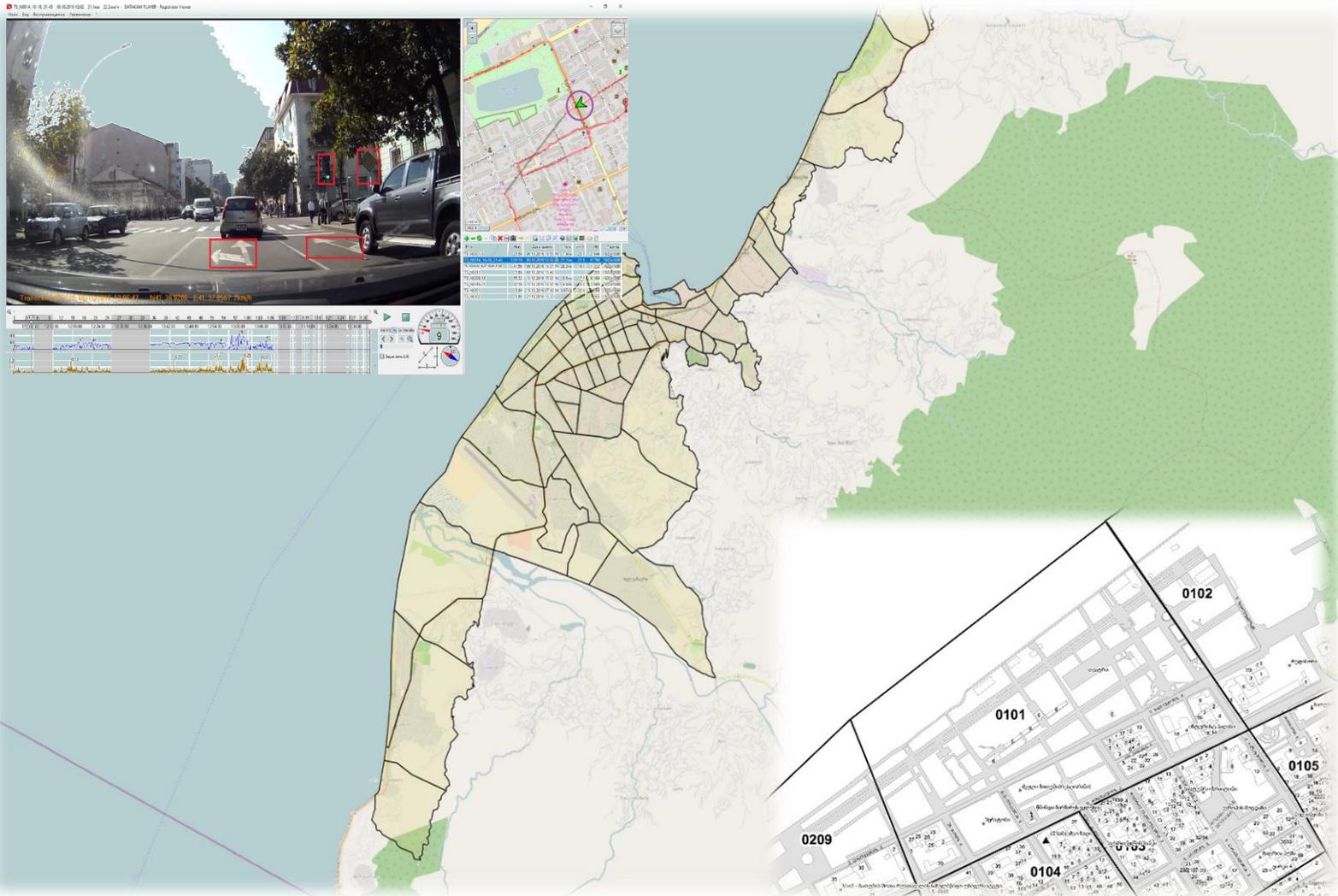




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Transport Data Collection and Baseline Assessment

Technical Report #1



The report has been prepared by a team of experts from A+S Consult GmbH



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Client: United Nations Development Programme (UNDP)

Project: Green Cities: Integrated Sustainable urban Transport for the City of Batumi and the Achara Region (ISTBAR)

Sub-project: Feasibility Studies for Pilot Low-Carbon Urban Transport Corridor and Integrated Sustainable Urban Mobility Plan for the City of Batumi (ISUMP)

Output 1: Traffic Data Collection and Baseline Assessment, Batumi Transport Model Development Process

The report has been prepared by A+S Consult GmbH

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Batumi
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The views expressed in this report are those of the Authors and do not necessarily represent those of GEF and UNDP



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INTRODUCTION

The Green Cities: ISTBAR Project seeks to initiate efforts towards reduction of transport-related GHG emissions through a green approach and in an environmentally sustainable manner. In particular, the Project will focus on the urban transport sector, a priority identified in the TNC where GHG emissions are continuously rising. As Georgia's leading tourist destination located on the Black Sea and with close economic relations with neighbouring countries, City of Batumi has an increasingly important role and function both as a sea resort and as a sea and land gate of Georgia. Due to its growth in area from 18 km² in 1990 to 65 km² through the inclusion of neighbouring towns and villages, Batumi's image has changed from a relatively small city into a non-uniform conglomerate with highly developed districts with modern architecture. The city's image, however, is evolving into a much larger urban conglomerate with increasingly congested streets that contribute to a growing air pollution problem. More recently, the City has shown a strong interest in green urban development and sustainable transport based on the active involvement of the City administration on these issues, and the willingness of the City to implement a demonstration for sustainable transport that can be replicated in other cities in Georgia.

First task within the project is traffic data collection, the analysis of available data and the establishment of a baseline assessment in a transport model.

This given report summarizes the findings of the first task "Traffic Data Collection and Baseline Assessment". It describes the findings of available documents and data review, description of current socio-economic situation, actual transport infrastructure, actual traffic patterns and current organizational and institutional characteristics, describing the surveys, traffic counts, methodology and their results.

1 DATA ACQUISITION PROCESS

One of the first tasks that has to be undertaken in a transport modelling project is also one of the most critical and difficult ones. The data acquisition and collection is a key for the success of a project and especially that counts for the development of a transport model. Often the process of establishing a transport model is also the first time for a city in collecting data and making data available in a digital way. Till then data only existed in written form or in a graphical way. We want to describe in this chapter shortly which challenges we faced while collecting the necessary data for the transport modelling.

1.1 Structural data of the transport network

Base data for the transport network for the city of Batumi was obtained by means of geo-information resource OpenStreetMap (OSM – is a nonprofit web mapping project for the creation detailed free map of the world).

After importing OSM in PTV Vision VISUM, the transport network has been carefully checked and edited. This task is one of the most work intensive tasks, which has to be done manually. As there is no technology like Google Street View available in Batumi we decided to develop an own technological approach. This approach consists of a dashcam with GPS to record a video from the street network. Our local colleagues spent about 2 weeks in recording all the necessary network links to get the base data for a Batumi Street View in high quality. In the office our colleagues analysed the captured video material with a special software (Figure 1 **Error! Reference source not found.**). With the help of this technology it was possible analyse the network with fresh video data (in Google Street View the age of data is generally unknown) and to have a much better resolution to recognize all the detailed information in the video stream (Figure 2 **Error! Reference source not found.**, Figure 3 **Error! Reference source not found.**, Figure 3 **Error! Reference source not found.**)

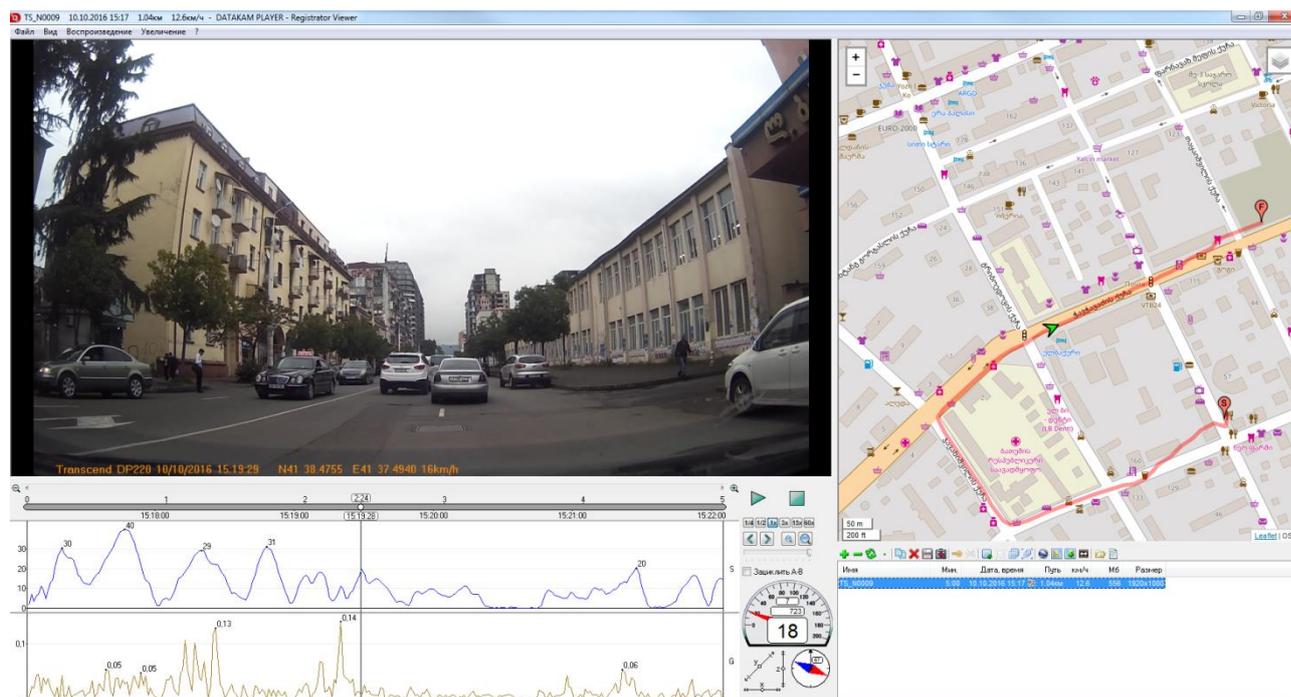


Figure 1 - Dashcam Video analyzing software used for street network review



Figure 2 - Maneuvers at the intersection

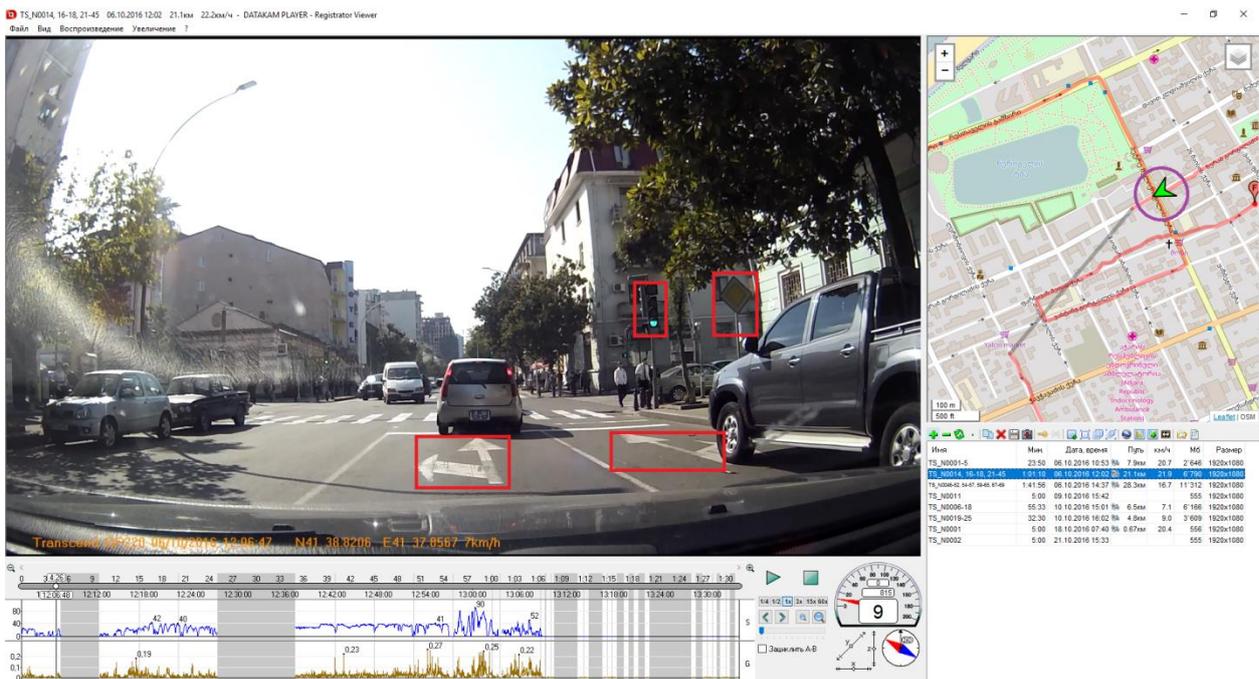


Figure 3 - Traffic light and maneuvers at the intersection

1.2 City Boundaries and administrative areas

The boundaries of the city (Figure 4) and the administrative-territorial division (Figure 5) were obtained from the Customer in *.shp format.

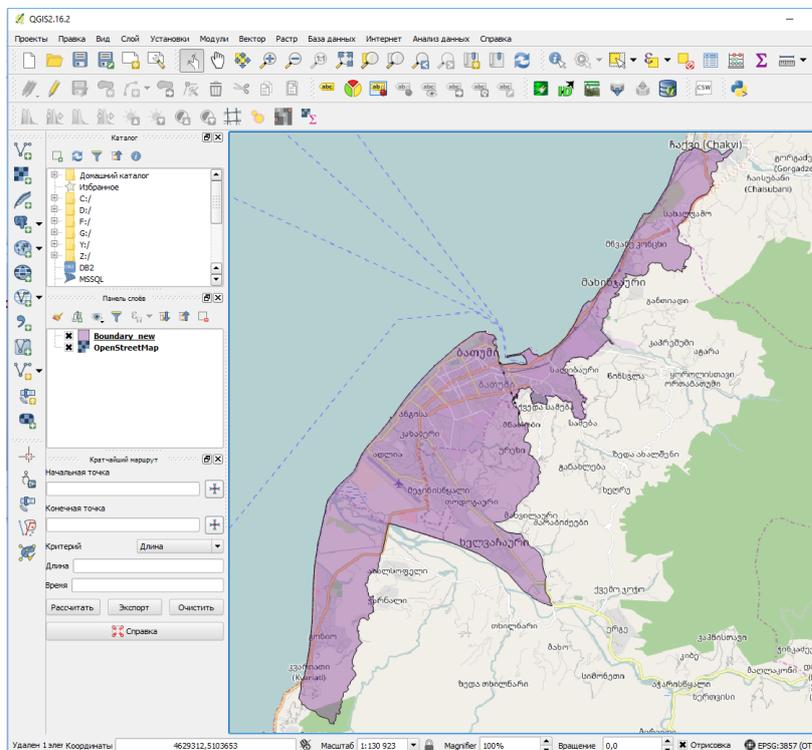


Figure 4 - The boundaries of the city

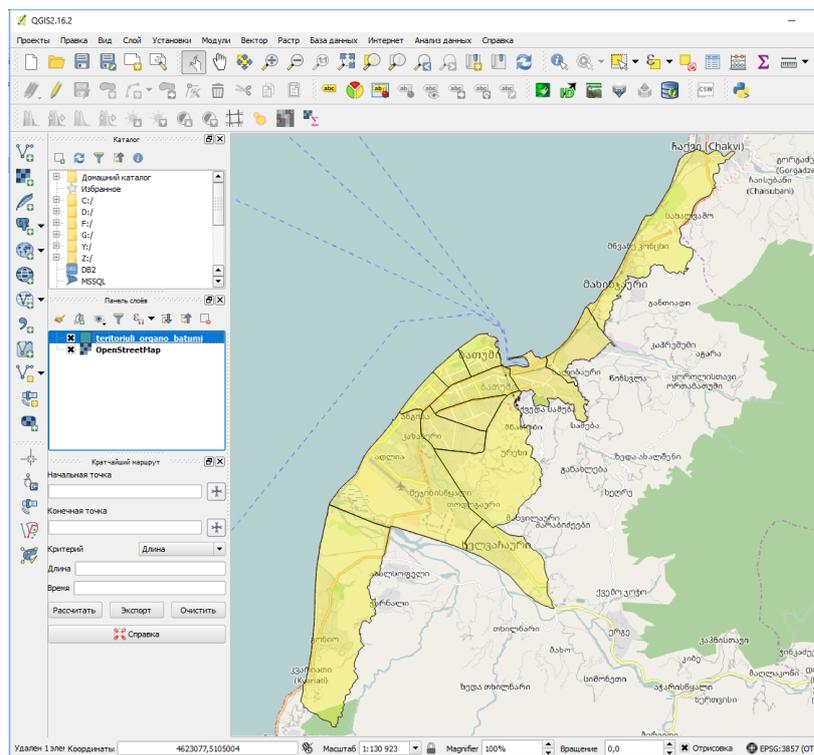


Figure 5 - Administrative-territorial division of the city Batumi

1.3 Data on Public transport network

Only available data on public transport network that could be provided by the client were pictures of public transport bus routes in the city. Unfortunately these pictures only show an excerpt of the whole network. Data was not available in an electronic form. In **Error! Reference source not found.** and **Error! Reference source not found.** the bus routes 10 and 15 are shown with cutting the northern part of the routes.



Figure 6 - Bus route №10



Figure 7 - Bus route №15

Schemes of Minibus network (Marshrutkis) were totally absent. No graphical representation of the data was available. Only lists of streets were available, where appropriated routes are allowed to operate. This was taken from the license description of the Marshrutka operators.

დანართი №21

„დამტკიცებულია“
თვითმმართველი ქალაქის - ბათუმის
საკრებულოს განკარგულება
2012 წლის 30 მარტი #73

სამარშრუტო ხაზი №30

მოდრობის სქემა:

გაფორმების ეკონომიკური ზონა „ბათუმი“ - აეროპორტი - ტბ.აბუსერიძის ქ. - ჭავჭავაძის ქ. - წერეთელის ქ. - ავტოსადგური - ს/ც „ბონი“

მოდრობის სქემა უკუ მიმართულებით:

ს/ც „ბონი“ - ავტოსადგური - წერეთელის ქ. - ჭავჭავაძის ქ. - ტბ.აბუსერიძის ქ. - აეროპორტი - გაფორმების ეკონომიკური ზონა „ბათუმი“.

- ინტერვალი - 10 წთ;

Figure 8 - Mini Bus route №30 description

Based on this data we modelled each mini bus route in the software. After validating the routes it was in some cases that the description could not fit the reality, as it went through one way streets in both directions. In this case we decided to adapt the route and change it to the most probable directions. We recommend to validate the Mini Bus network in a further step together with passenger counting and capturing the real GPS tracks of each of the Mini Bus routes.

There was also problem with getting data about public transport stops. In all public transport schemes the stops are not marked. On carrier's website are indicated only some stops (Figure 9) **Error! Reference source not found.**but in reality exist more.

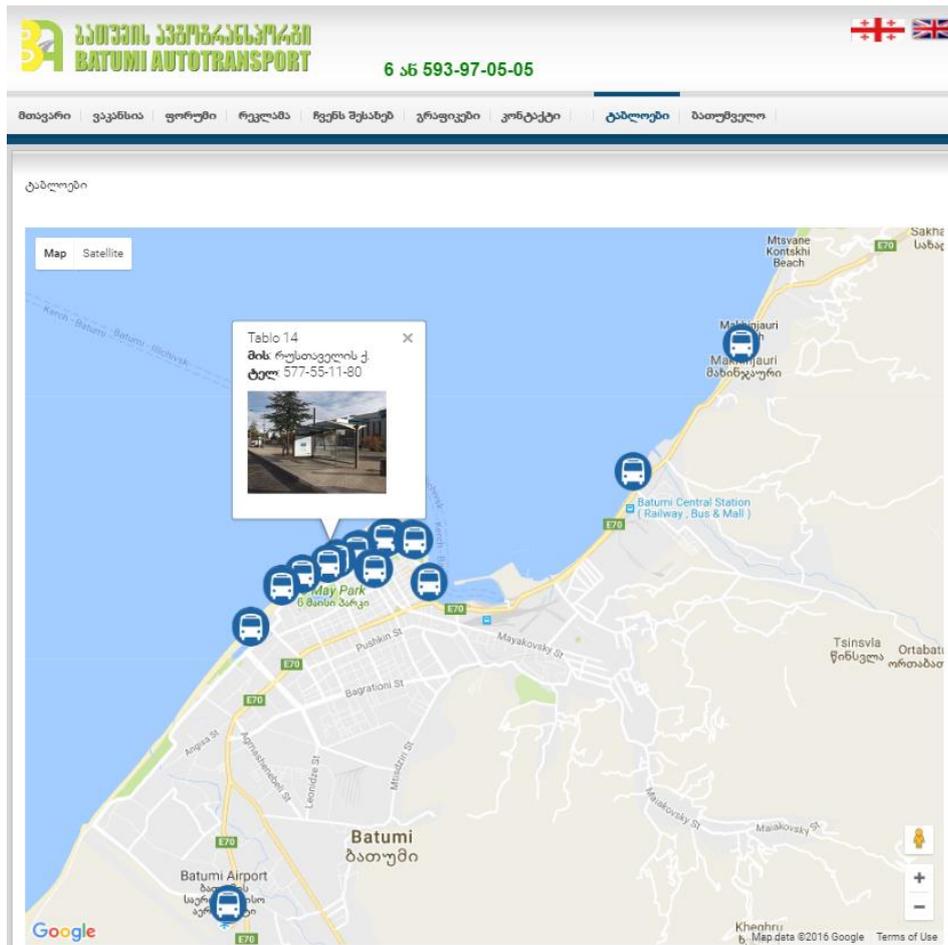


Figure 9 - Location of some of the stops on carrier's website

The customer provided locations of the stops in *shp format (Figure 10 **Error! Reference source not found.**). These data were obtained by the client by means of GPS Tracking. As shown in **Error! Reference source not found.** there were some deviations from the real positions.

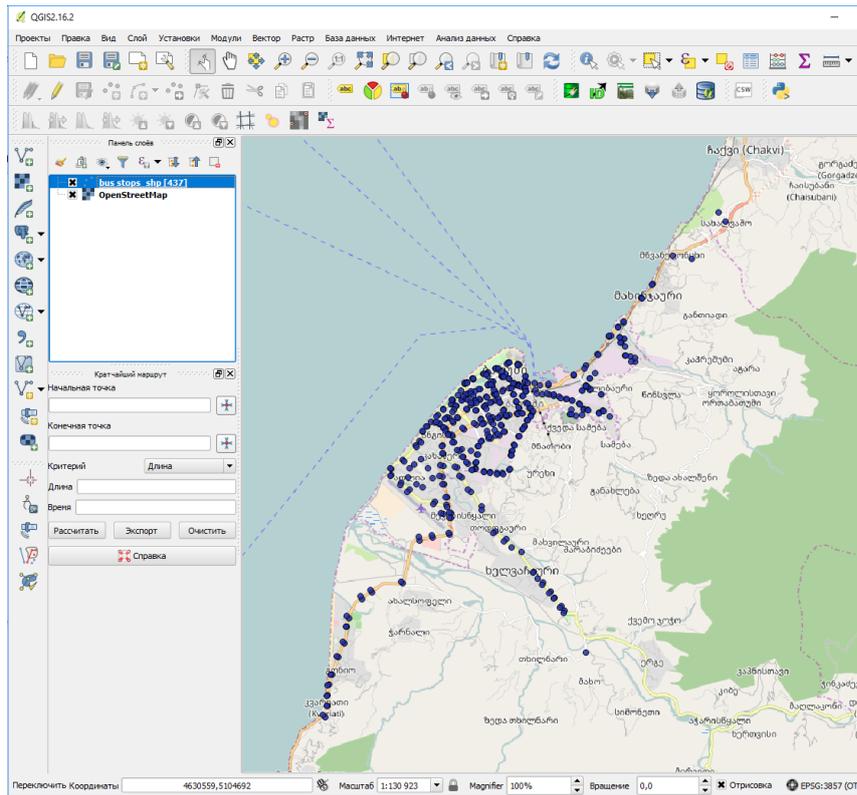


Figure 10 - Public Transport Stops locations received from the customer

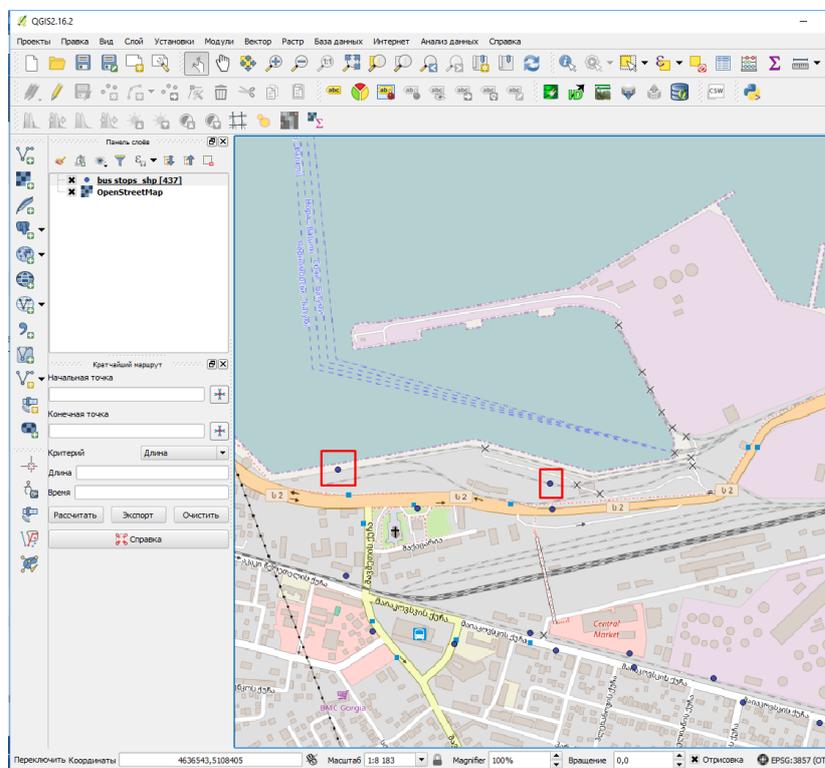


Figure 11 - Wrong location of some stops

To handle with these errors and to correct them we decided to conduct a survey by our own and to capture the routes of the public transport once more with all the stops. For this task we used the mobile application TransitWand (Figure 12 **Error! Reference source not found.**). As a result, we obtained the real routes (corrections for the already inserted routes were received) and location of public transport stops (Figure 13 **Error! Reference source not found.** and Figure 14 **Error! Reference source not found.**). The bus routes from the pictures that we received formerly did not show all the real situation. By means of the Transitwand Survey we could correct them and have now a conform image of the real situation.

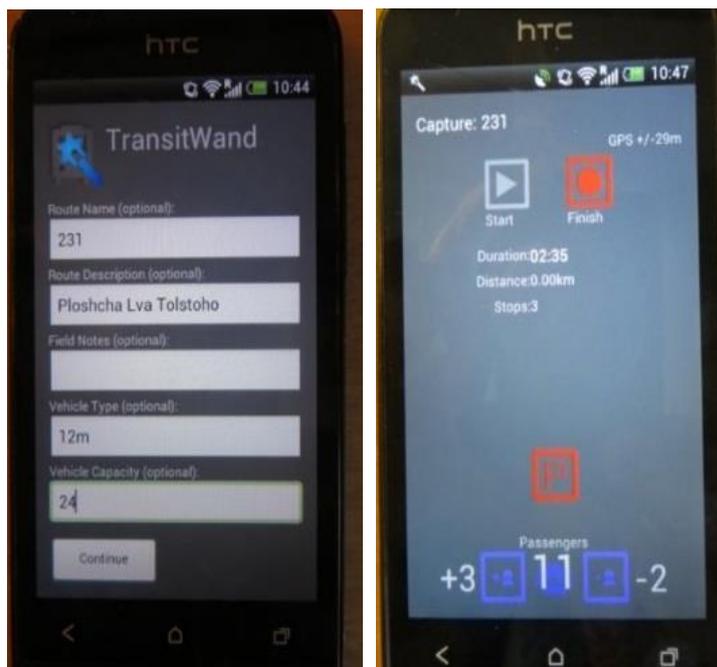


Figure 12 - Mobile applications TransitWand

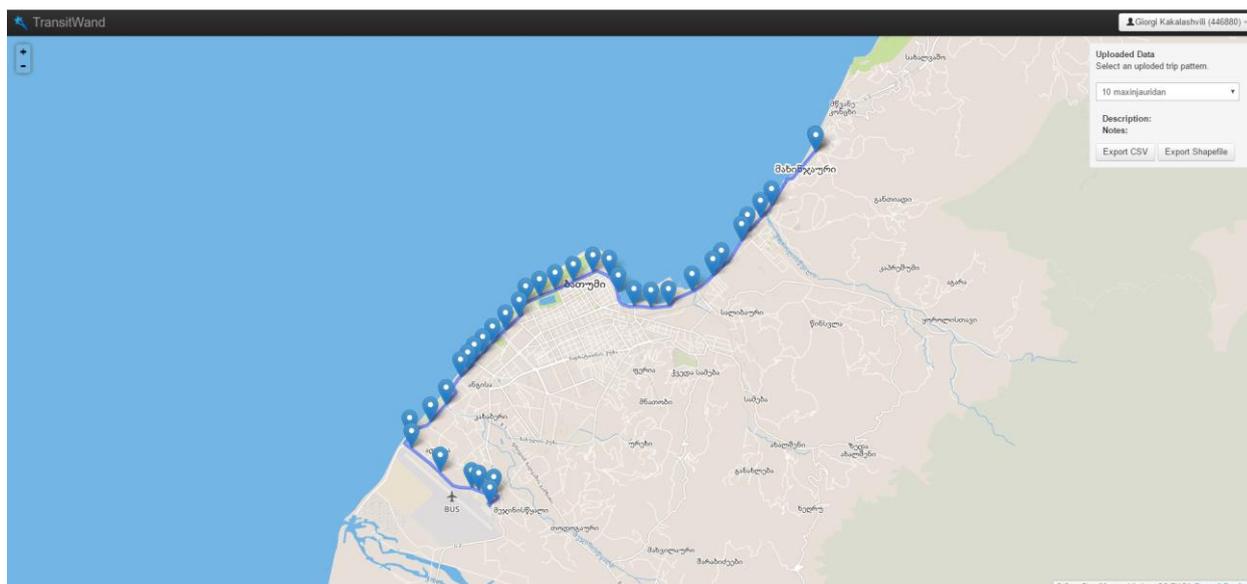


Figure 13 - Bus route №10 and location all stops in TransitWand

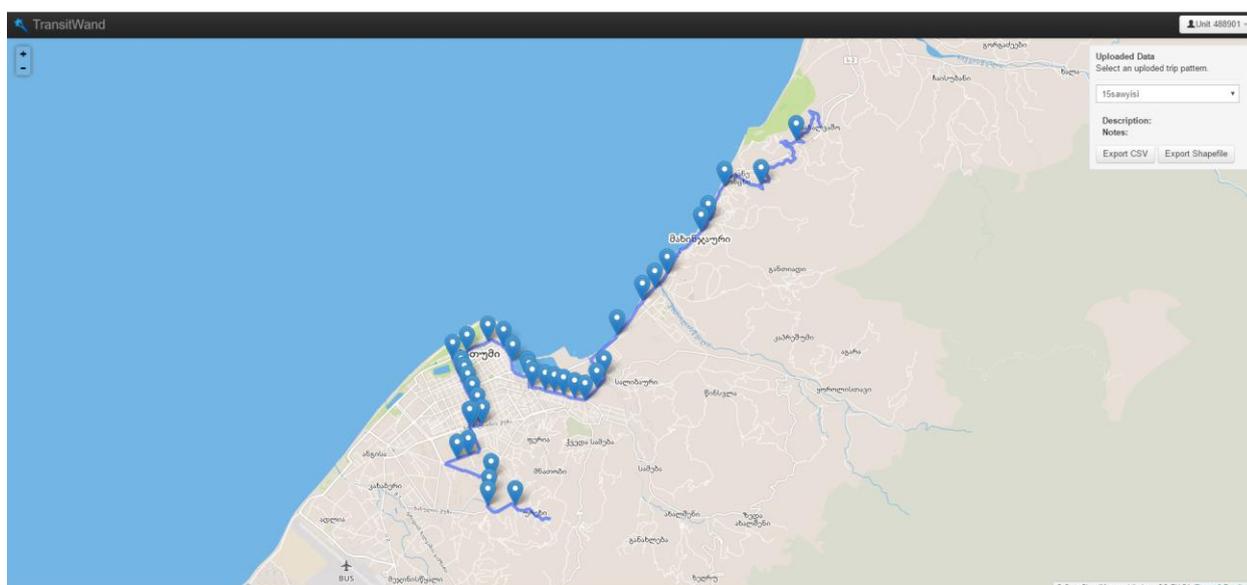


Figure 14 - Bus route №15 and location all stops in TransitWand

1.4 Socio-economic data of the transport zones

Transport modeling requires rich information on the socio-economic status of the study area. For each transportation zone this socio-economic statistics includes:

- Population
- Working-age population
- Number of kindergarten children, pupils and students that live in the transportation zones
- Number of places in the kindergartens, schools and universities

- Employment by the kind of economic activity

This data is structured as a statistics table, where each column represents a statistical item and every kind of economic activity is numbered with letters from A to Q. The structure of the table remains the same for different cities, so the data is managed in the way to fit this standard table. For this reason some zero-columns can exist: they represent the kinds of activity that is doesn't have their own type according to the Georgian standards.

The best practice is to obtain this data from the local authorities in the most disaggregated way possible. However, real-life cities often cannot provide all the information needed, in this cases estimation techniques are used. In the case of Batumi, city population and a part of educational statistics was provided, while employment data was not.

Population

Population data was obtained from the local authorities. It is disaggregated to the level of transportation zone, and also by age and sex that extends analytical capabilities of this data.

Working age population

This indicator was estimated using the official statistics for AR Adjara. A typical coefficient was applied for all the transportation zones of the city.

Number of kindergarten children, pupils and students that live in the transportation zones

Usually these categories are a proportion of population in the corresponding transport zone. We've got total numbers of these categories on the city level that allowed us to obtain the coefficients.

Number of places in the kindergartens, schools and universities

Numbers of places in the kindergartens and schools were provided by the local authorities; number of places in the universities was taken from their web-sites.

Employment by the kind of economic activity

To estimate it, we usually use available statistical information on the number of employed in the kinds of activity for the entire study area¹ and OpenStreetMap data² to obtain the distribution coefficients across

¹ Access at <http://www.geostat.ge/>

² Access at <http://www.openstreetmap.org/>

the transport zones. Unfortunately such statistics was not available, so the statistics of the AR Adjara was used and redistributed throughout the city and the rest of the region.

In general terms, the formula for calculation is as follows:

$$e_{ij} = k_{ij} E_j$$

Where:

- e_{ij} - the number of employees in the transport zone i , of economy sector j ;
- k_{ij} - The share of employment in the sector j transport zone i ;
- E_j - The total number of employees in the sector j .

Thus, the problem reduces to the estimation of distribution coefficients of employment in the transport zones. As we have to distribute regional-wide statistics, the part of Adjara outside Batumi is interpreted as an additional dummy transport zone.

The approach described here uses open information about the objects of employment and land use that are included in the OSM data in sufficient detail. This method is suitable for the most sectors of the economy, although there are exceptions to which the other methods are applicable.

The OSM data is being proceeded as follows:

1. **Downloading data layers.** Using the Quick OSM plugin for Quantum GIS, data from the map is downloaded as shape-files. Layers, needed for the respective coefficient estimation are listed in the Annex.
2. **Determining distribution coefficients.**
 - a. In case the layer is polygonal, we calculate the area of its features inside each transportation zone using QGIS. Then we calculate its proportion to the total area of the corresponding land use polygons. This percentage is the distribution coefficient of the employment in the corresponding economy sector.
 - b. If the working layer is a point layer, we count the number of points that fall into each transport zone. Then, this amount is divided by the total number of points, and this number is the distribution coefficient.

Some sectors of economy are not obviously distributed with the OSM data. For example columns K, N and O of the statistics table are strongly tied to the demand for their services, so we assume that the distribution of the number of employees in these economic activities is proportional to the population of the transportation zones.

The obtained data can be graphically represented as it is shown in the Figure 15 and Figure 16. **Error! Reference source not found.**

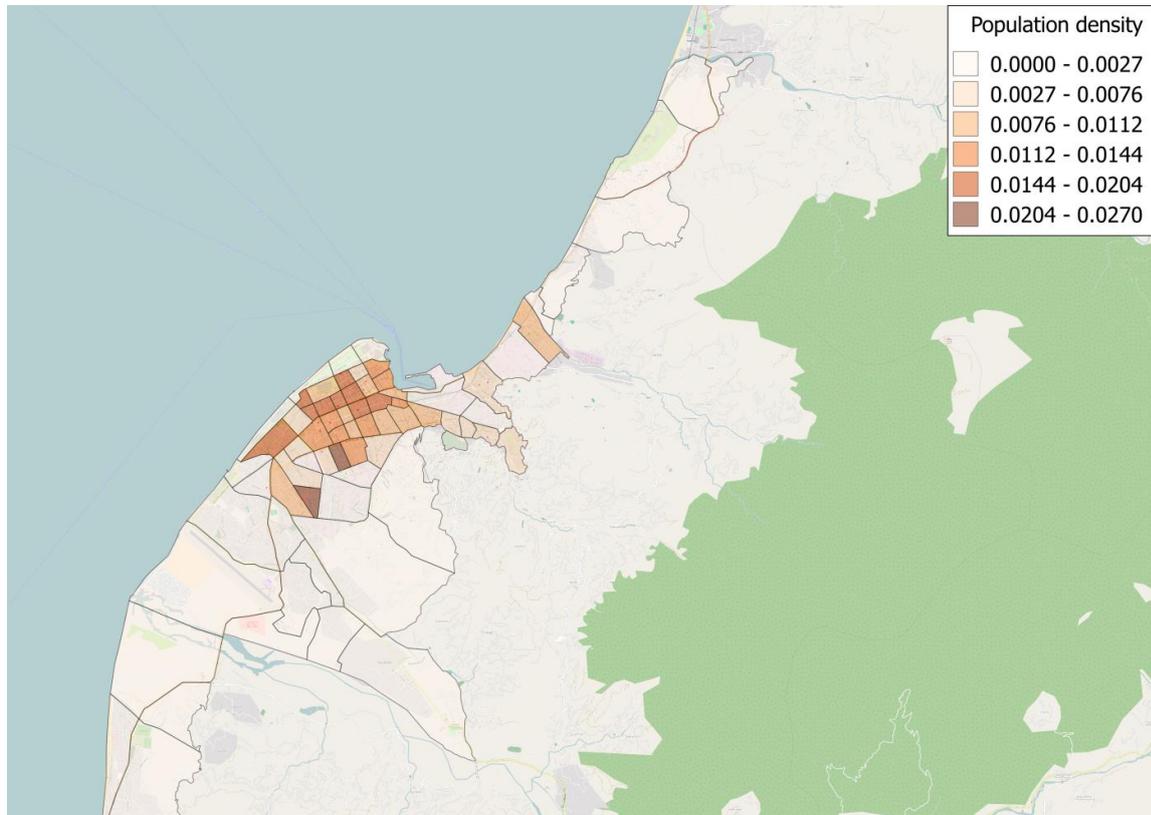


Figure 15 - Population density in Batumi

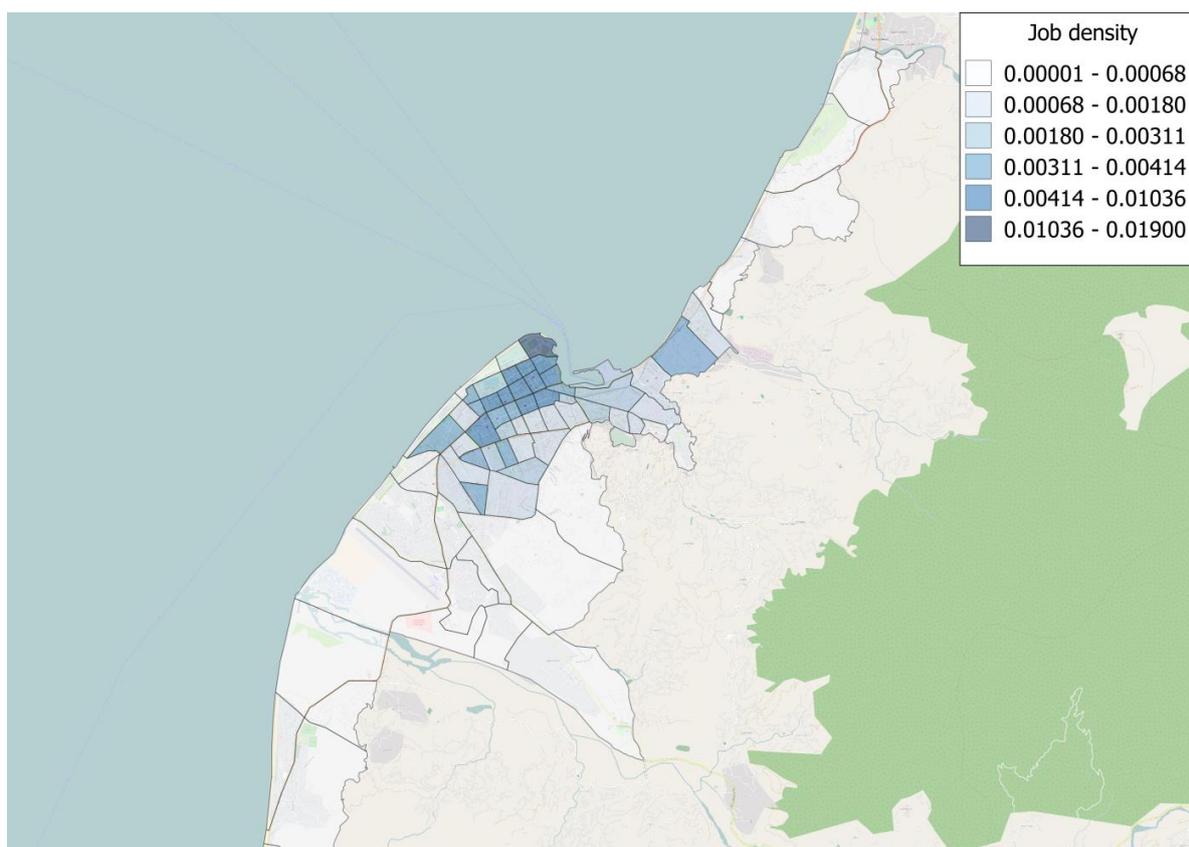


Figure 16 - Job density in Batumi

Table 1 - Example table of socio-economic statistics data on the current state

#	The name of transport zone	Population	Workplaces	Workplaces at the services sector	Working population	Preschool children	Pupils	Students	Places at the kindergartens	School places	University places
1.	1	17086	4885	4836	8182	584	1413	1417	584	1413	0
2.	2	18392	3106	3106	8808	628	1521	1526	628	1521	0
3.	3	33750	6088	6019	16162	1153	2790	2800	1153	2790	0
4.	4	5751	4194	3942	2754	196	475	10951	196	475	38000
5.	5	26068	3935	3928	12483	890	2155	2162	890	2155	0

Table 2 - Example table of socio-economic statistics data considering types of economic activity on the current state

#	The name of transport zone	Workplaces considering economic activities														
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1.	1	0	0	0	0	0	49	1885	102	0	601	1180	0	307	413	348
2.	2	0	0	0	0	0	0	567	0	0	120	1270	0	330	444	375
3.	3	0	0	0	9	0	60	1330	0	10	240	2331	0	606	815	688
4.	4	0	0	0	252	0	0	1261	307	291	240	397	0	1188	139	117
5.	5	0	0	0	0	0	7	207	51	0	240	1800	0	468	630	531

Explanation of workplaces considering economic activities codes classification:

- A – Agriculture, hunting and forestry;
- B – Fishing;
- C – Extractive industry;
- D – Manufacturing;
- E – Electricity, gas and water;
- F – Construction;
- G – Trade; repair of motor vehicles, household appliances and personal property;
- H – Hotels and restaurants;
- I – Transport and communications;
- J – Finance;
- K – Real estate, renting and business activities;
- L – Public administration;
- M – Education;
- N – Health care and social assistance;
- O – Public utility, personal services; activity in culture and sport.

Transport mobility - the mobility characteristic of the population. It is the average number of trips on each transport mode for one year per inhabitant. There are network transport mobility, taking into account the total number of trips from the starting point to the destination, regardless of the number of transfers and modes of transport, and routing transport mobility, which for the whole trip is taking a trip in the vehicle on one route, and the trip with one transfer is counted as two trips. The routing transport mobility it is easier to calculate (usually on the basis of sold tickets) and therefore it is used in the statistics usually.

Transport mobility depends on the territory size, population, planning and development of transport system. The growth of this value may be associated with the improvement of public transport, the growth of living standards and cultural level of the population, increase in population and the growth of the city, concentration of places of work and recreation.

1.5 Household mobility survey

Data collection on transport mobility of the population is based on household interviews of respondents distributed across the city in accordance with the principles of quota sampling in accordance with the spatial distribution of the population and its age and sex structure.

The survey was conducted on the basis of a specially designed questionnaire (to be found in Annex 1). Each data collector was carry with him an introductory letter presenting to the households the objectives of the surveys. The survey was performed at the domicile of the surveyed household. Every member of the household, aged 5 years or more, were interviewed. All the trips performed by each person the day before the interview will be recorded. All transportation mode (including non-motorized mode like bicycle and walking) are taken into account. The trips recorded are the one of Monday to Friday, and therefore the day of survey lay from Tuesday to Saturday.

1.5.1 Methodology of the Mobility Survey

The activities on household mobility survey started with the preparation of the questionnaire. The questionnaire is divided in three main parts, called cards. Each card intends to collect data about on respectively household, persons of the household and trips.

The two first cards (household and person characteristics) results are collected from the interview of the head of the household. The last card, relating to trip characteristics performed the day before the interviews, are collected from the interview of each household member.

The used questionnaire can be found in the Annexes.

Our good local contacts and knowledge allowed us to find about 50 interviewers for undertaking the household interviews. They were all trained by our local survey experts in a 5 day training from 3.10. till the 7.10.

The training presented the general framework of the survey, its objective, its functions and organization. The main definitions relating to zoning, household and trips were provided. The Trainer then went through the questionnaire. Examples were then examined and exercises were carried out.



Figure 17 - Interviewers Training

The field work was done within the following 3 weeks till the 30.10. data collectors visited more than 2.000 households to get finally about 1.550 filled questionnaires Based on data collector’s reports, the status of the various attempts to perform survey In average was 77% of the attempts were successful.

During the time of field work, already finished questionnaires were analyzed and digitized by our colleagues. The following logical analysis filtered the dataset in terms of incorrect or impossible answers and combination of answers. As a result, an aggregated database was compiled with the complete survey data in a format for further finalization and calculation of transport model coefficients.



Figure 18 - Mobility interview

1.5.2 Mobility Survey results

Mobility survey was performed with the goal to get the basic parameters to describe the mobility behavior in the transport model. So the analysis was focused exclusively on getting this base parameters.

For the transport model the following five coefficients and parameters were calculated from the survey database:

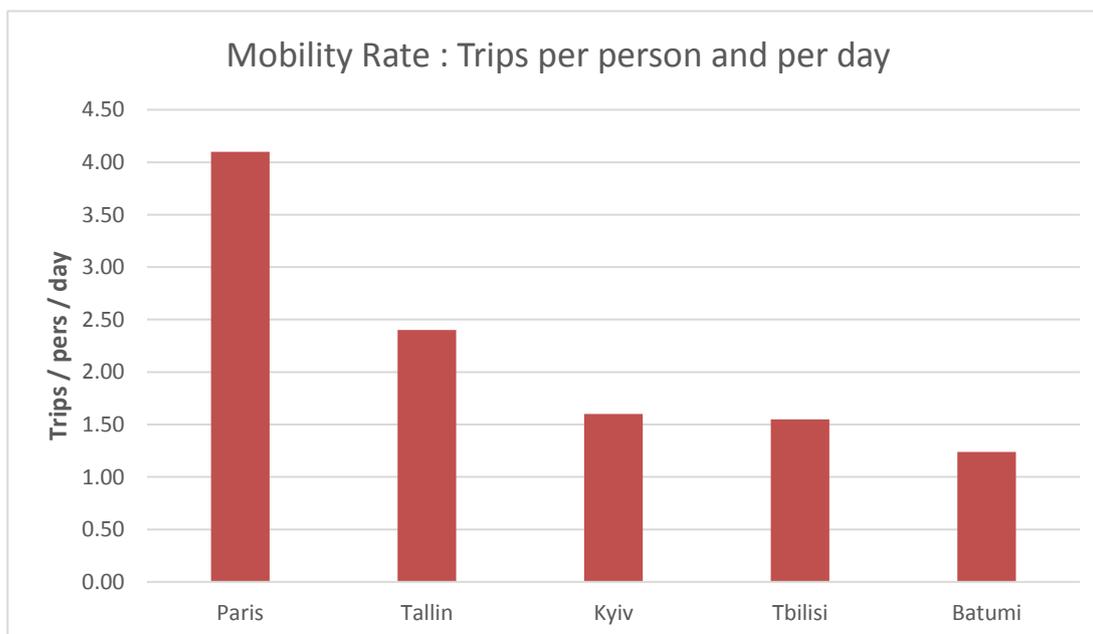
- Mobility Rate
- Car Ownership Ratio
- Car Usage Ratio
- Car Occupancy Rate
- Modal Split
- **Mobility rate.** This indicator represents an average quantity of trips per day by each citizen of the study area. It is very important to understand how people move across the study area. Also, this indicator indirectly refers to the city welfare and transportation system convenience: in case of low mobility rate, people try to avoid extra trips, performing only the obliged ones (to the job or study and back home) and refusing themselves to have some extracurricular activities or leisure. For example, mobility rates across the world are:
 - **Tbilisi – 1.55**
 - **Kyiv – 1.6**
 - **Tallinn – 2.4**
 - **Paris – 4.1**
- **Car ownership ratio.** This indicator shows how much cars is owned per 1000 city citizens. Low car ownership is typical for the cities with low welfare, high population and job densities and/or with public transport oriented city policy. On the contrary high car ownership is typical for the cities with richer citizens, large suburbia and low-quality public transport, as well as uncontrolled parking in the downtown area. For reference, car ownership rates across the world are:
 - **Hong Kong – 59/1000;**
 - **Istanbul – 139/1000;**
 - **Kyiv – 213/1000;**
 - **Moscow – 297/1000;**
 - **Berlin – 317/1000;**
 - **Sao Paulo – 368/1000;**
- **Car usage ratio.** Car usage ratio is an indicator strongly dependent on the city transportation policy. It is a probability to perform a trip using a car for the person who actually has it. Even though city citizens can be reach enough to have one car or more, if the city policy is oriented on car usage cost internalization, i.e the city makes car owners pay for all the consequences of the car usage such as traffic jams and land use for parking; if it provides efficient public transport, people don't use cars to travel to the downtown. For example:
 - **Typical for German cities – 0.6 – 0.7**
 - **Kyiv – 0.88**

- **Car occupancy rate.** This indicator shows is, how much people travel inside the car in average. It is very important for the transportation planner to be able to covert car traffic into number of people performing the trips. For reference:
 - **Perth – 1.2**
 - **Berlin – 1.3**
 - **Kyiv – 1.5**
- **Modal split.** As a consequence of city transportation policy, quality of infrastructure, people tend to chose the mode they use to perform trips. This is called modal split. This indicator is a percentage of trips using each mode, such as:
 - **Public transport**
 - **Private transport**
 - **Pedestrian movement**
 - **Bicycle**
 - **Taxi**
 - **Shared ride (park and ride, kiss and ride)**

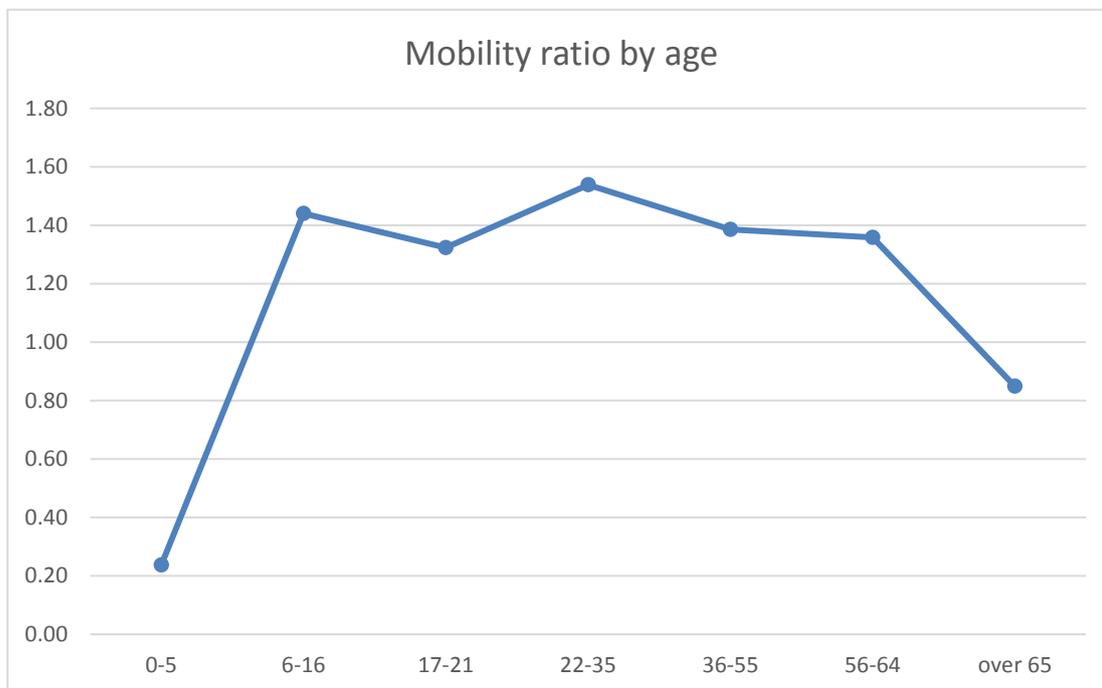
The best practice for modal split is generally adopted as 70% of public transport and pedestrian movements versus 30% for private transport.

The database includes some more data which are additional asked for but are actually not necessary for the transport modelling process.

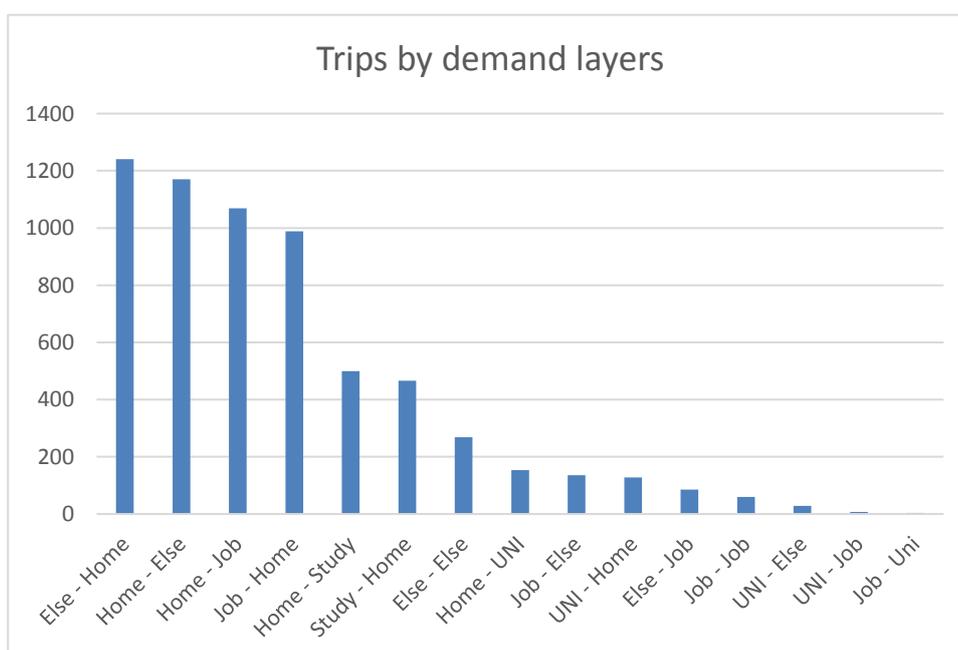
In Batumi, the mobility rate, defined as the **average number of trips per person and per day, is 1.24 trip / day / person**. In comparison to other cities, it is a low value. As an example, the mobility rate stands at 1.55 in Tbilisi and 2.4 in Tallinn. In developed economies it is usually higher than 3.5 (3.75 in the United States and 4.1 in Paris).



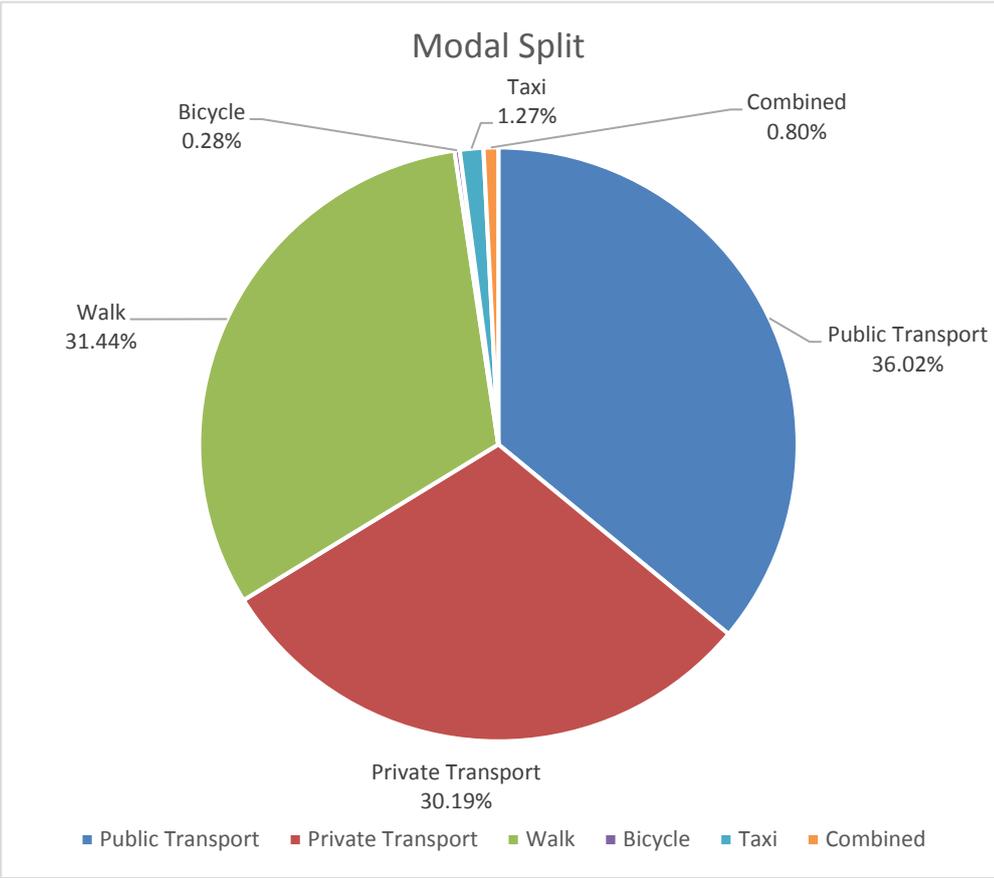
The most mobile population segment is 22-35. In addition, the segments 6-16 and 17-21 vary only a little from that value. This means that the mobility rate is expected to be stable in the close future unless city policies are changed.



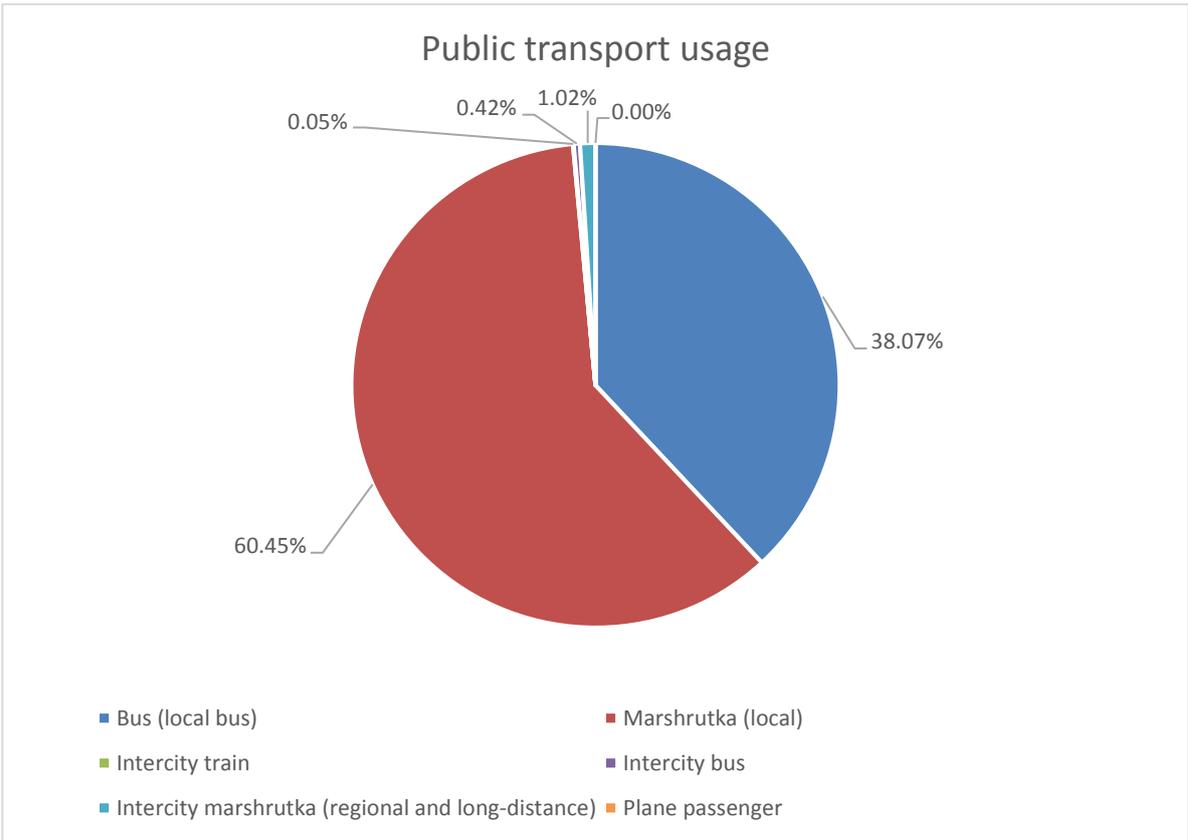
Most of the trips are "Else - Home"/"Home - Else", then "Home - Job" and "Job - Home" come. In case we had high mobility rate it could have been a sign of high leisure mobility. However, according to the HHS this ratio is very low, that means that people are trying to avoid extra trips. Together this means that in the case of Batumi trips "Else - Home"/"Home - Else" are obliged. Although people do not name their trip purpose "job", it is very likely to be some kind of shadow business or employment.



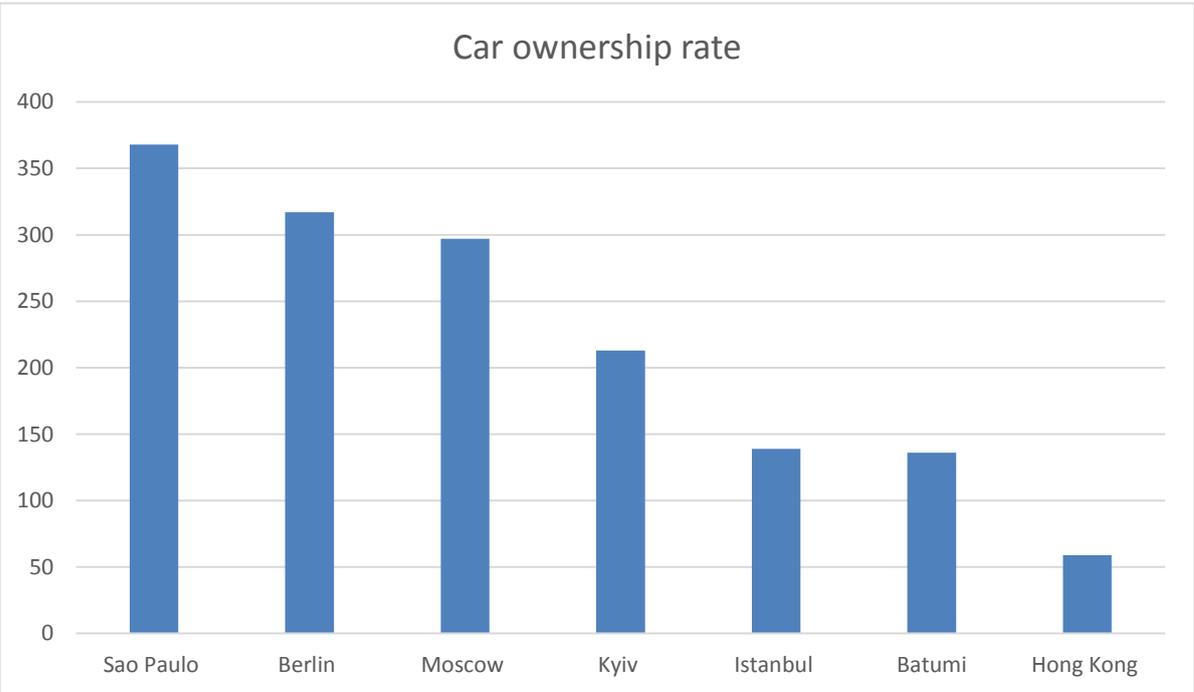
The market share of private car is approximately 30%. This modal split is very close to the best practices, although Batumi features very low share of bicycle. Low bicycle modal shares are usually explained by the lack of infrastructure, but it is not the case. This phenomenon of low bicycle usage in the city with flat terrain and extensive infrastructure needs further study. Across all the modes public transport remain the main mode, with 36% of trips, and walk is the second with a modal share of 31%.



Batumi has 2 city transportation systems: buses and minibuses (marshrutkas). The main transportation system is marshrutka that has 60% of the market. Buses take carry only 38% of the public transport trips.



Car ownership in Batumi is 136 per 1000 capita. This value is very close to the one of Istanbul city.



Car usage rate in Batumi is modest and is about 68%. This value is much smaller than that is now in Kyiv (88%), and is close to the typical car usage rate in Germany. However, German researchers consider this value as unpleasant and look for the ways to reduce it in order to make cities more livable.

2 DESCRIPTION OF TRANSPORT MODEL DEVELOPMENT

2.1 Software used for the task

Batumi transport model was developed using the modern transport planning software PTV Vision® VISUM.

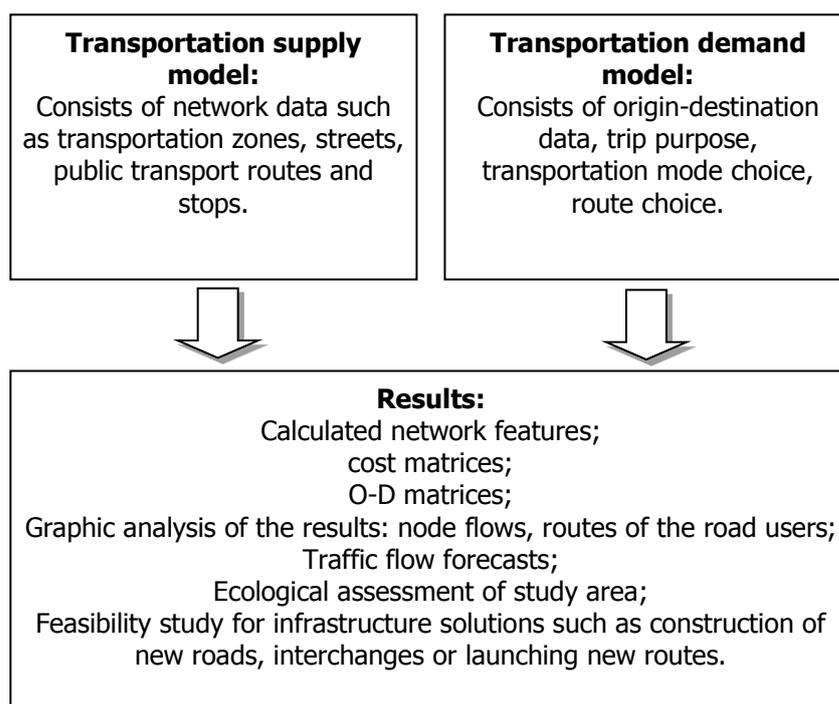
PTV Vision® is an industrial standard of transport planning in 75 countries. It is mostly applied for transportation planning of cities and regions, public transport optimization, feasibility studies, traffic volume forecasting. Over 2000 organizations in the USA, UK, Germany, Netherlands and other countries across Europe and Asia use PTV Vision® VISUM.

PTV Vision® VISUM is a modern analytic system that is used to support urban solutions, develop strategic and operational planning, forecast traffic volumes, estimate the feasibility of investment, store and visualize transportation data. The software integrates all participants of traffic (cars, pedestrians, public transport passengers, trucks, buses, trams, trolleybuses, cyclists etc.) into a single model. It also integrates GIS data and transport supply data into a joint multi-level database.

The main feature of PTV Vision® VISUM development is its connection to the fundamental R&D (the software is developed in USA, Germany and Japan) and, consequently, a wide pool of transportation modelling research is available for PTV Vision® VISUM developers that allows them improve the algorithms and widen system's capabilities.

Transport Model Development Methodology

Traffic flow modelling consists of two basic models – transportation supply and demand models.



The transport supply model is a transportation network consisting of nodes (crossings and interchanges), links connecting them (streets, highways) that makes trips available for system users and describes travel cost. Also, the supply model features public transport routes and stops.

The demand model describes the quantity and quality of trips including reasons of traffic generation destination choice, mode choice and route assignment.

The basic concept and the aim of transport model is traffic flow estimation on the network. Transport model allows creating high quality forecasts of urban and transportation solution subject to different factors and constraints that influence socio-economic development of the region or its transport situation.

3 Transport Supply Model

3.1 Structural data of the transport network

The street network, shown in Figure 19 was built on the base of geographical data and manual investigations. To bring the data to the right format and to reduce the data to a sufficient level it was necessary to spend additional work on data preparation:

- Merging of unconnected links in the street network graph
- Splitting of undivided network links
- Selection of main network for analysis
- Input of allowed turns on intersections for the different types of transport

The network links attributes were checked and adjusted where necessary: length of the link, maximum speed allowed, maximum capacity (veh/hour), number of lanes, street category.

The digitization of the street network was done for the following network objects:

- **Link** – object of the model which represents a transport supply. Links describe roads and railways of the transport network. They connect nodes, which means intersections in private transport or stop points in public transport. A link is represented as a directed element and is described by the From Node number and To Node number. The link attributes contain a number of parameters like length, number of lanes, maximum allowed speed and capacity as well as the transport systems, that are allowed to use the link.
- **Node** - object of the model which represents a transport supply. A node determines the locations of street junctions. They are starting and terminating elements of links, where there are turning relations from one link to another in private or public transport systems. A node is characterized by parameters like allowed/forbidden turns, existence of signal and organization of traffic flow (main street, etc.)

In the given developed transport model the categories of street links are more detailed, divided in sub categories.

The criteria for dividing the links in sub categories are the allowed maximum speed, capacity and the number of lanes in each direction.

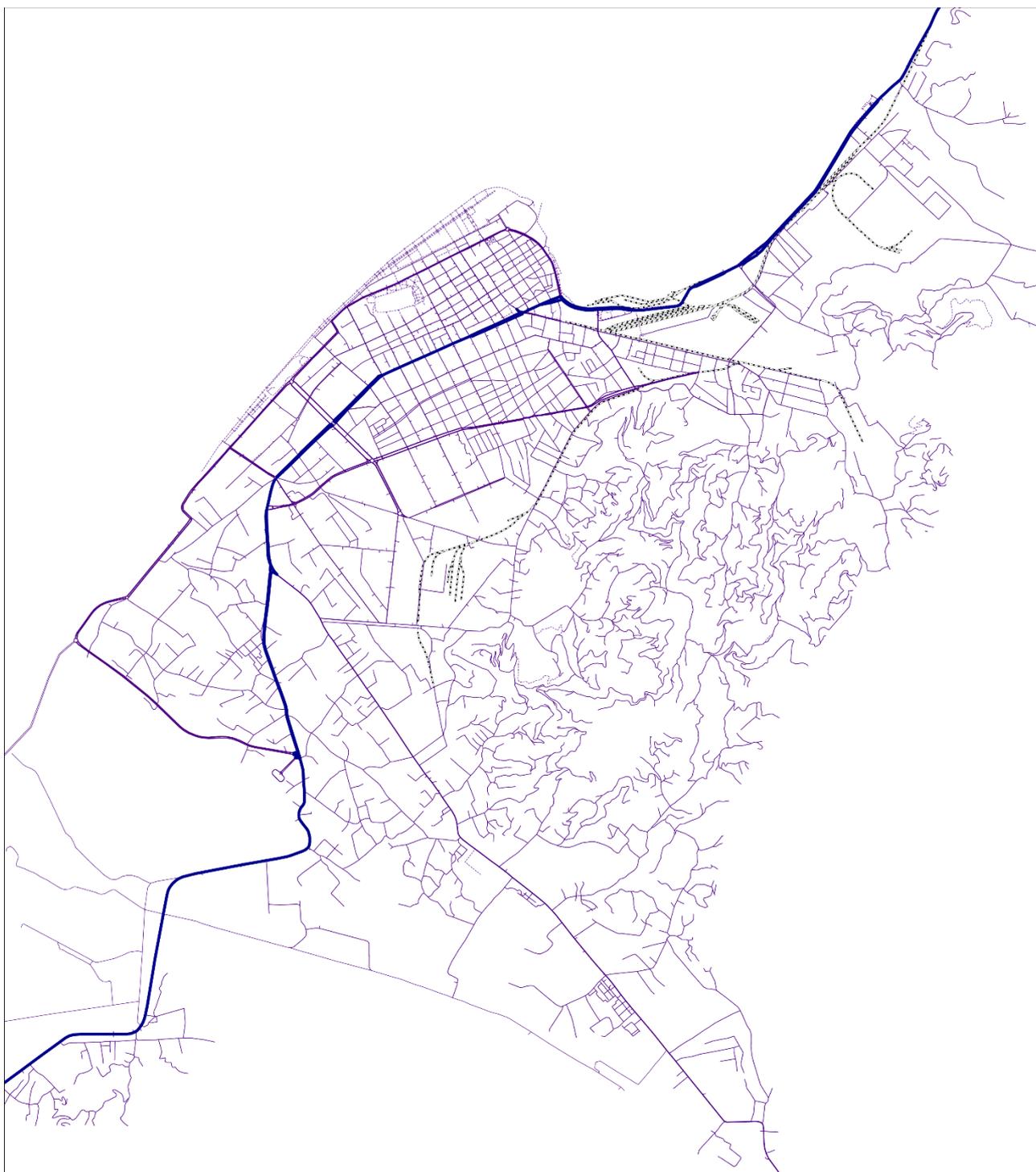


Figure 19 – Transport Network exported from the planning software PTV Vision® VISUM

The street transport network is represented as a directed graph with the following geometric and technical parameters:

- Geometry of the street network (position in space and configuration of graphical representation)

- Geographical position of intersections and junctions in form of points
- Configuration of slip roads
- Length of street network elements
- Category of streets
- Number of lanes in each direction
- Calculated and maximum allowed speed for each link
- Capacity of links in each direction
- Forbidden movements in the street network
- Allowed movements and turns on intersection and junctions
- Street rank

Characteristics of traffic organization

In the developed transport model traffic organization is described in detail on every link – existence of one-way direction, turn restrictions for different vehicle types, organization of traffic on intersections. For every junction which is part of the street network graph – that means it is a node in the network – the following parameters were established:

- Turn restrictions
- Capacity in every turn direction under consideration of number of lanes
- Accessible transport types

In the below picture the elements of the networks graph are shown with some parameters regarding traffic organization.

On Figure 20 link attributes are presented. In this case a one-way link restricted to private transport.

On Figure 21 node attributes are presented. In the picture the red marked arrow indicates allowed turn manoeuvre for the appropriated transport type and the dotted arrow indicates forbidden turn for all transport types.

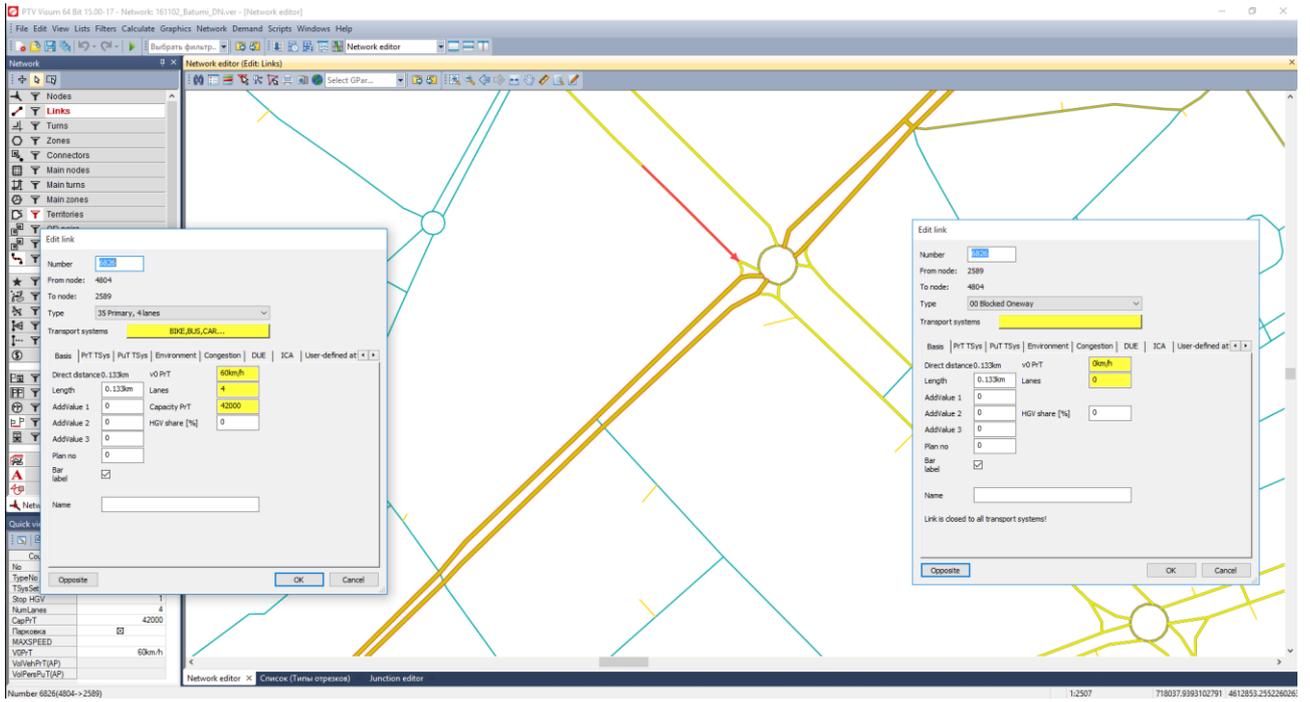


Figure 20 - Link attributes

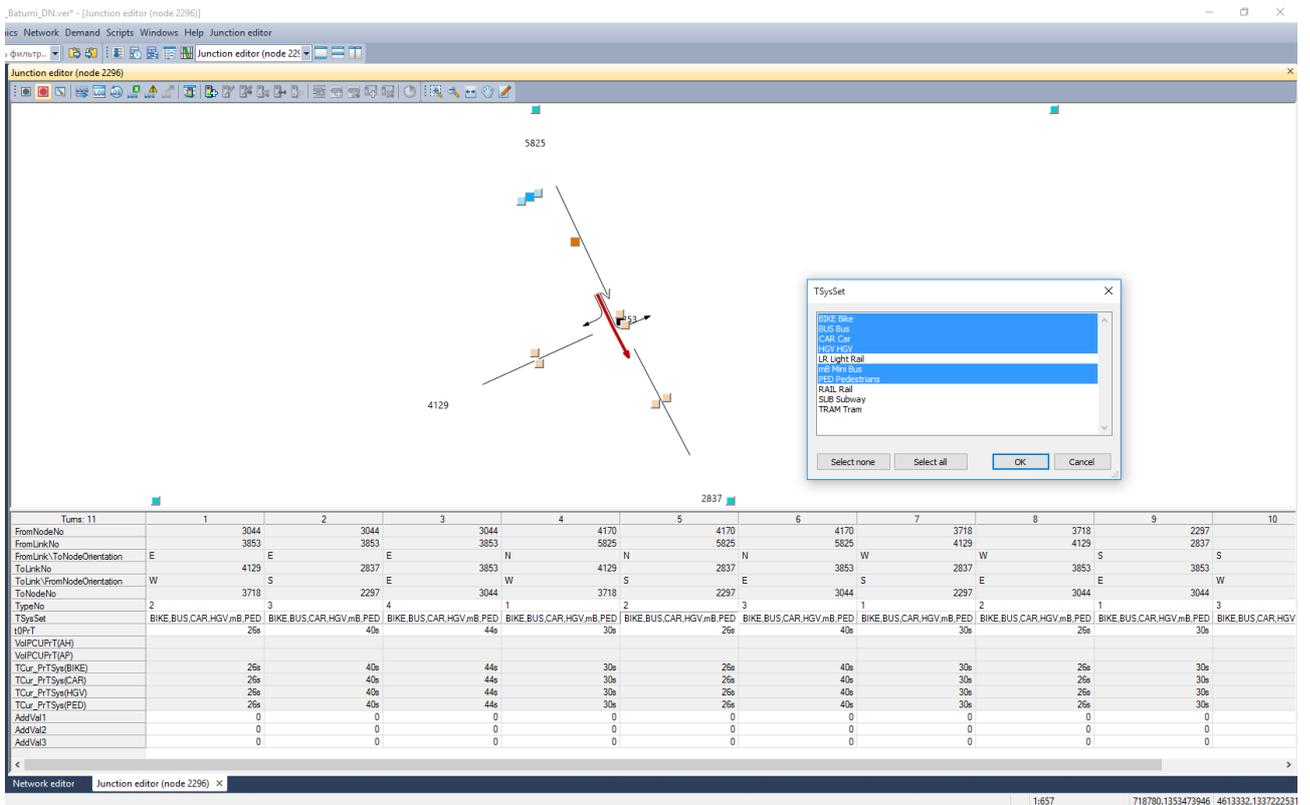


Figure 21 - Node attributes

In the transport model on every intersection/junction the following parameters are considered:

- Mode of traffic regulation (signalized, not signalized)
- Base delay when crossing the intersection or when turning
- Capacity of the intersection or turn

3.2 Transport System and Demand Segments

To describe the structure and composition of traffic flow, which makes up transport load on the network, in the model were introduced data about the transport types. The transport types realizes the traffic in the network. In the model the different types of transport are represented by different transport systems. Every transport system is related to one or more demand segments. Demand segments describe trips with one or several transport systems for different user groups which are related to demand matrices. Users of one demand segment of public transport can change their transport system during the journey in case of a e.g. transfer (bus to tram, metro to bus, etc.) Every demand segment is related to exactly one demand matrix. Figure 22 shows an example of the relationships between transport systems, transport modes and demand segments in the model. The list of transport systems and the demand segments used in the model is shown in Table 3.

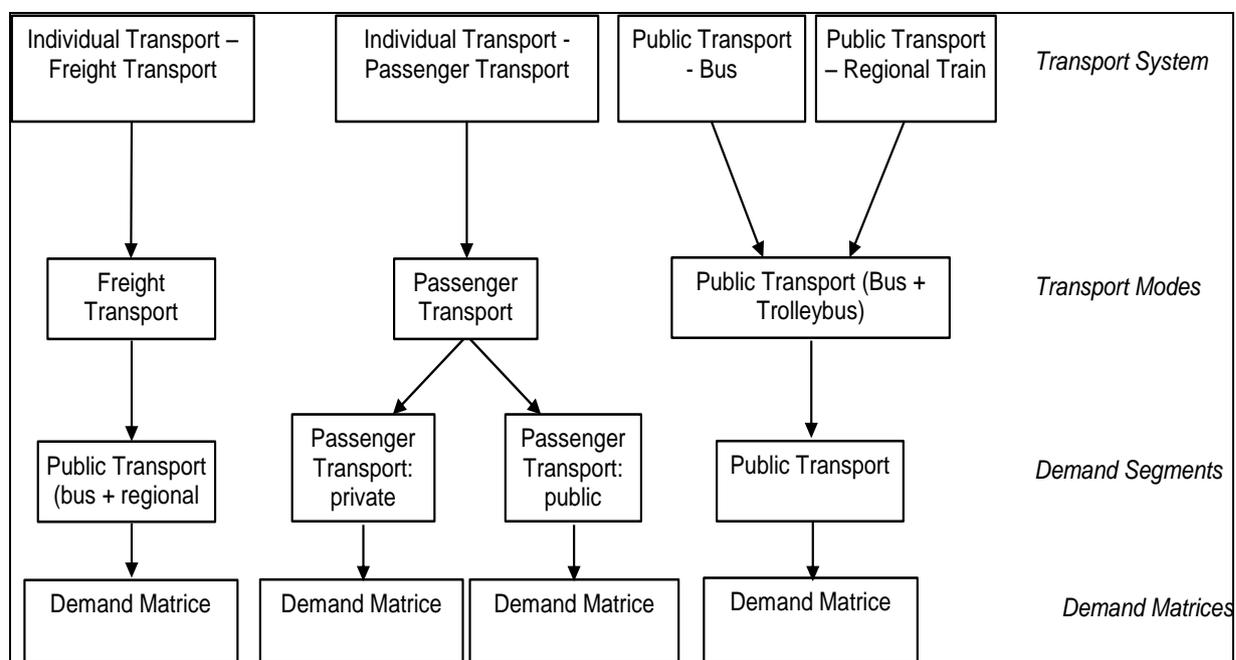


Figure 22 - Example of connections between transport systems, modes, damend segments and demand matrices

Table 3 - Systems of transport and demand layers in the model

Code	System of transport	Increase coefficient	Demand segment
B	Bus	-	Public Transport (PuT)
mB	Minibus	-	
RB	Regional Bus	-	
C	Car	1,0	Private Transport (PrT) (C)
HGV	Truck	1,5	Truck (HGV)
PR	PuT Transfers	-	Interchanging passengers (PR)

3.3 Data of regional development of the research zone. Transport Zones

The structure of regional development of the research zone is described with the help of the following data:

- Transport zones: borders of transport regions; location of gravity centres of the transport zones
- Data of socio-economic statistics of the transport regions: number of inhabitants (in cities and rural parts); number of workers; number of students, etc.

Transport zones – base object of spatial structure of the planning region. Most optimal zoning is made on base of functional indication (e.g. on base of functional zones regarding city’s Master Plan). In the case of lack of data for zones on base of functional indication it is possible to undertake zoning on base of administrative-territorial division. The transport zones are the objects and centres in the model where traffic is generated and traffic is attracted. In the model it is described with the help of centroids (attraction centre).

Transport zones are the origins and destinations of movements (demand). This means that each trip starts in a zone and ends in another zone. Zones connect the transport supply (network model with nodes, links, Public Transport lines, etc.) and the travel demand (in form of demand matrices), which contain the demand (trips) of all Origin-Destination pairs of the model.

The modelling region was determined on base of the client’s task description and the consultant’s experience under the consideration and requirement of a maximum of possibilities of passenger trips (business, work, recreation, transit) on different types of transport. The borders of the transport regions where agreed with the Client. In the model where defined 2 types of transport zones:

- **Common transport zones** – zoned which are located in the planning region. A map with the zones is shown in Figure 23.
- **Cordon transport zones** – transport zones which generate/receive transit traffic related to the modelling region. The cordon transport zones are shown in Figure 24.

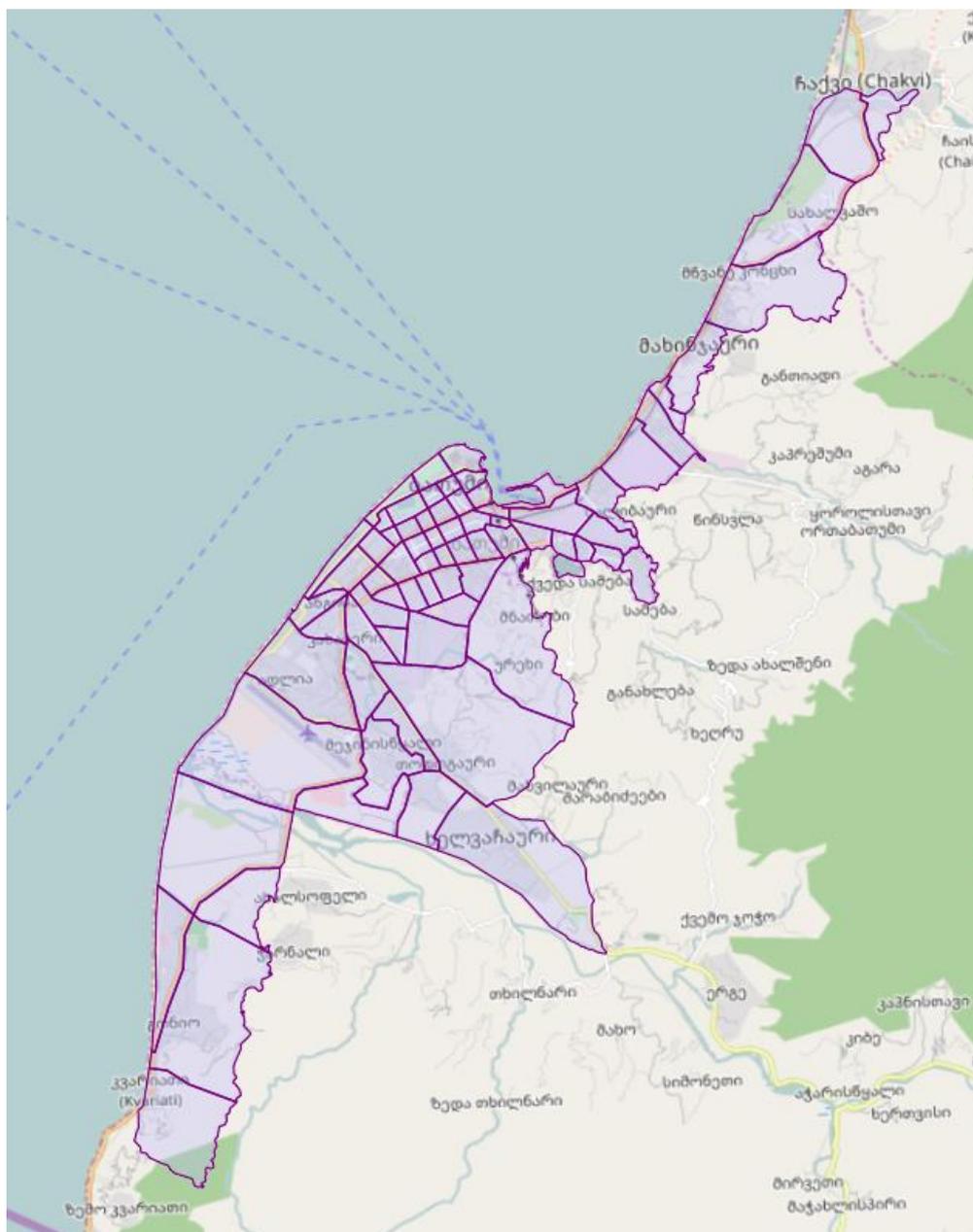


Figure 23 - Transport zones for Batumi

The location of cordon transport zones was made by determining the most densed outer city magistral (related to the modelling region). Cordon transport zones generate/receive traffic flow which forms an additional transport load on the modelling region, but they are located outside of the modelling region.

The attributes of the transport zones contain data about the amount of traffic flow for type of transport. The modelling of the generated and received traffic flow considers the following information:

1. Percentage of transit traffic in the flow per region – relation of number of transit trips to the number of all trips

The transport network which is used in the model is characterized by the following parameters:

- 4509 nodes;
- 10980 links;
- 75 transport zones and 3 cordon transport zones.

3.4 Data on the public transport network

The Customer provides all public transport network data.

3.4.1 Public transport routes

The model takes into account the following number of routes in different systems of transportation:

1. Bus – 16 routes;
2. Minibus (marshrutka) - 29 routes.

Each route features the following information:

- Route geometry
- Route name
- Route length
- Stops (including the stop dwelling time) along each route
- Headways

One of the public transport routes is graphically illustrated on Figure 25.

The transport model takes into account public transport routes, as listed in Table 4:

Table 4 - List of public transport routes

Name of Route	Route length, km	Headway, min.
Busses		
1	9.6	9
1s	19.9	9
2	13.5	17
3	14.2	7
4	9,7	10
7	10,85	13
7s	11,34	13
8	12,4	13
9	11,1	16
10	15.7	16
11	10,65	11
12	13,4	12
13	16,1	17
15	20,3	28
16	19,1	24
17	25,5	24
Minibusses (marshrutka)		
21	11.1	10
22	5.5	15
24	8.2	10
25	7.2	10
25s	7.3	10
26	6.2	10
28	10.1	7
29	7.3	10
30	8.6	10
32	8.2	10
33	16.9	15
34	8.95	10
35	9.5	10
36	9.1	10
37	4.2	15
39	6.4	7
40	9.0	10
42	7.2	5
44	6.1	10
45	9.2	10
46	9.1	10
47	5.3	10
48	7.2	15
49	4.3	15
51	3.5	15
52	7.6	10
55	8.9	10
56	5.8	15

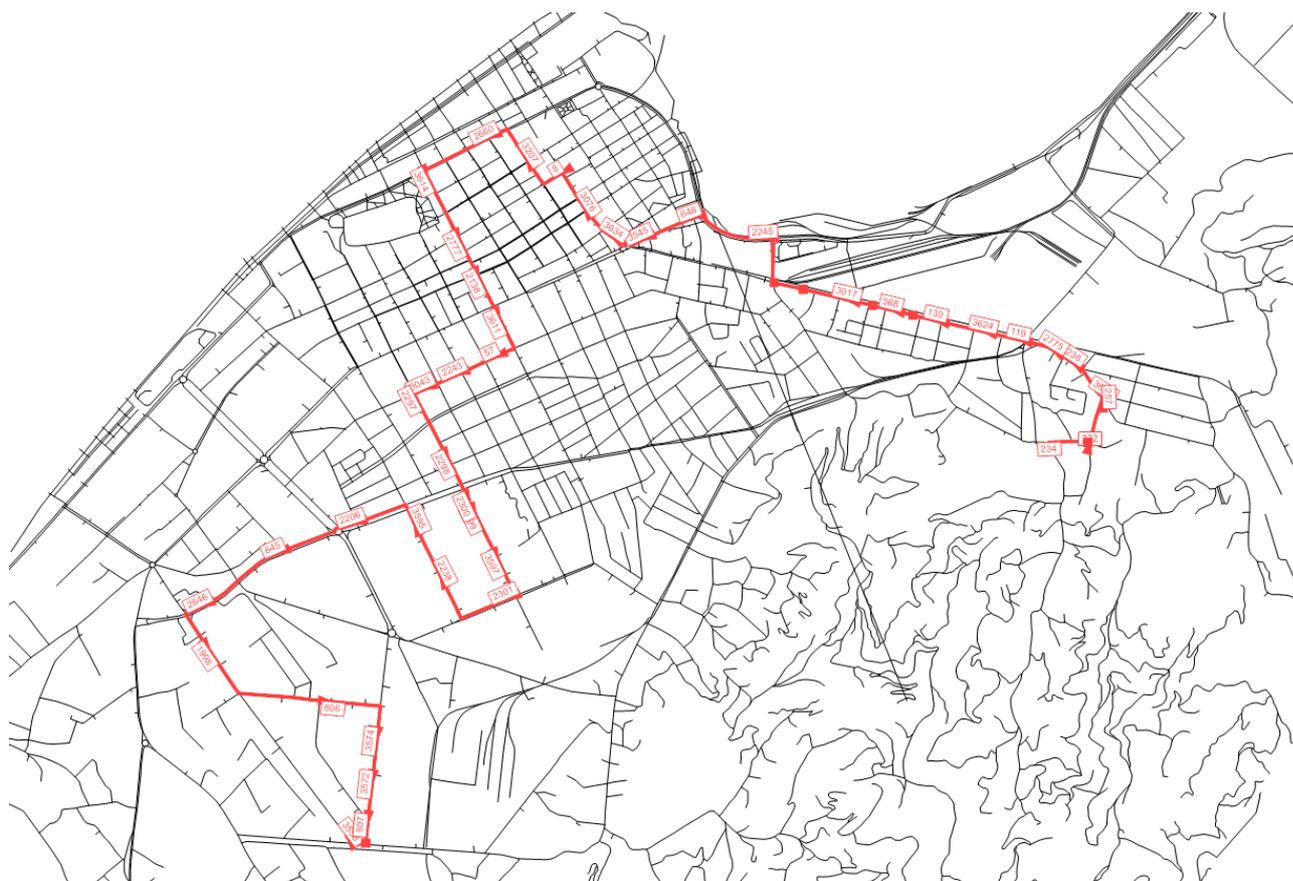


Figure 25 - Graphical representation of the route in the PTV VISUM software

3.4.2 Stops Model

The transport model features the public transport stops logic as follows

Interchange node that allows transfer of passengers from one mode of transport to another with some time loss is called "stop". The area within which there is a change between the specified points stops without loss of time, is called the "stop zone". The precise place of boarding/alighting is called "stopping point". Each "stopping point" is bound to a certain "zone stop." Each "stop zone" is tied to the "stop". The model takes into account the following number of objects examined:

1. Stops - 273;
2. Stops Zone - 452;
3. Items stops - 455.

Figure 26 shows a graphical representation of a stop in the developed model.

Each stop point features the dwell time by every kind of public transport - 30 seconds

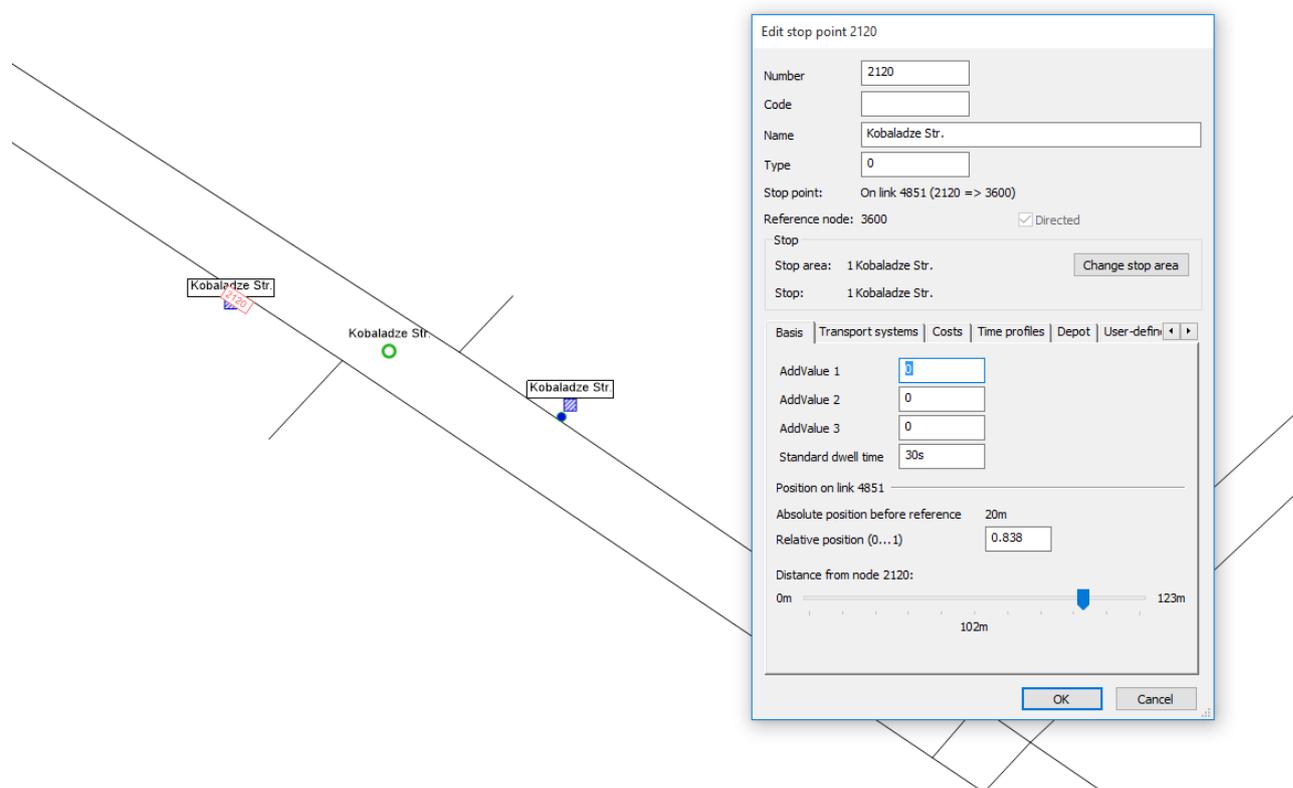


Figure 26 - A graphical representation of a stop in the PTV VISUM software

Each stop features a time loss matrix: time loss that happens during the interchange between each pair of stop zones within the same stop.

4 TRANSPORT DEMAND MODELLING

4.1 Four step transport demand model

Standard 4-step transport demand model has been used during the development of the transport model. There are several benefits of using this particular approach: it accurately describes all the stages of demand generation, allows to work with the aggregated data without loss of quality of model results, reduces the computation time and allows to evaluate a greater number of forecast scenarios at one time. The calculation is usually carried out on separate demand layers. The result of the model's algorithm computation are estimated (modelled) values of traffic volumes.

Standard 4-step model consists of the following phases:

Trip generation. At the stage of trip generation, number of trips from the origins and number of trips to the destinations for all transport zones is calculated; this information is detailed to demand layers level. The results of the calculation are the total rows and columns of the OD matrix.

Trip distribution. At the stage of the trip distribution, volumes of traffic across all transport zones detailed to demand layers are calculated, but without going into detail on the modes of transport. The results of the calculation are the elements of the OD matrix.

Mode choice. At the mode choice stage, OD matrices for each transportation mode are calculated.

Route assignment. Calculation of trip redistribution by routes, differentiated by the mode of transport allows you to estimate trip volumes. Redistribution is the final stage in the demand estimation cycle.

Transport demand calculations were performed for the daily period (with subsequent transfer to the estimated hours of the morning). Graphically the algorithm of transport demand modelling is shown in Figure 27

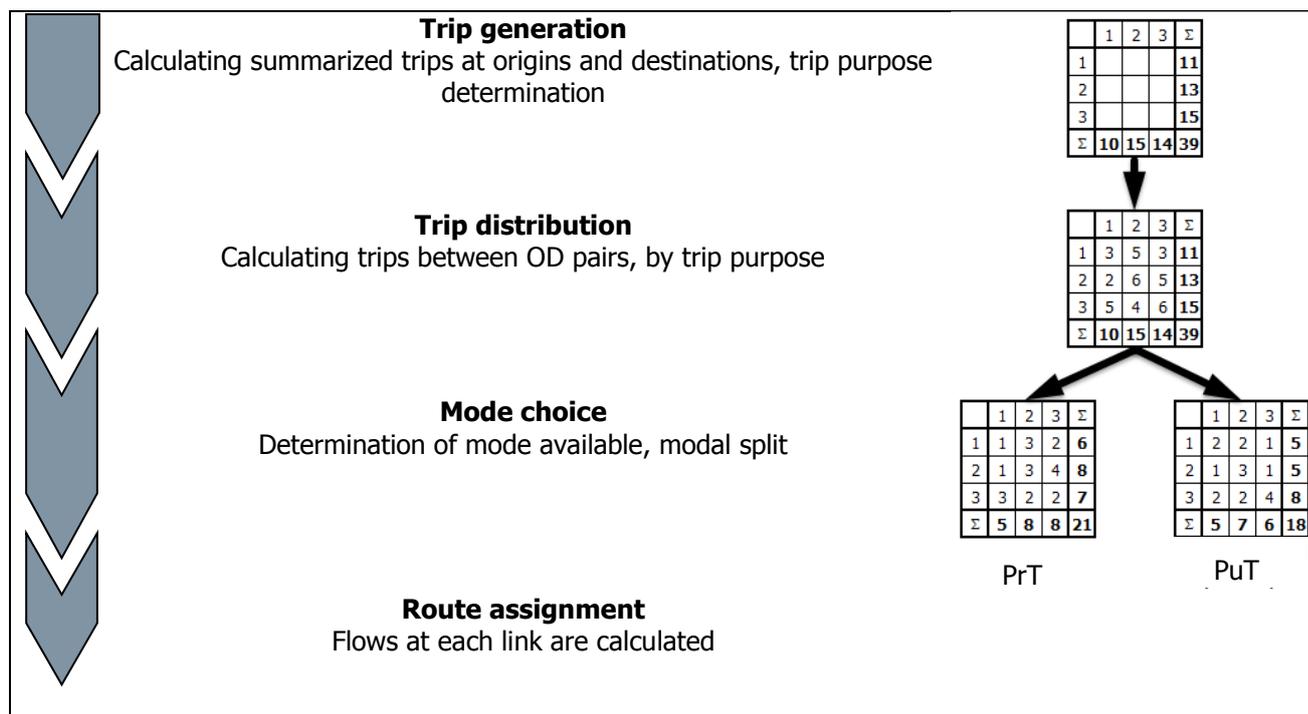


Figure 27 - 4-step transport model

Trip generation. The segments and layers of transport demand

Transport demand calculations are based on the following data:

- the number of generating and absorbing transport stream entities (for example, the population, the number of jobs);
- trip cost between the transport zones;
- indicators of mobility (the total number of movements, the number of movements of a certain transport mode, trip purpose), which are the source data to the task of generating traffic demand.

The result is an estimate of the total number of movements that go out and come in every transport zone. Thus, the results of the calculation are the totals of the rows and columns of the OD matrices, which contain data on traffic volumes from origins and to destinations for each transport zone.

The concept of demand layer is identical to the concept of trip purpose (for training, home, travel to work, and so on. d.). Normalizing factors are calculated for each layer of demand as follows: the number of reference entities of creation (in the origins) and entities of attraction (in the destinations).

The transport model identified 15 layers of demand presented in Table 5.

Table 5 - Creation and attraction entities by the demand layers

Nº	Layers demand	Creation entity	Attraction entity
1	House - Work	Working population	Labor places
2	Work - Home	Labor places	Working population
3	House - Study	Pupils	School places
4	Study - House	School places	Pupils
5	House - Other	Population	Places in schools, population, employment in the service sector, places in kindergartens
6	Other - House	Places in schools, population, employment in the service sector, places in kindergartens	Population
7	Work - Other	Labor places	Places in schools, population, employment in the service sector, places in kindergartens
8	Other - Work	Places in schools, population, employment in the service sector, places in kindergartens	Labor places
9	Work - Work	Labor places	Labor places
10	Other - Other	Places in schools, population, employment in the service sector, places in kindergartens	Places in schools, population, employment in the service sector, places in kindergartens
11	House - University	Students	Places at the universities
12	University - House	Places at the universities	Students
13	Work - University	Labor places	Places at the universities
14	University - Work	Places at the universities	Labor places
15	University - Other	Places at the universities	Jobs in the service sector

Cost matrices and estimates functions

Cost matrices are of the same dimension as the OD matrices (a square matrix with number of rows and columns equal to the number of transport zones) and describe the cost of travel between each pair of zones using various modes of transport. The travel cost can be represented by:

- Travel time in the free flow;
- Travel time taking into account the delays (congestion, etc.);
- Distance;
- Cost of travel and other.

Cost matrices are used at the trip distribution and mode choice stages.

Traffic distribution model

The purpose of this step is to determine the traffic volume (number of trips / movements) between each pair of transport zones in the study area.

The initial data for the traffic distribution by zone is the input and output traffic volume for each area, obtained at the previous step (traffic generation), as well as data on the trip cost between each pair of zones (cost matrix).

In order to calculate the distribution by zones, the gravity model is used. Its formula is similar to the physical formula of the gravitational interaction of bodies. The model is based on the assumption that the amount of interaction is proportional to the product of the indicators of importance (the volume of incoming and outgoing traffic) of objects and decreases with increasing "transportation distance" (expressed in cost) between the zones.

Gravitation model formula is used for the traffic distribution calculation as follows:

$$v_{ij} = f(U_{ij}) \cdot Q_i \cdot Z_j \cdot \alpha_i \cdot \beta_j, \text{ при умові:}$$
$$\begin{cases} \sum_j v_{ij} = Q_i \\ \sum_i v_{ij} = Z_j \end{cases} - \text{умови контрольних сум}$$

where

α_i, β_j – correction factors to fulfil the checksum conditions;

Q_i - the total number of departures from the zone;

Z_j - the total number of arrivals in the zone;

v_{ij} - traffic volume between zones i and j .

$f(U_{ij})$ - utility function (integral, monotonically decreasing) of trip, performed from zone i to j .

Modal Split

The purpose of this step is to determine the traffic volume (number of trips / movements) V_{ijk} between all traffic zones of the study area for each mode k .

The input data for this stage is as follows:

- the matrix of inter-zone trips calculated at the stage of distribution;
- cost matrices for each transportation mode;

Thus, the result of this stage are OD matrices, disaggregated by the transport mode.

Route Assignment

Traffic distribution across the routes in the network for all transport modes, with their mutual influence taken into account, allows obtaining the values of the traffic volumes.

This is the final stage in the cycle of demand calculation. This step is calculated using the equilibrium approach.

Network flow distribution is in equilibrium if it satisfies the principle of Wardrop. It lies in the fact that the traffic volumes should be distributed across the network so that the trip cost for all representatives of the same OD pair is identical. In other words, the distribution is in the state of equilibrium, if all the alternative routes feature greater or equal trip cost for all the users, and route switch doesn't cause travel cost reduction.

The result of this step is the load on each element of the network graph for each mode of transport.

4.2 Edge movement calculation

Edge movements are the trips entering or exiting the study area through its edges (edge movements passing the study area through are called through movements). These movements feature:

- Zones of departure and/or arrival of these movements are located outside the study area
- These correspondences do not have a generalized trip cost, as the uncontrollable part of their route is located outside the study area.

For edge movement calculation, dummy transportation zones called edge zones are formally defined. Volumes of arrival and departure for the edge zones were not calculated. They were evaluated basing on the traffic flows obtained by survey in the sections of highways nearby. The calculations involving the edge zones are based on the gravity model as well as ordinary transportation zones, however, these movements feature less sensitivity to the trip distance in comparison to the trips inside the study area.

Algorithm for calculating the edge trips can be represented by the following sequence:

1. Calculation of traffic bound to the edge zones from the modeling area.

This calculation is based on the weighted Logit model. The formula for the calculation is as follows::

$$v_{ij} = \frac{e^{-\beta A_{ij}} \cdot E_i}{\sum_k e^{-\beta A_{ik}} \cdot E_k} \cdot Z_j$$

where:

β – coefficient of Logit model;

A_{ij} – summarized travel costs between the i transport zone and j border transport zone;

Z_j – input flow of j border transport zone that we know from surveys;

E_i – population of i transport zone of modelling area.

It is important that input flow Z_j takes, considering the share of transit traffic in the border transport zones. As E_i indicator there is also other statistical data on the area can be selected, if it is considered that it is more likely to indicate traffic flow areas "the extent of creating" of the border.

2. Calculation of traffic between border and regular transport zones;

This part of the matrix can also be calculated based on the weighted Logit model.

The formula for the calculation is presented below:

$$v_{ij} = \frac{e^{-\beta A_{ij}} \cdot E_j}{\sum_k e^{-\beta A_{kj}} \cdot E_k} \cdot Q_i$$

where:

β – Logit model coefficient;

A_{ij} – summarized travel costs between the transport zone *i* and border transport zone *j*;

Q_i – outgoing flow from border transport zone *j*, known from surveys;

E_j – the population of transport zone *i* of modeling area.

It is important that the incoming flow **Q_i** taken considering the share of transit traffic in the border zones. Other statistical data on the transport zone can be selected as **E_j**, if it is considered that they are more reliably show "degree of severity" of the border transport zones.

3. Calculation of transit traffic movement between border transport zones.

The calculation results are consistent to transit and external traffic flows. This part of the matrix can be calculated based on the gravity model or entropy maximization model.

4.3 Measurements of traffic intensity and volume of passenger traffic

Traffic Counts

Generally, traffic count technologies can be split into two categories: the intrusive and non-intrusive methods.

The intrusive methods basically consist of a data recorder and a sensor placing on or in the road. Non-intrusive techniques are based on remote observations.

The city Batumi does have the non-intrusive traffic detectors but not all of them can be used because of many reasons which we will not discuss here. We have chosen the most traditional method of non-intrusive counting – "Manual counts".

Manual counts is the most traditional method of traffic counting. In this case trained observers gather traffic data that cannot be efficiently obtained through automated counts e.g. vehicle occupancy rate, pedestrians and vehicle classifications. The most common equipments used are tally sheet, mechanical count boards, electronic count board systems and mobile applications.

There were chosen 9 locations of the city Batumi to conduct traffic counts. They were chosen according to the traffic intensity on the roads of the city. None of the locations were on the crossroads because only 2 directions must be count (Figure 28). Each of the location had its unique Id number.

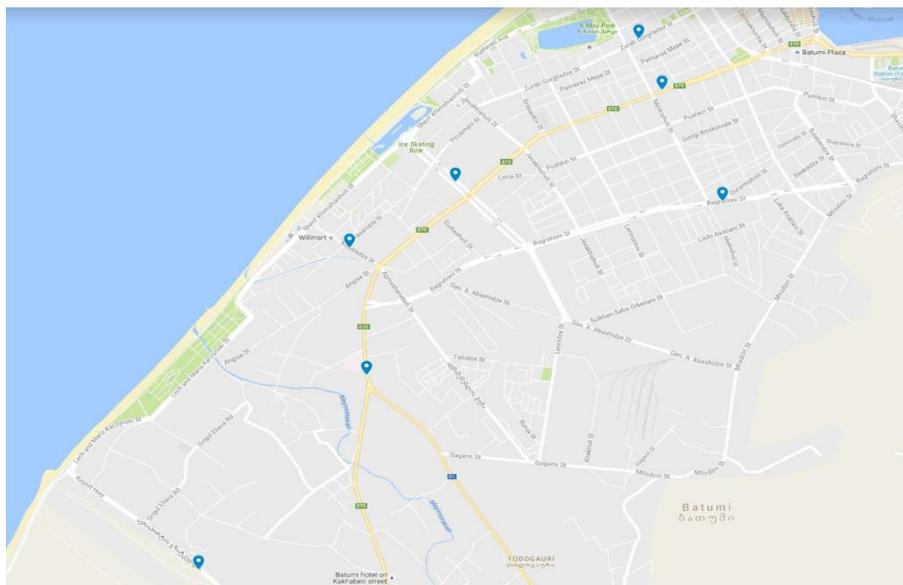


Figure 28 - Traffic Count locations in the City

With the help of Batumi University, 16 observers were found from the university of Batumi. All of them are students of the logistics faculty, so it was also an interesting experience for them to participate in such a survey.

Generally, mobile application was used for traffic counts. The name of the application is TrafficSurv (Figure 29)

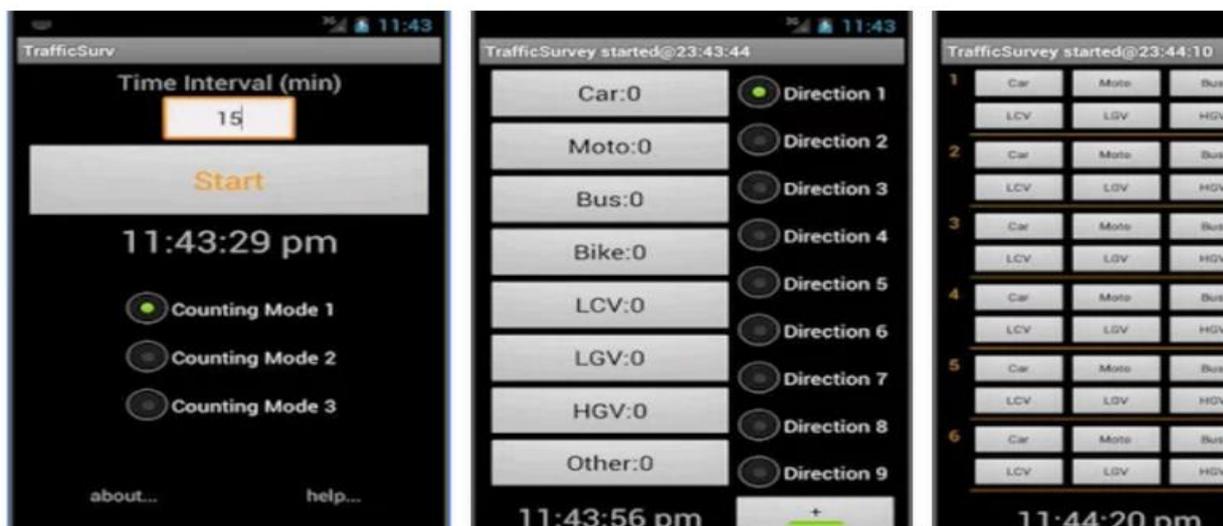


Figure 29 - Mobile Application TrafficSurv

But as we had some cases of hardware problems, tally sheets were also used (Figure 30)

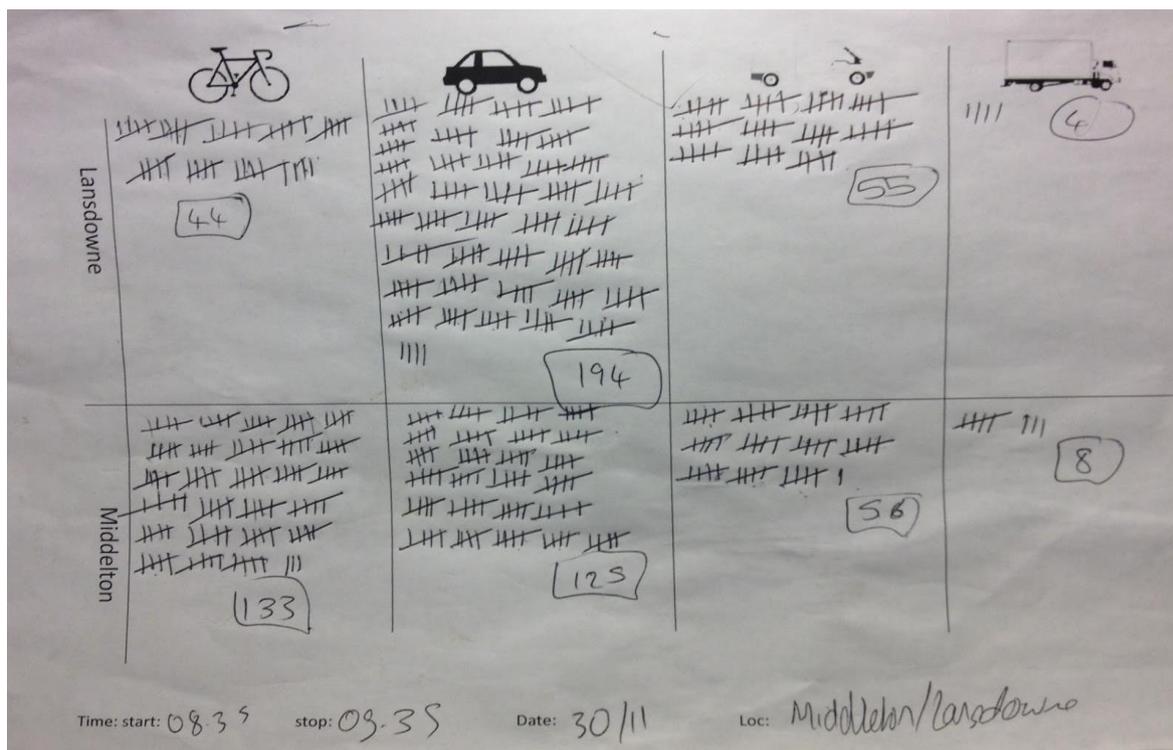


Figure 30 - Tilly Sheet used for Traffic Counts

The observers were trained in advance, how to use the soft or the sheets. The software has the ability to classify bus, mini bus, light vehicle and according to several directions.

For more efficiency, each of the observer had to count only one direction, so we used 2 observers on each location (Figure 31)

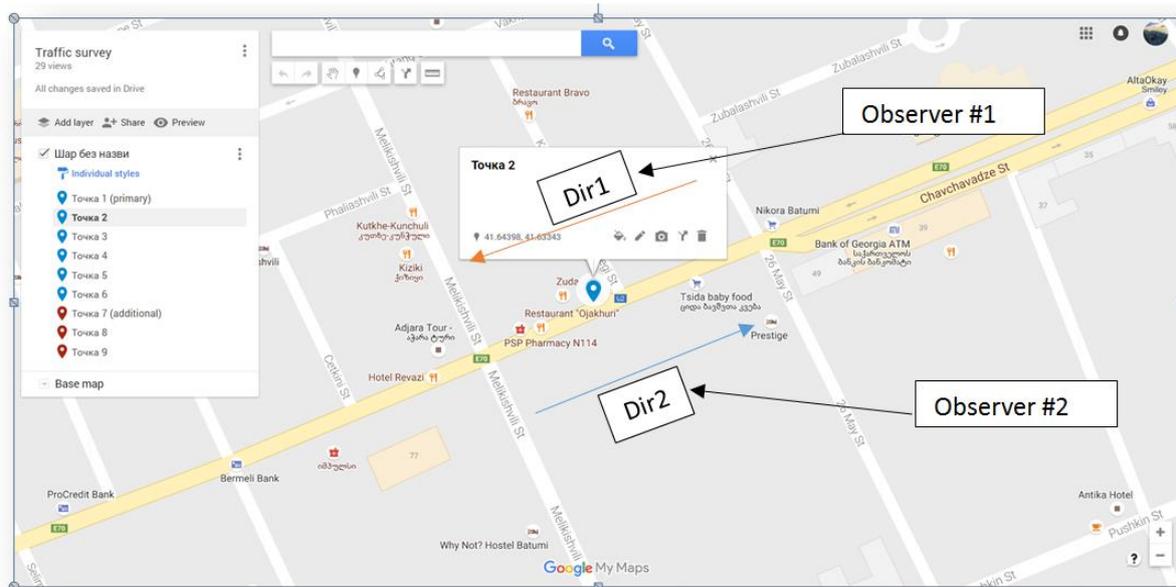


Figure 31 - Positioning of the Observers for Traffic Counting

For real image, traffic counts were planned for peak hours of the ordinary day of the week (not weekends, not Monday, not Friday). 3 hours were counted in the morning peak and 3 hours in the evening peak. Period of the day was from 08:00 to 11:00 and 17:00 – 20:00.

Table 6 - An example of the results of the traffic flows intensities measurements

#	Names of the streets	The intensity of traffic			
		1000 vehicles per day			
		Summary	including		
			cars	trucks	buses
	1000 vehicles per day	1000 vehicles per day	1000 vehicles per day		
2	Chavchavadze	17,79	13,34	0,16	4,29
3	Zurab Gorgiladze	11,95	10,56	0,26	1,13
5	Scheicha Nahain Mabusik Al Nahaini	11,99	11,28	0,69	0,02
6	Kobaladze	16,38	14,72	1,06	0,60
8	Ё2	25,49	20,59	3,21	1,69
9	Airport Highway	7,40	6,70	0,60	0,1

4.4 Model calibration process

Calibration of transport model was conducted after completing the first cycle of the calculations. During calibration we performed a series of numerical experiments with the model, while changing certain characteristics and parameters of the model in order to achieve the highest possible level of consistency of field surveys to intensity values.

As a result, we calculated the value of a standard set of indicators that characterizing the accuracy of the model. General parameters used in pre calibration of transport model are presented in Table 7.

Table 7 - Transport model calibration objects

Calibration object	Modification
Spatial development framework data (the degree of generation and attraction)	The number of movements in the demand layers and demand segments
Assessment functions - options and the type of features that estimate the probability of a trip depending on the length and / or travel time models the distribution of traffic and transport selection	Distribution of the duration and / or distance of travel and the proportion between cars and public transport
The diagonals of expense matrices	Changing the number of trips inside the transport zones
The speed and capacity on the links	Route assignment while distribution
Capacity constraints functions: the parameters and the type of functions, showing the dependence of the delay in the path of the load of the road (the ratio of traffic volume to capacity)	Route assignment while distribution
Places of the binding of connectors to the network	Route assignment while distribution
Shares of incoming / outgoing flows attributable to each abutment, in the general flow of the transport zone of the origin / destination	Changing the allocation proportions of ingoing and outgoing flows of the zones using connectors, changing ways of the redistribution

The following parameters have been tested during the calibration:

1. Transport proposal

1.1. The types of links: ranks, number of lines, capacity, allowed speed, permitted transport systems

1.2. The links: type number; checking of V_{act} и t_{act}

- 1.3. Capacity restraint function relevant to links type (depending on the characteristics and values of roads)
 - 1.4. The nodes and traffic movement schemes: type of control (# of type), capacity and t_0 of PrT (taking into account the whole costs for this node), the main flows, turns options (# of type, set of transportation systems, t_0 of PrT and capacities in case of their usage), geometry and signals timing (in case of ICA calculating)
 - 1.5. Turning standards (delay and capacity of PrT) - depending on the turning type (maneuver), flow hierarchy (the direction of the main road) and the node type (control type).
 - 1.6. Capacity restraint function of relevant types of turns (depending on the complexity of the maneuver) or nodes if you take into account the capacity. Setting the calculation of ICA (Intersection capacity analysis) when used.
 - 1.7. Transport network: alternative ways
 - 1.8. Resistance: Checking the resistance functions and attributes
 - 1.9. The coefficients for the bringing of transport systems to PrT (trucks) and PuT (when calculating the basic load)
2. Connectors
- 2.1. The places of connectors: PrT connectors - to the yard streets and parking lots; PuT connectors - to stop zones of PuT access nodes in zone, as well as outside (especially for subway, railway stations, major bus and others stops)
 - 2.2. The allowed set of transport systems (for example, to allow the movement of large trucks on the connectors to stores, warehouses, businesses and prohibit (or increase the time) at the connectors of the usual narrow yard streets)
 - 2.3. Time of movement at the junction for each transport system
 - 2.4. The share of PrT and PuT for each connector (for parts distribution) - set up in zones, as well as in the calculation of the costs matrix and redistribution of PuT
3. Matrix
- 3.1. Matrix of costs - elements of the main diagonal (movement within transport zones) – the smaller zones - the more the costs are had to be in diagonals
 - 3.2. OD-matrices checking
 - 3.2.1. Modal Split - ratio between PrT and PuT: (if there is no accurate survey data)
 - 3.2.2. The mobility of the population = in a larger city may be greater in a smaller - less
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3.2.3. Motorization level = number of motor vehicles per 1000 inhabitants

3.3. Vehicle occupancy (the average number of persons traveling in vehicle) for PrT demand segments. Using the factor during the transition (the combination of matrices and vectors) from OD-matrices PrT of demand segments (persons) to OD-matrices PrT of demand segments (vehicles).

3.4. The combination of matrixes for peak hours – coefficients correction.

4. Evaluation functions

4.1. Travel distance

4.2. The duration of trips

4.3. The proportions between the PrT and PuT (it can be also regulate by the generation and mode choice)

5. The model of traffic

5.1. Degrees of generation and attraction

5.2. Workplaces at the services sector $\approx 0,75 \cdot$ of workplaces if there is no data

5.3. The statistics on transport zones

5.4. Calculation of border transport zones traffic (calculation setting, adjusting the proportion of transit, clarify the volumes of incoming and outgoing flow, change (update) statistics on the areas of interaction, setting evaluation functions).

5 CONCLUSION

The given Report is the result of the first 2 months of work on the project "Feasibility Studies for Pilot Low-Carbon Urban Transport Corridor and Integrated Sustainable Urban Mobility Plan for the City of Batumi (ISUMP)". It is the most work intensive part of the project, because of the development of the base transport model and the related tasks with it.

The Household Survey for mobility behavior is the first one in Batumi. The preparation of the survey was started from the very first day of the project and the training of the local staff to conduct the interviews was already performed two weeks after project start. The interviews took about 3 weeks with the following data entering into digital formats and the logical validation of this big amount of data. As result we got the main mobility characteristics to use as base parameters in the transport model calculations.

The collection for the base data was a big challenge, as the availability of information was limited. The validation of network data was performed with the help of video capturing technology and the manual analysis of all parts of the street network. The public transport network data had to be verified many times and finally be validated by our own forces in a survey. As a result Batumi has for the first time the public transport network available in digital format and can use it for further projects, like public transport information services. The collection of socio-economic data was also a big challenge, as statistical information may be available in detail on the region level, but actually not at the city level or the level of transport zones. Our data analysis specialists were forced to develop, adapted to Batumi, methodologies to handle this issues.

The development of the first Transport Demand Model in Georgia, and maybe in the whole South-Caucasus, which belongs to the city is a real success Batumi. Within the short time we developed the transport model for the year 2016 which in the next tasks will be enhanced with features for forecasting and testing sustainable scenarios.

The next tasks will use the capabilities of the model extensively and will show future effects of planned measures, introduced into the Batumi transport network. The transport model is an effective tool for city decision makers to prioritize construction and organization measures.