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QUALIFICATION PAPER

(EXPLANATORY NOTES)

OF SEEKER OF ACADEMIC DEGREE

«MASTER»

THEME: **«Optimization of the city's transport systems functioning based on transport modeling»**

Specialty 073 «Management»

Educational and Professional Program « Logistics »

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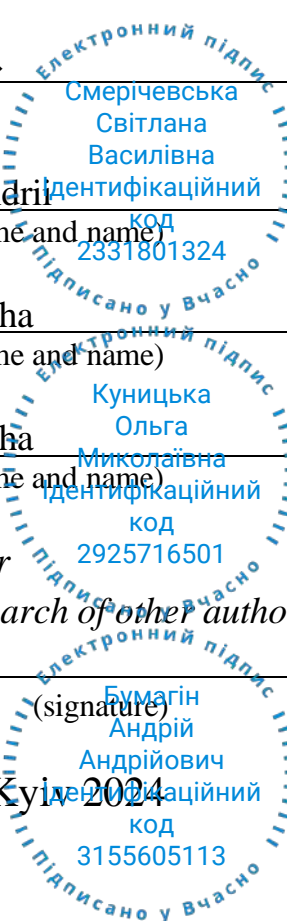
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TASK

FOR COMPLETION THE QUALIFICATION PAPER OF SEEKER

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1. Theme of the qualification paper: «Optimization of the city's transport systems functioning based on transport modeling» was approved by the Rector Directive №1559/ст. of August 26, 2024.

2. Term performance of qualification paper: from August 26, 2024 to November 14, 2024.

3. Date of submission qualification paper to graduation department: November 20, 2024.

4. Initial data required for writing the qualification paper: general and statistical information about transport system in Ukraine, information about public transport in Kyiv, literary sources on logistics and customer service process, Internet source.

5. Content of the explanatory notes: introduction, the history and essence of the transport modelling; the examples of transport models of Ukrainian cities; analysis the transport demand and supply in chosen area in th city of Kyiv; calculation of the main parts of the 4-steps model; conclusions.

6. List of obligatory graphic matters: tables, figures illustrating the current state of problems and methods of their solution.

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7. Calendar schedule:

№	Assignment	Deadline for completion	Mark on completion
1	2	3	4
1.	Study and analysis of scientific articles, literary sources, normative legal documents, preparation of the first version of the introduction and the theoretical chapter	26.08.24-20.09.24	Done
2.	Collection of statistical data, timing, detection of weaknesses, preparation of the first version of the analytical chapter	21.09.24-13.10.24	Done
3.	Development of project proposals and their organizational and economic substantiation, preparation of the first version of the project chapter and conclusions. Editing the first versions of qualification paper	14.10.24-03.11.24	Done
4.	Preparing the final version of the qualification paper, checking by standards inspector	04.11.24-14.11.24	Done
5.	Approval for a qualification paper with supervisor, getting of the report of the supervisor, getting internal and external reviews, transcript of academic record	15.11.24-19.11.24	Done
6.	Submission qualification paper to Logistics Department	20.11.24	Done

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8. Consultants of difference chapters of qualification paper:

Chapter	Consultant (position, surname and initials)	Date, signature	
		The task was given	The task was accepted
Chapter 1	Associate Professor, <u>Kunyska</u> O.M.	26.08.24	26.08.24
Chapter 2	Associate Professor, <u>Kunyska</u> O.M.	21.09.24	21.09.24
Chapter 3	Associate Professor, <u>Kunyska</u> O.M.	14.10.24	14.10.24

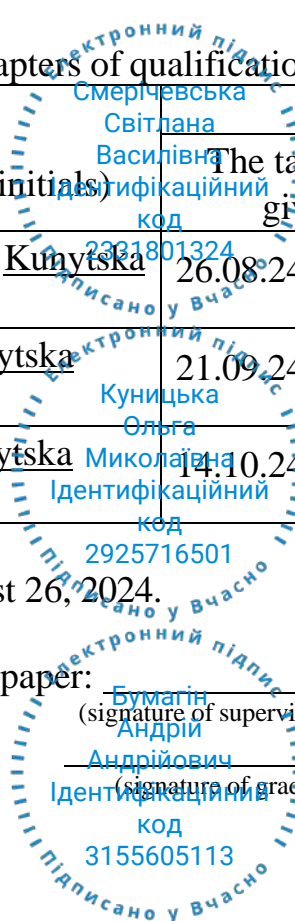
9. Given date of the task August 26, 2024.

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Task accepted for completion: _____
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ABSTRACT

The explanatory notes to the qualification paper «Optimization of the city's transport systems functioning based on transport modeling» comprises of 98 pages, 79 figures, 1 table, 57 references.

KEY WORDS: TRANSPORT MODEL, TRANSPORT ZONES, PUBLIC TRANSPORT, PRIVAT TRANSPORT, FOUR STEP MODEL, DEMAND MODEL, SUPPLY MODEL

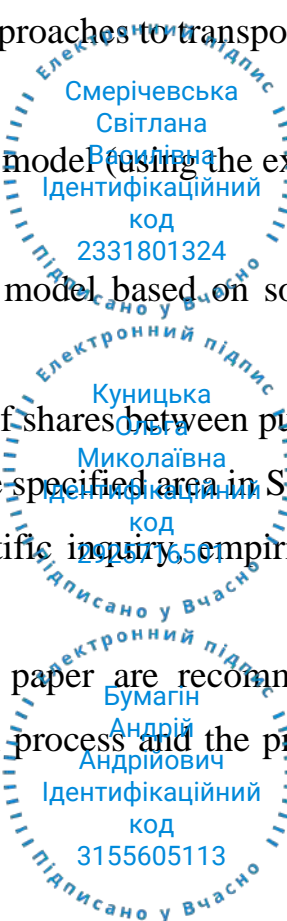
The purpose of research is to understand, analyze, and predict the behavior of transportation systems to improve their efficiency, safety, and sustainability by creation of mathematical models and simulations to represent transportation networks, travel demand, and the movement of people. The subject of the research is the modelling an area in the city of Kyiv.

To achieve the set goal, the following tasks were addressed in the study:

- examining methodological approaches to transport modeling using the PTV Visum software environment;
- developing a transport supply model (using the example of a neighborhood in Kyiv);
- creating a transport demand model based on socio-economic data for the selected neighborhood in Kyiv;
- simulating the redistribution of shares between public and private transport.

The object of the research is the specified area in Solomianskyi district in Kyiv. Methods of research are scientific inquiry, empirical, analysis and synthesis, modeling, expert assessments.

Materials of the qualification paper are recommended for applying during scientific research, in the educational process and the practical activities of logistics department specialists.



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INTRODUCTION

Transport systems are critical to the economic, social, and environmental well-being of communities. As urbanization and mobility demands grow, efficient planning and management of transportation networks have become paramount. Transport modelling plays a crucial role in understanding, predicting, and optimizing the movement of people and goods within a given area, contributing to better decision-making for infrastructure development, policy formulation, and sustainability initiatives.

This project aims to develop and apply transport models to analyze the dynamics of transportation systems, with a focus on key challenges such as congestion, accessibility, and multimodal integration. By simulating traffic flow, travel patterns, and the effects of different interventions, the project seeks to provide insights that can inform transportation planning, help optimize resource allocation, and support the creation of more resilient and efficient transport systems.

The scope of this project includes data collection, model development, calibration, and validation, followed by scenario analysis to evaluate potential improvements in network performance. Through this, the project will contribute to a deeper understanding of transportation issues, facilitating the design of systems that promote mobility, reduce congestion, and support sustainable urban development.

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CHAPTER 1

THE BASICS AND TASCs OF TRANSPORT MODELLING.

1.1 Development of transport modeling in the world

One of the most authoritative English dictionaries “Britannica” defines “Model” as a process in which computers use a set of ideas and numbers to describe the past, present, or future state of something (such as an economy or a business). [1]

A model is a simplified representation of a specific part of the real world—known as the system of interest—which emphasizes certain elements deemed important from a particular perspective. Consequently, models are specific to the problem at hand and the viewpoint from which they are developed. This broad definition allows for the inclusion of both physical and abstract models. Physical models, such as those used in architecture or fluid mechanics, are often focused on design. Abstract models, on the other hand, range from the mental models we use in our everyday interactions to formal, analytical representations of theories about how a system functions. Mental models play a crucial role in helping us understand and interpret both the real world and our analytical models. They are refined through discussion, training, observation, and, most importantly, experience. However, mental models are often challenging to communicate and discuss. [2]

History of Transport Modeling. Nearly 50 years have passed since the first comprehensive urban transport studies were conducted in the United States, beginning in Detroit (1953) and Chicago (1956). Although the methods used have evolved over time, the general approach to transport analysis in Ukraine still closely mirrors those early studies, relying on an aggregate four-stage computerized transport model. Over the years, these models have steadily grown in complexity and sophistication. They are widely used both locally and internationally, with numerous variations of computer modeling suites developed to support their application.

Early Beginnings (1950s-1960s): The early days of transport modeling were influenced by the rapid growth of urban areas and the need to plan road networks efficiently. The first models focused primarily on predicting traffic flow and were based on empirical observations and mathematical formulations.

Key Developments: Detroit Metropolitan Area Traffic Study (1953): One of the earliest large-scale transport models.

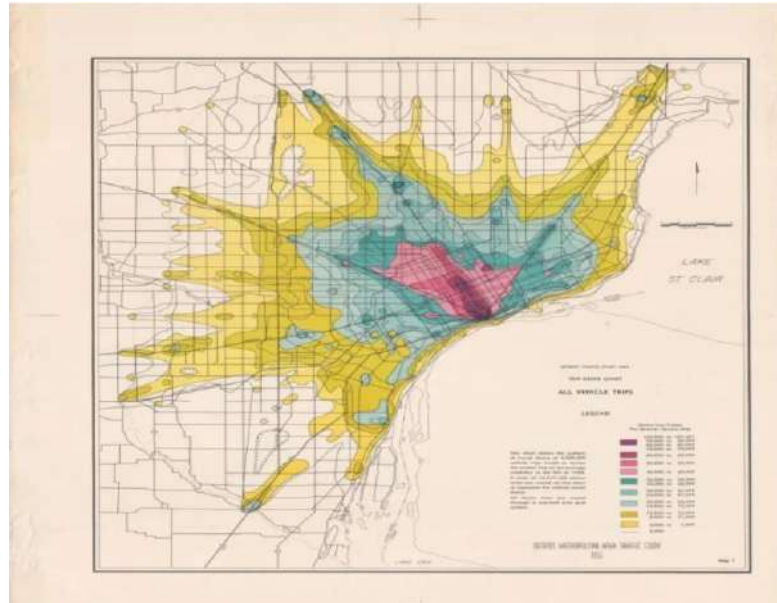


Figure 1.1 - Detroit Metropolitan Area transport model

Four-Step Model: Developed in the 1950s and still widely used today, this model includes trip generation, trip distribution, mode choice, and route assignment.



Figure 1.2 - Four-Step Model

Growth of Computational Models (1970s-1980s): Advances in computing allowed for more sophisticated models that could handle larger datasets and provide more detailed predictions.

Key Developments: Urban Transportation Planning System (UTPS): Developed by the US Federal Highway Administration, UTPS provided standardized tools for transport modeling. Equilibrium Traffic Assignment Models: Introduced the concept of network equilibrium, where demand and supply are balanced.

Activity-Based Models (1990s): In the 1990s, the limitations of the traditional four-step model led to the development of more detailed models that considered individual travel behavior. These models were called Activity-Based Models (ABM) [3], focusing on the sequences of activities and trips by individuals throughout the day.

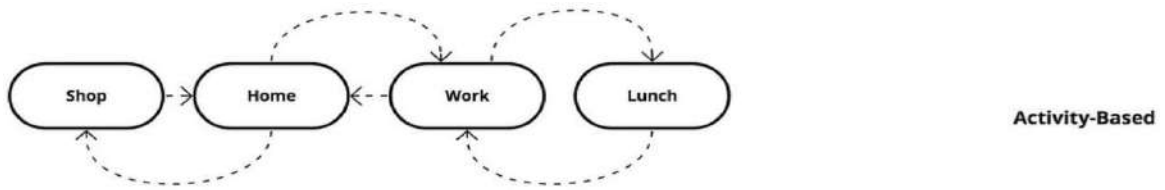


Figure 1.3 - Activity – based model

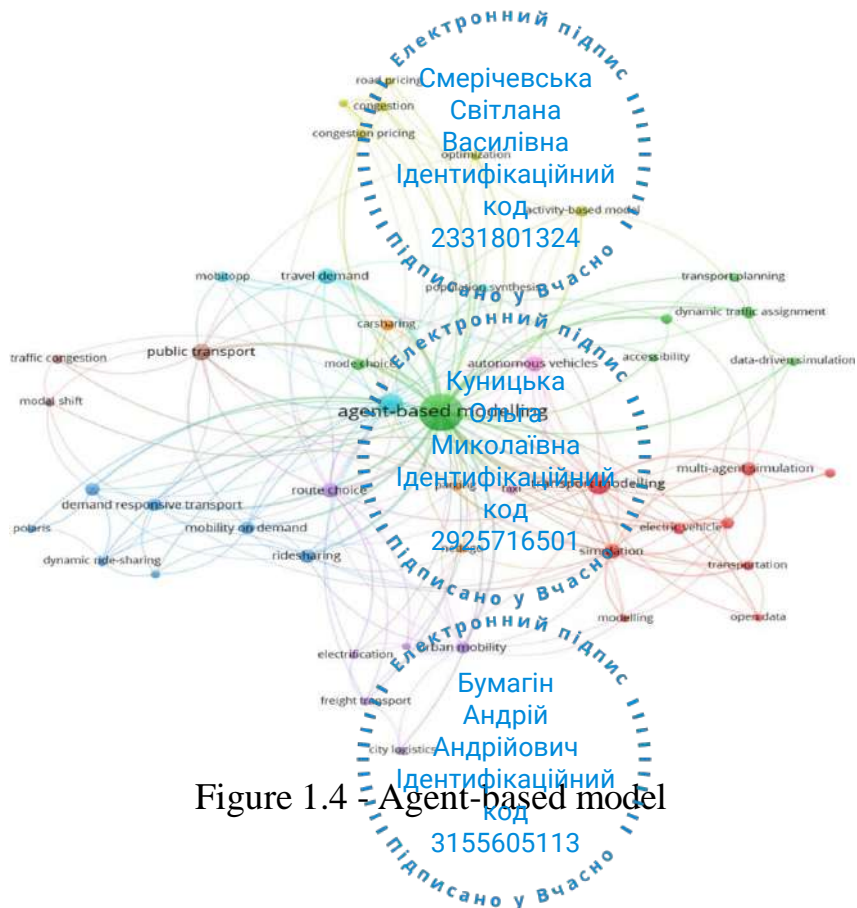


Figure 1.4 - Agent-based model

Agent-Based Models (2000s-Present): Agent-Based Models (ABMs) [4], simulate the actions and interactions of individual agents (e.g., travelers, vehicles) to assess the effects on the transportation system. These models are particularly useful for capturing complex, dynamic systems.

Integration with Land Use and Environmental Models (2000s-Present): Modern models integrate transport with land use, environmental impacts, and socio-economic factors to provide a holistic view of urban dynamics.[5], [6]

Big Data and Machine Learning (2010s-Present): The advent of big data and machine learning has transformed transport modeling by enabling real-time data analysis, more accurate predictions, and dynamic modeling capabilities. [7]

History of Transport Modeling in Ukraine.

Soviet Period (up to 1991): During the Soviet period, transport planning in Ukraine was part of the overall Soviet planning system. The main focus was on mass transportation modes, such as public transport, railways, and freight transport. Modeling methods were based on simple mathematical models and empirical data, without considering behavioral aspects of passengers or integrating other elements of urban infrastructure.

Beginning of Independence (1990s): After the collapse of the Soviet Union, economic difficulties and insufficient funding led to stagnation in the development of transport modeling. Most approaches remained at the level of Soviet methods. Interest in Western approaches, such as the four-stage model, grew, but limited resources hindered the implementation of innovative methods.

Period of International Experience Implementation (2000s): Starting in the 2000s, Ukraine began actively adopting European and American approaches to transport modeling. The first comprehensive studies of urban transport systems were conducted, particularly in Kyiv, Kharkiv, and Lviv, involving Western experts and using computer models.

Modernization and Use of Advanced Technologies (2010s - Present): In the 2010s, transport modeling in Ukraine received significant development impetus due to international technical assistance programs and investments in urban infrastructure.

The first modern computerized models appeared, using software like PTV Vissim, Aimsun, and other tools for traffic flow modeling. Research began integrating data from GPS, mobile apps, and social networks to analyze citizens' transportation behavior.

Adaptation to Modern Challenges and Integration with Urban Planning. Contemporary transport modeling in Ukraine aims to integrate environmental aspects, develop bicycle infrastructure and pedestrian zones, and consider public opinion through big data analytics. Projects aimed at improving urban transport, such as Smart City Kyiv, play a significant role, integrating IoT technologies for traffic management. In recent years, several Ukrainian cities have developed transport models using PTV Vision VISUM software and are now successfully operating them. Among these cities are Lviv, Ivano-Frankivsk, Kyiv, Mariupol, Mykolaiv, Poltava, Zhytomyr, Vinnytsia, Chernivtsi, and Dnipro. [23], [24], [25]

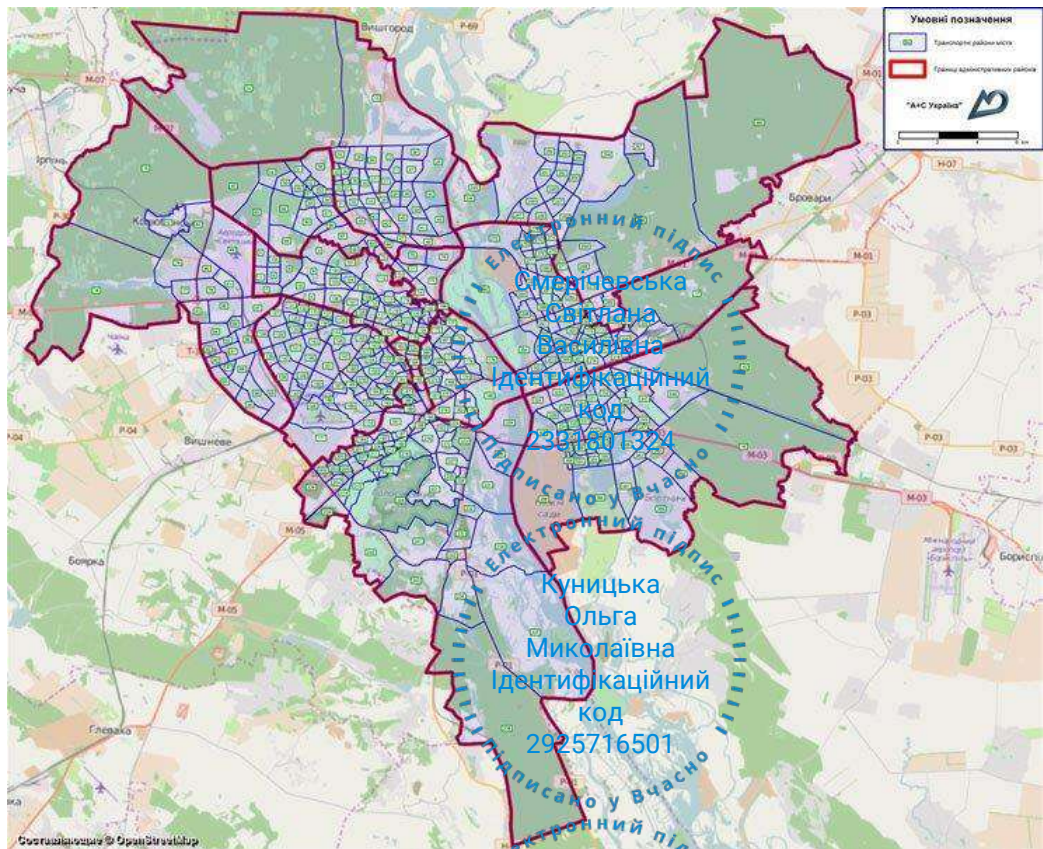


Figure 1.5 - Kyiv transport zones model



Figure 1.6 - Transport model of Mariupol

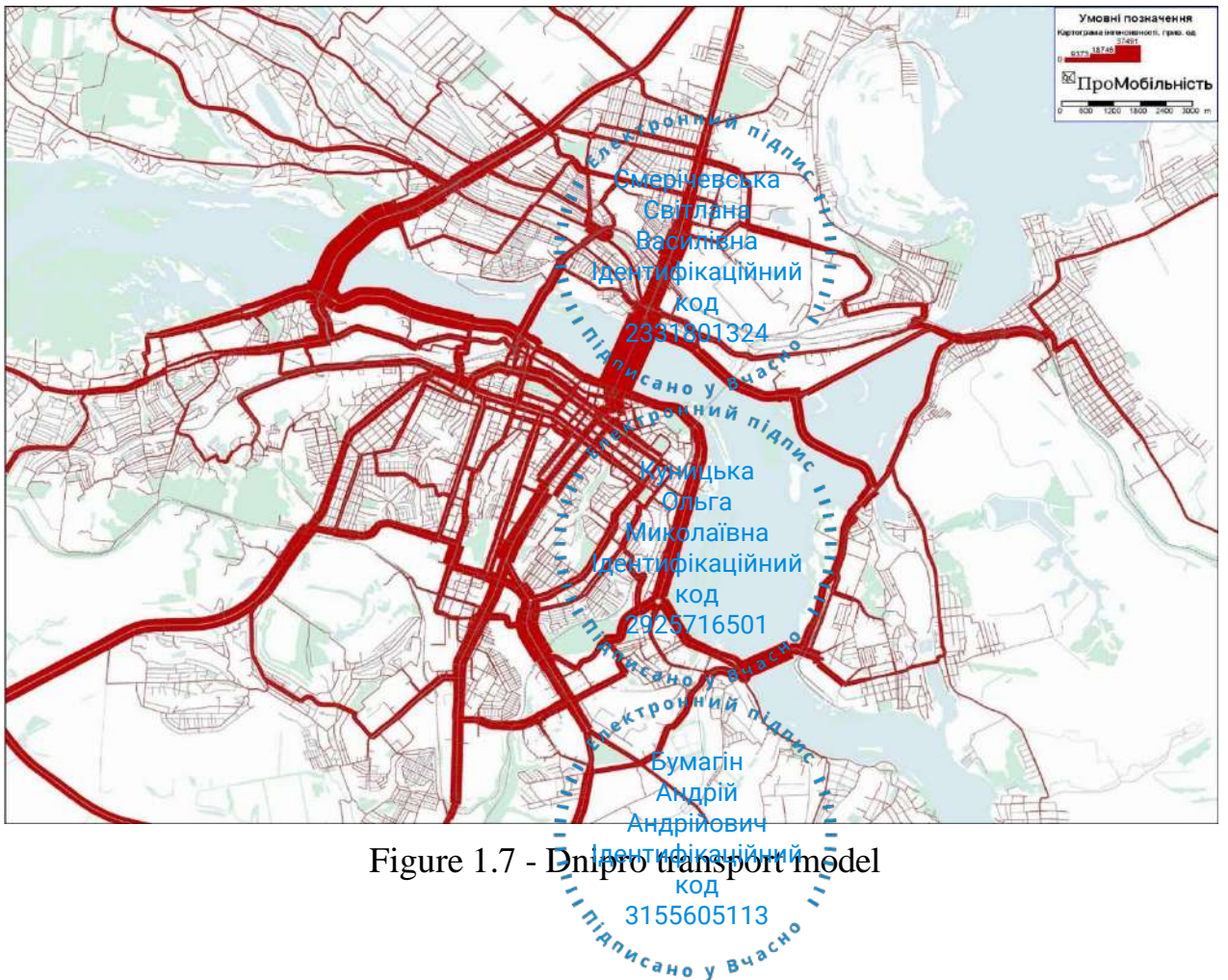


Figure 1.7 - Dnipro transport model

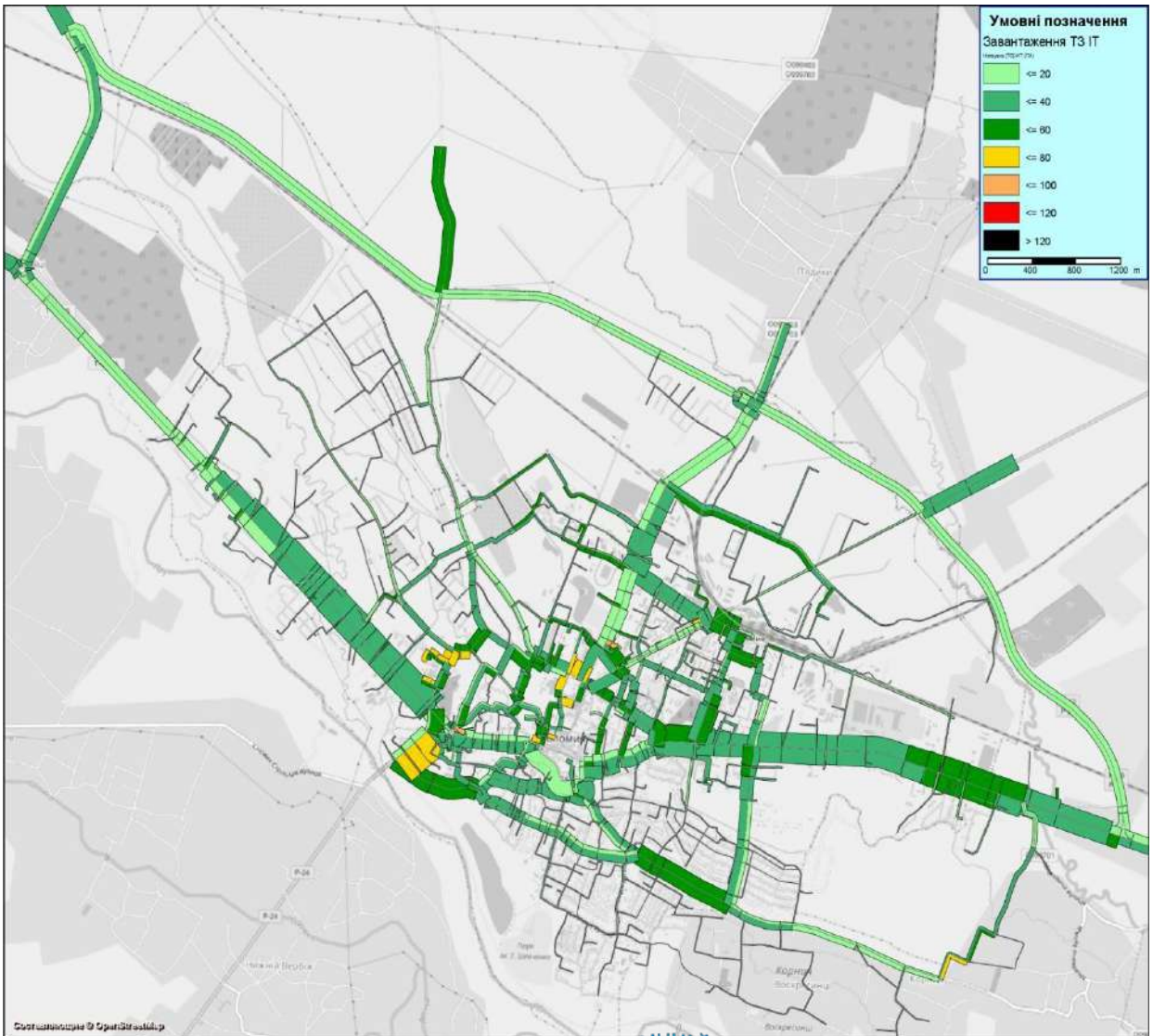


Figure 1.8 - Kolomyia transport model

1.2 Macro-scale transport modeling software review.

Macro-scale transport modeling involves analyzing large-scale transportation networks, often at the city, regional, or even national level, to assess travel demand, traffic flow, and overall system performance. The software used for this type of modeling typically focuses on strategic planning, policy analysis, and long-term forecasting. Here are some of the most widely used and highly regarded software tools for macro-scale transport modeling:

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1. EMME.

Overview: EMME, developed by INRO, is a high-performance software designed for multi-modal transportation planning. It is commonly used by government agencies, metropolitan planning organizations, and consulting firms.

Features: Flexible Modeling: Supports macro, meso, and micro-level modeling, making it versatile for different scales.

Advanced Demand Modeling: Offers advanced trip generation, distribution, mode choice, and assignment algorithms.

Scenario Analysis: Allows users to create multiple scenarios to evaluate the impact of different transportation policies or infrastructure changes.

Dynamic Traffic Assignment (DTA): Provides capabilities for simulating real-time traffic flows, improving model accuracy.

Customizable Interface: Scriptable using Python, allowing users to customize models and automate processes.

Robust Reporting Tools: Offers advanced reporting and visualization tools for presenting results to stakeholders.

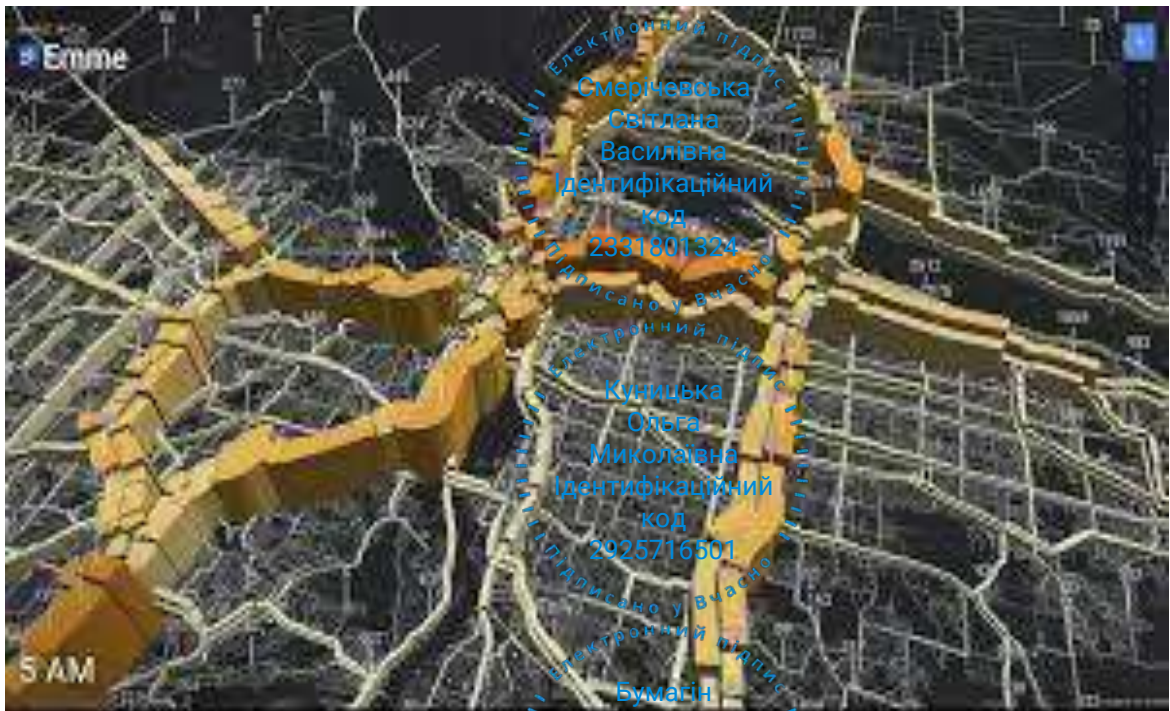


Figure 1.9 - Transport model in Emme software

3. TransCAD.

Overview: TransCAD, developed by Caliper Corporation, is a powerful GIS-based software specifically designed for transportation planning and logistics.

Features: GIS-Based Modeling: Combines GIS capabilities with traditional transport modeling tools, providing a comprehensive platform for spatial and transport analysis.

Flexible Demand Modeling: Supports various demand modeling techniques, including four-step, activity-based, and tour-based approaches.

Data Visualization: Advanced tools for visualizing transport networks, demand patterns, and traffic flows.

Scenario Testing: Facilitates the creation and comparison of different transport scenarios, such as policy changes or infrastructure improvements.

Intermodal Analysis: Capable of modeling intermodal transport, including public transit, highways, and freight logistics.

Optimization Tools: Includes optimization for route planning, scheduling, and network design. [9]

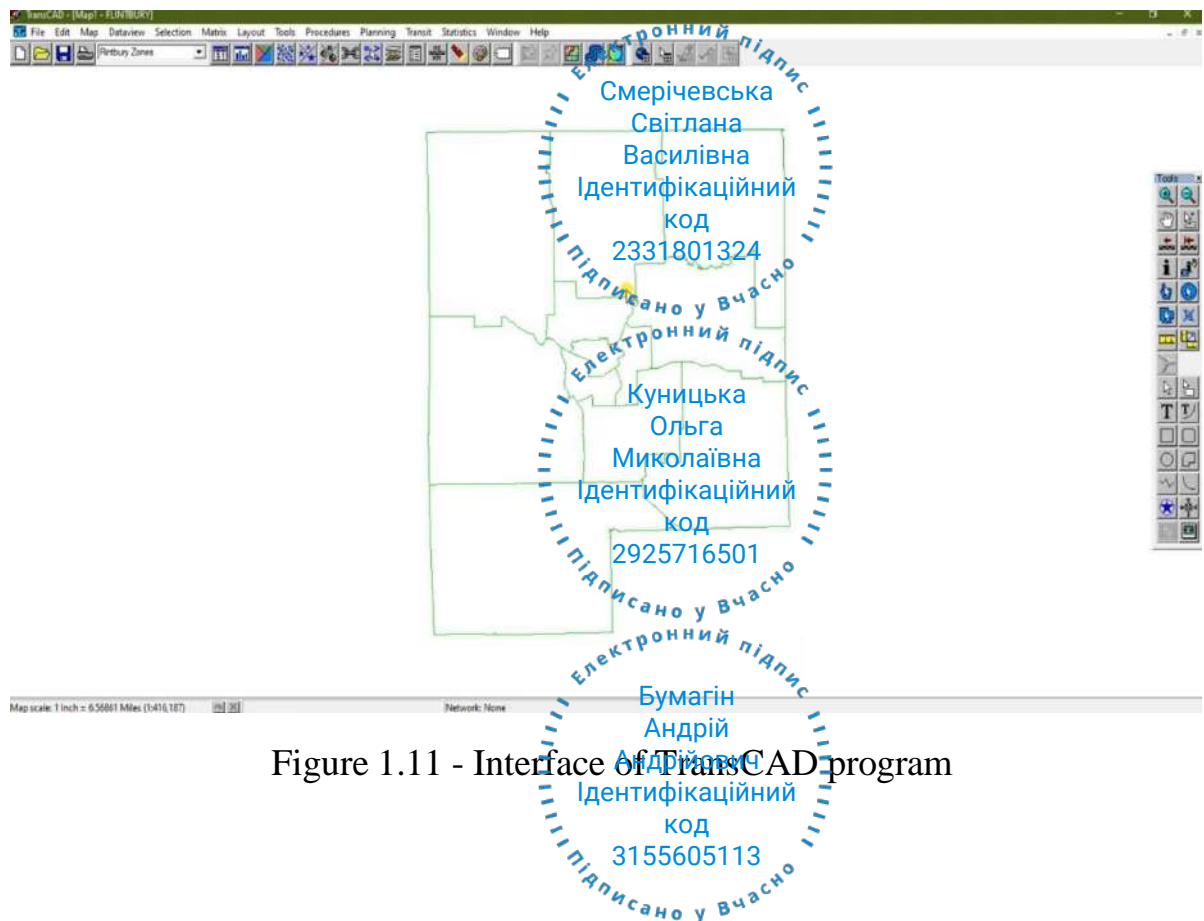


Figure 1.11 - Interface of TransCAD program

4. SATURN.

Overview: SATURN (Simulation and Assignment of Traffic to Urban Road Networks), developed by the University of Leeds, is widely used in the UK for modeling road traffic at both micro and macro scales.

Features: Traffic Assignment: Robust assignment techniques, including capacity restraint and dynamic assignment for congestion modeling.

Detailed Network Representation: Ability to model detailed junctions, signal controls, and road layouts.

Scenario Analysis: Users can evaluate the impact of different transport policies, road improvements, and traffic management strategies.

Signal Optimization: Tools for optimizing traffic signals and improving flow in congested urban networks.

Integration with Other Models: Can be integrated with meso and micro-simulation models for more detailed analysis. [10]

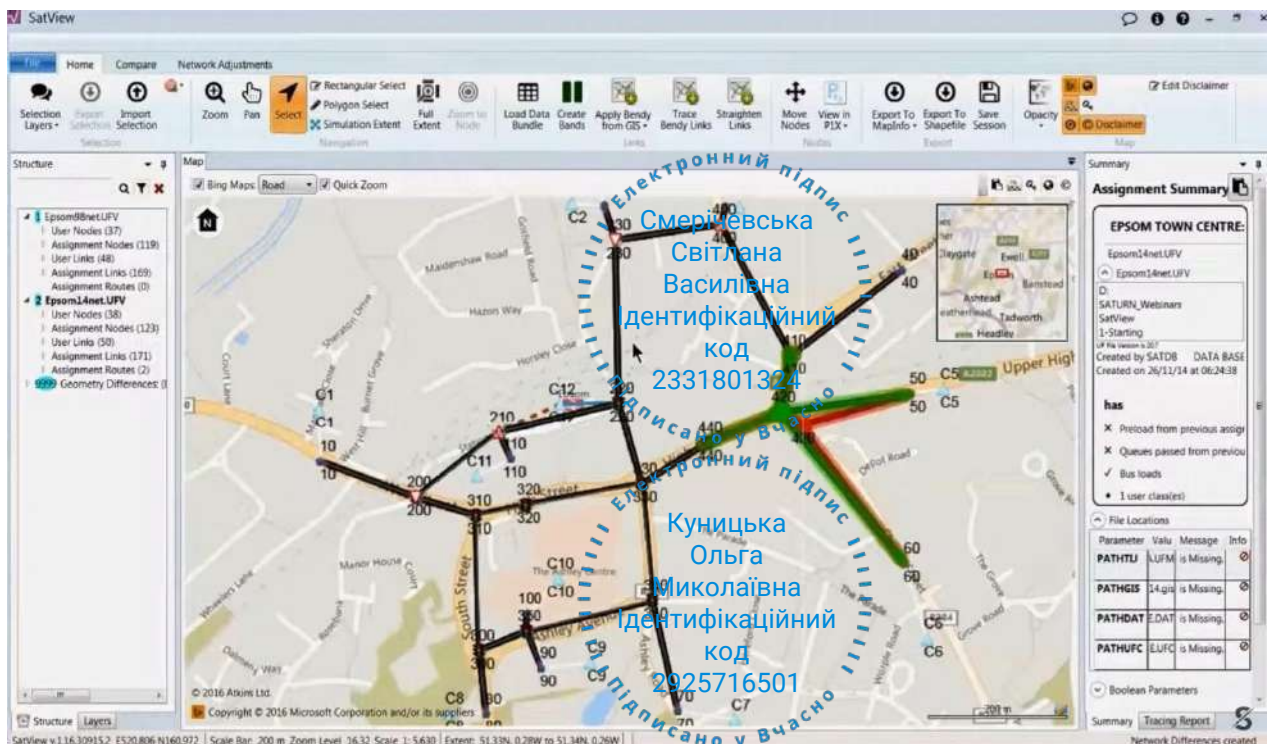


Figure 1.12 - Interface of SATURN program

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1.3 Macro-Scale Modeling Using PTV VISUM

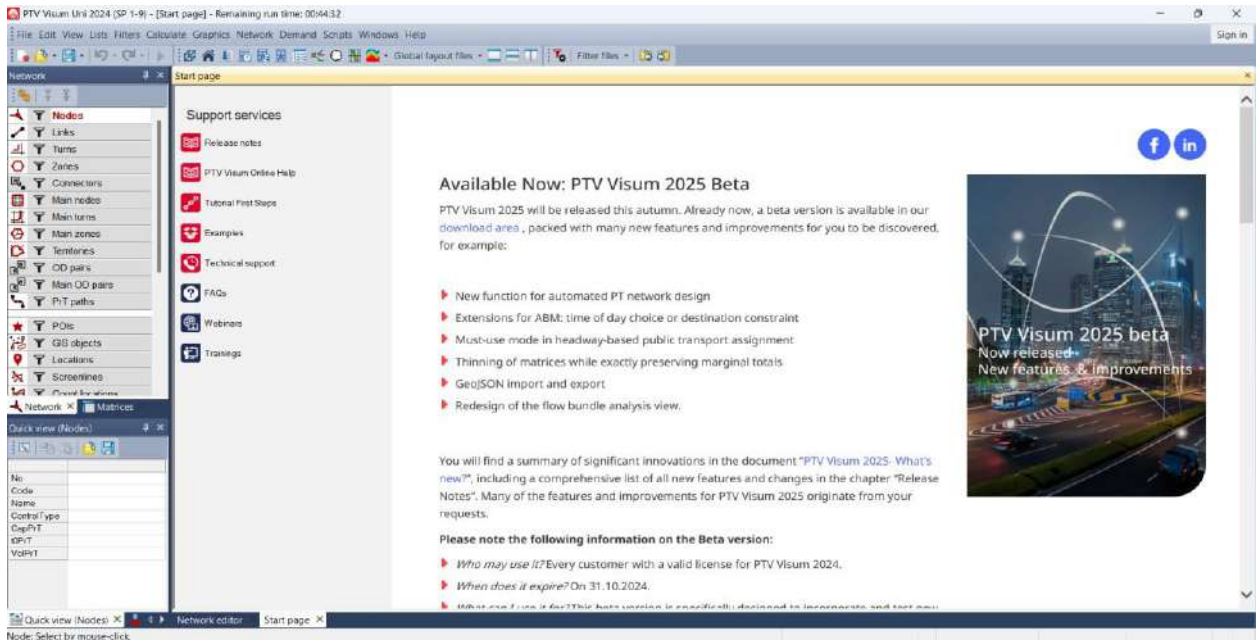


Figure 1.13 - Interface of PTV VISUM program

PTV VISUM is a leading software for transportation planning and macro-scale modeling, developed by PTV Group. It is designed to support strategic planning and policy analysis by providing robust tools for modeling transportation networks at city, regional, and national levels. Here's a detailed description of its features and main characteristics:

Features of PTV VISUM. Comprehensive Modeling Capabilities: Four-Step Modeling Process: VISUM supports the traditional four-step model, which includes trip generation, trip distribution, mode choice, and trip assignment. This approach is foundational for macro-scale transportation planning. **Activity-Based Modeling:** For more detailed analysis, VISUM also offers support for activity-based modeling, which accounts for the complexity of travel behavior by considering daily activity patterns.

Flexible Data Integration: GIS Integration: VISUM integrates with Geographic Information Systems (GIS), allowing users to incorporate spatial data into their models. This feature enhances the visualization and analysis of transportation

networks and land use. Data Import/Export: Supports a wide range of data formats for importing and exporting data, ensuring compatibility with other software and data sources.

Advanced Scenario Management. Scenario Analysis: Users can create and evaluate multiple scenarios to assess the impact of different transportation policies, infrastructure changes, or land use developments. This is crucial for strategic planning and decision-making. Scenario Comparison: VISUM allows for the comparison of different scenarios to analyze the effects on traffic flow, travel demand, and network performance.

Traffic Assignment and Network Analysis. Traffic Assignment: VISUM offers detailed traffic assignment techniques, including static and dynamic assignment methods, to simulate how traffic distributes across a network under various conditions. Network Analysis: Provides tools for analyzing network performance, including congestion analysis, travel time estimation, and capacity analysis.

Public Transport Modeling. Public Transport Integration: VISUM includes advanced features for modeling public transportation systems, such as buses, trams, and trains. It supports schedule-based modeling, route planning, and optimization. Accessibility Analysis: Evaluates accessibility to public transport services and their impact on travel behavior.

User-Friendly Interface: Graphical User Interface: VISUM offers an intuitive graphical user interface that simplifies model setup, data input, and visualization. Users can easily interact with the model using drag-and-drop features and customizable views. Visualization Tools: Provides various visualization options, including maps, charts, and graphs, to help users interpret model results and present findings effectively.

Optimization and Performance Evaluation. Optimization Tools: Includes tools for optimizing traffic signals, public transport schedules, and other aspects of transportation management to improve overall system performance. Performance Metrics: Offers a range of performance metrics to evaluate the effectiveness of different transport scenarios and strategies.

Integration with Other Tools. Interoperability: VISUM can be integrated with other PTV tools, such as PTV Vissim for micro-simulation and PTV Optima for real-time traffic management, providing a comprehensive solution for transportation planning. **APIs and Extensions:** Supports custom extensions and APIs, allowing users to tailor the software to their specific needs and integrate with other systems.

Main Characteristics. Scalability: VISUM is designed to handle large-scale transportation networks, making it suitable for city-wide, regional, and national level modeling. **Flexibility:** The software's flexibility allows users to model a wide range of transportation scenarios, from simple traffic flow analysis to complex multi-modal planning. **Accuracy:** With advanced algorithms and data integration capabilities, VISUM provides accurate predictions and insights into transportation system performance. **Ease of Use:** The user-friendly interface and extensive support resources make VISUM accessible to both experienced modelers and newcomers to transportation planning.

Applications. Strategic Planning: Used for long-term planning and policy analysis, including evaluating the impact of new infrastructure projects, land use changes, and transportation policies.

Demand Forecasting: Helps forecast future travel demand and assess the effectiveness of different transportation strategies.

Scenario Evaluation: Enables the analysis of various scenarios to support decision-making processes related to transportation planning and management.

Overall, PTV VISUM is a powerful and versatile tool for macro-scale transportation modeling, offering a range of features that support comprehensive analysis and strategic planning.

Key functions of PTV Visum.

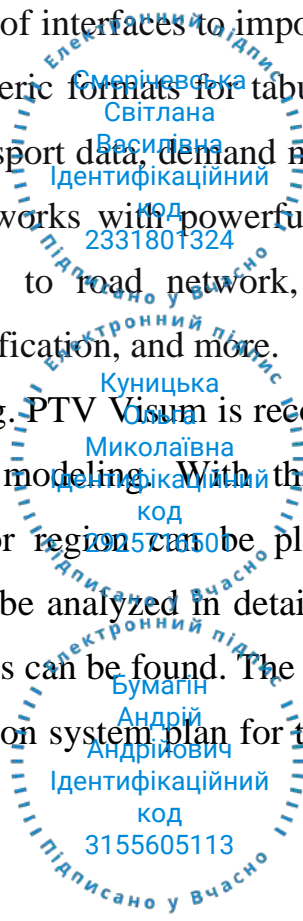
Efficiently set up and managed development scenarios. As the transport system evolves, the right decisions need to be made. With integrated scenario management, PTV Visum allows for effective preparation and evaluation of numerous scenarios. Modifications to the model, such as infrastructure developments, new transit lines, population forecasts, and zoning policies, can be created and managed. Scenarios are

then composed and evaluated through batch computations. Key KPIs are defined and extracted according to planning goals, and comparisons are made to determine the best plan for the community. Individual scenario variants are compared down to the smallest detail. When networks or inputs are changed, the scenario manager highlights results that may no longer be valid.

High-performance algorithms for quick and accurate results. PTV Visum transport planning software enhances the evolution of mobility systems by providing data-driven scenario assessments. These models are inherently complex due to the diverse nature of human mobility and its interactions with the environment. To efficiently assess numerous potential future scenarios, minimizing model run times is crucial. To this end, PTV Visum's algorithms are regularly refined with advanced methods and techniques, including contraction hierarchies and parallel processing. Significant performance boosts, particularly in traffic assignment, have been achieved in recent years. Additionally, ongoing improvements are made to other tools, such as loading, filtering, and result display functionalities.

Efficiently created and maintained transportation models. Developing and maintaining transportation models means using data from many providers and sources. PTV Visum offers a variety of interfaces to import such data and to integrate it into the model. In addition to generic formats for tabular and GIS data, there are specialized interfaces for public transport data, demand matrices, and signal controls. Build and maintain multimodal networks with powerful tools for data integration, matching of public transport lines to road network, merging of redundant or neighboring objects, timetable simplification, and more.

Multimodal transport modeling. PTV Visum is recognized as the right solution for efficient multimodal transport modeling. With this PTV transport planning software, transportation in a city or region can be planned, mode splits can be determined, all travel processes can be analyzed in detail, and the best solutions for present and future mobility challenges can be found. The PTV Visum software can be used to develop a master transportation system plan for the entire region, even when data availability is limited.



Public transport planning software. Optimization of operations and user experience. PTV Visum is the ideal public transport planning software: it provides key figures on user experience (travel times, frequency, walking times, fares), as well as operational aspects and costs (operating times, performance kilometers, empty runs, vehicle requirements, depot use). Network and timetable variants, as well as operating concepts, can be evaluated. By combining strategic transport demand models with operational assessment tools, well-informed decisions are ensured.

Public transport planning software. Fleet, infrastructure and electrification planning. For the best long-term fleet procurement and maintenance, PTV Visum provides tools for travel demand forecasting, fleet planning, and operational concepts. Fleets with different types of vehicles can be allocated according to flexible criteria, including demand. PTV Visum considers depot capacities, turning times, empty runs, and other factors. The optimal options for fleet procurement and operating costs are derived by comparing different scenarios. The transport planning software also considers electric vehicles - their unique energy consumption, charging processes, and charging infrastructure. Different operating concepts, such as overnight and opportunity charging, can be compared.

Planning and integrating new modes of mobility. PTV Visum helps transport planners and engineers to design, analyze, and integrate new modes of mobility. The transport planning software models cars, bikes, walking, and ride-sharing schemes, as well as their integration with all the variants of public transport. With PTV Visum, it's also possible to study the effects of autonomous and connected vehicles.

Assessing air and noise pollution from transport. PTV Visum includes procedures for calculations of emissions and noise from transport, so you can assess these impacts without additional software. When used early in the planning process, it can help to detect unwanted effects of transport measures, such as increases in total emissions due to detours.

Analyzing toll systems, low emission zones and access restrictions. PTV Visum can be used to model toll systems and access restrictions, such as low emissions zones (LEZs) or bans on trips for through-traffic. For area-wide restrictions

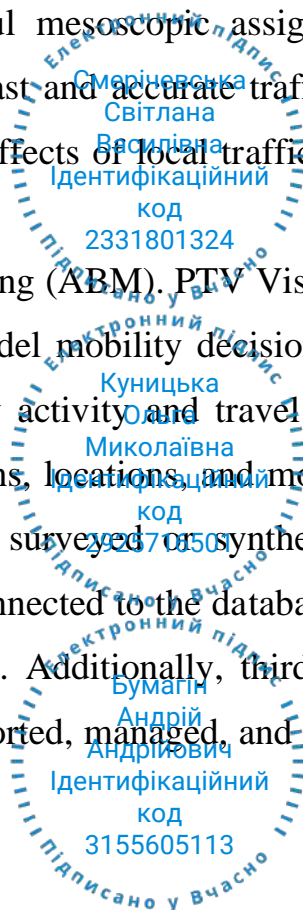
like LEZs, resulting detours in routing and KPIs are considered by the software. Toll systems are studied as distance-based, area-wide, or as tariffs between network access points. A special assignment procedure is employed to provide a realistic representation of user preferences between toll costs and travel times. As a result, the effects of tolls on users' route lengths, travel times, and costs, as well as the expected revenues for operators, can be evaluated.

Visualization and flexible graphics. With PTV Visum, transport model has more impact through meaningful maps, diagrams, and 3D presentations. Even non-experts will easily understand the results and conclusions. PTV Visum offers a variety of interactive graphic tools for analyzing and editing data – all flexible and adoptable for different users needs. Special tools for public transport include graphical timetable, schematic line network plan, and graphical block editor. The windows can be arranged on several screens, and can be switched between configurations. A synchronization mechanism ensures that different representations are focused on the same selected objects.

Detailed traffic flow simulation of large-scale transport networks. To get a better level of detail when planning roads, PTV Visum offers enhanced operational modeling capabilities. The powerful mesoscopic assignment method Simulation-Based Assignment (SBA) enables fast and accurate traffic flow simulation of large networks. As a result, the network effects of local traffic management strategies are assessed easily and accurately.

Activity-based demand modeling (ABM). PTV Visum supports Activity-Based Demand Models (ABM), which model mobility decisions of individuals instead of groups of people. As a result, daily activity and travel schedules are created with information on start times, time spans, locations, and mode. ABM demand data can be easily integrated and managed; surveyed or synthesized households, persons, tours, and trips can be stored and connected to the database. Trips can be assigned to static assignment paths for analysis. Additionally, third-party highway and transit simulation model results can be imported, managed, and analyzed using PTV Visum.

[11]



Examples of solutions made with PTV Visum in Ukraine. PTV Visum allows professionals in logistics, urban planning, public transportation field and other related industries create models of different scales and purposes.

Transport modeling of the marathon organization in Kyiv. The purpose of the project: Evaluation of traffic reorganization options on the street and road network related to sports events. [26]

Results: Comparative characteristics of the transport system characteristics, traffic volumes, congestion level and difference maps, location of “bottlenecks” with different streets blocking options. [12]

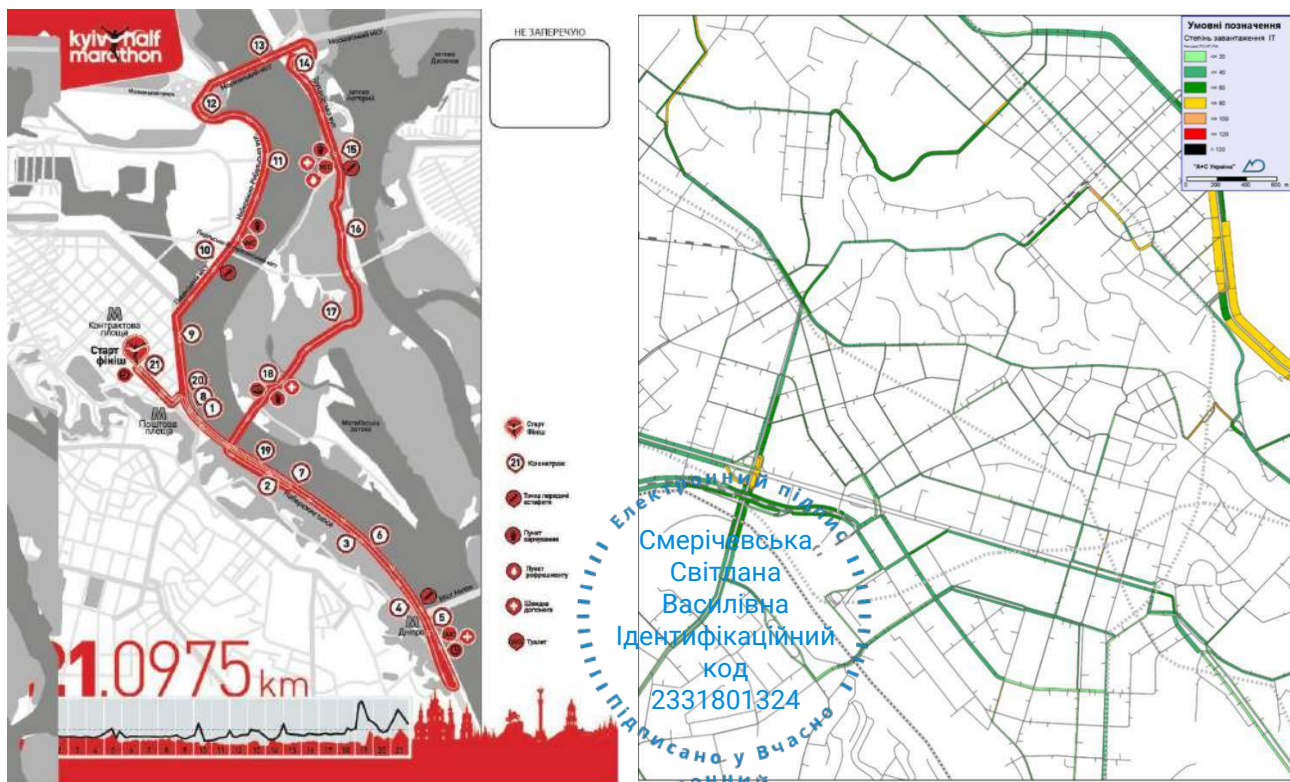


Figure 1.14 - Transport modeling of the marathon organization in Kyiv

Updating the transport model of Vinnytsia. The purpose of the project: Update of the transport model of Vinnytsia. Results: report with a description of the work performed and identified problem areas of the city's transport system, updated city transport model files, geospatial data files characterizing the city's transport system. [13]

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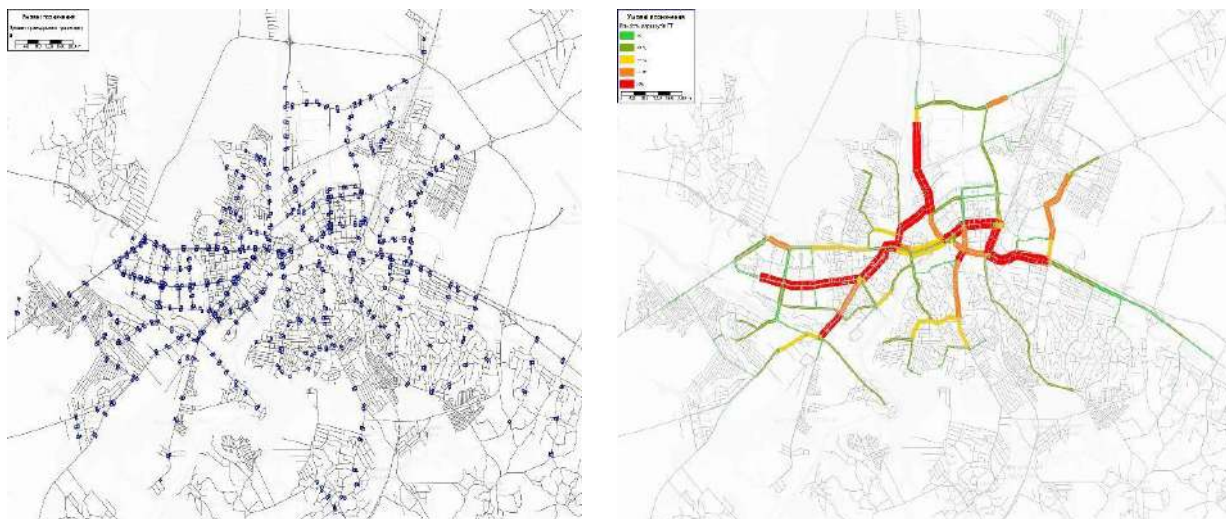


Figure 1.15 - Updated transport model of Vinnytsia

Development of the transport model of city of Kyiv and its suburban area. Formation of a database of information on transport demand and transport supply. The purpose of the project: Establishment of an expert tool to support justification and decision-making in the field of transport infrastructure management of city of Kyiv and its suburban area based on a unified transport model. Results: Transport model development report. Survey databases. [14]

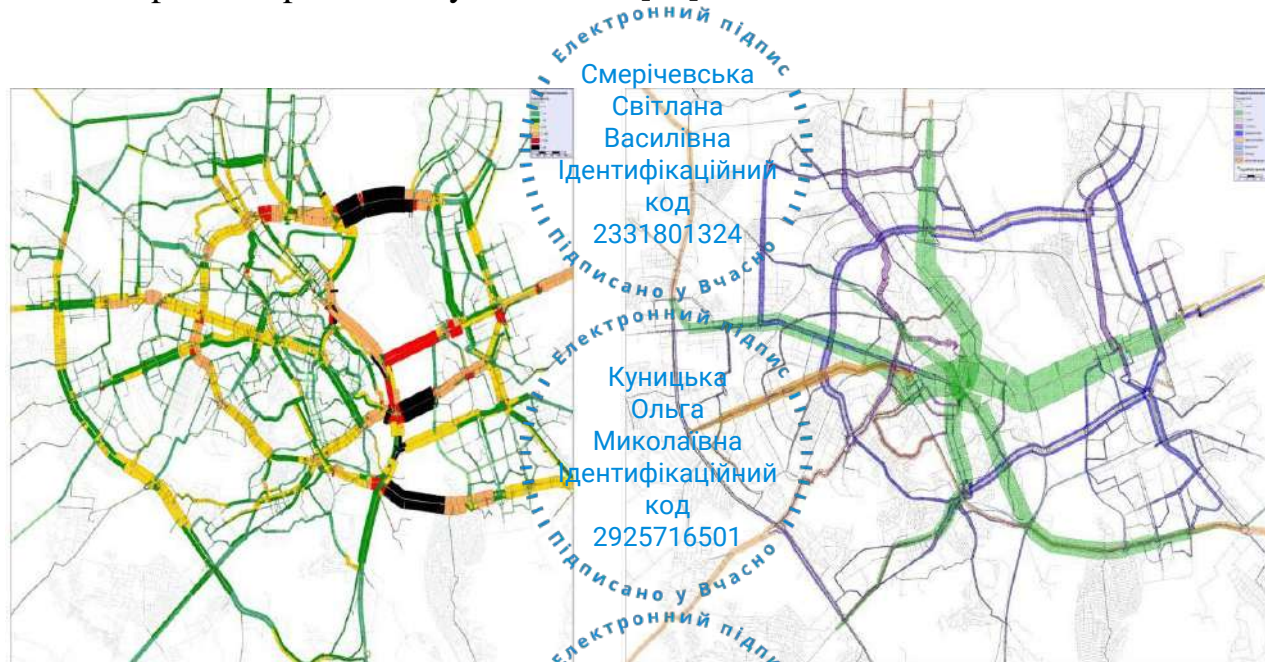


Figure 1.16 - Kyiv transport model

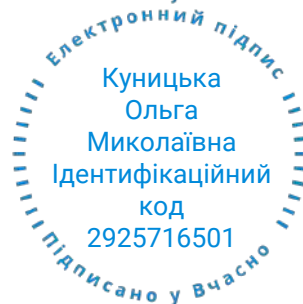
Chapter 1 summary

This chapter collectively provides a comprehensive foundation for understanding the evolution and current practices in transport modeling, with a particular emphasis on the tools and methodologies employed in large-scale transportation planning. It offers a detailed exploration of how transport modeling has developed over time, from its early beginnings rooted in simple empirical methods to its modern-day applications that involve sophisticated computational models, big data integration, and advanced simulation techniques. The chapter not only discusses the historical context of transport modeling but also examines the specific methodologies used in macro-scale planning, which often involves analyzing transportation networks that span entire cities, regions, or even countries. These large-scale models are crucial for addressing complex issues such as traffic congestion, urban sprawl, multimodal transportation, environmental impact, and the integration of new transportation technologies.

The chapter delves into the strengths and limitations of various macro-scale modeling tools, offering an in-depth review of leading software used by transportation professionals worldwide. By evaluating popular modeling platforms, including PTV VISUM, VISSIM, EMME, and SATURN, it highlights the diverse capabilities each offers in simulating traffic flows, modeling different transportation modes, assessing infrastructure needs, and supporting policy decision-making processes.

A central focus of the chapter is on PTV VISUM, a widely used software tool that excels in large-scale transport modeling. It examines VISUM's unique features, such as its ability to integrate multi-modal transport systems, handle complex demand scenarios, and provide detailed traffic assignments. The chapter also illustrates how VISUM aids in the optimization of transportation networks by helping planners evaluate the effects of different scenarios, including changes in land use, infrastructure investment, and transportation policies. By using case studies and real-

world applications, the chapter demonstrates how PTV VISUM plays a pivotal role in addressing the challenges of macro-scale modeling, offering transportation planners a powerful tool for informed decision-making and fostering the development of sustainable, efficient, and well-connected transportation systems. Overall, this chapter underscores the importance of advanced modeling tools in contemporary transport planning and the critical role they play in shaping the future of transportation infrastructure on a large scale.



CHAPTER 2

METHODOLOGY OF CREATING TRANSPORT MODEL

2.1 Basics and types of transport models

A Transport Model is a computer-based simulation that represents the movement of people and goods (trips) within a defined ‘Study Area’ with specific socio-economic and land-use characteristics. It is designed to predict how trips will adapt over time to changes in transport supply and demand, which could result from variations in transport needs or modifications to the transport network, such as the construction of new infrastructure.

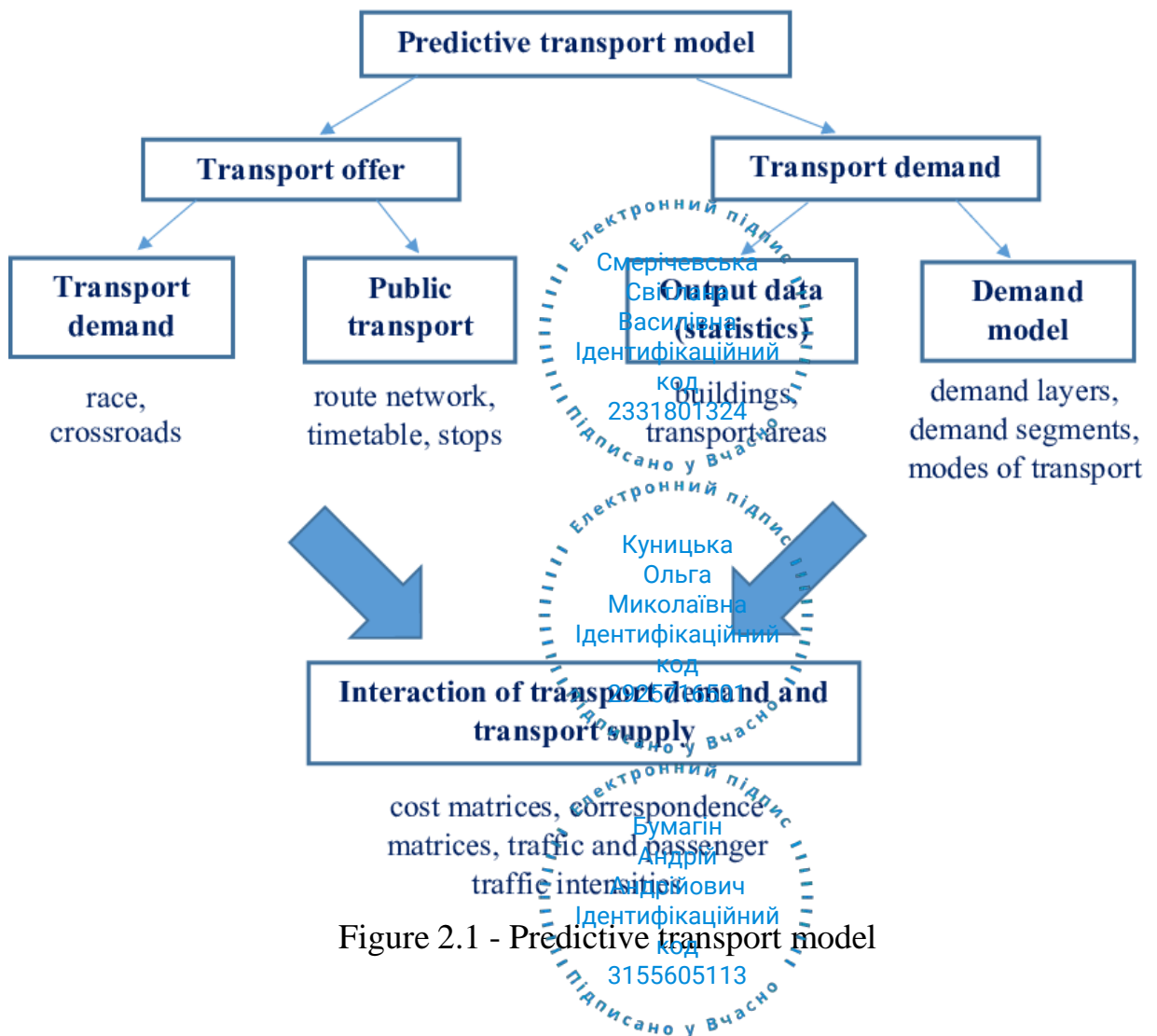


Figure 2.1 - Predictive transport model

The outputs of a Transport Model provide valuable insights into current or future transport issues, aiding in the design of infrastructure and operational planning. Additionally, it can assess the potential impacts of proposed projects, strategies, or transport/environmental policies. Thus, the Transport Model serves as a critical tool for decision-making support.

A Transport Model is a tool that provides quantitative and qualitative assessments of the potential impacts of various planning-level scenarios ("What if?"). It serves as a critical analytical input for the planning and decision-making process. The model can be applied in various ways to inform this process, including:

- analyzing the function of existing infrastructure in terms of passenger demographics, freight types, trip types, and their origins and destinations;
- identifying network bottlenecks and determining the need for additional capacity;
- supplying demand data for evaluating, designing, and sizing new infrastructure and operational services (e.g., public transport schedules) that meet forecast traffic and functional requirements;
- assessing the impact of new transport schemes on traffic flows within the modeled network, including multi-modal analysis, if necessary, to show how demand responds to new infrastructure and the resulting conditions;
- evaluating how transport conditions will evolve in response to changes in population, employment, economic activity, car ownership, and development patterns;
- analyzing the impacts of changes in public transport routes, frequencies, speeds, or accessibility on passenger numbers and revenues;
- examining the relationship between land use changes and the resulting transport demand.

Ultimately, the outputs from a transport model provide critical quantitative data that support scheme design, Cost-Benefit Analysis, Financial Analysis, and Environmental Assessment. It is essential for modeling teams to ensure that the outputs are reliable, as end-users depend on robust transport forecasts. A well-

designed model, based on high-quality data, will produce valuable inputs for concept and design, allowing for more informed decisions and evaluations. [15]

When creating a traffic model, it is essential to consider the purpose of the model. Transport models can be categorized based on:

- the scope of the modeled area;
- the mode of transport;
- consideration of time across the territory;
- the approach to modeling daily activities.

In practice, transport models often combine different types, which can overlap. Below are the main types of transport models:

A. Based on the extent of the modeled territory.

A.1 Macroscopic models - Used for large areas with extensive road networks to model transport flow, routing, and distribution of transport tasks. These models are often used to evaluate strategic measures, extensive transport projects (e.g., infrastructure construction), or changes in transport policies (e.g., parking policies). They are usually deterministic with low detail, focusing on broad time periods like peak hours or average days without accounting for vehicle interactions.

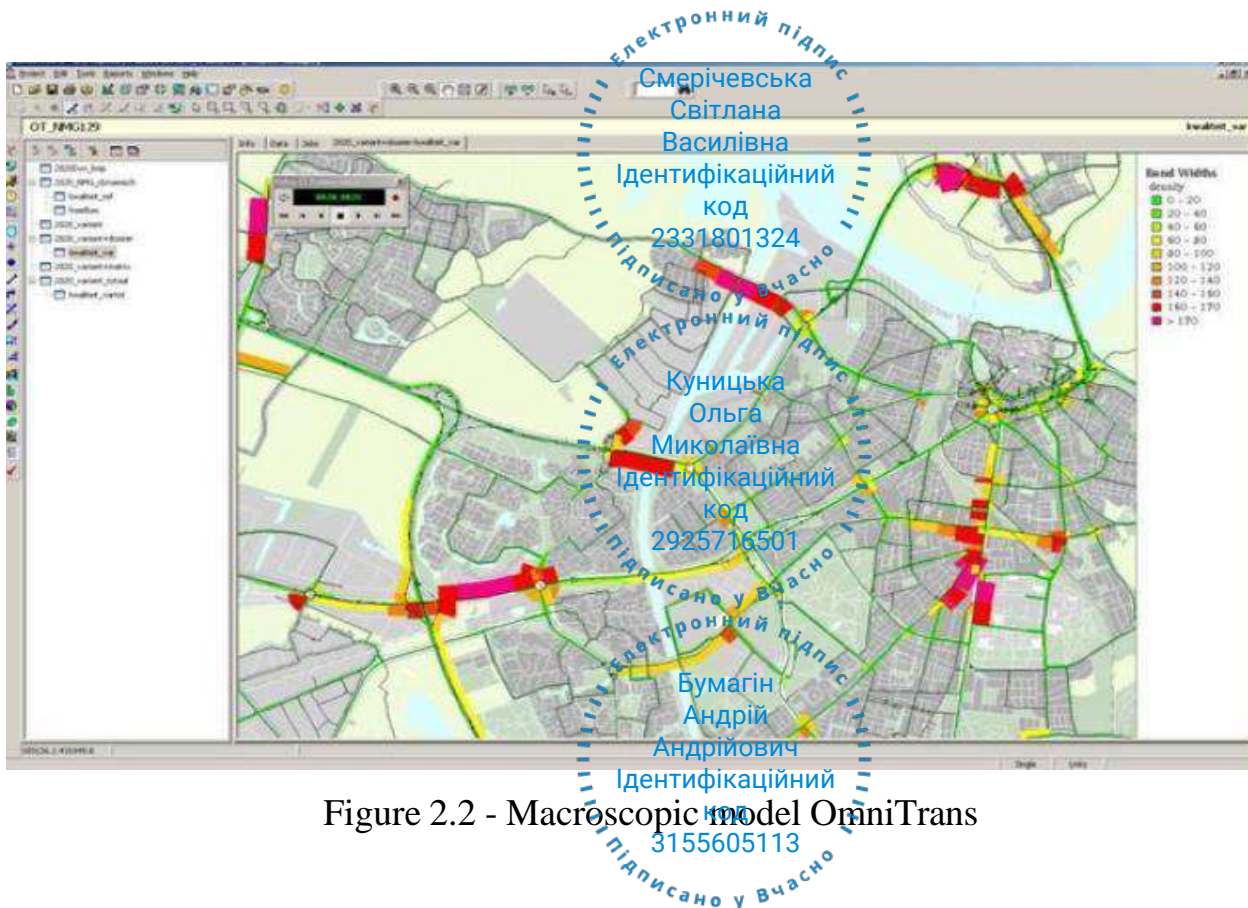


Figure 2.2 - Macroscopic model OmniTrans

A.2 Microscopic models - Focus on individual vehicles, driver behavior, and interactions within the transport flow. They require detailed spatial data, including vehicle dimensions, weight, speed, and acceleration. These models are suitable for assessing specific infrastructure designs or transport measures in localized areas (e.g., intersections).



Figure 2.3 - Microscopic model VISSIM

A.3 Mesoscopic models - Combine elements of macroscopic and microscopic models, providing detailed territory analysis without considering vehicle interactions. They model transport flows and traffic relationships with a higher territorial detail suitable for smaller units like districts or cities, useful for local public transport modeling or optimizing traffic signals.

A.4 Nanoscopic models - A subset of microscopic models, these offer greater detail in specific parameters, simulating the driving characteristics of individual elements such as lorry, bus, car drivers, cyclists, pedestrians, and people with reduced mobility.

A.5 Hybrid models - Combine the features of different models to provide varied levels of detail across different locations, optimizing model size and efficiency. These models use current traffic data and future demand predictions to reflect realistic scenarios.

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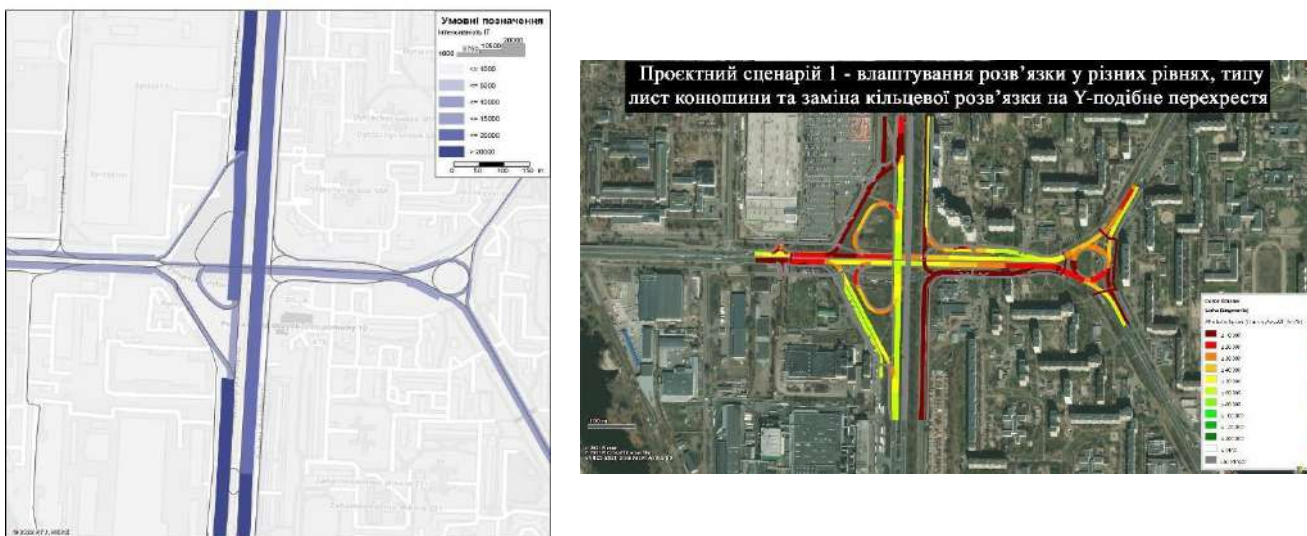


Figure 2.4 - Project of intersection in Kyiv region

B. Based on the number of transport modes:

B.1 Unimodal models - Focus on a single mode of transport, such as road or public transport. They simplify modeling by excluding decisions related to transport mode choice but are less suitable for medium- to long-term forecasts due to the lack of demand prediction capabilities.

B.2 Multimodal models - Analyze multiple transport modes and consider how competition between modes affects transport demand. They compare transport modes using generalized cost indicators (e.g., travel time, tolls, fuel costs) and simulate passenger and freight choices, making them suitable for complex transport networks.

C. Based on time considerations:

C.1 Static models - Do not account for time dynamics, calculating traffic volumes for set periods (e.g., peak hours). They generate cartograms of traffic intensities that do not change over time.

C.2 Dynamic models - Consider changes over time, suitable for analyzing phenomena that vary at short intervals. These models simulate congestion and

identify future problem areas, presenting results as animations or dynamic cartograms.

D. Based on daily activity modeling:

D.1 Models based on individual trips - Treat each trip as an independent event, widely used due to data availability and suitable for simplified modeling.

D.2 Models based on trip chains - Model daily activities as interconnected journeys, commonly used for both passenger and freight transport.

D.3 Models of trip pairs - Simulate detailed daily activity schedules based on trip purpose pairs, providing a comprehensive approach to transport demand simulation. These models require extensive data and are computationally demanding.

E. Based on the level of detail:

E.1 Aggregated models - Simulate the behavior of homogeneous population groups with specific transport needs, iteratively refining results.

E.2 Disaggregated models - Simulate individual behaviors and aggregate them into overall transport relationships, requiring detailed traffic-sociological data.

Transport models consist of a demand model, which defines transport potential based on demographic, economic, and mobility changes, and a supply model, which defines the available infrastructure to meet these needs. Transport relationships are determined by origin-destination zones, with zone size and detail varying by model type and area of interest.

F. Size of the territory and zonal division: National, regional, and local models have different zonal structures, with smaller zones needed near the area of interest.

G. Time aspect: Timeframes and modeling details differ based on the requirements of each model type.

Table 2.1 - Time periods for processing models by size

		National	Regional	Local	Microscopic
Reference period	24h	x		x	
	1h peak	x		x	x
	morning/afternoon peak hour	x			x

This structured approach helps ensure that traffic models accurately reflect the complexities of real-world transport dynamics and provide valuable insights for planning and decision-making. [16]

2.2 Model of transport supply

In developing the transport model, the following input data are utilized:

Transport infrastructure: Includes data on motorways, expressways, other road categories by national classification, local roads, railways, waterways, public transport lines, and their specific parameters.

Functional land use: Data on zone attractiveness, including the number of jobs, school places, shops, offices, and hospitals.

Zone demography: Population data segmented by different demographic groups.

Transport and traffic flows: Information on traffic intensity, composition of transport flows, routing, and occupancy levels.

Mobility of goods and people: Data on movement dynamics, car accessibility, public transport accessibility, and road lengths.

In PTV Visum the main elements of transport supply model are: nodes, links, zones and stops.

Nodes: Nodes in PTV Visum are used to represent points of interest within a transportation network. They can be used to represent various locations, such as:

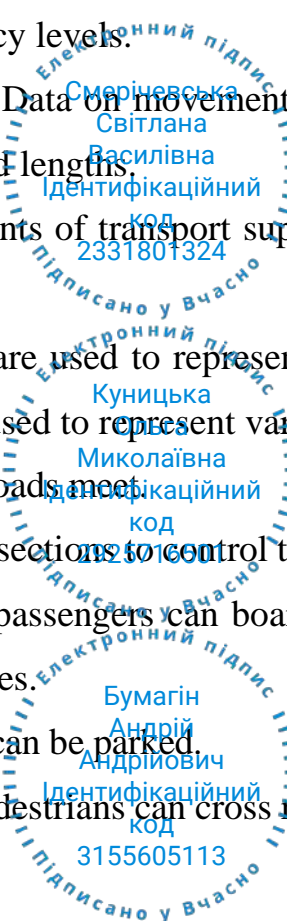
Intersections: Where multiple roads meet.

Traffic signals: Located at intersections to control traffic flow.

Public transport stops: Where passengers can board or disembark from buses, trains, or other public transport vehicles.

Parking areas: Where vehicles can be parked.

Pedestrian crossings: Where pedestrians can cross roads safely.



Other points of interest: Such as landmarks, tourist attractions, or specific locations within a network.

Nodes are essential for building and analyzing transportation networks in PTV Visum. They are used to define the geometry of the network, assign attributes to network elements (such as speed limits or road types), and route vehicles through the network.

Key information about nodes in PTV Visum typically includes:

Node ID: A unique identifier for each node.

Coordinates: The geographic location of the node (latitude and longitude).

Attributes: Additional information about the node, such as its type (intersection, stop, etc.), traffic signal timing, or parking capacity.

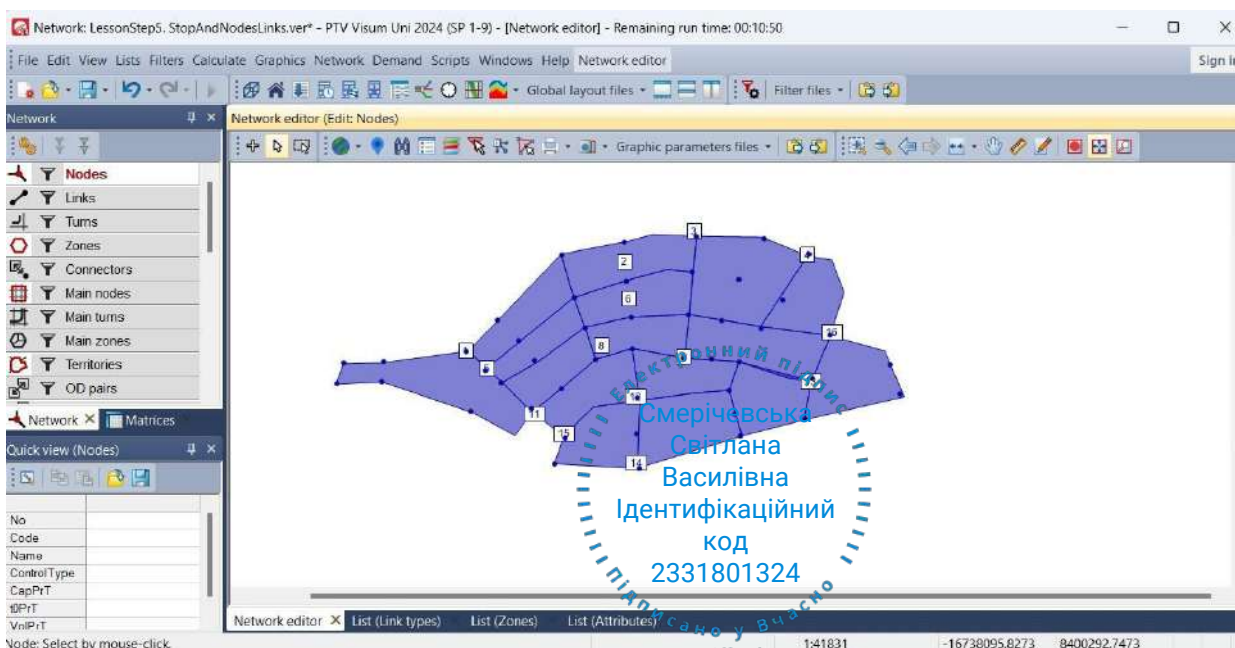


Figure 2.5 - Example of nodes distribution in PTV Visum

Links: links in PTV Visum represent the physical connections between nodes in transportation network. They are the roads, highways, railways, or even pedestrian paths that allow vehicles, pedestrians, or cyclists to move from one location to another.

Key Attributes of Links in PTV Visum.

Nodes: Each link connects two nodes.

Length: The physical distance between the two nodes.

Geometry: The shape or path of the link.

Attributes: Various properties that define the link, such as:

Capacity: The maximum number of vehicles that can pass through the link per unit time.

Speed Limit: The maximum allowable speed on the link.

Road Type: The type of road (e.g., highway, arterial, local street).

Lane Configuration: The number and type of lanes (e.g., general-purpose, bus-only, bike lane).

Traffic Control: Any traffic control devices (e.g., traffic lights, stop signs) associated with the link.

Cost: The cost associated with using the link (e.g., tolls, fuel consumption).

Creating and Editing Links in PTV Visum:

Manual Creation: Use the drawing tools to connect two nodes.

Import from External Data: Import link data from other sources (e.g., GIS data, CAD drawings).

Editing Attributes: Modify link attributes using the link editing tools.

Importance of Links in Transportation Modeling:

Network Structure: Links form the fundamental structure of your transportation network.

Traffic Flow: The flow of vehicles through the network is determined by the characteristics of links (e.g., capacity, speed limit).

Travel Time: The time it takes to travel between nodes is influenced by link attributes.

Route Choice: Links play a crucial role in determining the optimal routes for vehicles.

Network Analysis: Links are used for various analyses, such as traffic assignment, congestion modeling, and network optimization.



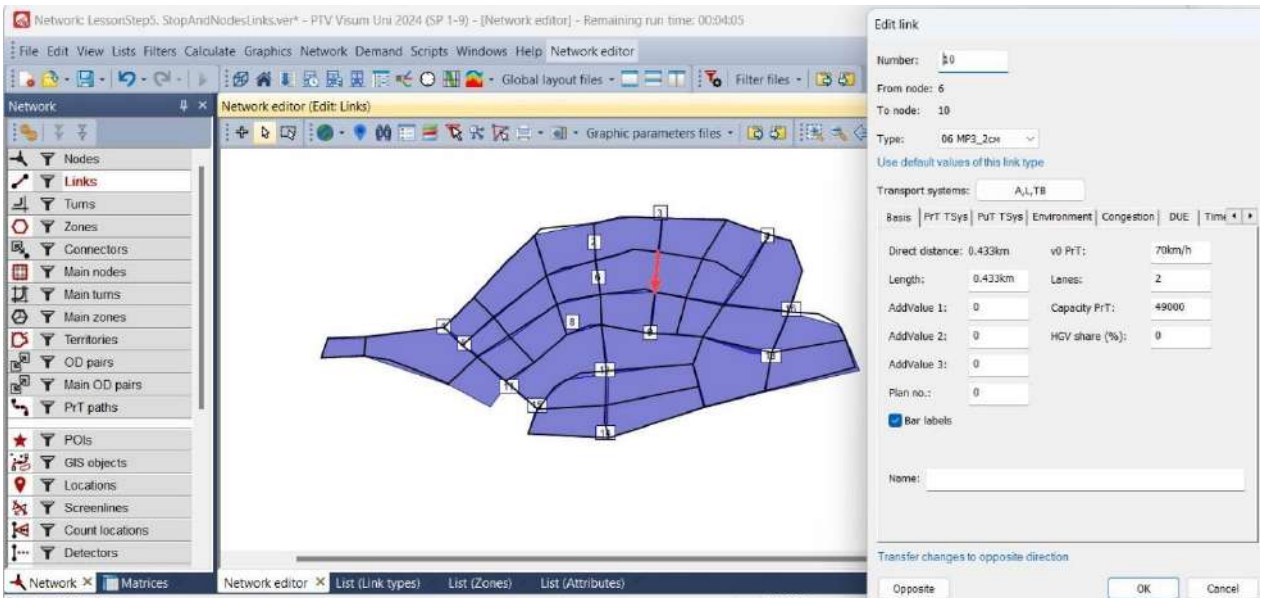


Figure 2.6 - Example of links in PTV Visum

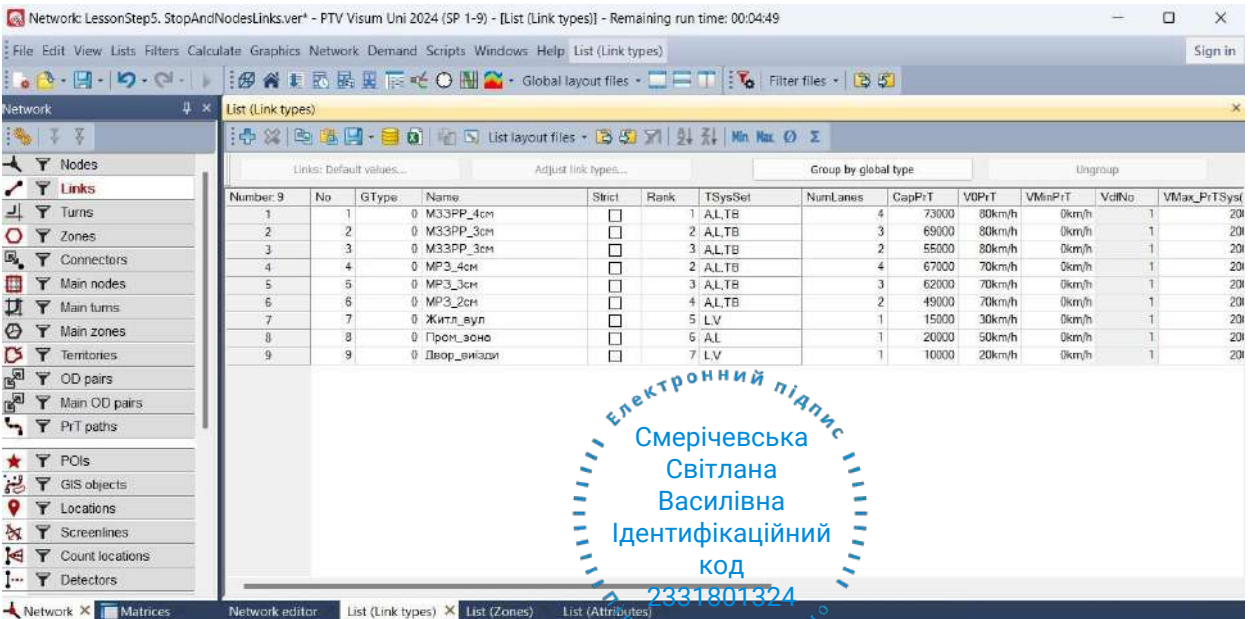


Figure 2.7 - List of links with types in PTV Visum

Zones: Zones are predefined geographic areas within the transport model that aggregate data related to land use, population, employment, and travel demand. Each zone is a distinct unit for which specific data can be collected and analyzed.

Purpose: Zones help in managing and analyzing travel demand by serving as the origin and destination points for trips. They also facilitate the aggregation of socio-economic and land use data, enabling a structured approach to modeling transportation needs.

Key Elements of Zones.

Zone Boundaries:

Definition: The geographic boundaries that define each zone within the model.

Purpose: To delineate the spatial extent of each zone, ensuring that data is aggregated and analyzed accurately within these boundaries.

Zone Attributes:

Population: Information on the number of residents within the zone.

Employment: Data on the number of jobs and types of businesses located in the zone.

Land Use: Details on the types of land use (e.g., residential, commercial, industrial) and their distribution within the zone.

Trip Generation: Metrics indicating the volume of trips generated and attracted by the zone.

Zone Types:

Traffic Zones: Basic units for modeling travel demand, used to aggregate and analyze traffic flows and trips.

Public Transport Zones: Areas specifically used to analyze and model public transport demand, including access to transit services.

Activity Zones: Zones representing specific types of activities (e.g., business districts, shopping centers) that generate or attract trips.

Zone Systems:

Grid-Based Zones: Zones defined using a grid overlay on the study area, often used for detailed local analyses.

Custom Zones: Zones based on specific administrative boundaries or areas of interest defined by the user, such as municipalities or neighborhoods.

Zone Interaction:

Origin-Destination Matrix: A matrix representing trips between different zones. It is used to model trip distribution and demand.

Demand Modeling: Zones are used to generate and allocate trips based on socio-economic characteristics and land use.



Data Aggregation:

Socio-Economic Data: Aggregated data such as population density, employment figures, and land use types are assigned to zones.

Travel Demand Data: Data on trip origins and destinations is aggregated within each zone to facilitate analysis and planning.

Visualization: Maps and Diagrams: Zones are visualized on maps to show spatial distributions and interactions, aiding in the analysis of transport networks and land use.

Applications in PTV Visum

Trip Generation: Zones help in calculating how many trips are generated or attracted by each area based on its characteristics.

Trip Distribution: Zones are used to model how trips are distributed across the network, linking origins and destinations.

Mode Choice Analysis: Zones help in analyzing how travel demand is influenced by different modes of transport.

Scenario Analysis: Zones allow users to test and analyze various planning scenarios and their impacts on transport demand and network performance.

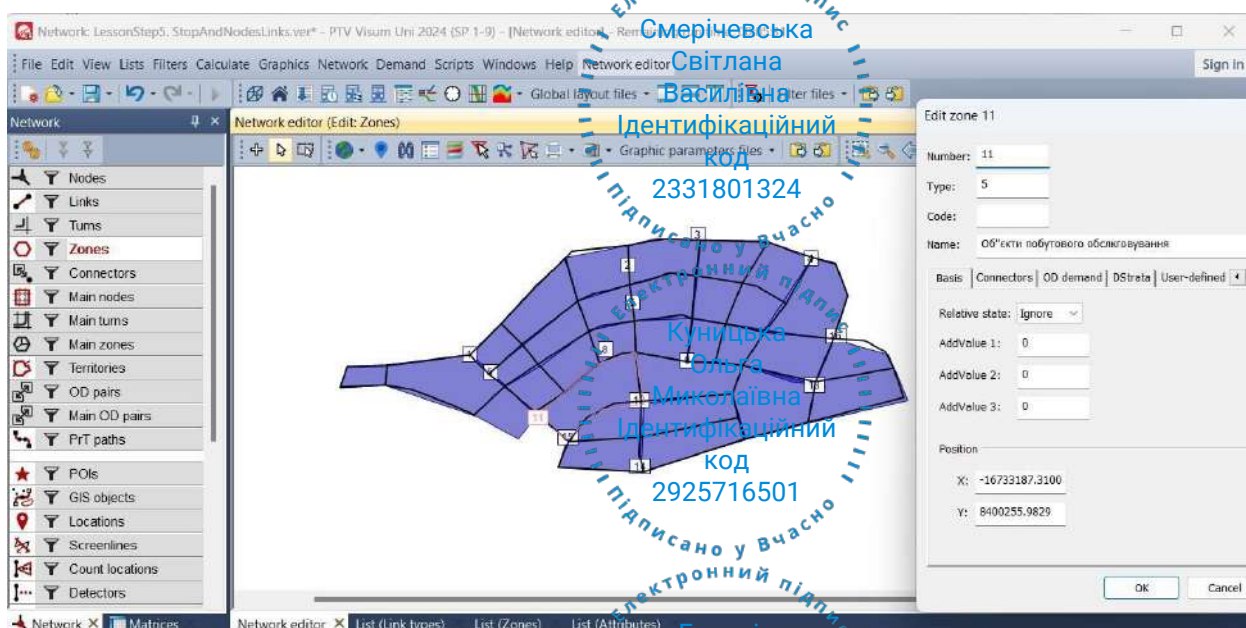


Figure 2.8 - Zones in PTV Visum

Number	No	Name	Type	AreaKm2	Населення	Працівні	Учні	Студенти	Робочі_місяц	Учебні_місяц	Місяц_у_
1	1	Житловий район	2	0.41km2	18322	6413	2748	1283	534	534	2876
2	2	Житловий район	2	0.51km2	22791	7977	3419	1595	665	665	3578
3	3	Житловий район	2	0.79km2	35303	12356	5295	2471	1030	1030	5542
4	4	Житловий район	2	0.41km2	18322	6413	2748	1283	534	534	2876
5	5	Житловий район	2	0.29km2	12959	4536	1944	907	378	378	2036
6	6	Житловий район	2	0.45km2	20109	7038	3016	1408	587	587	3157
7	7	Житловий район	2	0.33km2	15194	5318	2279	1064	443	443	2385
8	8	Зелені насадження загальног	3	0.35km2	0	0	0	0	482	482	0
9	9	Зелені насадження санітарно-	4	0.60km2	0	0	0	0	808	808	0
10	10	Підприємства і установи	7	0.70km2	0	0	0	0	14372	965	6822
11	11	Об'єкти побутового обслугову	5	0.44km2	0	0	0	0	547	547	0
12	12	Підприємства і установи	7	0.38km2	0	0	0	0	7768	521	3688
13	13	Зелені насадження загальног	3	0.43km2	0	0	0	0	534	534	0
14	14	Промислова зона	1	0.57km2	0	0	0	0	10487	704	0
15	15	Склад	6	0.44km2	0	0	0	0	587	587	0
16	16	Промислова зона	1	0.53km2	0	0	0	0	10283	691	0

Figure 2.9 - List of zones with demographic data

Stops: Stops are designated points along public transport routes where passengers can get on or off the vehicle. They are integral to modeling and analyzing the operation and accessibility of public transport services.

Purpose: Stops help in defining the public transport network, enabling accurate simulation of passenger flow, route efficiency, and service coverage.

Key Elements of Stops:

Stop Locations:

Definition: The geographic position of each stop within the transport network.

Purpose: To accurately place stops on maps and within the network model, ensuring they are aligned with the actual public transport infrastructure.

Stop Attributes:

Stop ID: A unique identifier for each stop.

Name: The name or label of the stop, often used for display and reference purposes.

Type: Classification of the stop (e.g., bus stop, tram stop, train station).

Facilities: Information about amenities available at the stop (e.g., shelters, seating, accessibility features).

Coordinates: Geographic coordinates (latitude and longitude) specifying the location of the stop.

Connection to Routes:

Route Mapping: Stops are linked to specific public transport routes, showing where vehicles pick up and drop off passengers.

Schedule Information: Data on the schedule and frequency of services that stop at each location, which helps in analyzing service provision and passenger wait times.

Passenger Flow:

Demand Modeling: Stops are used to model passenger demand and flow, including boarding and alighting patterns.

Capacity Analysis: Assessing the capacity of stops to handle passenger volumes and potential congestion.

Accessibility:

Design: Ensuring stops are accessible to all passengers, including those with reduced mobility.

Integration: Coordination with other modes of transport and connections to ensure smooth passenger transfers.

Data Collection and Management:

Real-Time Data: Stops may be linked with real-time data for monitoring and analysis of service performance and passenger counts.

Historical Data: Analyzing historical data on stop usage to inform planning and operational decisions.

Visualization:

Maps and Diagrams: Stops are visualized on network maps to show their locations and connections with routes. This helps in planning and assessing service coverage and accessibility.

Applications in PTV Visum.

Public Transport Planning: Stops are used to design and optimize public transport routes and schedules, ensuring efficient and accessible services.

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Passenger Analysis: Analyzing how passengers use stops, including boarding and alighting patterns, to improve service planning.

Service Improvement: Identifying areas for service enhancements based on stop usage data and passenger feedback.

Network Integration: Ensuring that stops are well-integrated with the overall transport network, including connections with other transport modes and services.

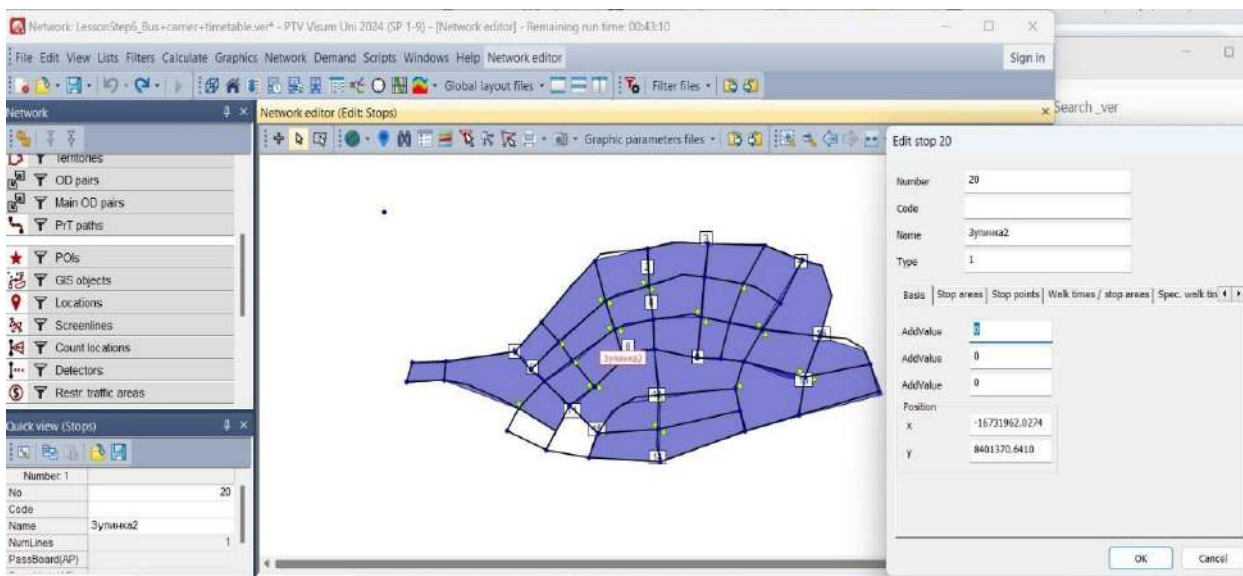


Figure 2.10 - Stops in PTV Visum

2.3 Model of transport demand

4-Stage Transport Model.

The demand model estimates the traffic volume required between different traffic zones for a specified demographic group, at a particular time, and for a specific purpose. This is represented by a PT (Passenger Transport) matrix.

In simpler modeling approaches, it may be possible to bypass creating a synthetic demand model and instead use actual transport relationship matrices, if available. These might include data from freight toll systems, public transport sales,

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or movement analysis from SIM cards. Such matrices can also be adapted to project future demand.

If using PT matrices or incremental methods for future state estimation, the need for detailed input data can be reduced (e.g., detailed mobility data may not be required).

The demand model follows the classical four-stage model, which is structured as follows:

Trip Generation.

The first stage in the classic four-stage transport model is Trip Generation. This stage identifies transport trips between origins and destinations, independent of the current transport supply.

The output includes the production rate of trips from each zone, the attractiveness level of each zone, and variations based on different demographic groups (such as workers or students). It determines the number of trips generated by each zone and the number of trips ending in each zone, ensuring that the total number of trips generated equals the total number of trips ending in the zone. This balance is typically applied in 24-hour models rather than in peak-hour models.

Trip Distribution.

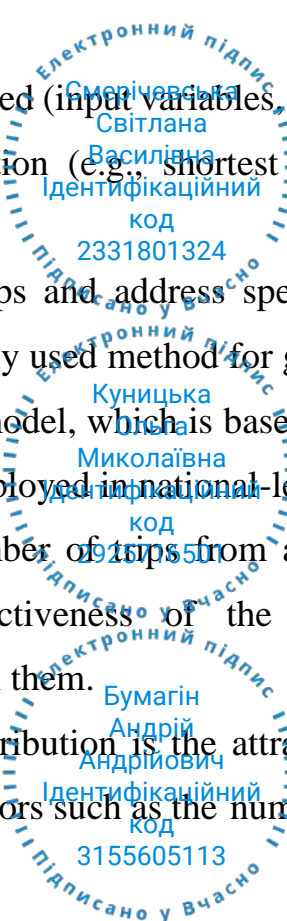
Establish how trips are distributed (input variables, calculation methods).

Set the criteria for trip selection (e.g., shortest route, fastest route, lowest generalized cost).

Determine the purposes of trips and address specific issues such as gravity models. Currently, the most commonly used method for generating transport relations in transport modeling is the gravity model, which is based on an analogy to Newton's law of gravity. This model is also employed in national level transport modeling.

In the gravity model, the number of trips from an origin to a destination is directly proportional to the attractiveness of the destination and inversely proportional to the resistance between them.

The primary factor in trip distribution is the attractiveness of the destination zone, which can be influenced by factors such as the number of jobs or the presence



of commercial establishments. Generalized costs, often simplified to travel time and distance, are another crucial factor. Zones with higher attractiveness are more likely to attract trips, given similar levels of attractiveness elsewhere.

The parameters used in the gravity model can be tailored to specific demographic groups, trip purposes, or characteristics of the zones to improve accuracy.

Mode Choice. It is recommended to model the transport mode in two steps: First: division into individual (car, bicycle, walking) and mass (train, bus, ship, airplane) modes, Second: selection of the transport mode from the given category.

Traffic Assignment. The outcome of modeling transport relations is represented by origin-destination (O-D) matrices for various transport modes. These matrices are used in the final step of modeling to determine the load on the transport network. Standardized algorithms are employed for this calculation, including:

- "All or Nothing";
- Progressive (Incremental) Attribution;
- Equilibrium Allocation.

These algorithms aim to identify one or more optimal routes between origin and destination zones, evaluating routes based on total impedance (resistance). Additional factors such as mileage, infrastructure charges, and fuel consumption are often considered in the evaluation process.

2.4 Analyzed simulation results (Skim matrix of individual and public transport costs; Trip distribution; Mode choice)

Skim matrix (also known as a cost matrix) in transport modeling is a representation of the various costs associated with traveling between different origin-destination pairs. It typically includes individual and public transport options and helps in calculating travel times, distances, and associated expenses.

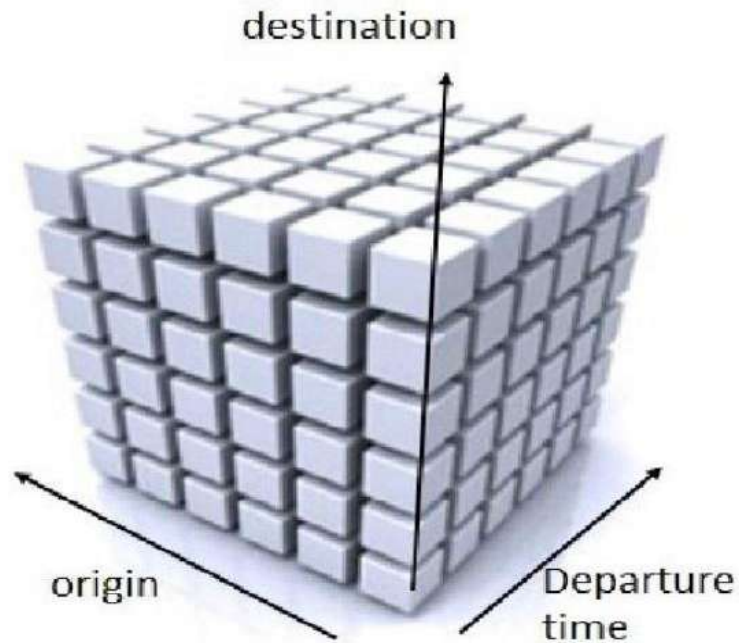


Figure 2.11 - Structure of skim matrix. The matrix is of memory size $|O|*|D|*|T|$

Components of a Skim Matrix for Individual and Public Transport Costs:

Individual Transport Costs:

Travel Time: Time taken for a trip, including driving, parking, and delays (e.g., traffic congestion).

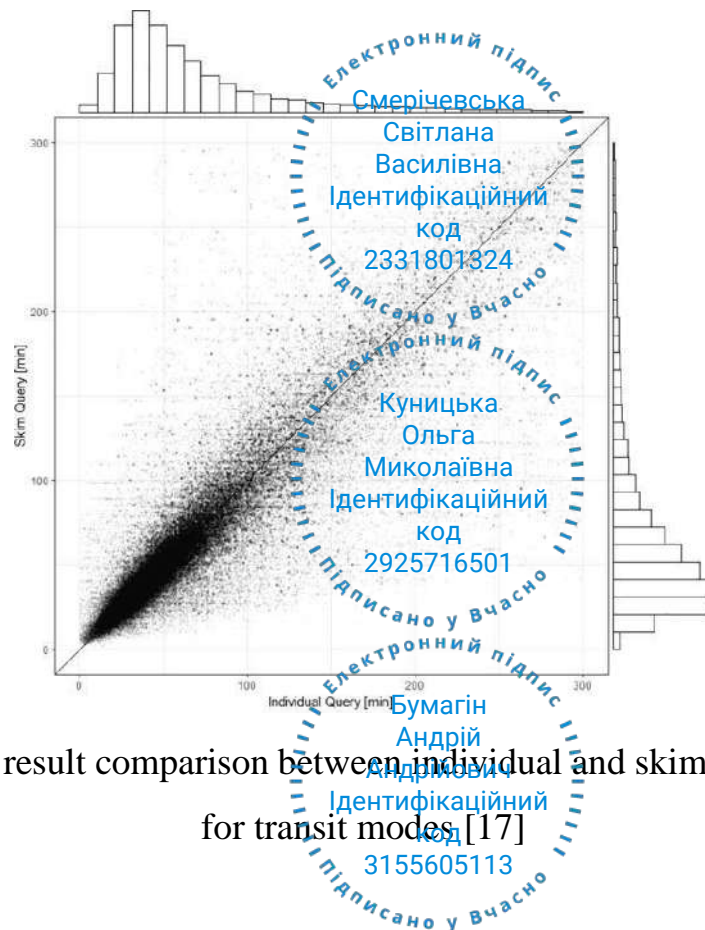


Fig. 2.12 - Query result comparison between individual and skim-based travel times for transit modes [17]

Fuel Costs: Costs related to fuel consumption based on distance traveled.

Vehicle Operating Costs: Maintenance, insurance, and depreciation.

Toll Fees: Costs associated with toll roads, bridges, or tunnels.

Parking Costs: Charges for parking at the destination.

Trip distribution is a key component of transport modeling that predicts how trips originating from various zones (origins) are distributed to different zones (destinations) in a study area. It essentially answers the question: Where do people travel to from a given location? Trip distribution is typically the second step in the traditional four-step transport modeling process, after trip generation and before mode choice and route assignment.

Main Concepts in Trip Distribution:

1. Origins and Destinations (O-D Pairs):

- The number of trips originating from a zone and the number of trips destined for another zone are connected through O-D pairs.
- These trips are influenced by the trip generation step, which calculates how many trips are produced or attracted by each zone.

2. Gravity Model:

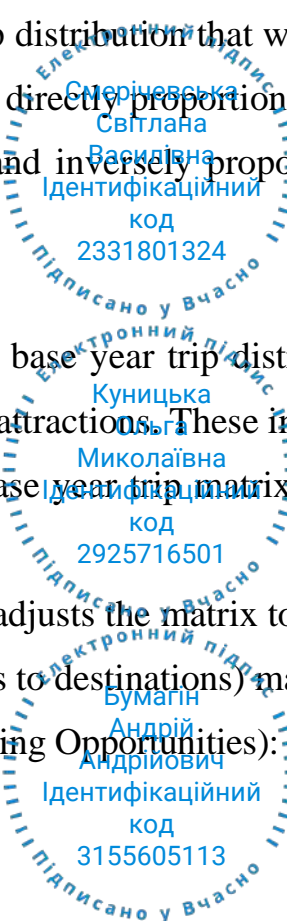
- A widely used method in trip distribution that works on the principle that the number of trips between two zones is directly proportional to the attractiveness of the destination (e.g., job opportunities) and inversely proportional to the travel time or cost between the zones.

Growth Factor Models:

Models that focus on updating base year trip distributions based on projected future growth in trip productions and attractions. These include:

- Fratar Model: Adjusts the base year trip matrix by applying growth factors for both origin and destination zones.
- Furness Method: Iteratively adjusts the matrix to ensure that the sum of rows (trips from origins) and columns (trips to destinations) match predicted values.

Opportunities Models (Intervening Opportunities):



This model suggests that travelers choose their destinations not purely based on distance or cost but based on the availability of opportunities (e.g., jobs, services) along the way. The assumption is that travelers will stop at an acceptable destination before traveling further.

Mode choice in transport modeling refers to the process of predicting the mode of transport individuals or groups will select for a particular trip. It is the third step in the four-step transport modeling process, following trip generation and trip distribution, and is critical for understanding travel behavior and planning transportation infrastructure. This step allows urban planners and policymakers to estimate the demand for different modes of transportation (e.g., car, bus, train, walking, cycling). [18]

Key Factors Influencing Mode Choice:

Traveler Characteristics: income, car ownership, demographics.

Trip Characteristics: trip purpose and trip distance.

Transportation System Characteristics: travel time, cost, comfort and convenience.

Environmental and Policy Factors: environmental awareness, Incentives/Disincentives.

Mode choice models are used by urban planners to forecast the demand for various transportation modes under different scenarios, such as changes in fuel prices, public transport improvements, or the introduction of congestion pricing. These models help assess the potential impact of transportation policies and investments on overall travel behavior. [19]

Mode choice analysis plays a crucial role in sustainable transport planning, ensuring that infrastructure development meets future demands while considering environmental and social goals.

Chapter 2 summary

Overall, this chapter provides a comprehensive and detailed overview of the methodology involved in creating transport models, offering a deep dive into the key

processes and analytical techniques used to assess and predict transportation systems. It outlines the foundational principles that govern both the transport supply and demand models, helping to establish a clear understanding of how these models simulate real-world conditions and travel behavior. By examining the types of models available, from simpler macro-scale models to more complex activity-based models, the chapter emphasizes the importance of choosing the right approach based on the specific goals and scope of the transportation analysis.

Moreover, the chapter explores how transport supply models incorporate the physical infrastructure of transportation networks and how demand models forecast how people will use these networks, based on factors like socioeconomic characteristics, land use patterns, and the availability of different transport modes. A significant portion of the chapter is devoted to explaining how the transport demand model accounts for key elements such as trip generation, trip distribution, mode choice, and route choice, demonstrating the interconnectedness of these components and their critical role in shaping realistic, data-driven models.

The section on simulation results analysis highlights the practical applications of transport modeling by demonstrating how the simulation outputs, such as the skim matrix of individual and public transport costs, trip distribution patterns, and mode choice decisions, can be analyzed to derive meaningful insights. These results not only help assess the current performance of transport systems but also enable planners to explore the effects of various interventions, such as changes in pricing, infrastructure development, or the introduction of new transport policies. The use of such simulation techniques can be pivotal in identifying bottlenecks, evaluating congestion, and optimizing the distribution of travel demand across the network.

Ultimately, this chapter underscores the critical role that transport modeling plays in the planning and management of transportation systems. By integrating comprehensive supply and demand models with simulation results, transportation planners and policymakers are better equipped to make data-driven decisions that enhance the efficiency, sustainability, and equity of transportation networks. Whether addressing issues such as congestion, pollution, or accessibility, the methodology

outlined in this chapter forms the foundation for evidence-based solutions that can improve the functionality and resilience of transportation systems, both in the present and for future growth.



CHAPTER 3

CONDUCTING TRANSPORT MODELLING PROCESS FOR CHOSEN AREA

3.1 Description of the research object (district of the city of Kyiv).

Transport offer model

The street and road network, constructed using geospatial data and field surveys, is depicted in Figure 3.1. To prepare the data for import, additional processing steps were carried out, including: connecting previously unlinked sections of the network, subdividing undivided sections, and selecting the reference network for analysis. Permitted turning movements for different transport modes were defined at the intersections (nodes).

For the model, the following attributes were assigned to the one-way segments of the road network: length (in kilometers), maximum allowed speed (in km/h), capacity (in vehicles per day), the number of lanes in each direction, and the road category.

As the object of the study, an area with Liubomyra Huzara Ave in its center was chosen, its graphic image is shown in Figure 3.2.

In the developed transport model, each road category is further subdivided into several subcategories to provide a more precise and detailed representation of the city's highways. The key distinguishing features of these subcategories include road attributes such as allowed speed, capacity, and the number of lanes in each direction.

The transport network is represented as an oriented graph with the following geometric and technical characteristics:

- The geometry of the street and road network, including the spatial layout and configuration of the roads, which closely mirrors their actual real-world positions and design parameters.

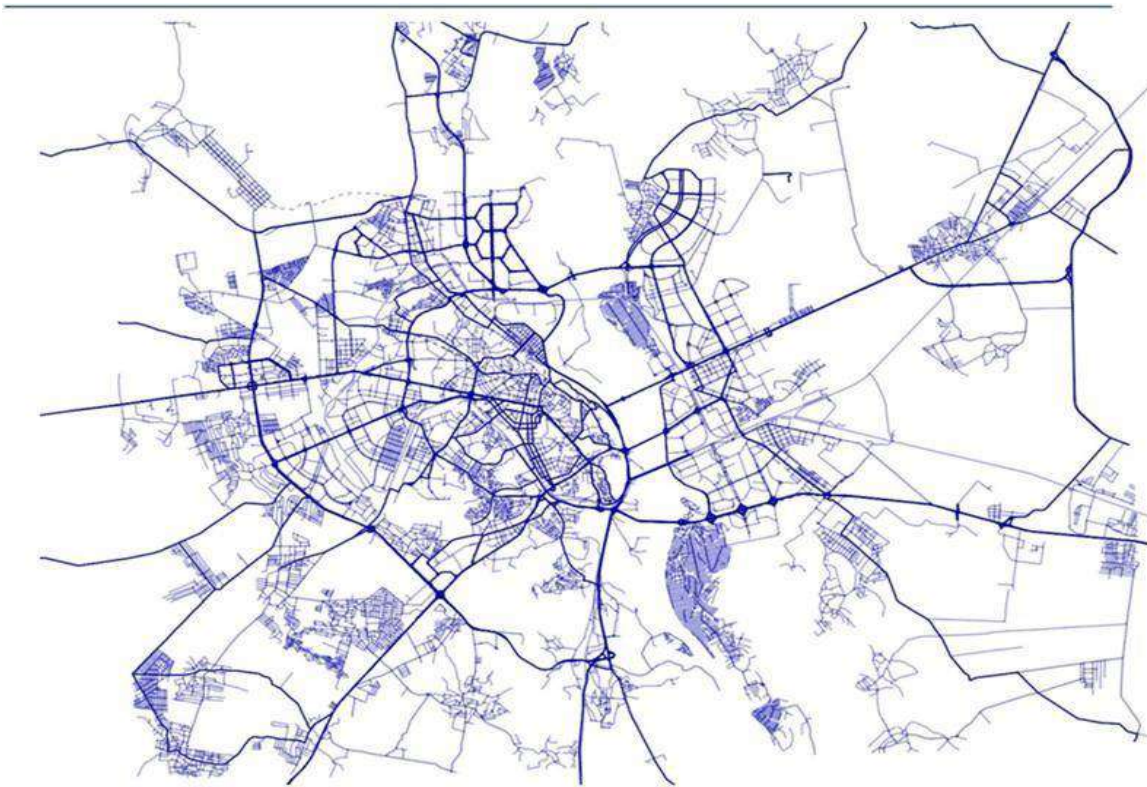


Figure 3.1 - Kyiv's transport network in the PTV VISUM program complex

- The locations of intersections, junctions, and crossings, represented as point objects.
- The design of exits at transport junctions.
- The length of each segment of the street and road network.
- The classification of the main road types.
- The number of traffic lanes in each direction.
- The estimated and allowed traffic speeds on each section of the network.
- The capacity of each direction of the street or road.
- Permitted traffic directions at intersections, junctions, and crossings.
- The rank or classification of the main roads, reflecting their relative importance or attractiveness to users.
- This comprehensive set of road parameters provides a thorough description of the key factors that influence traffic flow dynamics on streets and highways, while also accounting for the main restrictions governing the distribution of traffic.

Transport systems and demand segments

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To model the composition and structure of traffic flows that generate demand on the transport network in the area of interest, data on the types of vehicles used for transportation within the simulated region were incorporated into the model. In this model, different transport modes are represented through transport systems, with each transport system linked to one or more demand segments.

Demand segments represent trips made using one or more transport systems by different groups of people and are associated with origin-destination matrices. Participants in a public transport demand segment have the option to switch between transport systems during a single trip, such as when transferring between modes. Each demand segment is associated with a specific origin-destination matrix.

Data on the spatial development of the research field. Transport zoning.

The spatial development structure of the study area is described using the following data:

Transport zoning: The boundaries of transport districts and the locations of their centers of gravity.

Socio-economic statistics for transport zones: Information such as urban and rural population figures, average number of employees, and the total number of employed individuals, among other data.

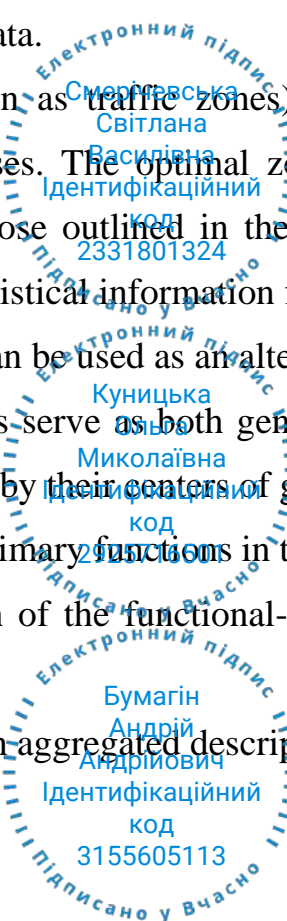
Transport districts (also known as traffic zones) are the basic units of the spatial structure for planning purposes. The optimal zoning approach is based on functional characteristics, such as those outlined in the General City Development Plan. If it is not possible to obtain statistical information for functional zoning, zoning based on administrative boundaries can be used as an alternative.

In the model, transport districts serve as both generation centers and hubs for transport flows. They are represented by their centers of gravity (centroids).

Transport districts fulfill two primary functions in the model:

They represent the distribution of the functional-spatial potential within the modeling area.

They form the foundation for an aggregated description of the state of the transport system in the study area.



Stop Model.

The logic for constructing the stop model in the developed transport system is defined as follows:

A "Stop" is a transfer hub where passengers switch from one mode of transport to another, incurring temporary delays. A "Stop Zone" refers to the area within which transfers between specific stop points occur without any time loss. The exact location where passengers board or alight is known as a "Stopping Point". Each "Stopping Point" is associated with a specific "Stop Zone", and each "Stop Zone" is connected to a particular "Stop".

On the selected area there are Liubomyra Huzara Ave, Mykoly Vasylenka, Vitaliia Skakuna, Metrobudivska, Vasyliia Chumaka, Akademika Shalimova, Akademika Strazheska streets and Vatslava Havela boulevard.

Among the objects important for modeling, it is possible to single out City Hospital No.6 (with different clinics and other medical organizations on the territory), Polytechnic Lyceum NTUU "KPI", Higher professional school of NAU and part of National Aviation University.

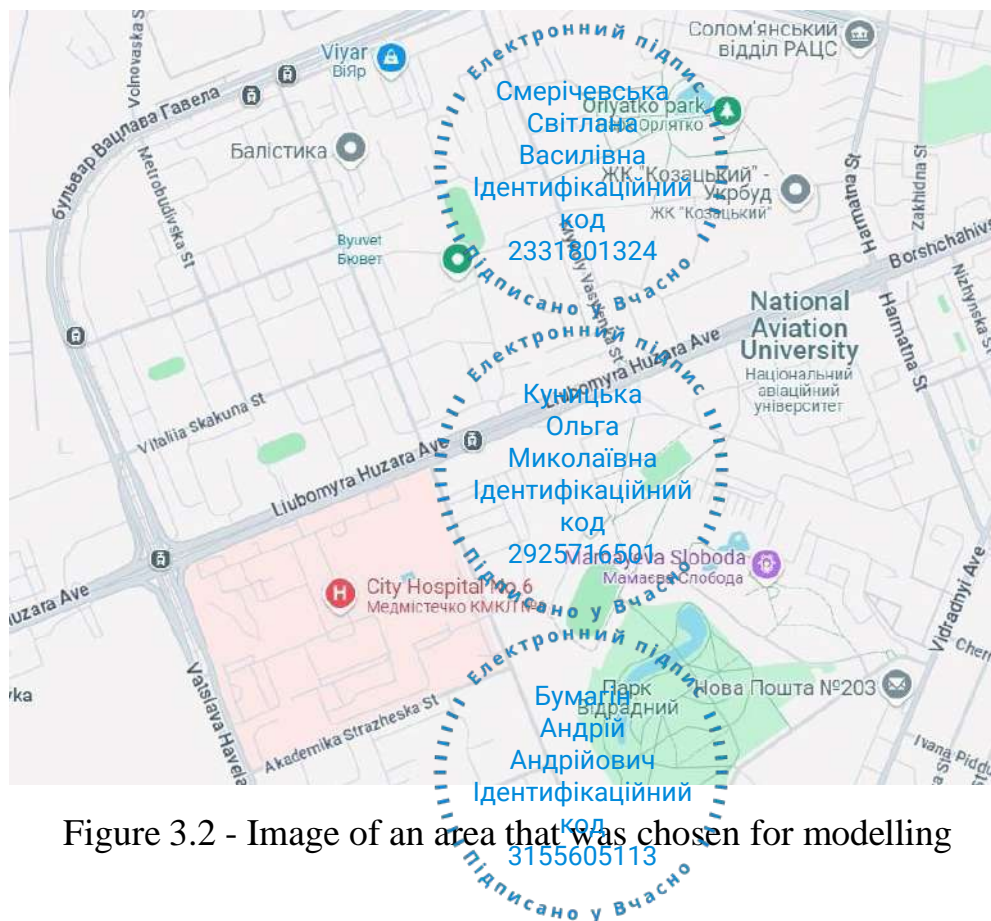


Figure 3.2 - Image of an area that was chosen for modelling

3.2. Creating infrastructure objects in PTV Visum

To create a network model in PTV Visum, the OpenStreetMap [20], service was used, which allows to use an already created street network with possibility of importing of a file (downloaded from the site) in .osm format through the functionality of the PTV software.

After the successful import of the file, a modeled area can be seen. Figure 3.3.

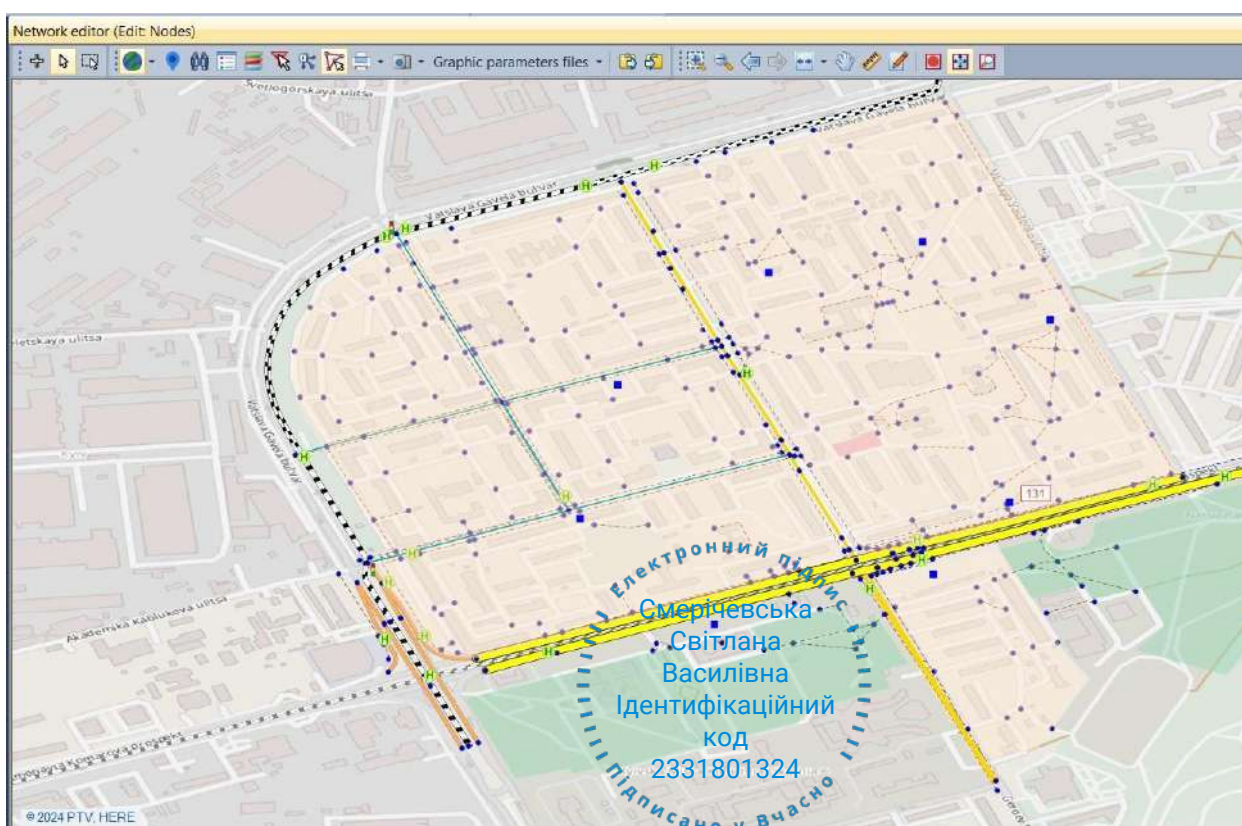


Figure 3.3 - Modeled area in PTV Visum

The key definitions, concepts and attributes of basic elements of transport modeling in PTV Visum – nodes, links and zones were reviewed in more detail in chapter 2.

Functionality of PTV Visum allows to import the area from the OpenStreetMap with already defined nodes, links and stops (this will be shown further).

In PTV Visum, nodes are the individual points in the transportation system where different segments of roads, railways, or other transportation infrastructure meet or intersect plus some points of interest for pedestrians (shops, buildings entries etc.). They represent key locations such as intersections, entry/exit points, or other critical points in the network. Nodes are the basic and the starting point as the primary connection points between links (the road or rail segments), and they are crucial for modeling and analyzing traffic flow, traffic jam, and transport network performance.

Student version of PTV Visum which was used in project supports up to 500 nodes [21]. After importing a plot from the OpenStreetMap around 400 of them were predefined. So, the first step is to add more nodes according to the real situation. Google street view was used to determine the “points of interest” in chosen area.

Nodes can be added by clicking on the defined points on map in “Insert mode” with “Nodes” button pressed in “Network” bar in Visum. (Figure 3.4)

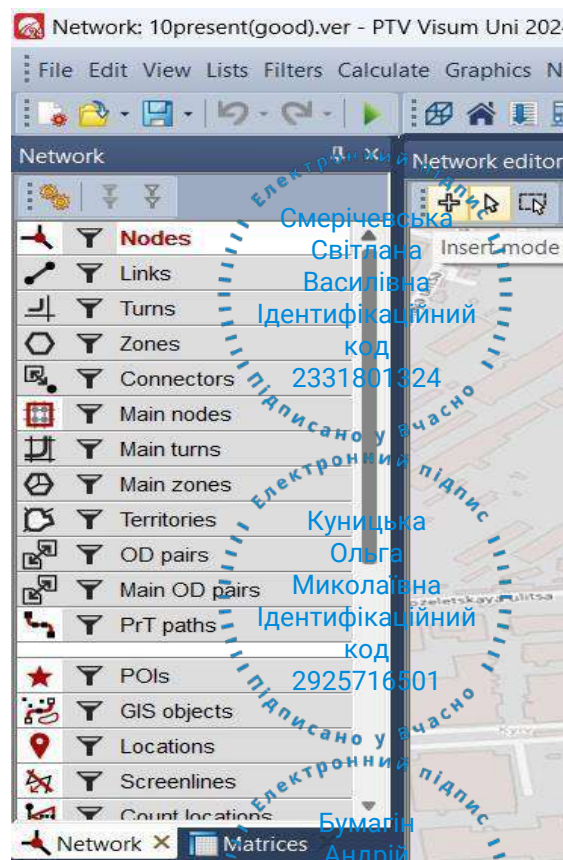


Figure 3.4 – Insertion of nodes

The final picture with all allowed by limited student version of software can be seen in Figure 3.5.

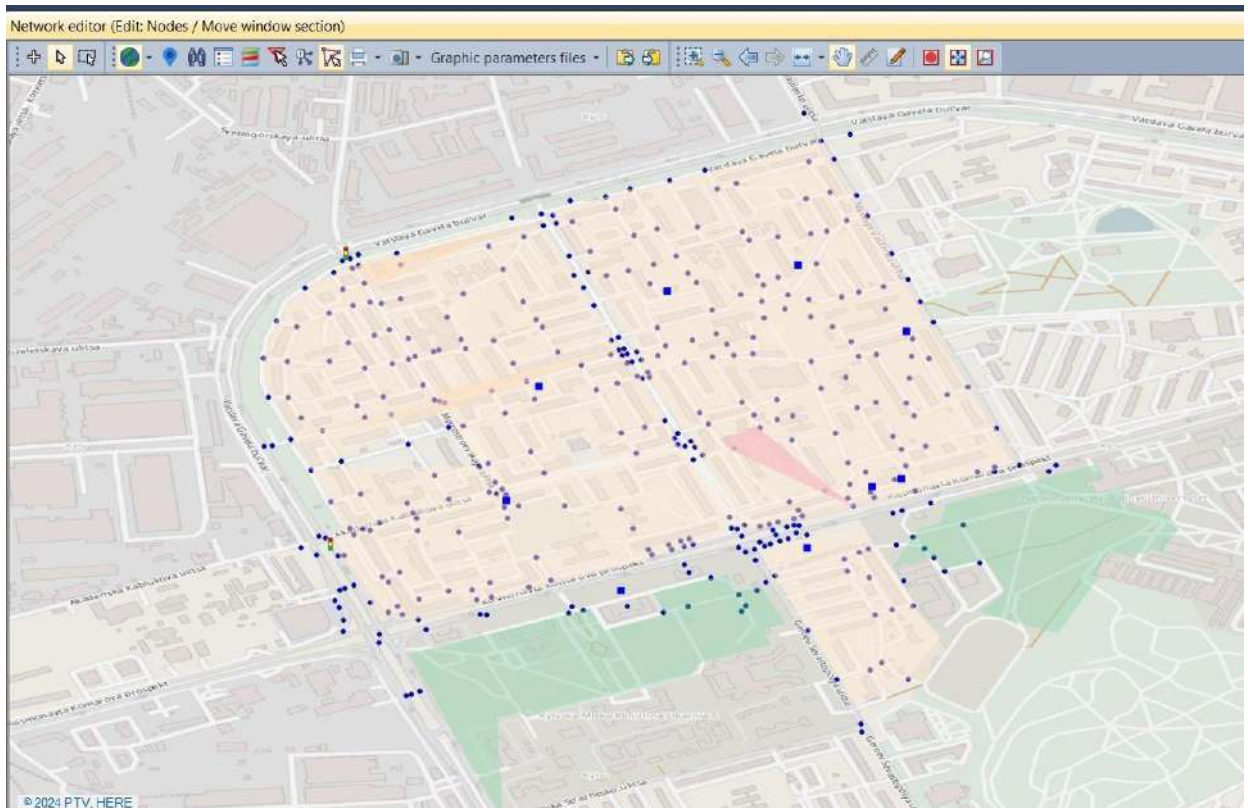
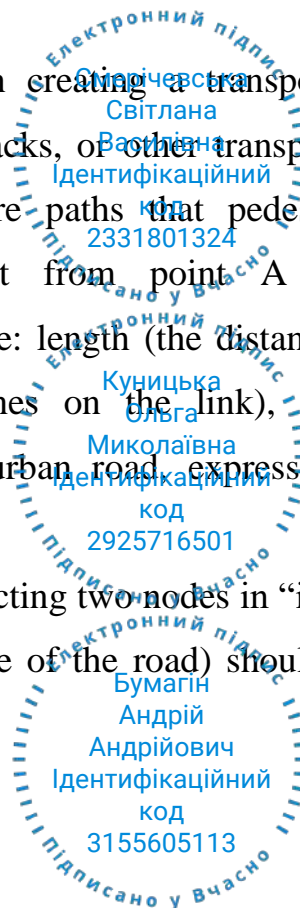


Figure 3.5 - Researched area with nodes

The next level of entities in creating a transport model are links. Links represent the road segments, rail tracks, or other transportation routes that connect different nodes. Basically, they are paths that pedestrians, vehicles and other members of traffic take to get from point A to point B. The main characteristics(attributes) of links are: length (the distance between the two nodes), lane configuration (number of lanes on the link), type of link (the type of transportation infrastructure (e.g., urban road, expressway, railway track, or bus corridor) and speed on the link.

Links can be created by connecting two nodes in “insert mode”. At the moment of creation of a link, link type (type of the road) should be defined. (Figure 3.6).



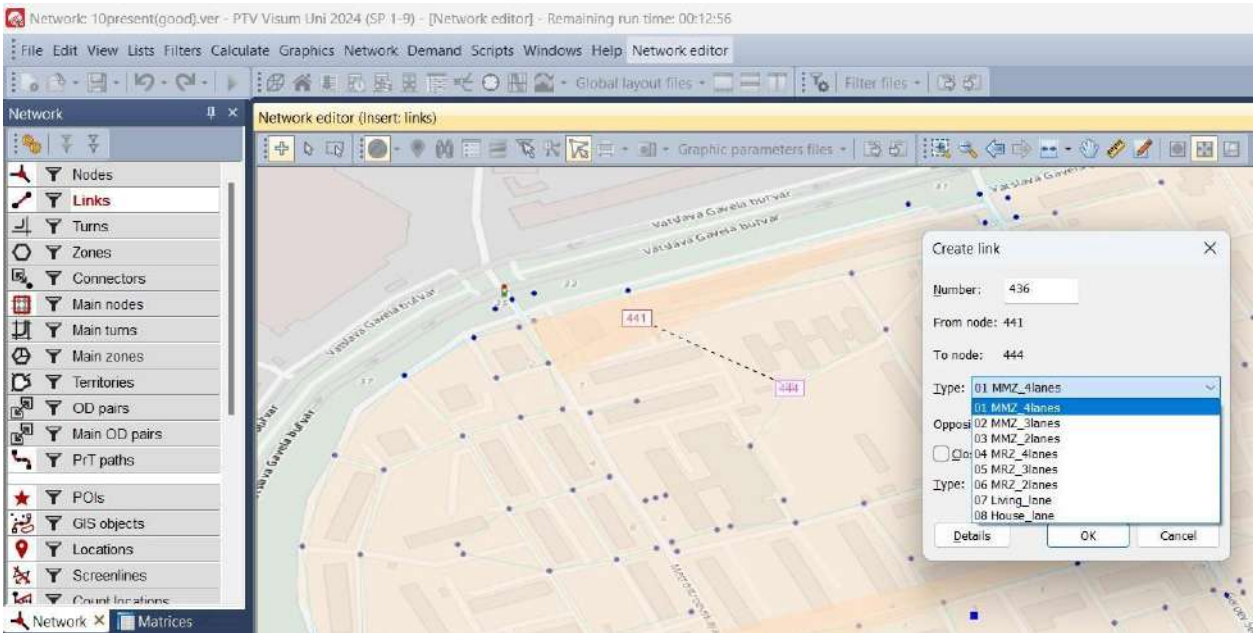


Figure 3.6 - Creation of a link

Any link can be inspected by double click on it. In a drop-down menu All the link's characteristics can be seen and edited. (Figure 3.7)

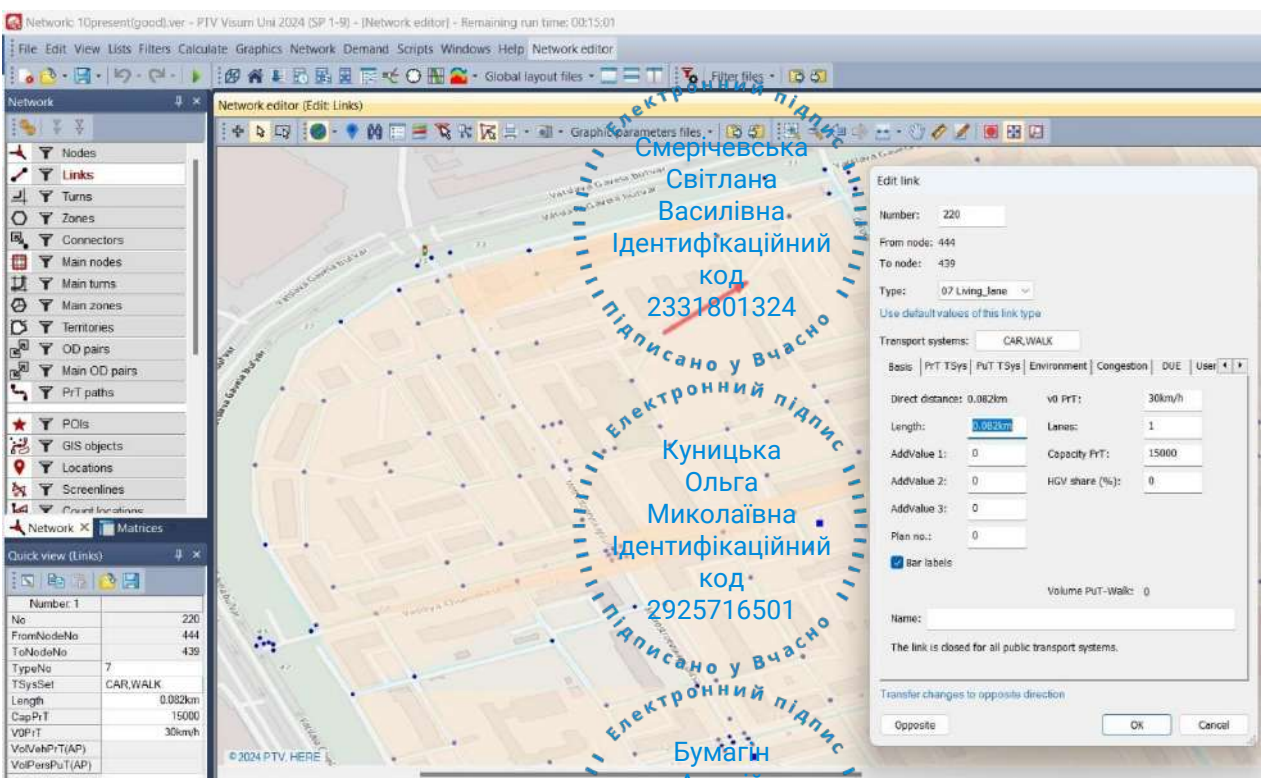


Figure 3.7 - Attributes of an active link

Completed link network for researched area are represented in Figure 3.8

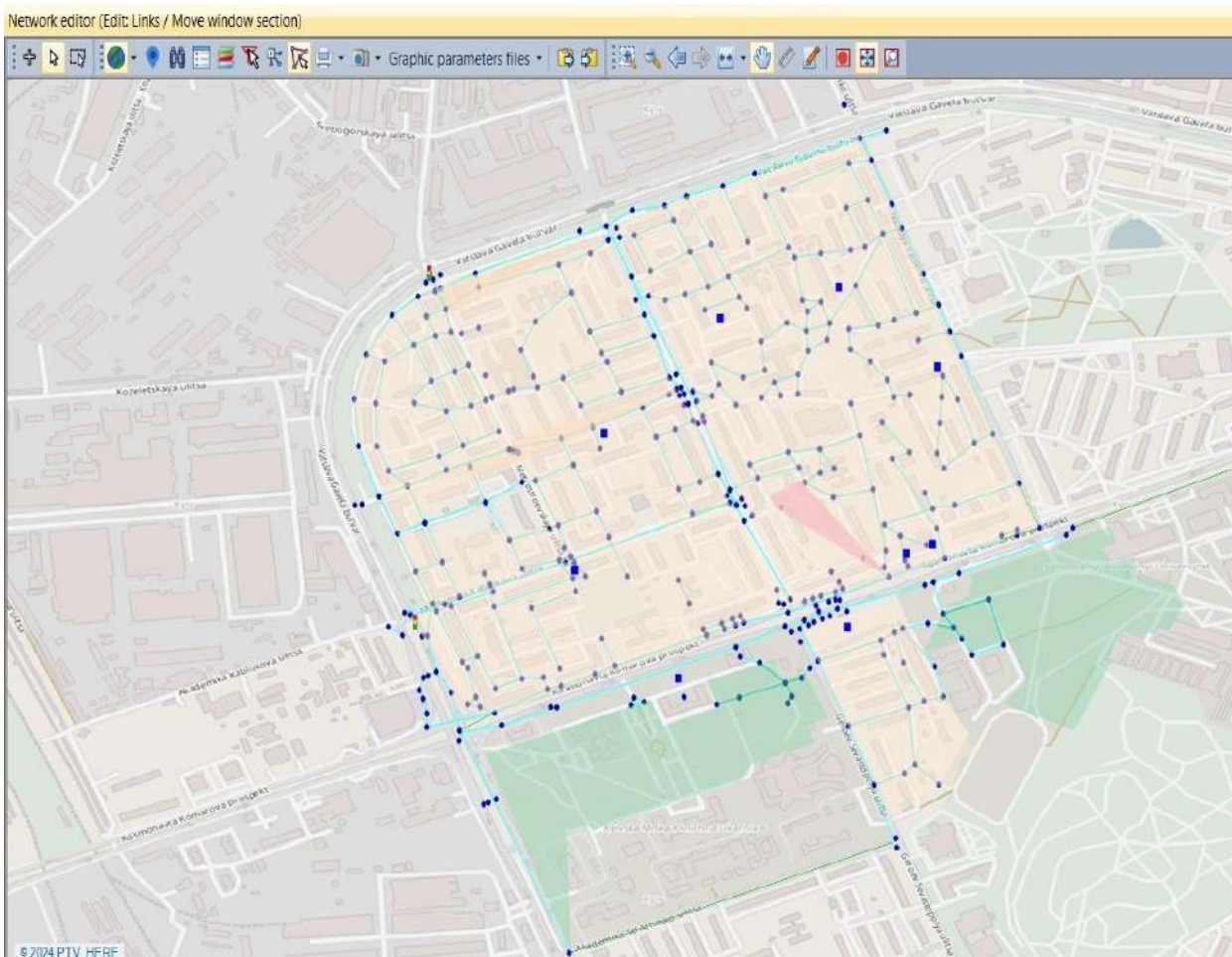


Figure 3.8 - Completed link network

The next step is creating zones. In PTV Visum, zones are geographical areas that represent locations for trip generation and distribution analysis in transportation modeling. These zones are used to aggregate traffic or passenger demand and to help model the flow of people or vehicles between different areas of the network.

The zone is connected to the network through connections (segments) of its center of gravity to nodes of the transport network.

Similarly, to the previous objects (nodes and links) zones are also created through the “Network” menu by choosing “Zones” button and “+” (Insert mode), adding gravity center and connecting segments of the zone.

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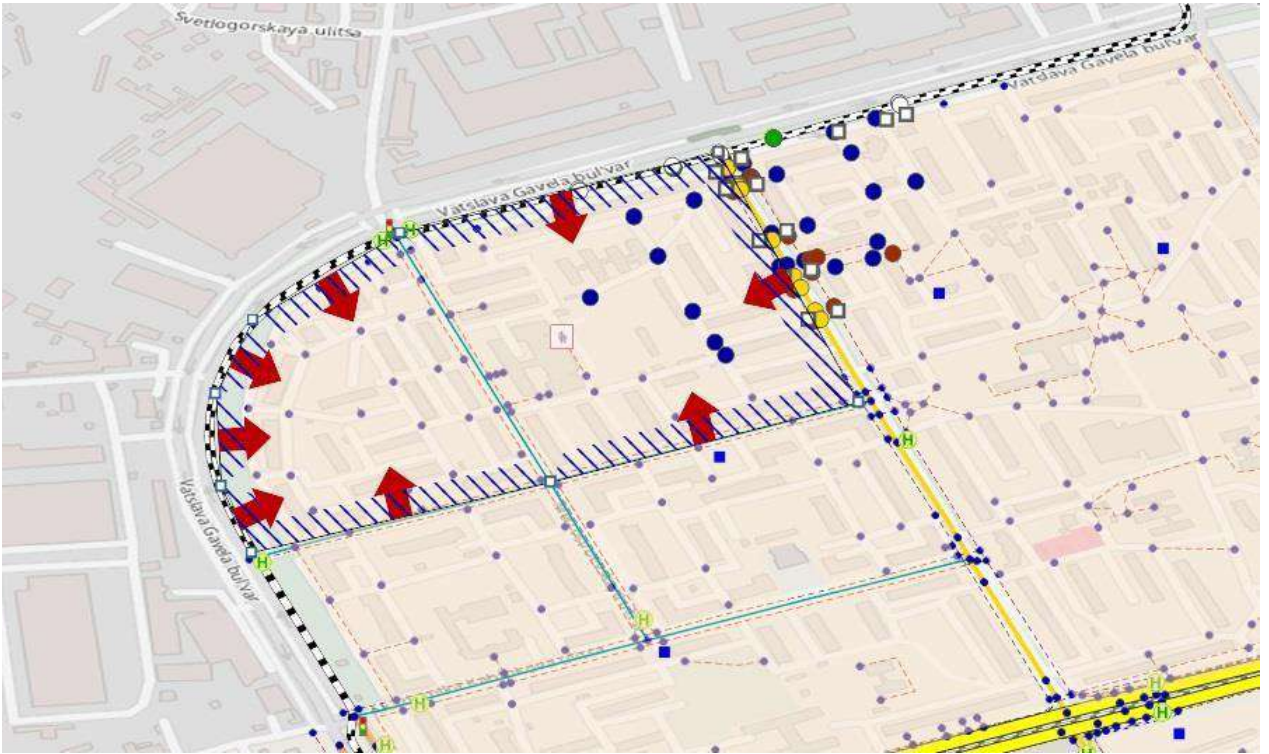


Figure 3.9 - An example of creating a transport zone

After all the manipulations 7 zones were created.

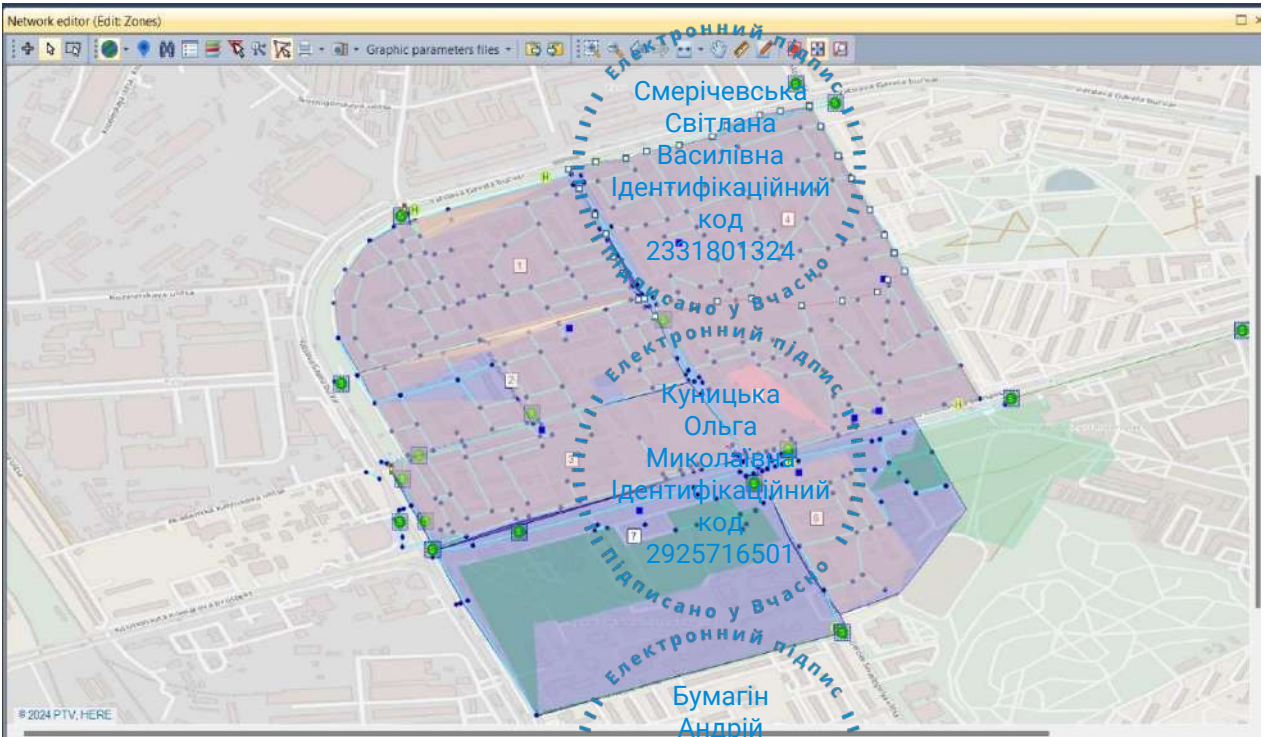


Figure 3.10 - 7 Transport zones

After the creation of transport zones, the statistics of transport districts should be set. But before that, the user defined attributes for zones should be created. User defined attributes / User defined attributes

To set attributes, Network – User-defined attributes menu can be used.

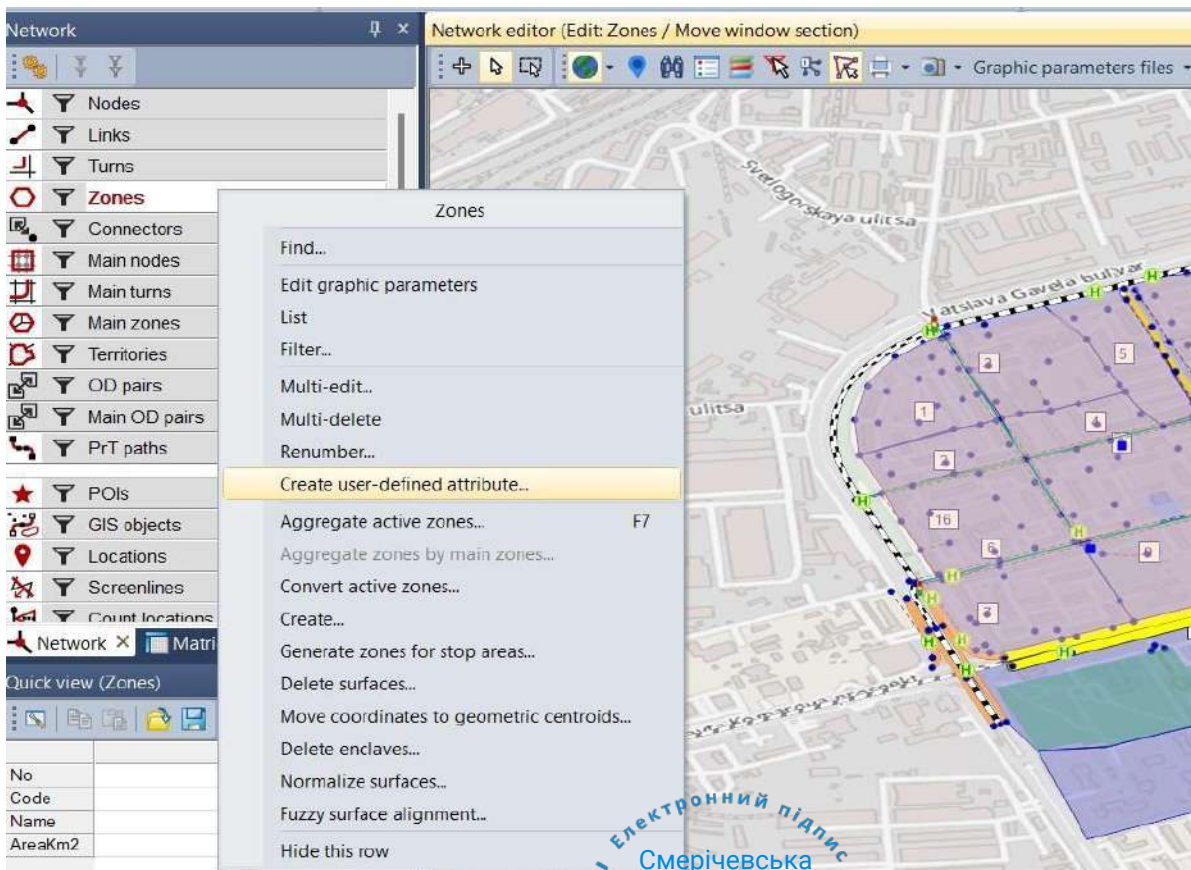


Figure 3.11 - Adding User-Defined attributes

By clicking "Add" and from the drop-down menu - selecting objects of the "Regions/Zones" network attributes will be added.

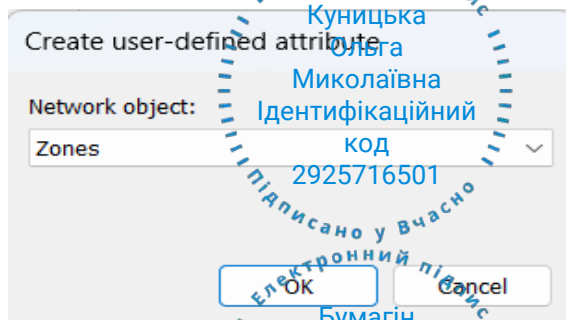


Figure 3.12 - Applying attributes to the "Zones" objects

The following attributes of zones have to be set:

- Population
- Working population
- Pupils
- Students
- Working places
- Service jobs
- Study places
- Places in higher education institutions (HEIs)

Step 1. We write the name of the attribute in Attribute ID (for example, Population). After entering the Attribute ID, other lines are automatically filled.

Step 2. "Integer / Integer" should be set.

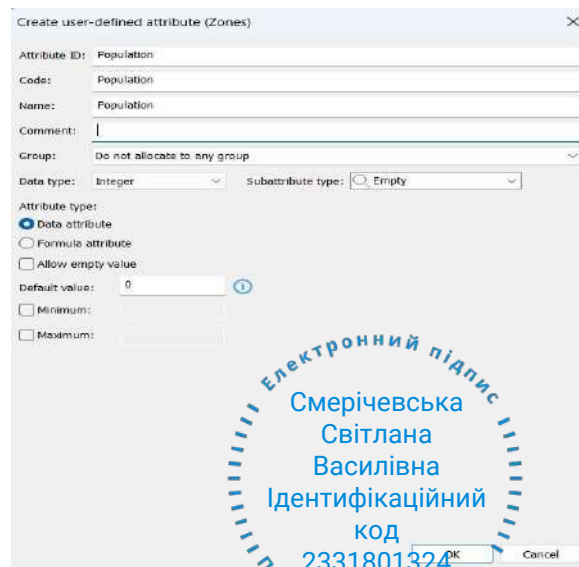


Figure 3.13 - Naming the attributes

In the end there are 8 attributes defined

Number 8	ObjTypeName	ObjID	AttrID	ShortName	LongName	Value Type
1	Zones	ZONE	POPULATION	Population	Population	Integer
2	Zones	ZONE	PUPILS	pupils	pupils	Integer
3	Zones	ZONE	SERVICE_WORK_PLACE	Service_work_place	Service_work_place	Integer
4	Zones	ZONE	STUDENTS	students	students	Integer
5	Zones	ZONE	STUDYING_PLACES	Studying_places	Studying_places	Integer
6	Zones	ZONE	STUDYING_PLACES_UNIVERSITY	studying_places_University	studying_places_University	Integer
7	Zones	ZONE	WORKING_PLACES	Working_places	Working_places	Integer
8	Zones	ZONE	WORKING_POPULATION	Working_Population	Working_Population	Integer

Figure 3.14 - List of defined attributes

After creating transport zones and their attributes, we need to set their statistics. To do this, firstly one more attribute - Area of districts in square kilometers should be added.



Figure 3.15 - Menu for adding area attribute

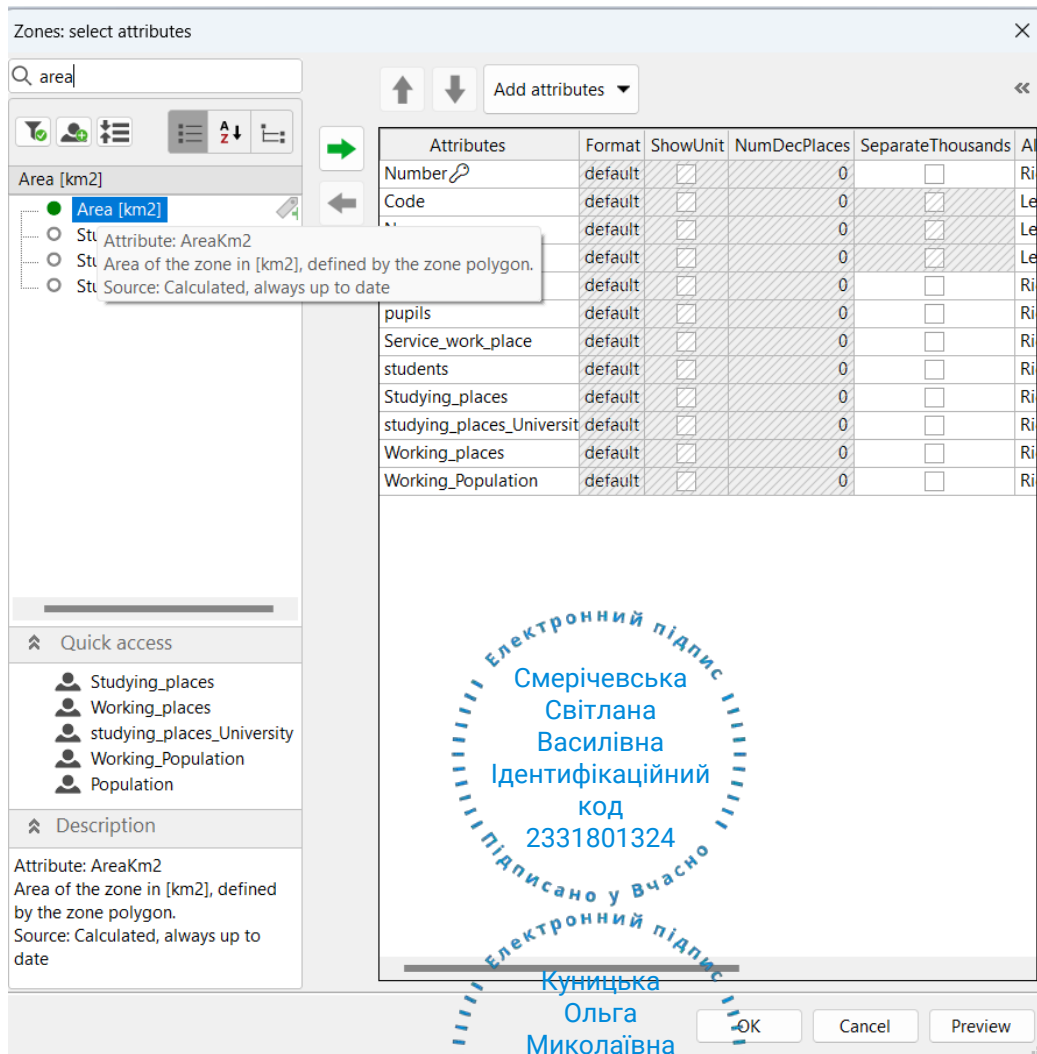
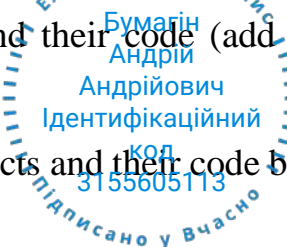


Figure 3.16 - Adding the area

Introduction of socio-economic statistics of Zones.

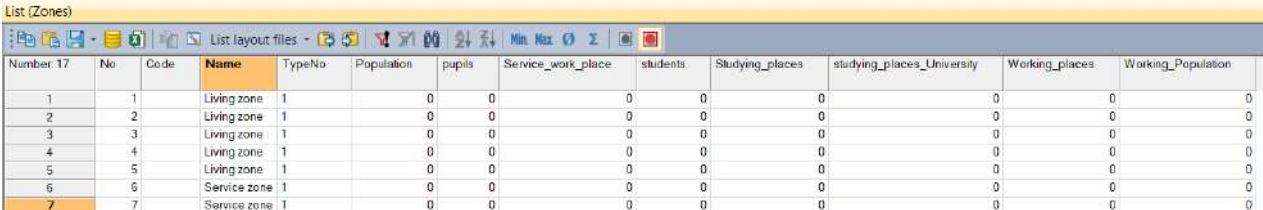
Enter the names of districts and their code (add columns using the Select attributes tool).

Let the following types of districts and their code be given:



1. Service zone
2. Living zone

The list for the possible zone types is much longer. For example: enterprises and institutions, green zones, storages etc. can be added, but in my project, there are no such a zone, so only mentioned two were used.



Number 17	No	Code	Name	TypeNo	Population	pupils	Service_work_place	students	Studying_places	studying_places_University	Working_places	Working_Population
1	1		Living zone	1	0	0	0	0	0	0	0	0
2	2		Living zone	1	0	0	0	0	0	0	0	0
3	3		Living zone	1	0	0	0	0	0	0	0	0
4	4		Living zone	1	0	0	0	0	0	0	0	0
5	5		Living zone	1	0	0	0	0	0	0	0	0
6	6		Service zone	1	0	0	0	0	0	0	0	0
7	7		Service zone	1	0	0	0	0	0	0	0	0

Figure 3.17 - List of transport zones with attributes

Data obtained from population censuses, surveys, field studies, data from mobile operators and other sources are used to fill in the socio-economic characteristics of the zones - the number of the population, its distribution by age, gender, and social groups. In this project, the method of average analysis of the number of residents of each individual building within the transport zone was used using Google maps and an approximate (but quite accurate) count of the number of apartments and, accordingly, residents. To calculate the distribution of the population by different social groups, the following coefficients were calculated:

1. Working-age population

Coefficient of 0.35 from Population.

2. Jobs.

For calculations, we take into account:

- 2.1 Jobs in industry.

0.8 of the working-age population works in industry.

This number is distributed among the "Industrial Zone" and "Enterprises|Institutions" zones as well as some in Living zones.

- 2.2 Service working places.

The coefficient of this category is 0.2 of the working population.



2.3. Jobs.

Based on 2.1. and 2.2. we can determine the sum of working places in a zone.

3. Calculation of the number of pupils and students.

3.1. Students - a coefficient of 0.07 from the Population. They are found only in living areas.

3.2. Pupils - a factor of 0.15 from the Population. They are found only in living areas.

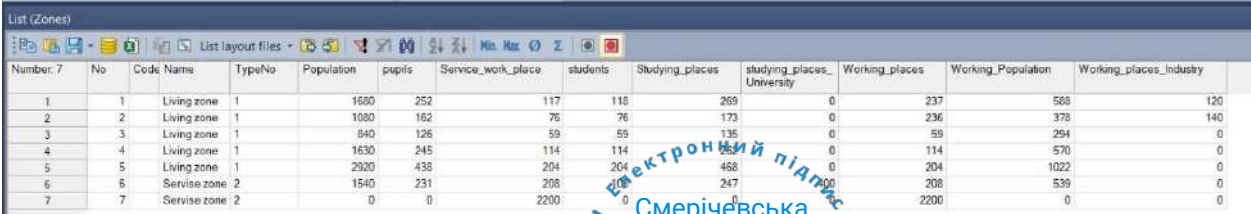
4. Calculating studying places and studying places in universities.

4.1. Studying places in universities are located in the Service zone where NAU is located.

4.2. Studying places, which are all distributed among residential districts

At the same time, we take into account that the number of Studying places per 1000 places is more than students.

After all the calculations data can be transferred to PTV Visum.



Number	No	Code	Name	TypeNo	Population	pupils	Service_work_place	students	Studying_places	studying_places_University	Working_places	Working_Population	Working_places_Industry
1	1		Living zone	1	1680	252	117	118	269	0	237	588	120
2	2		Living zone	1	1080	162	76	76	173	0	236	378	140
3	3		Living zone	1	840	126	59	59	135	0	59	294	0
4	4		Living zone	1	1630	245	114	114	0	0	114	570	0
5	5		Living zone	1	2920	438	204	204	468	0	204	1022	0
6	6		Service zone	2	1540	231	208	208	247	0	208	539	0
7	7		Service zone	2	0	0	2200	0	0	0	2200	0	0

Figure 3.18 - Zones with demographical data

Public transport routes and stops modeling.

The transport model created in the PTV VISUM format also allows for the simulation of the public transport system.

Public transport systems are integrated into the model, including different types of rolling stock with their specific characteristics. A public transport route network is then developed.

The public transport route network is mapped onto the street and road network, with each route passing through segments that connect nodes and stop points.

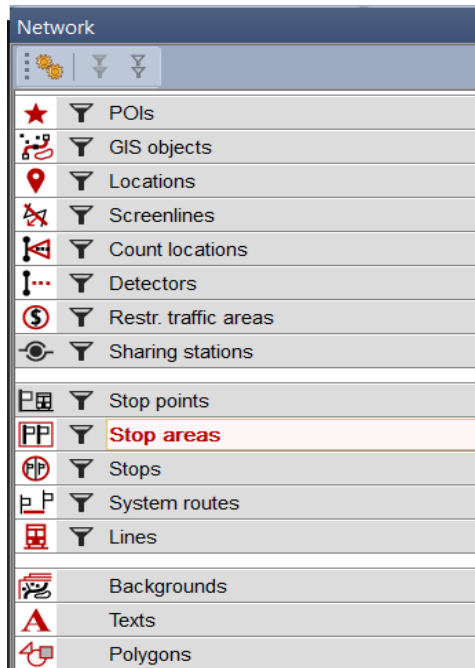


Figure 3.19 - Stop areas menu

As it was mentioned earlier in the project “Stop” entity in Visum is a 3-layer structure: A “Stop” is the largest element in the hierarchy, which includes zones and stop points.

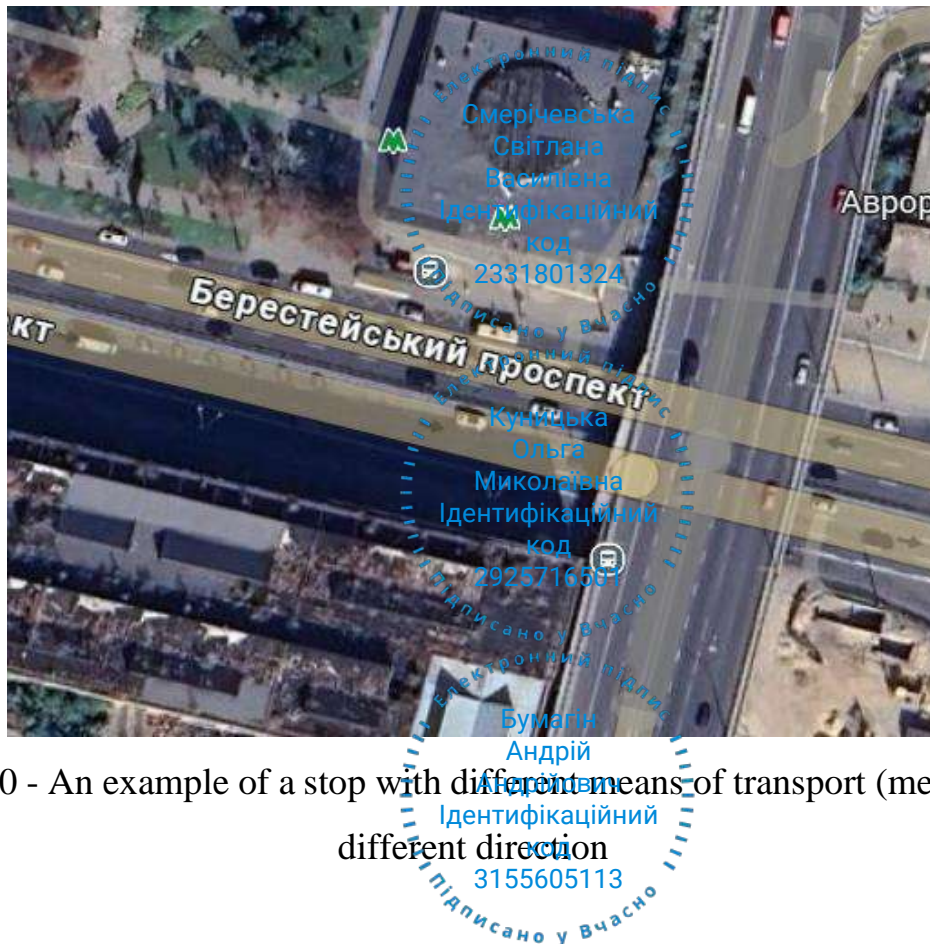


Figure 3.20 - An example of a stop with different means of transport (metro, bus) in different direction

A “Stop zone” can encompass multiple stop points from different transport systems. For each stop zone, an access node is specified, which serves as the point where public transport connects to the transport district.



Figure 3.21 - An example of a stop zone - transfer from 1 transportation to another, where the time for transfer can be ignored

A “Stop point” is the smallest element in the hierarchy, representing the physical location for passenger boarding and alighting for one or more transport systems.

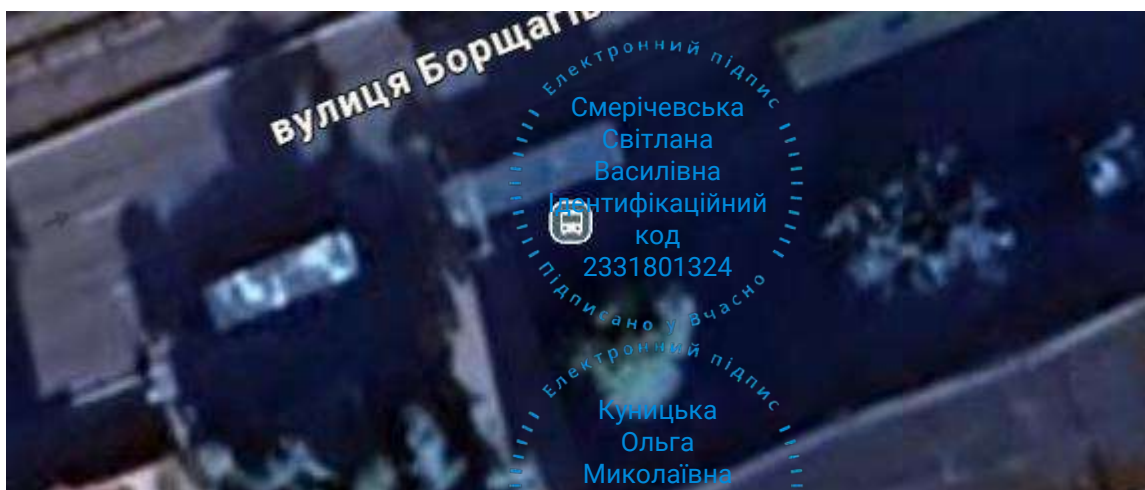


Figure 3.22 - Stop point – actual stop point for the public transport

VISUM automatically creates all three elements — "Stop", "Stop Area", and "Stop Point".

To combine all these elements into a single stop, it's necessary to:



Go to "Stop Area", open the settings in edit mode, and assign the settings to a single stop point, based on the number of the nearest node.

If the stop is not located at a node, splitting the segment and creating a node near the stop should be done.

After the mentioned above procedure Stop/Stop area/Stop point is created.

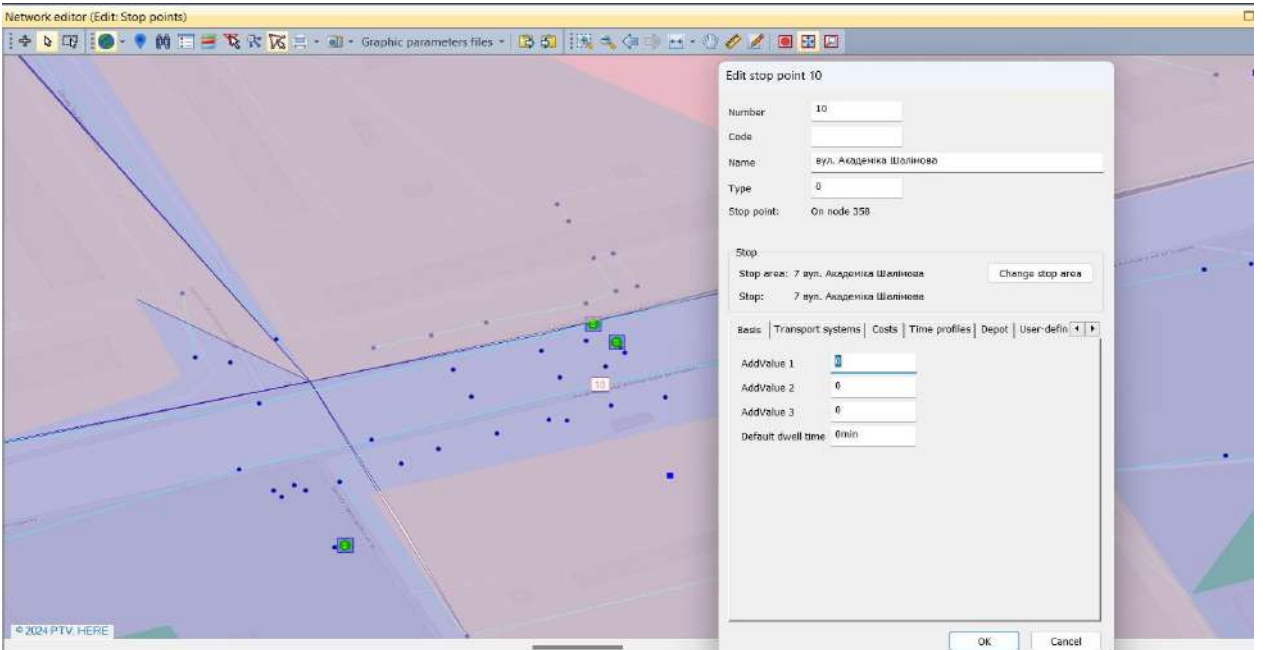


Figure 3.23 - Stop point with the attributes (name, corresponding stop area and node)

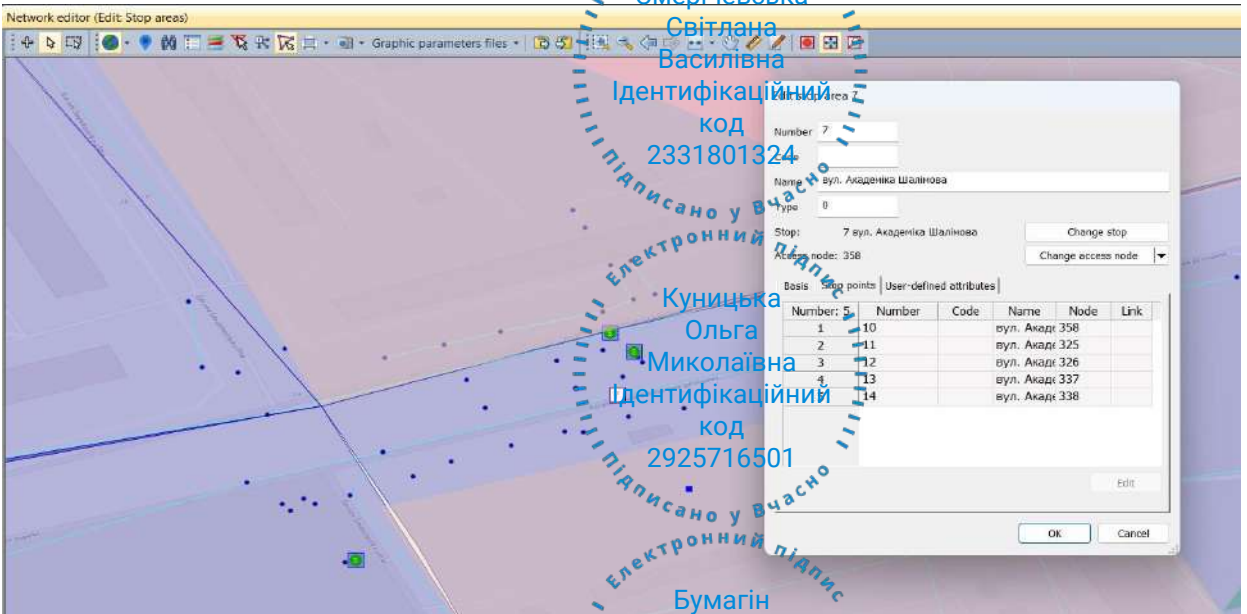


Figure 3.24 - Stop area with the attributes (name, corresponding stop, stop points and node)

Means of transportation and operators.

The next step after creating stops infrastructure is setting up of means of transportation and operators.

Menu Network – PuT vehicles is designed for these purposes.

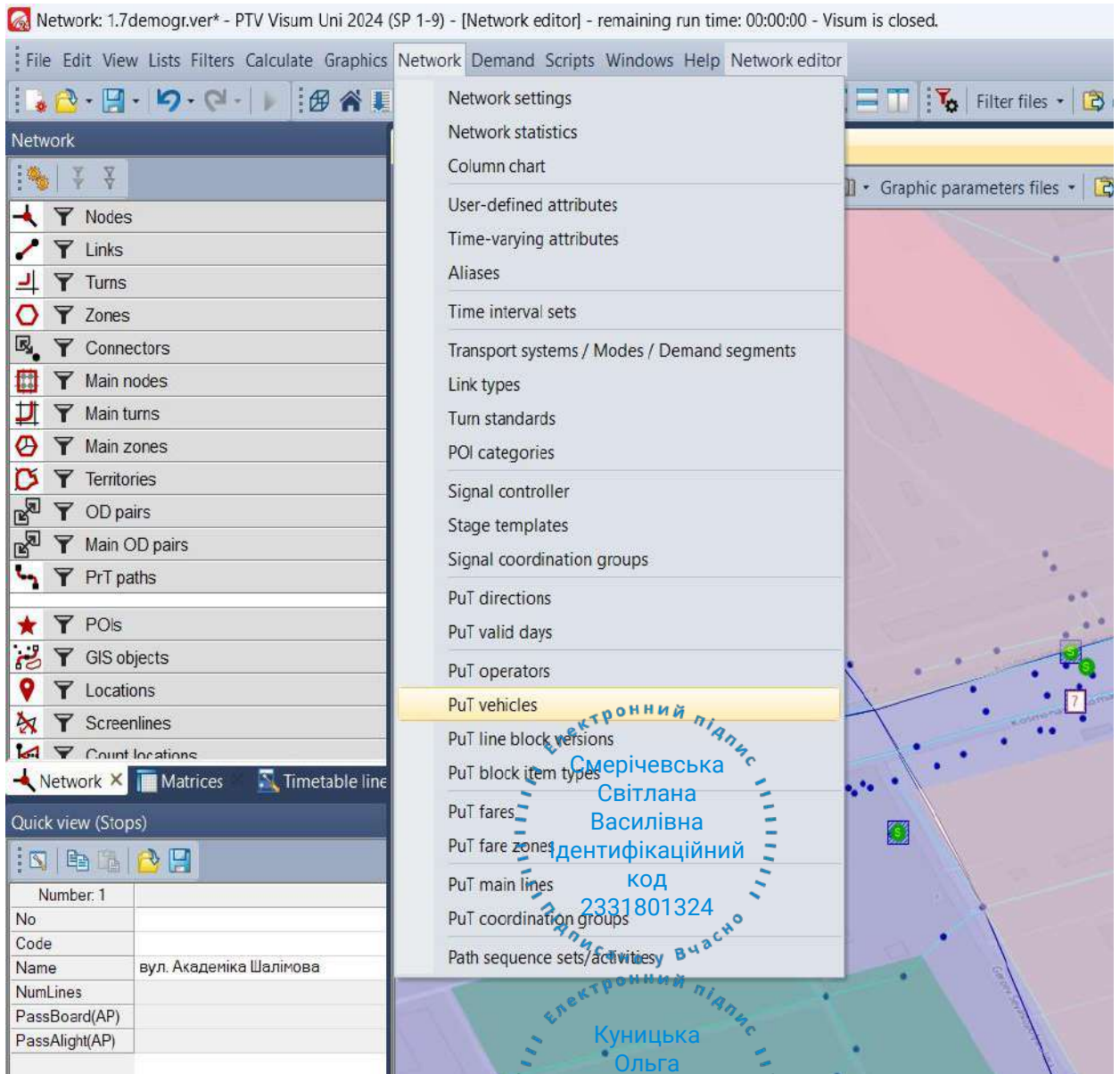


Figure 3.25 - Public transport vehicles menu

Using “Create” button different vehicles can be added with their functional attributes as transport system (defined earlier), name, capacity etc.

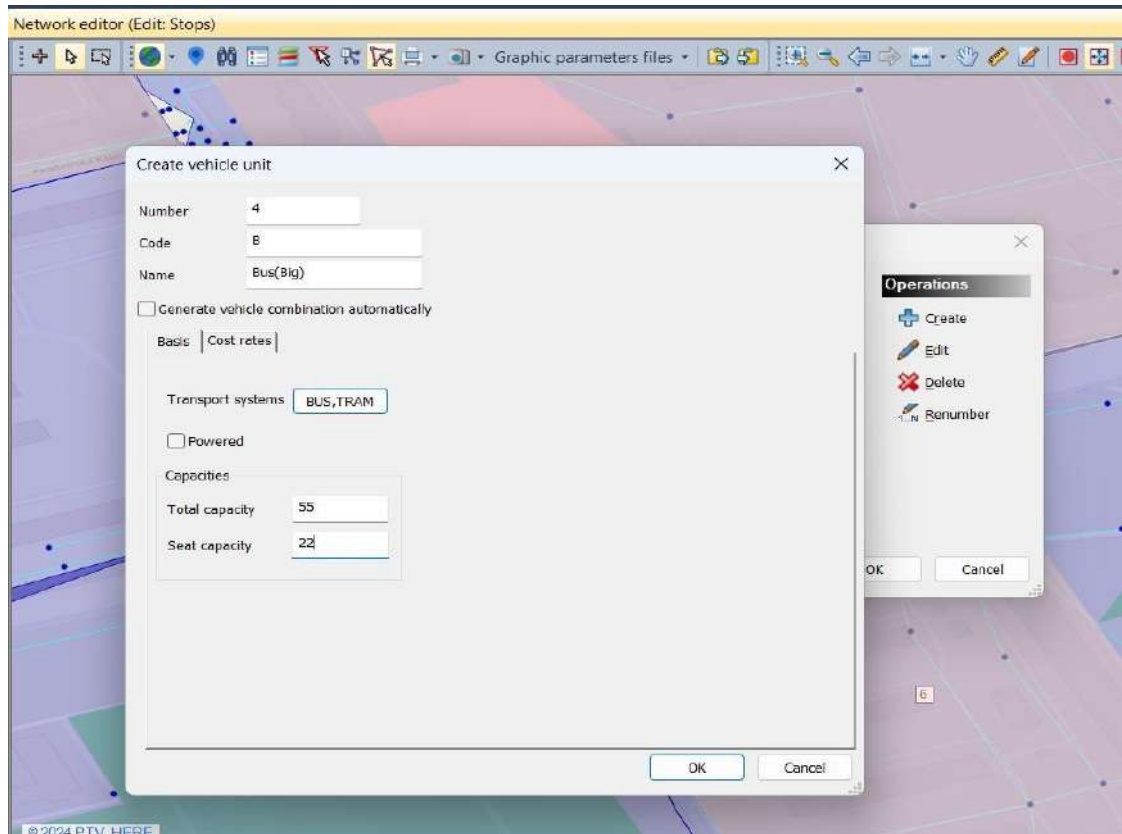


Figure 3.26 - Adding a vehicle

In chosen area there are three different means of transportation: marshrutka (small buses, big buses and trams). Complete list of the vehicles operating in chosen area is presented in Figure 3.27.

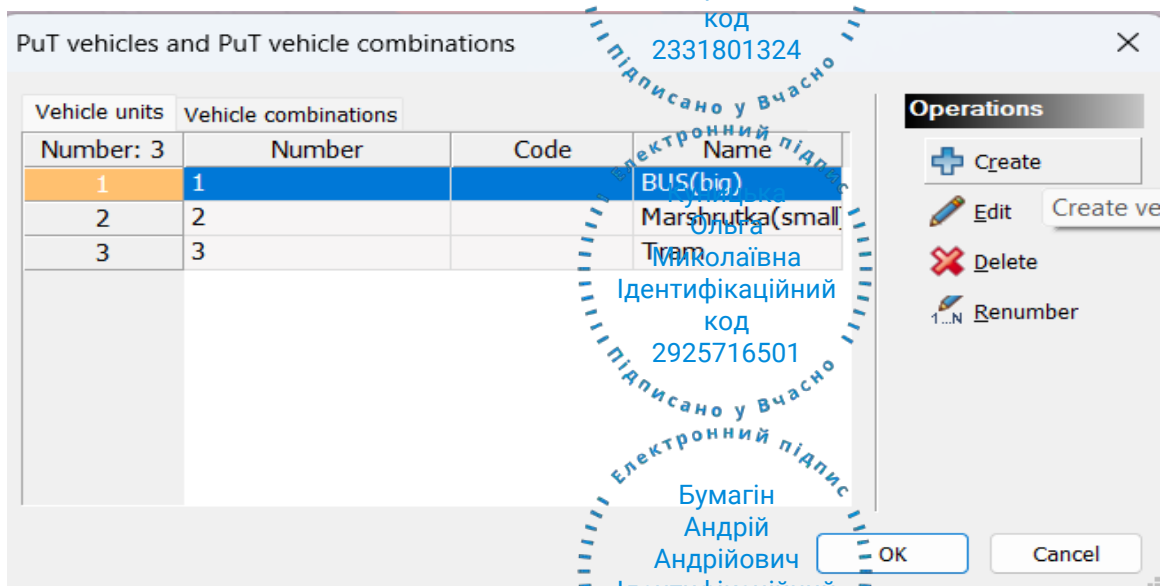


Figure 3.27 - An example of adding different vehicles

PuT operators menu allows to add companies – operators of public transport. The algorithm is similar to adding a vehicle through the Network – PuT operators menu.

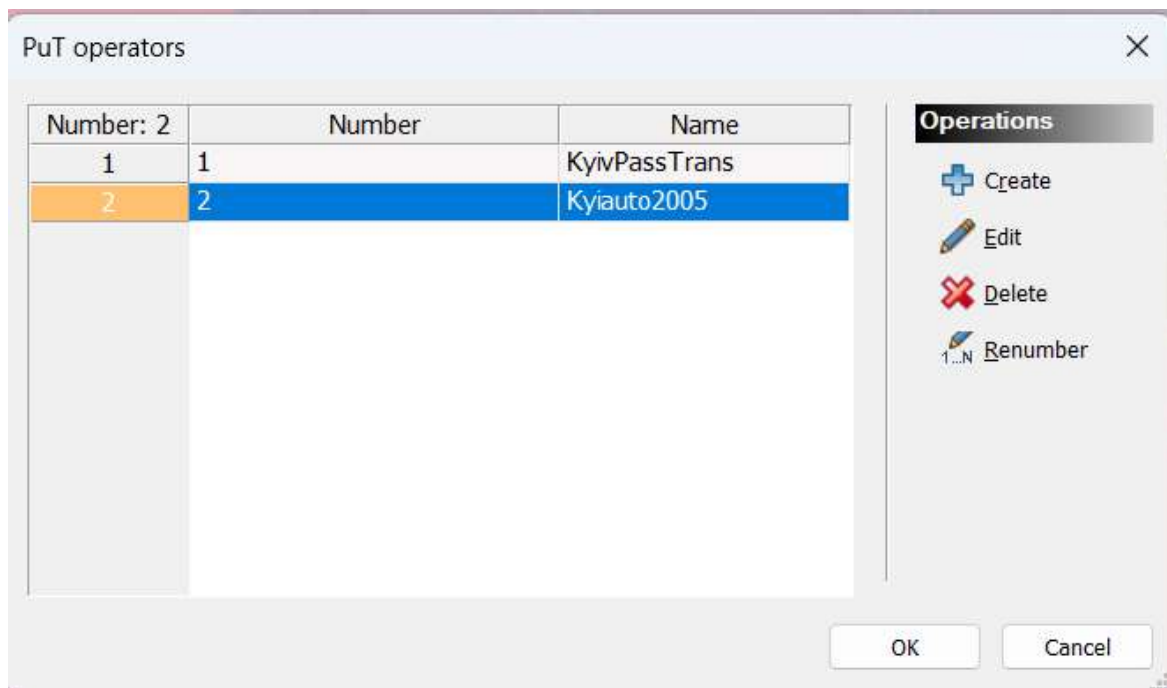


Figure 3.28 - Operators added

After creating the carrier and transport vehicle, creation of the routes can be done.

Public transport routes creation.

After creating the stop system, "routes" for public transport are added to the transport model.

Each route in the transport model created in PTV VISUM consists of several (usually two) "route variants" (line routes), each representing one direction of the route (from the starting stop to the destination and back). One of the variants is typically referred to as the "outbound route" and the other as the "return route".

Adding a line.

By pressing a "Line" button in Network side bar in insert mode adding a line can be completed.

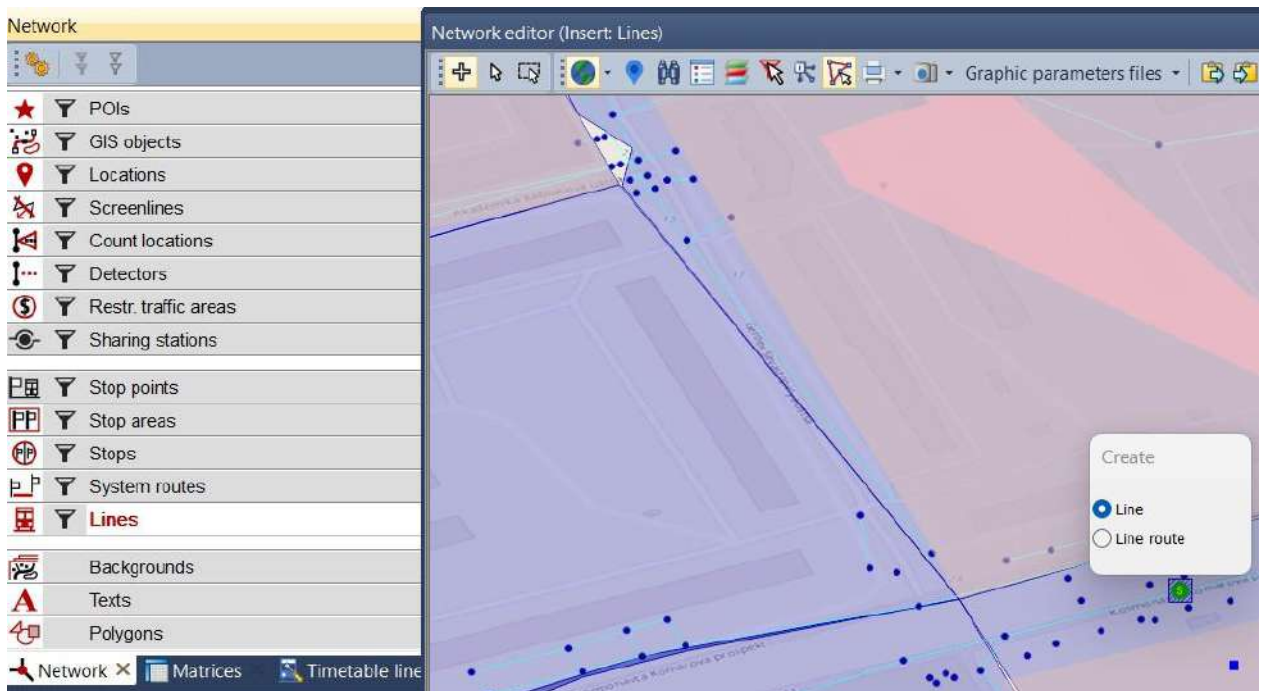


Figure 3.29 - An example of Line adding procedure.

After editing the necessary elements such as name, transport system, operator and type of vehicle a line will be added to the network.

Adding a line route.

After creating the route, Line Routes need to be defined. (Route Variants).

In PTV Visum, a line routes refers to a representation of a public transport route, such as a bus, tram, or metro line, which connects various stop points and moves along the transport network. The line defines the path that vehicles (such as buses or trains) follow, and it includes information about the stops, the direction of travel, and the operating schedule.

A waypoint can be either a node or a stop point located along the route variant.

All stop points along the route variant where a stop can occur must be considered waypoints. All nodes along the route variant can optionally be treated as waypoints.

Typically, route variants are arranged in pairs, one for each direction of travel. However, a single route may include any number of route variants.

By pressing a “Line route” button in Network side bar in insert mode adding a line route can be done. During the creation a line has to be chosen from the list of previously created lines, name set and directions of the route defined.

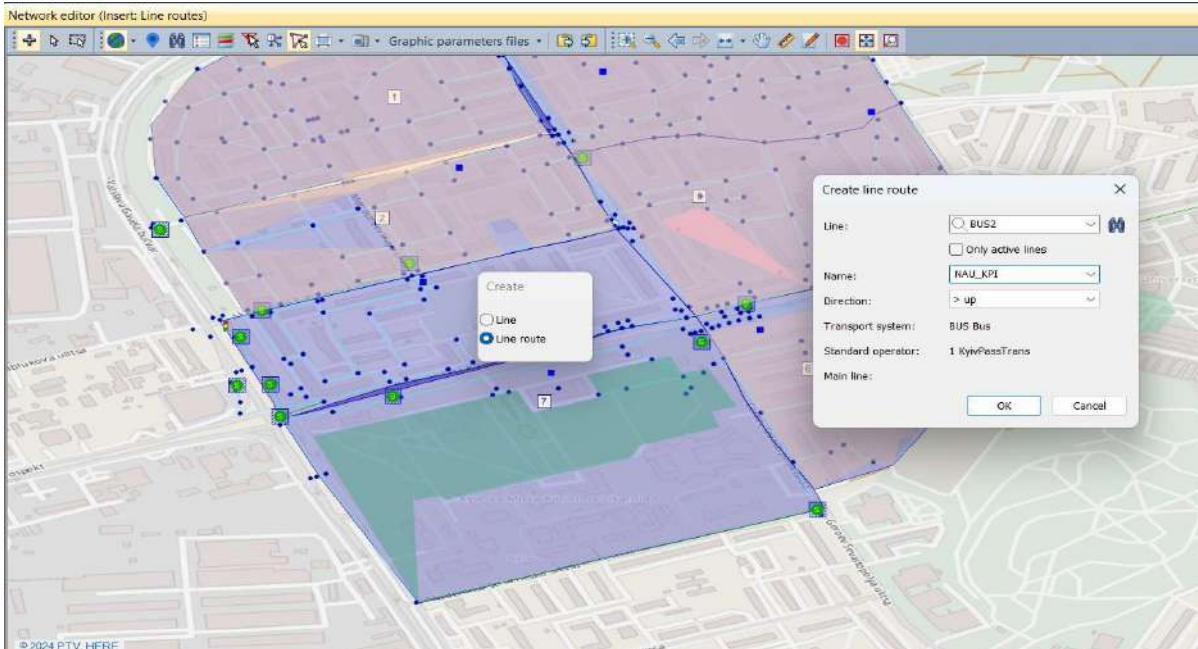


Figure 3.30 - Creating a line route

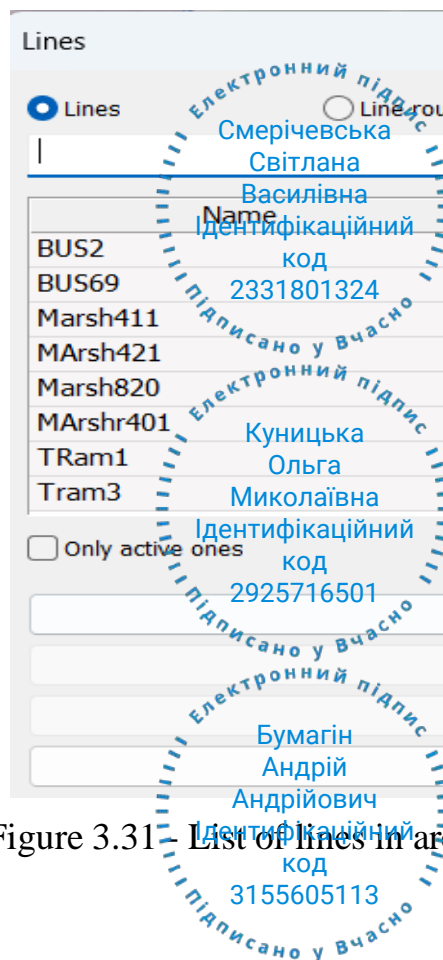


Figure 3.31 - List of lines in area

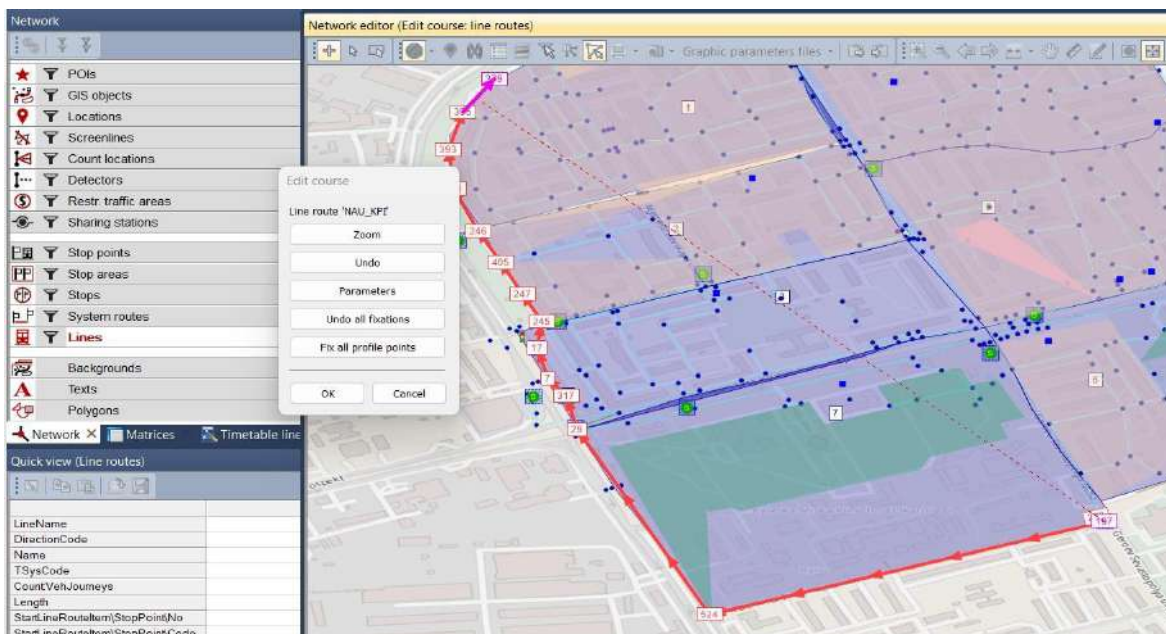


Figure 3.32 - An example of a route from starting point 197 to point 339 creation

After the outbound direction using the same technic return route can be processed. [42], [43]

Line routes

Lines Line routes

Line name	Name	Direction code
BUS2	Bulgakova-Sholudenka	>
BUS2	Sholudenka-Bulgakova	<
BUS69	Litv-PalSportu	>
BUS69	PS-Litv	<
Marsh411	411	>
Marsh411	PalSportu-Symyrenka	<
MArsh421	421	>
MArsh421	Pochina-Symyrenka	<
Marsh820	820	>
Marsh820	Kontraktova-Vyshneve	<
MArshr401	401	>
MArshr401	Vokzal-Akademy	<
TRam1	tr1	>
TRam1	Vokz-Borschahivka	<
Tram3	tr3	>
Tram3	Vokzal-Okruzhna	<

Only active ones

Reset selection

Zoom

Remove zigzags

Timetable

Figure 3.33 - List of the line routes in area (outbound and return routes)

Timetable for public transport.

After the lines and line routes a timetable for routes that were created can be done.

In the "Line" tab in editing mode a route option needs to be chosen and "TimeTable" pressed.

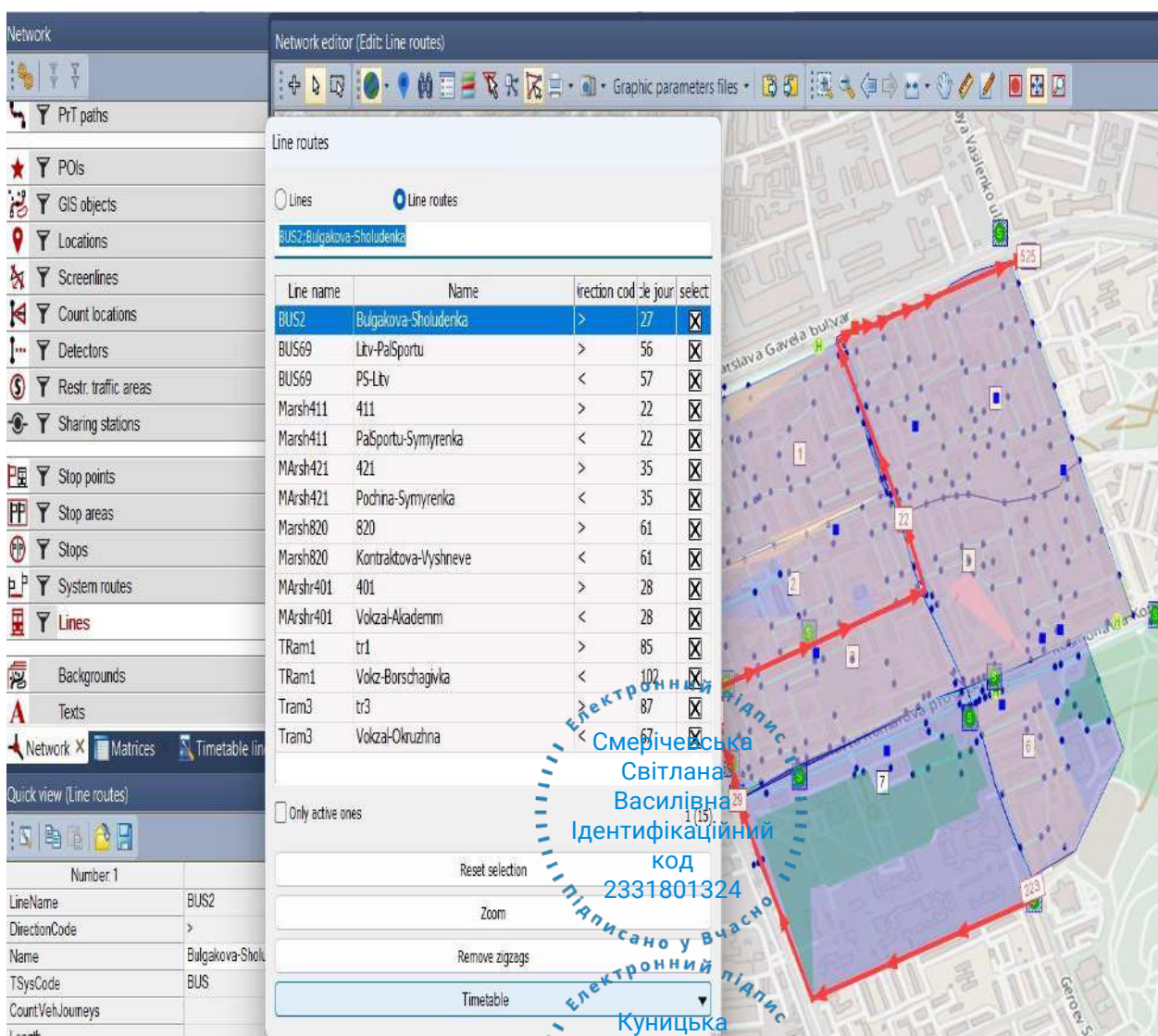
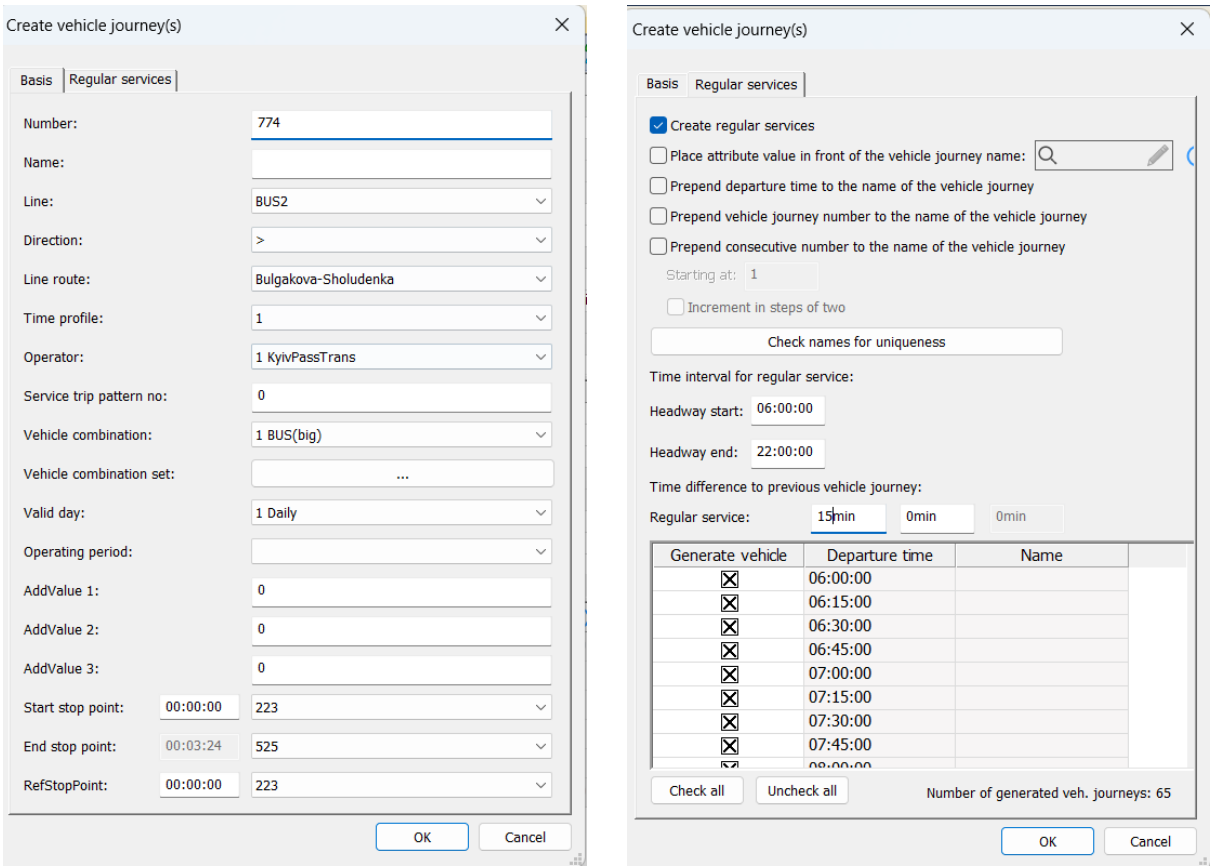


Figure 3.34 - Timetable of available routes creation

All the parameters (name, direction, line and operator) are adding during this step. As well as starting and ending time of the route and regularity of the route.



In the end the completed timetable for routes is created.

No	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762
Name	bus2	bus2	bus2	bus2	bus2	bus2	bus2	bus2	bus2	bus2	bus2	bus2	bus2	bus2	bus2	bus2
LineName	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2	BUS2
DirectionCode	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>	>
ConcatenateVehJour	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
FromTProfileIdentifier	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223
Dep	06:15:00	06:52:00	07:29:00	08:06:00	08:43:00	09:20:00	09:57:00	10:34:00	11:11:00	11:48:00	12:25:00	13:02:00	13:39:00	14:16:00	14:53:00	15:30:00
Arr	06:18:24	06:55:24	07:32:24	08:09:24	08:46:24	09:23:24	10:00:24	10:37:24	11:14:24	11:51:24	12:28:24	13:05:24	13:42:24	14:19:24	14:56:24	15:33:24
TaTProfileIdentifier	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525
OperatorIdentifier	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans	KyivPassTrans
CountVehJourneySec	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
IsCoupled																
ValidDaysIdentifier	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
ValidDaysIdentifier	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily	1 Daily
FromTProfileIdentifier	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223	1:223
Dep	06:15:00	06:52:00	07:29:00	08:06:00	08:43:00	09:20:00	09:57:00	10:34:00	11:11:00	11:48:00	12:25:00	13:02:00	13:39:00	14:16:00	14:53:00	15:30:00
Arr	06:18:24	06:55:24	07:32:24	08:09:24	08:46:24	09:23:24	10:00:24	10:37:24	11:14:24	11:51:24	12:28:24	13:05:24	13:42:24	14:19:24	14:56:24	15:33:24
TaTProfileIdentifier	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525	5:525
PreDepTime	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min
PreDepTime	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min	0min

Figure 3.36 - Completed timetable of the route

Creating connectors for individual transport and public transport.

Connectors connect districts with the road network of the modeling area and represent a virtual segment through which traffic flows are generated and absorbed by the district. After creation of the connectors type of connector should be determined. In case of private transport type “1” have to be chosen.

Connections for individual transport.

These connections link the center of a transport district with the nodes of driveway exits, adjacent areas, residential streets, parking spaces, and locations for long-term vehicle storage.

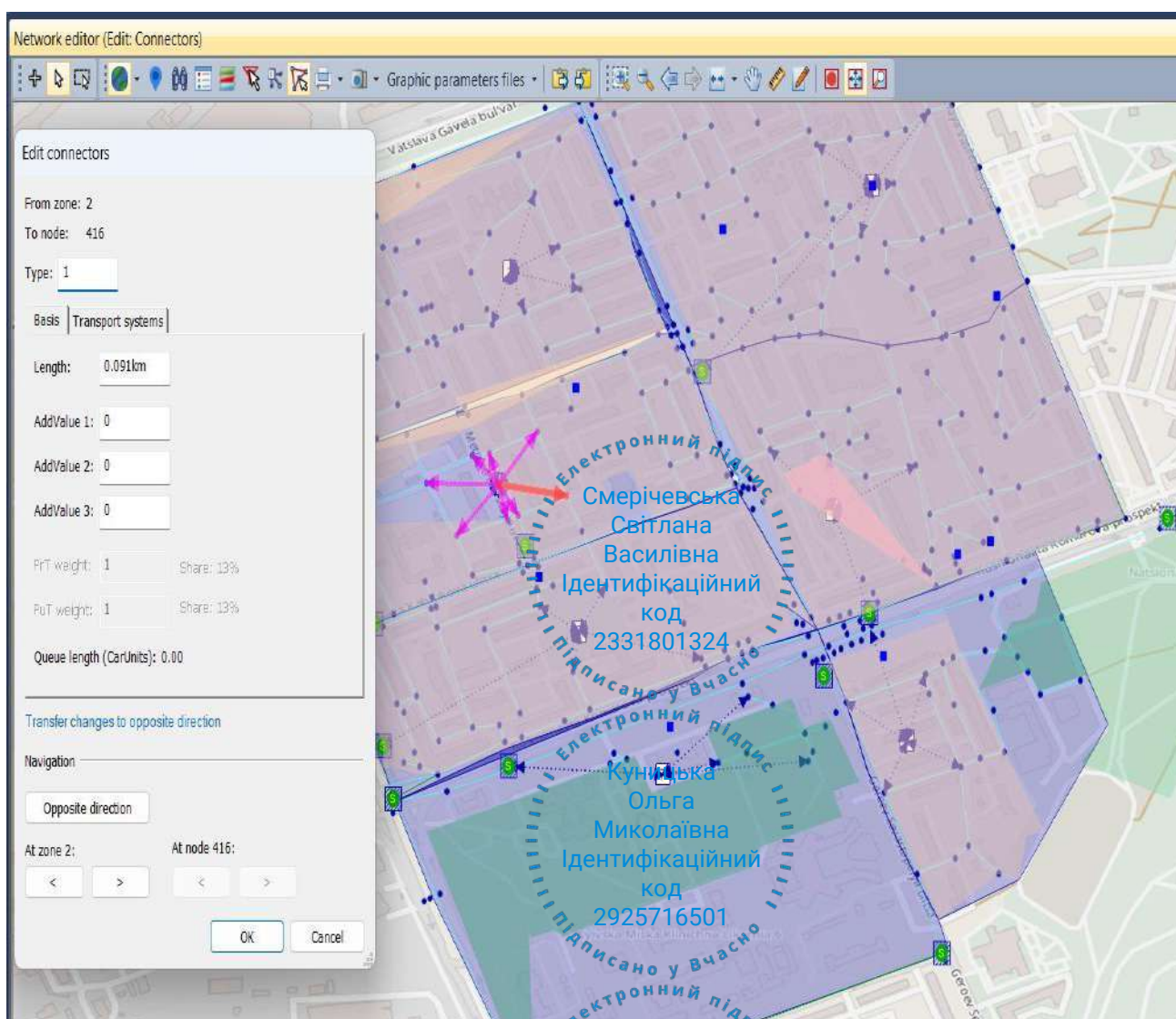


Figure 3.36 - Creating connectors for individual transport and editing attributes

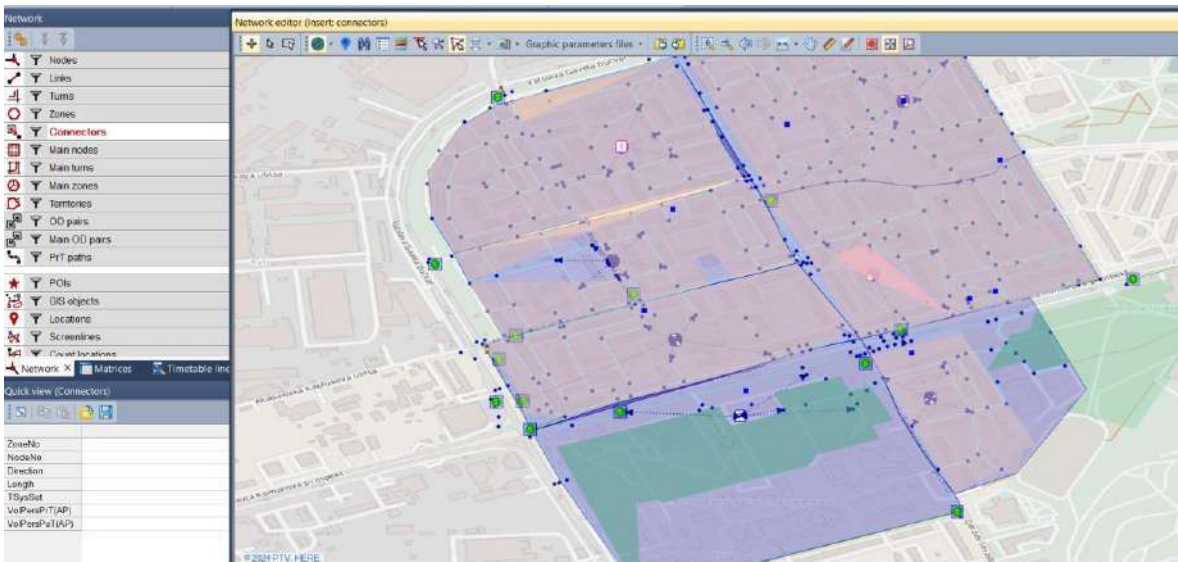


Figure 3.37 - Completed connectors for individual transport

Connections for public transport.

These connections link the center of a transport district with access points to bus or tram stops and are within walking distance from the district's central area.

Connectors for public transport creating in the same way as for private transport with the difference in “type” option. In case of public transport type 2 should be used.

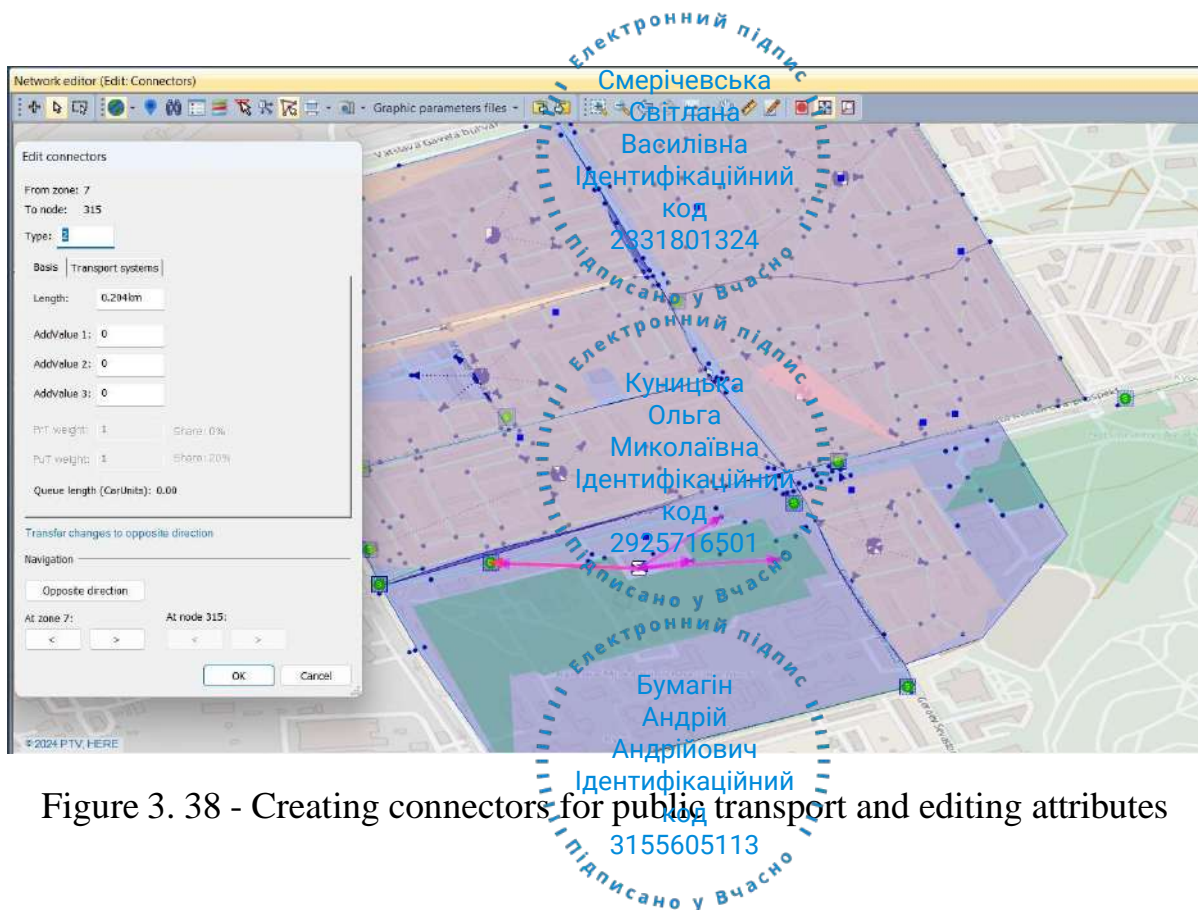


Figure 3. 38 - Creating connectors for public transport and editing attributes

List of all created connections with distances between the center of the zone and connectors endings can be seen in Connector/list menu.

List (Connectors)							
Number: 76	ZoneNo	NodeNo	Direction	TypeNo	TSysSet	Length	
1	1	428	O	1	CAR,WALK	0.059km	
2	1	428	D	1	CAR,WALK	0.059km	
3	1	429	O	1	CAR,WALK	0.095km	
4	1	429	D	1	CAR,WALK	0.095km	
5	1	430	O	1	CAR,WALK	0.079km	
6	1	430	D	1	CAR,WALK	0.079km	
7	1	437	O	1	CAR,WALK	0.072km	
8	1	437	D	1	CAR,WALK	0.072km	
9	1	439	O	1	CAR,WALK	0.116km	
10	1	439	D	1	CAR,WALK	0.116km	
11	2	406	O	1	CAR,WALK	0.095km	
12	2	406	D	1	CAR,WALK	0.095km	
13	2	408	O	1	CAR,WALK	0.054km	
14	2	408	D	1	CAR,WALK	0.054km	
15	2	409	O	1	CAR,WALK	0.091km	
16	2	409	D	1	CAR,WALK	0.091km	
17	2	411	O	1	CAR,WALK	0.051km	
18	2	411	D	1	CAR,WALK	0.051km	
19	2	412	O	1	CAR,WALK	0.091km	
20	2	412	D	1	CAR,WALK	0.091km	
21	2	414	O	1	CAR,WALK	0.046km	
22	2	414	D	1	CAR,WALK	0.046km	
23	2	415	O	1	CAR,WALK	0.050km	
24	2	415	D	1	CAR,WALK	0.050km	
25	2	416	O	1	CAR,WALK	0.091km	
26	2	416	D	1	CAR,WALK	0.091km	
27	3	190	O	1	CAR,WALK	0.074km	
28	3	190	D	1	CAR,WALK	0.074km	
29	3	208	O	1	CAR,WALK	0.165km	
30	3	208	D	1	CAR,WALK	0.165km	
31	3	213	O	1	CAR,WALK	0.058km	
32	3	213	D	1	CAR,WALK	0.058km	
33	3	317	O	2	WALK	0.305km	
34	3	317	D	2	WALK	0.305km	
35	3	521	O	1	CAR,WALK	0.063km	
36	3	521	D	1	CAR,WALK	0.063km	
37	4	271	O	1	CAR,WALK	0.072km	
38	4	271	D	1	CAR,WALK	0.072km	
39	4	228	O	2	WALK	0.247km	

Figure 3.39 List of all created connectors

3.3 Calculations of demand and offer models. Skim matrices.

Creation of a demand model.

The demand model consists of four elements (Actions, Groups, Demand Layer, and Mode Selection Matrix), which overlap to form various structures of the demand model. Knowledge of transportation demand in the area for which transport planning is being conducted is an essential foundation for evaluating the transport network. Determining correspondence matrices for transport through data collection can only be done partially.

Therefore, to reflect the actual demand relationships, mathematical models are used. These models calculate transport flows between districts in the planning area based on structural data, information about how the population uses transport, as well as data on the spatial distribution of infrastructure and existing transport supply. An additional important function of such a model is providing forecasts and scenarios for the future.

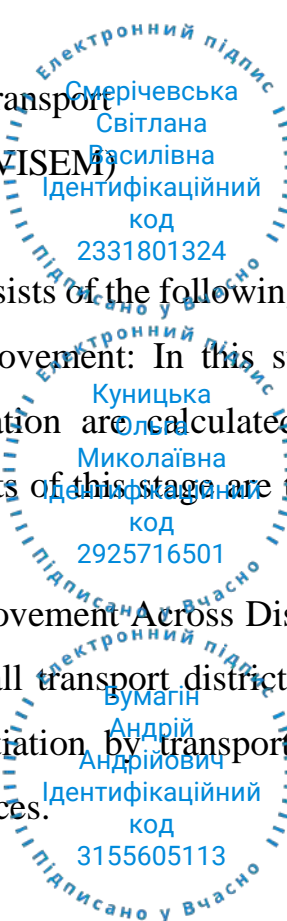
PTV Visum offers four demand modeling procedures:

1. Standard 4-step model
2. EVA Model for Passenger Transport
3. Action Chain-based Model (VISEM)
4. Freight Transport Model

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

1. Generation of Transport Movement: In this stage, the volumes of traffic from the source and to the destination are calculated for all transport districts, detailed by demand layers. The results of this stage are the row and column sums of the correspondence matrices.

2. Distribution of Transport Movement Across Districts: During this stage, the volumes of transport flow between all transport districts are calculated, detailed by demand layers but without differentiation by transport mode. The results are the elements of the correspondence matrices.



3. Mode Choice: At this stage, the mode choice is calculated, resulting in correspondence matrices, each representing trips made using a specific transport mode.

4. Redistribution Model (Route Choice): The redistribution calculation, differentiated by transport mode, allows for obtaining model values of transport flow intensities. The redistribution stage is the final step in the demand calculation cycle.

Configuration of the demand model for the next execution of the 4-step model.

An essential stage in building the Transport Demand Model is the creation of the transport demand structure.

A structural element of the transport demand structure is the demand layers.

For transport activities, the most typical demand layers are: Home – Work; Work – Home; Home – Study; Study – Home; Home – Other; Other – Home; Work – Other; Other – Work; Work – Work; Other – Other

Tab Demand/Demand model can be used for this purpose.

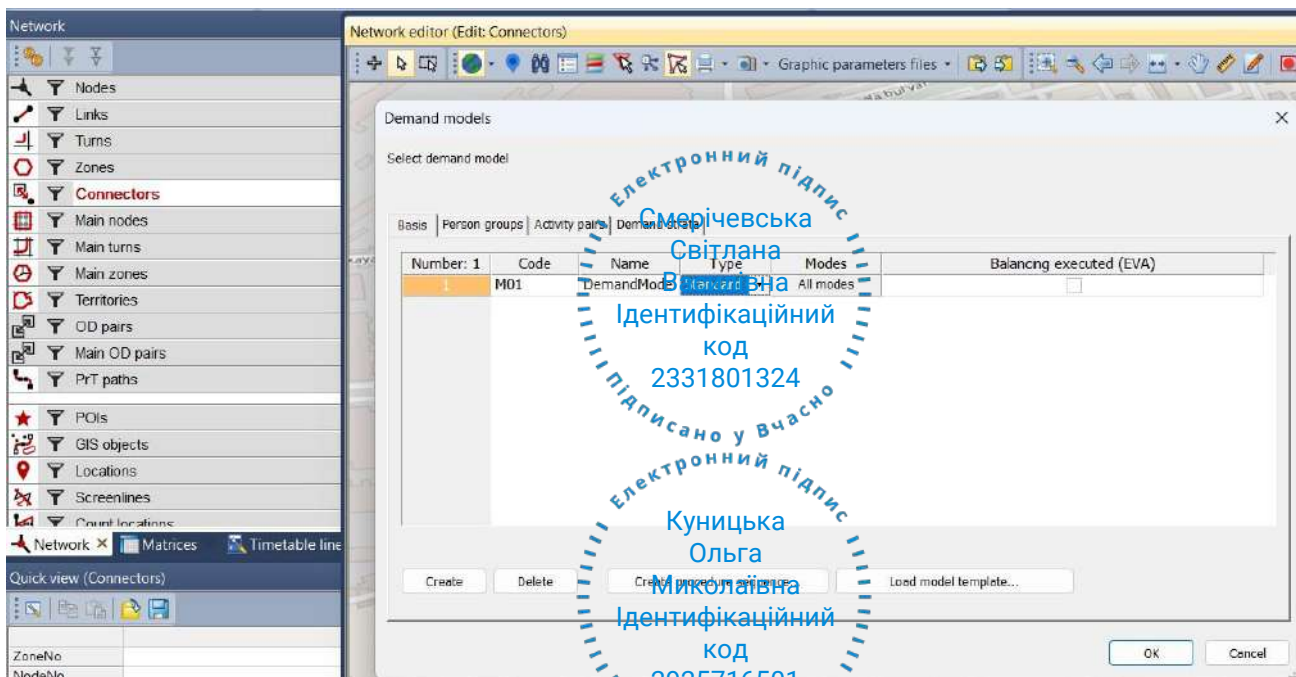


Figure 3.40 - Creating demand models

After completing the process 10 demand layers are created.

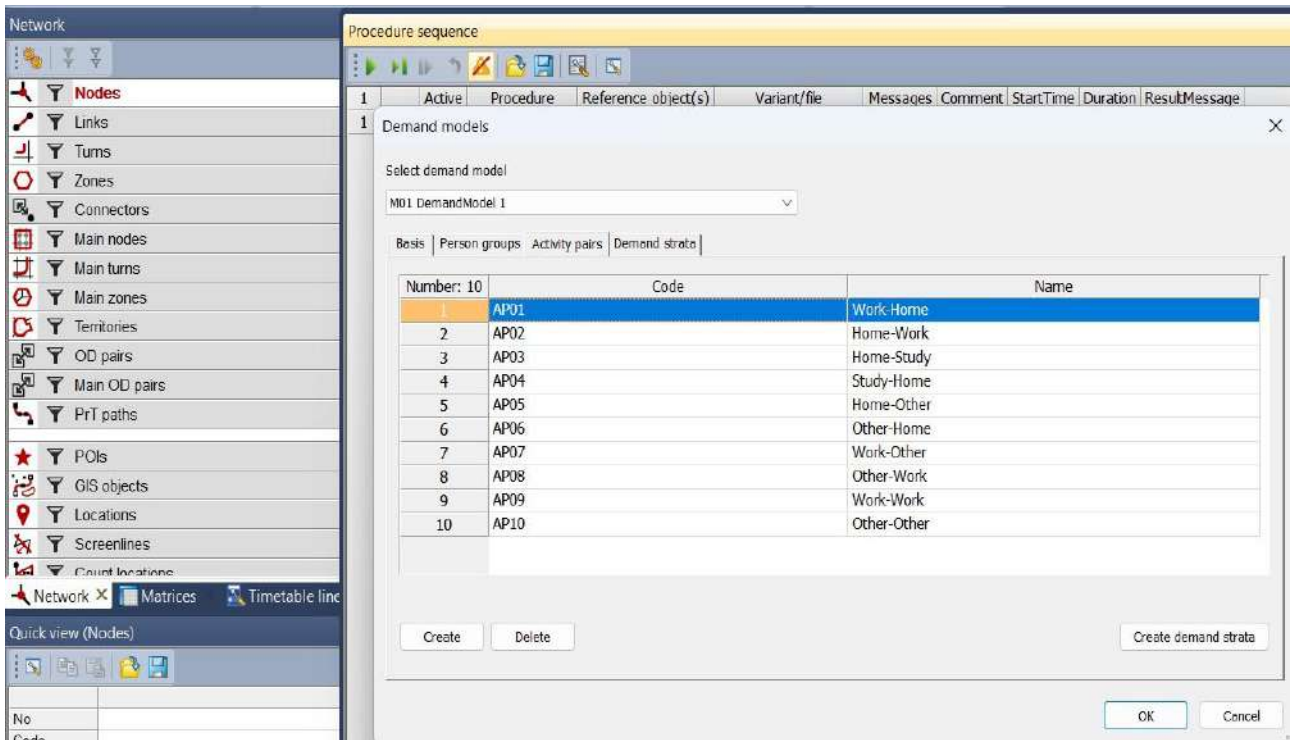


Figure 3.41 - 10 demand layers

After completing addition of layer Trip generation process can be started.

Trip Generation.

At this stage, the volume of transport flow from the source (origin) to the destination is calculated for each district and each demand layer. These parameters are also referred to as "generation" and "attraction".

The volume of transport flow from the source fully reflects the actual traffic originating from that district, i.e., the number of trips starting there. Alternatively, it may only represent the attractiveness of the district for a particular demand layer, thereby influencing the likelihood that, in the next stage of transport flow distribution, trips will originate from this area.

Which of these two interpretations should be considered depends on the parameter used in the Transport Flow Distribution procedure. The same applies to the volume of transport flow to the destination.

To enter the procedure for creating transport traffic, the "Calculate"/"Procedure sequence"/"Demand model" - "Trip generation" functionality can be used.

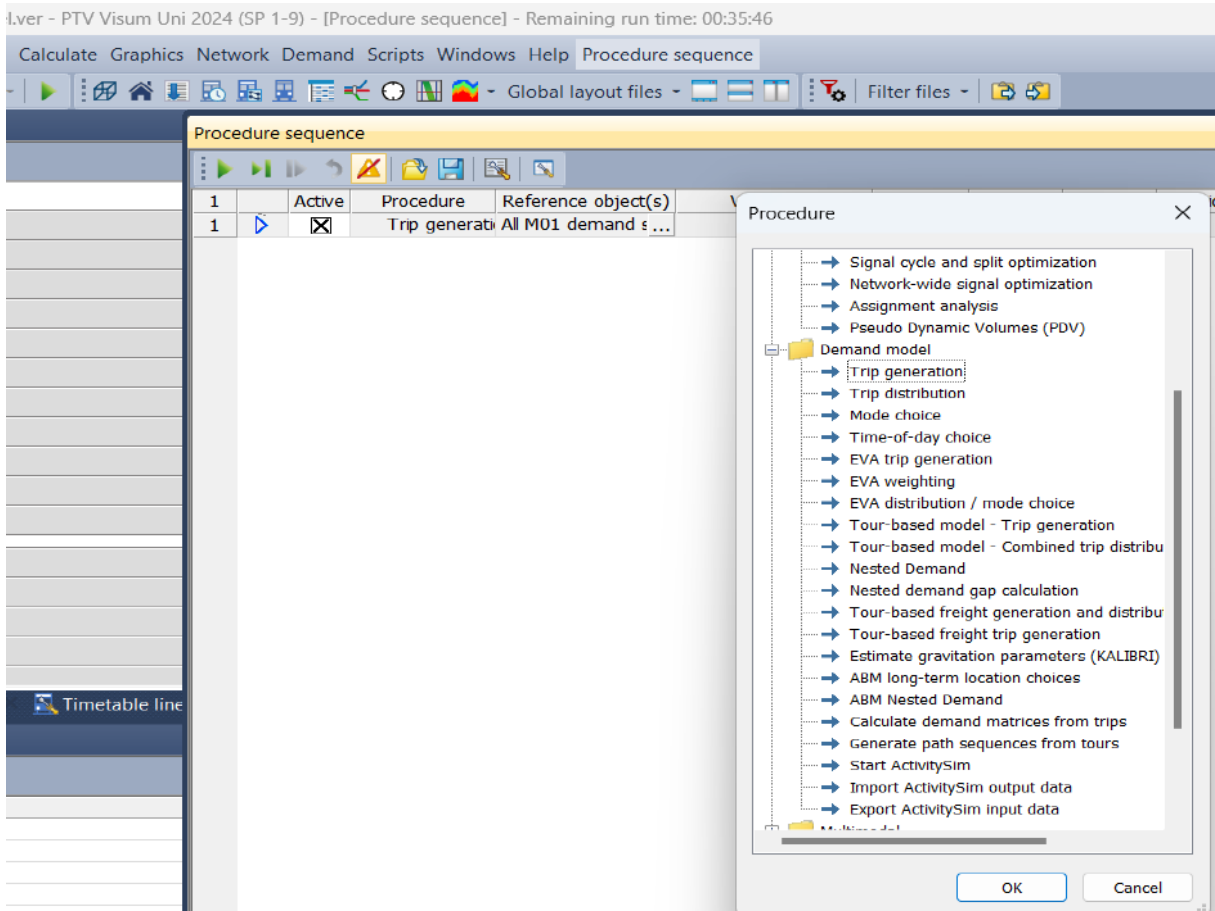


Figure 3.42 - Creating trip generating procedure

During this step all demand layers should be added.

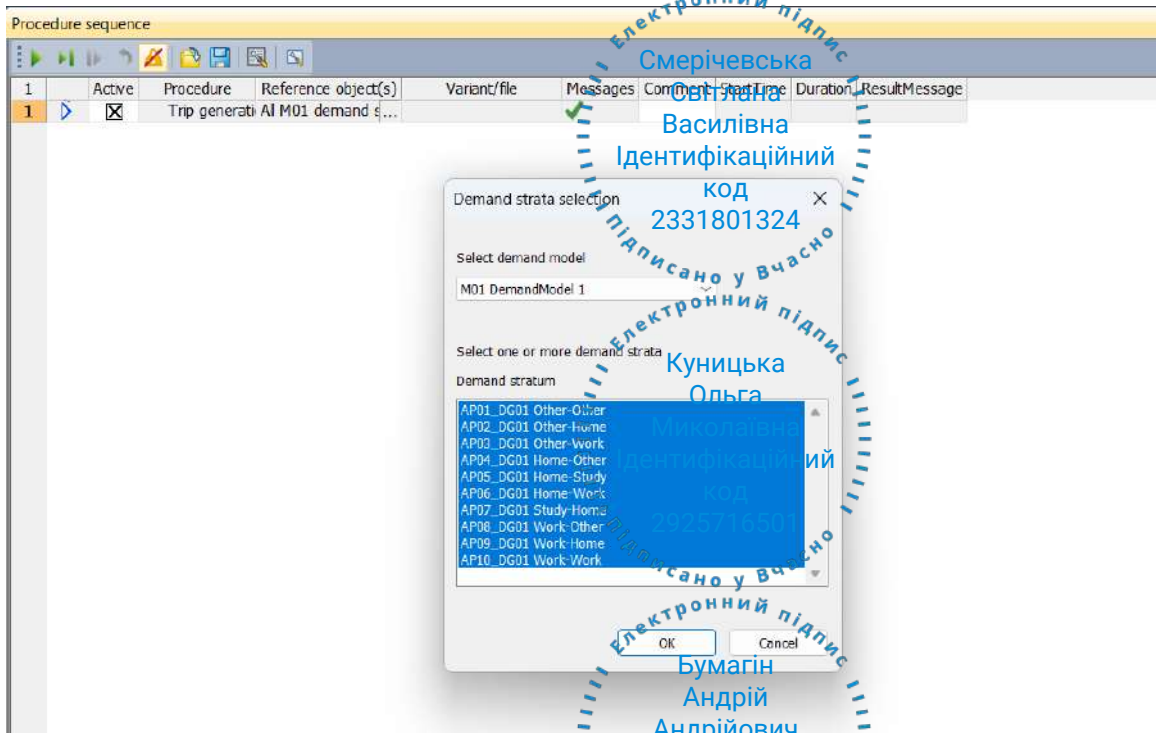


Figure 3.43 - Demand strata selection

While entering traffic volumes, coefficients for each layer have to be calculated.

For this reason, the number of movements is divided by the number of reference persons (these data are determined on the basis of surveys, data from mobile operators, etc.).

We set the coefficients for calculation.

Demand layers:

Home–Other:

Production function (from source) (House) volume of creation will be Population with a factor of 0.16 : $[POPULATION]*0.16$

Attraction function:

$[SERVISE_WORK_PLACES]*0.2+[POPULATION]*0.3+[STUDYING_PLACES]*0.09$

Home–Work:

Production function: $[WORKING_POPULATION]*0.45$

Attraction function: $[WORKING_PLACES]*0.45$ Home–

Study:

Production function: $[PUPILS]*0.38+[STUDENTS]*0.36$

Attraction function: $[STUDYING_PLACES]*0.38+[$

$STUDYING_PLACES_UNIVERSITY]*0.36$

Other-Home:

Production function:

$[SERVISE_WORK_PLACES]*0.02+[POPULATION]*0.09+[STUDYING_PLACES]*0.3$

Attraction function: $[POPULATION]*0.16$

Other-Other

Production function: $[SERVISE_WORK_PLACES]*0.05+[POPULATION]*0.09+[STUDYING_PLACES]*0.02$

Attraction function:

$[SERVISE_WORK_PLACES]*0.05+[POPULATION]*0.09+[STUDYING_PLACES]*0.02$



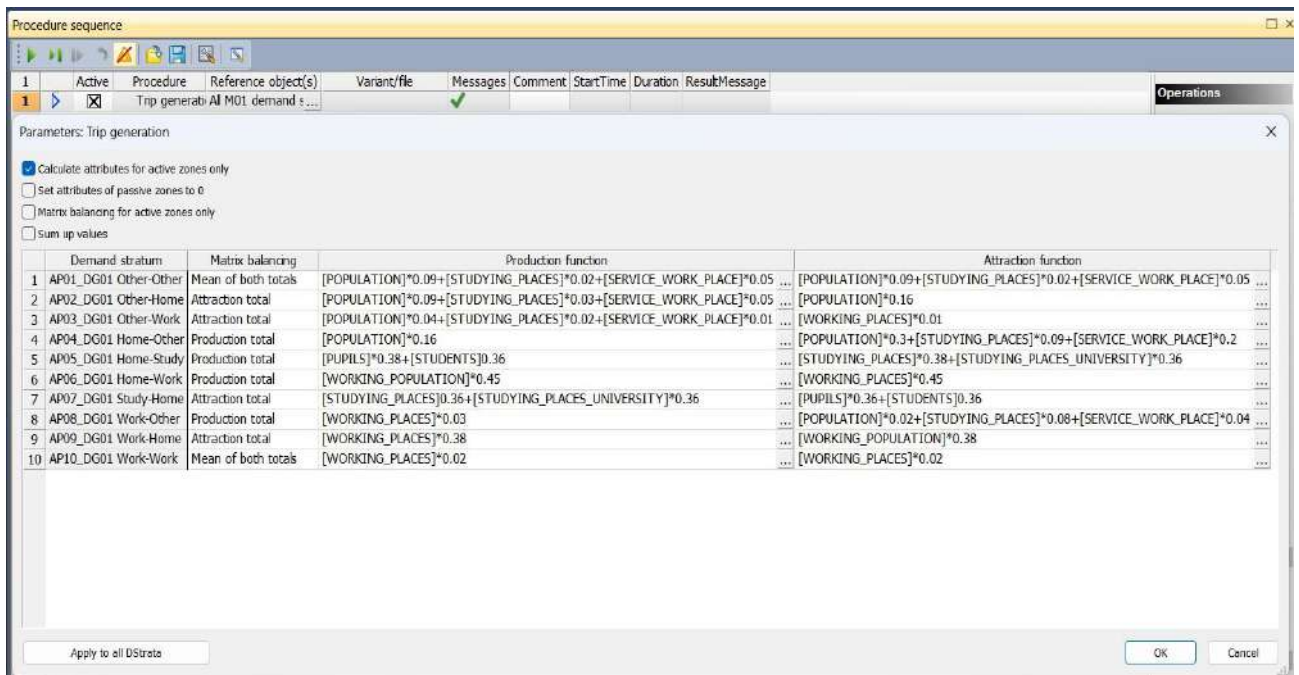


Figure 3.44 - Trip generation. Layers with functions

Cost matrices of individual and public transport/Skim matrix.

The skim matrix is a fundamental concept used in transportation modeling, especially for private transport (car) or other modes of travel. It is used to represent the travel cost (such as time or distance) between different zones within the transportation network. The skim matrix is essentially a matrix that contains the travel time, cost, or distance values for each pair of origin and destination zones.

The matrix can represent various types of skims, such as travel time, distance, cost, or other factors. These matrices are integral in the travel demand modeling process, influencing the generation of trip matrices, route choice modeling, and mode choice analysis. PTV Visum allows for customization of the skim process, specific parameters or constraints (e.g., adding penalties for tolls or different traffic conditions) can be set.

The calculation of transport demand is based on the costs associated with travel between transport districts. These costs are calculated and stored in the form of "cost matrices" (skim matrix).

The elements of the skim matrix represent any costs related to movement between all transport districts in the study area.

Cost values are used when calculating the utility functions (distribution model) for the stages of trip distribution and mode choice.

A variety of parameters can be chosen as the basis for calculating cost matrices. For individual transport, these parameters include: Travel time on the free network; Travel time on the congested network; Travel distance; Resistance (e.g., delays or obstacles); Toll fees (charges for using toll roads); Speed; Operating costs, and others.

The skim matrix for public transport serves a similar purpose to the skim matrix for private transport, but it specifically handles public transportation modes, such as buses, trams, subways, or trains. It represents travel costs (usually time or distance) for public transport between different zones or locations in the transport network.

The algorithm for skim matrix creation in PTV Visum is Calculate/Procedure sequence/Create/ Calculate PrT skim matrix and Put skim matrix.

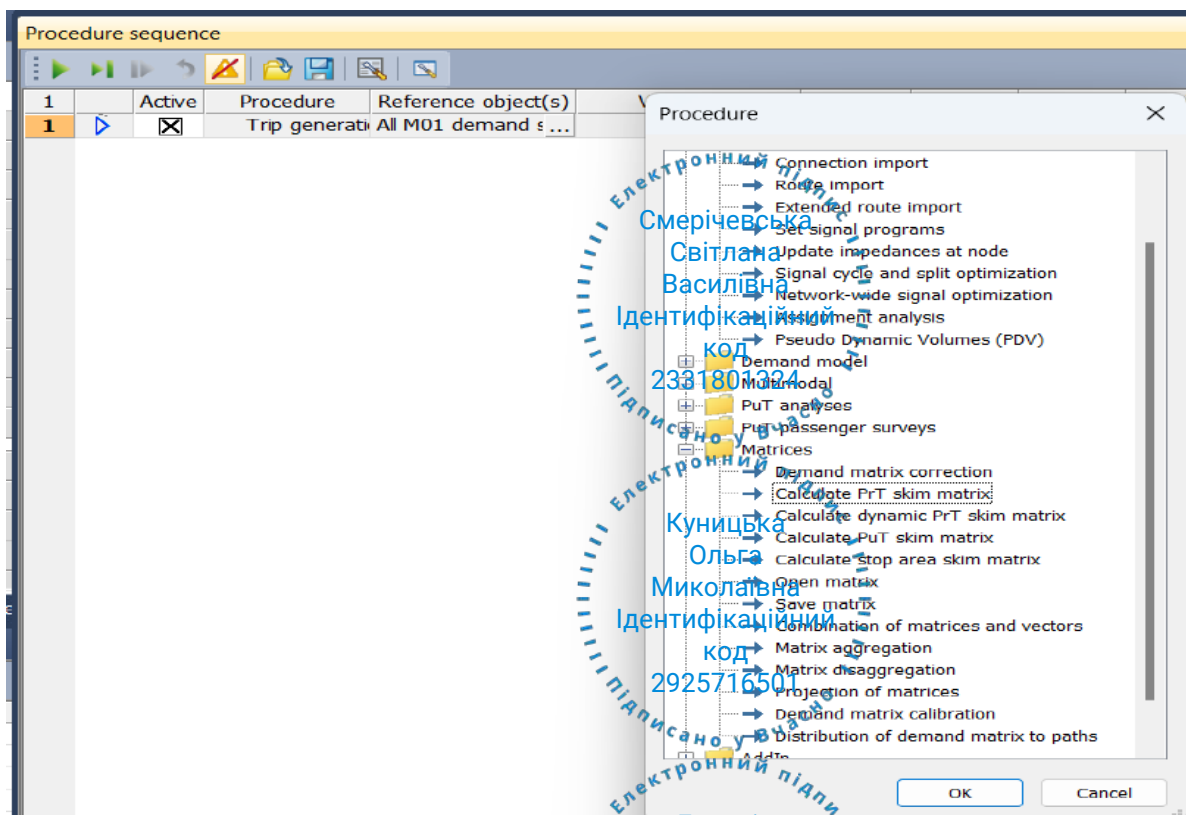


Figure 3.45 - Creation of a skim matrix

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8	Active	Procedure	Reference object(s)	Variant/file	Messages	Comment	Start	Duration	ResultMessage
1	<input checked="" type="checkbox"/>	Trip generation	All MD1 demand s ...				Nov 13, 2	0min	
2	<input checked="" type="checkbox"/>	Calculate PrT skim matrix	C. Car				Nov 13, 2	0min	
3	<input checked="" type="checkbox"/>	Calculate PuT skim matrix	PuT Public traspo ...	Timetable-based			Nov 13, 2	0min	The assignment was successfully completed.

Figure 3.46 Available skim matrices with reference objects(Car/Public transport) chosen

Trip distribution. Trip distribution determines the values of transport correspondence for different layers of demand between transport areas. In the Trip distribution model, the created flows are distributed by correspondence.

For this, skim matrix and evaluation functions are used.

For creating the Trip distribution procedure Create button/add a new procedure to the Demand model - select Trip distribution from the list and dropping it down in the list of functions should be used. Additionally all the demand layers must be added.

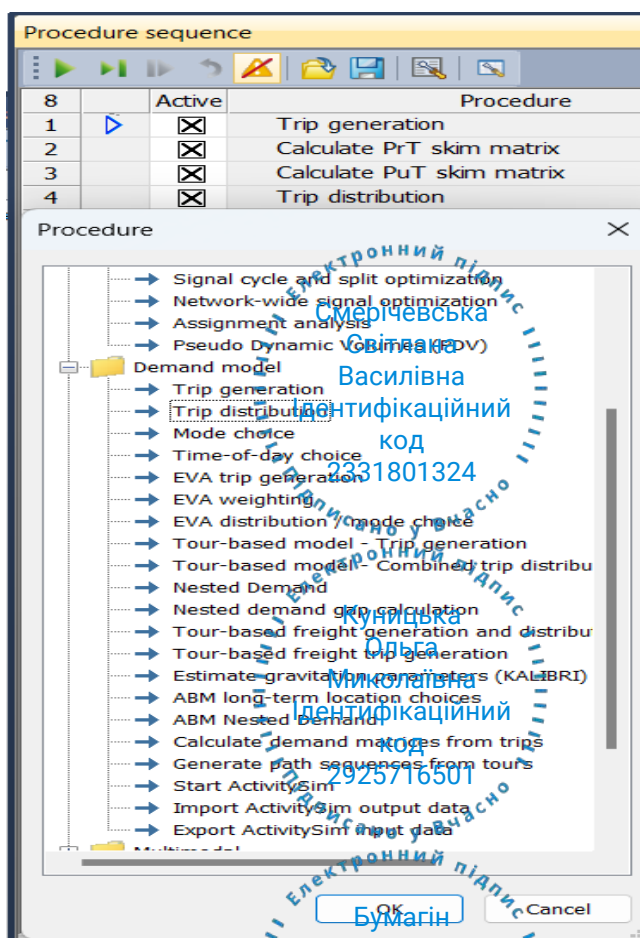


Figure 3.47. Adding trip distribution.

Mode choice.

After calculating correspondences by demand layers, it is necessary to divide these matrices (correspondences) by traffic modes - i.e. what type of transport will be used by passengers – private or public.

To add Mode of movement / Mode choice, Mode choice in the Procedure sequence tab from the Demand Model folder should be added.

After adding, the procedure has to be lowered down in the list of procedures.

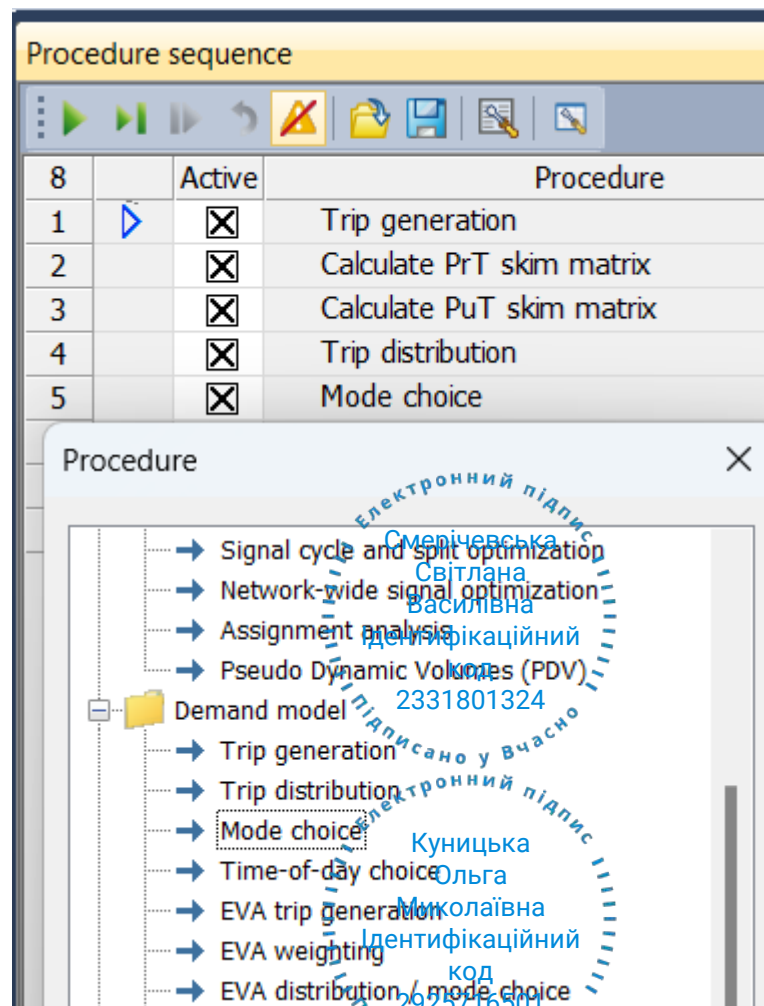


Figure 3.48 - Adding a mode choice

In edit mode once again all the demand layers should be added as well as Utility function, function type and coefficients. When the utility function is specified:

- For individual transport - cost matrix No. 2

- For HT of transport - matrix No. 4

With the given function, the Logit model and the coefficient 0.2 are chosen.

Parameters: Mode choice

Set any result demand matrix to 0 prior to calculation

Key	Demand stratum	Mode	Utility function	Function type	a	b	c			
1	AP01_DG01/C	AP01_DG01 Other-Other	C Car	Matrix([NO] = 2) ...	Logit	0	0	-0.2	...	Matrix
2	AP01_DG01/PuT	AP01_DG01 Other-Other	PuT PuT	Matrix([NO] = 4) ...	Logit	0	0	-0.2	...	Matrix
3	AP02_DG01/C	AP02_DG01 Other-Home	C Car	Matrix([NO] = 2) ...	Logit	0	0	-0.2	...	Matrix
4	AP02_DG01/PuT	AP02_DG01 Other-Home	PuT PuT	Matrix([NO] = 4) ...	Logit	0	0	-0.2	...	Matrix
5	AP03_DG01/C	AP03_DG01 Other-Work	C Car	Matrix([NO] = 2) ...	Logit	0	0	-0.2	...	Matrix
6	AP03_DG01/PuT	AP03_DG01 Other-Work	PuT PuT	Matrix([NO] = 4) ...	Logit	0	0	-0.2	...	Matrix
7	AP04_DG01/C	AP04_DG01 Home-Other	C Car	Matrix([NO] = 2) ...	Logit	0	0	-0.2	...	Matrix
8	AP04_DG01/PuT	AP04_DG01 Home-Other	PuT PuT	Matrix([NO] = 4) ...	Logit	0	0	-0.2	...	Matrix
9	AP05_DG01/C	AP05_DG01 Home-Study	C Car	Matrix([NO] = 2) ...	Logit	0	0	-0.2	...	Matrix
10	AP05_DG01/PuT	AP05_DG01 Home-Study	PuT PuT	Matrix([NO] = 4) ...	Logit	0	0	-0.2	...	Matrix
11	AP06_DG01/C	AP06_DG01 Home-Work	C Car	Matrix([NO] = 2) ...	Logit	0	0	-0.2	...	Matrix
12	AP06_DG01/PuT	AP06_DG01 Home-Work	PuT PuT	Matrix([NO] = 4) ...	Logit	0	0	-0.2	...	Matrix
13	AP07_DG01/C	AP07_DG01 Study-Home	C Car	Matrix([NO] = 2) ...	Logit	0	0	-0.2	...	Matrix
14	AP07_DG01/PuT	AP07_DG01 Study-Home	PuT PuT	Matrix([NO] = 4) ...	Logit	0	0	-0.2	...	Matrix
15	AP08_DG01/C	AP08_DG01 Work-Other	C Car	Matrix([NO] = 2) ...	Logit	0	0	-0.2	...	Matrix
16	AP08_DG01/PuT	AP08_DG01 Work-Other	PuT PuT	Matrix([NO] = 4) ...	Logit	0	0	-0.2	...	Matrix
17	AP09_DG01/C	AP09_DG01 Work-Home	C Car	Matrix([NO] = 2) ...	Logit	0	0	-0.2	...	Matrix

Apply to all DStrata

OK Cancel

Figure 3.49 - Mode choice data

After creating data in the matrices can be checked.

Matrices

Here, all matrices can centrally be managed and opened for further processing and analyses

AP01_DG01 x PuT

7x7

Name	1	2	3	4	5	6	7
1 Living zone	81.21	81.21	0.00	0.00	0.00	0.00	0.00
2 Living zone	46.11	0.00	37.26	7.87	0.99	0.00	0.00
3 Living zone	25.71	0.00	0.00	11.10	0.50	4.76	0.00
4 Living zone	78.82	0.00	0.00	0.00	78.82	0.00	0.00
5 Living zone	130.36	0.00	0.00	5.90	0.00	124.46	0.00
6 Service zone	68.89	0.00	0.00	0.00	0.00	0.00	59.33
7 Service zone	26.92	0.00	0.00	0.00	0.00	0.00	9.56

16 Mode choice AP01_DG01 x PuT

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Figure 3.50 - Data in mode choice matrices

As a result of performing the Mode choice procedure, we receive a message (the last column) about Modal Split, that is, what passengers probably will chose as a way of transportation. In figure 3.51 the result of modelling can be seen. According

to the model in researched area with all the input data population will rather choose private transportation(56 to 44 percent). This is not ideal distribution and cities officials try to increase the level of attractiveness of public transport up to 70%.

The results will be analyzed and improvements provided in “Recommendation and implementation” section.

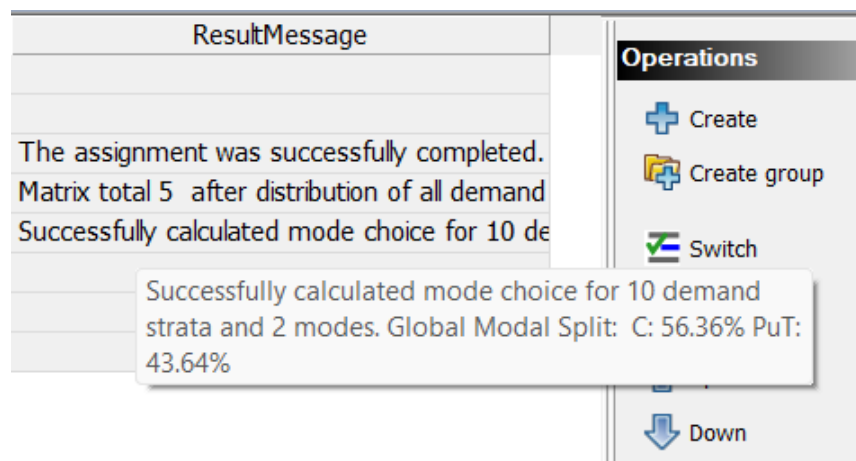


Figure 3.51 - Results of analysis of mode choice

Chapter 3 summary

Chapter 3 provides a detailed framework for conducting transport modelling in a district of Kyiv, emphasizing the integration of both demand and supply models to assess the performance of the transportation system. By utilizing tools like PTV Visum, the chapter outlines how to represent the transport infrastructure and simulate the interactions between travel demand and available services. Through this process, the chapter demonstrates how transport modeling can generate critical insights into the efficiency of the transport network, identify potential bottlenecks, and inform strategies for improving mobility and accessibility within the district.

The findings and models developed in this chapter provide a foundation for future transport planning, policy-making, and optimization efforts, contributing to a more sustainable and effective transportation system in Kyiv.

CONCLUSIONS AND RECOMMENDATIONS

Modeling the processes of street and road network elements is a crucial aspect of urban transport system planning and management. It helps to understand the interactions between different parts of the network, forecast and optimize vehicle movement, as well as address issues related to traffic congestion and road safety.

Models can account for various factors such as the geographical features of urban areas, the location of key objects and infrastructure, demand for transportation services, traffic flow, and the interaction between different types of transport. They provide the ability to predict the impact of various urban development scenarios and changes in the transport system on comfort, efficiency, and traffic safety.

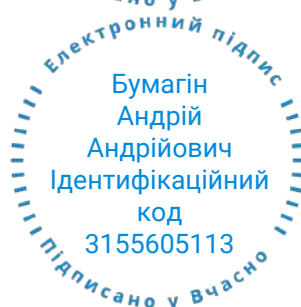
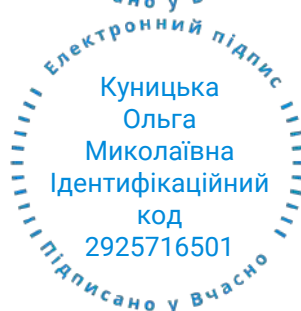
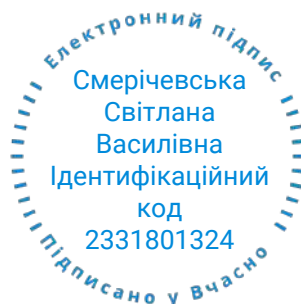
The study involved developing a transport model for a neighborhood in Kyiv. The model includes both transport supply and demand components. When modeling the transport supply for the neighborhood, the following network graph elements were introduced: 474 nodes, 864 segments, 7 transport districts, 25 stops, and 8 public transport routes (each with two directions), along with the public transport schedule. The transport flows (population movement) were generated, meaning the assessment of the total volumes of arrivals and departures in each transport district. The evaluation of arrivals and departures was done separately for each movement layer based on socio-economic statistics of transport demand.

A four-step model was used to simulate transport demand, and transport flows were calculated using demand procedures. Movement (correspondence) matrices and cost matrices between each pair of transport districts were computed. The distribution of inter-district correspondence across available transport modes was carried out using probabilistic choice models. The selection criterion used was either the maximization of user utility or the minimization of their costs.

The modeling results revealed that the share of private car use is 56%, while public transport use stands at 44%. It can be concluded that measures should be taken to improve the attractiveness of public transport for users.

Encouraging the use of public transport over private cars can be achieved through several strategies focused on convenience, affordability, accessibility, and the overall user experience. Some of the approaches include: [22]

1. Improving Public Transport Infrastructure
2. Enhancing the Quality of Service
3. Incentivizing Public Transport Use
4. Encouraging Sustainable Transport Choices
5. Promoting Public Transport as a Convenient and Smart Option
6. Raising Public Awareness and Promoting Behavioral Change
7. Creating Attractive Urban Spaces
8. Leveraging Technology and Data
9. Providing Incentives for Switching Modes
10. Designing for Future Needs



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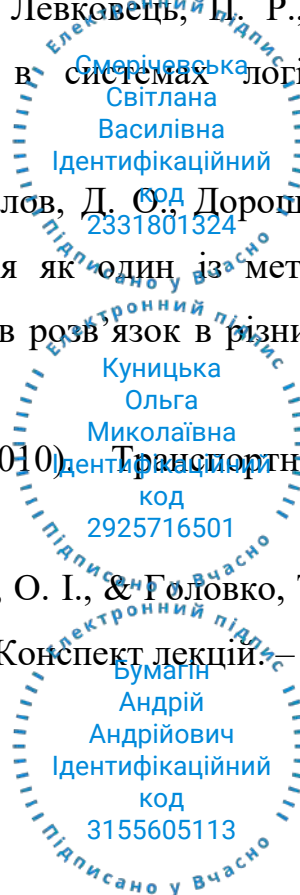
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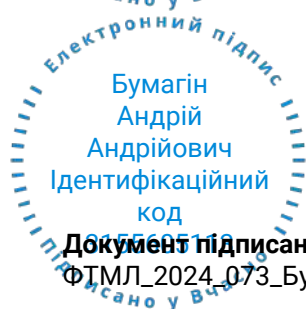
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Ідентифікаційний код: 3155605113

Бумагін Андрій Андрійович

Власник ключа: Бумагін Андрій Андрійович

Час перевірки КЕП/ЕЦП: 18:01 26.11.2024

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Серійний номер: 382367105294AF97040000006A250E004D4A0303

Тип підпису: кваліфікований

Електронний підпис

13:04 28.11.2024

Ідентифікаційний код: 2925716501

Куницька Ольга Миколаївна

Власник ключа: Куницька Ольга Миколаївна

Час перевірки КЕП/ЕЦП: 13:04 28.11.2024

Статус перевірки сертифікату: Сертифікат діє

Серійний номер: 382367105294AF9704000000354A0B002AC62703

Тип підпису: кваліфікований

Електронний підпис

21:28 28.11.2024

Ідентифікаційний код: 2331801324

Смерічевська Світлана Василівна

Власник ключа: Смерічевська Світлана Василівна

Час перевірки КЕП/ЕЦП: 21:28 28.11.2024

Статус перевірки сертифікату: Сертифікат діє

Серійний номер: 382367105294AF97040000002F7F1100B35EDB01

Тип підпису: кваліфікований