
                    CASE
                    WHEN
                      "pole" >= 1000
                            AND @pelne_dostepy
                    THEN 'Niskoemisyjna zabudowa mieszkaniowa'
                    ELSE NULL
                    END,

                    CASE
                    WHEN
                        "pole" >= 2000
                            AND @pelne_dostepy
                    THEN 'Kooperatywy- budownictwo oddolne'
                      ELSE NULL
                    END,

                    CASE
                    WHEN
                        "pole" >= 10000
                            AND @pelne_dostepy
                    THEN 'Eco- wioski'
                    ELSE NULL
                    END
                )
                ),

                @element IS NOT NULL
                AND trim(@element) <> ''
                )
        ),
        ', '
        )
        )
)
```

Checking the result

1. Check several plots that meet a single rule and several that meet multiple rules.
2. Confirm that earlier values in the ‘INTERWENCJA’ field have been retained.
3. Run the expression again and check that entries have not been duplicated.
4. If the result is empty, verify the exact spelling of field names and text values.

Housing solutions

For plots that meet the criteria concerning area and access to basic services and elements of urban infrastructure, the tool can assign solutions related to the development of residential functions.

The following `may be entered` in the INTERWENCJA field:

- **Low-emission** housing;
- **Housing cooperatives – bottom-up** development;
- **Ecovillages**.

Low-emission housing means the possibility of complementing the suburban structure with development that uses technologies reducing energy and resource **consumption. Housing** cooperatives indicate the possibility of organising the investment process from the bottom up **and managing** space jointly. Ecovillages refer to larger residential complexes based on sharing space and resources and integrating residential, social, energy and environmental functions.

Mobility solutions

Based on plot area, access to public spaces and ownership type, ECO_RET identifies locations where the transport system could be supplemented.

The following `may be entered` in the INTERWENCJA field:

- **Zero-energy public-transport** interchange;
- **Street with a pedestrian and cycle route and an avenue of** trees.

These solutions support the development of public transport, walking and cycling and improve travel comfort. Avenues of trees also perform climatic, landscape and environmental functions, while zero-energy interchanges can use renewable energy sources and solutions that improve passenger comfort.

Green-space and retention solutions

The output layers of the environmental analyses identify plots where managed green spaces or water-retention solutions could be introduced.

The following `may be entered` in the INTERWENCJA field:

- **Public managed green** spaces;
- **Water reservoirs and rain** gardens.

Public managed green spaces address shortages of recreational areas and improve access to green space. Water reservoirs and rain gardens enable rainwater to be retained locally, reduce flood risk and increase the resilience of suburban areas to the effects of climate change.

Energy solutions

For plots of a suitable size, ECO_RET can identify potential locations for infrastructure associated with energy production from renewable sources.

The following `may be entered` in the INTERWENCJA field:

- **Large-scale photovoltaic power** generation;
- **Large-scale biogas** plant.

These interventions identify plots that, based on the adopted spatial criteria, may be designated for further, more detailed analysis of the feasibility of locating energy installations. Identifying a plot does not replace the technical, environmental or legal analyses required when preparing an investment.

Service and social solutions

Based on plot area, transport accessibility, proximity to public spaces, access to green spaces and land-use designation, ECO_RET identifies locations where service and social deficits could be addressed.

The following `may be entered` in the INTERWENCJA field:

- **Self-sufficient service** buildings;
- **Ecological education services –** kindergarten;
- **Ecological education services –** schools;
- **Self-sufficient service buildings – healthcare** clinics;
- **Self-sufficient service buildings – other public** services;
- **Self-sufficient service buildings – third** places;
- **Eco-markets**.

These solutions respond to the functional deficits identified in the accessibility layers. Self-sufficient service buildings can use renewable energy sources, local rainwater retention and resource-saving technologies. Third places include spaces that encourage everyday contact and the integration of residents, while eco-markets support local services and short supply chains.

Tool outputs

The primary ECO_RET outputs are spatial layers created at successive stages of the analysis. They contain information on access to services and infrastructure, environmental conditions, functional structure and the potential of individual plots.

The final product is a layer containing all plots selected on the basis of the adopted criteria. Its attribute table contains the `INTERWENCJA` field, which records the names of the ecological solutions best suited to the conditions of each plot.

A single plot may receive more than one recommendation if it meets the conditions defined for several types of intervention. The output layer enables plots to be filtered by proposed solution, analysed further and used to prepare cartographic visualisations in a GIS environment.

The tool therefore creates:

- accessibility-analysis output layers;
- layers of plots meeting specific criteria;
- a final layer of recommended plots;
- an `INTERWENCJA` field with assigned ecological solutions.

The catalogue of ecological solutions is not a separate output generated by the tool. It is a set of rules that ECO_RET uses to assign interventions to individual plots. The attribute table of the final layer can, however, serve as a list of recommended locations.

Applications of the tool

ECO_RET was developed to support the analysis and planning of the sustainable transformation of suburban areas. Its design enables it to be used in planning practice, research and participatory processes related to shaping space.

The tool is intended primarily for **local-government units responsible for spatial policy and the preparation of planning and strategic documents. The output layers** provide structured information about the environmental, social, transport and functional conditions of the analysed areas. They can support decisions on the development directions of suburban areas and the location of future investments.

ECO_RET can also be used by urban designers, spatial planners and other designers. **Combining multiple criteria in a single procedure makes it possible to identify plots that can be used to add missing urban functions to the existing structure.** The tool does not replace a design decision, but provides a spatial and analytical basis for making one.

Potential users also include landscape architects and public-space designers. The output layers can support the identification of areas requiring the development of green spaces, water retention, public spaces, social infrastructure or solutions that improve walking and cycling accessibility.

ECO_RET can be applied in research on suburbanisation, spatial transformation and sustainable development. The automated procedure enables comparable analyses to be performed for different areas, provided that appropriate input data and consistent assessment criteria are used.

The layers created by the tool can also be used during planning consultations and participatory processes. They make it possible to present residents not only with the final recommendations, but also with the criteria used to identify particular plots for specific functions.

ECO_RET's main value lies in conducting a coherent process: from analysing spatial conditions and access to urban infrastructure, through plot selection, to the automatic assignment of possible ecological interventions. Users receive layers containing both a diagnosis of the existing structure and indications of possible directions for supplementing it.

ECO_RET supports the transition from a dispersed model of suburbanisation to a model of ecological urbanisation based on addressing functional deficits, increasing access to services, strengthening local social ties and protecting environmental resources.