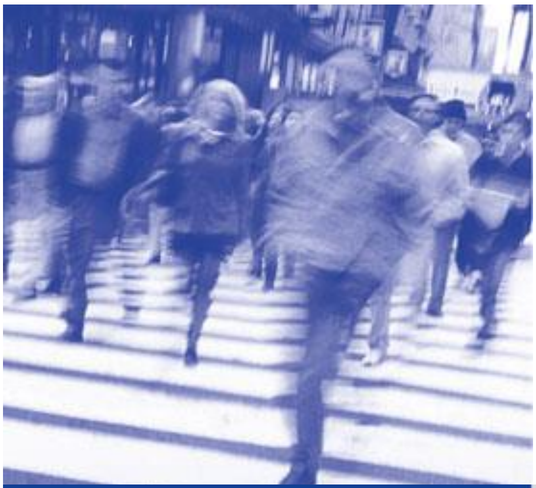

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Report on the traffic model development for SUMP

Implementation Status Report G3.1

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Abstract

This report summarizes the activities up to now (April 2016) in the City of Gdynia's CIVITAS DYN@MO measure G3.1 "Traffic model development to expand Gdynia's SUMP". Planning of transport networks is a fairly complicated process, because for its construction and expansion weighing decisions are needed. Building of efficient transport networks requires solving complex optimization problems in transportation. The results of analyses carried out by using various tools, which include various types of forecasting software, are used to facilitate the process of making planning decisions. Forecasting is based on scientific analysis, to formulate opinions about the future state of the studied phenomenon on the basis of knowledge about its current course. In the case of transportation systems forecasting mostly concerns the prediction of the future (medium or long term) traffic volume or volume of passenger travel or freight for existing or planned transport network. The need for traffic models to forecast and test transport networks is obvious due to the inability to survey the events and relationships occurring in the transport networks in an empirical way [17].

The approach described below is a multi-level and multi-layer model based on the idea adopted by the Department of Planning and Transportation of the City of London [12]. The levels are determined by the type of administrative area and the layers are determined by the kind of transport analysis or transport management. MST (Multilevel Model of Transport Systems) will be fed with data from detection systems located in the architecture and infrastructure of the TRISTAR system, the common integrated traffic management system of the cities of Gdynia, Sopot and Gdańsk, and ultimately also using localization devices in vehicles, mobile phones and navigation devices (Bluetooth, wifi) [21].

The strategic level of MST includes the provision of data to develop a transport policy, the implementation of planning studies and network studies. At the strategic level a macroscopic model (based on the VISUM programme) (PTV AG) will be applied. The model requires a disaggregation of districts within the area of the City of Gdynia together with input on detailed road network and public transport services parameters. The model will be used to collect and estimate data for the mesoscopic model, complying with the planned routes located in the vicinity of the city [19].

The tactical level includes the provision of data to develop decision-making papers (network and corridor studies, feasibility studies), development projects of traffic arrangement, traffic control and evaluation of the effectiveness of planning solutions, as well as for traffic management purpose. The object of research will be the transport network, a sequence of roads or streets sections, in this case a segment of public transport services. At the tactical level the mesoscopic model (based on the VISUM and SATURN programmes (ATKINS) as well as the BALANCE offline programme (GEVAS) implemented within the TRISTAR system) will be applied. This model will be used to analyse the scenarios of traffic arrangement modifications as well as to estimate the efficiency measures of planned modifications. The model will derive the results from the macroscopic model within the scope of demand modelling with a parallel division into particular modes of transport. This will enable calibration, taking into account the road network within the Pomeranian Region (results from the macroscopic model). The model will be powered and calibrated with data from TRISTAR

(in the future the implementation of public transport passenger counters in vehicles to update and calibrate the models will also be used as data for statistical analysis, respectively). The macroscopic and the mesoscopic models will provide the basis for the elaboration of the microscopic model (simulations) which will be powered by current or historical data from the data warehouse of the TRISTAR system and traffic control system BALANCE [21].

The operational level includes the provision of data to develop specific projects of traffic arrangement, traffic control programmes, projects of transportation services for the selected objects and primarily visualize the operation of transport facilities. The object of research will be a section of road or street, a section of the public transport service or a junction. At the operational level the microscopic model (based on the VISSIM programme (PTV AG) or DRACULA programme [10], [11] will be applied. This model will allow for verification and demonstration of results obtained from the macro- and mesoscopic models and will provide important input for the community projects and the planned internet platform (Mobility 2.0) within the CIVITAS DYN@MO project to communicate with inhabitants. The DRACULA software allows simulating traffic in an area much larger than VISSIM (the ability to simulate traffic at only a few intersections at the same time). It is very useful for testing control strategies in large areas.

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1 The Multi-level Transport Systems Model (MST) concept

1.1 Introduction

Within CIVITAS DYN@MO, the City of Gdynia has elaborated a three-level transport model for both individual and public transport for the city. It was based on traffic research for the City of Gdynia and is being used to complete the City's Sustainable Urban Mobility Plan (SUMP). It already starts to serve as an excellent visualisation tool to present urban mobility strategies and implementation options to stakeholders and the public. In relation with web 2.0 applications the information will also be available to citizens and stakeholders.

The main objectives of the CIVITAS DYN@MO measure "G3.1 Traffic model development to expand Gdynia's SUMP" were and are:

- Set-up sound data and information for updating Gdynia's SUMP (together with the analyses conducted within measure G1.2)
- Set-up of a 3-level transport model for Gdynia
- Accomplishment of detailed analyses of different proposals and measures indicated in the SUMP with the use of an elaborated 3-level transport model and on this basis assessment of their effectiveness and impact on transport system reliability, as an input to a dynamic SUMP
- Choice of infrastructure improvements aimed at increasing the attractiveness of alternative modes of transport based on the analysis conducted with the use of the transport model

Developing an effective and efficient transport network requires solving complex optimization problems of transport. The results of analyses carried out using various types of tools, which include various types of prognostic software, provide important input when making planning decisions. Forecasting, based on scientific analyses, facilitate judgements about the future state of the studied phenomenon on the basis of its knowledge of its present course [1]. In the case of transport systems, forecasting is often the estimation of the future (medium or long-term) traffic, travel volume of passenger or freight on an existing or planned transport network.

The subject of analysis in the optimization of transport networks is the iterative calculation of the size of traffic flows depending on the size of the demand for transport (resulting from the distribution of the function of land use and their associated attributes), and the supply of the transport system (usually measured capacity of individual elements of the system). Issues of capacity calculation and optimization problems of transport networks cannot be solved analytically, using a single calculation step. Therefore, to solve these issues, a multi-level, complex mathematical model can provide important input.

Mathematical modelling of travel and vehicle flows was developed quite intensively in the second half of the last century [2], [3], [4] and as a result a lot of software for forecasting traffic in cities was developed. The software (EMME, INTEGTARION, VISUM, SATURN, etc.)

include mathematical models and complex computational procedures. The used computer software to enable the development of a model of the transport system of the selected object or area of road, include basic procedures of the mathematical model of the transport system, whereas the role of the transport analyst is the selection of appropriate parameters of these models. The selected parameters should reflect the actual transport behaviour of inhabitants of the area and characteristics of the area and transport networks in the present state, as well as the principles of their development.

The experience of the authors in recent years shows that within the area of the Pomorskie region in Poland various tools for forecasting and analysis of transport are used. Also various models developed under different assumptions and forecasts are used, and unfortunately the analytical results significantly different from each other.

Taking this into account the Department of Highway Engineering at Gdansk University of Technology is developing and implementing an integrated, hierarchical system of forecasts and analysis of transport, of which the first steps are being implemented in the framework of the CIVITAS DYN@MO project.

1.2 The experience of conducting analyses and forecasting of traffic

Tools for traffic forecasting and analysis used in the Pomorskie region

In the Pomorskie region the following tools are currently being used for forecasting of traffic and transport analyses: VISUM, SATURN, TRANSYT, DRACULA, and VISSIM.

VISUM: In Poland and in Europe one of the most popular tools for modelling transport behaviour of residents and for traffic forecasting is the VISUM software developed by PTV. This programme is one of the best tools to determine the demand for travel, analyses and evaluation of existing planned transport systems. The VISUM is software integrates all types of public and private transport in a single model (multimodal models). The software has the ability to analyse modal split and the creation of a classic 4 level model (generating travel, travel schedule, choice of means of transport, traffic distribution). It can be used both for urban areas, agglomerations and sub-regions, countries and states. Currently, the software is used by Gdansk University of Technology, project offices, the City of Gdynia – Roads and Green Management in Gdynia and Gdansk, as well as recently by the Gdansk City Development Office.

SATURN: The SATURN software package has been developed since 1976 by the Institute of Transportation Studies at the University of Leeds [5], [6], [7]. In the package, a number of tools for modelling transport systems can be distinguished. In the package it is possible to use both conventional macroscopic static traffic distribution in the transport networks of various sizes (defining functions of the resistance of the connections between nodes, without taking into account the type and parameters of intersections in details) and a simulation including the specific types and characteristics of the intersections and their members scale averaged (inter alia Webster's method and its modifications, TRRL methods) or a combination of these approaches makes the package more flexible and versatile in the areal applications and objectives which are to serve the analysis (starting with the analysis of planning, through feasibility studies to analyse specific solutions, e.g. traffic organization at intersections). Between the distribution model and traffic simulation model covering the intersections there is a feedback loop, i.e. the resulting data is iterated between models and their convergence monitored. A dispersion of traffic flow between intersections is included. Each iteration of the traffic distribution includes dynamics of parameters of traffic intersections, which has an impact on the choice of a route.

The usefulness of applying the SATURN package to Polish conditions was analysed in the description [8]. In Poland, the SATURN package is used among others in Gdansk (Gdansk University of Technology), Poznan (BIT Office) and Krakow (Cracow City Council).

TRANSYT is a commonly used software to optimize and coordinate traffic lights in the arteries and network intersections. The optimization process takes place after the search for such parameters of plans of constant time traffic lights at present traffic flows for which the value of the index PI (Performance Index) as a function of linking the cost of wasted time and number of stops is the smallest. The software uses an optimization of parameters of signalling programmes method, developed originally by D. I. Robertson in 1967, and then refined in the Transport Research Laboratory [9]. Currently, the fourteenth version of this software is available. In the Pomorskie region, this software is used by the Gdansk University of Technology (since 1978 - Version 6) and by the Office of Municipal Engineering Design in Gdansk, as well as the TRAFIK Office and the City of Gdansk - Zarząd Dróg i Zieleni.

DRACULA: This is a simulation software [10], [11] which enables microsimulation of traffic in the area of the transport network, including all types of intersections and junctions. The DRACULA software simulates the traffic of public transport vehicles using the public transport network model, which can be built and analysed in the PT-SATURN. The DRACULA software takes into account the behaviour of drivers and passengers using the “follow the leader” model, the model of a lane change (also before the intersection and when overtaking or avoiding e.g. a bus waiting at the bus stop or the location of the incident or road works), simulation of the detector, filling time of a mean of public transport depending on the number of passengers, traffic priority for public transport vehicles, including the structure of vehicles, traffic control, etc.

VISSIM is a popular software for modelling at the microscopic level in both urban traffic, public transport, cyclists and pedestrians traffic flows. The parameters of driving behaviour are based on the “follow the leader” Wiedemann model. The created model simulates the interactions between road users and the environment designed so that we are able to predict the consequences arising out of different scenarios for the development of the study area [12]. This software is used to supplement the analysis performed using other tools such as VISUM, SATURN, TRANSYT. It allows performing the assessment of traffic conditions not only at intersections and distances between them, but also for planned parking, gate fees and analysing the behaviour of pedestrians at interchanges. In the Pomorskie region, this programme is used by Gdansk University of Technology, as well as by the city of Gdynia and Gdansk – Zarzad Drog i Zieleni and Transprojekt Office in Gdansk.

Within the CIVITAS DYN@MO project the software packages VISUM, VISSIM and SATURN are being implemented.

Transport models

In the Pomorskie region models for the transport of four types of areas are being used: national model, regional model, provincial model, agglomeration and urban models.

National model: In 2007-2008, at the request of the General Directorate for National Roads and Motorways, Warsaw University of Technology has developed a national traffic model. To build the network a network of national and regional roads was used. The division into homogeneous sections on national roads and regional roads included such features as:

- existing and planned intersections of national and regional roads,
- points of changes in cross-section,
- places where a change in road surroundings occurs (e.g. suburban road turns into urban, built-up area, etc.).

In order to provide a faithful representation of the national and provincial road network a total of 49 types of sections have been defined in the model. The sections were divided with regard to the cross-section, the class of the road, number of lanes, capacity, and maximum speed allowed. Generation and absorption of traffic is done for the 355 internal regions (districts) and 85 external regions at the border of the country [13].

Regional model: Gdansk University of Technology has developed a regional traffic model for the Pomorskie region. To build the model, the network of national roads, provincial, district and major municipal roads were used. Similarly to the national model, the division into homogeneous sections, included existing and planned road junctions, the places of changes in the cross-section, places where a change of road environment occurs (e.g. suburban road turns into urban, built-up area, etc.) [14].

In order to provide a faithful representation of the national and provincial road network a total of 80 types of sections have been defined in the model. The sections were divided with regard to the cross-section, the class of the road, number of lanes, capacity, and maximum speed allowed. Generation and absorption of traffic is done for the 166 regions: 140 internal regions (municipality) and 25 exernal regions (roads crossing the border of the province).

Agglomeration model: In 2010, for the purpose of the Metropolitan Railway, a predictive model of traffic and transport was developed for the Tri-City Agglomeration by the Railway Institute in Warsaw. The model covered the area of three townships (Gdansk, Gdynia, Sopot) and five administrative districts: Wejherowski, Kartuski, Bytów, Kościerzyna and Gdańsk [15]. Particular areas have been mapped in the model at different levels of details. Most accurately a network street of Gdansk was mapped, including important streets. For Gdynia and Sopot the basic street network has been mapped. In other cases, it includes national and regional roads, and these local roads, which are essential connections of the Metropolitan Area with the Tri-City.

Urban models: In the cities of the Pomorskie region different models are being used for traffic forecasting and analyses of transport. For example in Gdansk three different packages of calculation software (EMME, SATURN and VISUM) apply.

1.3 The multi-level transport systems model (TSM) concept

Assumptions

Earlier experience of conducting analysis and forecasting of traffic in the area of the Pomorskie region indicate the need to organize an approach for the development of predictive models for the analysis of transport. According to these assumptions the system of forecasting and analysis of traffic should:

- Include the whole area of the Pomorskie region, as well as individual cities and counties.
- Have a hierarchical structure, comprising layers penetrating the division of area (administrative) region and the layer resulting from the management level, in which the data collected from the TRISTAR system will play the most important role.
- Enable efficient exchange of information and data between the individual layers, as well as with the Traffic Planning System and software for motion control, which will be implemented within the TRISTAR system.
- Enable providing data to perform a variety of tasks resulting from the process of living systems and transport objects, which will help making optimal decisions.
- Provide data for work planning, feasibility studies of transport objects, projects, changes in the organization of traffic and geometry solutions at intersections and junctions, as well as data for Traffic Management System and Traffic Planning System, TRISTAR modules and for authorities of public transport and maintenance road authorities.
- Provide information on the various parameters of traffic and measures of effectiveness assessment: transport work, travel time, utilization of capacity on the section, fuel consumption, emissions, safety etc. For the purposes of planning and operational cooperation with the TRISTAR system, the tools will be integrated into a multi-level traffic model.

The concept

The approach is the model of multi-level and multi-layer based on the idea acquired by the Transport Department of the City of London [12]. The levels determine the administrative area, and the layers determine the levels of traffic analyses and traffic management.

Area	Level of management	Strategic	Tactical	Operational
	Object	Transport network	Transport network/street and PT lines	Street, PT line, set of junctions, junction
	Model kind	Dedicated - prognostic	Advanced	Simulation
	Model type	Macroscopic	Mezoscopic	Microscopic
Country	Tool	VISUM	VISUM	
Region		VISUM	VISUM	
Agglomeration		VISUM	VISUM, SATURN	DRACULA
City/cordon/ local		VISUM	SATURN, TRANSYT, DRACULA	VISSIM, DRACULA

Table 1.1: Modelling tools depending on the management level and area

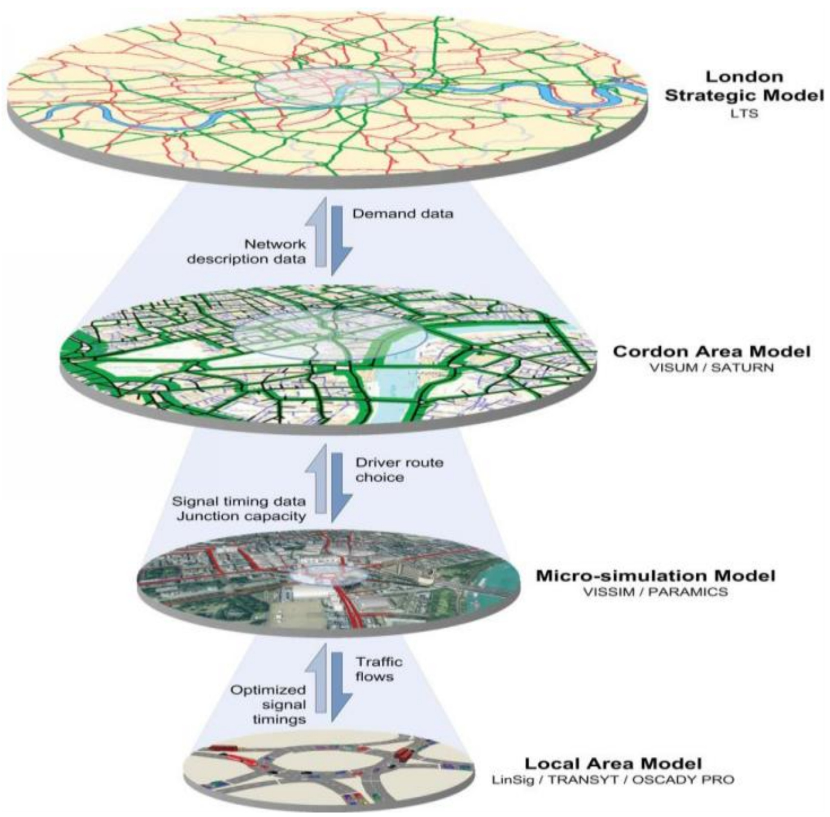

Figure 1.1: The model structure for the city of London (source [12])

The **strategic level** includes the provision of data for the development of transport policy, the implementation of planning works, and development of network studies. The basic problem in the construction of this traffic modelling system is the development on the strategic level of dedicated forecasting models for various areas of transport management. There are four types of areas for which models for forecasting and analysis of transport will be built or developed: country, region, metropolitan area and the city or district.

The **tactical level** includes the provision of data for the development of decision-making materials on transport projects (network studies, feasibility studies), the development of traffic management projects, traffic control and assessment of effectiveness. The object of the model in this case will be a transport network, roads or streets, or a section of the public transport system.

The **operational level** includes the provision of data to develop specific projects, traffic management, traffic control programmes, projects, transport service of selected objects, and visualizing the functioning of transport objects. The object of the model will be in this case roads or streets, section of the public transport system, or intersection.

1.4 Use of Traffic Planning System in TRISTAR in MST

Within the concept of a detailed TRISTAR system a regional architecture of the system was developed, so that the future development of the system, which in individual cities in the agglomeration can be carried out independently, did not cause its disintegration [16]. The regional architecture defines the logical and hardware structures for the elements implemented in the early stages of the system under the Operational Programme – Infrastructure and Environment. The architecture defines the four-level, hierarchical functional structure (management level of metropolitan, urban, areal and local), which can be noted in the various levels of the model (primarily model of agglomeration and urban models). At this level (also called the central layer) mainly key messages arising from the transport policies of individual cities of the Tri-City Agglomeration will be implemented. The main function of the central level, physically located in the centres of Transport Management in Gdansk and Gdynia, will be the integration of all systems within the TRISTAR system (see Figure 1.2). Integration will be ensured by common hardware and software, a common data transmission network and a common database to enable the mutual processing of information provided by the Urban Traffic Management System. A Public Transport Management System and a Transport Planning System will use the analyses carried out through the model of multi-level and simultaneously support the model with the data necessary to update the analyses. The use of a hierarchical and modular structure of the system will allow for the future expansion by including new elements and supplementing it with new functions. The main task of the central system is the integration of systems, subsystems and modules through the collection, processing and distribution of data [17].

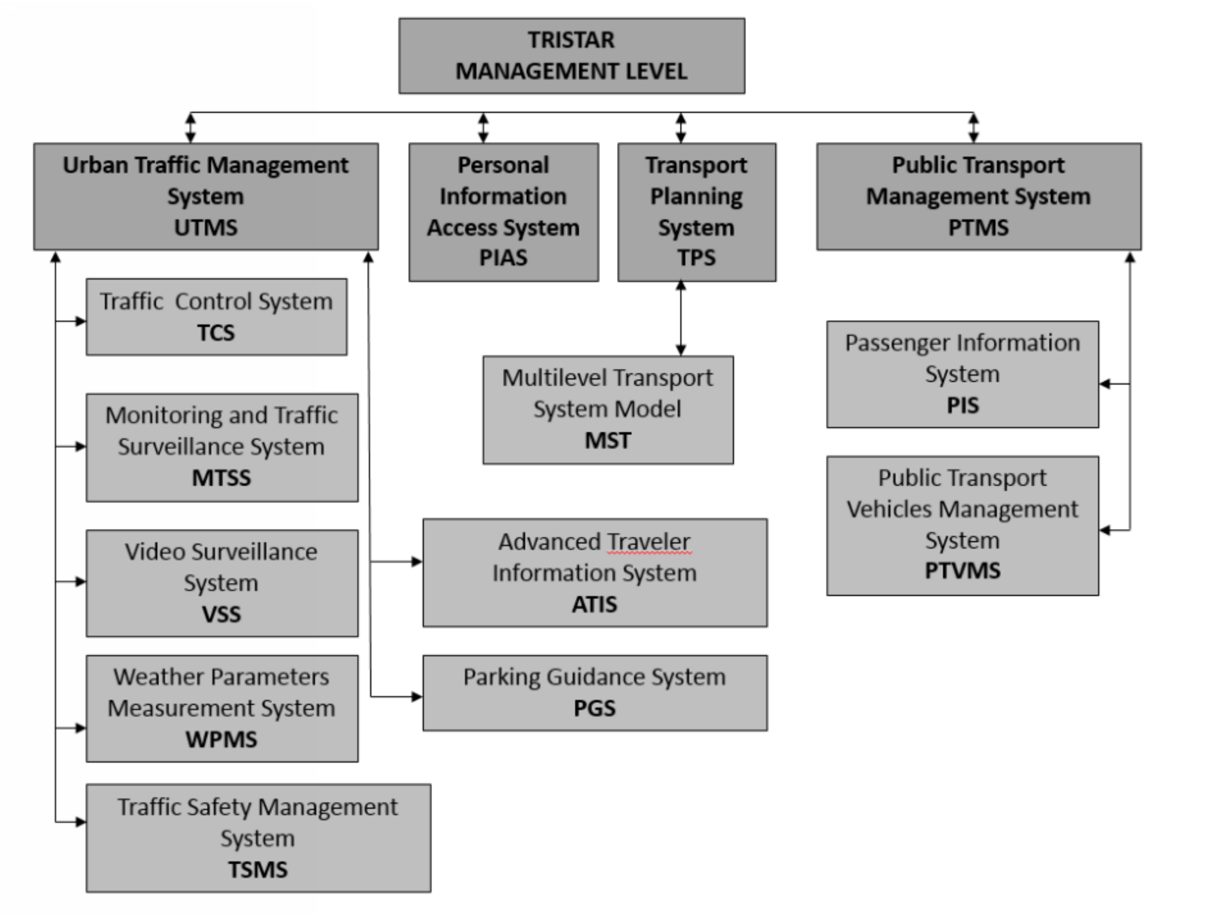

Figure 1.2: Functional structure of the first stage of the TRISTAR system (Source [17], [18])

The Transport Planning System will be supported with tools (software packages) as listed in table 1.1, through which the individual elements of the multi-level model are developed, useful in the planning of transport systems, analysis of traffic conditions and the testing and simulation solutions of traffic expected to be introduced or necessary to be introduced in the framework of operational management. All software will use the data from devices and detection systems, collected in the data warehouse.

Software and models developed under the MST module of the Transport Planning System will support the strategic traffic management. Also, the models will support the dispatcher management of public transport. It is planned to implement and integrate of TPS multilevel model transport systems, which will enable the development of analyses and traffic forecasts for planning purposes, but also for the needs of the current traffic management. The multi-level model concept assumes that the model will cover the entire area of the city, however, it will be supported by the regional model (Tri-City, the regional and national), and it will cover both individual transport and its infrastructure, as well as public transport and a network of public transport, it will have a hierarchical structure, consisting of layers for different levels of management, it will enable the efficient exchange of data between the various levels of management, it will enable the delivery of analysis results to the tasks arising from the need to improve the functioning of the transport system and the decision-making process in terms of planning, planning of transport systems, feasibility studies, project changes in the organization traffic (reconstruction of the geometry of the road system, or changes in traffic management). Moreover, a multi-level model will provide the information necessary from the point of view of updating and implementation of solutions in the field of Sustainable Urban Mobility Planning (SUMP) and allow detailed analyses and verify the effects of the proposed mobility management tasks provided for in SUMPs. The model will also provide visualization and simulation tools that will support the process of convincing the community to accept the implementation of scheduled tasks [17], [19], e.g. in the planned information platform of the City of Gdynia: MobilnaGdynia – www.mobilnagdynia.pl. The strategic level will provide data for the development of transport policy, planning works and analysis of the street network and public transport. At the strategic level model the macroscopic will apply (e.g. VISUM or a network buffer packet SATURN).

The planning system provides linkage of MST models to databases of the TRISTAR system. For this purpose, models were supplemented with information needed to link to the database of the TRISTAR system. These actions made it possible to extend the individual models with additional features:

Macroscopic model VISUM and mesoscopic model SATURN:

Downloading the data from the TRISTAR system inter alia traffic volume and type structure. For this purpose, a database was developed bound to the elements of the macroscopic TRISTAR model.

Microscopic model VISSIM:

Linking the macro and micro models using databases. The microscopic model has current and historical information about traffic volumes, directed road structures and direction at various intersections. This allows modelling any time horizon, and the calibration of driver behaviour models.

1.5 Methodology of MST construction

For the development and implementation of a three-level model of transportation for the city of Gdynia, MST is a tool for testing the prepared pilot projects and supporting the operational management of traffic/ public transport planning and analysis (mainly developing SUMP) and estimating and presenting results on the planning and operational management of transport.

The development of a three-level model of transport systems (MST) is supported with the data warehouse of TRISTAR (Tri-City Integrated Traffic Management System) traffic management system.

The methodology of research includes:

- the establishment of research facilities for research and construction of models,
- the preparation of databases (to collect available data of demographic, economic, sociological related to spatial planning and research of traffic and travel of public transport, processing of data from surveys on residents' travel, collect data on the supply layer of modelling: the existing parameters of sections of the transport network, parameters of intersections, routes and public transport stops)
- the analysis of the possibilities of using the TRISTAR traffic management system to support the three-level model with traffic data,
- to develop a method for supporting models with the data from TRISTAR,
- the development of principles for construction and integration of macroscopic, mesoscopic and microscopic models within the transport nodes and network sections (supply) and demand layers (matrices), construction methods and models as well as specific identification purposes, which are to serve,
- to carry out additional traffic measurements (fieldwork),
- testing the calibration of the model (function analysis of space resistance, design and verification of functions of the resistance section in the macroscopic and mesoscopic model, speed-volume function, verification of simulation parameters in microscope model, developing for Polish conditions and verification of traffic parameters, e.g. volume limit, max. intervals on inlets at the intersection, raised and suppressed demand analysis, modelling intermodal systems) – field research and simulation,
- the development of a macroscopic model (package VISUM)
- the development of a mesoscopic model (package SATURN)
- the development of a microscopic model (package VISSIM)
- collecting the data for the control group to verify the models (fieldwork)
- the development and implementation of training for the employees of the Road and Greenery Authority in Gdynia on the use of three-level traffic model,
- calibration and verification of developed transport models, and
- final evaluation task.

Planned results: development of a tool to support the operational management of traffic/ public transport planning and analysis in the short and long term horizons (mainly developing an SUMP) and estimating and presenting results on the planning and operational management of transport including cooperation with the TRISTAR system.

1.6 Conclusion

The existence of modern tools for forecasting and analysis of transport allows both to improve the process of planning and the operational management of transport systems. The terms of variable traffic demand imply the necessity of obtaining information on the functioning of transport systems in order to enable the optimization of transport processes. Due to the above it is extremely important to link models of traffic analysis with the implemented solutions in the field of Intelligent Transport Systems, as well as allowing analysts to select and test model parameters which can be obtained from detection systems of traffic management systems. It is extremely important to enable collaboration of traffic management systems with individual elements of a multi-level model through the development of an appropriate compiler, allowing automatic use of data without tedious data entry for each model. Due to the fact that the individual packages and programmes described in this report have features that distinguish them from each other, it is reasonable to use a wide range of software, complementary and enabling support of the planning and traffic management at different levels and plans, distinguished in the structure of the multilevel model.

2 MACROSCOPIC MODEL (VISUM)

2.1 Methodology

For the development of a transport model for the city of Gdynia, the classic four-level transport model was used, which is the most common model in Poland and in the world. This method consists of four successive stages:

- traffic generation: setting the number of trips generated and absorbed depending on the travel motivation in different areas of transport taking into account the functional nature and statistical data such as: the number of inhabitants, the number of jobs, the number of places in schools, retail and service surfaces, etc.
- spatial traffic distribution: to determine the relationship of trips (destinations of trips) with regard to potential transport areas and the distance between them.
- modal split: to determine the mean of transport used for the implementation of travel, taking into account the preferences and behaviour of transport users of the transport system and the generalized cost of travel.
- distribution of traffic in the network: to determine a precise route in the transport network, including the capacity of the sections and its use, authorized relationships etc.

2.2 Data Sources

The research was made on the basis of data obtained from the Office of Planning of the city of Gdynia (the Roads and Green Authority of Gdynia) and partly on the data used to build the transport simulation model for the City of Gdansk [22] [23]. The study also used data from their own databases (FRIL), marketing surveys, marketing on the preferences and transport behaviour of inhabitants of Gdynia 2013, comprehensive traffic measurements in 1998 and in 2009 for Gdansk [24]. To calibrate the model traffic measurements carried out in the framework of the TRISTAR project data from April-May 2012 and October 2012, data from databases from the Foundation for the Development of Civil Engineering, and additional complementary measurements made in November 2013 were used. Also data from TRISTAR traffic system was used, obtained from the Roads and Green Authority of Gdynia, which in a later stage of the operation will be the basis for updating the model.

2.3 Model development

2.3.1 Basic input data

The division of the city into transport regions

The travel model covers the administrative boundaries of the city of Gdynia. When modelling the travel in Gdynia, a division into 173 areas of internal transport was assumed. The division into areas of transport has been developed jointly with the Planning Office in Gdynia.

Figure 2.1: The division of Gdynia into transport regions

In terms of areas of transport, the size of potentials, i.e. physiographic conditions, the number of inhabitants and the availability of the road network were taken into account. Also the development of the area was included; the division separated the various functions of areas. The size and shape of the regions also depended on the position in relation to the centre, where the designated areas are smaller than those in more remote areas, due to differences in the density of housing and urbanization areas.

Modelling the travel generation in Gdynia

The travel generation modelling is to change the transport activity of residents of the city measurements for the number of trips by including numerical relations that exist between urban activities and travels. Travel generation modelling for Gdynia used the results of a comprehensive traffic study conducted in Gdansk in 2009. An analogy of trasport behaviour was assumed for residents of both cities. This assumption stems from the similar nature of Gdansk and Gdynia, which together with Sopot is one urban agglomeration, which also shows similar transport behaviour of its inhabitants. On the basis of these data and the road traffic structure, the modal split model was validated and a base rate of mobility of residents was assumed.

The independent variables used in modelling

During the travel generation modelling, collected independent variables aggregated to the level of the area of communication were analysed. Modelling adopted four explanatory variables:

LM - Number of inhabitants [thousand]

LME - Number of places in secondary and high schools [thousand

LPO - Number of jobs in total (employment) [thousand]

LPU - Number of jobs in services [thousand]

Travel generation of inhabitants of Gdynia

Based on the performed statistical analysis of the variables, models to generate travels were developed, i.e. production models and attractions areas of communication, for individual travel motivation. The models were selected from the many already developed models for each category of functions, on the basis of selected indexes, that allow the evaluation of fit and accuracy of models [23]:

The coefficient of determination R^2: "indicates what part of the phenomenon is explained by the observed changes in the values of the independent variables in the sample" [25]: **Rating of model plausibility**: usage of the engineering practices to assess the relevance or veracity of the relationship between the data, assessment of the feasibility to obtain data, and so on.

Built for individual motivations, models of production and attractions are shown in Table 2.1.

Motivation	Production (travels - out)	R^2	Attraction (travels - in)	R^2
home - work	$P_{DP} = 0{,}32 * LM^{1{,}02}$	0,90	$A_{DP} = 0{,}6 * LPO^{1{,}03}$	0,77
work – home	$P_{PD} = 0{,}56 * LPO^{1{,}01}$	0,76	$A_{PD} = 0{,}27 * LM^{1{,}04}$	0,89
home - education	$P_{DN} = 0{,}12 * LM^{0{,}96}$	0,77	$A_{DN} = (0{,}33 * LME + 0{,}19)$	0,76
education - home	$P_{ND} = (0{,}4 * LME^{0{,}88} + 0{,}15)$	0,72	$A_{ND} = 0{,}11 * LM^{0{,}99}$	0,75
home – other	$P_{DI} = 0{,}36 * LM^{0{,}91}$	0,81	$A_{DI} = 0{,}93 * LPU^{0{,}77}$	0,54
other – home	$P_{ID} = 0{,}99 * LPU^{0{,}78}$	0,49	$A_{ID} = 0{,}39 * LM^{0{,}89}$	0,81
Not connected with home	$P_{NZD} = 0{,}38 * LPU + 0{,}08$	0,73	$A_{NZD} = 0{,}53 * LPU^{0{,}8}$	0,56

Table 2.1: Travel generation models in Gdynia (Source: own study based on Comprehensive Traffic Researches, Gdańsk, 2009)

Generation of external traffic

Based on a survey conducted in November 2013, carried out at cordon points, matrices of external traffic were developed. Surveys were conducted in a typical day of the week: Tuesday, Wednesday, and Thursday at six cordon points: ul. Szkolna, ul. Hutnicza, ul. Morska, ul. Chwaszczyńska, al. Grunwaldzka, ul. Wiejska. Detailed results are in the database.

The survey covers the drivers of vehicles divided into categories:

- Passenger cars,
- Light good vehicles,
- Commercial trucks,
- Commercial trucks with trailer

2.3.2 Assumptions for traffic forecasts

Analysed periods

The calibration of the model and forecast for each of the stages made for the following periods of the existing condition:

- peak morning (7:00 - 7:59)
- peak afternoon (15:00 - 15:59)

Mobility

The rate of growth of the mobility of the inhabitants of Gdynia varies. To calculate an increase of the mobility index of the inhabitants of Gdynia in subsequent years to the number of travels made by one person per day according to table 2.2 was assumed. These assumptions are necessary to estimate the projected number of trips made per day in the forecasting states.

Year of the forecast	2014	2015	2020	2030	2040
Mobility index	1,57	1,6	1,9	2,3	2,6

Table 2.2: Variants of the development of mobility index of inhabitants of Gdynia in non-pedestrian trips - assumptions (source: own study based on preferences and transport behaviour of inhabitants of Gdynia ZKM Gdynia 2013)

Vehicle occupation

A reduction in the average of vehicle occupation in trips of residents of Gdynia is assumed from 1.37 (analogy in relation to Gdansk was assumed - comprehensive data based on motion studies, Gdańsk 2009) to 1.34 persons in 2015 and 1.22 in 2040. Detailed data is shown in the table 2.3. These assumptions are necessary to estimate the projected number of trips made per day in the forecasting conditions.

Pred. year	Filling of individual means of transport in travel of Gdynia inhabitants	Filling of individual transport in cordon points
2009	1.37	1.51
2015	1.34	1.47
2020	1.31	1.44
2030	1.26	1.38
2040	1,22	1,33

Table 2.3: Average occupation of individual transport (source: own study based on KBR Gdańsk 2009)

2.3.3 Models of transport networks

Road network model

The road network model is one of the basic elements of a transport model of the city. The transport network model for 2012 was developed on the basis of patterns of existing road infrastructure and public transport. The transport network model consists of the following components:

The street network of Gdynia has been divided into five main groups of sections copying the classification of the road. In each group a number of subtypes was extracted, giving a total of 18 types of sections used in the development of the network model of individual transport (table 2.4). Each of them includes:

- road class,
- capacity of road section per 1 lane,
- free speed of vehicles on the section,
- conditions for the traffic of public transport,
- speed limit,
- the type of vehicle that can move (taking into account driving restrictions),
- the number of lanes.

No.	Section type	Road class	Capacity	Free Flow Speed
1	10	Autostrada	2,200	130/140*
2	20	Ekspresowa	2,200	110
3	30	Główna ruchu przyspieszonego z wezłami	2,000	80
4	31	Główna ruchu przyspieszonego z sygnalizacja	1,600	70
5	32	Droga serwisowa	1,800	90
6	33	Łącznica bezpośrednia	2,200	70
7	34	Łącznica półbezpośrednia	2,000	70
8	35	Łącznica z sygnalizacją	1,000	50
9	40	Główna	950	65
10	41	Główna_Cmax	1,100	65
11	42	Główna_Cmin	700	65
12	50	Zbiorcza	700	45
13	51	Zbiorcza_Cmax	1,000	45
14	52	Zbiorcza_Cmin	500	45
15	60	Lokalna	400	40
16	61	Lokalna_podporządkowana	300	35
17	66	Lokalna_Cmax	600	40
18	70	Dojazdowa	-	20

Table 2.4: Table of sections used in the model of individual transport [23]

During the process of network development, special attention and care is paid to the limitations of the turning relations occurring at intersections. This has a considerable impact on the proper representation of actual behaviour of the drivers. Turning relations were analysed and coded for both individual transport vehicles, and for selected types of transport system, depending on the organization of traffic at intersections occurring in reality. Figure 2.2 shows the different types of sections in the model of transport network.

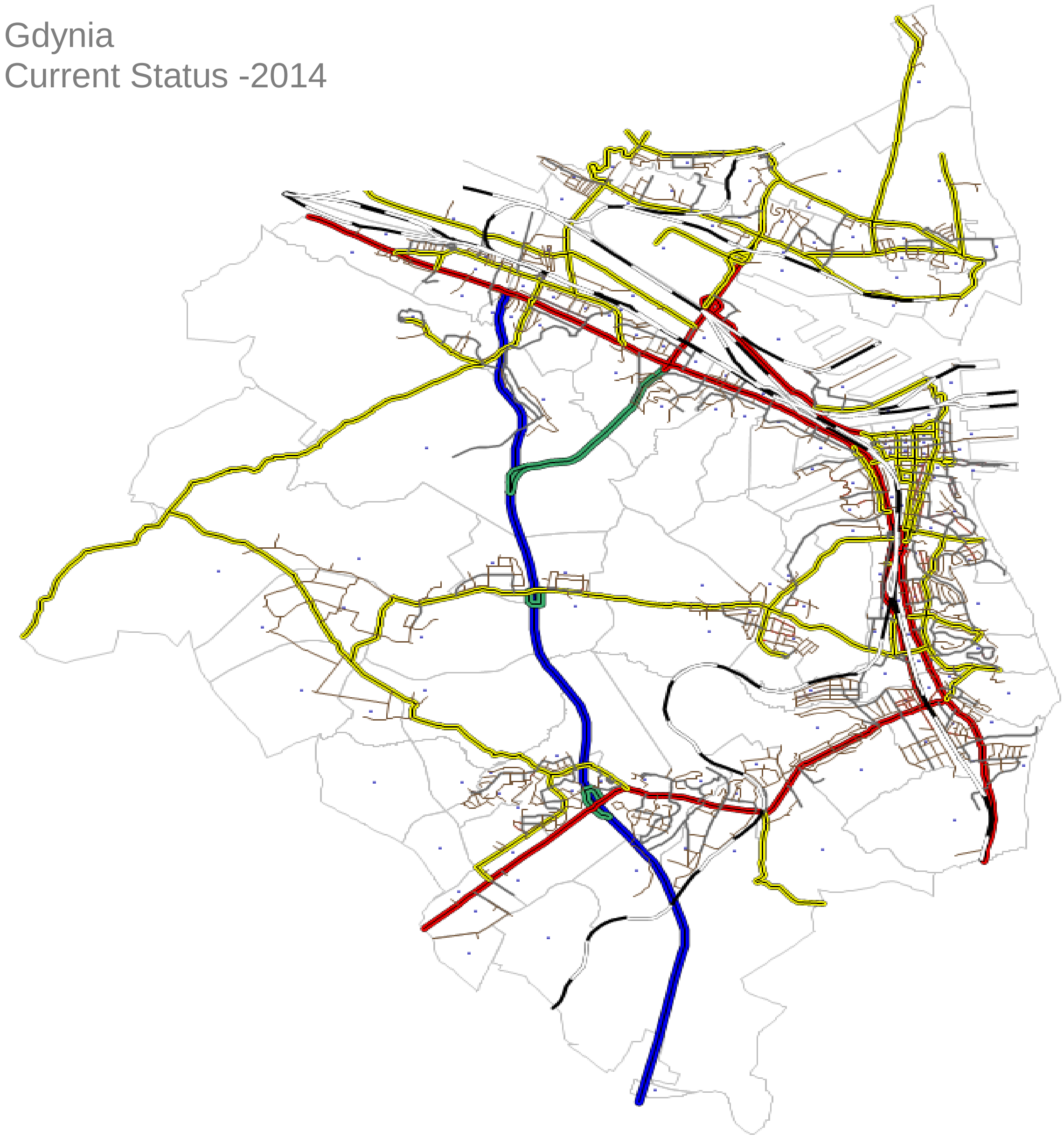

Figure 2.2: The division of the transport network due to the types of sections (Source: own)

The resistance function of the section

The capacity of individual types of sections was calculated for the section and the inlet of the intersection. The values of the capacity for each class of sections were calculated on the basis of data from the existing street network in Gdynia. The capacities were calculated according to national methods [26], [27], [28].

Based on the analysis of theoretical models [29], [30] and the results of research conducted by Gdansk University of Technology, and on the basis of data obtained from the Targeo service, dependence speed models on the traffic volume and road class were developed. Then the function BPR 2 applied, as a resistance function of the section of Koi, best mapping the mechanism of the effect of the volume on the section of the road on the time of the ride. The determined resistance functions of the section are shown in Figure 2.3.

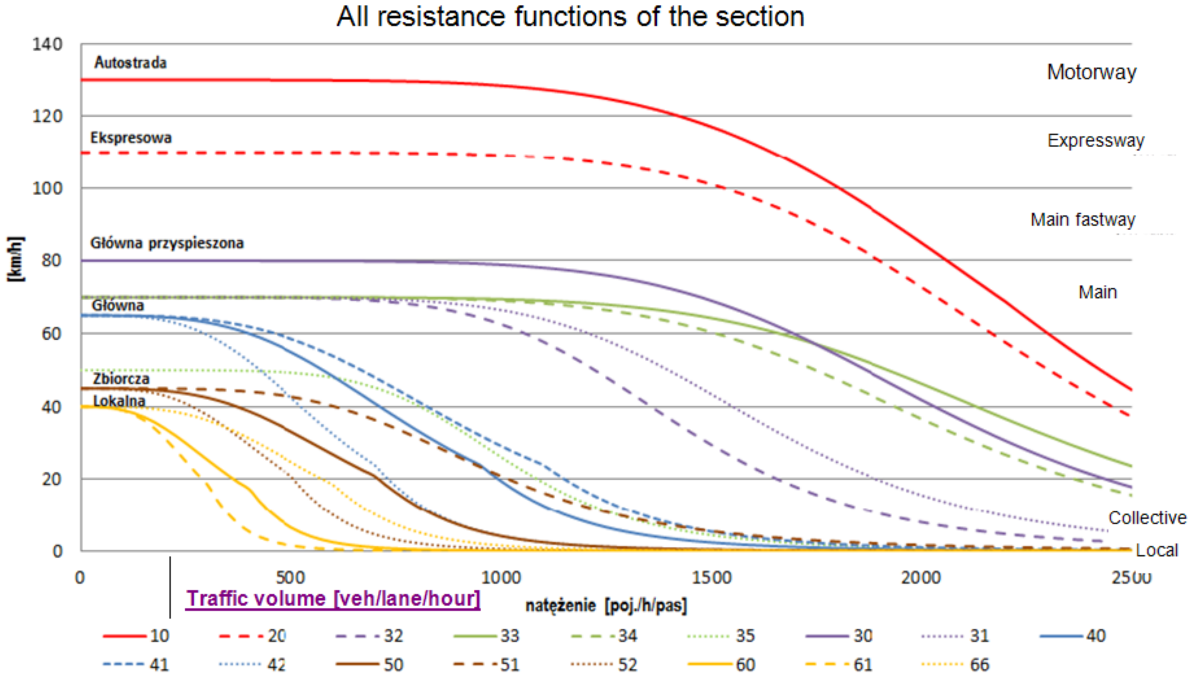

Figure 2.3: All resistance functions of the section adopted in the model (Source: own)

The network of public transport

The public transport network covers all public transport systems operating in the modelled area: rail, bus and trolleybus.

For the most accurate mapping of volume of individual sections of the network all the connections of public transport were coded divided into categories depending on the transport system, tariffs or organizer: long-distance railway, urban and regional railway, bus and city trolleybuses.

Connection systems and travel times of individual sections of the public transport vehicles have been calibrated in relation to the actual timetable applicable in December 2012.In the model, types of vehicles were specified and assigned to appropriate lines, as in **Fehler! Verweisquelle konnte nicht gefunden werden.**

The timetable was made based on the frequency of use of the service. The frequency is divided into four periods of the day:

- morning peak (4:30 - 9:00)
- afternoon peak (14:00 - 18:30)

In the model appropriate types of vehicles were specified and assigned to the specified services (see table 2.5).

Vehicle type	Cylinder Capacity	Number of seats
Standard bus	100	35
Big bus	150	45
Regional bus	51	39
Tram	100	35
Urban railway	1200	300
Long – distance rail	1600	340

Table 2.5: Vehicle types of public transport included in the model (Source: own)

2.4 Spatial distribution model

The spatial distribution of the trip is the second stage of the four-stage transport model in which it separates the travel between transport regions using algorithms available. For the development of the spatial distribution of internal travel a gravity model was used. In this model, the number of trips between regions is proportional to the value of the potential generating origin region and the potential of the absorbing final region and inversely proportional to the distance measured with travel times.

One of the key elements of this method is a space resistance function, which describes the impact of the travel distance (often measured by travel time) on the probability of its implementation. It is designed to fit best the distribution of travel time matrix modelled and empirical.

For each of the chains of motivation (home-work-home, home-to-home, home-other-house-not connected with the house), on the basis of the inhabitants and the travel time between regions, trips were aggregated to one-minute time slots. In this way, a distribution of travel time for each of the chains was determined. The resistance space function has been calibrated in such a way as to get the maximum matching of the distribution of travel time in the model with research results. The space resistance function designated for Gdynia is a power-exponential function. Table 2.6 shows the function parameters of resistance for individual motivation chains. The determination coefficient indicates the degree to which the model distribution of travel maps the distribution obtained from the research results.

Motivation	Estimated parameters	coefficient of

	a	b	c	determinationR^2
home-work-home	0,015	0,861	-0,111	0.91
home-education-home	0,075	0,361	-0,216	0.82
home-other-home-not connected with home	0,018	1,395	-,0248	0.71
Total matrix				0.85

Table 2.6: Resistance function parameters and affinity indexes of road traffic structure to motivation chains motivation (Source: own)

Table 2.7 shows the measures of fit of these distributions. It can be seen in analogy to the distribution of traveling time, the high fit in each chain of motivation. This confirms that the model of the spatial distribution is correct.

Motivation	coefficient of determinationR^2
home-work-home	0,91
home-education-home	0,78
home-other-home-not connected with home	0,94

Table 2.7: Measures fit of distribution of the travel lengths modelled and observed (Source: own)

In a similar manner a model for the spatial distribution of commercial vehicles and trucks was designated. The resistance function has been designated for commercial vehicles and for the aggregated trucks and truck-trailers, with no breakdown for motivations. In order to check the quality of the travel matrices for individual means of transport, distributions of model travel time matrices with research results were compared. For commercial vehicles the coefficient of determination of 0.58 and 0.88 for heavy goods vehicles was reached (see table 2.8).

	Parameters of resistance function			coefficient of determinationR^2
	a	B	c	
Goods vehicle	0,12	0,049	-0,122	0.58
Trucks	0,043	0,275	-0,02	0.88

Table 2.8: Resistance function parameters and affinity indexes of road traffic structure for motivation chains (Source: own)

2.4.1 Modal split model

In order to represent the number of travels made in the modes of transport, based on the results of Comprehensive Traffic Researches (Gdańsk 2009), modal split models were developed. Of the total matrix of travels, walking and cycling trips, and later participation in individual and public travel was defined.

To determine the share of travel of pedestrians the following logit model depending on the distance of travel was built:

$$U_p = 0{,}8675e^{-0{,}633x},$$

where:

$\mathrm{U_p}$ - Share of pedestrians

x - Distance to be covered

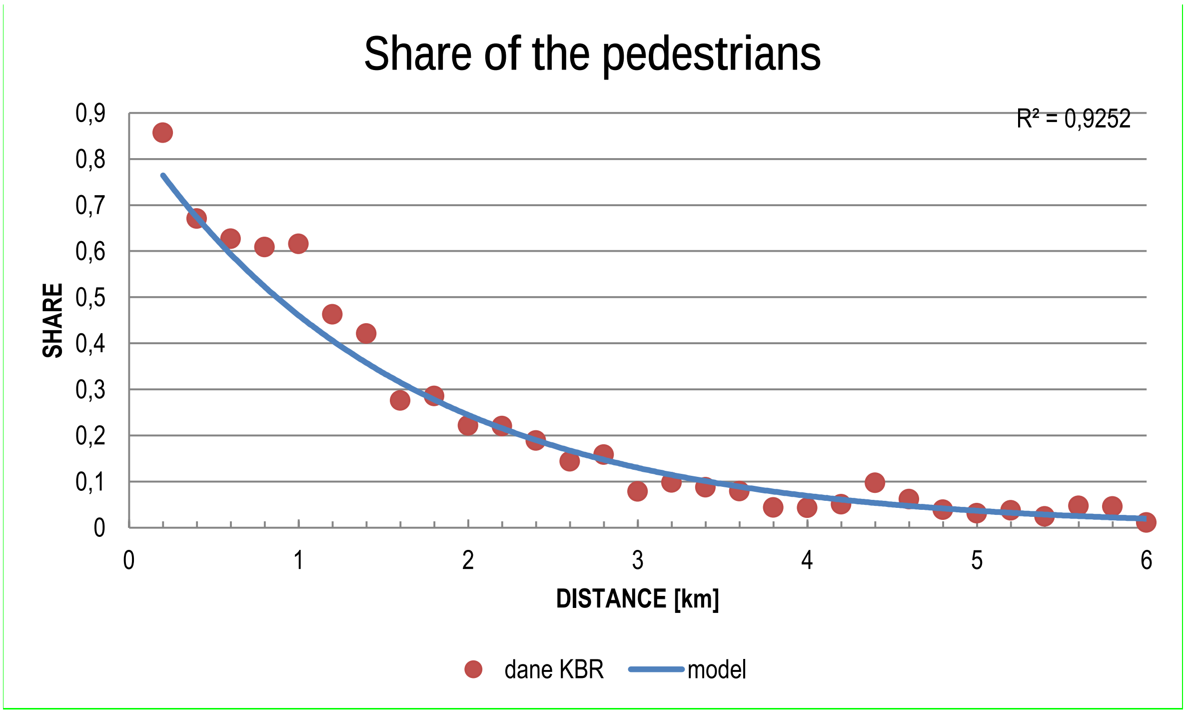

Figure 2.4: Share of pedestrians (source: own study based KBR, Gdańsk 2009)

The travel share of transport modes was determined depending on the ratio of travel time with individual transport to the perceived travel time on public transport and described with logit function. This feature has been adjusted iteratively based on comparisons of the traffic distribution model with the results of measurements of traffic volume and public transport vehicles occupation made in Gdynia.

The quality model of modal split has been determined on the basis of checking compliance of the model results with the results of the survey. For the above-described model a correlation coefficient R^2 = 0.81 was achieved. This result is acceptable and allows carrying out further analyses. For prognostic conditions the same model was used, but with modified parameters a. and b. Accepted parameters are shown in Table 2.9.

$$U_{ti} = 1 - \frac{1}{1 + ae^{-bWWKP}}$$

where:

- U_{ti} – Share of individual trips
- WWKP – Indicator of relative costs of travelling by individual transport in relation to public transport
- a, b - Model parameters

Prediction year	2012	2015
Function parameters in the modal split model	*a=1,85* *b=-0,73*	*a=2,2* *b=-0,71*

Table 2.9: Function parameters of the modal split model for prognostic conditions (Source: own)

2.5 Assessment of model conformity

2.5.1 Assessment of conformity of the model of individual transport

A comparison was made between the values of the number of traffic volume arising from the model and the values obtained from the measurements. The following graphs show the comparison made for sections broken down into all types of vehicles modelled:

Examples of the results of conformity assessment model are shown in Figures 2.5 and 2.6.

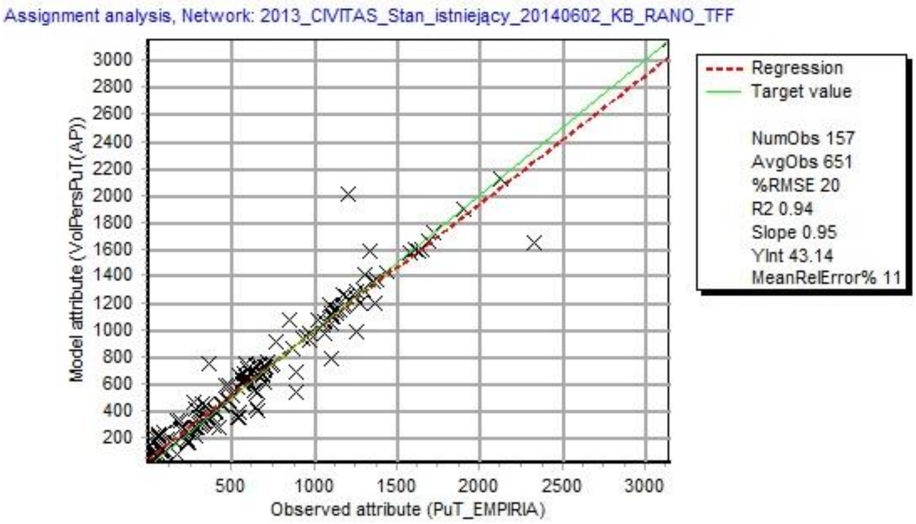

Figure 2.5: Conformity assessment of the values obtained from the model with the values obtained from measurements [morning rush hour - 7:00-8:00]

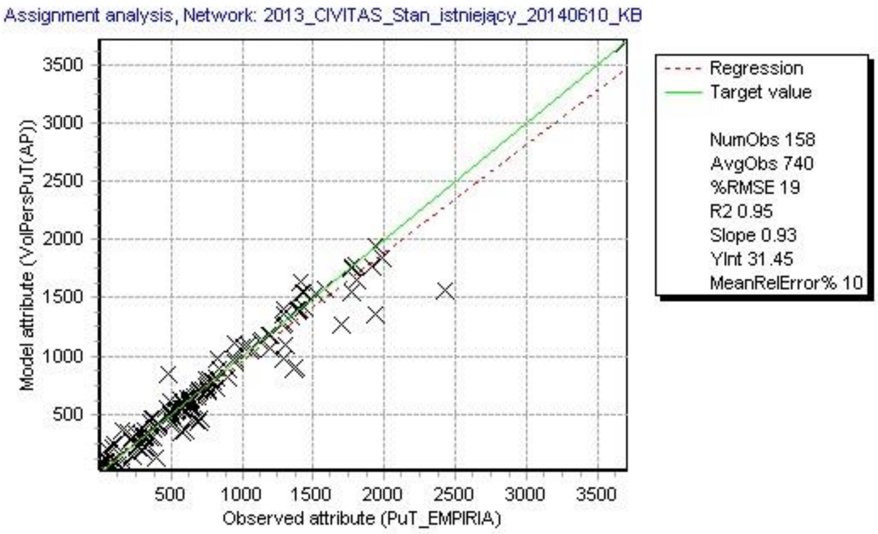

Figure 2.6: Conformity assessment of the values obtained from the model with the values obtained from measurements of [the afternoon rush hour - 15:00-16:00].

The coefficient of determination R^2 for this value has a value of 0.95 which confirms the high accuracy of the model.

2.6 Traffic distribution in the network

Distribution of traffic on the network is the last stage of the four-stage model. Previously prepared traffic matrices between transport regions were used. Matrices have been developed for different transport modes. Distribution was carried out for individual and public transport, and the result was the number of traffic volume in the road network, and the flows of passengers on public transport services. For traffic distribution, procedures implemented in the VISUM programme were used. In the case of individual transport, a procedure of network assignment (Equilibrium Assignment) was used, while for the distribution of traffic on the public transport network the distribution of "headway-based" will be used based on the frequency and perceived travel time different variants of routes for each relation.

Cartograms with traffic volumes divided into modes of transport, and fillings of the modes of transport for the morning and afternoon rush hour in the existing state are shown in the following figures:

Analysed periods of the day:
– morning rush hour 7:00-8:00
– afternoon rush hour 15:00-16:00

Elements included in the cartograms:
– Volume of vehicular traffic
– Occupation of public transport vehicles

Figure 2.7: Cartogram of vehicular traffic in the morning rush hour (Source: own)

Figure 2.8: Cartogram of passenger flows in the morning rush hour (Source: own)

3 MESOSCOPIC MODEL (SATURN)

In mesoscopic models an intermediate solutions between the microscopic and macroscopic models are used. Mesoscopic models describe most of the elements at high detail level, characterizing their interaction and behaviour in much less detail than the microscopic model (e.g. decision on the lane by a vehicle does not come, as in the case of microscopic models, from interactions between vehicles and on the volume of traffic in that lane). The mesoscopic approaches as applied in the package CONTRAM [31], which takes into account network intersections with and without traffic lights, and in packages NETFLO1, DYNASMART and TRANSIMS [32] and DynaMIT, METROPOLIS [33], SATURN [6], TrEPS (based on packages DynaMIT and DYNASMART), EMME2 [34] and the TRIPS [35] were analysed. The package SATURN can use both conventional static traffic distribution in large networks, and simulation of microscopic smaller networks or network elements – between the model of traffic distribution and micro simulating model including intersections, there is feedback, i.e. the resulting data are iterated between models [8].

3.1 Data sources

The model was made, based on an inventory of intersections, conducted by the authors and the data obtained from the City of Gdynia – Zarząd Dróg i Zieleni in Gdynia (programmes of traffic lights). The demand model was adapted from the macroscopic model. To calibrate the model, just as in the case of the macroscopic model, traffic measurements carried out in the framework of the TRISTAR project in April-May 2012 and October 2012, data of the Foundation for Civil Engineering Development and additional measurements made in November 2013 were used. Also traffic volume data from the TRISTAR system – obtained from the City of Gdynia – Zarząd Dróg i Zieleni in Gdynia were used, which in a later stage of the operation will be the basis for updating the model.

3.2 Model development

3.2.1 Research and analysis software selection

Developing a model requires the collection of numerous data and the performance of a series of tests. In order to build a transport infrastructure model an inventory of the street network on interstitial sections (number of lanes, the distance between intersections) and at intersections (type of intersection, traffic organization at the inlet junction, traffic light programmes) was/ has been carried out. Implementation of research and analysis required data collection, processing and analysis of data. For this reason the team had to:

- collect the data from the data held in numerical form,
- build EXCELL applications enable transport of data packets between VISUM and SATURN and storing data in the form of a rectangular matrix,
- use the SATURN package as a database in which information about the elements of the street network was recorded: areas of transport and their connections to the network, intersections and connections between them.

In order to calibrate and verify the models, measurements of driving time on selected sections of routes and street network and measurements of traffic volume at intersections and cross streets were taken. Traffic measurements were conducted for the period of the day and during transport peak hours (morning, afternoon, and commercial). The model covers the administrative boundaries of the city of Gdynia. When modelling the travel in Gdynia a division into 173 transport internal regions was assumed, analogously to the macroscopic model, in order to meet the objectives of MST. Trip generation models, spatial distribution and modal split were adopted analogously to the macroscopic model, also in line with the MST multi-level model.

The calibration of the model was made, also according to the macroscopic model, for the following periods existing state:

- morning rush hour (7:00 - 8:00)
- peak afternoon hour (15:00 - 16:00)

3.2.2 Transport network model

Model of road network

The model of the road network is one of the basic elements of a transport model of the city. Gdynia's transport network model was developed based on an inventory of existing road infrastructure.

The building blocks of the network model are the nodes representing the intersections and connections representing sections of streets between intersections. The nodes are described by defining the type of intersection (of way, traffic lights or a roundabout), traffic organization at inlets (number of lanes and the relations that are supported by individual lanes), the saturation flow of traffic for the relations, time limits on intakes and programme traffic lights (the phases system, green light split, inter green time, the length of each phase, offsets). In addition, the type of subordination (subordination of the intake with connection lane and without connection lane and subordination of turning to left relation on the main road). Connections are defined by the average speed of free flow traffic (or speed limit signs), capacity (current density) and the length of connections and the number of lanes. The network model is complemented with connected transport areas. The transport areas were attached to sections of streets in apparent nodes, which are defined only by the number of lanes on the inlets and represent the place of traffic inflow through the local streets. The location of each node and the gravity centres of areas of transport are determined by their coordinates.

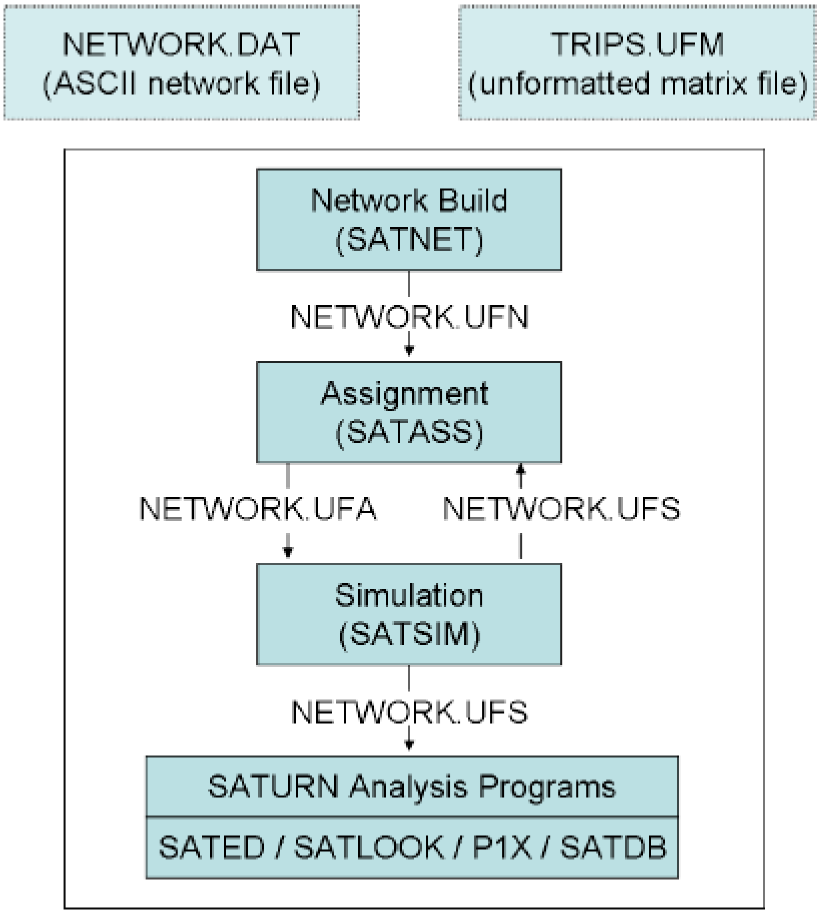

Figure 3.1: Exemplary scheme of the development and analysis of transportation systems in the package SATURN. [6]

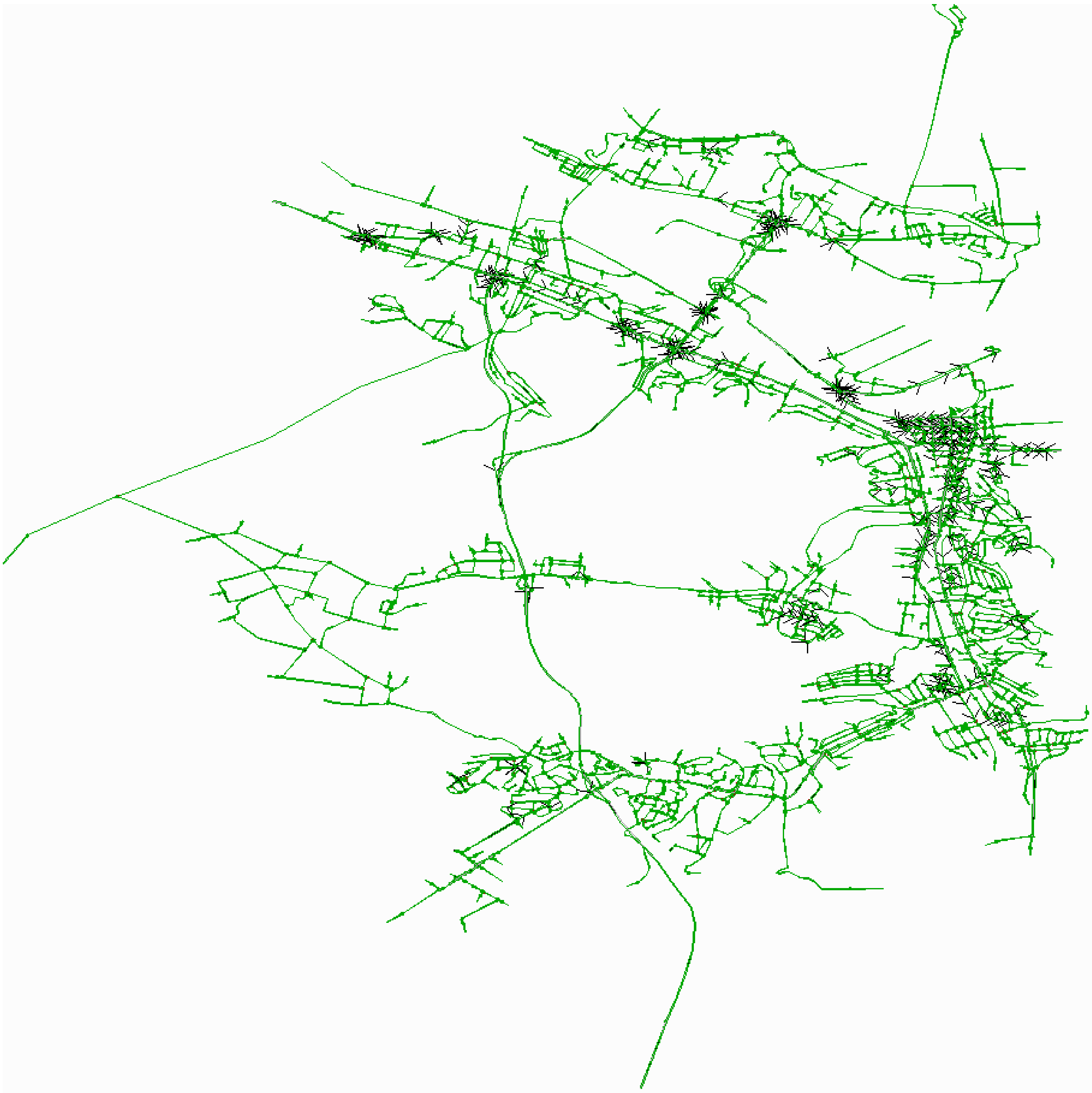

Figure 3.2: Diagram of the street network in Gdynia (whole area of the city)

3.3 Traffic distribution in the network

The last phase of the traffic modelling concerns the distribution of traffic among regions on the road network. The demand for transport (defined matrices of travel) is confronted with the supply of the transport network, defined by features such as capacity, speed, traffic management, road tolls and other resistance factors in the network. The starting point for this phase is the matrix of travel between regions of the means of transport. The final product is the size of traffic flows on each section of the network. The size of traffic flows on individual sections of the street network is not only the result of the distribution of network traffic. This process is also assessing the indexes, characterizing the street network. The main objectives of the distribution network traffic are [8]:

- calculation of aggregate measures of the street network (e.g. transport work, total traffic volume, travel time on the network)
- calculation of the cost of travel between the regions of transport for a given level of demand for travel (for the scenario matrix of travel demand)
- estimate the size of traffic flows in the street network and of the crowded parts of the system,
- determine travel routes between each pair of areas of transport,
- analysis of the use of individual network connections by traveling between a given pair of regions,
- calculation of the size of traffic flows on individual turning relations at inlets of intersections.

For the distribution of traffic a deterministic method of load balancing (deterministic equilibrium assignment or Wardrop equilubrium - EU) was used, which includes the dependence of travel time on the size of the traffic flow (iterative algorithms apply here). In this method, total traffic flow on the relations “source-to-target” is divided among a number of routes. The basic assumption of this method is that every traveller has information about the individual elements of the street network and chooses a route that minimizes the travel time (or cost). The deterministic optimization model system assumes that the total time in the street network is minimalized. This model may be useful in studies of applications of telematics in management and traffic control.

Distributions were carried out for multiple classes of users (Multiple Class Users) – divided into passenger cars, vans, heavy with trailers and heavy trailers/ semi-trailers. Sample Cartograms intensities of existing traffic condition are shown in the following figures:

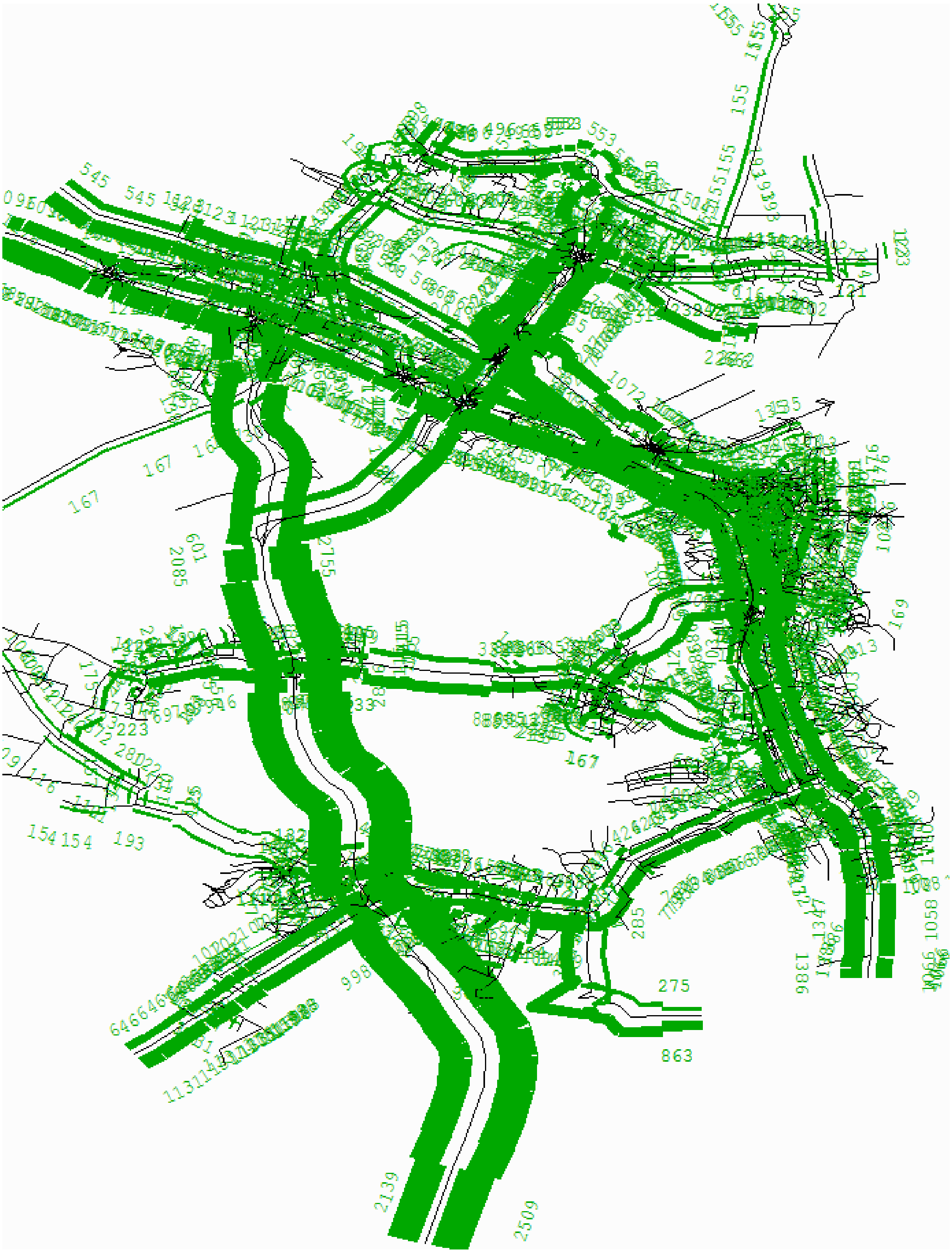

Figure 3.3: Cartogram of the traffic volumes in the morning rush hour in the area around the city (all vehicles) - in PCU

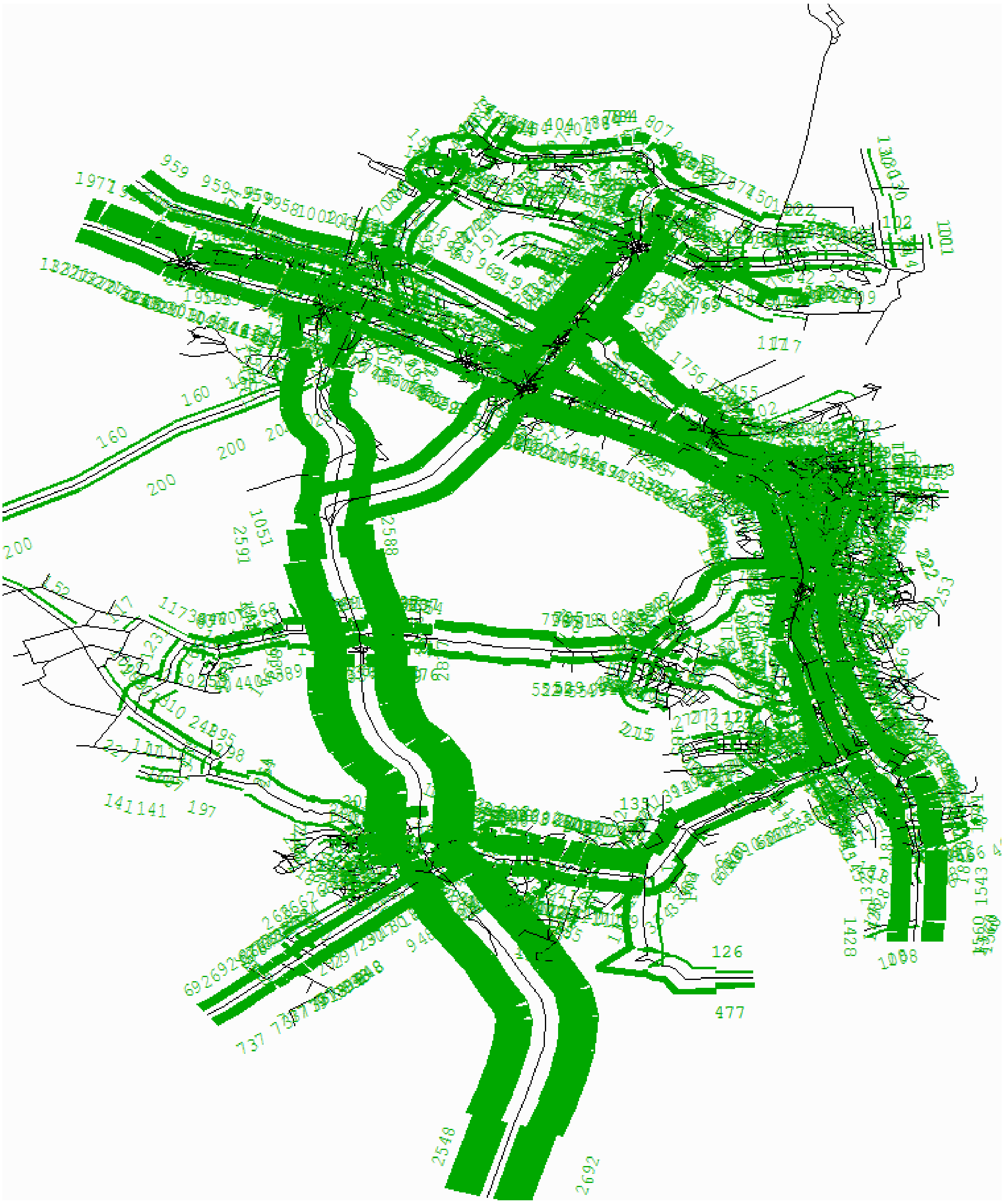

Figure 3.4: Cartogram of traffic volumes at rush hour in the afternoon throughout the city (all vehicles) - in PCU vehicles

3.4 Assessment of conformity model

3.4.1 The convergence of the internal model

In order to verify the correctness of the calculations and the results the following parameters [8] were considered:

1. The balance of the model.
2. Mean absolute changes in the profiles of the flows leaving the intersection.
3. Comparison of the cost of travel connections allocated in the current simulation with the cost of travel connections allocated in the previous iteration analysed, assuming calculating travel costs taking account of the loss of time from the preceding iteration analysed.
4. The difference between the current total cost of travel of vehicles on the network and the total cost of traveling in the distribution of All-Or-Nothing (in relation to the total cost of vehicles in the distribution of AOL). In case of the model for the morning rush a value was reached - a condition fulfilled in the last eight iteration steps.
5. Convergence of the demand balance.

These parameters have shown that the model is consistent, correct and can be used to analyse transport.

3.4.2 Model calibration

In order to determine compliance of the model system with a real-stage system, during the calibration phase a regression analysis and correlation between the values of traffic intensity was performed, measured during field studies and traffic flows obtained by simulation at the measuring points – it is assumed that between these values a strong linear correlation should occur with the angular coefficient of the regression function which equals 1.00, and the free expression of the function equal to 0.00.

The calculations for the measurement points (sections and relations at intersections) found that for each network models of all the cities the coefficient of determination R^2 (for the function Y = X) accepted values range from 0.89 (peak morning) to 0.93 (peak afternoon). Examples of the results of statistical analysis for model cities are shown in Figures 3.5 and 3.6.

Due to the large number of volumes of field measurements used in the model of the city, it turned out to be extremely difficult to calibrate the model to achieve a satisfactory convergence of all measuring points. Although the results indicate that in this example 89% of the volume is explained by the model.

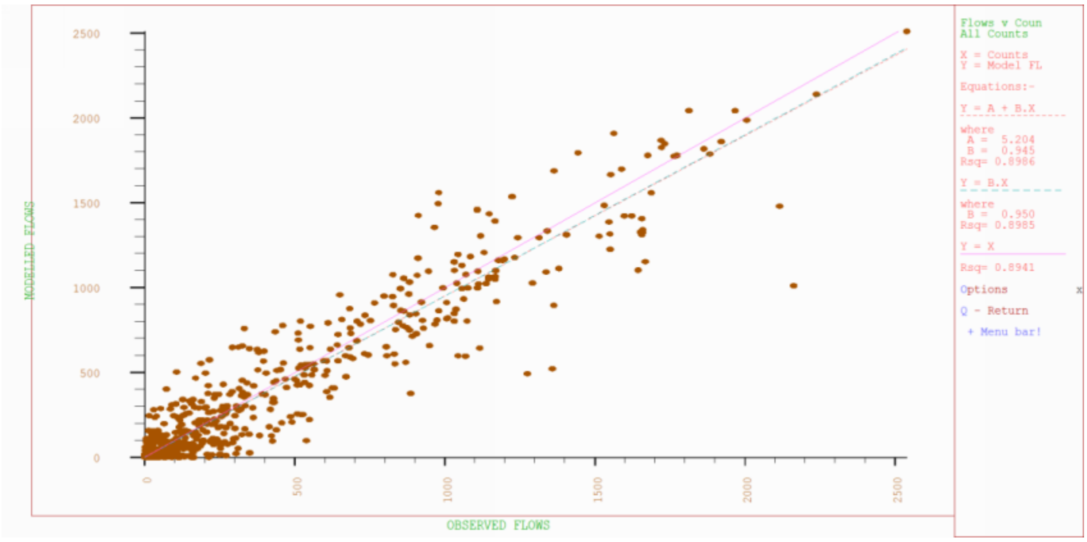

Figure 3.5: Comparison of the intensity of traffic measured in field studies with the values obtained from the city model in the morning peak hours - all vehicles (R2 = 0.89)

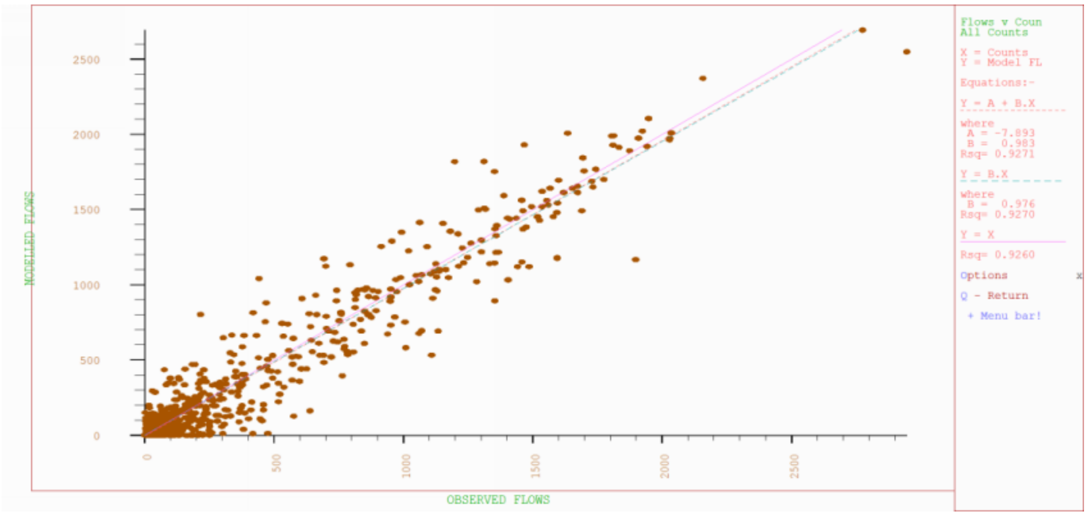

Figure 3.6: Comparison of the intensity of traffic measured in field studies with the values obtained from the city model in in the afternoon peak hours - all vehicles (R2 = 0.93)

For each of the models also statistical analyses were performed, allowing a more accurate comparison of the measured intensity values obtained from the model. For this purpose, an analytical method was used, which is a form of statistics $\chi 2$ (GEH) which takes into account both the relative error and absolute. The results of the analyses of statistics for GEH, which analysed an exemplary model of the network of Gdynia, are presented in tables 3.1 and 3.2.

Statistics	Value of the statistics
The volumes measured in the range of <700 [passenger cars/ hour] (Relative change compared to the volume of a model <100 passenger cars/ hour]	90,4%
The volumes measured in the range 700 - [passenger cars/ hour] (Absolute change compared to the volumes of the model <15%)	85,3%
Statistics GEH < 5	68,3%
Statistics GEH < 10	89,7%
The average value of statistics GEH	8,32
Coefficient of determination R^2	89,4%

Table 3.1: Statistical results of compliance of the volumes observed and obtained from the city model for the morning rush hour

Statistics	Value of the statistics
The volumes measured in the range of <700 [passenger cars/ hour] (Relative change compared to the volume of a model <100 [passenger cars/ hour])	88,6%
The volumes measured in the range 700 - 2700 [passenger cars/ hour] (Absolute change compared to the volumes of the model <15%)	87,2%
Statistics GEH < 5	70,6%
Statistics GEH < 10	87,7%
The average value of statistics GEH	8,45
Coefficient of determination R^2	92,6%

Table 3.2: Statistical results of compliance of the volumes observed and obtained from the city model city for the afternoon rush hour

These results, taking into account the size of the analysed city and a significant range of measurement points, indicate a satisfactory convergence of the volumes observed and obtained from the model. It was found that the size of the error more depended on the differences in measured and derived from the model flows in the range of volumes above 700 [passenger cars/ hour].

4 MICROSCOPIC MODEL (VISSIM)

The purpose of the microscopic model is to verify the effectiveness and above all the visualization of traffic operation within the framework of the changes proposed in the CIVITAS DYN@MO project, which visualizations will be presented for public consultation using the Mobility 2.0 platform www.mobilnagdynia.pl. The microscopic model (based on the VISSIM programme) will allow for the verification or presentation of the results obtained from the macro and mesoscopic models.

4.1 Model development

PTV VISSIM is a microscopic, of a fixed time step and based on events, simulation model designed to model urban traffic and the operation of public transport. The programme allows the analysis of the conditions of individual traffic and public transport, taking into account considerations such as the configuration of lanes, type of traffic structure, the impact of traffic lights, bus transport, etc., which makes it a useful tool for the evaluation of various alternatives based on traffic engineering and planning measures.

The traffic simulator is a microscopic traffic simulation model of traffic flow containing the logic “car following” and the logic of lane change. An important feature for the accuracy of the simulation model of traffic is the quality of modelling of the behaviour of vehicles; i.e. the methodology of movement of vehicles in the network. In contrast to less complex models using constant speed and deterministic logic to follow the leader, VISSIM uses a psychophysical model of driver behaviour developed by Wiedemann (1974). The basic assumption of this model is that the driver of a faster moving vehicle starts to brake when he/ she reaches his/ her individual threshold of perception of the vehicle moving slowly. Because the driver cannot accurately determine the speed of the vehicle moving slower, he/ she breaks as long as the speed drops below the speed of the other vehicle and then gently accelerates upon reaching a subsequent threshold of perception. This leads to the iterative process of acceleration and deceleration. Stochastic distributions of the speed and spatial thresholds show the characteristics of the individual behaviour of the driver. The model was calibrated by multiple field measurements at the Technical University in Karlsruhe. Periodic measurements and the subsequent updating of the model parameters guarantee the consideration of changes in driver behaviour and vehicle construction [Manual PTV VISSIM 5.40, Chapter 1]. Stochastic distributions of speed and spatial thresholds and thresholds of spatial show the characteristics of the individual behaviour of the driver.

PTV VISSIM can be used as a useful tool in solving many problems of transport. The following list shows the selected review of the earlier application of the programme [Manual PTV VISSIM 5.40, Chapter 1]:

- the development, assessment and final tuning of the control logic for the priorities of public transport at traffic lights,
- the programme is used for the evaluation and optimization (interface Signal97/ TEAPAC) of traffic flow in the connected network of the coordinated and accommodated traffic lights,

- The motion simulator is used to prepare an assessment feasibility study and impact of the integration of fast tram with the network of city streets,
- analysis of traffic disruption caused by low speed and interleave traffic areas,
- comparison of alternative projects involving the intersection with traffic, an intersection with signs of subordination, roundabouts and big multi-level hubs,
- analysis of the capacity and operation of complex systems of rail stations and bus stops are possible to do using PTV VISSIM,
- the solutions adopted and their assessment of preferential buses service (e.g. bypassing the queue, extension of restrictions, dedicated bus lanes).

PTV VISSIM offers a wide range of assessments that can be displayed on the screen during the course of the simulation/ test and/ or in the form of data stored in text files and/ or database. [Manual VisSim 5.40, Chapter 10].

Using VISSIM one can obtain information, such as:

- speed of vehicles flows,
- time of travel,
- time of delays (lost time)
- times of stops,
- counting the length of queues,
- information about the vehicle,
- environmental parameters,
- parameters concerning the number of passengers in public transport,
- downtime of public transport vehicles,
- parameters of network performance.

The network built in VISSIM is made up of:

- intersections (nodes): intersection in VISSIM are drawn using sections and connectors (see Figure 4.1):
- sections on which vehicles move (roads, viaducts, tunnels)
- sections on which pedestrians move (pedestrian crossing)
- sections on which bicycles move (bike rides within intersections)
- sections between junctions (interstitial) are drawn using sections and connectors, as shown in Figure 4.2.

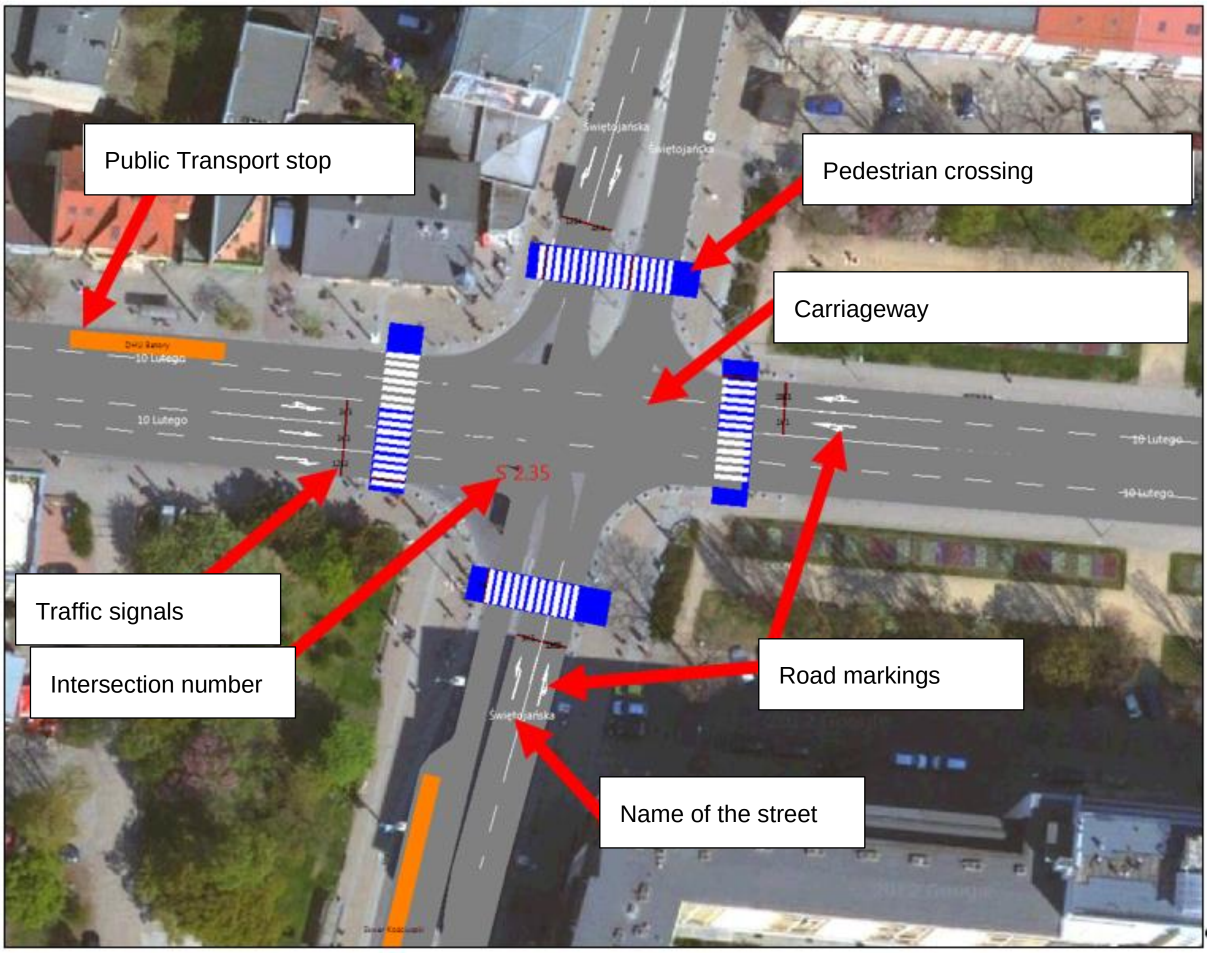

Figure 4.1: Building a network – intersections

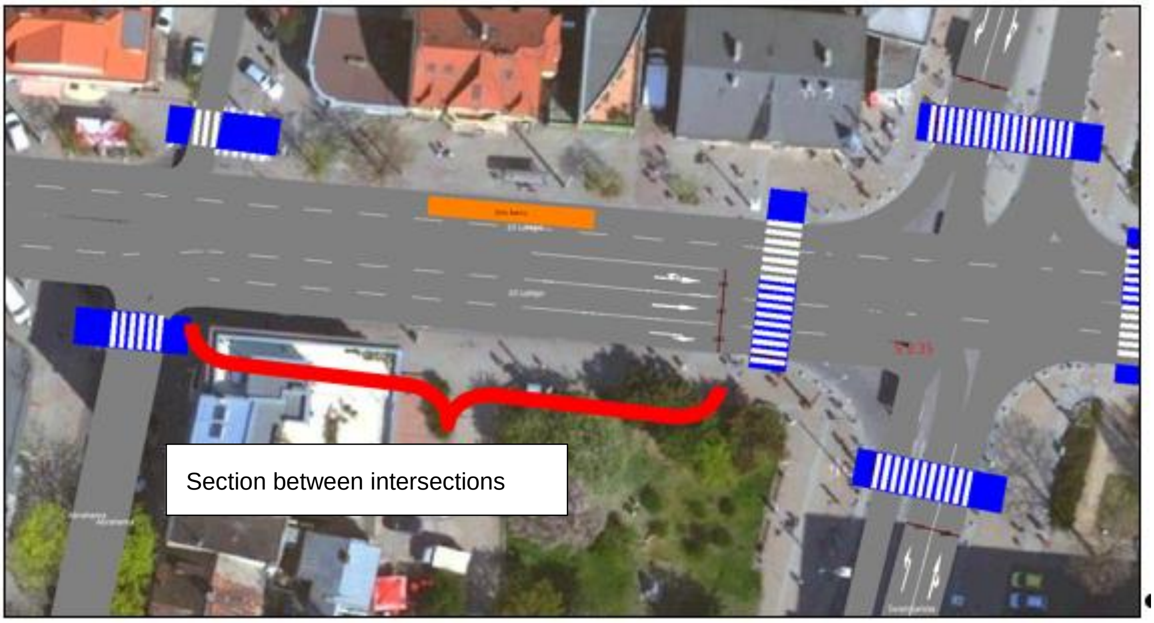

Figure 4.2: Building a network – sections between intersections

The model was developed, according to the macroscopic and mesoscopic model, for the following periods:

– morning rush hour (7:00 - 8:00)

– afternoon rush hour (15:00 - 16:00)

Below there are some areas for which microscopic models are developed:

1. Node – ul. sw. Maksymiliana and ul. 10 lutego
2. Al. Zwycięstwa (from the intersection with ul. Wielkopolska to the intersection with ul. Spoldzielcza
3. Streets: Wielkopolska-Chwaszczynska – from ul. Zwycięstwa to Nowowiczlinska
4. ul. Morska and ul. Kwiatkowskiego
5. ul. Władysława IV

5 MODEL VERIFICATION

5.1 Verification of the macroscopic model

The model of individual and public transport was verified.

5.1.1 Individual transport model conformity assessment

To verify the traffic model the traffic data of 2 April 2015 was used, both the morning peak hours (7.00-8.00) and afternoon peak hours (15.00-16.00). These data were obtained from a TRISTAR control centre in Gdynia. Comparisons of the results of the model with the results from the measurements for the morning rush hour (7.00-8.00) are illustrated in Figures 5.2 - 5.4.

Traffic data for 374 points was obtained. To verify the model a part of these measurements (approx. 35%) was used. The location of selected points is shown in Figure 5.1: a total of 127 selected points.

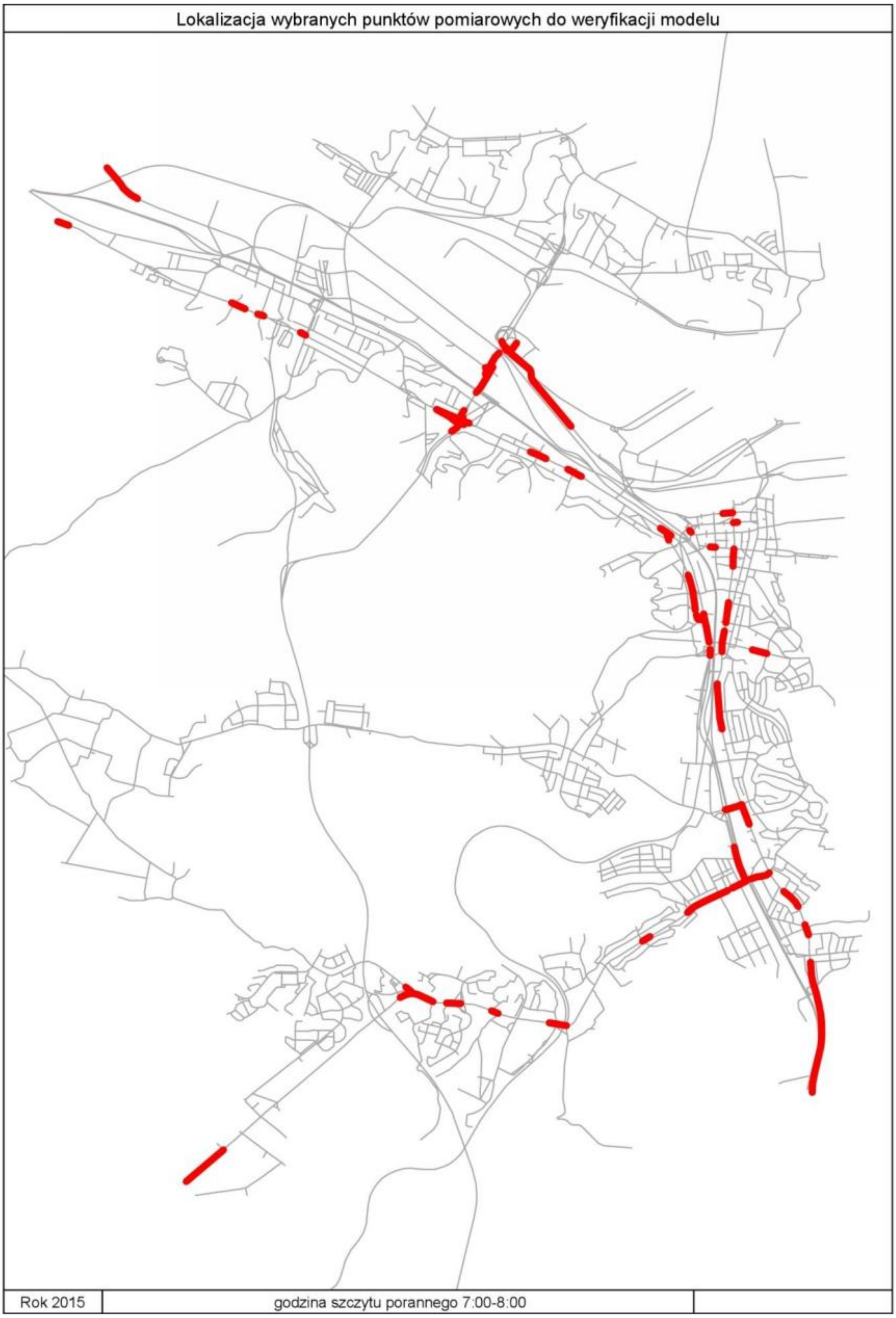

Figure 5.1: Location of the selected measuring points for verification of the model for the morning rush hour (7.00-8.00)

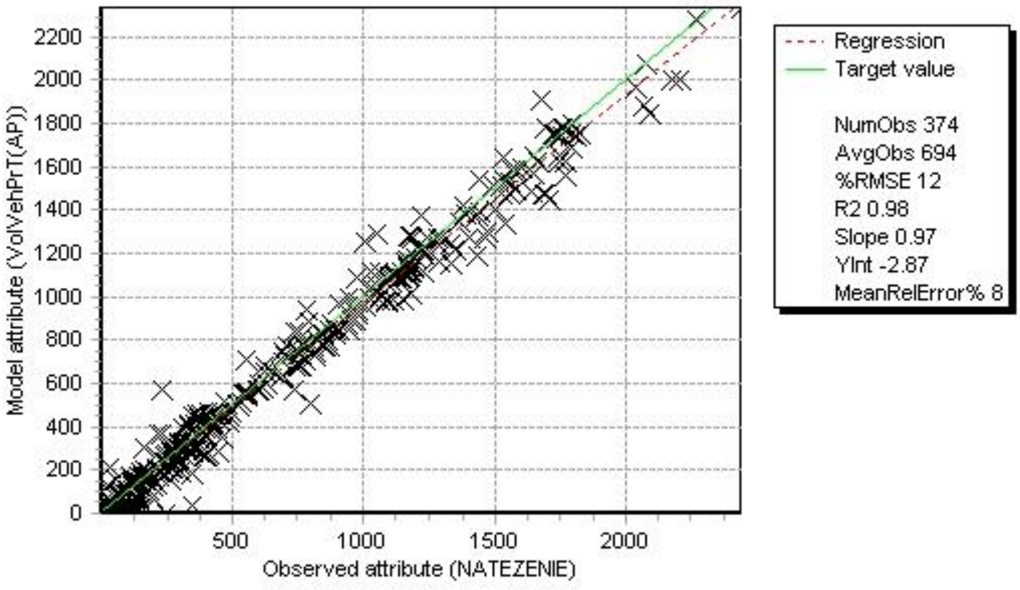

Figure 5.2: Verification results of the model (morning rush hour 7.00-8.00)

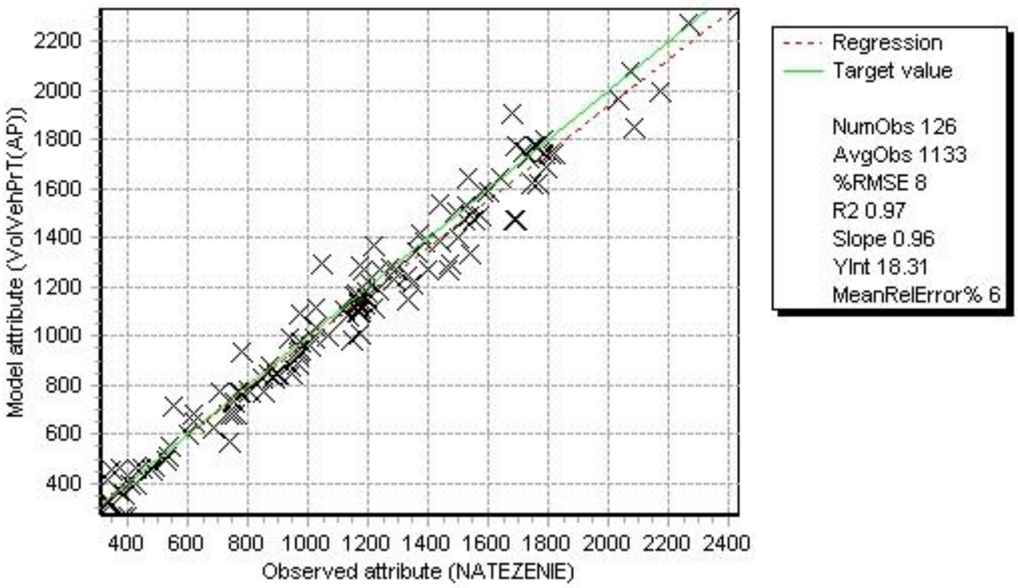

Figure 5.3: Verification results of the model (morning rush hour 7.00-8.00)

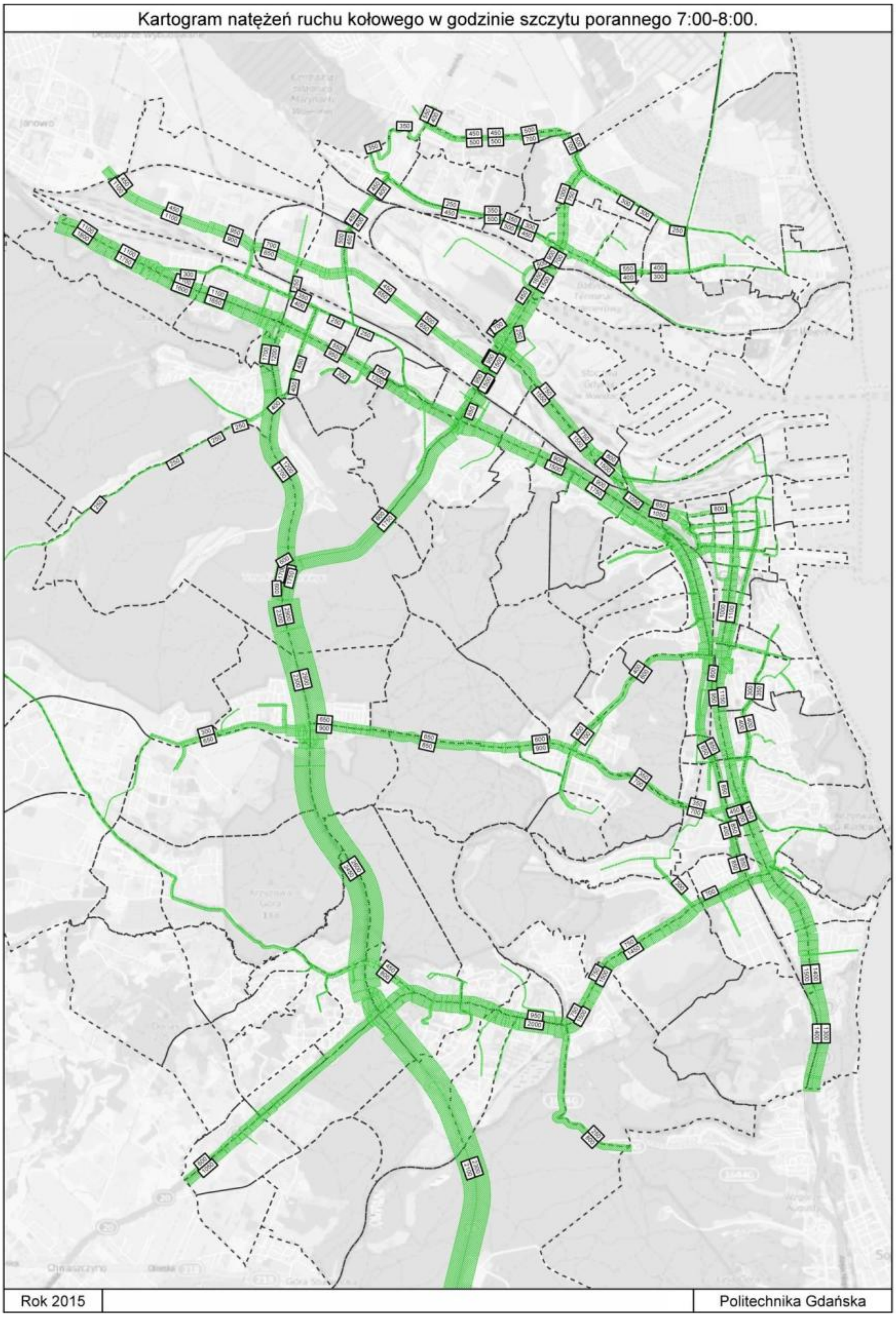

Figure 5.4: Cartogram of vehicular traffic volume in the morning rush hour (7.00-8.00)

Comparisons of the results of the model with the results from the measurements for the afternoon rush hours (15.00-16.00) are illustrated in figures (5.6 - 5.9).

Traffic data for 382 points was obtained. To verify the model a part of these measurements (approx. 35%) is used. The location of selected points is shown in Figure 5.5: a total of 133 selected points.

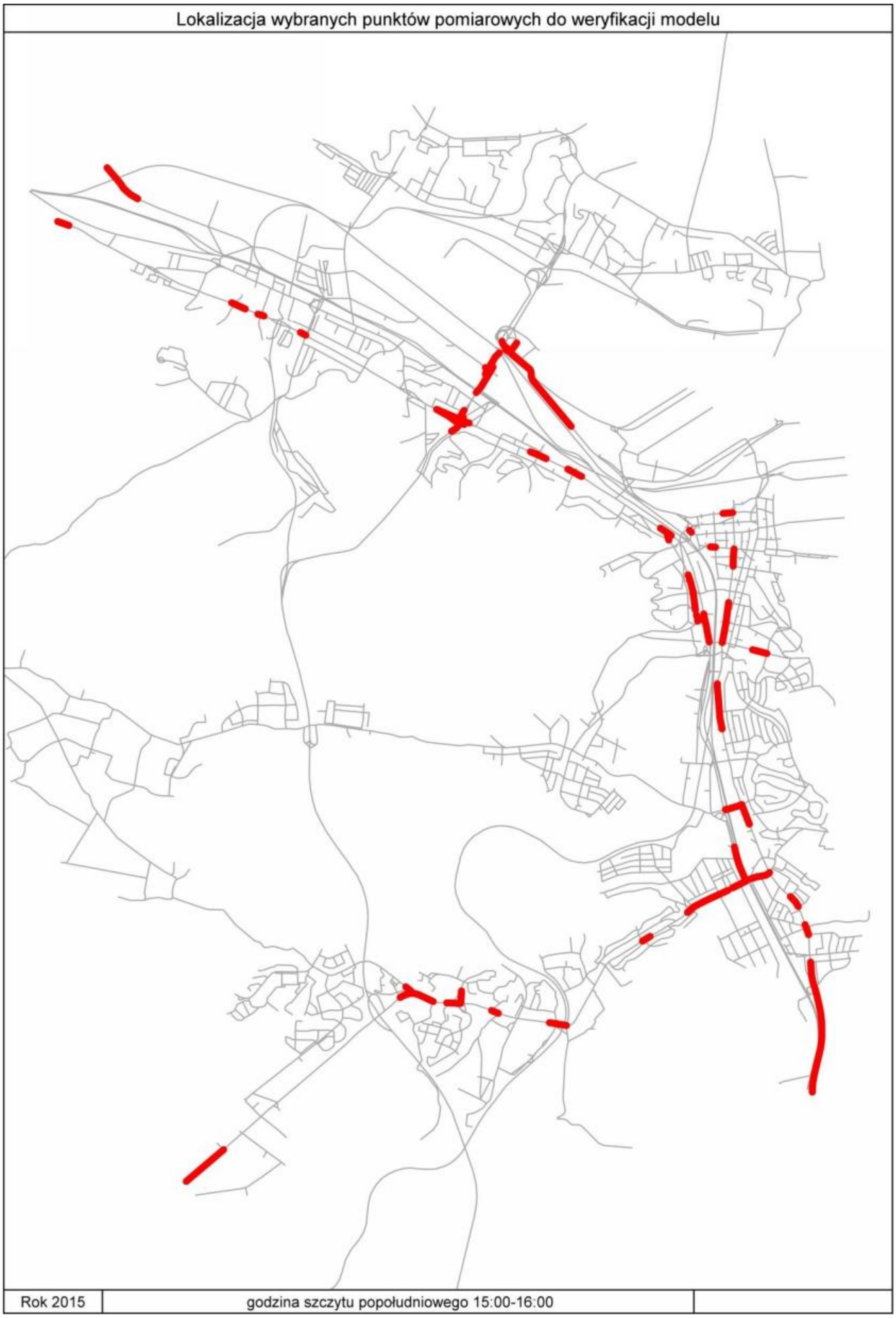

Figure 5.5: Location of the selected measuring points for model verification for the afternoon rush hour 15.00-16.00

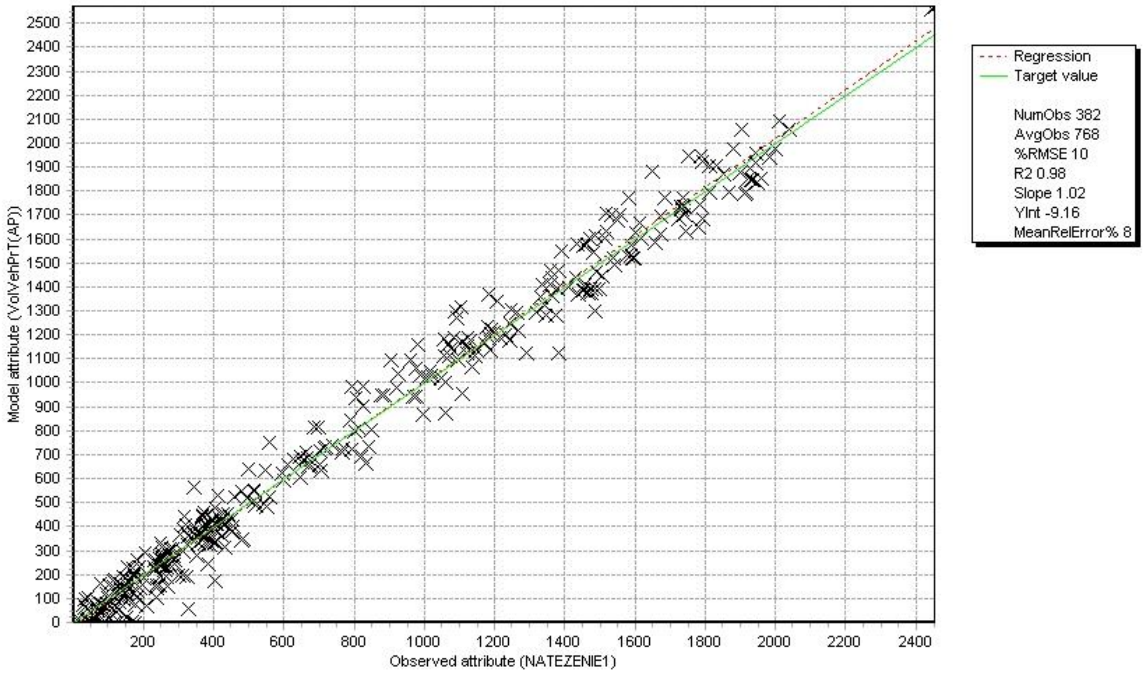

Figure 5.6: Results of model verification (afternoon rush hour 15.00-16.00)

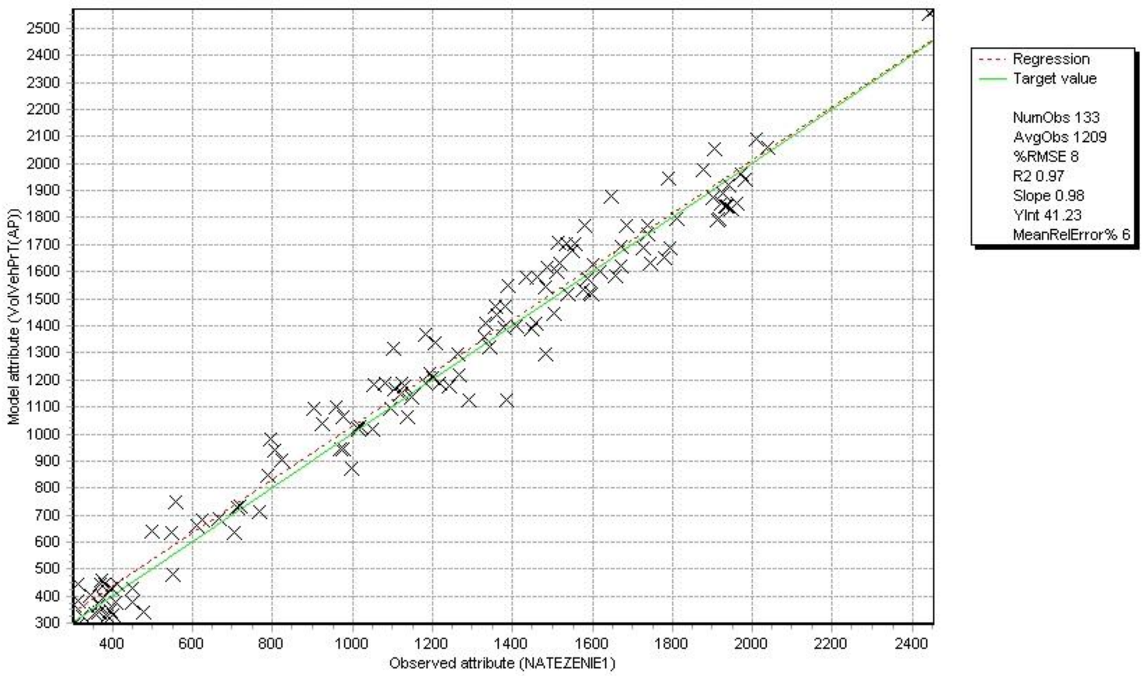

Figure 5.7: Results of model verification (afternoon rush hour 15.00-16.00)

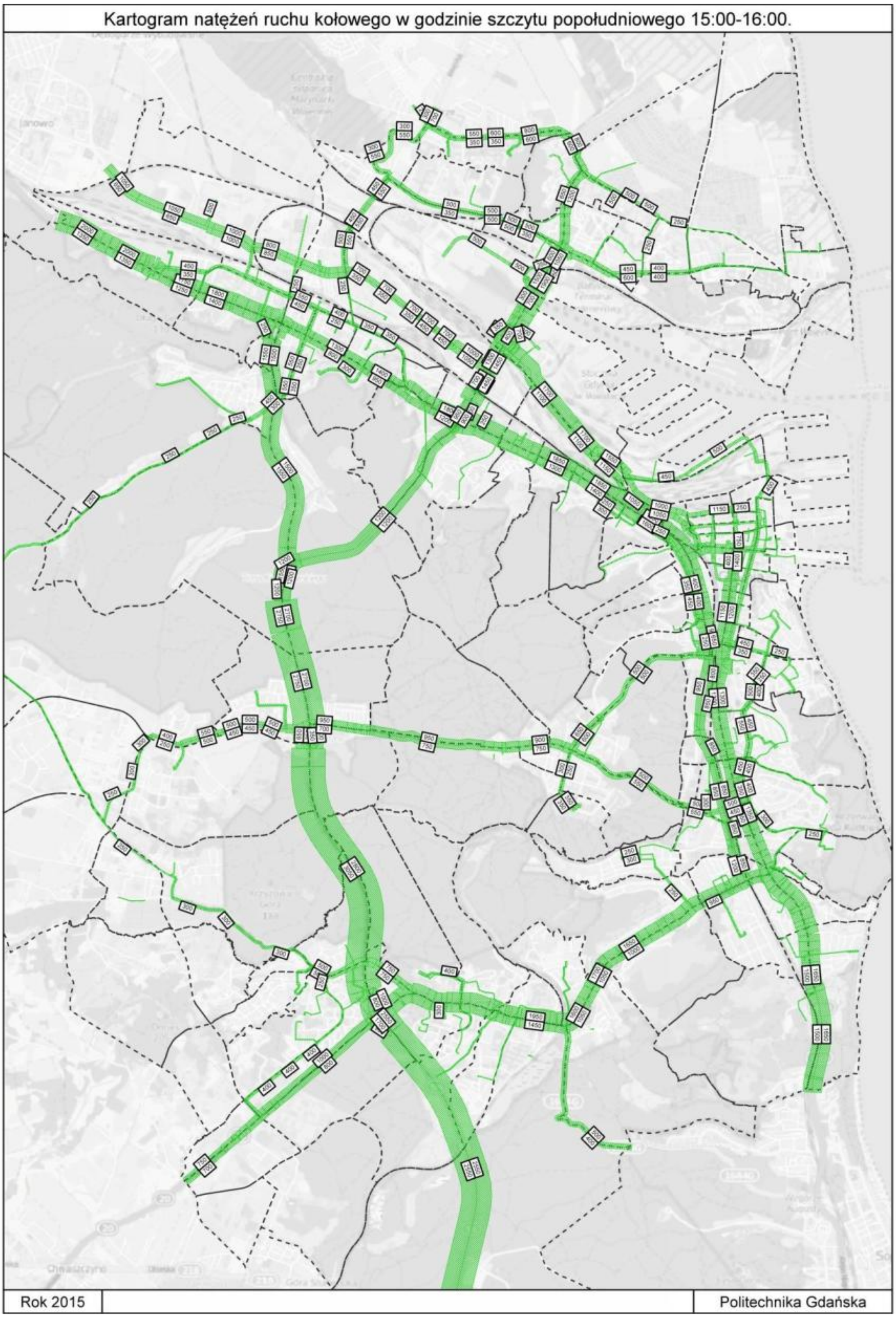

Figure 5.8: Cartogram of vehicular traffic volume in the afternoon rush hour (15.00-16.00)

5.1.2 Public transport model conformity assessment

To verify the traffic model, data of passenger traffic obtained during the months of October and November 2015 for both the morning peak hours (7.00-8.00) and afternoon peak hours (15.00-16.00) was used. These data were obtained in the framework of measuring the effectiveness of the TRISTAR traffic control system in Gdynia. The study measured the volume of passenger traffic in vehicles of public transport in the area of Gdynia during the morning and afternoon peak hours. A comparison of the results of the model with the results of the measurements for the different hours are shown in figures (5.10 - 5.13).

Traffic data for 175 points was obtained. To verify the model a part of these measurements (approx. 40%) is used. The location of selected points is shown in Figure 5.9: a total of 70 selected points.

In addition, the verification of the model was made by comparing the average speed of communication on transport flows in the area of the TRISTAR system. To do this, the data from the same measurements was used. The average speed of the services was calculated based on the average travel time of public transport vehicle along a section of known length. The result was compared to the model of travel time for this type of vehicle of the same section. Comparisons were made for nine streets. The verification of model results was consistent with the results of the actual measurements (coefficient of determination R^2 = 0.83). The results are shown in table 5.1 and figure 5.14.

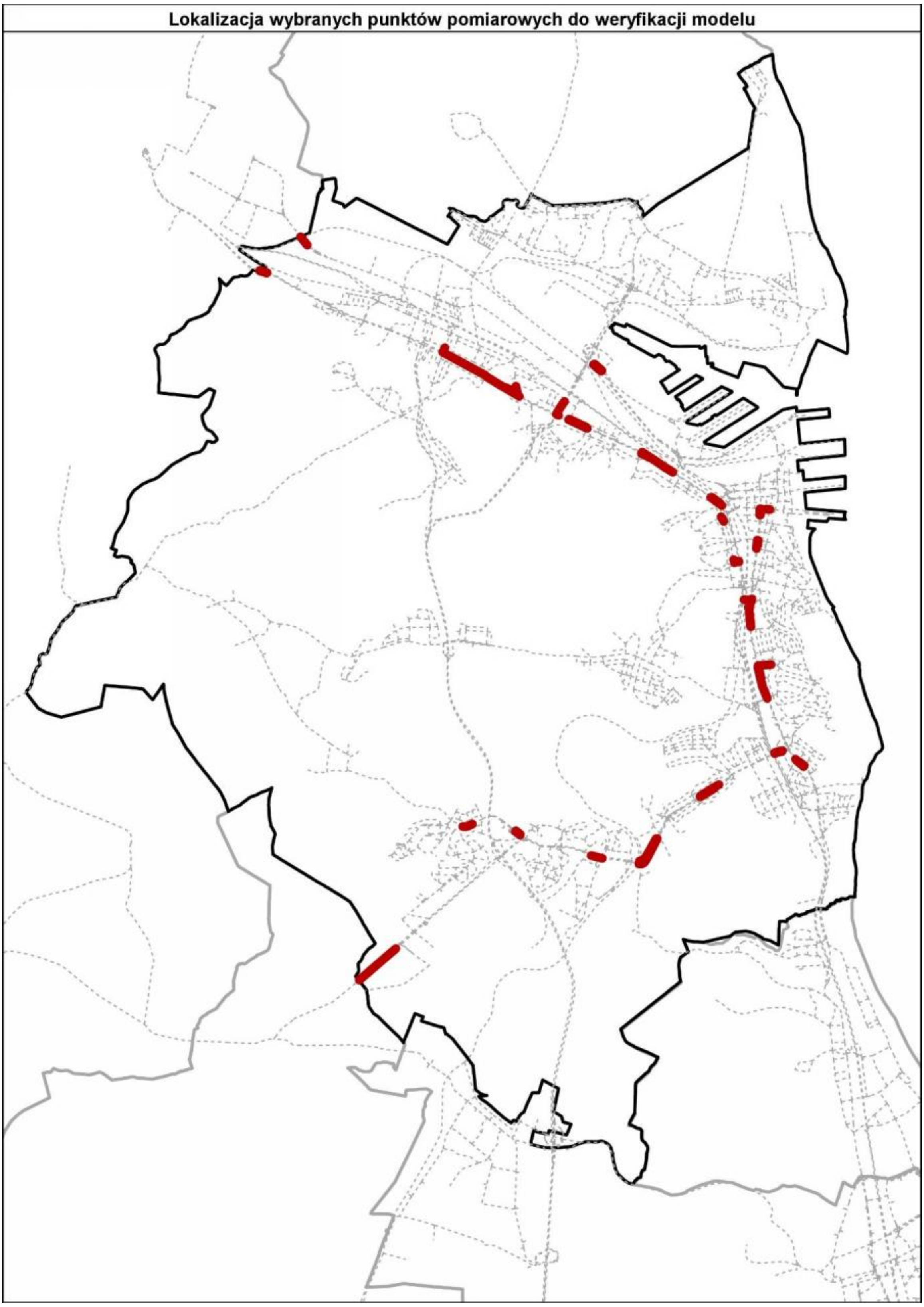

Figure 5.9: Location of the selected measuring points for model verification for the morning rush hour (7.00-8.00)

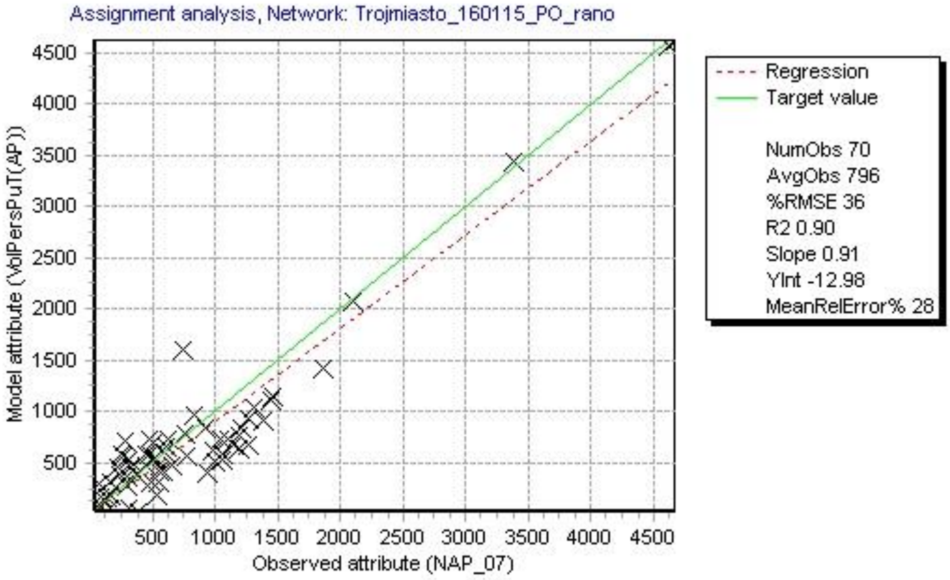

Figure 5.10: Results of public transport model verification (morning rush hour)

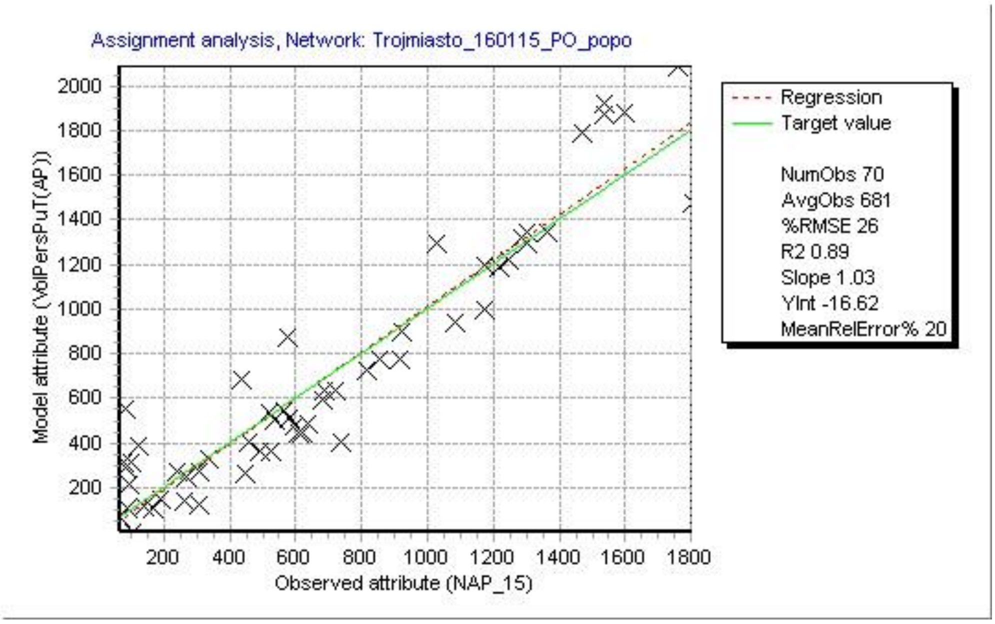

Figure 5.11: Results of public transport model verification (afternoon rush hour)

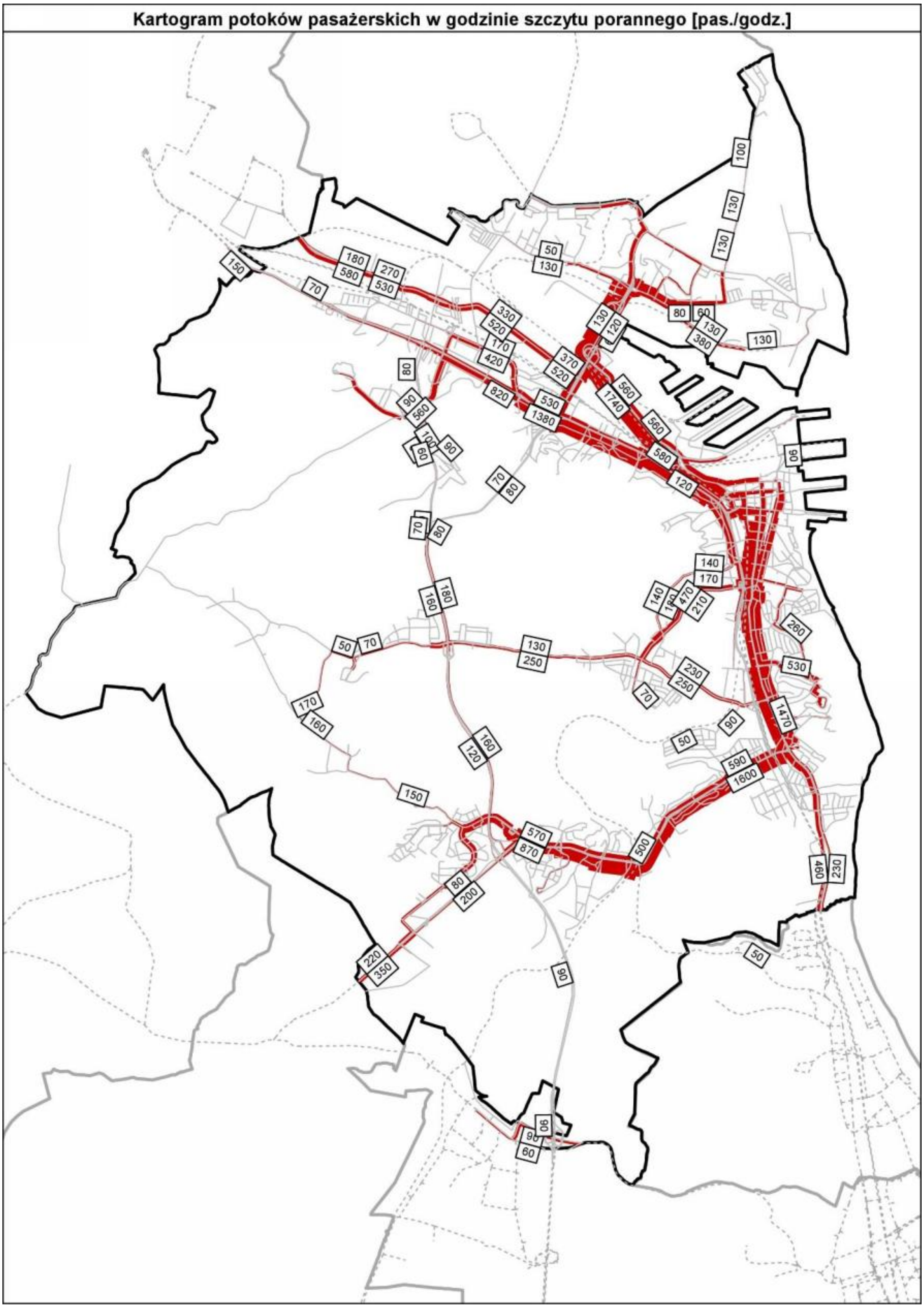

Figure 5.12: Cartogram of passenger flows in the morning rush hour

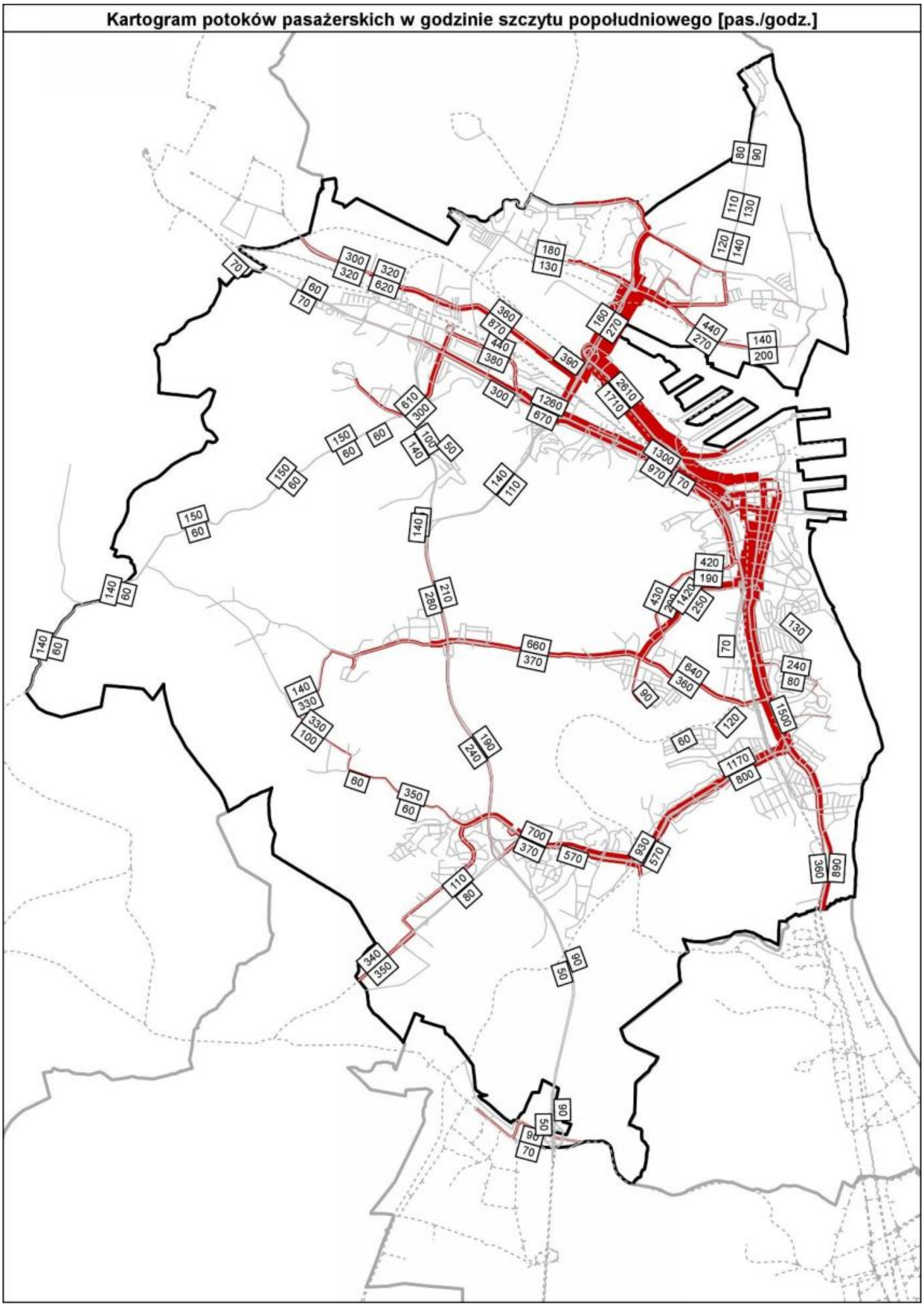

Figure 5.13: Cartogram of passenger flows in the afternoon rush hour

Section	From	To	Average speed [km/h]	
			Measurement	Model
Trasa Średnicowa	Sępia (Sopot)	Piłsudkiego	22,60	21,23
Śląska-Morska	Kielecka	Chylońska II	20,80	20,40
Wlkp-Chwaszcz	Zwycięstwa	Nowowiczlińska	20,54	21,21
Piłsudskiego	Legionów	Śląska	12,41	16,80
10 Lutego	Podjazd	Świętojańska	13,91	16,00
Trasa Kwiatkowskiego	Wiśniewskiego	Obwodnica Trójmiasta	22,99	22,70
Nowowiczlińska	Chwaszczyńska	Rdestowa	17,18	17,42
Warszawska	Śląska	Morska	15,50	15,80
Władysława IV	Piłsudskiego	Wójta Radtkego	18,40	17,29

Table 5.1: Comparison of average speed of public transport vehicles at selected sections

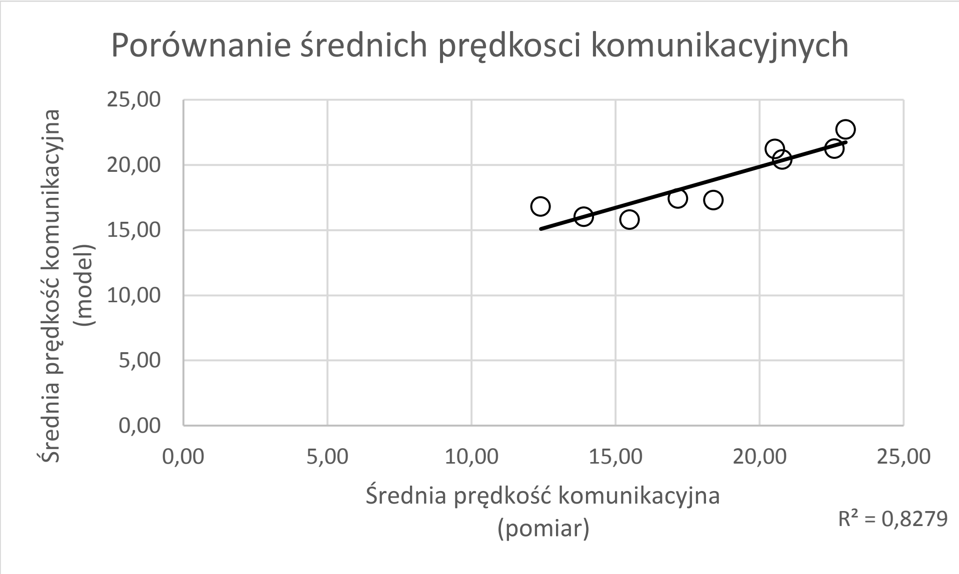

Figure 5.14: Comparison of average speed of public transport vehicles at selected sections

5.2 Mesoscopic model verification

The verification of the mesoscopic model was made on the basis of identical data as in the case of the macroscopic model for individual transport. To verify the traffic model, traffic data from 2 April 2015 was used.

5.2.1 The internal convergence of the model

In order to verify the correctness of the calculations and the results the following parameters were considered: [8]

1. Parameter δ, which testifies the model equilibrium.

$$\delta = \frac{\sum T_{pij}(c_{pij} - c_{ij}^{0})}{\sum T_{ij} \cdot c_{ij}^{0}}$$

where:

- Tpij - the size of the flow on the route p, connecting the regions ij
- cpij - the cost of travel in the forced conditions on the route p, connecting regions ij,
- cij0 - minimum cost of travel between regions j.

δ parameter is useful in monitoring the convergence in the process of network load of the travel matrix in the SATASS programme (application of the SATURN programme), which selects routes for each pair of source: destination, based on the minimum value of the cost of travel time. δ parameter provides information about the extent to which the selected routes are the routes with minimal travel cost. In [38] it is recommended that δ <5%.

In the case of the model for the morning rush hour achieved value: up to 1%.

In the case of the model for the afternoon rush hour achieved value: up to 1%.

2. The parameter CC, which represents the mean absolute changes in the profiles of the flows leaving the intersection, allows monitoring convergence in the simulation of traffic at intersections. The size of the flows leaving the intersection in subsequent iterations of the simulation process is monitored. The simulation of traffic at intersections is performed using the SATSIM application. In [6] it is recommended that in successive iteration steps, CC <1 [passenger cars/ hour] (considered all the intersections in the network). In practice, satisfactory results are obtained when the parameter CC does not exceed substantially 1 [passenger cars/ hour] [6].

   In the case of the model for the morning rush hour achieved value: max 0,26.

   In the case of the model for the afternoon rush hour achieved value: max 0,38.

Another parameter allows monitoring the convergence results in loops SATASS/ SATSIM (in SATURN iterations are performed between the process of loading the network with travel matrix and the process of traffic simulation at intersections):

3. Parameter PF (% flows) informs about the fraction of connections in the network, where the relative change in the size of the allocated flow in subsequent iterations SATASS/ SATSIM are smaller than 5%. This parameter indicates the option to terminate the iterative process when PF> 95%.

   In the case of the model for the morning rush hour achieved value: 95,9%.

   In the case of the model for the afternoon rush hour achieved value: 96,1%.

4. Parameter PD (% Delays) reports on the relationship at intersections fraction of simulation in which relative changes in the total loss of time in subsequent iterations SATASS/ SATSIM are less than 5%. This parameter indicates the appropriateness of the end of the iterative process when PF> 95%.

   In the case of the model for the morning rush hour achieved value: 96,4%.

   In the case of the model for the afternoon rush hour achieved value: 95,3%.

   The calculation results are considered to be satisfactory if one of the parameters PF or PD in the final iteration step is greater than 95%.

   Loss of time in the SATURN package is calculated as time spent in momentary or remaining queues (the simulation process does not include delays resulting from traffic flows on a combination of (section of) road). In contrast, these values are taken into account when calculating the total travel time on the network.

5. Parameter V.I. (% V.I) allows comparing the costs of travel with the connections allocated in the current simulation to the cost of travel with connections allocated in the previous iteration analysed assuming the calculation of travel costs including the loss of time from the iteration preceding the analyses. Parameter V.I. should take into account the next iterations' positive values. A negative value indicates that the costs of travel on the routes in the current iteration are larger than in the previous which may be the result of a significant change in the distribution of traffic.

   In the case of the model for the morning rush hour achieved value: positive in the last 2 steps of iterations

   In the case of the model for the afternoon rush hour achieved value: positive in the last 2 steps of iterations

6. The parameter PG (% GAP) represents the difference between the current total cost of travelling vehicles in the network and the total cost of travelling vehicles in the distribution

of All-or-Nothing (relatively to the total cost of the vehicle in the AOL distribution). This parameter is analogous to parameter δ, but it is calculated after the simulation process with the SATSIM application. Convergence in subsequent iterations is satisfactory, if the parameter PG has a value of less than 5%.

In the case of the model for the morning rush hour achieved value: condition fulfilled in the last eight iteration steps

In the case of the model for the afternoon rush hour achieved value: condition fulfilled in the last six iteration steps

7. Convergence of the demand balance: Parameter DD (% DD) is monitored with the difference in calculated demand in relation to the output demand (relative measure is obtained by dividing the above difference by the total number of travels in the network), which changes should aim to 0. The parameter is monitored during the flexible distribution.

Moreover, it is recommended to monitor the value of the objective function, so that the difference between the value of the objective function in subsequent iterations subject to minimization (aimed to 0), which was achieved in the case of the model for the peak morning and afternoon.

Compliance with these principles requires detailed analyses to adopt the correct number of iterations in the process of selecting a route, simulation process and iteration between these processes and the proper adoption of parameters characterizing the network of connections and intersections, as well as the correct definition of the travel expenses.

5.2.2 Model verification

The verification of the developed models is based on the assessment of the similarity between the real system and the model system. Transport systems models are homomorphic models which means that not all elements of the real system are described by means of a model system. While mapping the transport network consisting of intersections (nodes) and connections between them (connections) can be regarded as accurate, the mapping of areas to generate and absorb traffic model, which are contractual areas of transport, characterized by their centres of gravity, is far from the real system.

The consequence of the above-described is that the components mapping system is to reduce the actual number of links between the various elements of the model. However, one can only imagine such a model, in which, despite the lack of mapping of all elements of the real system, there is consensus of the model system with the real system, i.e. the size of flows or speed values obtained in the model are consistent or similar to those observed in practice. Therefore, the most important task in the model verification is to check the correctness of the calculation results obtained on the basis of the model.

In order to determine compliance of the model system with real data, on the stage of model verification the regression analysis and correlation between the values of traffic intensity measured during field studies and traffic flows obtained by simulation at the measuring points was conducted: it is assumed that between these values a strong linear correlation should occur of angular regression function equal to 1.00, and the absolute term of the function equal to 0.00.

The calculations for the measurement points (sections and relationships at intersections) found that for each network models the coefficient of determination R^2 (for the function Y = X) accepted values range from 0.86 (peak morning) to 0.85 (peak afternoon). The results of the statistical analysis for model cities are shown in figures 5.15 and 5.16.

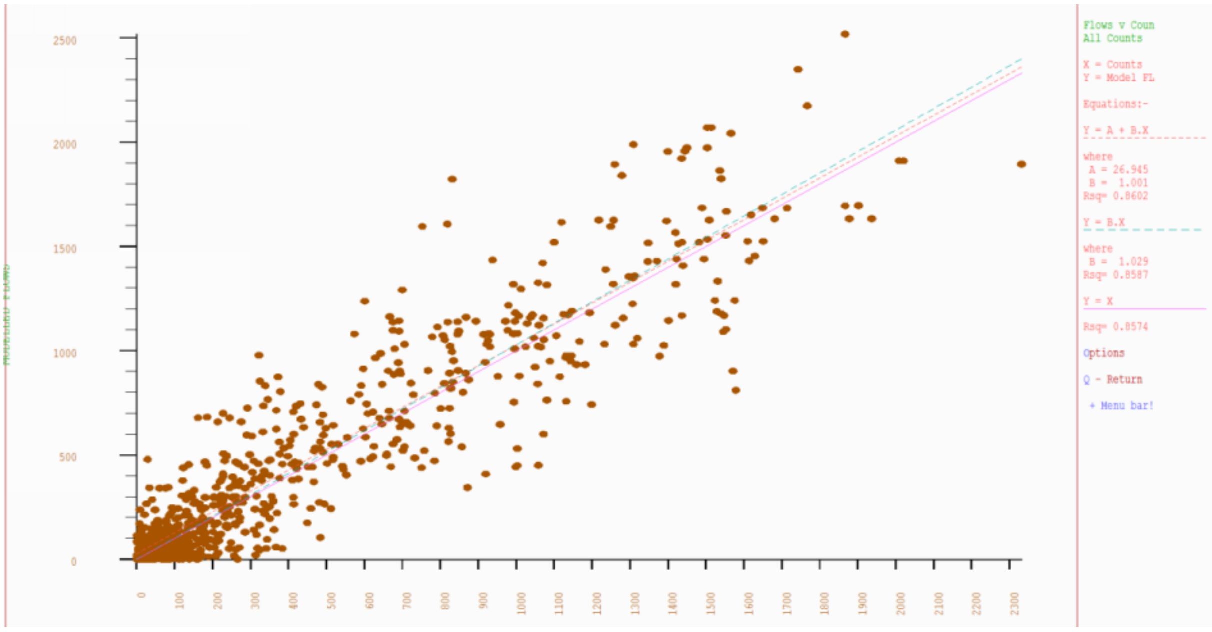

Figure 5.15: Comparison of the volume of traffic measured in field studies with the values obtained from the city model in the morning peak - all the vehicles (R2 = 0.86)

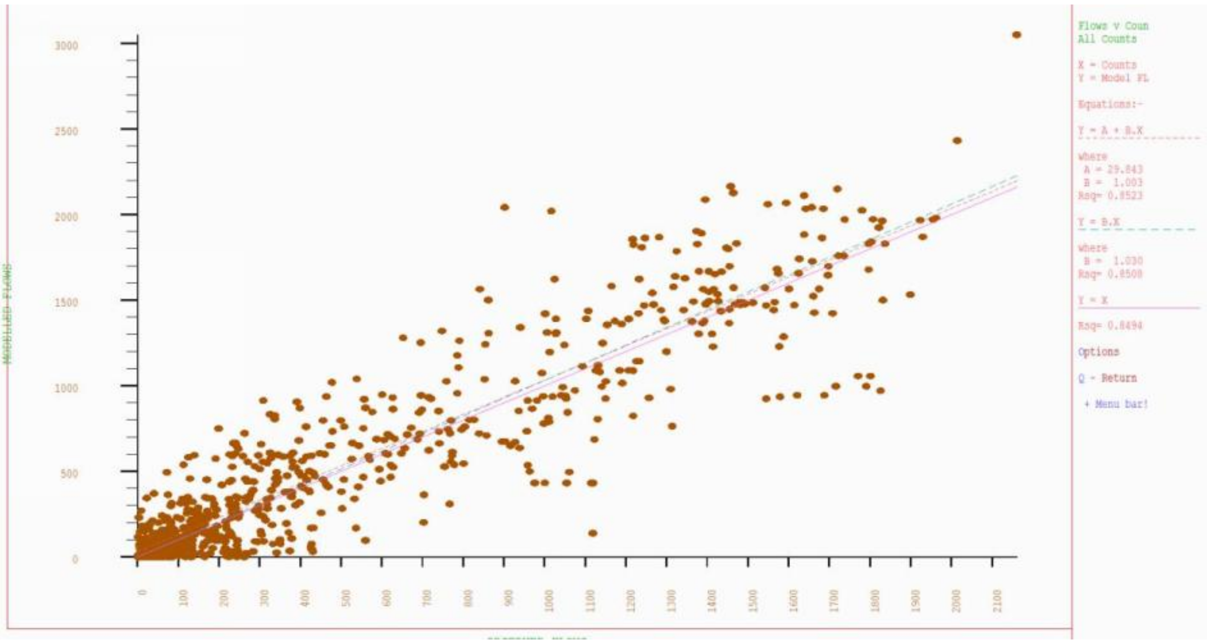

Figure 5.16: Comparison of the intensity of traffic measured in field studies with the values obtained from the city model in the morning peak - all the vehicles (R2 = 0.85)

For each of the models statistical analyses were also performed, allowing more accurate comparisons of the measured traffic volume values obtained from the model. For this purpose, an analytical method was used, which is a form of statistics $\chi 2$, which includes both the relative error and absolute. Described statistics is described by formula (GEH)

$$GEH = \sqrt{\frac{(M-C)^2}{0{,}5 \cdot (M+C)}}$$

where:

- GEH – considered statistics GEH,
- M – the traffic volumes derived from a model,
- C – values of the measured (observed) traffic flows.

In the formula (GEH) factor (M-C) means absolute error, and the factor (M + C) / 2 means relative error. The use of this method is recommended by British guidelines.

Statistics GEH should not have values less than 5 (it is unacceptable to exceed a value of 10) for 85% of cases [38].

The results of the analysis of GEH statistics for a considered exemplary model are shown in tables 5.1 and 5.3.

Statistics	Value of the statistics
The volumes measured in the range of <700 [veh/ hour] (Relative change compared to the volume of a model <100 veh/ hour]	83,4%
The volumes measured in the range 700 - [passenger cars/ hour] (Absolute change compared to the volumes of the model <15%)	80,2%
Statistics GEH < 5	62,3%
Statistics GEH < 10	85,7%
The average value of statistics GEH	0,24
Coefficient of determination R^2	85,7%

Table 5.2: Statistical results of compliance of volumes observed and obtained from the city model for the morning peak hour

Statistics	Value of the statistics
The volumes measured in the range of <700 [veh/ hour] (Relative change compared to the volume of a model <100 veh/ hour]	83,6%
The volumes measured in the range 700 - [veh/ hour] (Absolute change compared to the volumes of the model <15%)	79,2%
Statistics GEH < 5	68,6%
Statistics GEH < 10	84,7%
The average value of statistics GEH	0,65
Coefficient of determination R^2	84,7%

Table 5.3: Statistical results of compliance of volumes observed and obtained from the city model for the afternoon peak hour

These results, including the size of the analysed city and a significant range of measurement points, indicate satisfactory convergence of the volumes observed and obtained from the model. It was found that greater impact on the size of the error had differences between volumes measured and derived from the model in the range of volumes “above 700” [veh/ hour].

The following process of the verification allowed including the entire network (both intersections and interconnections).

Table 5.4 compares the transit times with the times of the model on selected sections. Convergence is satisfactory (not exceeding 5%).

Street	Section from	Section to	Section lenght L [m]	7:00-8:00				15:00-16:00			
				Measured time t[s]	Time from the model t1 [s]	Difference [s]	Difference [%]	Measured time t[s]	Time from the model t1 [s]	Difference [s]	Difference [%]
Trasa Średnicowa-Gdynia	Sępia		500	115	30			131	26		
Trasa Średnicowa-Gdynia		Spółdzielcza	1183		79				117		
Trasa Średnicowa-Gdynia	Spółdzielcza	ul. Przebendowskich	402	48	45			50	50		
Trasa Średnicowa-Gdynia	ul. Przebendowskich	ul. Orłowska	350	33	33			34	34		
Trasa Średnicowa-Gdynia	ul. Orłowska	ul. Nawigatorów	414	36	30			36	35		
Trasa Średnicowa-Gdynia	ul. Nawigatorów	ul. Wielkopolska	385	34	36			50	49		
Trasa Średnicowa-Gdynia	ul. Wielkopolska	ul. Stryjska	850	66	68			91	100		
Trasa Średnicowa-Gdynia	ul. Stryjska	ul. Redłowska	550	77	68			83	72		
Trasa Średnicowa-Gdynia	ul. Redłowska	ul. Harcerska	600	42	41			46	45		
Trasa Średnicowa-Gdynia	ul. Harcerska	Wzgórze Św. Maks. I	250	30	36			46	45		
Trasa Średnicowa-Gdynia	Wzgórze Św. Maks. I	Wzgórze Św. Maks. II	171	15	19			22	19		
Trasa Średnicowa-Gdynia	Wzgórze Św. Maks. II		120	17	18			33	11		
Trasa Średnicowa-Gdynia			96		9				9		
Trasa Średnicowa-Gdynia			70		7				7		
Trasa Średnicowa-Gdynia		ul. Piłsudskiego	70		15				13		
Trasa Średnicowa-Gdynia	ul. Piłsudskiego		125	124	10			134	10		
Trasa Średnicowa-Gdynia			125		10				10		
Trasa Średnicowa-Gdynia			120		8				8		
Trasa Średnicowa-Gdynia			120		8				8		
Trasa Średnicowa-Gdynia			70		5				5		
Trasa Średnicowa-Gdynia			70		8				9		
Trasa Średnicowa-Gdynia			134		12				12		
Trasa Średnicowa-Gdynia			80		7				7		
Trasa Średnicowa-Gdynia			80		7				8		
Trasa Średnicowa-Gdynia			98		6				6		
Trasa Średnicowa-Gdynia		ul. 10 Lutego	99		25				33		
			7132	636	641	5	0,9	757	749	-8	-1,1
			5775	512	503	-9	-1,8	623	603	-19	-3,1
Trasa Średnicowa-Gdynia	ul. 10lutego		99	157	6			191	6		
Trasa Średnicowa-Gdynia			98		6				7		
Trasa Średnicowa-Gdynia			80		7				7		
Trasa Średnicowa-Gdynia			80		10				9		
Trasa Średnicowa-Gdynia			134		16				17		
Trasa Średnicowa-Gdynia			70		5				5		
Trasa Średnicowa-Gdynia			70		7				6		
Trasa Średnicowa-Gdynia			120		8				8		
Trasa Średnicowa-Gdynia			120		9				9		
Trasa Średnicowa-Gdynia			125		9				9		
Trasa Średnicowa-Gdynia		ul. Piłsudskiego	125		44				91		
Trasa Średnicowa-Gdynia	ul. Piłsudskiego		70	14	7			17	7		
Trasa Średnicowa-Gdynia			70		7				7		
Trasa Średnicowa-Gdynia			96		9				9		
Trasa Średnicowa-Gdynia		Wzgórze Św. Maks. II	120		21				20		
Trasa Średnicowa-Gdynia	Wzgórze Św. Maks. II	Wzgórze Św. Maks. I	171	24	25			19	24		
Trasa Średnicowa-Gdynia	Wzgórze Św. Maks. I	ul. Harcerska	250	35	23			32	24		
Trasa Średnicowa-Gdynia	ul. Harcerska	ul. Redłowska	600	42	41			41	41		
Trasa Średnicowa-Gdynia	ul. Redłowska	ul. Stryjska	550	39	35			38	33		
Trasa Średnicowa-Gdynia	ul. Stryjska	ul. Wielkopolska	850	93	95			112	112		
Trasa Średnicowa-Gdynia	ul. Wielkopolska	ul. Nawigatorów	385	40	36			42	44		
Trasa Średnicowa-Gdynia	ul. Nawigatorów	ul. Orłowska	414	40	46			41	44		
Trasa Średnicowa-Gdynia	ul. Orłowska	ul. Przebendowskich	350	38	38			29	35		
Trasa Średnicowa-Gdynia	ul. Przebendowskich	ul. Spółdzielcza	402	32	28			38	42		
Trasa Średnicowa-Gdynia	ul. Spółdzielcza	ul. Sępia	1183	128	98			131	61		
Trasa Średnicowa-Gdynia			500		28				59		
			7132	683	664	-19	-2,8	733	737	4	0,6
			5775	512	514	2	0,4	524	539	15	2,9

Street	Section from	Section to	Section lenght L [m]	7:00-8:00 Measured time t[s]	7:00-8:00 Time from the model t1 [s]	7:00-8:00 Difference [s]	7:00-8:00 Difference [%]	15:00-16:00 Measured time t[s]	15:00-16:00 Time from the model t1 [s]	15:00-16:00 Difference [s]	15:00-16:00 Difference [%]
Wielkopolska-Chwaszczyńska	al. Zwycięstwa	ul. Lotników	300	59	60			92	92		
Wielkopolska-Chwaszczyńska	ul. Lotników		100	62	8			59	17		
Wielkopolska-Chwaszczyńska		ul. Wrocławska	250		47				29		
Wielkopolska-Chwaszczyńska	ul. Wrocławska	ul. Łowicka	350	64	56			54	54		
Wielkopolska-Chwaszczyńska	ul. Łowicka	ul. Gedymina	700	55	52			54	53		
Wielkopolska-Chwaszczyńska	ul. Gedymina		300	56	22			59	22		
Wielkopolska-Chwaszczyńska		ul. Racławicka	500		36				36		
Wielkopolska-Chwaszczyńska	ul. Racławicka		50	45	5			67	4		
Wielkopolska-Chwaszczyńska		ul. Sopocka	550		45				58		
Wielkopolska-Chwaszczyńska	ul. Sopocka	ul. Nowodworcowa	250	12	31			20	34		
Wielkopolska-Chwaszczyńska	ul. Nowodworcowa	ul. Starodworcowa	400	57	35			69	61		
Wielkopolska-Chwaszczyńska	ul. Starodworcowa	ul. Źródło Marii	200	21	17			20	17		
Wielkopolska-Chwaszczyńska	ul. Źródło Marii	ul. Brzechwy	550	41	48			35	43		
Wielkopolska-Chwaszczyńska	ul. Brzechwy	ul. Myśliwska	150	19	19			13	11		
Wielkopolska-Chwaszczyńska	ul. Myśliwska	ul. Górnicza	150	19	21			12	11		
Wielkopolska-Chwaszczyńska	ul. Górnicza	ul. Nowowiczlińska	300	47	49			30	32		
Wielkopolska-Chwaszczyńska	ul. Nowowiczlińska	Obwodnica	252	94	83			65	65		
			5352	651	633	-18	-2,8	649	639	-10	-1,5
			5100	557	550	-7	-1,3	583	574	-9	-1,6
Wielkopolska-Chwaszczyńska	Obwodnica	ul. Nowowiczlińska	252	40	42			44	44		
Wielkopolska-Chwaszczyńska	ul. Nowowiczlińska	ul. Górnicza	300	28	26			24	22		
Wielkopolska-Chwaszczyńska	ul. Górnicza	ul. Myśliwska	150	24	21			11	11		
Wielkopolska-Chwaszczyńska	ul. Myśliwska	ul. Brzechwy	150	24	22			18	20		
Wielkopolska-Chwaszczyńska	ul. Brzechwy	ul. Źródło Marii	550	50	42			38	41		
Wielkopolska-Chwaszczyńska	ul. Źródło Marii	ul. Starodworcowa	200	32	30			34	34		
Wielkopolska-Chwaszczyńska	ul. Starodworcowa	ul. Nowodworcowa	400	49	51			42	34		
Wielkopolska-Chwaszczyńska	ul. Nowodworcowa	ul. Sopocka	250	16	24			12	29		
Wielkopolska-Chwaszczyńska	ul. Sopocka		550	51	40			50	40		
Wielkopolska-Chwaszczyńska		ul. Racławicka	50		12				4		
Wielkopolska-Chwaszczyńska	ul. Racławicka		500	54	36			52	36		
Wielkopolska-Chwaszczyńska		ul. Gedymina	300		24				23		
Wielkopolska-Chwaszczyńska	ul. Gedymina	ul. Łowicka	700	48	51			52	51		
Wielkopolska-Chwaszczyńska	ul. Łowicka	ul. Wrocławska	350	32	42			36	54		
Wielkopolska-Chwaszczyńska	ul. Wrocławska		250	65	23			57	31		
Wielkopolska-Chwaszczyńska		ul. Lotników	100		49				39		
Wielkopolska-Chwaszczyńska	ul. Lotników	al. Zwycięstwa	300	91	90			86	57		
			5352	604	623	19	3,2	558	568	10	1,9
			5100	564	581	17	3,0	514	524	11	2,1

Table 5.4: Comparison of travel times obtained from the model with the measured field measurements within the measurements after implementation of the TRISTAR system

6 CONCLUSIONS AND NEXT STEPS

The share of public transport in Gdynia is 52%. Individual transport is at 47% and cycling is only at 1%.

Unfortunately, with more than 500 cars per 1,000 residents and an increase in the modal share of cars by more than 6% since 2008, Gdynia is facing a problem of raising congestion and pollution. Gdynia is also facing parking problems in the city center, a lack of park and rides, and a lack of pedestrian zones.

To tackle this problem, within CIVITAS DYN@MO, City of Gdynia has developed and introduced an innovative tool - 3-level transport model for both individual and public transport for the city.

The CIVITAS DYN@MO MST – Multilevel Transport Systems Model – is used to:

- Analysis of the effectiveness of Personal Rapid Transit system
- Analysis of changes in traffic organization (changing course or line extension of public transport, including trolley lines, bus lanes, closures and modernisation of streets) – tasks 1.2, 1.3, 3.1 and 3.5
- Impact of road accidents on traffic condition – task 3.2
- Analisys of usage of the Weight in motion system to manage freight transport accessibility – task 3.3
- Publication of the results on Mobilna Gdynia website – task 3.4

Transport model is used in many ways to help with planning and operating sustainable traffic measures and personal mobility.

- Using the model we are able to analyse traffic in Gdynia and implement changes to give priority to sustainable mobility over individual car traffic.
- We are able to analyse and visualize changes in traffic during road repairs and minimize congestion created by them (i.e. during implementation of bus lanes).
- Our newly developed tool was also used during the implementation of bus lanes (at 10 Lutego, Władysława IV, Morska, Estakada Kwiatkowskiego and Chwarznieńska streets) and bicycle lanes (3 Maja street) in Gdynia.
- The model is used to monitor impact of changes in traffic control system and testing different traffic control strategies and programmes.
- We also use the model to examine changes proposed by different stakeholders: NGOs and citizens requests.

The City's newly developed tool will be used after the duration of CIVITAS DYN@MO project. The model will continue to be used for operational management, planning and decision making as well as will be further developed. Forthcoming activities in City of Gdynia linked with the 3-level model are connected with realization of FLOW project financed from Horizon 2020 framework programme. FLOW – Furthering Less congestion by creating Opportunities for more Walking and cycling –Gdynia will expand the model with walking and cycling data. It will support the recalibration of the models developed within DYN@MO and will give us a decision-making tool to focus on the measures that have great impact on congestion reduction.

During the FLOW Gdynia will analyse the implementation of measures that contribute to increasing walking and to busting congestion. We will also review and complete the cycle network in Gdynia and the Tri-city metropolitan area. Analysis of road traffic modifications will be conducted in connection to planning new bicycle lanes.

We expect that the model developed within CIVITAS DYN@MO project will have many widely recognized environmental and socially important impacts on mobility in Gdynia.

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