2050 CliMobCity
Interreg Europe

European Union
European Regional
Development Fund

2050 CLIMOBCITY: Climate-friendly Mobility in Cities

Appendix – Bydgoszcz – Report

Prepared by:

GRADIENS Sp. z o. o.

Supervised by:

City of Bydgoszcz – Energy Management Office

Bydgoszcz, Kielce, Krakow

Final version, June 2023

Prepared by GRADIENS Sp. z o. o.:

- Arkadiusz **Drabicki**
- Jacek **Chmielewski**

Supervision and consultations:

- Ekki **Kreutzberger** (Delft University of Technology)
- Arjan **van Binsbergen** (Delft University of Technology)
- Hanna **Lewandowska** (Energy Management Office – City of Bydgoszcz)

Contents

1. Introduction

The following report describes the contribution results to the Interreg CliMobCity project [1] from transport analysis for the Bydgoszcz city (Poland), i.e. one of the CliMobCity project partners.

Scope of the report:

- introduction and analysis objectives,
- input data and methodology – transportation modelling,
- case study description – transport system of the Bydgoszcz city (Poland),
- future transport and land-use developments, projected in the Bydgoszcz urban area,
- analysis results – for the reference **2050 [W0]** ‘business-as-usual’ (BAU) scenario,
- CliMobCity measures’ and intervention packages, incl. their modelling methodology,
- CliMobCity analysis results – for the **2050 [W1] and [W2]** CliMobCity scenarios, incl. additional mobility changes (the **[W1 plus] and [W2 plus]** CliMobCity scenarios),
- summary of the CliMobCity Action Plan for the Bydgoszcz city,
- conclusions and recommendations.

Principal objectives of the CliMobCity research analyses for the city of Bydgoszcz:

- to ***define*** measures and interventions, which can be instrumental and implementable in future mitigation of transport-related GHG emissions in the Bydgoszcz city,
- to ***assess*** the prospective impacts of the CliMobCity measures’ packages by means of the multimodal transport model (of the Bydgoszcz city) and the CO2 calculator tool (developed by the PIK – Potsdam Institute for Climate Impact Research, i.e. CliMobCity project partner),
- to ***formulate*** recommendations – both in terms of a short-term action plan, as well as the long-term strategic developments – aiming at sustainable, climate-neutral urban mobility in the Bydgoszcz city.

Figure 1. City of Bydgoszcz location (and selected major cities) in Poland (source: OpenStreetMap).

1.1. Input data

The following datasets were used for the purposes of CliMobCity transport analysis for the Bydgoszcz city:

- **Bydgoszcz multimodal transport model**. The Bydgoszcz strategic transport model served as the crucial analytical tool in this project. It was used for assessing the plausible impact of future development schemes and CliMobCity interventions upon transport system performance, journey parameters, and ultimately – for the GHG emissions' evaluations. Modelling works provided a wide set of numerical and graphical outputs, which proved to be very insightful in determining the outcomes of various transport development scenarios. A more detailed description of the Bydgoszcz transport model is provided further in this report and external sources [2], [3].

- **Current transport system data**. Detailed information on the present-state transport system in Bydgoszcz city was acquired to verify and update the modelling data. This comprised: the latest available data on the road and street network (from various data sources: the City Road and Public Transport Department – ZDMiKP [4]; the Bydgoszcz GIS database; OpenStreetMap); the public transport network data (from the ZDMiKP; the GTFS database; railway timetable of the Polish National Railways – PKP). The land-use data in the Bydgoszcz transport model was also checked to account for the recent urban developments. The validation process aimed to ensure the up-to-date representation of the Bydgoszcz transport system in the multimodal simulation model as of 2021.

- **Transport network development plans for the Bydgoszcz city**. Information on planned transport projects, schemes and policies was required to set up the CliMobCity analysis scenarios (for the year 2050). The baseline data on future transport scenarios was already provided in the Bydgoszcz transport model. These assumptions were then verified with further information obtained from the relevant public authorities, i.e. chiefly from ZDMiKP (the City Road and Public Transport Department [4]), MPU (the Municipal Urban Planning Authority [5], [6]), and the Bydgoszcz Metropolitan Association. Moreover, regional plans (incl. the ERDF policy manager [7]) and national transport plans [8], [9] were also consulted to account for the major (road and rail) investment schemes in the external context.

- **Socio-demographic, economic and land-use data forecasts**. Additional inputs for the CliMobCity analysis involved the projected population changes within the Bydgoszcz city and the surrounding (functional) area. Further data requirements concerned the land-use changes' forecasts within (and outside) the city, incl. projected greenfield and brownfield developments, as well as economic forecasts. This type of data was of paramount importance to the setup of CliMobCity transport scenarios, as the (likely on-going) suburbanisation processes, in conjunction with rising mobility (resultant from economic growth), will play a significant role in the transport system performance, and thus its ultimate carbon footprint. This information was principally obtained from the MPU (the Municipal Urban Planning Authority [5], [6]), the GUS database (National Statistical Office of Poland) [11], [12] and other city- and national-level strategic documents [3], [13], [14], [15].

- **Integrated Nationwide Transport Model (ZMR).** The nationwide multimodal transport model [16] was a crucial data source for updating the Bydgoszcz transport demand model, in particular with regards to external trips' data – i.e., long-distance trips between Bydgoszcz and other parts of the country, or through trips (trunk traffic) crossing the Bydgoszcz area. The newly developed Nationwide

Transport Model (ZMR) by the (CUPT) allowed to derive detailed data on external trips – both for existing model, as well as future travel demand projections [16].

- **The CliMobCity stakeholders' and partners' inputs and feedback**. Last but not least, advice and remarks gathered during the CliMobCity works from the project partners, and later during stakeholder meetings, served as valid guidance for transport analyses. Regular project meetings, in particular with the CliMobCity leader (TU Delft), provided a valuable support in eventual development of the analytical outputs. Moreover, stakeholder meetings were crucial to formulate the possible measures implemented in the CliMobCity simulation scenarios.

2. Methodology

The following sections describes the detailed assumptions and methodology of CliMobCity analytical works for Bydgoszcz.

2.1. Analysis workplan

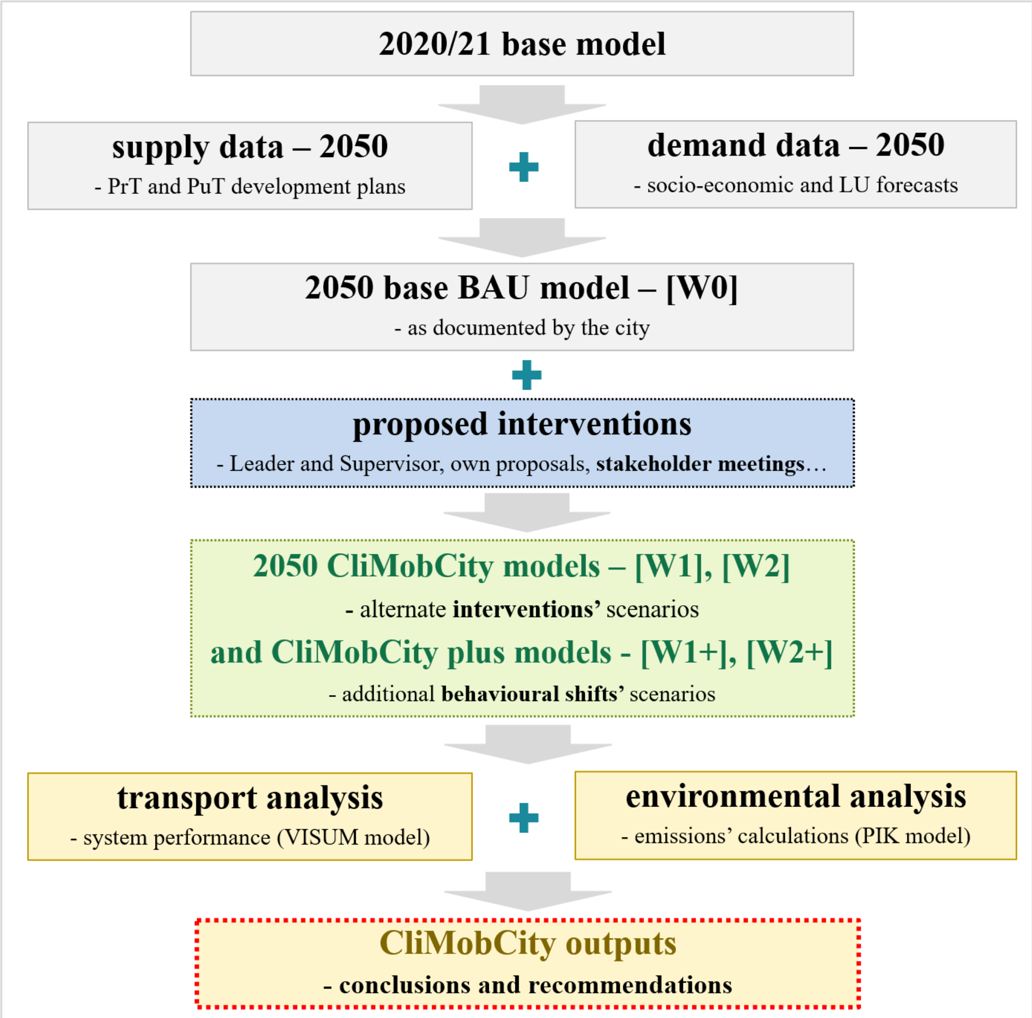


Figure 2. Methodology and work plan – overview.

The overview of CliMobCity analysis workplan for Bydgoszcz is presented in Figure 2. The main work stages included as follows:

- ***Development of the 2020/21 base transport model.*** The first stage involved preparing and updating the Bydgoszcz transport model with input data. Then, the simulation analysis for the 2020 existing scenario followed, whose results provided an overview of the existing transport system performance.
- ***Data collection and processing for the 2050 reference (BAU) model.*** This was a major prerequisite in preparations of the transport model for CliMobCity forecasts. Information on future transport investments, schemes and projects was collected mainly from the municipality and strategic documents and used to construct the network model for the year 2050. Also, socio-economic and land-use projections were acquired to update the future transport demand model.

- ***2050 reference (BAU) scenario – transport modelling***. Simulations were performed for the baseline 2050 Bydgoszcz transport model, i.e. the *business as usual* scenario **[W0]**. Outputs showed the plausible changes in transport network with current development assumptions.
- ***Stakeholder meetings and input collection for CliMobCity analyses.*** A series of *brainstorming* meetings were organised with different stakeholders to gather proposals for achieving a more efficient, sustainable and climate-friendly mobility in Bydgoszcz. Further ideas were also conceived during regular project meetings with CliMobCity consortium partners.
- ***2050 CliMobCity scenarios – transport modelling.*** In the next step, the **[W1]** and **[W2]** CliMobCity scenarios were set up, comprising 2 sets of specific network and policy measures. Simulation analyses revealed their consequences in Bydgoszcz transport model and allowed to trace the arising differences vs. the baseline [W0] scenario. In the course of this project, 2 additional scenarios **[W1 plus]** and **[W2 plus]** were also analysed to demonstrate the (potential) synergic effects of travel behaviour changes.
- ***2050 CliMobCity scenarios – GHG emissions' calculations.*** Simulation model outputs were then provided to the consortium partner PIK for in-depth analysis of GHG emissions in analysed scenarios.
- ***CliMobCity analyses for Bydgoszcz – conclusions and summary.*** Findings, observations and conclusions from this analysis are discussed in the final part of this report.
- ***Development of the CliMobCity Action Plan.*** Based on results of transport model analysis, the CliMobCity Action Plan for Bydgoszcz city was developed. It envisages a set of actions to be carried out and monitored within the final project period.

2.2. Analysis methododology - multimodal transport modelling

The **multimodal transport model of the Bydgoszcz city** (denoted further as (transport) model) was the primary analytical tool assumed for the purposes of this project. The model is a mathematical representation of the transportation system for the whole city of Bydgoszcz and surrounding agglomeration area.

The first version of Bydgoszcz model was developed in the year 2012 on the basis of comprehensive travel surveys conducted among the city population, travel demand counts and measurements and travel behaviour surveys. It was developed as the primary tool for strategic transport planning purposes in Bydgoszcz metropolitan area. Its applicability covers, among others, feasibility analysis of new road and public transport investment schemes; effects of changes in the existing transport network; land-use impacts upon transport performance; interactions between transport system conditions and travel behaviour; etc.

The transport model of Bydgoszcz city has been developed as a **macroscopic-level simulation model** in the PTV VISUM software. The macroscopic transport model is essentially composed of 2 submodels, representing the transportation supply (network) and transportation demand. Transport model of Bydgoszcz includes the following **transportation modes**:

- road traffic (cars, LGVs and HGVs),
- public transport (buses, trams and trains),
- active modes (cycling and walking).

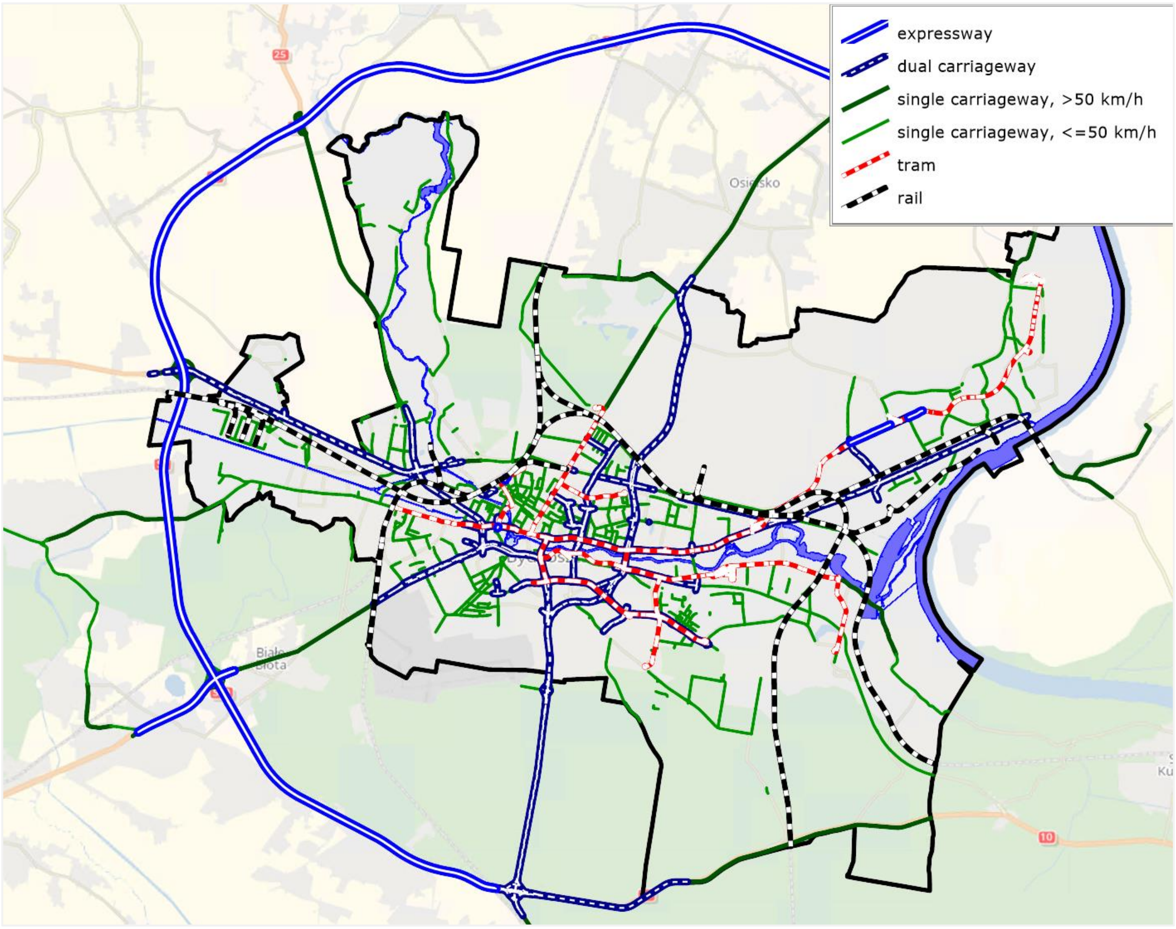


Figure 3. Bydgoszcz transport model – overview of transport network.

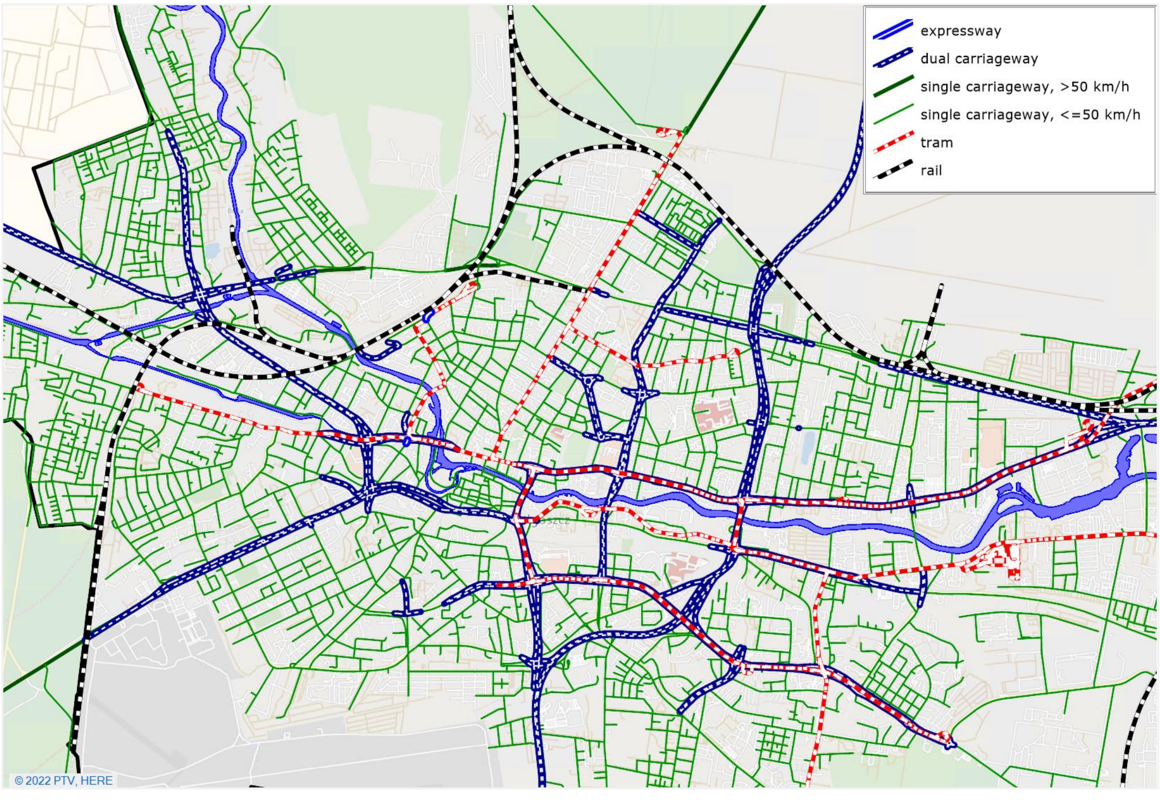


Figure 4. Bydgoszcz transport model – road network in central Bydgoszcz area.

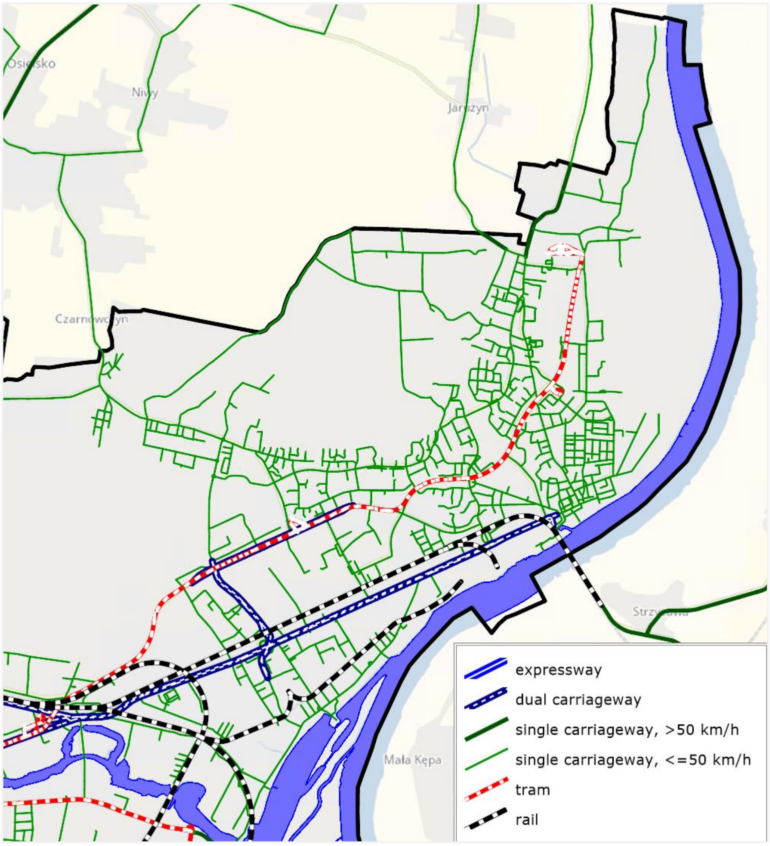


Figure 5. Bydgoszcz transport model – overview of road network in eastern (Fordon) area.

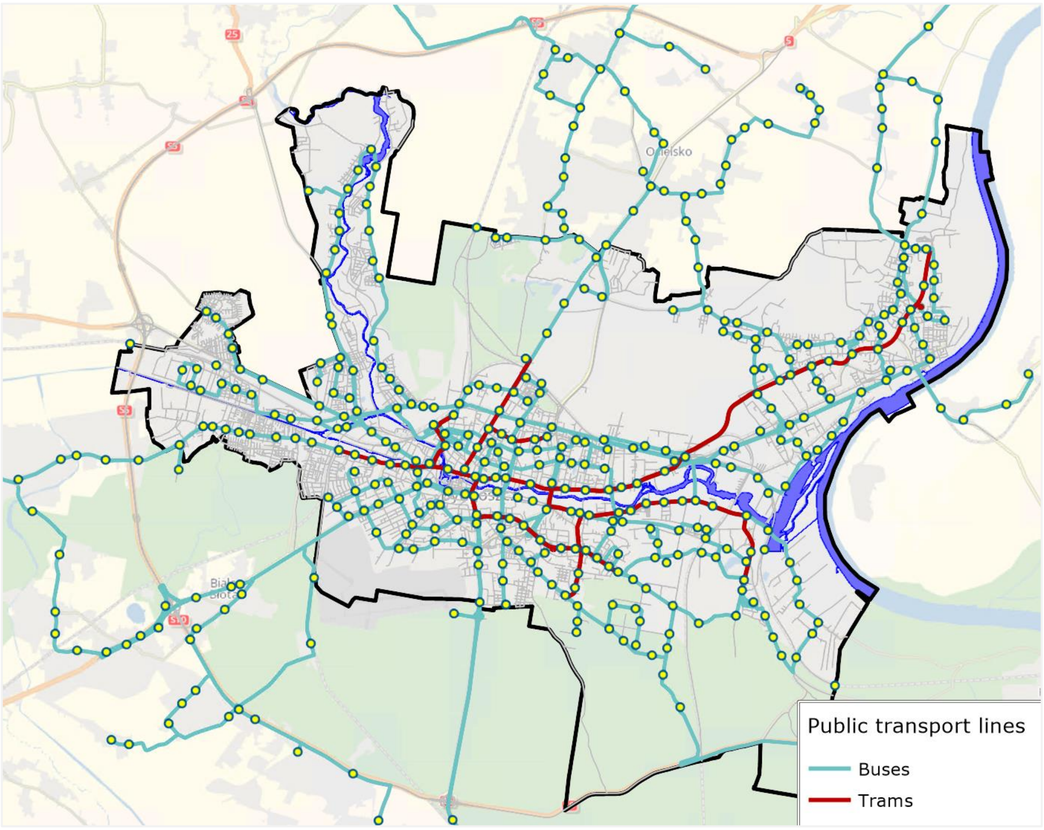


Figure 6. Bydgoszcz transport model – overview of public transport network.

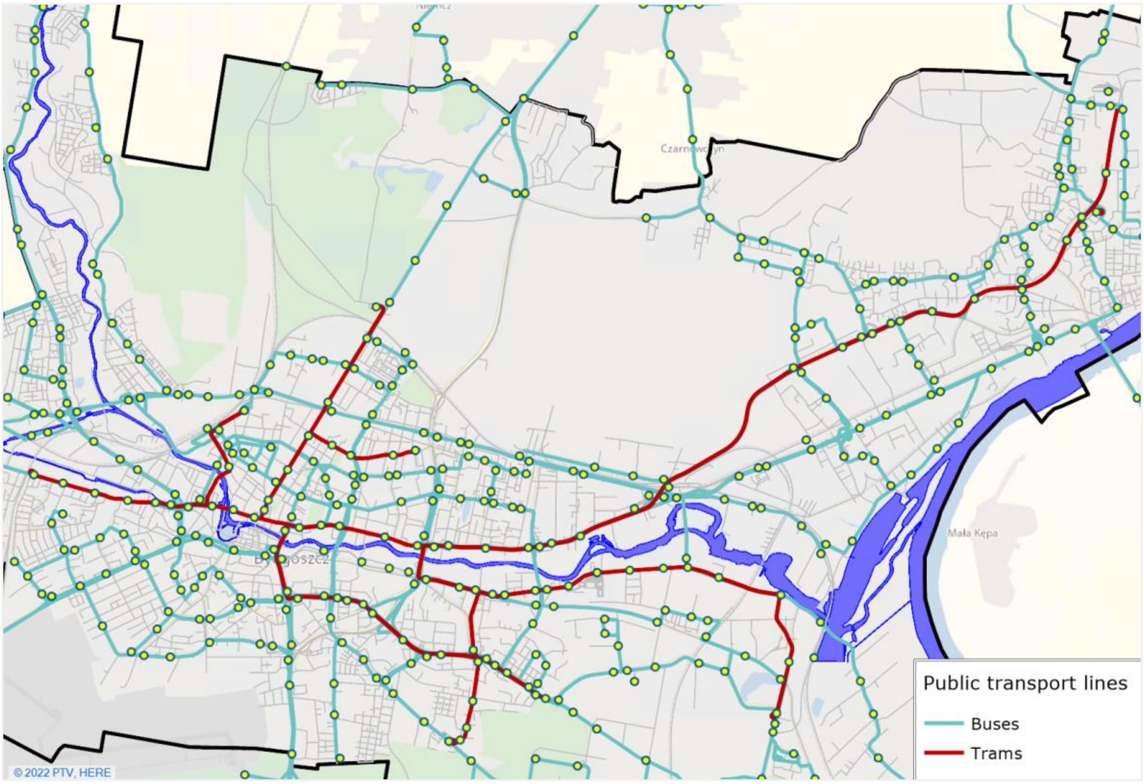


Figure 7. Bydgoszcz transport model – public transport network in central Bydgoszcz and Fordon area.

Transport supply (network) model is constructed as mathematical, parameterised graph of nodes and arcs (links). Each link represents a connection between 2 adjacent nodes (i.e. junctions, intersections, public transport stations and stops). Road links are characterised by their max. capacity [veh/hr] and free-flow speed [km/h], while actual link travel times are determined by specific volume-delay functions (VDF), i.e. non-increasing functions of volume-capacity ratio. Network links are classified according to specific (allowable) transport systems: road and street links, rail links, designated tramway links, and (where necessary) – additional walking and cycling links.

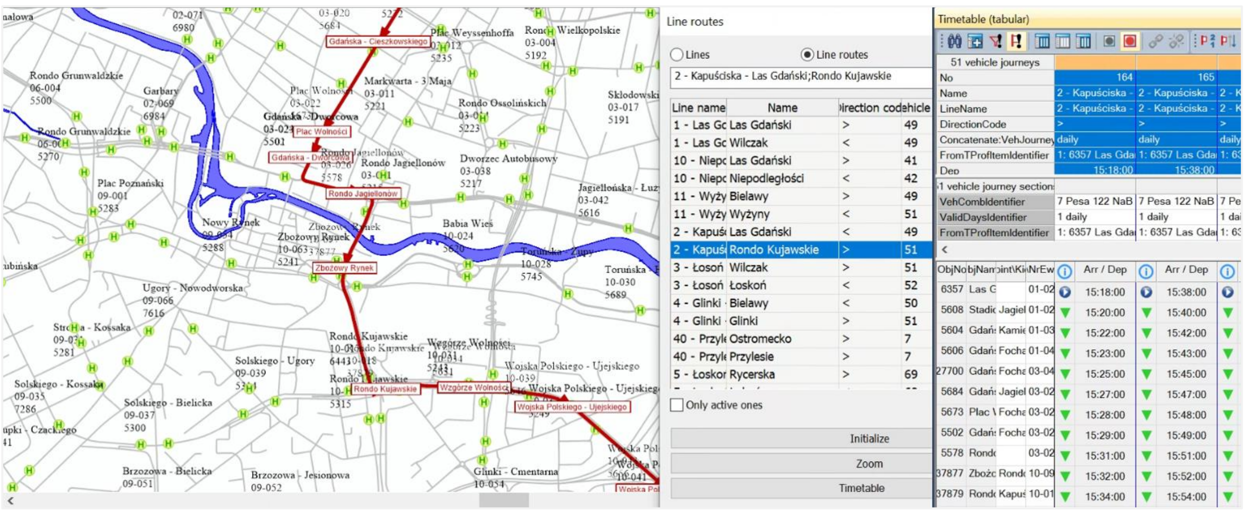


Figure 8. Bydgoszcz transport model – detailed coding example of public transport network.

Road nodes represent intersections and junctions in the street network and the allowable connections (turning movements) between the links. Public transport stops and stations are distinguished separately, with defined access and transfer walking links. Public transport connections are modelled in form of lines (line routes) replicating individual bus, tram and railway lines. Each line route connects an ordered sequence of stops with precisely defined timetables and riding times between the stops. Service times are assumed according to the public transport timetables.

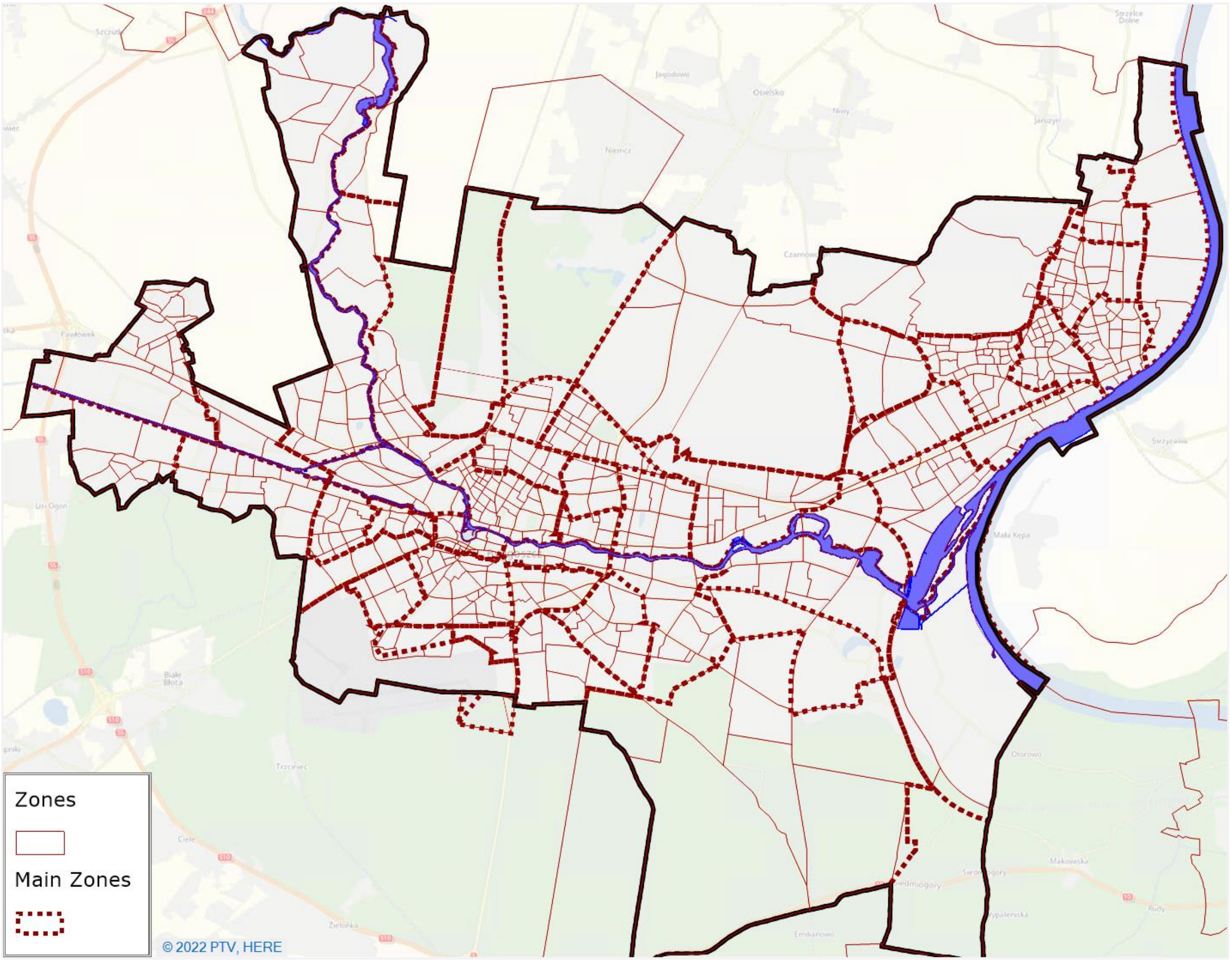


Figure 9. Bydgoszcz transport model – division into transport zones.

In accordance with the common macroscopic modelling approach, network model area is divided into transport zones. Each zone covers a specific sub-area of the Bydgoszcz city with specific trip generation and trip absorption volumes. A transport zone aims to represent a sub-area with fairly homogenous trip generation characteristics, land-use data (residential, industrial, service, leisure areas) population numbers (ranging usually between 1 – 10k inhabitants). Zone limits are designated along accessibility barriers such as: rivers, railway corridors, main roads, terrain barriers (trenches, embankments, watersheds etc.). Transport zones are reference objects for travel demand calculations, and are described by relevant parameters such as:

- number of inhabitants (total and distinguished by age groups),
- number of workplaces (total and distinguished by categories),
- number of schoolplaces,
- land-use data (buidling / usable floor area, GLA etc.).

In total, the Bydgoszcz transport supply model consists of:

- 8,300 nodes,
- 20,720 links,
- 1,120 public transport stops,
- 140 public transport line routes,
- 590 transport zones.

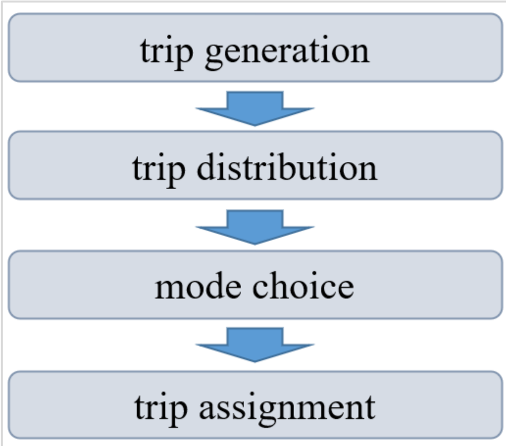


Figure 10. Methodology overview of the 4-step transport demand model.

Transport demand model is represented according to the classical 4-step demand modelling procedure (i.e. standard approach in macroscopic models). The 4-step model contains a set of mathematical models for describing how everyday trips are generated and then distributed in the Bydgoszcz transport network. These models were developed according to the 2012 household survey data (and other input data) during the Bydgoszcz model setup and maintained ever since by the Bydgoszcz authorities (ZDMiKP).

The 4-step demand model consists of the following stages:

- *Trip generation*: number of trips originating (production) and ending (production) in each transport zone is calculated from the input socio-demographic and land-use data.
- *Trip distribution*: trip values between each pair of zones is computed in form of the O-D (origin-destination) matrices. Trip distribution is a function of production and attraction figures and trip distance between 2 zones (i.e., distance-decay function).
- *Mode choice*: trip volumes between 2 zones are then distributed among transport modes (car, public transport, walk, cycle) available for a given O-D pair. Mode choice probability is calculated according to the random utility formula, based on travel time, distance and selected trip factors (e.g. waiting time, number of transfers).
- *Trip assignment*: in this final step, the O-D trip matrices for transport modes are assigned (distributed) onto the transport network model.

Demand modal calculations are conducted for specific *trip purposes (motivations)*, which improves the plausibility of its results. Trip purposes are distinguished in the Bydgoszcz transport model depending on a range of trip destination (and/or origin) categories, including:

- home,
- workplace,

- schoolplace,
- higher education,
- shopping centre (superstore),
- retail shopping
- leisure and/or private trips.

The final demand model is an aggregate output of the following trip categories:

- *Internal trips*: within-city trips performed by the Bydgoszcz residents. Internal trips are evaluated according to the above described 4-step modelling procedure.
- *Inbound and outbound trips*: trips between Bydgoszcz and external (agglomeration) area. Inbound trips originate outside of the city and terminate in transport zones in the city area. Outbound trips are performed in the opposite direction (i.e. from city to the agglomeration / external zones). Analogously, inbound and outbound trips are computed in the 4-step demand model (with different formulas).
- *External (through) trips:* trips that fully originate and terminate outside the analysis area, but cross through the model area. Data (matrices) describing the external trips in Bydgoszcz area are essentially obtained from the nationwide transport model (ZMR).

.

The Bydgoszcz demand model is computed for the whole-day (24-hour) period. The ultimate result of the 4-step demand model are travel flows in transport network, yielding a wide range of performance parameters:

- network loads: vehicle and passenger volumes along specific links (line segments, stops),
- journey parameters: travel times and speeds,
- spatial trip distribution,
- modal shares,
- (and others).

A detailed technical description (in Polish) of the Bydgoszcz multimodal transport model is provided in [2], [3]. This is also a baseline strategic source, documenting the model setup and development. Transport model of Bydgoszcz has been maintained ever since by the city authorities and local professionals, preserving its original structure (working principles) and methodology.

3. Case study – Bydgoszcz (Poland)

This section gives an overview description of the city of Bydgoszcz in Poland, including: information on the transport system in Bydgoszcz, its current state and future development plans. These are then followed by summary of stakeholder meetings and the conceived CliMobCity measure packages (scenarios).

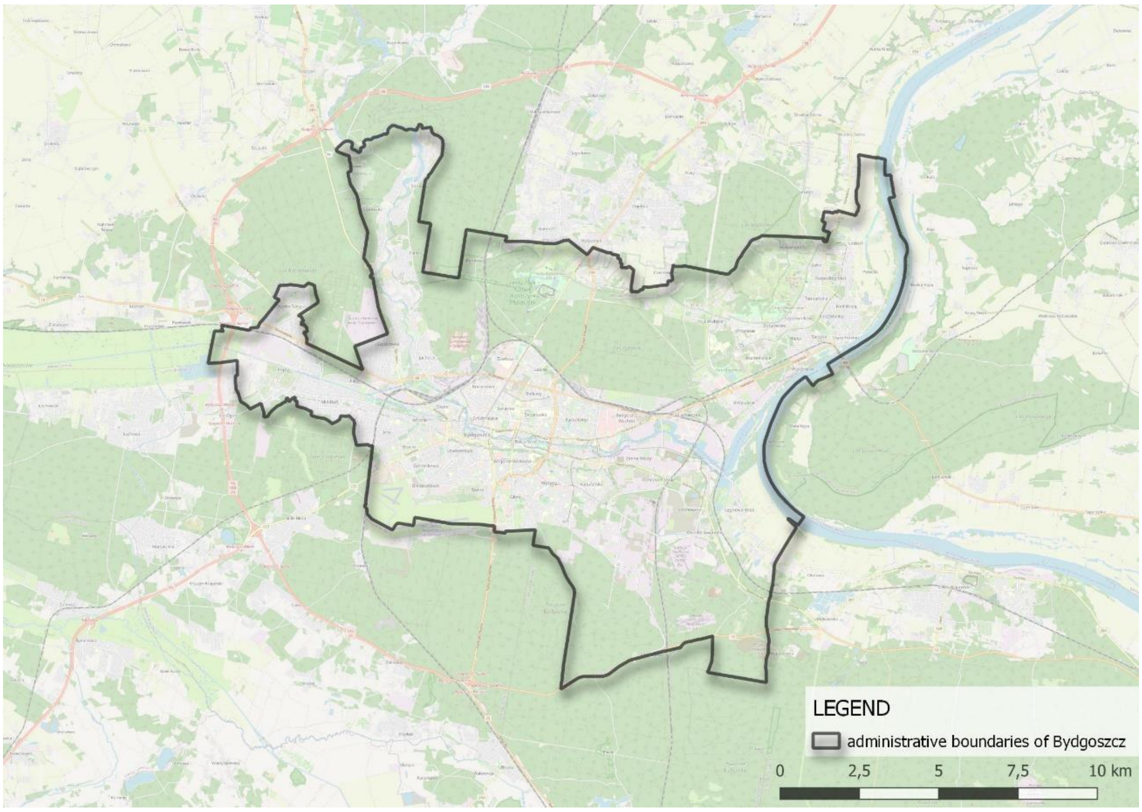


Figure 11. City of Bydgoszcz with surrounding area (source: OpenStreetMap).

3.1. Present-day transport system in Bydgoszcz

Bydgoszcz city is located in northern Poland, close to the River Vistula. As of December 2021, **the city population** was ca. **348k** inhabitants, with **620k** in the agglomeration **(functional) area.** It is the eighth-largest city in Poland and seat of regional (voivodeship) authorities. Together with nearby city of Toruń (population ca. 198k), it forms a major Bydgoszcz – Toruń metropolitan area (850k total population).

Total city area is 176 sq. km. The vast majority of urban development is concentrated within the central area, surrounded by woodlands and valuable green areas (about 35% of city area).

The Bydgoszcz city is a major regional hub, located at the crossroads of major **(inter)national transport corridors**:

- **road network:**
  - **S5 expressway**, i.e. a major N-S route: PL/CZ border – Wrocław – Poznań – Bydgoszcz – (Gdańsk/Gdynia); it is a part of the **European road route E261**,

    - **(S)10 national road**, i.e. main W-E route: PL/DE border – Szczecin – Bydgoszcz – Toruń – Warsaw,
- **rail network:**
    - **rail route no. 131**, i.e. a major N-S corridor: Silesia – Bydgoszcz – Gdańsk/Gdynia.; it is a part of the **European rail route C-E 65/1** with high importance for rail freight traffic (AGTC),
    - **rail route no. 18,** i.e. an important W-E corridor, connecting Bydgoszcz and Toruń with Warsaw, Poznań, and (in further distance) with Szczecin and Berlin,
- **Bydgoszcz – Szwederowo Airport**, which belongs to the TEN-T network, and operates regular domestic and international flights (LOT Polish Airlines, Ryanair, chartered flights).

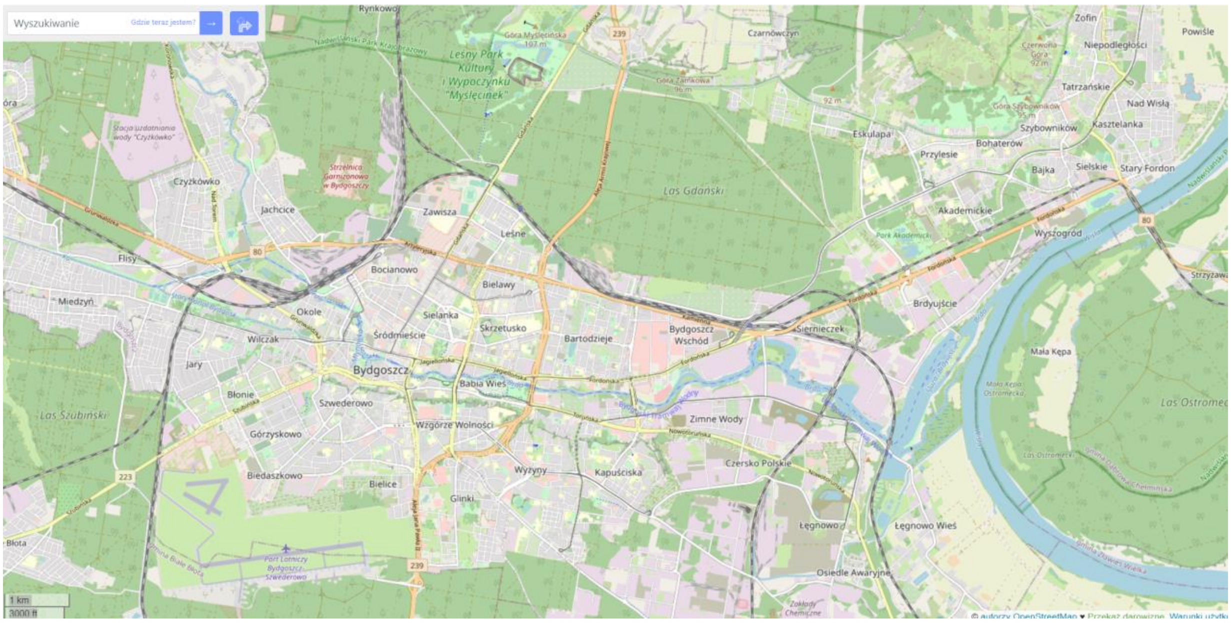


Figure 12. Central area of Bydgoszcz and the eastern Fordon subcentre (source: OpenStreetMap).

City public transport network in Bydgoszcz consists of bus and tram lines. It is supervised by the Municipal Road and Public Transport Department (ZDMiKP – *Zarząd Dróg Miejskich i Komunikacji Publicznej*). There 2 main public transport operators in Bydgoszcz: *MZK* (*Miejskie Zakłady Komunikacyjne Sp. z o. o.*) and *Tramwaj Fordon Sp. z o. o.* According to the 2019 data (ZDMiKP), total (annual) ridership in bus and tram network in Bydgoszcz was ca. 92m passengers. Average ride times were equal to 22.6 [km/h] for bus services and 20.0 [km/h] for tram services. Average distance between stops is ca. 570 [m] across the whole network.

Tram network comprises the 'core' of public transport system in Bydgoszcz. It consists of 8 main routes (lines no. 2, 3, 4, 5, 6, 8, 9, 11) and 3 feeder routes (no. 1, 7, 10). Typical peak frequency is 20 [mins], with the exception of line no. 5, which operates every 10 [mins]. Total length of tram lines is equal to 126 [km]. The central part of Bydgoszcz tram network is designed in a grid-like structure, with radial tram routes spanning outwards (towards main suburban developments). Among them, the longest radial tram route connects the city centre with major eastern development of Fordon – ca. 12.5 [km] (notably, without any alternative tram corridor in this major travel axis).

Bus network consists of ca. 47 regular lines, including: 30 city lines, 11 suburban lines and 6 night bus lines. Bus network provides supplementary services to tram operations, both as high-frequency main lines, as well as low-frequency feeder lines in less-densely populated areas. Area covered by public bus operations includes the city of Bydgoszcz and surrounding communes (Polish: *gminy*). Selected bus lines in Bydgoszcz are subject to corridor synchronisation (co-ordination) with modular frequencies.

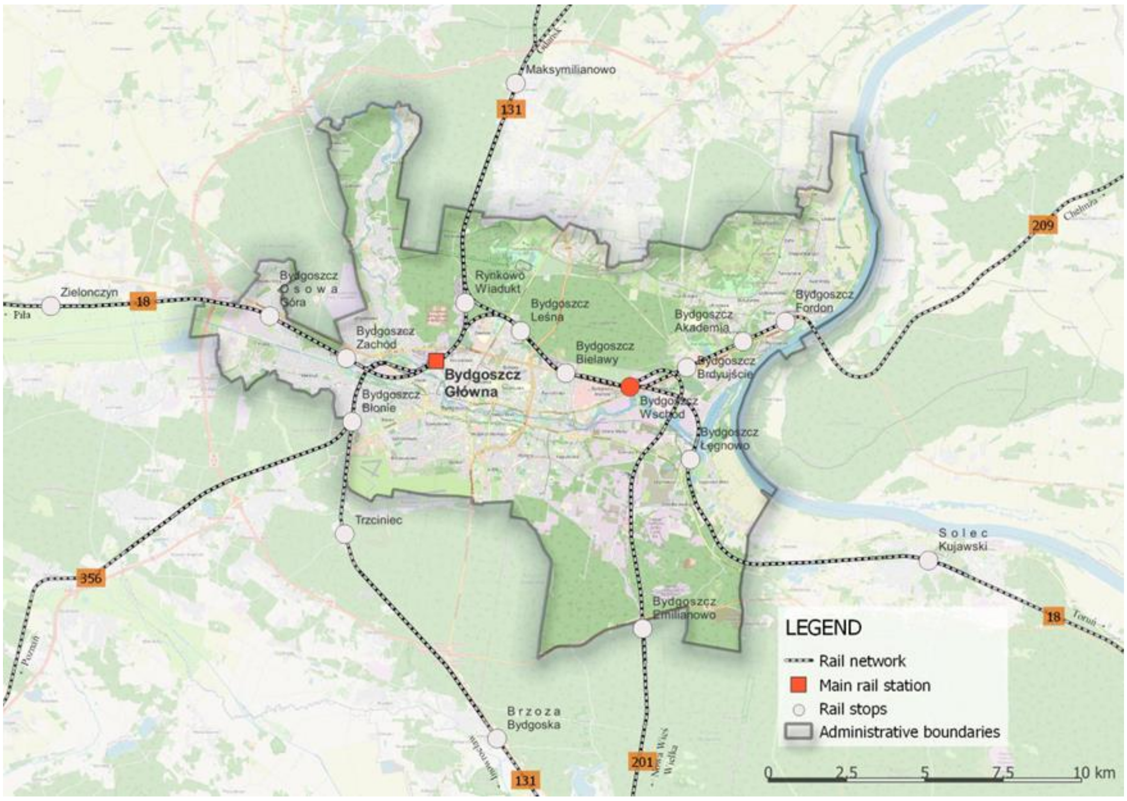


Figure 13. Rail network in the Bydgoszcz city area (source: OpenStreetMap).

Rail network in Bydgoszcz has a total length of ca. 60 [km] and 11 passenger stops (stations) within city boundaries. It has historically developed (since 19th century) as an important rail interchange both for passenger and freight traffic. **Main rail lines -** double-tracked and electrified - connect Bydgoszcz with other Polish cities and regions in all major directions:

- northbound – Gdańsk and Gdynia (line no. 131),
- eastbound - Toruń (line no. 18), with further connections towards Olsztyn and Warsaw,
- southbound - Silesia (line no. 131), with further connections towards Łódź and Poznań,
- westbound – Szczecin (line no. 18).

This main rail network is complemented by **local rail lines**, single-tracked and non-electrified, heading out of Bydgoszcz in north-east (no. 208 – Chełmża) and south-west (no. 356 – Kcynia and Poznań) directions.

The **Bydgoszcz Main railway station** *(Bydgoszcz Główna)* is the main rail interchange, situated in the north-western part of the city centre. According to the 2021 data, passenger volumes (boardings and alightings) oscillate around 10k [pass./day], with about 150 train connections on daily basis. Rail passenger system in Bydgoszcz includes long-distance (**intercity**) and **regional** train connections. In the future, a new Rapid Metropolitan Railway system (SKM) is also envisaged to be rolled out across the wider Bydgoszcz – Toruń metropolitan area, providing high-frequency suburban train services.

Road and street network in Bydgoszcz has historically grown in par with city urban development, originating from the inner-city core area. Expansion of street network has accelerated in the 19th and 20th century, as the city expanded outwards and has grown in size from the population of 6,000 in 1815, 130,000 in 1935, up to 348,200 in 2021. The present-day road network resembles a grid-type structure, with historical development along main radial (arterial) routes The supervising authority is the Municipal Road and Public Transport Department (*ZDMiKP*).

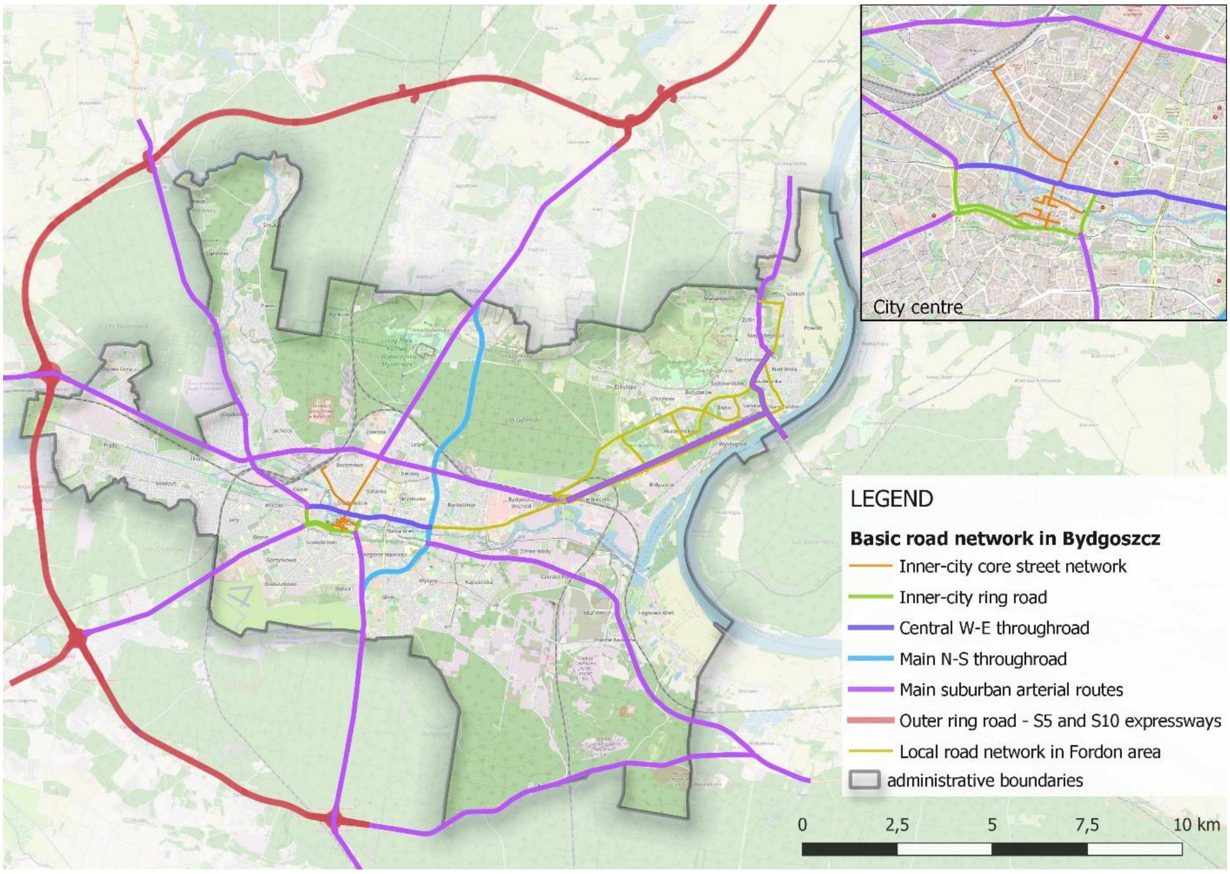


Figure 14. Basic road network in the Bydgoszcz city area (source: OpenStreetMap).

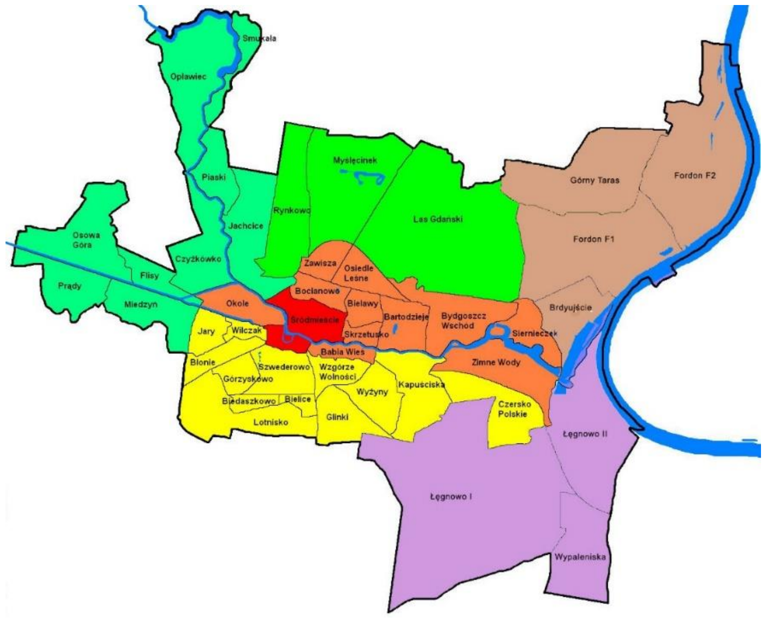
The basic road network in Bydgoszcz is composed (among others) of the following elements:

- **Inner-city core street network:** *Mostowa, Niedźwiedzia, Jana Kazimierza, Długa, Grodzka, Gdańska, Dworcowa etc.*
  - Historical streets in the very central Bydgoszcz area, situated in a densely built-up environment. These streets served as historical access routes to medieval-era Bydgoszcz, leading from/to the Old Market Square *(Stary Rynek*). Later on (i.e. in recent times), some of these historical streets would be expanded as radial axes for outward urban development of Bydgoszcz. In present era, these streets are often important central-city destinations, either pedestrianised (and closed to general car traffic) or subject to traffic calming/reduction measures.
- **Inner-city ring road:** *Kruszwicka, Grudziądzka, Poznańska, Wały Jagiellońskie, Bernardyńska.*
  - Dual-carriageway roads surrounding the historical city centre (expect for the missing northern section). These roads are located in the densely built-up central area and provide a direct delimitation of the inner-city core area. Their intersection points act simultaneously as busy road traffic junctions and important public transport interchanges in Bydgoszcz.
- **Central W-E throughroad:** *Focha, Jagiellońska. Fordońska.*
  - A dual-carriageway road traversing very close to the core city centre, just ca. 250 [m] north of the Old Market Square. This is an important W-E route, connecting the Bydgoszcz central area with main

suburban areas (*Miedzyń, Wilczak, Czyżkówko*, as well as *Bartodzieje*, *Os. Akademickie*, *Fordon*). Hence, this route is subject to substantial traffic volumes of up to 50,000 [veh./day] along its central section (*Jagiellońska*) and even over 85,000 [veh./day] further to the east (*Fordońska*).

- **Main N-S throughroad:** *Jana Pawła II, Wyszyńskiego*, *Armii Krajowej.*
  - A dual-carriageway trunk road passing through east of the Bydgoszcz central area with traffic volumes of 30,000 – 50,000 [veh./day]. Until recently, this was envisaged as part of an urban expressway, i.e. part of the S5 (E261) trunk route which has been eventually re-routed to the west of Bydgoszcz. In present state, the main N-S arterial in Bydgoszcz is a high-standard, dual-carriageway road, with some junctions being grade-separated.
- **Main suburban arterial routes:** *Fordońska, Wojska Polskiego, Kujawska, Szubińska*, *Grunwaldzka, Sułkowskiego, Pileckiego, Kamienna etc.*
  - Main road network outside the city centre of Bydgoszcz was envisaged as a dual-carriageway system of routes spanning from the central Bydgoszcz towards suburban and outer areas, as well as orbital roads in the suburban Bydgoszcz area. Most of these roads have been developed as originally planned, with the exceptions of certain single-carriageway road sections.
- **Local street network in Fordon (eastern) subcentre:** *Fordońska, Andersa, Kasztelańska, Akademicka, Pelplińska etc.*
  - A network of mostly single-carriageway roads (with a few dual-carriageway roads) expanded in recent decades to accommodate new housing developments in eastern parts of Bydgoszcz. These streets feature wide cross-sections, with the extra provisioned space allowing for potential future upgrades. These may include e.g. green infrastructure expansion, tram line construction, new parking lots, or (as originally foreseen in city plans) road widening projects.
- **Outer expressway ring road:** *S5 and (S)10 trunk roads.*
  - An outer ring road is located outside of Bydgoszcz city boundaries, approx. 7 - 10 [km] from the city centre. It encircles Bydgoszcz from the northern, western and southern sides, connecting the arterial routes heading towards other cities of Gdańsk (S5), Szczecin (DK10), Poznań (DK5), Inowrocław (DK25), Toruń and Warsaw (DK10, DK80). The northern and western sections have been recently upgraded to a dual-carriageway expressway standard (as part of the S5 construction). This will be followed up in the next few years by the upgrading of southern section (with the S10 construction starting soon). The outer ring road is the basic corridor for heavy trunk traffic and plays important role in everyday car trips (i.e. commuting and others) within the Bydgoszcz agglomeration area.

3.2. Urban development and implications for transport performance



Population – 2020 data: ['000 inhabitants]	
[1.] Historical Centre *(Śródmieście)*	27.3
[2.] Lower Terrace *(Taras Dolny)*	125.0
[3.] Upper Terrace *(Taras Górny)*	54.8
[4.] Western Residential District *(Zachodnia Dzielnica Willowa)*	41.8
[5.] Northern Leisure District *(Północny Pas Rekreacyjny)*	30.7
[6.] Eastern District – Fordon *(Fordon)*	66.0
[7.] South-East Industrial District *(Płd.-Wsch. Dzielnica Przemysłowa)*	2.6
TOTAL:	**348.2**

Figure 15. Population distribution (2020) between main districts of the Bydgoszcz city (source: bydgoszcz.pl).

Historically, the Bydgoszcz city has evolved longitudinally along the valley of Brda river. Its urban development is constrained from the north and the south by railway routes and surrounding woodlands (which are also the *green lungs* of the city). The incorporation of Fordon town in the 1970s into the city of Bydgoszcz further reinforced the longitudinal direction of urban development. Consequently, the *proper* (functional) city area nowadays spans approx. 9 [km] in the N-S direction, and over 21 [km] in the W-E direction. Urban growth of the Bydgoszcz city was heavily influenced by its location at the Brda river crossing(s) and along the historical W-E travel route, which is nowadays the main transportation axis within Bydgoszcz.

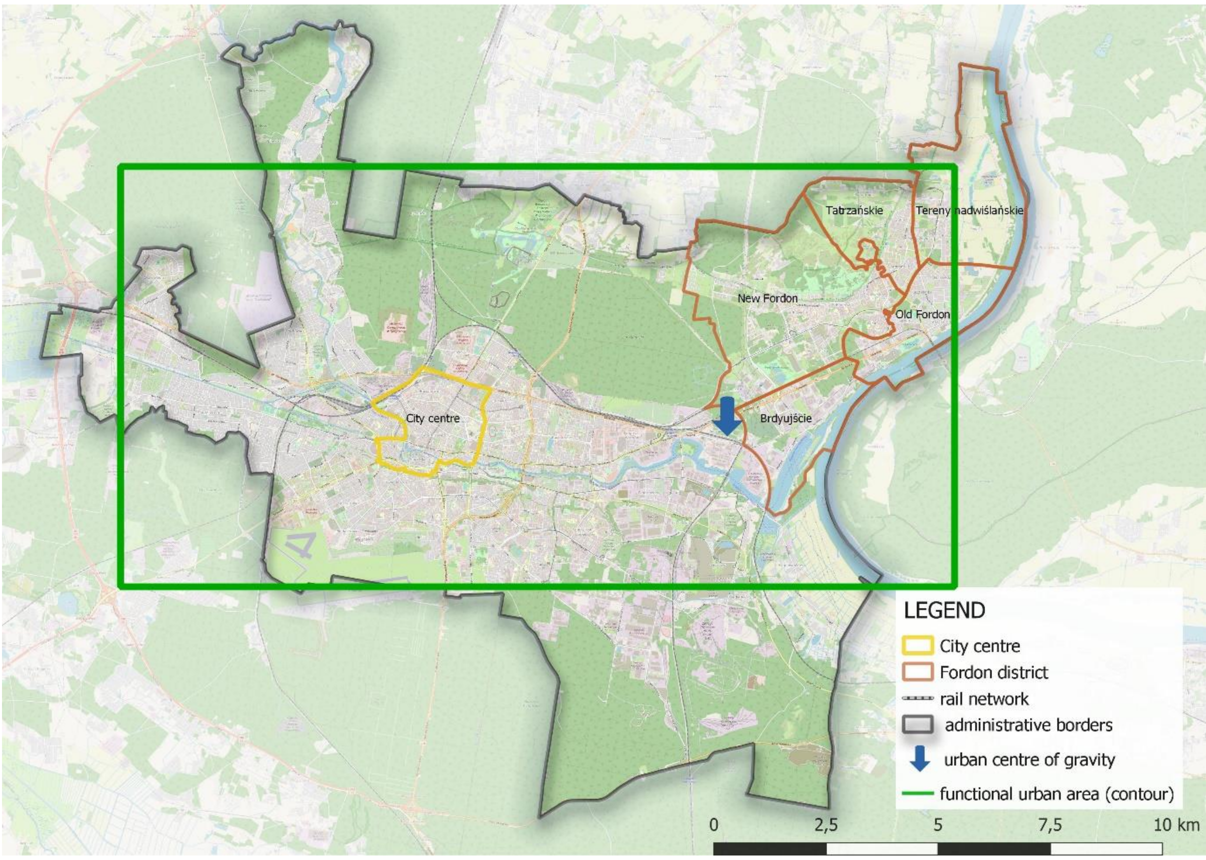


Figure 16. Schematic outline of **Bydgoszcz city perimeter** (**red**) vs. its ***actual*** **functional urban area** (**green**). The blue arrow denotes the ***urban centre of gravity*** in the Bydgoszcz, weighted by distribution of city population, workplaces, services etc.

An overview of urban (spatial) development structure for Bydgoszcz indicates that the ***functional centre of gravity*** is actually located further **east (about 7 [km]) of the historical, proper city centre** – i.e., in the vicinity of Bydgoszcz East (*Bydgoszcz Wschód*) transport interchange. This place is an intersection of main road, rail and water transport corridors in Bydgoszcz. Simultaneously, it features a fairly limited scale of urban development, principally due to natural constraints – i.e. river confluence (merging point) to the south, and wide railways and woodlands to the north. Hence, this results in an **unbalanced city performance, since the urban centre of Bydgoszcz substantially diverges from its centre of gravity**.

This phenomenon has been reinforced in recent decades by **urban policy focused on intensification of high-housing development in eastern parts of Bydgoszcz – i.e. the Fordon subcentre,** which provides relatively affordable and accessible areas for residential development. With limited housing investment in other (central and western) parts of Bydgoszcz, eventually a certain **feedback effect** has been induced. An outflux of population and businesses has been observed in recent years from central Bydgoszcz area, towards (especially) the eastern suburbs and (to a limited extent) western areas as well. **Unfavourably, central city areas became underpopulated, less-attractive and even perceived as unsafe.** Rising suburbanisation has put higher strain onto developing the W-E transport connections over larger distances. Meanwhile, the housing demand has been constantly growing in Fordon area. Housing development, which has hitherto concentrated in the *Lower Terrace* Fordon area, is nowadays expanding onto the vast, greenfield (and yet less accessible) hilly areas of the *Upper Terrace* Fordon.

However, as concluded in own transport and urban analysis, **such urban policy leads to unfavourable rise in transportation demand, especially for longer-distance city trips**. This requires even greater expansion of public transport and road infrastructure, which in turn stimulates further the urban sprawl tendencies. Consequently, transport system in Bydgoszcz is characterised by rising travel time delays, energy consumption and (negative) environmental impacts.

Detailed (own) urban planning analyses reveal that **central area of Bydgoszcz still contains significant (both greenfield and brownfield) land reserves**, which can provide an alternative to massive housing developments in the eastern Fordon area. The existing, unattractive housing and post-industrial developments offer major opportunities for urban regeneration projects. Such policy could lead to much shorter trip distances, and especially - a major share of motorised trips less than 2 [km] long could be substituted by active travel modes (walking and cycling). Consequently, positive outcomes could be expected with regards to urban quality of life, perceived city attractiveness, and – last but not least - safety and *cleanliness* of Bydgoszcz transport system.

Importantly, the above vision may only be achieved with step-wise, long-term – and consequent - urban planning and development strategy. **Initial changes (towards the reversal of *expansionist* spatial policy) took place in the past decade**, as the city halted further housing expansion of the Upper Terrace Fordon area and increased the support for inner-city brownfield recultivation projects instead. This has resulted in a number of redevelopment investment schemes now underway in central Bydgoszcz, with more projects in planning and preparation phases. Moreover, major road construction projects (such as south-eastern suburban ring road) were postponed in favour of greater public transport investment in city centre, including new tram lines.

Further actions aimed at inhibiting the urban sprawl and promoting inner-city re-densification (including mixed-use residential, retail and business projects) would be needed to effectively reduce the longer-distance car trip volumes, and instead - support the growth of short-distance trips made by walking, cycling or by (climate-friendly) public transport.

3.3. Future development – the 2050 *business-as-usual* (BAU) scenario

To assess prospective transport system performance in the Bydgoszcz city, the reference scenario of transport model has been constructed for the year 2050. The **2050 *business-as-usual (BAU)* scenario, i.e. 2050 [W0] scenario**, includes relevant changes in the transport supply (network) and transport demand (mobility). These assumptions were formulated based on the review of city strategic documents and sources, primarily:

- baseline assumptions included in the Bydgoszcz multimodal transport model in year 2050 [2], [3],
- Spatial Development Masterplan for the City of Bydgoszcz (Polish: *SUiKZP*) [5],
- Sustainable Transport System Development Plan for the Bydgoszcz Metropolitan Area [13],
- inputs and information on transport projects and investment plans from city authorities, especially the Municipal Road and Public Transport Department (*ZDMiKP*) [4],
- Central Statistical Office of Poland – forecasts' database (Polish: *GUS – Główny Urząd Statystyczny*) [11], [12]).

Transport supply changes in the 2050 BAU scenario, which were formulated on the basis of abovementioned strategic sources, are primarily related to new tram and road network investment projects. Public transport development plans in the 2050 BAU scenario foresee an expansion of **tram network in Bydgoszcz city**, as indicated in Figure 17. New line sections will increase tram network coverage (density) and foster its grid topography – **creating 2 'fully-closed' tram ring routes in northern and southern parts of Bydgoszcz city centre**. Limited-scale tram extensions are also planned east and north of inner-city Bydgoszcz area. Future tram lines will be double-tracked, fully **equipped with ITS-based priorities**, and mostly separated from general (road) traffic.

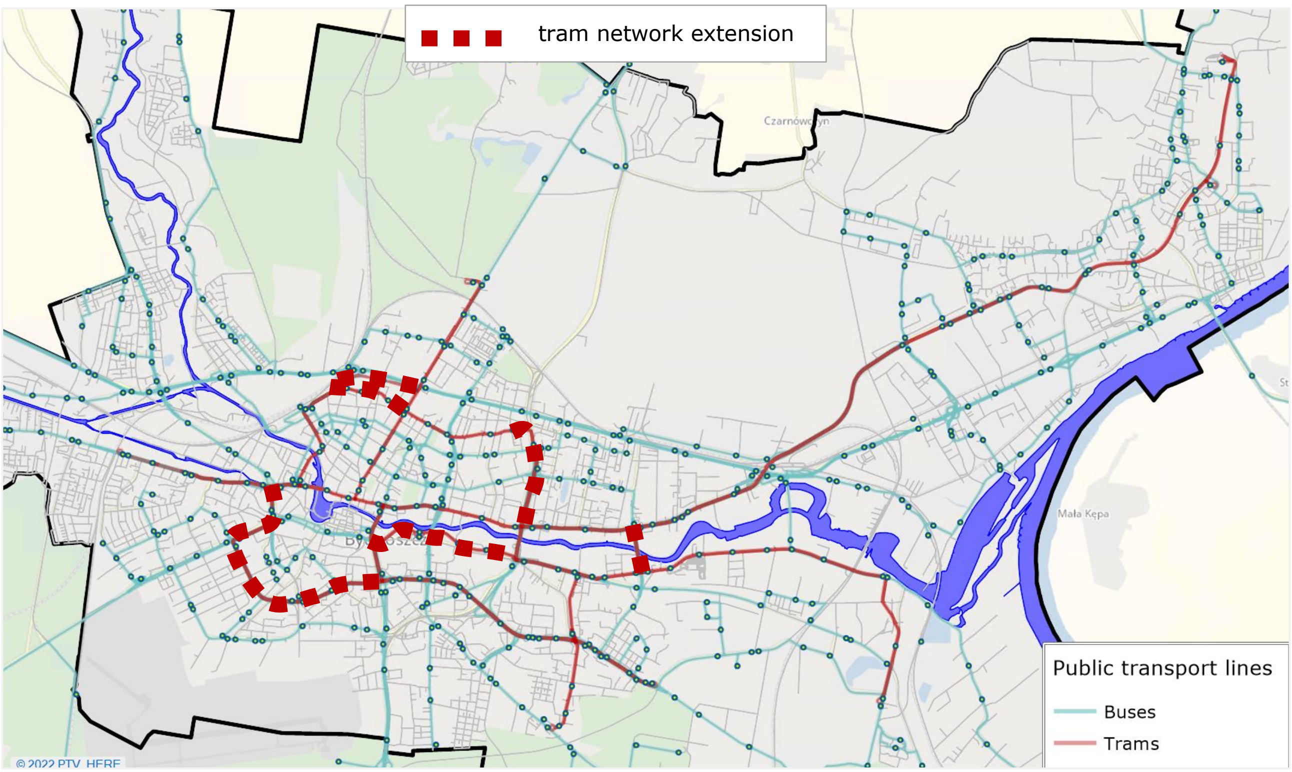


Figure 17. Public transport network developments in the 2050 BAU [W0] scenario.

Road network plans include new and upgraded ring road sections within the Bydgoszcz urban area, with main schemes summarised as follows:

- **Northern section of urban ring road** (*Grunwaldzka – Pileckiego – Artyleryjska – Kamienna*). The existing single-carriageway northern bypass of Bydgoszcz central area will be upgraded and widened to dual-carriageway standard, with grade-separated junctions at main 'choke' points. This route should ultimately form the main W - E road corridor in Bydgoszcz and purportedly relieve road traffic loads in the inner-city core area.
- **South-western sections of urban ring road** (*Stroma / Piękna – Solskiego*). Analogously, existing single-carriageway streets, situated south-west of the city centre, are part of a future reconstruction scheme of new tram lines and dual-carriageway road. Together with the existing southern bypass section (*Solskiego – Wojska Polskiego*) these will provide a complete, continuous urban ring road south of the city centre. Notably, strategic plans envisage major upgrades to both *Piękna* and *Stroma* street corridors, which run parallel and in close proximity of each other (ca. 0.5 [km] apart).
- **New eastern river crossing** (*Most Kazimierza Wielkiego*). A new road and tram bridge crossing over Brda river will be constructed east of the Bydgoszcz city centre. Its objective will be to improve connectivity and accessibility between major housing and workplace developments in eastern Bydgoszcz (*Bartodzieje, Wyżyny, Łęgnowo*).
- **Eastern suburban bypass** (*Obwodnica Wschodnia Bydgoszczy*). A major project which involves construction of a 15-[km] new south-eastern road bypass, running approx. 2 – 5 [km] east of the existing main N - S throughroad (*Jana Pawła II – Wyszyńskiego*) and crossing the city urban corridor

'halfway' between central Bydgoszcz and eastern Fordon areas. This suburban ring road has been conceived with the objectives of providing both traffic relief and improved accessibility, although its ultimate effectiveness has been often debated.

- Notably, the 2050 BAU scenario foresees **no road narrowing or traffic reduction measures**, i.e. in addition to present-day 2021 scenario. These are only mentioned as generic recommendations at the strategic level, yet with no specific e.g. road narrowing or closure schemes.

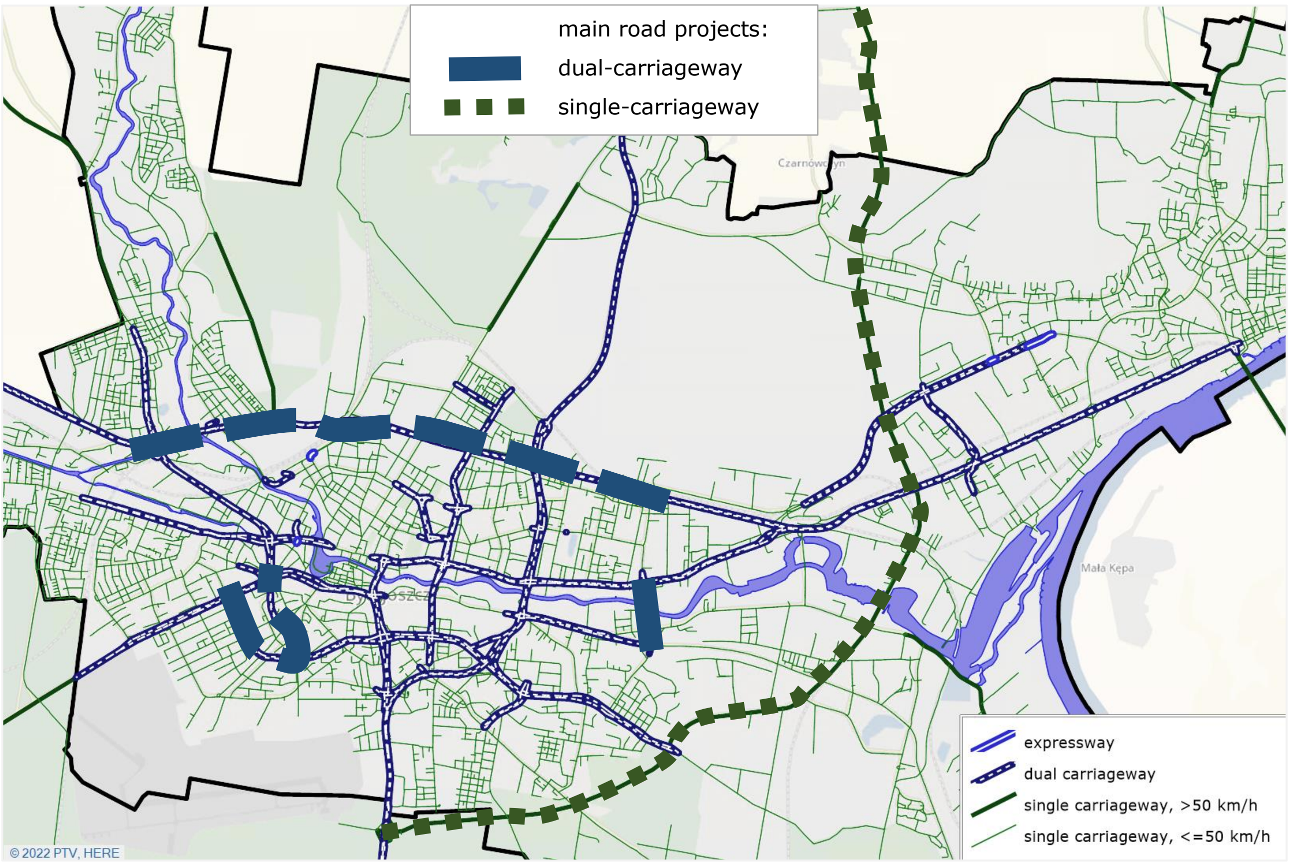


Figure 18. Road network developments (main projects) in the 2050 BAU [W0] scenario.

Meanwhile, **transport demand outlooks** for the year 2050 will be substantially influenced by socio-demographic trends and land-use development projections within Bydgoszcz and its agglomeration area. Main aspects shaping the 2050 BAU mobility scenario can be summarised as follows:

- **Socio-demographic changes.** The city population of Bydgoszcz is expected to decrease from the present-day rate of 348,000 (2021) down to 336,000 by the year 2050 – i.e. by about 3.5%. Future demographic picture of Bydgoszcz will be determined by an increasingly ageing population, whose relative share (i.e. 65+ years) will jump from 24% (2021) up to 35% (2050) of city population [12]. This trend will only be partially offset by inward migration of education- and working-age population from wider voivodeship area, thanks to Bydgoszcz retaining its status as a regional economic and higher-education hub. Hence, total number of workplaces in Bydgoszcz – assumed in the 2050 BAU scenario - will rise slightly from 236,000 (2021) to 244,000 (2050), i.e. by 3.3%. Meanwhile, the Bydgoszcz FUA (Functional Urban Area) population is assumed to decrease by an analogous rate (3.5%), from approx. 602,000 (2021) down to 578,000 by the year 2050, with similar socio-economic shifts. Educational sector is assumed to retain constant number of schoolplaces both at higher-education level (26,000), as well as in primary and secondary education (54,000). Against the aforementioned ageing population trends, such figures imply that a relatively higher share of schoolplaces in Bydgoszcz will be taken up by schoolchildren commuting from the agglomeration (FUA) area.

- **Economic development.** Official forecasts envisage sustained upward economic trends, with annualised GDP growth projections in the range of 2 – 3% over long-term horizon. Since the overall socio-economic welfare and development often drives the growth in transportation needs, this aspect has been reflected in terms of rising mobility rate (i.e. number of daily trips per person) of approx. 35% by the year 2050 – i.e. corresponding to 1% annually. Present-day mobility rates in Polish cities are estimated at 1.5 – 2.2 [trips/person/day], which is noted to be visibly lower than estimates for Western countries [17].
- **Land-use changes and sustained suburbanisation.** Land-use development in Bydgoszcz will be profoundly shaped by prevalent suburbanisation trend that will continue in the near future, owing to a number of factors: social and lifestyle changes, lax urban planning laws, availability of *greenfield* opportunity areas. Land-use patterns - entailing primarily housing dwellings, industrial and service areas - in the 2050 BAU scenario have been assumed according to projects in the Sustainable Transport Plan [3], [13] and the Spatial Development Masterplan [5]. The 2050 BAU scenario assumptions foresee limited yet gradual changes in population distribution from the city centre towards eastern Bydgoszcz (*Fordon*) and agglomeration (FUA) area. Workplace distribution will be likewise tilted towards eastern Bydgoszcz, influenced by expanding service and industrial developments in the south-eastern part of city (*Emilianowo, Łęgnowo*) and also in north-eastern areas (*Fordon, Brdyujście*).

Resultant impact of the above outlined transport demand assumptions is presented in Figure 19 below. It contains projected changes in daily trip volumes in the 2050 BAU scenario, compared against the present-day 2021 scenario. These are plotted at the TAZ level across the whole Bydgoszcz city and reveal that future transportation patterns will further strengthen the eastward tilt of the functional centre of gravity of Bydgoszcz against its spatial structure (as noted earlier in the Figure 16) above. Moreover, it evidently exposes the decreasing mobility in central and southern Bydgoszcz area, coupled with much greater trip generation in the eastern and outer city areas.

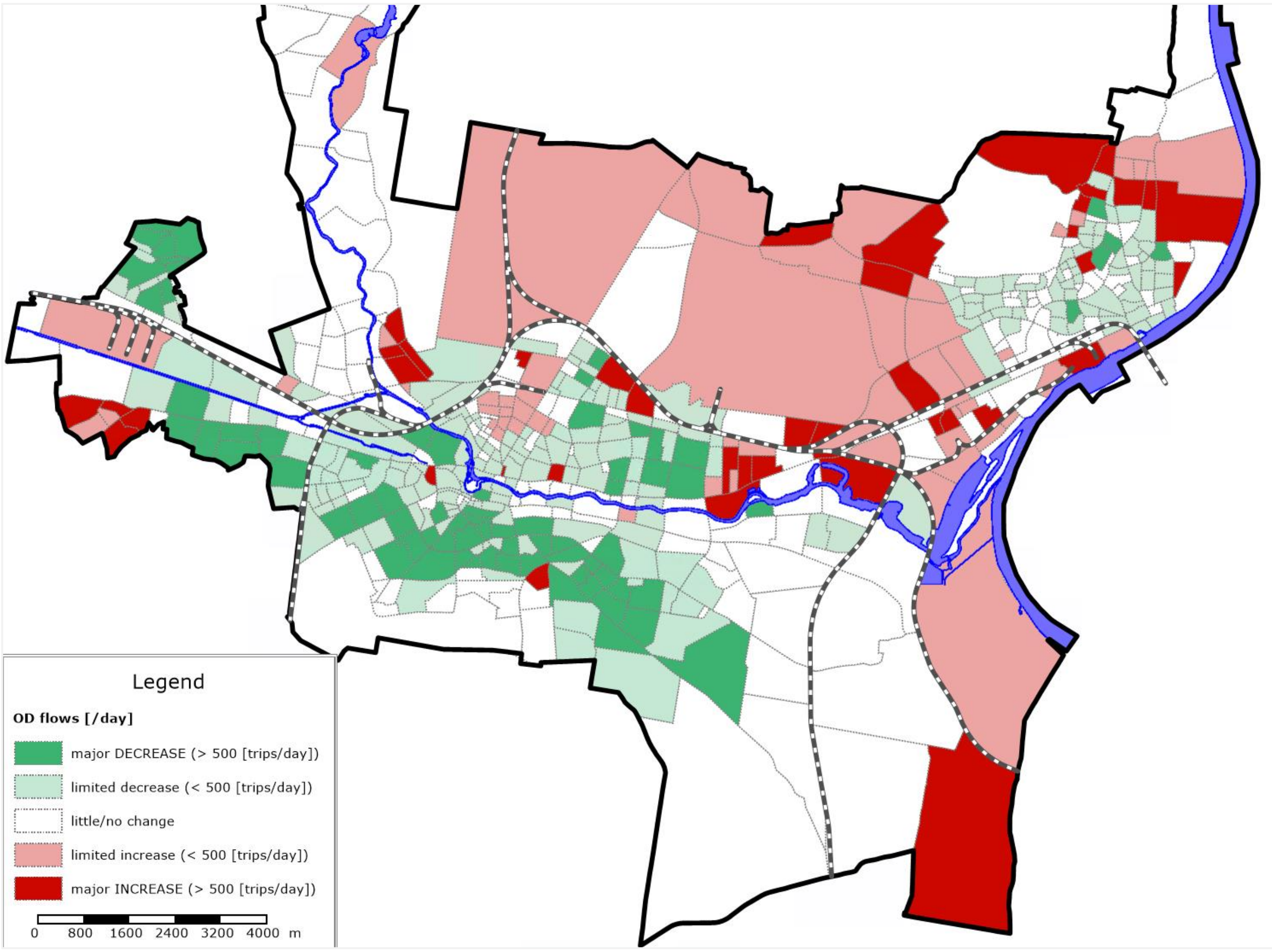


Figure 19. Resultant trip generation changes in Bydgoszcz in the 2050 BAU [W0] scenario (vs. the 2021 scenario).

The future transportation demand assumptions are tainted by **certain implausibility and inconsistency of socio-demographic projections which have to be explicitly underlined here.** Putting their methodological differences aside, the above-cited sources have been produced over past 10 years and may already vary between each other when it comes to projected population figures, economic/workplace data etc. For example, national population projections for the year 2050 [12] are based on the 2011 National Census Data (NSP 2011 [11]) and foresee even up to ca. 90k population drop in the worst-case scenario. However, the Spatial Development Masterplan [5] projects city population rate of ca. 360 – 380k in the year 2050 – somewhat higher than present-day values. Additionally, there is yet a dearth of population forecasts that would account for major shifts in socio-demographic picture of the Republic of Poland that have just been gaining momentum in the past few years, i.e. rising immigration from Eastern European and Asian countries, which at the end of 2021 has already been estimated in the range of 1 - 2m (i.e. 3 - 6% of national population) [18]. The on-going geopolitical events are likely to foster these immigration trends in an even more impactful way: recent estimates reveal that Bydgoszcz city population has grown by 35k (Ukrainian immigrants and refugees) in the wake of 2022 Russian invasion of Ukraine [19]. Ultimately, balancing all these considerations, population changes in the 2050 BAU scenario were assumed with an overall downward trend - yet much lower in its magnitude, i.e. 3.5% drop against the 2021 figures.

3.4. Summary of the CliMobCity stakeholder meetings in Bydgoszcz

To gather ideas and proposals for CliMobCity measure packages, a series of stakeholder meetings have been organised in the course of this project. The concerned stakeholder groups were identified among: public authorities (municipality departments, regional authorities), public transport operators, transportation-related NGOs, university researchers, private consultancies involved in current transport development in Bydgoszcz.

The meetings were held individually in the Q4 2022 and Q1 2023. Owing to covid-19 pandemic-related restrictions at the time, majority of these meetings had to be held on-line. **Each meeting was organised with a specific stakeholder group, in form of focus-group discussions**. The meetings commenced with the presentation of CliMobCity project scope and objectives and initial transport analyses. The projected implications of the BAU scenario in year 2050, and working ideas, presented to the stakeholders, were instrumental in inspiring an in-depth, *brainstorming* discussion on own reflections regarding the transport system in Bydgoszcz, future proposals, potential opportunities and risks for developing the sustainable, climate-neutral and efficient transport services in the city. On average, the meetings lasted approx. 90 – 120 [mins] and were attended by 5 – 10 participants.

Majority of invited stakeholders could have been successfully reached for consultation purposes. Finally, the meetings were organised with the following **stakeholder groups**:

- **Municipality of Bydgoszcz authorities:** Energy Management Office – the CliMobCity project supervisor (*ZZE – Zespół ds. Zarządzania Energią*); City Road and Public Transport Department (*ZDMiKP – Zarząd Dróg Miejskich i Komunikacji Publicznej*), Spatial Planning Department (*MPU – Miejska Pracownia Urbanistyczna*).
- **Regional authorities:** Integrated Investment Bureau of the Bydgoszcz FUA (*ZIT BOF – Zintegrowane Inwestycje Terytorialne Bydgoskiego Obszaru Funkcjonalnego*), ERDF instrument managing authority (*Urząd Marszałkowski Województwa Kujawsko-Pomorskiego – zarządca instrumentu RPO*).
- **University researchers:** Bydgoszcz University of Technology – Department of Road, Transport and Geotechnical Engineering (*KIDTiG – Katedra Inżynierii Drogowej, Transportu i Geotechniki*); Cracow University of Technology – Department of Transportation Systems (KST – *Katedra Systemów Transportowych*).
- **NGO sector:** Pedestrian Ombudsman (*Społeczny Rzecznik Pieszych*).
- **Transport practitioners:** transport consultancy team currently active in development of SUMP for the Bydgoszcz FUA (*LPW Sp. z o. o.*).

Selected remarks from discussions with stakeholders:

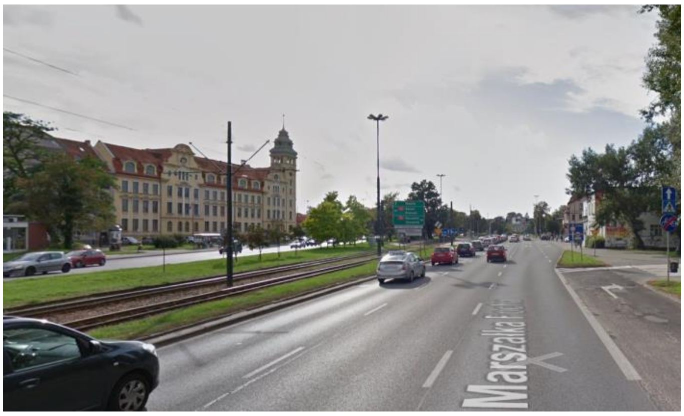
- Current **car traffic restrictions in the city centre** are observed to be appropriate, yet they can be more effective and should be further extended – both in terms of methods (measures), as well as the coverage area. Aside from the historical core (e.g. the main market square), popular public spaces and pedestrianised streets, they should not focus on *strict* closures to car traffic, as these will cause accessibility problems for local households and businesses. Instead, they can comprise a range of measures *discouraging* the car usage in central Bydgoszcz: higher parking fees; 30-kph zones with traffic calming solutions; access-only streets with no through traffic.
- Stakeholders also express open attitudes towards **Clean Traffic Zone** (i.e., Polish equivalent of Low Emission Zones) introduction in central Bydgoszcz. This may be coupled in the future with high-emission access fee or (general) congestion pricing system, though these require careful

considerations, as they may be a *socially exclusive* measure. Moreover, the CTZ can be implemented outside the city centre, in the low-housing neighbourhoods or in the proximity of green areas and woodlands surrounding the urban area of Bydgoszcz. Likewise, the 30-kph zones with traffic calming should be considered on a larger scale in suburban residential areas.

- **Road investment and expansion projects**, envisaged in the BAU scenario, are perceived as oversized in specific locations. Upgrading the W-E ring road in the northern Bydgoszcz is an important project, but can be *watered down* to a certain extent. The grade-separation schemes take up the valuable urban space and may not be eventually effective in the built-up area. Instead, a certain share funds can be saved and earmarked for other transport schemes. Once the W-E route is completed, it should be accompanied by traffic calming in the central area to prevent the road traffic rebound risks (i.e. the Lewis-Mogridge paradox), achieve a durable traffic relief and create attractive conditions for walking and cycling. Furthermore, certain stakeholders noted that road investment scale should be reduced to counteract the suburbanisation trends.
- **Bicycle infrastructure network** should be further expanded and subject to tailored investment programmes (with a certain earmarked budget each year). Stakeholders note that cycling is emerging as an increasingly popular means of transport in multiple Polish cities, and this should be supported by long-term and consequent transport policy. Problematic issues relate to insufficient standard of bicycle infrastructure, discontinuities in cycling network (colloquially named as *cycling teleports*) and yet prevalent role of car traffic at different locations across Bydgoszcz. Moreover, the public bicycle rental scheme is a desirable solution both for residents and commuters, as well as infrequent visitors that may induce positive travel habits and raise the modal share of cycling. Considering the hilly topography of certain parts of Bydgoszcz (mainly the southern suburbs), the scheme should include electric bicycles as well.
- The present-day **tram network in Bydgoszcz** covers most of the main travel routes and passenger demand corridors. No major tram extensions have been proposed during the meetings. Stakeholders do not deem them very necessary and observe that the focus should be on the existing resource utilisation and mobility management. Main bus and tram routes should operate a high-frequency and regular service, with trips at least every 10 [mins] during peak hours.
- With regards to **public transport service quality**, travel time reliability is a major performance factor that should be well-maintained to ensure proper service standards. Additionally designated bus lanes and separated tram tracks can play a useful role in that regard. ITS-based management is a promising direction and further control and priority measures might be explored. Moreover, particular attention should be paid towards transfer convenience at public transport interchanges, as stops can be located far away from each other at various intersections. Door-to-door transfers should be implemented where possible, e.g. at bus and tram terminal interchanges. Dynamic, advanced traveller information system (ATIS), available via electronic stop displays and journey planner apps are noted to be popular among passengers and contribute towards perceived attractiveness of public transport.
- The **city/metropolitan rail system in Bydgoszcz** (akin e.g. to S-Bahn in German cities) has been often proposed and will be eventually launched in the future. However, certain stakeholders note that such system was concluded in past appraisal studies to have a relatively limited potential in Bydgoszcz transport network. This is attributable to factors such as city population size, insufficient intensity of prospective passenger demand, as well as non-alignment with main O-D demand corridors. Though relatively extensive (in infrastructure terms), rail stations tend to be situated in a certain distance from main urban development areas. Besides, the main W-E route between Bydgoszcz central area and Fordon subcentre (in the east) is already served by multiple tram lines. As a side remark, the P+R facilities should be primarily located at train (or tram and train) interchanges.
- The **idea of compact-city development** has raised interest during stakeholder meetings with various responses. The scale of required population shifts would need to amount to as much as 25 - 35%,

which is deemed to be hardly implementable, at least in the foreseeable future. Nevertheless, efforts taken in such direction - in terms of spatial planning policy changes - can contribute positively to overall quality of urban life in Bydgoszcz and decrease (at least by a certain degree) the dominant suburbanisation trends. Promotion of transit-oriented development around main tram and train interchanges is a recommendable solution and can lead to high-quality urban development schemes. It was also emphasised by some stakeholders that eventual spatial planning policy shifts should consider wider socio-economic impacts. Negative feedback risks should be mitigated, as a fully reoriented reurbanisation policy can potentially induce e.g. spiralling *depopulation* and *degradation* effects in the suburban areas.

- An interesting area raised during the meetings comprises the **potential of combined transport and urban transformation schemes** at historical sites in central Bydgoszcz. Such an example is the historical Bydgoszcz Canal (*Kanał Bydgoski*) route, which was covered in the 1970s to construct a nowadays major W-E dual-carriageway route (*Focha* avenue) across the city centre. Once an alternative ring road is completed, the road capacity of *Focha* avenue can be reduced - effectively removing transit traffic through the very central part of the city. The W-E route could be thus reinstated as an attractive urban boulevard. This is a bold scheme which should be planned in long term, yet it might become a prominent urban regeneration example (similar e.g. to the restoration of *Catharijnesingel* Canal in Utrecht, Netherlands).



***Focha* avenue – past**	***Focha* avenue – present**

Figure 20. *Focha* avenue in Bydgoszcz – the historical route of Bydgoszcz canal (left), which in 1970s has been covered to by main W-E arterial route (right) traversing the city centre (*castlesofpoland.com; Google Street View*).

3.5. CliMobCity measure packages

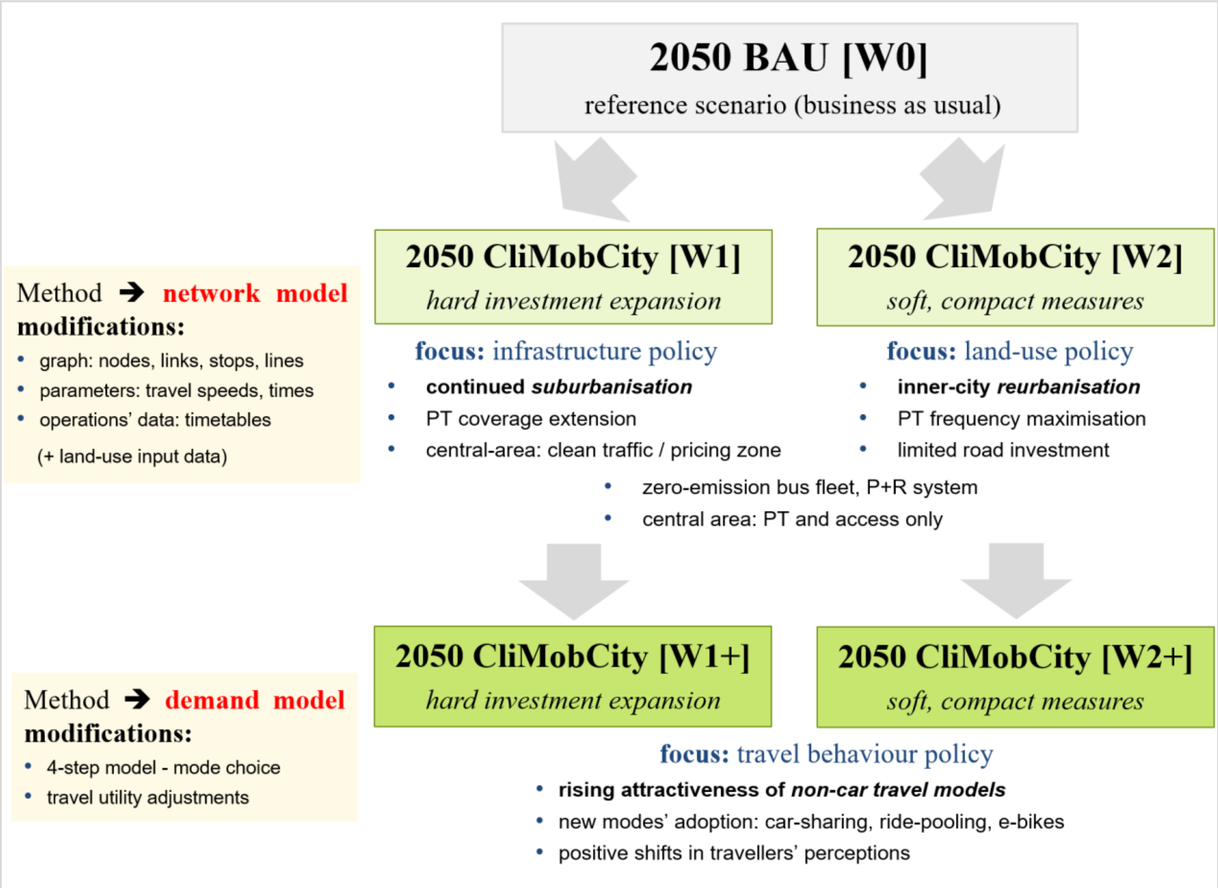


Figure 21. Overview of the CliMobCity measure packages and analytical workflow.

Based on feedback from stakeholders and CliMobCity partners, 2 policy scenarios have been formulated for subsequent transport analysis. Each of these scenarios combines both analogous measures (resultant from exogeneous assumptions, e.g. low-emission fleet introduction) as well as distinct development directions (with regards to e.g. spatial planning policy, public transport system). Primary objective of the **[W1] CliMobCity scenario** is ***hard and outward* infrastructure expansion** strategy, whereas the **[W2] CliMobCity scenario** emphasises the ***soft* mobility *and reurbanisation* policy**.

Table 1. Summary of CliMobCity interventions in transport analyses.

Bydgoszcz 2050 – CliMobCity intervention scenarios		
sectors:	**[W1]** - *'hard' infrastructural development*	**[W2]** - *'soft' city reurbanisation*
land-use development	• **population:** sustained suburbanisation towards outer areas; TOD around main PT hubs • **services:** new investment (and industrial) opportunity areas, e.g. Emilianowo (south-eastern Bydgoszcz)	• **population:** 35% shift from suburbs towards the city centre • **services:** 2 focus areas: Bydgoszcz (main centre) and Fordon (eastern sub-centre)
public transport	• **zero-emission bus fleet** (100% of buses) (both scenarios) • **travel speeds**: 10% higher for city buses and trams (new bus lanes, ITS priorities measures) • **new tram lines** to the north and south of the Bydgoszcz central areas • **Bydgoszcz Metropolitan Rail system** – the main W-E rail corridor with 2 lines and new rail stations in Bydgoszcz • **travel convenience:** perceived transfer disutility 2x lower with improved PT interchanges and ITS-fed travel information	• **travel speeds**: 20% higher for city buses and trams (further enhancements in new bus lanes and ITS steering priorities, greater separation from road traffic) • **increased PT frequency** (up to 2x) for main tram and bus lines – especially in Bydgoszcz central area • **travel convenience:** perceived waiting disutility 2x lower with greater PT frequency and ITS-fed travel information
road traffic	• **historical inner-city core:** car-free zone (authorised access only) • **central Bydgoszcz area:** local access and PT only (no through traffic) • **Clean Traffic Zone** in the Bydgoszcz city centre and the eastern Fordon sub-centre (both scenarios) • **road narrowing:** main E-W route in central area and inner-city radial routes (approaches) • **Tempo 30 zones** implemented in central Bydgoszcz and (selected) local suburbs	• **road closure:** main W-E route (*Jagiellońska*) in central area – local traffic and PT only • **Tempo 30 zone** implemented in central Bydgoszcz • **suburban ring road cancelled** in eastern Bydgoszcz area
Park and Ride system	• **P+R** facilities located at the main rail and city PT interchanges	• **P+R** facilities located at the main city PT interchanges

Specific measures and target policies in CliMobCity scenarios are as follows:

- **Vehicle emissions:**
  - **Both [W1] and [W2] scenarios** envisage analogous changes in vehicle composition and their emission standards. National guidelines [15] state that **100% of public transport fleet** should be electric- or hydrogen-powered by the year 2030. Hence, all bus operations in Bydgoszcz in the 2050 horizon will become **zero-emission**.
  - **Both scenarios** assume an **introduction of Clean Traffic Zone** (Polish: *Strefa Czystego Transportu*), which will cover the most sensitive urban areas of **historical Bydgoszcz centre and eastern Fordon subcentre** (i.e. historically a separate township). This follows from

strategic recommendations [15] at the national level, whereby urban CTZ zones should be launched in first major Polish cities (of 100k+ inhabitants) by the end of this decade.

- **Spatial planning:**
  - The **[W1] scenario** assumes the **continuation of current suburbanisation processes**, similar as in the [W0] BAU scenario. A major share of new residential, industrial and service developments will be thus located across the city and in the surrounding outer area. Since the overall population of Bydgoszcz will stay intact as in the BAU scenario, these shifts will occur *at the expense of* population and workplaces in other parts of the city, including central Bydgoszcz area.
  - The **[W2] scenario** is based upon **a major reorientation of land-use strategy** in Bydgoszcz, discouraging the suburban investment and **promoting the compact-city development**. It assumes that, in the 30-year horizon (from now), ca. 30% of Bydgoszcz population (and a similar share of workplaces) will be relocated elsewhere than in the BAU scenario. The primary objective will be to increase the population density in the inner-city area. This will occur at the expense of selected suburban areas, particularly those with excessive population growth in relation to their transport accessibility (e.g. the overscaled Mariampol residential developments in the far east of Bydgoszcz).
- **Public transport:**
  - **Both scenarios** account for ITS-driven speed improvements of bus and tram services. On a city-wide scale, service run times are shorter by approx. 15% in reference to the [W0] scenario.
  - The **[W1] scenario** includes construction of new tram lines towards northern and southern suburbs of Bydgoszcz. These corridors will be served by ca. 10-[mins] service during peak hours. A major development pertains to the introduction of Bydgoszcz Metropolitan Rail system, comprising 2 rail lines in the W-E axis and new rail stops. Each of the city rail line operates with peak frequency of 20 [mins]. Finally, improved public transport interchanges raise the perceived attractiveness of transfer connections among potential PT transport users.
  - The **[W2] scenario** focuses instead on higher utilisation of the existing connections. The frequency of main bus and tram lines is increased within the densified urban area, up to every 5 [mins] in peak times. In conjunction with the ATIS system availability across the whole system, this helps to reduce the perceived waiting disutility.
- **Road and street network:**
  - **In both scenarios**, current inner-city car restrictions are maintained. These are coupled with extra engineering and policy measures in the Bydgoszcz central area and the Fordon subcentre, so that they become eventually accessible for local car traffic only (i.e. no transit traffic) and subject to the Clean Traffic Zone regulations.
  - The **[W1] scenario** witnesses a city-wide implementation of 30-kph zones with traffic calming measures across local streets. Furthermore, main arterial routes in central Bydgoszcz area are subject to road narrowing schemes, with single lane only provided for general car traffic. (The *removed* traffic lanes are redistributed then as new bus lanes, cycle tracks, wider pavements or parking bays.)
  - The **[W2] scenario** assumes more limited car restriction measures in comparison with the [W1] scenario. In the city centre, the main W-E thoroughfare (i.e. *Focha – Jagiellońska* avenue) is downgraded to a single-carriageway street for general traffic. As a consequence of major spatial policy changes, the eastern suburban ring road is eventually cancelled.
- **P+R system:**
  - **Both scenarios** assume the development of P+R system (200 - 300 parking spaces each) across Bydgoszcz. The P+R lots were envisaged at main train and tram interchanges, with more extensive set of P+R facilities in the [W1] scenario.

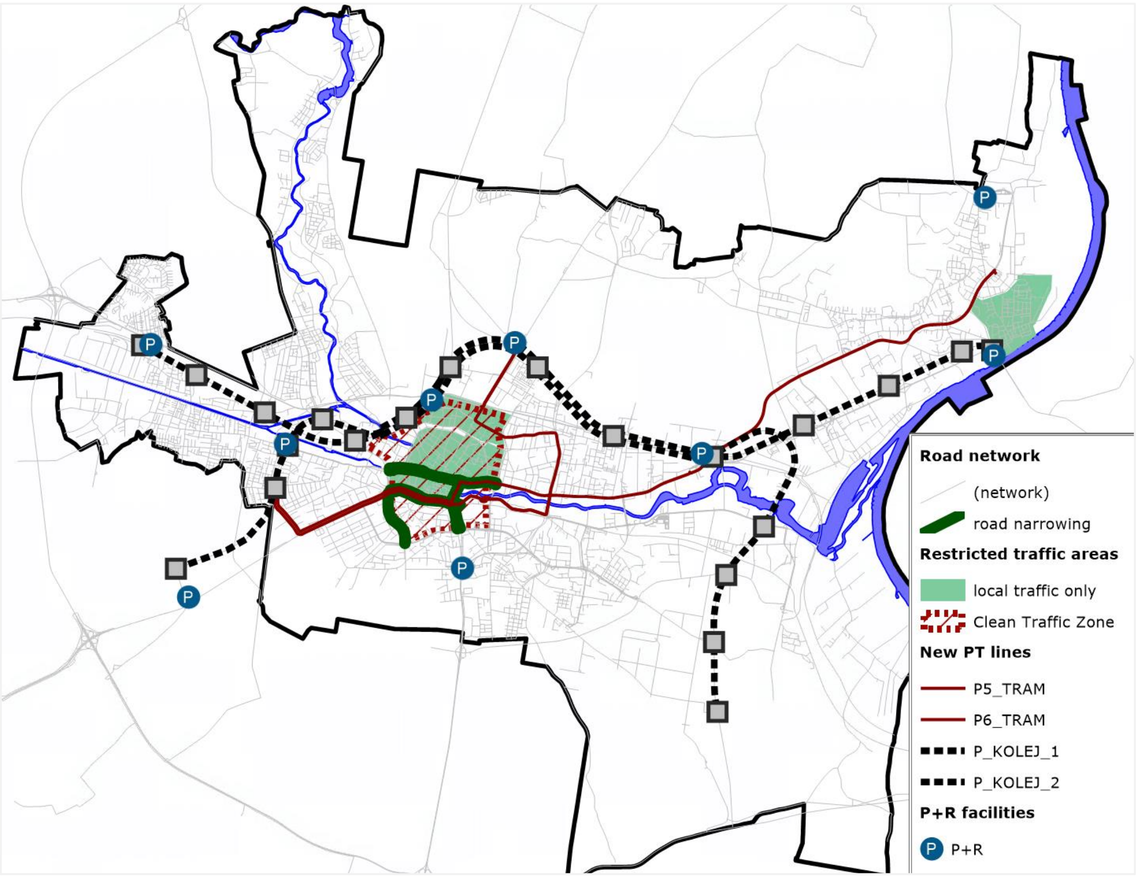


Figure 22. Network measures in the [W1] CliMobCity scenario.

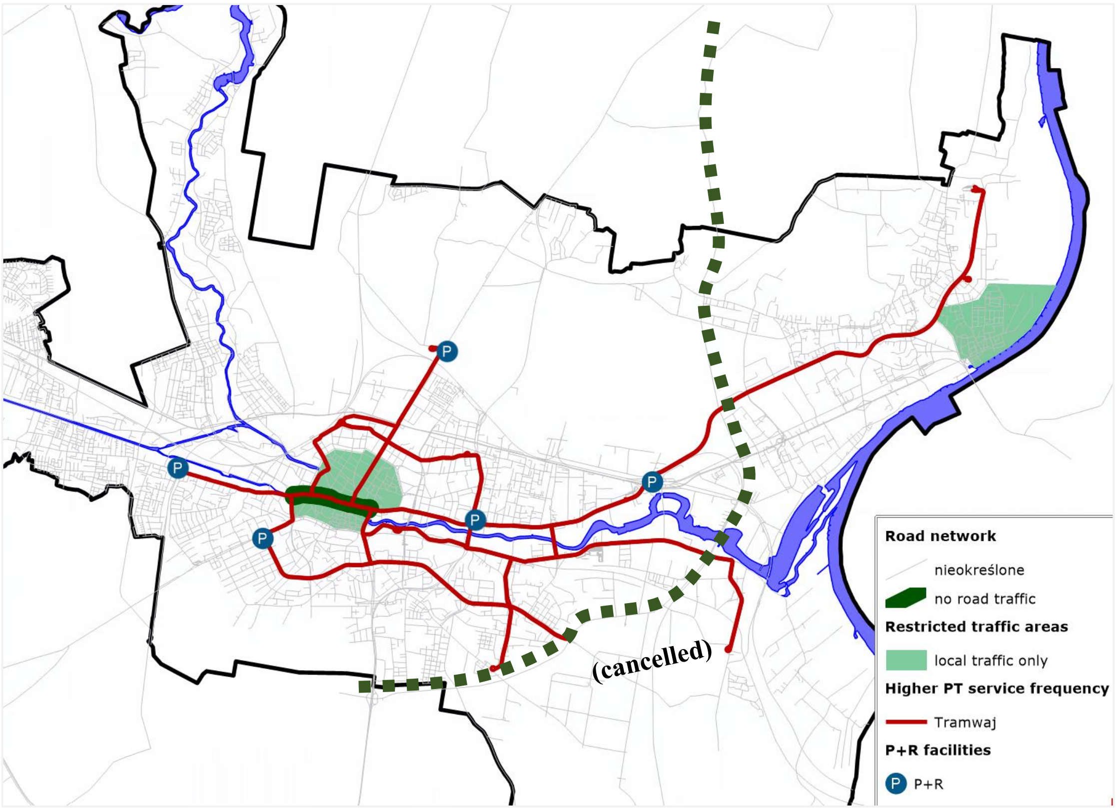


Figure 23. Network measures in the [W2] CliMobCity scenario.

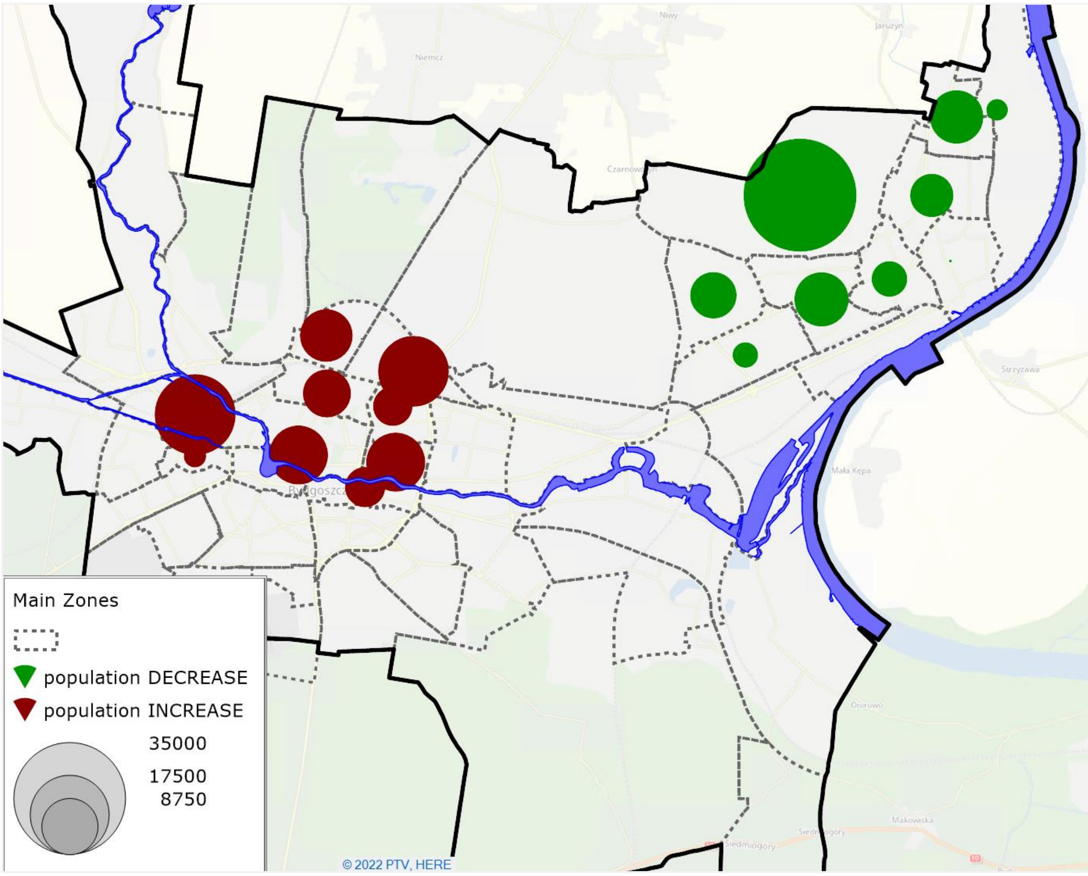


Figure 24. Population changes in the [W2] CliMobCity scenario (vs. the [W0] BAU scenario).

The [W1] and [W2] CliMobCity scenarios comprise mostly transport network modifications and supply-side measures. To demonstrate the eventual impact of demand-side changes, additional **[W1 plus] and [W2 plus] CliMobCity scenarios** have been analysed. Their aim is to reflect the sole potential of favourable mobility behaviour shifts among Bydgoszcz travellers, which cannot be induced directly, yet may occur as a result of long-term, consequential sustainable transport development strategy.

The [W1 plus] and [W2 plus] are based upon the respective [W1] and [W2] scenarios. **The [W1 plus] and [W2 plus] assumptions are modelled by changing the perceived utility co-efficients at the mode choice stage** (of the 4-step demand model):

- **10% higher utility** of: walk, cycle, public transport, or car (as a passenger) modes,
- **10% lower utility** of: car (as a driver) mode,

The above values denote the relative change in perceived (dis)utility co-efficient of a specific travel mode, vs. the baseline co-efficient rate in the [W0], [W1] and [W2] scenarios. (The baseline utility co-efficients have been estimated from household/passenger travel surveys in Bydgoszcz [2], [3].)

This approach can be deemed as a *proxy* representation of passengers' more (or less) favourable attitudes towards – and thus greater perceived utility of - specific travel modes, which may emerge in the future.

4. Results

The following subsection summarises observations from the CliMobcity analytical works for Bydgoszcz. Detailed outputs are discussed in subsequent paragraphs.

4.1. Transport modelling – 2020 results

The first stage of modelling works involved simulation analysis for the 2020 scenario, i.e. the base year for which the Bydgoszcz multimodal transport model was developed. Outputs of this scenario will form a reference point for evaluating the projected changes in transport system performance by the year 2050.

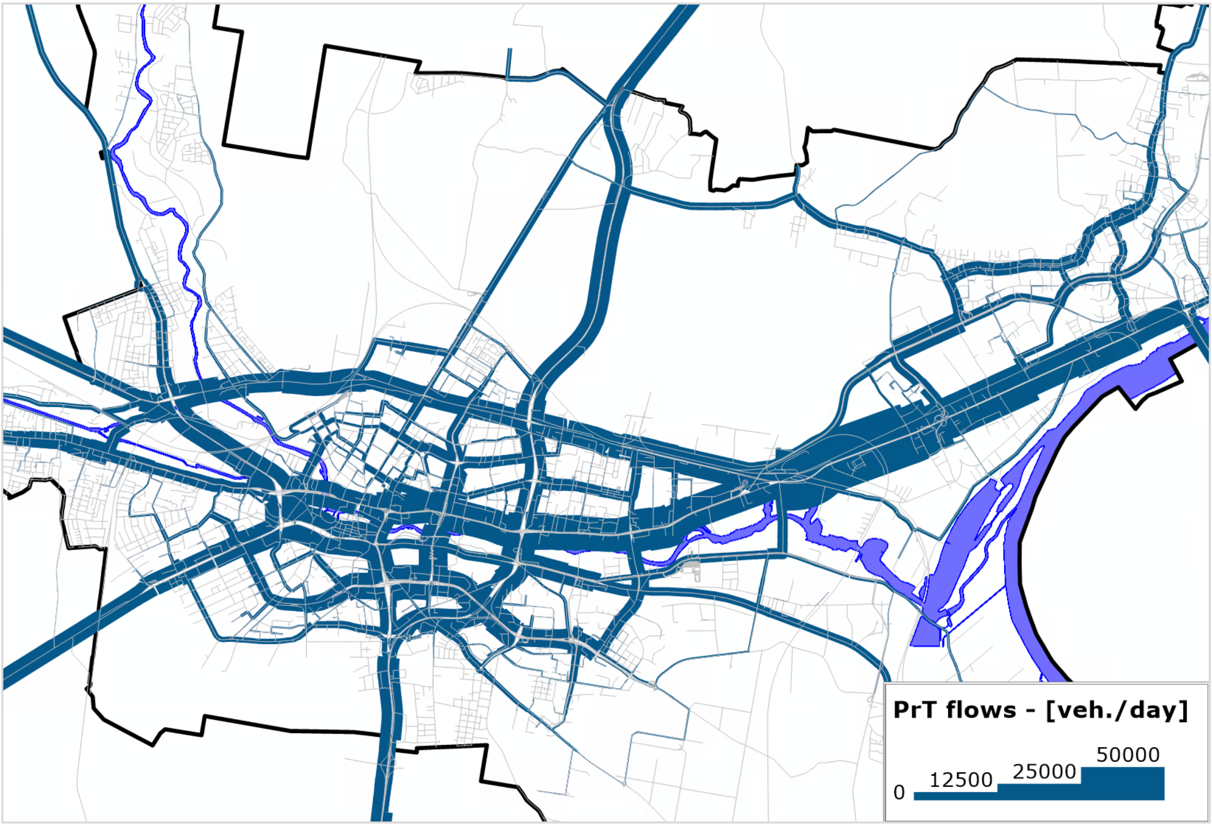


Figure 25. Simulation results – traffic flows in Bydgoszcz transport network in the **2021 [W0] base scenario**.

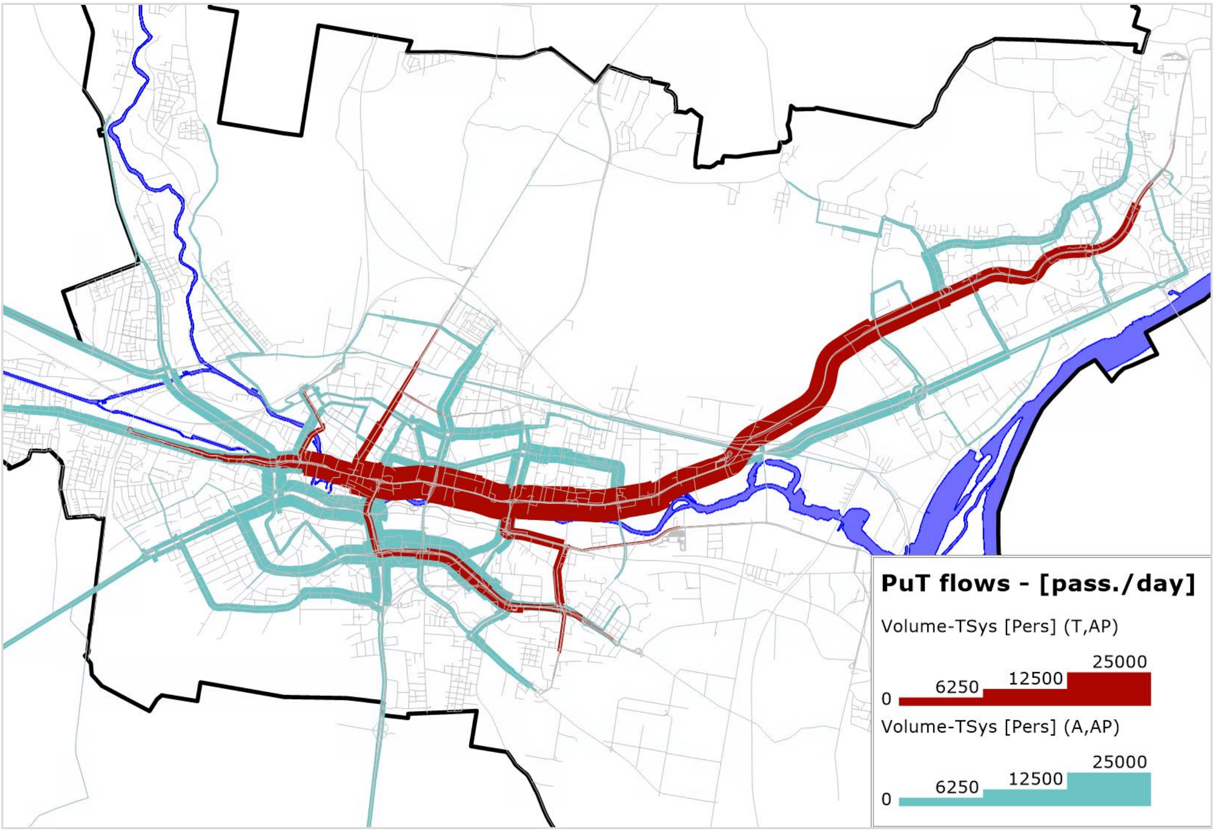


Figure 26. Simulation results – passenger flows in Bydgoszcz transport network in the **2021 [W0] base scenario**.

Overview of the 2021 model assignment results:

- In terms of **modal share,** private car is confirmed as the most popular travelling option (over 50% of all trips, and 42% in central Bydgoszcz area). Walking is ranked second, with ca. 26% share across the city (34% in the city centre). Public transport is used for 22% of all trips. Meanwhile, cycling accounts for only ca. 1.3% of trips in Bydgoszcz. **Average car occupancy** stands at 1.23 [pass./veh.], which is an analogous figure to other Polish cities.
- **Average journey parameters** for Bydgoszcz transport network reveal similar travel times of 12.2 [mins] for private car and of 13.4 [mins] for public transport. Mean trip distance is twice higher for car trips (10.0 [km]) than for public transport trips (4.8 [km]). Consequently, mean travel speeds oscillate around 49.3 [km/h] and 21.4 [km/h], respectively.
- With regards to **public transport patronage** in Bydgoszcz, the bus system accounts for the majority (almost 67%) of city trips. The remainder (33%) is served by the Bydgoszcz tram system. Meanwhile, bus operations comprise over 75% of total **public transport operations** (i.e., [service-km]).
- Network assignment shows **the highest car traffic volumes** along the following routes:
    - **the main W-E connections** between proper Bydgoszcz area and the eastern Fordon subcentre, i.e. both in the suburban area (the DK80 route, *Fordońska*) and in the very city centre (*Focha* – ***Jagiellońska***), with volumes between **50 – 85k [veh/day],**
    - **the main N-S thoroughfare (***Jana Pawła II, Wyszyńskiego* – the former DK5 route), with forecast volumes of up to **30 – 50k [veh/day],**
    - dual carriageway routes in central Bydgoszcz area in the W-E direction (*Focha*, *Poznańska/Grudziądzka*), as well as the N-S direction (*Kruszwicka*, *Kujawska*, *Trasa Uniwersytecka*), ranging around 15 – 50k [veh/day] (in the cross-section),
    - dual carriageway arterials between central Bydgoszcz and the suburbs (*Szubińska, Grunwaldzka, Wojska Polskiego, Sułkowskiego*): ca. 10 - 35k [veh/day].

- In public transport network, **the highest passenger volumes** are observable in case of:
    - **the main W-E tram corridor** (*Wilczak - Bydgoszcz central area – Fordońska – Os. Akademickie – Fordon*), with loads of **15 – 30k [pass./day]** (in the cross-section),
    - main bus routes in central Bydgoszcz area (*Poznańska/Grudziądzka, Kujawska, Wojska Polskiego, Solskiego*), whereby passenger volumes range between 10 – 30k [pass./day],
    - bus access routes across the suburban areas of Bydgoszcz: i.e., the west (*Grunwaldzka, Szubińska*), the north (*Sułkowskiego, Skłodowskiej-Curie*), the south (*Wojska Polskiego*), and the east (*Fordońska, Twardzickiego*): 5 – 15k [pass./day].

To summarise, the 2021 base year scenario results reveal that the (wider) central Bydgoszcz area is subject to substantial road traffic volumes, especially along major route crossings both in the W-E and N-S direction. These road sections are the most prone to recurrent traffic congestion in peak times. Moreover, these routes have fairly extensive cross-sections (with 2 – 3 traffic lines in each direction) and yet limited alternative routes in outer, suburban areas. The inner-city area of Bydgoszcz is accessible for general traffic, except for individual streets in the historical city core. Favourably though, most of the central area is covered by the paid parking zone, which improves the parking space utilisation. Also, public transport routes in central Bydgoszcz exhibit relatively high passenger numbers, *on par* with private car trip volumes.

4.2. Transport modelling – 2050 forecasts

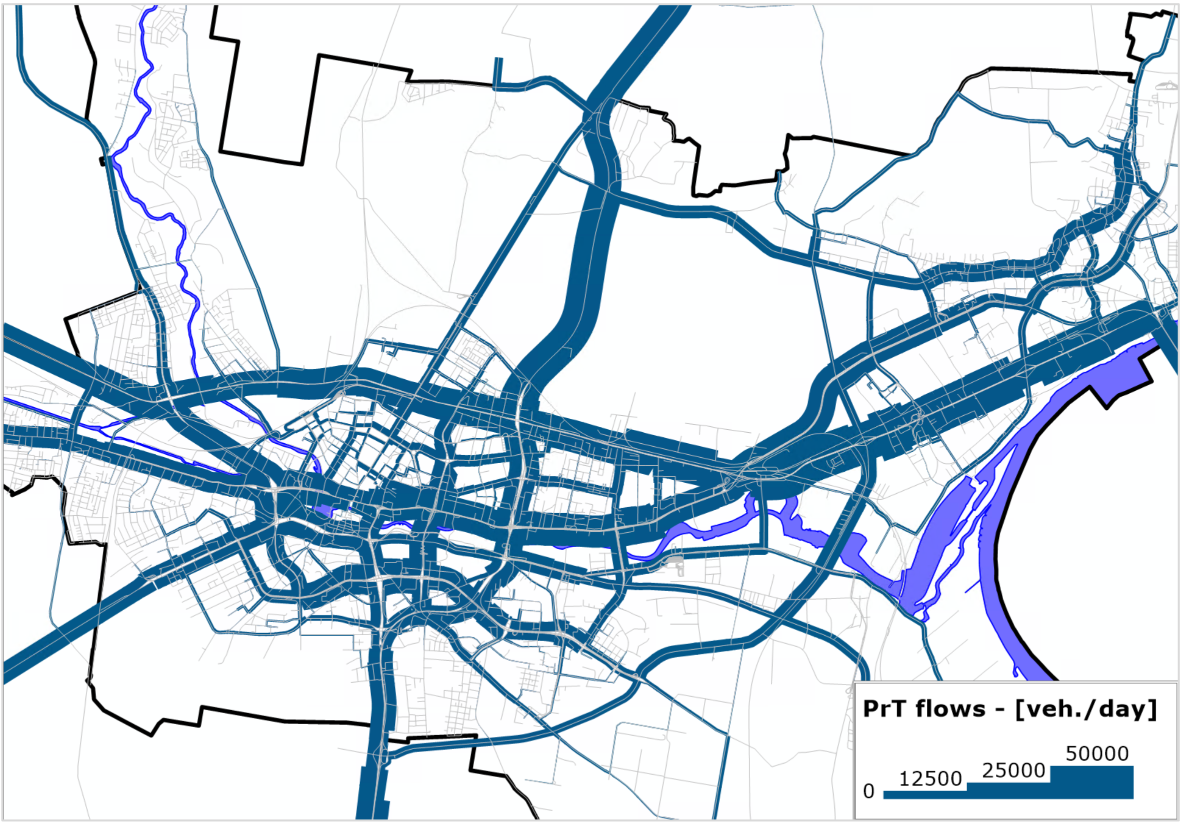


Figure 27. Simulation results – traffic flows in Bydgoszcz transport network in the **2050 [W0] BAU scenario**.

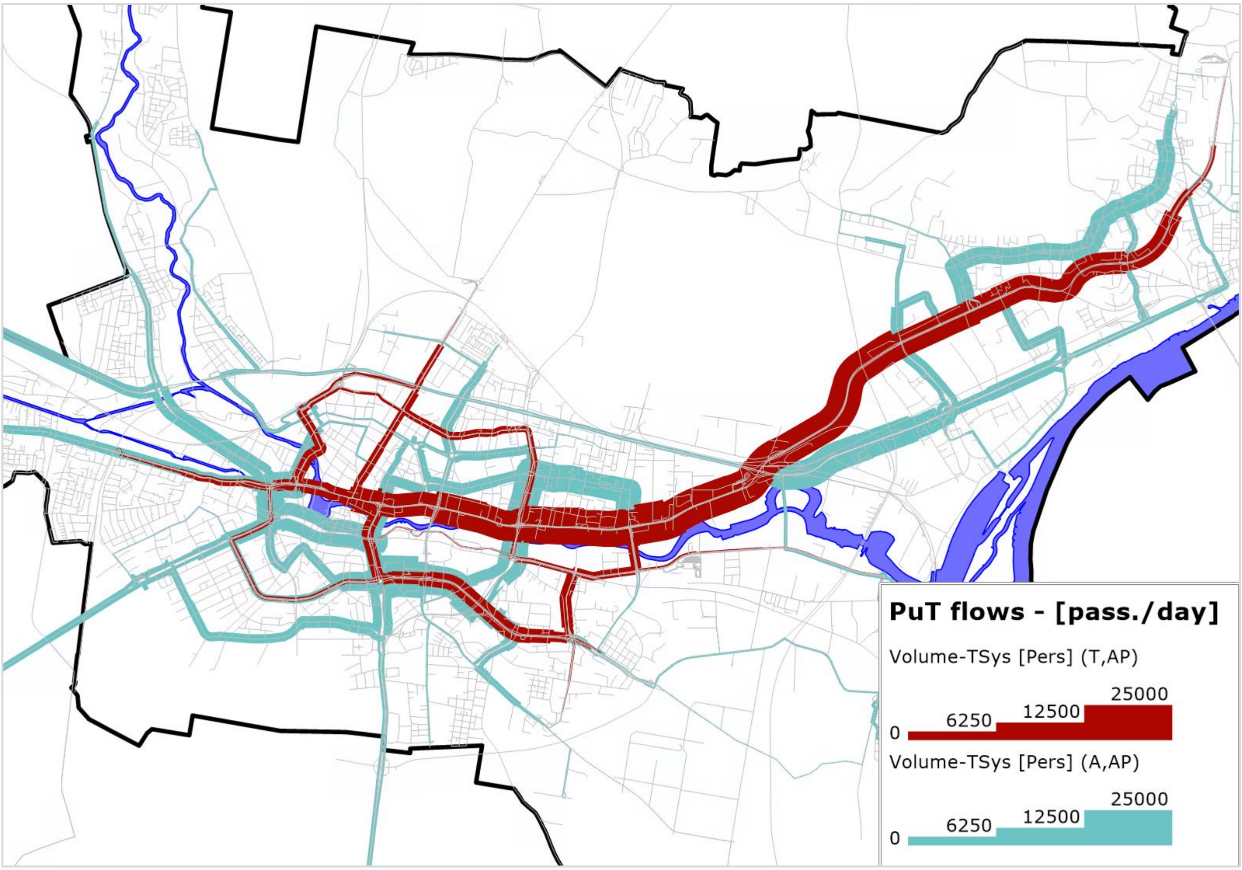


Figure 28. Simulation results – passenger flows in Bydgoszcz transport network in the **2050 [W0] BAU scenario**.

Network flows in the BAU scenario, compared against the base year results, exhibit further road traffic growth, especially along main routes in Bydgoszcz. This is mostly attributable to larger car trip volumes from suburban and outer areas. Depending on road sections, traffic volumes projected along the main N-S (*Jana Pawła II – Wyszyńskiego*) and W-E (*Pileckiego – Kamienna*) axes rise by ca. 20 - 40%, while other main road sections in central Bydgoszcz witness increases of 10 - 20%. Traffic volumes are also evidently higher in the eastern (Fordon) area, where they increase by ca. 20%. Yet, car traffic flows in central Bydgoszcz street network do not change much, with substantial loads still visible along dual carriageway routes in the inner-city area, e.g. *Focha* and *Jagiellońska* avenues. Meanwhile, public transport network features limited growths in passenger volumes, which are evident mostly along the main W-E tram and bus lines (10 - 30%) and selected arterial routes (*Gdańska, Wojska Polskiego* – ca. 10%). Public transport patronage rate rises by a certain extent in the eastern (Fordon) area, as a consequence of population growth under the BAU assumptions. On the other hand, little changes occur in public transport usage in central Bydgoszcz area.

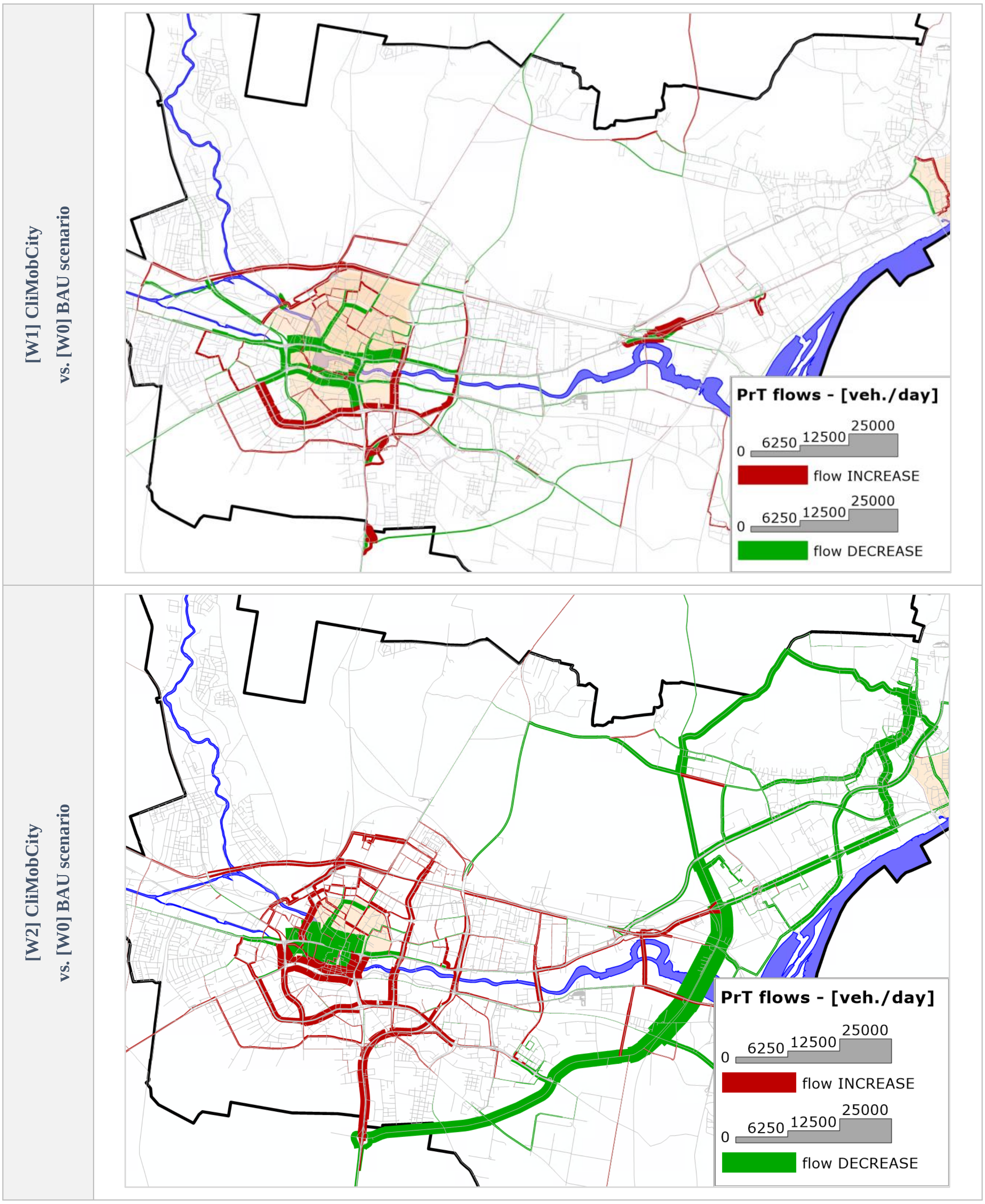


Figure 29. Simulation results – projected **changes in traffic flows** in the CliMobCity scenarios, plotted against the BAU scenario outputs.

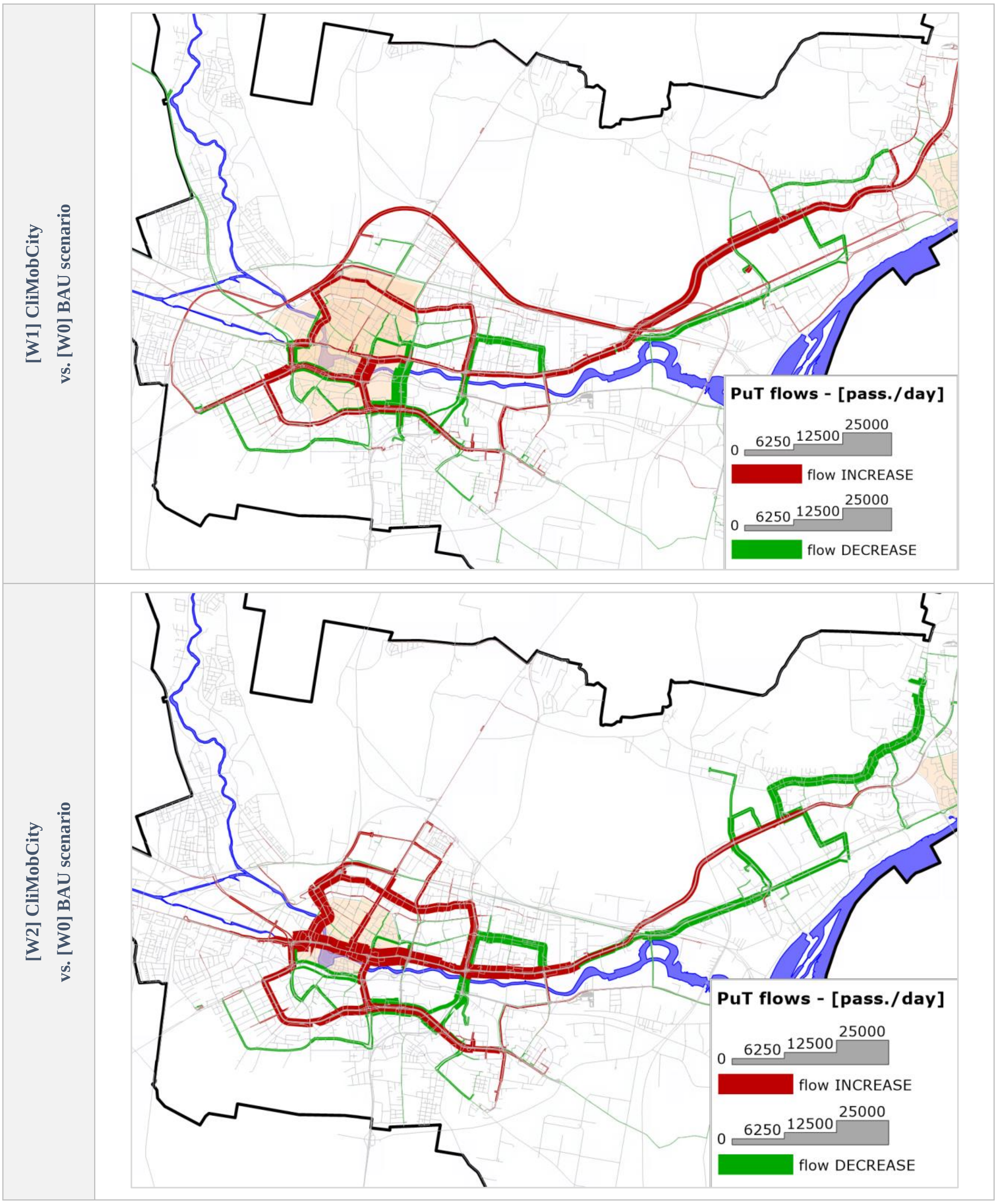


Figure 30. Simulation results – projected **changes in passenger flows** in the CliMobCity scenarios, plotted against the BAU scenario outputs.

Network flows – changes in the [W1] CliMobCity scenario: simulation findings underline significant traffic reductions in central Bydgoszcz as a result of assumed traffic calming reductions. Car volumes along the main arteries (*Focha, Jagiellońska, Grunwaldzka, Poznańska*) drop by even 50% in comparison with the BAU [W0] scenario, or by 5,000 – 10,000 [veh./day] in absolute terms. These are compensated by ca. 20 - 40% traffic volume growths along the alternative city ring roads. Otherwise, minor shifts in car flows occur outside the central Bydgoszcz area, and overall car traffic volumes do not decrease in the outer Bydgoszcz area.

Public transport network flows may differ by 10% - 20% along main routes in central Bydgoszcz (vs. the [W0] BAU scenario), though rising tram network patronage is oftentimes offset by reductions in bus network usage (e.g. *Kujawska, Łęczycka, Skłodowskiej-Curie*). Also, the newly constructed metropolitan rail line carries approx. 5,000 [pass./day]. It is a noticeable passenger flow, yet less significant against bus / tram volumes, which reach up to 20,000 - 32,000 [pass./day]. The existing tram corridor remains the most popular travel route between Fordon and central Bydgoszcz, especially with ITS-enabled improvements in journey times.

Network flows – changes in the [W2] CliMobCity scenario: in comparison with the [W0] BAU results, the [W2] scenario witnesses distributed increases of in car traffic volumes across the wider central Bydgoszcz area – extra 1,000 – 7,000 [veh/day] along individual road sections. This is a consequence of inner-city reurbanisation assumptions. However, it is also observable that closure of the main W-E throughroad (*Focha – Jagiellońska*) leads to substantial drop in traffic flows through the very city centre – less by 38,000 [veh/day]. These trips are redistributed onto several alternative routes with corresponding traffic volume growth of approx. 5,000 – 15,000 [veh/day] and taking place in further distance from the inner-city core. Outside the city centre, significant drops in car trips are registered in eastern parts of Bydgoszcz (lower by 20 - 60%). Notably, cancellation of the south-east suburban road (with 5,000 – 15,000 fewer [veh/day]) is not clearly offset by corresponding car traffic growths on adjacent routes. The local road network is actually subject to extra traffic relief in comparison with the [W0] BAU scenario.

The [W2] CliMobCity findings also point to greater public transport flows within the wider central Bydgoszcz area, as a result of population growth (facilitated by reurbanisation shifts). In particular, passenger numbers along the main W-E tram route rise by 20 - 50% (up to extra 10,000 – 18,000 [pass./day]), and other tram routes exhibit increases of 10% - 30% in relation the [W0] BAU results. In case of the [W2] scenario, the increasing tram ridership is a favourable outcome of higher travel intensity in central area, coupled with greater service frequency and ITS-enabled journey times' improvements. On the other hand, public transport patronage declines in the eastern Bydgoszcz areas due to assumed population outflow. Interestingly though, these occur mostly along the local and feeder bus routes in Fordon area, but not along the main W-E tram route itself (except for its very far-east section).

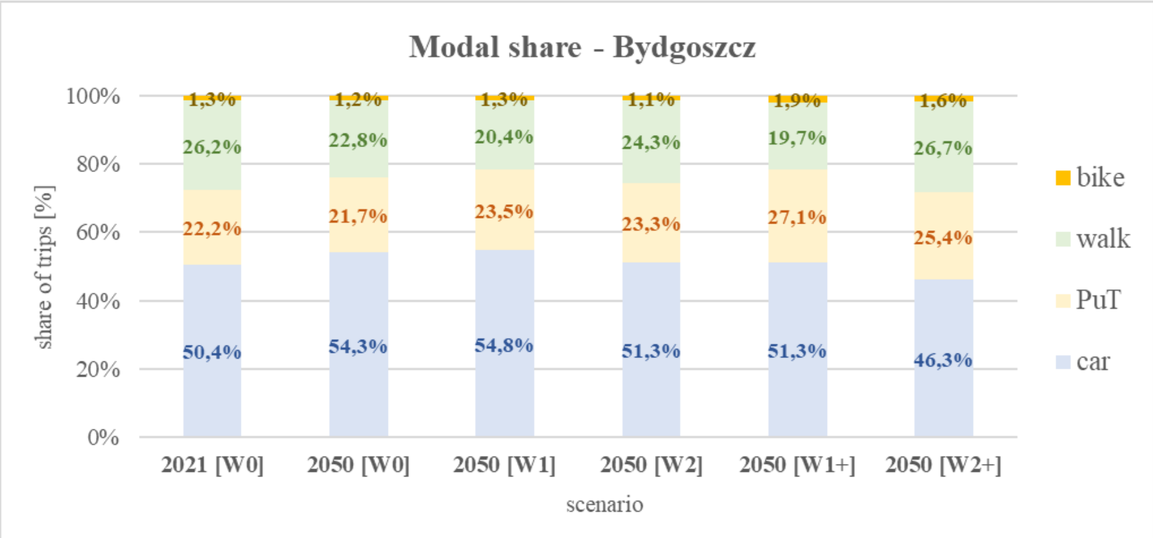


Figure 31. Simulation results – modal split in the Bydgoszcz model.

Modal share in the Bydgoszcz model area: findings point towards an increasing dominance of private car in the BAU scenario: its share rises from ca. 50% (2021 base scenario) to 54% (2050 BAU scenario). This occurs mostly at the expense of walking trips, whose share decreases from about 26% to 23%. The CliMobCity measures assumed in the [W1] scenario do not influence much the modal share, while the [W2] scenario leads to lower patronage of private car (51%) and higher popularity of walking (24%) and public transport (over 23%). Interestingly, travel behaviour assumptions in the 'plus' scenarios – i.e., more positive perceptions of car-alternative modes – induce evident changes in modal split in Bydgoszcz. In the [W1+] scenario, the public transport popularity rises to 27%, mostly at the expense of private transport. Furthermore, the [W2+] scenario witnesses the private car share plunging to 46%, while share of walking trips rises up to almost 27%.

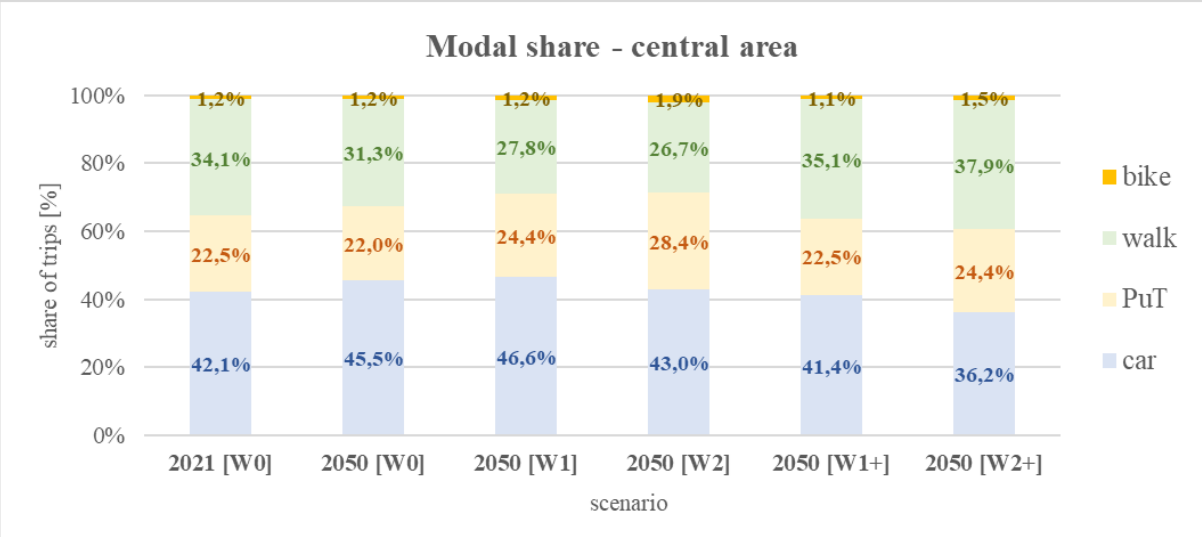


Figure 32. Simulation results – modal split in the Bydgoszcz central area.

Modal share in central Bydgoszcz: the BAU scenario results indicate the prevalence of private car trips (ca. 46%), with walking ranked on second place at 31%. The [W1] measures result in greater role of private car and public transport also in the city centre. Meanwhile, the [W2] compact city development inhibits the car traffic growth, whose share is capped at 43%, and public transport share rises up to 28%. Travel behaviour shifts in the [W1+] and [W2+] scenarios are even more favourable, as they foster the walking trips' popularity up to 35 – 38% in central Bydgoszcz. Simultaneously, private car trips are less attractive and their share reduces down to even 36% in the [W2+] scenario.

Table 2. Simulation results – daily trip volumes in the Bydgoszcz model.

Daily travel volumes [trips]		car		alternative modes			total
scenario:		driver	passenger	PuT	walk	bike	
2021 – base year	**[W0]**	380996	86861	205751	242997	11766	928371
2050 – BAU	**[W0]**	418605	86322	201379	212030	11318	929654
2050 – interventions	**[W1]**	423855	88167	219762	190699	11793	934276
	[W2]	407102	78758	220048	229821	10484	946214
2050 – interventions and behavioural shifts	**[W1+]**	365682	114098	253402	183940	17886	935009
	[W2+]	340407	96987	240147	252111	14862	944514

Daily travel volumes in Bydgoszcz: the 2050 BAU scenario witnesses approx. 40k extra car trips, compared against the 2021 base year outputs. Unfavourably, these occur at the expense of walking trips, which are less popular due to rising trip distances and suburbanisation developments. The [W1] and [W2] CliMobCity interventions are somewhat successful at promoting the public transport usage, with ca. 20k extra trips daily vs. BAU scenario. Furthermore, the [W2] compact-city scenario foresees a substantial rise of 50k walking trips across Bydgoszcz, coupled with ca. 25k fewer car trips. As expected, these trends are facilitated further in the [W1+] and [W2+] scenarios. In the latter case, there are 80k more walking and public transport trips than in the BAU scenario, which is offset by 80k fewer car trips (made as a driver). Interestingly, there is also a substantial increase (of approx. 10 – 25k) of car-sharing and car-pooling trips in Bydgoszcz (vs. the BAU results). Finally, the [W1+] and [W2+] scenarios witness extra 3 – 7k cycling trips every day in Bydgoszcz – a relative increase of 30 – 60%.

Table 3. Simulation results – mean journey parameters in the Bydgoszcz model.

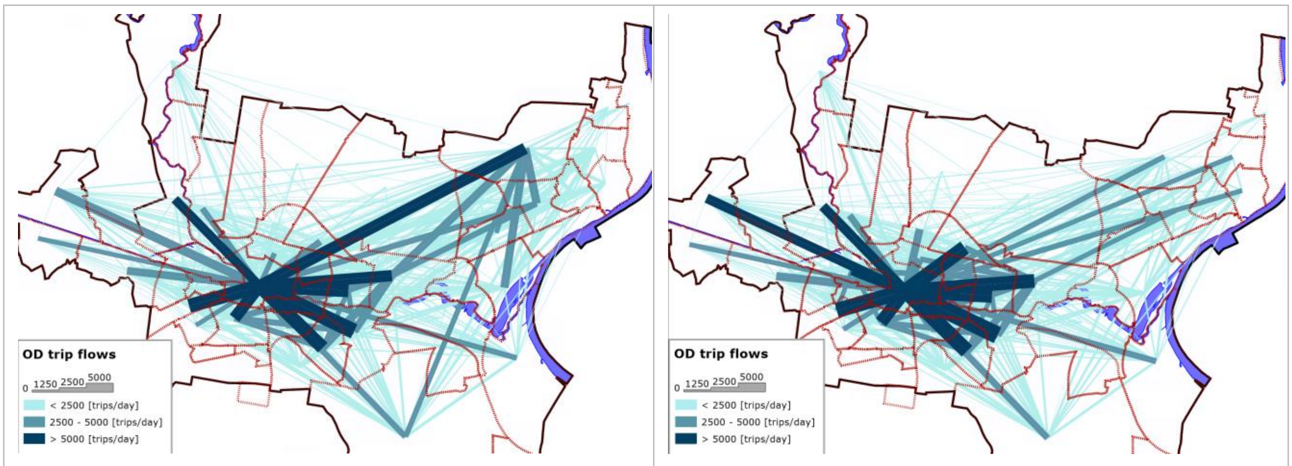
Average journey parameters		speed [km/h]		distance [km]		time [mins]	
scenario:		PrT	PuT	PrT	PuT	PrT	PuT
2021 – base year	**[W0]**	49.3	21.4	10.0	4.8	12.2	13.4
2050 – BAU	**[W0]**	50.9	24.2	12.6	6.0	14.8	14.8
2050 – interventions	**[W1]**	50.5	27.2	12.5	6.1	14.9	13.4
	[W2]	51.3	29.6	12.3	5.7	14.4	11.5
2050 – interventions and behavioural shifts	**[W1+]**	51.7	26.6	13.3	6.1	15.4	13.8
	[W2+]	52.4	29.6	13.3	5.8	15.3	11.7

Mean journey parameters: findings of the BAU scenario reveal an unfavourable paradox: although journey speeds increase both in private and public transport (by 2 – 3 [km/h]) vs. the 2021 base scenario, these do not improve journey times, which are actually on average 2 – 3 [mins] longer. This is intertwined with ca. 20% longer trip distances in Bydgoszcz transport network. The CliMobCity interventions projected in the [W1] scenario do not influence much these outcomes, owing to the sustained suburbanisation trends. Certain gains are observable in public transport sector, with mean travel time reductions of 1.5 [mins]. The [W2] scenario shows further reductions in travel times, especially in public transport (ca. 3 [mins] shorter vs. BAU scenario), thanks to wider improvements in the city bus and tram network – ITS priorities, designated bus/tram lanes etc. Analogous results are reported for the [W1+] and [W2+] scenarios.

Table 4. Simulation results – global (network) performance parameters of the Bydgoszcz model.

Network parameters		PrT – network loads		average occupancy	PuT – network loads			average no. of transfers
scenario:		[veh-km]	[veh-hrs]	[pass./veh]	[pass-km]	[pass-hrs]	[veh-km]	[trips/pass.]
2021 – base year	**[W0]**	4550414	92368	1.23	987808	46088	53583	1.04
2050 – BAU	**[W0]**	6065158	119078	1.21	1205238	49795	60471	1.08
2050 – interventions	**[W1]**	6109278	121043	1.21	1339222	49182	68368	1.17
	[W2]	5796994	112983	1.19	1249545	42273	81770	1.12
2050 – interventions and behav. shifts	**[W1+]**	5701596	110270	1.31	1545421	58082	68368	1.15
	[W2+]	5392773	102849	1.28	1386183	46780	81770	1.14

Network loads are projected to increase substantially in the 2050 BAU scenario, with ca. 35% growth in total [veh-km], [pass-km], and [veh-hrs] in the whole Bydgoszcz network. This reflects that the future transport supply will have to cope with greater trip volumes stretched over larger distances. Results barely change in the [W1] scenario, and even increase slightly. Favourably, the [W2] scenario results exhibit an opposite trend with certain relief in network loads. Ultimately, in the [W2+] scenario, road traffic loads drop by 10 – 15% vs. the BAU scenario, and the emphasis shifts towards public transport trips. In both the [W1+] and [W2+] scenarios, changes in travel behaviour and preferences imply that **average car occupancy** jumps to ca. 1.3 [pass./veh.].



2050 [W0] BAU	2050 [W2] CliMobCity

Figure 33. Simulation results – OD (origin-destination) daily trip distribution in Bydgoszcz.

OD (spatial) trip distribution: findings for the BAU scenario expose the consequences of suburban development growth, as the OD flow structure is more polycentric than in the 2021 base year. In particular, major new developments in the north-eastern (Fordon, Mariampol), south-eastern (Emilianowo) and western (Osowa Góra) parts of Bydgoszcz induce high trip volumes, spanning over longer distances – both to/from the city centre, as well as between these major areas. This disadvantageous pattern is sustained in the [W1] scenario, but it changes substantially in the [W2] scenario. The [W2] scenario findings resemble much more a concentrated, *compact city* OD flow pattern. The intensity of long-distance trips in the eastern Bydgoszcz area, which is otherwise evident in the BAU and [W1] scenarios, is significantly watered down. These respective patterns are sustained in the [W1+] and [W2+] scenarios as well.

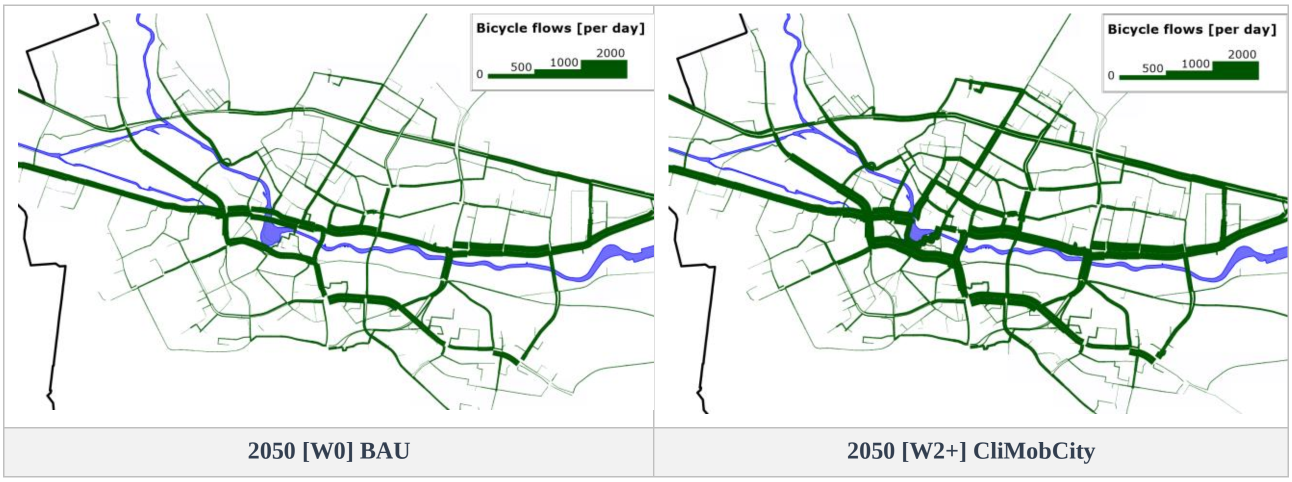


Figure 34. Simulation results – bicycle flows' distribution in Bydgoszcz transport model.

Bicycle traffic plays a relatively minor role in simulated trip patterns. In most of the scenarios, bicycle traffic flows are main visible in the city centre and along main radial connections towards suburban areas (Fordon, Wilczak, Bielawy, Wyżyny). Improvements are the most evident in the [W2+] scenario, with bicycle traffic flows emerging across multiple local streets in the proper Bydgoszcz area, and further volume increases along the existing bicycle routes – reaching up to 50 - 80% vs. the [W0] BAU scenario. Rising popularity of bicycle ridership stems from the compact city reurbanisation and favourable travel behaviour changes.

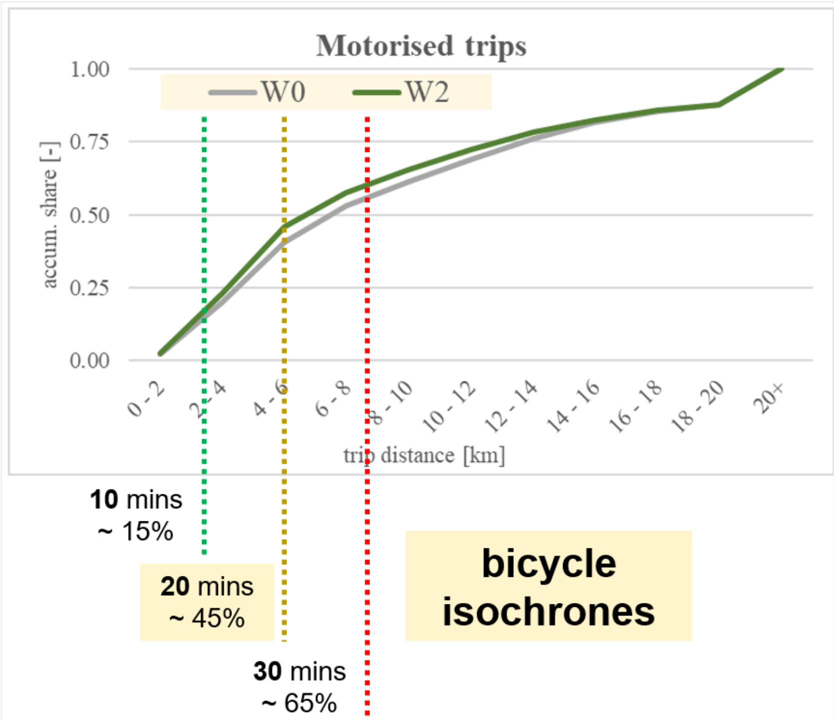


Figure 35. Simulation results – cumulative distribution of motorised trips, classified by trip distance. Indicative bicycle travel times, highlighting the **potential for bicycle traffic growth in Bydgoszcz**.

A closer inspection of simulation results may also help underline the potential of further bicycle traffic growth in the Bydgoszcz area. The cumulative distribution of motorised trips (i.e. car or public transport trips) shows that about 15% of them are made on distances of up to 2.5 [km]. This value corresponds to an approx. 10-minute bicycle journey (assuming cycling speed of 15 [km/h]). Almost 50% of motorised trips in Bydgoszcz are made within a ca. 20-minute cycling distance. Under the existing travel behaviour assumptions in Bydgoszcz transport model, these trips are made by car or public transport in the [W0] – [W2] scenarios. These findings, however, illustrate how eventual changes in travel habits and preferences of Bydgoszcz inhabitants can foster the bicycle ridership, thus yielding more advantageous, climate-wise travel decisions.

4.3. Environmental modelling results

Transport modelling results (described above) served next as input for environmental emissions' modelling, conducted by another CliMobCity project partner – the Potsdam Institute for Climate Impact Research (*PIK - Potsdam-Institut für Klimafolgenforschung*). A customised and calibrated EU-Calc model was used to evaluate total CO2 emissions from road traffic in Bydgoszcz city area. Input data for environmental modelling in the EU-Calc tool involve primarily:

- transport modelling results: total traffic volumes (incl. cars, LGVs, HGVs), network loads ([veh-km] and [veh-hrs] travelled), travel times, speeds and distances,
- vehicle fleet emissions' assumptions – formulated on basis of the EU- and national-level regulations and guidelines; the following **low-emission fleet composition scenarios** were considered in the PIK calculations:
    - **0%** low-emission car fleet share (i.e. 100% of fossil-fuel vehicles, corresponding roughly to present-day scenario),
    - **23%** low-emission car fleet share: 16% of battery electric vehicles (BEVs) and 7% of hydrogen (fuel cell) vehicles (FCVs),
    - **43%** low-emission car fleet share: 30% of battery electric vehicles (BEVs) and 13% of hydrogen (fuel cell) vehicles (FCVs).

Detailed assumptions, methodology and analysis is described in the separate CliMobCity project documentation. Table below (Table 5) summarises resultant CO2 emissions' estimates from road traffic for the all the Bydgoszcz scenarios:

Table 5. Environmental modelling results – projected CO2 emissions from road traffic (source: PIK estimates).

CO2 emissions – road traffic			Total [tonnes]	Projected changes - Δ [%]	
scenario:		low-emission car fleet share [%]		vs. 2021	vs. 2050 [W0]
2021 – base year	**[W0]**	*none*	427.3	*n/a*	*n/a*
2050 – BAU	**[W0]**	*none*	478.1	**+ 11.9%**	
2050 – interventions	**[W1]**	16% BEV + 7% FCV	383.0	- 10.4%	- 19.9%
		30% BEV + **13%** FCV	376.4	- 11.9%	- 21.3%
	[W2]	16% BEV + 7% FCV	337.1	- 21.1%	- 29.5%
		30% BEV + **13%** FCV	328.7	- 23.1%	- 31.2%
2050 – interventions and behav. shifts	**[W1+]**	16% BEV + 7% FCV	337.4	- 21.0%	- 29.4%
		30% BEV + **13%** FCV	333.2	- 22.0%	- 30.3%
	[W2+]	16% BEV + 7% FCV	326.7	- 23.5%	- 31.7%
		30% BEV + **13%** FCV	326.0	- 23.7%	- 31.8%

Environmental modelling results highlight that transport system changes in the **2050 BAU scenario result in higher CO2 emissions than in the present-day 2021 scenario**. The **12%** growth rate underpins negative ramifications of current trends (i.e. suburbanisation processes) and insufficiency of BAU interventions. Meanwhile, the **favourable potential of proposed CliMobCity intervention scenarios** is evidently observable in obtained estimates. These lead to decrease of total projected CO2 emissions (from road traffic) of ca. 10 - 24% against the 2021 scenario, and **20 - 32%** in comparison vs. the [W0] 2050 BAU scenario.

In a broad overview, the [W2] *compact-city* scenario delivers better CO2 reduction results among the two considered CliMobCity scenarios: extra 10 percentage points of emission reductions than in the [W1] scenario. **The highest CO2 reductions are obtained in the CliMobCity *plus* scenarios,** i.e. combination of transport interventions and additionally - behavioural shifts. Both the [W1+] and [W2+] scenarios exhibit analogous emission reductions, reinforcing further the potential of [W1] and [W2] measure packages. The attainable CO2 reduction equals 30 – 32% vs. the [W0] BAU scenario.

5. Conclusions

This sections wraps up the conclusions from CliMobCity analyses for the Bydgoszcz city. Main outputs and takeaways are summarised in the following 2 subsections (Figure 36), as follows:

- First part – the *diagnostic* summary of **BAU scenario outlook**, with regards to the key 5 intervention pillars (formulated by PIK), which are required to mitigate the climate impacts of transport sector.
- Second part – the *interventional* summary of **CliMobCity policy recommendations**, formulated on (and supported by) the analytical outputs of this project.

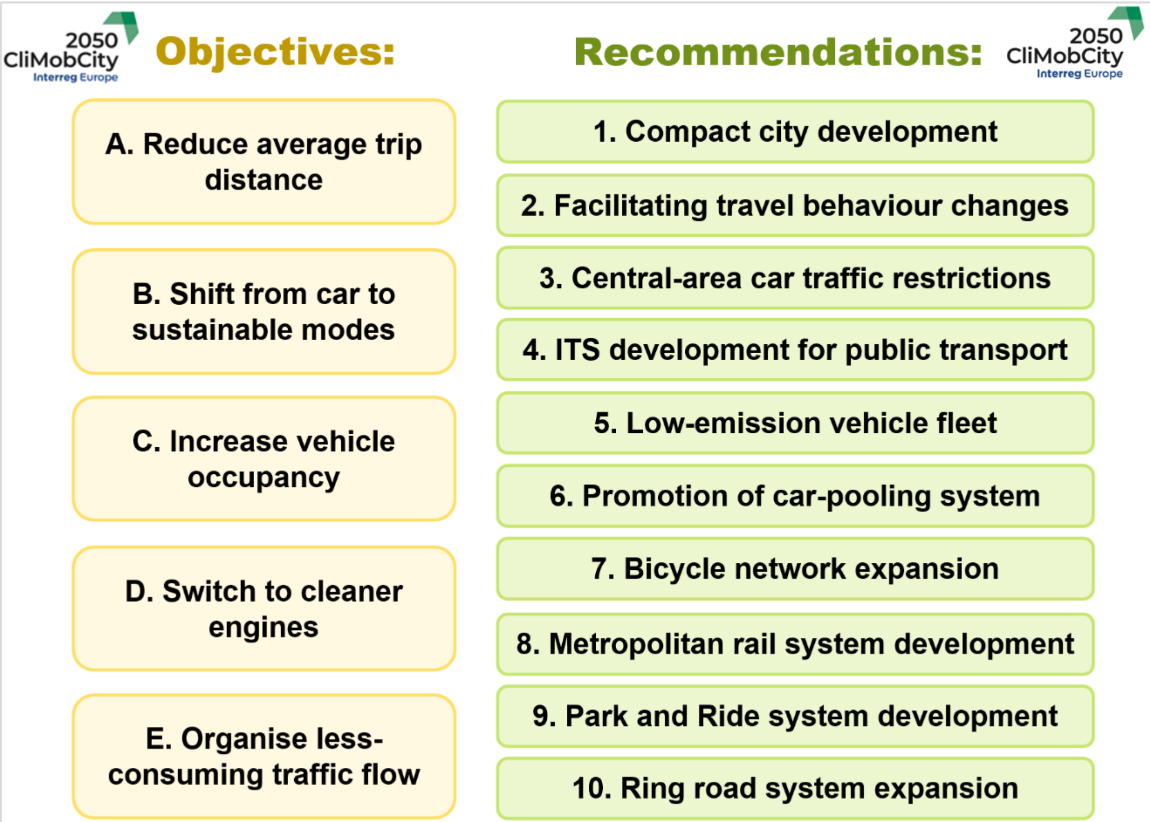


Figure 36. Output summary – BAU outlook and CliMobCity recommendations for Bydgoszcz.

5.1. Summary – business as usual (BAU) outlook for Bydgoszcz

Table 6. Conclusions – BAU outlook for the [A.] CliMobCity project objective in Bydgoszcz.

Objective:	**A. Reduce average trip distance**
Outlook (*BAU*):	**NEGATIVE**
	• Simulation results for the 2050 BAU [W0] scenario show that, under current trends and network development assumptions, trips in Bydgoszcz will be conducted over even greater distances. **Average trip distance in 2050 [W0] increases by ca. 20% in comparison with the 2020 results.** For private (car) transport, this implies a growth from 10.0 [km] up to 12.6 [km]; the corresponding figures are 4.8 [km] up to 6.0 [km]. Remarkably, while average travel *speeds* improve in the 2050 [W0] scenario, **average travel *times* will be actually**

	10% - 20% longer than in 2020. This is a clear evidence of a certain paradox (and major risk), whereby trips in Bydgoszcz will actually become *quicker* yet *longer* in the year 2050. • Judging by the above findings, the **added value of new transport investments will be *consumed* (outweighed) by rising trip distances**. Consequently, the transport system of Bydgoszcz by the year 2050 will be subject to greater network loads (as measured by total [veh-km] travelled). **The principal reason is the sustained trend of suburbanisation in Bydgoszcz metro area**. Unless unbalanced by a range of strategic and policy measures, the urban sprawl process will continue in the foreseeable future. It may even accelerate further if future transport and urban planning policy is overtly focused on the outer areas, while inner-city area is at risk of relative degradation.

Table 7. Conclusions – BAU outlook for the [B.] CliMobCity project objective in Bydgoszcz.

Objective:	**B. Shift from car to sustainable modes**
Outlook (*BAU*):	**NEGATIVE** • Simulation forecasts shed light onto an **increasing role of private car in the future Bydgoszcz transport** system. Compared against the 2020 results, in the 2050 [W0] scenario the modal share of private car trips rises **from 50.4% to 54.3%**. In absolute terms, this translates to approx. 38,000 extra car trips daily. Unfortunately, such changes are accompanied by **plummeting share of walking trips (from 26.2% to 22.8%)**, and (to lesser extent) **decreasing role of public transport (by 0.5 p.p.)**. • Furthermore, **the 2050 BAU scenario envisages approx. 20,000 less daily trips in the central Bydgoszcz area,** which is in ca. 90% attributable to the declining usage of walking, cycling and public transport modes (vs. the 2020 results). Meanwhile, car traffic volumes in central Bydgoszcz are forecast to drop only by ca. 2,000 [veh./day]. • The above findings underline that the **BAU assumptions are insufficient to encourage sustainable modal shifts** in Bydgoszcz transport system. The envisaged public transport projects (tram network extensions, P+R investments, bus priorities etc.) are not likely to increase its patronage rates. Concurrently, urban sprawl developments will lead to even greater role of private car trips, especially over longer trip distances. **The share of active modes (walking and cycling trips) will be negatively affected, in particular in the inner-city area, where car volumes will hardly decrease without any road capacity restrictions** and bolder cycling network expansion programme.

Table 8. Conclusions – BAU outlook for the [C.] CliMobCity project objective in Bydgoszcz.

Objective:	**C. Increase vehicle occupancy**
Outlook (*BAU*):	**NEUTRAL** • The **average car occupancy in Bydgoszcz is forecast to remain roughly constant**, with a slight decrease from 1.23 (2020 scenario) to 1.21 [pass./veh.] (2050 [W0] scenario). Such occupancy rate is consistent with figures for multiple other Polish cities (1.1 – 1.3 [pass./veh.]). **The public transport system in Bydgoszcz witnesses limited yet positive changes**. In terms of average weighted passenger flow (i.e., the ratio of total [pass-km] to total [veh-km]), the 2050 [W0] witnesses a slight increase to 19.3 [pass./km] vs. 18.4 [pass./km] in the 2020 scenario. • According to transport model analysis, the **BAU scenario measures do not affect significantly the vehicle occupancy rates**. Despite the overall car traffic growth, private car occupancy should not deteriorate much (at least under current travel behaviour

	characteristics in Bydgoszcz), and bus and tram network occupancy may even slightly increase. **Yet, this also underscores the need for additional measures and policy changes that can facilitate positive vehicle occupancy shifts**. With regards to private transport, this especially pertains to e.g. potential uptake of car-pooling system which is not included in the BAU scenario.

Table 9. Conclusions – BAU outlook for the [D.] CliMobCity project objective in Bydgoszcz.

Objective:	**D. Switch to cleaner engines**
	NEUTRAL
Outlook (*BAU*):	• According to environmental modelling results conducted by PIK, **the 2050 BAU scenario may actually risk higher CO2 emissions from road traffic than today (i.e. 2021 scenario) -** ca. 12% growth. This clearly underscores the insufficiency of BAU assumptions in mitigating transport emission impacts in Bydgoszcz. • On the other hand, an important BAU scenario assumption which **will positively contribute towards GHG emissions' reduction is the national-level guideline of the 100% zero-emission bus fleet by the year 2030.** The phasing out of high-emission vehicles will be enacted gradually yet consequently. Thus, the bus and tram service in Bydgoszcz has the chance of becoming fully climate-neutral by the year 2050. • Favourably, **extra incentives for green transition policy and adoption of zero-emission car fleet may emerge soon in national and regional policy guidelines.** These topics are subject of rising public debate and support. As of now, the national strategy [15] envisages doubling of electric-powered car vehicles by ca. 2027, but more far-reaching proposals are gaining momentum in public debate - and shoring up public support as well. The EU-wide phase-out of new fossil fuel cars from 2035 onwards will have to be addressed at the national level with legally-binding policies in the near future. Nevertheless, this still leaves a wide-open field for **further measures that can further facilitate the climate-neutral mobility in Bydgoszcz city**.

Table 10. Conclusions – BAU outlook for the [E.] CliMobCity project objective in Bydgoszcz.

Objective:	**E. Organise less energy-consuming traffic flow**
	NEGATIVE
Outlook (*BAU*):	• The 2050 [W0] simulation results indicate that traffic flow in Bydgoszcz will not become less intensive in terms of network loadings. **Average vehicle mileage (per trip) increases by ca. 20% in the BAU scenario** against the current trends. This is (unfavourably) consistent with the overall increases in trip distances, stemming from BAU assumptions. **Likewise, environmental modelling estimates point towards higher total road traffic emissions** against the present-day 2021 projections. • The BAU findings reveal thus unfavourable consequences of current land-use development patterns and its interactions with transport performance. Population migration towards outer suburbs implies that **future mobility activities will require greater resources – fuel / energy, travel time budget, network infrastructure etc**. Rising average trip distance coupled with (roughly) similar population rates will likely result in **higher energy consumption per capita** (with regards to transportation needs) **by 2050 unless further measures are considered**.

5.2. Summary – CliMobCity recommendations for Bydgoszcz

Table 11. Conclusions – the [1.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**1. Compact city development**
Addressed objectives:	• [A.] Reduce average trip distance • [B.] Promote shift to sustainable modes • [E.] Organise less energy-consuming traffic flow
Potential effectiveness (*CliMobCity*):	**SIGNIFICANT** • The **[W2] CliMobCity scenario reveals a range of positive results** in transport system performance in Bydgoszcz with long-term spatial development policy changes. Compared against the BAU scenario, the **modal share of private car reduces by 3 p.p.**, offset by a higher share of public transport and walking trips. Consequently, the 2050 [W2] scenario measures reverse the negative trends visible in the 2050 [W0] scenario and sustain modal shares and journey parameters more aligned with the present-day characteristics. • Car trip distances and network loads are lower by 5% globally and **car travel times are shorter by 0.4 [mins]**. Even with conservative estimates, such travel times benefits can be put at ca. 3.8m [EUR] annually, solely for road transport network. Favourable changes occur **in public transport system, where average travel time is shorter by 3.3 [mins] and daily number of trips is higher by 20,000.** Moreover, the **share of cycling trips in central Bydgoszcz rises from 1.1% to 1.9%**. • Environmental modelling (PIK) results reveal approx. **20 – 30% decrease in total road traffic emissions in Bydgoszcz in the *compact city* scenario**.
Recommendations:	• Long-term and consequent promotion of sustainable, compact **urban development policy that mitigates the suburbanisation and urban sprawl tendencies**. These measures have to be enacted in the strategic documents, defining and influencing the long-term spatial planning policy. They should **discourage extensive, *greenfield* development**, especially in outer areas which are poorly served by the public transport system**. Instead, *brownfield* and urban regeneration policies shall have greater preference,** as they eventually allow a more efficient utilisation of the existing transport system resources and urban realm in Bydgoszcz. • **Coordination of transport and spatial planning policy between Bydgoszcz municipality and the agglomeration-area communes.** This is of paramount importance to eventual implementation of the compact city development policy. A major share of urban sprawl development takes place outside of Bydgoszcz city, and can be only influenced by local communes. Co-operation in transport and spatial planning measures with the Bydgoszcz municipality may help the local communes' authorities avoid the (eventually substantial) costs associated with uncontrollable suburban development, and recognise the long-term benefits of a co-ordinated approach. • **The first action of the Bydgoszcz CliMobCity Action Plan** has been designed to support (and hopefully initiate) favourable changes in urban planning approach in the short-term.

Table 12. Conclusions – the [2.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**2. Facilitating travel behaviour changes**
Addressed objectives:	• [A.] Reduce average trip distance • [B.] Promote shift to sustainable modes • [C.] Increase vehicle occupancy
	SIGNIFICANT
Potential effectiveness (*CliMobCity*):	• **Analyses for the CliMobCity [W1 plus] and [W2 plus] scenarios underline the prospective benefits than may arise from higher perceived attractiveness of alternative means of transport** among Bydgoszcz population – i.e., walking, cycling, public transport. Compared against the [W1] and [W2] scenarios, their outputs show solely the impact of increased utility of these modes (over choosing an own car), without any extra network or policy measures. Consequently, the **modal share of private car decreases by 3 – 5 p.p., while that of public transport rises by 2 – 4 p.p. Active travel modes are also more popular.** Eventually, in the [W2 plus] scenario, the share of car trips is reduced to 46.3%, while walking becomes the second most popular option (26.7%). Furthermore, the **average car occupancy increases to ca. 1.3,** corresponding to approx. 15,000 – 25,000 additional trips made as car passengers. Finally, the **CliMobCity plus scenarios foster the projected road traffic emission savings, as these reach up to 30 – 32% vs. BAU results**, while benefits attainable in [W1], [W2] scenarios are limited to max. 20 – 30%.
Recommendations:	• Consequent **promotion of alternative, sustainable transport modes**. Various short- and long-term policies and measures can (and should) be recalibrated to raise the relative attractiveness of non-motorised travel options. For example, this may include: awareness-raising campaigns, organising car-free or bicycle mass events, implementation of local traffic neighbourhoods, school street schemes, workplace levy programmes etc **Eventually, a wide array of such policies and strategies should aim at achieving a more favourable perception of cycling, walking, public transport and car-pooling travel modes** among Bydgoszcz (and its agglomeration area) inhabitants. • **Importance of *soft* mobility measures**. Enhancing the relative image of car-alternative travel modes will be supported by *hard* infrastructure and network expansion schemes, but these should be equally complemented with *soft* mobility measures. This pertains, among others, to development of effective travel demand management policies (e.g. sustainable mobility plans or ITS-based strategies), travel information solutions, wayfinding systems (for pedestrians and cyclists as well), congestion mitigation strategies (via ITS and active traffic management). • **Regular monitoring of travel behaviour**. This is a crucial prerequisite to assess the effectiveness of hitherto undertaken policy measures upon travel attitudes and preferences. Household and passenger travel surveys should be conducted on a regular basis (every few years) to evaluate travel behaviour changes, evolving modal shifts and identify fields requiring further attention. **Monitoring of urban mobility in Bydgoszcz can be gathered both by means of** behavioural investigation (**SP surveys**) and actual trip pattern records, e.g. from ITS system and cellular network (**RP data**). • The scope of **Bydgoszcz CliMobCity Action Plan** envisages 3 measures supporting the uptake of policies that have the potential to foster long-term, favourable urban mobility shifts in the city (i.e., sustainable spatial planning policy, micromobility and car-pooling development, bicycle promotion).

Table 13. Conclusions – the [3.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**3. Central-area car traffic restrictions**
Addressed objectives:	• [B]. Promote shift to sustainable modes • [E.] Organise less energy-consuming traffic flow
	SIGNIFICANT
Potential effectiveness (*CliMobCity*):	• **The [W1] CliMobCity results** underpin potentially **substantial reductions in the central-area traffic loads with *bolder* car traffic restrictions.** The [W1] measures **combine both inner-city restrictions** (access traffic only, 30-kph zone, area-wide traffic calming) **and narrowing of radial routes (approaches)** to the city centre to single-carriageway (for general traffic). As a result, **traffic loads in central Bydgoszcz decrease by 25 – 35%** in the [W1] scenario, in comparison with the [W0] scenario. Average car speed in the city centre drops by 6 [kph], yet in the whole network it is only lower by 0.5 [kph].
Recommendations:	• Consequent **design and implementation of policies discouraging car traffic in the central Bydgoszcz area**. These should cover a range of measures either launched on a wider scale and/or targeting specific areas. For example, the **historical core of Bydgoszcz should be a strictly car-free zone** that can be also extended towards the adjacent streets. **The wider central area should become a 30-kph zone with traffic calming solutions, and eventually the first stage of Clean Traffic Zone in Bydgoszcz.** The zone may be then extended in the future towards specific outer areas, e.g. the Fordon subcentre (in eastern Bydgoszcz) or suburban housing areas. Additionally, **parking policy should play a more active and advantageous role** in managing the road traffic in Bydgoszcz. Parking fees should be increased in high-demand areas **to utilise more efficiently the existing road and parking space**. • **Eventual narrowing of main thoroughfares and arterial routes in central Bydgoszcz area**. Reducing the capacity of dual carriageway roads approaching (and crossing through) the city centre will be an effective measure, contributing to lower traffic volumes in Bydgoszcz. **It is also justifiable given the limited road traffic capacity of central-area street network**. The *freed-up* road capacity can be **instead redistributed** to more efficient transport modes, especially for **designating new bus lanes, cycling routes and wider pedestrian pavements**. Furthermore, **road narrowing projects can be coupled with urban regeneration schemes,** e.g. the main W-E thoroughfare (Focha and Jagiellońska streets) - a historical canal route that can be reinstated as an attractive city boulevard.

Table 14. Conclusions – the [4.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**4. ITS development for public transport**
Addressed objectives:	• [B]. Promote shift to sustainable modes • [C.] Increase vehicle occupancy • [E.] Organise less energy-consuming traffic flow
Potential effectiveness (*CliMobCity*):	**SIGNIFICANT** • Outputs of the **[W2] CliMobCity scenario** reveal the advantageous impacts of the modelled bus and tram priority measures upon **public transport performance. Travel speeds and travel times improve by ca. 20%** against the baseline [W0] scenario. Crucially, the decrease in average travel time by public transport (from 14.8 [mins] in 11.5 [mins**]) stands out favourably against the average travel time in road network,** which barely changes (from 14.8 [mins] to 14.4 [mins]). Consequently, ca. 20,000 extra trips daily are made by **public transport in Bydgoszcz, whose patronage rate in central city area is projected to rise by over 25%** in comparison with the [W0] results.
Recommendations:	• **Wide implementation of ITS-based real-time control and management of public transport operations**. **Travel time speed and travel time reliability are key indicators reflecting the proper quality of public transport service**. Real-time control and management of public transport movements has been shown in research literature to provide potentially significant benefits in this regard**.** Such solutions are implementable within the ITS framework, which is already under development in the Bydgoszcz city. A prominent solution pertains to **priority traffic signal settings for the approaching bus and tram vehicles, which should be enacted** especially in case of high passenger volumes or risks of delay induced by traffic congestion. The ITS-fed data on current vehicle movements (AVL and GPS tracking), disruption events in the road network, and potentially also data on passenger flows (APC, ticketing systems) should be exploited to effectively manage the real-time bus and tram operations. **This underlines the need for high-quality ITS data collection and processing** to define efficient and robust control management strategies. • **Development of dynamic, advanced traveller information system (ATIS).** The ITS-fed data can be simultaneously conveyed to passengers to inform them in real-time on current performance of bus and tram services in Bydgoszcz. A commonplace solution is the real-time estimation of arrival times at bus and tram stops, which is already provided for selected public transport services in Bydgoszcz. **In the future, the ATIS framework can be extended to provide additional travel advice, such as real-time alerts on service disruptions, suggested travel alternatives, or real-time crowding information** of bus and tram vehicles. **Credible and useful travel information may significantly contribute towards higher perceived attractiveness and reliability of public transport services** among the prospective users. • **Prioritising bus and tram traffic in road infrastructure design**. Street and intersection layout should preferably allow for seamless, undisrupted movement of bus and tram vehicles. **Designated bus lanes and bus gates** are recommendable traffic engineering solutions in that matter. An important aspect to watch out for is that interruptions with general traffic (e.g. at busy intersection approaches) can drastically decrease the added value of preceding bus lanes. Efforts should be taken therefore to implement such priority measures in form of a continuous and efficient network, and with **consequent separation from general road traffic wherever necessary**.

Table 15. Conclusions – the [5.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**5. Low-emission vehicle fleet**
Addressed objectives:	• [D]. Switch to cleaner engines • [E.] Organise less energy-consuming traffic flow
Potential effectiveness (*CliMobCity*):	**SIGNIFICANT** • Environmental modelling (PIK) results for **both [W1] and [W2] scenarios point towards reductions of ca. 20 – 30% in road traffic emissions, compared against the BAU scenario.** These benefits are more pronounced in the *CliMobCity plus* scenarios and reach over 32%. • While the above cited rates are not seemingly significant at first glance, **they underscore the potential (and need) for more advanced car emission standards and low-emission policies. PIK estimates are based on currently binding policy guidelines** which are relatively lax compared to other EU countries and should be enhanced in the near future.
Recommendations:	• **Step-wise introduction of Clean Traffic Zones (CTZ) in Bydgoszcz**. The first site of CTZ zone should be the inner-city area of Bydgoszcz, where achieving the car traffic relief is an especially important target. **Then, the scope of CTZ can be gradually extended over next years to include additional areas** sensitive to road traffic externalities – e.g. low-housing suburbs or green areas. Ultimately, the Bydgoszcz CTZ may cover a major city area within a completed ring road. Introduction of CTZ zone(s) **should be considered carefully though,** especially with regards to feasible pace of car fleet replacement in Bydgoszcz agglomeration (i.e. considering social and economic factors). Such **gradual CTZ implementation over long-term horizon** can facilitate the favourable transition towards low- and zero-emission car fleet among local population. • **Preferential measures for low- (zero-)emission car vehicles**. The municipality of Bydgoszcz may utilise policies such as lower parking fees or designated parking spaces for electric (or hydrogen) vehicles. This may additionally encourage the long-term replacement of high-emission car fleet.

Table 16. Conclusions – the [6.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**6. Promotion of car-pooling system**
Addressed objectives:	• [B.] Promote shift to sustainable modes • [C.] Increase vehicle occupancy • [E.] Organise less energy-consuming traffic flow
Potential effectiveness (*CliMobCity*):	MODERATE • **In the CliMobCity [W1 plus] and [W2 plus] scenarios,** the assumptions regarding an enhanced perceived attractiveness of car-pooling trips lead to **increase in average car occupancy to 1.3 [pass./veh.]. This corresponds to approx. 15,000 – 25,000 extra trips made as car *passengers*, importantly - without generating new road traffic volumes**. Otherwise, all the measures assumed in the [W1] and [W2] CliMobCity scenarios do not affect the car occupancy rates, which remains intact at roughly 1.2 [pass./veh.].
Recommendations:	• **Encouraging the development of car-pooling systems in Bydgoszcz**. Different policy instruments can instrumental in facilitating the uptake of car-pooling system in the city. For example, the municipality should consider **designating parking spaces in busier areas for car-pooling vehicles only**, or lowering the parking fees**. Workplace levy schemes** can also encourage the car-pooling developments. Admittedly, some of the measures can only be enacted once (existing) legal obstacles are overcome, but may be nevertheless desirable and efficient tools in this regard. • **Research investigation into car-pooling development prospects.** Since the car-pooling is a pretty much unknown transport solution, the city should firstly conduct an **in-depth surveying study** into prospective potential for car-pooling growth in Bydgoszcz. It should **examine the travel behaviour characteristics** than can affect the propensity to use car-pooling in everyday trips. This will provide a much-needed empirical underpinning, applicable then in transport modelling analysis – whose goal will be to **determine the potential market for car-pooling services across various O-D relations in Bydgoszcz city, efficient supporting measures and the projected performance of car-pooling under various scenarios**. Such a study should be supported by research expertise due to its relative novelty (i.e. supported by a team of municipality workers, transport academics and/or practitioners). • **The second action of the Bydgoszcz CliMobCity Action Plan** has been conceived as a short-term measure, paving the way towards the potential development of car-pooling system in Bydgoszcz.

Table 17. Conclusions – the [7.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**7. Bicycle network expansion**
Addressed objectives:	• [B]. Promote shift to sustainable modes • [D]. Switch to cleaner engines • [E.] Organise less energy-consuming traffic flow
Potential effectiveness (*CliMobCity*):	**MODERATE** • The baseline share of bicycle trips in Bydgoszcz is fairly low, at ca. 1.3% in the 2050 [W0] scenario. Greater perceived attractiveness of bicycle **in the [W1 plus] and [W2 plus] CliMobCity scenario leads to bicycle traffic higher up to 50%** vs. the [W1] and [W2] scenarios. This translates to as much as ca. 18,000 bicycle trips (in total) daily in Bydgoszcz. • Favourably, **a substantial potential for bicycle traffic growth** in Bydgoszcz is deducible from the baseline travel patterns. In all the [W0] – [W2] scenarios, **approx. 15% of motorised trips fall within a range of a 10-minute bicycle trip, while almost 45% can be made in max. 20 [mins] by bicycle**.
Recommendations:	• **Long-term development of cycling infrastructure in Bydgoszcz**. The ultimate goal should be a continuous, attractive cycling network across the whole city, especially between main urban development areas. Depending on specific site circumstances, **a wide set of cycling infrastructure measures should be considered in every single road/street project,** including: dedicated bicycle lanes and tracks; contraflow bicycle lanes (along local streets); road traffic calming and 30-kph zone implementations; cyclist-only shortcuts, turnings and advanced stop lines (ASLs) at the intersections. • **Promotion policies and campaigns of bicycle trips**, whose objective will be to enhance the perceived attractiveness of bicycle as a means of transport. This can include multiple policies such as: regular bicycle *mass events*, workplace levy schemes. • **Consequent development of bicycle rental scheme(s)** should be encouraged in the city of Bydgoszcz. Such schemes were shown to have positive impacts in multiple case-study cities, also in Polish conditions (e.g. Warsaw, Krakow). **Bicycle parking spaces should be also provided across the Bydgoszcz transport network,** in particular close to major trip generators. • **The third action of the Bydgoszcz CliMobCity Action Plan** has been designed as one of the measures (i.e. pilot launching of bicycle wayfinding system) that may eventually contribute towards bicycle traffic promotion in Bydgoszcz in the future.

Table 18. Conclusions – the [8.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**8. Metropolitan rail system development**
Addressed objectives:	• [B]. Promote shift to sustainable modes • [C.] Increase vehicle occupancy • [D]. Switch to cleaner engines • [E.] Organise less energy-consuming traffic flow
Potential effectiveness (*CliMobCity*):	**MODERATE** • **The metropolitan rail system** introduced in the [W1] CliMobCity scenario **plays a positive, though (relatively) limited role in public transport system** of Bydgoszcz metro area. Simulation forecasts reveal its patronage rate of approx. 8,000 [trips/day], which is not a significant share of public transport trips (ca. 215,000 [trips/day] in total). **The Bydgoszcz metropolitan rail system is popular within individual O-D corridors i.e. in context of main agglomeration (FUA) travel routes**.
Recommendations:	• **Improve the accessibility of train stops and stations**. Currently, many rail stations are located further afield from main urban developments, outside of attractive walking/cycling distance. These access connections should be improved **by constructing new, shortest-path approaches, P+R and B+R *(bike and ride)* facilities at rail stations**, **enhancing the quality (and safety) of walking and cycling routes**. As a general guidance, rail stations should be located no further than 500 [m] away from major trip generators. • **Facilitate transit-oriented development (TOD) around train and tram interchanges. High-intensity urban planning projects** should be preferably located in the close proximity of public transport hubs. In contrast with urban sprawl development, the TOD policy will contribute towards shorter and more sustainable trip patterns in Bydgoszcz. Situating such developments around train stations will also increase the patronage rate of rail system. • **Prioritise tram network development in Bydgoszcz**. In line with previous transport analyses for the Bydgoszcz area, the CliMobCity simulations do not reveal highly significant role of rail system in the within-city trips. This is attributable to population size and distribution and (unfavourable, distant) location of rail corridors with respect to main urban development areas. **Seemingly, the tram system can serve a greater share of transportation demand in Bydgoszcz, especially within the city limits** and along the major W-E axis (i.e. between the inner-city and Fordon subcentre). In turn, the metropolitan rail system will efficiently complement tram network services along the main, long-distance O-D routes within the wider Bydgoszcz-Toruń metropolitan area.

Table 19. Conclusions – the [9.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**9. Park and Ride system development**
Addressed objectives:	• [B]. Promote shift to sustainable modes • [C.] Increase vehicle occupancy • [E.] Organise less energy-consuming traffic flow
Potential effectiveness (*CliMobCity*):	LIMITED • In both the [W1] and [W2] CliMobCity scenarios, **the proposed P+R system were shown to attract a certain share of car-based trips from the outer areas**, which transferred to public transport (train and tram) connections to reach the central Bydgoszcz areas. Thus, **some long-distance car traffic was *removed* off the Bydgoszcz road network**. However, the P+R system seems not to be attractive enough for a major share of O-D relations in Bydgoszcz that are not served by public transport system. It should be also noted that, according to simulations, the road capacity *freed up* by the P+R system is eventually consumed by growths in short-range car traffic.
Recommendations:	• **Development of P+R facilities** at multiple bus, tram and train interchanges, **primarily in the suburban Bydgoszcz areas**. Additional proposals for the P+R locations can be considered, which will help serve additional O-D trip relations across Bydgoszcz metro area. Moreover, **the P+R capacity can be expanded step-wise in the future**, whereby additional parking lots can be built later (on safeguarded land reserves), as the system becomes more popular in time. • **Integration of P+R and public transport systems**. This primarily pertains to a combined tariff for P+R users, who should be able to pay a single fare both for parking and the subsequent usage of public transport. **Promotion of seamless transfers between private and public transport, in terms of fare policy and infrastructure solutions** will help increase the popularity of P+R system. The P+R termini should allow for direct, *door-to-door* transfers as much as possible. • Long-term policies should aim for **raising the relative attractiveness of public transport connections over private car trips between central Bydgoszcz and outer area**. Transport network in Bydgoszcz should be ultimately developed in such a way that car users do not perceive greater utility in driving further towards the city centre, but would likely transfer at the P+R facilities to more attractive (i.e. fast, frequent and comfortable) public transport connections.

Table 20. Conclusions – the [10.] CliMobCity policy recommendation for Bydgoszcz.

Solution:	**10. Ring road system expansion**
Addressed objectives:	• [E.] Organise less energy-consuming traffic flow
Potential effectiveness (*CliMobCity*):	**LIMITED** • The [W2] CliMobCity scenario results demonstrate that **the completion of ring road system in Bydgoszcz, just on its own, will lead to reduction in inner-city traffic loads of at most 3%** (against the [W0] scenario**). Only with additional road capacity narrowing in the city centre,** envisaged in the [W1] CliMobCity scenario, **traffic loads may decrease much more, by 30%.** Interestingly though, average car speeds (across the whole network) are even slightly higher in the [W2] scenario – 51.3 [kph], against 50.5 [kph] in the [W1] scenario.
Recommendations:	• **Counterweight any road expansion projects in outer area with inner-city road narrowing schemes**. Analysis results referred above are indicative of a well-known **Lewis-Mogridge paradox, i.e. the *car traffic will ultimately fill up the available space in urban road networks*.** The completion of Bydgoszcz ring road sections will be helpful in providing an alternative to existing (and often congested) streets. However, any durable traffic relief on a city scale is often achievable only with subsequent reduction of the abundant road capacity. In such case, the new road connection is most likely to be used by the existing, *diverted traffic*, whereas without narrowing measures, the overall increase of road network capacity will lead to unfavourable phenomenon of *induced traffic*.

5.3. Summary of the CliMobCity Action Plan for Bydgoszcz

Development of the CliMobCity Action Plan for Bydgoszcz city was the next step in this project. The Action Plan has been drafted based on the transport analyses' outputs, as a document providing details on ***how*** the lessons learnt from the co-operation ***will be implemented*** in order to improve the addressed policy instrument.

The addressed policy instrument is the ERDF (Local Development Policy Instrument), i.e. the Regional Operational Programme for the Kujawsko-Pomorskie Voivodship 2014 – 2020 [7]. The Action Plan aims to target the priority 4e of the ERDF, which reads as follows:

"Promoting low-carbon strategies for all types of territories, particularly for urban areas, including support for sustainable urban mobility and adaptation measures having a mitigating effect on climate change."

The proposed measures are pillared on the intervention areas defined by the 2050 CliMobCity project, namely: land use; public transport; actives modes; individual car transport. The scope of the Bydgoszcz CliMobCity Action Plan has been formulated to initiate and support transport measures in the areas that have been hitherto insufficiently addressed by the City's strategic documents and activities. These pertain to promotion of new travel modes, fostering the role of active modes (walking and cycling) and long-term adjustments in the City's transport and urban planning strategy. These measures have been revealed in the CliMobCity modelling analysis as prospective in reducing the negative climate externalities (CO2 emissions etc.) and, simultaneously, preserving the sustainability and efficiency of the city transport sector.

The fact that the impact of formulated CliMobCity measures are calculated and tested using the Bydgoszcz strategic transport model can be a strong validation of the Action Plan proposals. Hence, the measures presented further in the Action Plans can be perceived as favourable and promising steps towards the achievement of ultimate 2050 CliMobCity project objectives. Importantly, the Action Plan should be implementable and monitorable during the second phase of the project. Hence, **the relative narrowness of time window has to be taken into account**.

The 2050 CliMobCity Action Plan for the Municipality of Bydgoszcz consists of the 3 following actions:

1. 2050 CliMobCity contribution report for the Bydgoszcz Spatial Development Masterplan

- The scope of proposed action is to produce a contribution report from the 2050 CliMobCity Bydgoszcz project for the Spatial Development Masterplan (SUiKZP), which is currently being updated. The CliMobCity project team can support the above co-creation process with a series of recommendations based on the CliMobCity analytical works. **The Spatial Planning Department will be provided with a series of evidence-based proposals for updating the newly developed SUiKZP masterplan.** This will reinforce the analytical fundament for crafting the ultimate SUiKZP strategy. Moreover, the potential success of this action could inspire the development of follow-up (and synergical) actions that will foster further the efforts towards the GHG emission reductions.
- Since the ultimate effects of this action cannot be monitored in the short-term phase of this project, the monitoring will be limited to 1) municipal decision to carry out the 2050 CliMobCity contribution report and produce a draft version, 2) conduct corresponding consultations and feed the results back to the city and its experts, and 3) launch the final contribution report.
- Projected timeframe: from Q3 2022 until Q1 2023.

2. Technical specification for the "Feasibility study into the micromobility and car-sharing development in the City of Bydgoszcz"

- **This action will provide a document formulating the technical specifications for a later "Feasibility study into the micromobility and car-sharing development in the City of Bydgoszcz".** As less conventional and underexplored transport modes are involved, a comprehensive understanding of their features and functioning (e.g. mobility chains, types and locations of hubs, mobility and CO2 effects, potential and spatial demand) is needed, and of the required innovations of methods and mobility modelling. A professionally designed technical specification will define clearly: objectives, methods and expected outcomes of such feasibility study. The output study will eventually put the Municipality in an advantageous position to facilitate further development of micromobility and car-sharing systems in Bydgoszcz.
- The action will include and the monitoring will focus on 1) the municipal decision to carry out the Technical specifications document, and the production of a draft version, 2) conducting corresponding consultations and feeding the results back to the city, and 3) launching the final Technical specifications report.
- Projected timeframe: from Q1 2023 until Q2 2023.

3. Pilot enrolment of the Bydgoszcz Cycling Network wayfinding system

- **The action relates to pilot development of wayfinding and signposting elements dedicated for cyclists in the Bydgoszcz central area.** Such system will help cyclists navigate through road network more easily and conveniently. New signposts located at the crossroads will indicate cycling directions to main districts (or POIs), including cycling distance or (estimated) time. These signs could either follow the main cycling routes, as well as indicate low-traffic 'quietways' as recommended cycling routes. The first major step of the action is to describe the concept and its benefits and give an overview of the locations in the Bydgoszcz central area. This includes defining the technical and visual design features and all what is required to implement a set of cycling signposts. The second step is to implement the pilot cycling signposts themselves. The third step will involve the monitoring and short-term evaluation of this pilot project.

- Preferably, the impacts of pilot cycling signposting system will have to be monitored ex-post and ex-ante, with the following approaches: bicycle traffic counts (before vs. after); and user satisfaction survey (before vs. after). Within the (relatively short) timeframe of this action, only a limited scope of monitoring and evaluation analysis will be viable (e.g. analysing users' perceptions of newly installed signposts).
- Projected timeframe: from Q4 2022 until Q2 2023.

6. Main references

[1.] Interreg Europe (2019, 2022): ***2050 CliMobCity: Climate-Friendly Mobility in Cities.*** European Regional Development Fund. Available at: https://projects2014-2020.interregeurope.eu/2050climobcity/

[2.] Chmielewski J, Szczuraszek T. (2016): *Bydgoszcz – Toruń Partnership Area transport model.* [Polish: *Model transportowy Bydgosko – Toruńskiego Obszaru Partnerstwa.*] Transport Miejski i Regionalny, 06/2016.

[3.] Szczuraszek et al (2012): *Bydgoszcz transport study with road traffic safety evaluation*. [Polish: *Studium Transportowe Miasta Bydgoszczy wraz z Oceną Stanu Bezpieczeństwa Drogowego.*] Fundacja „Rozwój UTP".

[4.] ZDMiKP Bydgoszcz (2021): *Municipal Road and Public Transport Authority in Bydgoszcz* (2021) [Polish: *Zarząd Dróg Miejskich i Komunikacji Publicznej w Bydgoszczy*.]. Available at: https://zdmikp.bydgoszcz.pl

[5.] MPU Bydgoszcz (2009): *Spatial Development Masterplan for the City of Bydgoszcz.* [Polish: *Studium Uwarunkowań i Kierunków Zagospodarowania Przestrzennego Miasta Bydgoszczy.*] Miejska Pracownia Urbanistyczna w Bydgoszczy.

[6.] MPU Bydgoszcz (2004): *Conceptual urban development plan for Bydgoszcz central area.* [Polish: *Propozycje założeń rozwoju przestrzennego śródmieścia Miasta Bydgoszczy.*] Miejska Pracownia Urbanistyczna w Bydgoszczy.

[7.] Marshal Office of the Kujawsko - Pomorskie Voivodeship (2014): *Regional Operational Programme for the Kujawsko – Pomorskie Voivodeship 2014 – 2020*. [Polish: *Regionalny Program Operacyjny Województwa Kujawsko - Pomorskiego 2011 – 2020*]. Urząd Marszałkowski Województwa Kujawsko – Pomorskiego.

[8.] Government of Poland (2014, 2021): *National Road Construction Programme for the years 2014 – 2023 (with the 2025 perspective)* [Polish: *Program Budowy Dróg Krajowych na lata 2014-2023 (z perspektywą do 2025 r.)*] Rada Ministrów Rzeczypospolitej Polskiej.

[9.] Government of Poland (2021): *National Railway Plan* [Polish: *Krajowy Program Kolejowy*] Rada Ministrów Rzeczypospolitej Polskiej.

[10.] Solidarity Transport Hub (CPK) (2021): *Railway Component of the Solidarity Transport Hub.* [Polish: *Program Kolejowy Centralnego Portu Komunikacyjnego.*] Centralny Port Komunikacyjny. Available at: https://www.cpk.pl/en/about/railway-component

[11.] Central Statistical Office (GUS) (2011): *2011 National Census.* [Polish: *Narodowy Spis Powszechny w 2011 r.*] Available at: https://stat.gov.pl/spisy-powszechne/nsp-2011/

[12.] Central Statistical Office (GUS) (2015): *Population forecast for the Republic of Poland*. [Polish: *Prognoza ludności dla Rzeczypospolitej Polskiej*.] Available at: https://stat.gov.pl/obszary-tematyczne/ludnosc/prognoza-ludnosci/

[13.] City of Bydgoszcz (2013): *Sustainable Public Transport Development Plan for the Bydgoszcz city*. [Polish: Plan zrównoważonego rozwoju publicznego transportu zbiorowego dla miasta Bydgoszczy.] Available at: https://bip.zdmikp.bydgoszcz.pl/attachments/article/151/plan.pdf

[14.] PNEC, ZZE UM Bydgoszcz (2021): *Sustainable Energy and Climate Action Plan (SECAP) for Bydgoszcz City by 2030*. [Polish: *Plan działań na rzecz zrównoważonej energii I klimatu (SECAP) dla Miasta Bydgoszczy do 2030 roku*.]

[15.] Government of Poland (2022): *National Recovery and Resilience Building Plan* (KPO). [Polish: *Krajowy Plan Odbudowy i Zwiększania Odporności*.] Rada Ministrów Rzeczypospolitej Polskiej. Available at: https://www.gov.pl/web/planodbudowy

[16.] The Centre for EU Transport Projects (CUPT) (2021): *Integrated National Transport Model* [Polish: *Zintegrowany Model Ruchu*]. Centrum Unijnych Projektów Transportowych. Available at: https://www.cupt.gov.pl/centrum-unijnych-projektow-transportowych/zintegrowany-model-ruchu/

[17.] Gadziński J., Goras E. (2019): *How the daily mobility of inhabitants of Polish cities has been changing? 50 years of travel behaviour researches in Poland.* [Polish: *Jak zmieniła się codzienna ruchliwość mieszkańców polskich miast? 50 lat badań zachowańtransportowych ludności w Polsce.*] Prace Komisji Geografii Komunikacji PTG.

[18.] Social Insurance Institution (ZUS) (2021): *Foreigners in the Polish social security system.* [Polish: *Cudzoziemcy w polskim systemie ubezpieczeń społecznych*.] Zakład Ubezpieczeń Społecznych. Available at: https://www.zus.pl/baza-wiedzy/statystyka/opracowania-tematyczne/cudzoziemcy

[19.] Union of Polish Metropolises (2022): *Urban hospitality: A report on Ukrainian refugees in the Largest Polish Cities*. Unia Metropolii Polskich. Available at: https://metropolie.pl/artykul/34-million-ukrainians-in-poland-new-report-by-the-union-of-polish-metropolises

List of figures

List of tables