D.4.1.6. Analysis and modelling. Traffic data gathering, a traffic model to improve public transport passenger flows using smart solutions and a mobile app based on traffic model.

WP 4. Analysing and piloting new sustainable mobility solutions

A 4.1. Analysis of new intermodality solutions

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List of abbreviations and terms

HZMO	Croatian Pension Insurance Institute
NKD07	National classification of economic activities
GIS	Geographic information system
ADT	Average daily traffic
AADT	Annual Average Daily Traffic
RMSE	Root Mean Square Error
GEH	GEH Statistic
BPR	The Bureau of Public Roads

1.Introduction

Maritime and multimodal sustainable passenger transport solutions and services (MIMOSA) project, financed form the Intereg Croatia-Italy programme, was started with the aim of improving the offer of multimodal sustainable passengers transport solutions and services, promoting a new cross-border approach for passenger mobility in the Programme area. The project partnership, composed by the main actors at regional and national level in Italy and Croatia, is determined to jointly tackle the common challenge of increasing multimodality, reducing the impact of transport on environment. Having a result-oriented approach, in developing visible outputs, ranging from multimodal solutions to innovative and smart tools and technologies, MIMOSA is focused to change the current situation affecting the cross-border and regional connections, making more accessible, low-carbon and sustainable the mobility of passengers in the whole Programme area. A cross-border cooperation approach is necessary for solving the common problems of a predominant road traffic and of a low level of connectivity between the two countries, for providing to citizens and tourists a wider offer of mobility sustainable options, based on a shared knowledge on transport demand and passengers habits and needs. Thus contributing in achieving the medium-term result of passengers behavioral changes.

Within the MIMOSA Technical Work Package (WPT) 4, the project's partner Lika-Senj County (PP15) had the goal to define a traffic model based on the relevant traffic data gathering and collection. The development of this MIMOSA traffic model had the goal to provide appropriate inputs for the improvement of public transport passenger flows using smart solutions and a mobile App based on the defined traffic model. Within this work package, through activities under the responsibility of the Licka-Senj County, a set of analysis, focused on new sustainable mobility solutions with aim at increasing the accessibility of health and social services in Lika-Senj County through improved traffic modalities, was performed.

The results of this Activity 4.1. "Analysis of the new intermodality solutions", will also provide valuable inputs for the WP5 technical activities in charge to PP15. The WP5 is dealing with the development of a tools and a related services aimed to sustainable intermodal mobility promotion in the project's area. In particular the WP5 technical activities in charge to PP15 will start from an analysis of existing new smart technological, tools and advanced solutions. Licka-Senj County will develop a digital information tool (mobile App) aimed to present new sustainable mobility solution able to increasing the accessibility of health and social services (D5.1.1.1). The functionalities of this new sustainable mobility solution foreseen in WP5 will be based on the results of WP4 data collection and analysis activities, as well as the relevant outputs generated by the model developed in this technical report.

2.Territorial context

Lika-Senj County is located between the Primorsko-goranska County in the northwest, Karlovac County in the north, Zadar County in the south and southeast and Bosnia and Herzegovina in the east. It has a central geographical position and an important connecting meaning within the territory of the Republic of Croatia.

Picture 1: Ličko-senjska County In the Republic of Croatia (Source: https://www.licko-senjska.hr/)

In terms of the territory area among the counties in the Republic of Croatia, it is the largest county with 5,350.50 km2 and covers 9.46% of the state territory. It spreads exclusively in most of the Lika hinterland and includes most of the Velebit mountain and its Senj-Karlobag coast and the north-western part of the nearest island of Pag. The county also owns a part of the territorial sea (596.63 km2 or 1.9% of Croatian sea area), which increases not only its area but also its significance, and with 2.29 km2 of island area, it makes 0.07% of all Croatian islands.

Picture 2. Ličko-senjska County (Source: https://www.licko-senjska.hr/)

The position of the County between the southern - Adriatic and northern - Danube areas of the Croatian state gives it special significance. According to physiognomic-homogeneous characteristics, the County consists of two larger and significantly different spatial units: continental Lika-mountain and coastal foothills-island units.

Lika-Senj County includes 4 cities (Gospić, Novalja, Otočac and Senj) and 8 municipalities (Brinje, Donji Lapac, Karlobag, Lovinac, Perušić, Plitvice Lakes, Udbina and Vrhovine). The seat of the County is the City of Gospić.

The importance of the County in Croatia and abroad is primarily determined by the function of the geopolitical crossroads between the three leading polarization hotspots in the country Zagreb, Rijeka and Split, then its continental area belongs to the geostrategic and ecological core of Croatia

wealth, and tourist-valuable areas (coastal areas), areas of national parks and nature parks and karst river basins.

Picture 3: Distance to hotspots in the Republic of Croatia (Source: https://www.licko-senjska.hr/)

A special place belongs to Velebit, the longest and most prominent Croatian mountain, which divides the County into two facades: coastal and continental. Velebit is also a Nature Park and a world biosphere reserve within which there are two national parks (Paklenica National Park and Northern Velebit National Park).

According to the number and diversity of protected natural objects and sites, the County has one of the leading, and by their share in the total area, the absolute leading place among Croatian counties (2,368 km2 or 58% of all national parks and nature parks in Croatia). Among them, the Plitvice Lakes National Park, Paklenica National Park, Northern Velebit National Park and Velebit Nature Park have a central place.

Picture 4: National parks in Ličko-senjska County (Source: https://www.licko-senjska.hr/)

According to the 2011 census, the County has 50,927 inhabitants, which is a significant decrease of 5.12% compared to year 2001, when it had 53,677 inhabitants. Population density fell from 10.03 inhabitants/km2 to 9.52 inhabitants/km2, which is significantly below the average for the Republic of Croatia (75.16 inhabitants/km2) and is the least populated county.

The population median age is 45.3 years, which is more than the Croatian average of 41.7 years, making the County the oldest county in the Republic of Croatia. Since the predominantly older population predominates, the data indicate an increase in the number of people aged 60 and over, which is especially pronounced in the continental and mountainous part, and in the former war-occupied area, where there is a negative natural increase. The age index, which shows the ratio of the number of people aged 60 and over and those aged 19, is also extremely unfavorable and amounts to 66.0% (the critical value of the index is 40%).

Namely, there are 12,574 inhabitants over the age of 65 in the County (24.6%), while there are 6,226 (12.2%) over the age of 75 and older, making our County ahead of all counties in the Republic of Croatia. The cities of Gospić and Otočac have the largest share of the population over the age of 75 (above 26 per km²).

3.Analysis and assessment of data quality and availability, and collection of missing data

To create an appropriate basis for the development of a quality traffic model, the verified quality and availability of data necessary for the development of models and mobile applications was carried out, taking into account all relevant strategic and planning documents.
The first step was to establish a list of all relevant data needed to develop a traffic model, identify potential data sources, and check the availability of existing data.
Relevant data are classified according to the following categories:

- Socio-economic data
- Strategic documents
- Spatial plans
- Studies and projects
- Transport sectors
    - Road traffic
    - Railway traffic
    - Public passenger transport
    - Maritime transport

According to the criterion of completeness, quality and timeliness of existing data, an analysis and assessment of the quality and availability of data was performed, which ultimately leads to the identification of the necessary data collected as part of the task.

Table 1. Evaluation of the availability of relevant data (Source: Authors)

Data	Source	Availability			
		Complete	Quality	Actuality	Rating
Socio-economic data					
Population contingents and related data	DZS (2011 Census)	+	+	+/-	+
Employees	DZS (2011 Census)	+	+	+/-	+
Pupils and Students	DZS (2011 Census)	+	+	+/-	+
Workplaces	HZMO (Pension Insurance Registry)	+	+/-	+	+

	CBS (Business Entities Registry)	+	+	+	+
High Schools and Universities	MZO (Registry)	+	+	+	+
Travel behaviour					
Republic of Croatia (2014)	MMPI (Ministry of the Sea, Transport and Infrastructure)	+	+	+/-	+
Functional region Northern Adriatic (2018)	Ličko-senjska County	+	+	+	+
Strategic documents					
Transport Development Strategy of the Republic of Croatia 2017-2030	MMPI (Ministry of the Sea, Transport and Infrastructure)	+	+	+	+
Transport Master plan for functional region Northern Adriatic	LSŽ	+	+	+	+
Spatial planning documentation					
Ličko-senjska County spatial plan	LSŽ	+	+	+	+
Road transport					
Categorization	HC	+	+	+	+
Infrastructure	HC; HAC	+	+	+	+
Traffic indicators	HC, HAC	+	+	+	+
Safety	HC, MUP	+	+	+	+
Financing, maintenance and management	HC; HAC	+	+	+	+
Railway transport					
Network	HŽI (Izvješće o mreži)	+	+	+	+
Stations, stops	HŽI (Izvješće o mreži)	+	+	+	+
Timetables	HŽPP (GTFS podaci)	+	+	+	+
Traffic indicators	HŽPP, LSŽ	+/-	+	+/-	+/-
Public transport					
Line routes, Timetables	LSŽ, MMPI	+	+	+	+
Financing	LSŽ	-	+/-	+/-	-
Traffic indicators	LSŽ	-	+/-	+/-	-
Maritime transport					
Ports	AZOLPP	+	+	+	+
Ferries, Timetable	Jadrolinija, AZOLPP	+	+	+	+

All available data, collected from relevant stakeholders, form a single data inventory. Existing documentation and data are classified according to content, time of creation and relevance. The

collected data are presented in the form of individual or aggregate data in a manner appropriate for analysis.

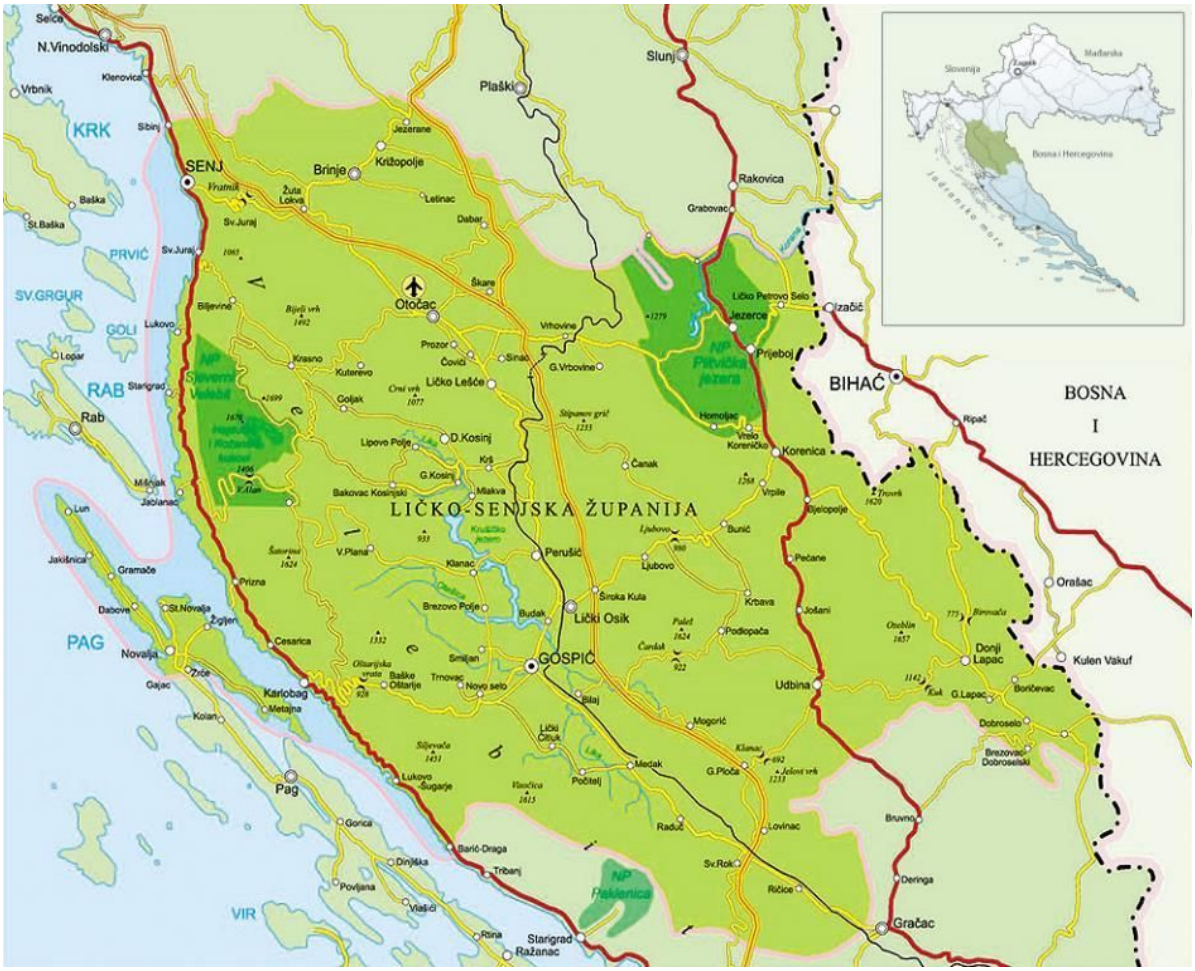
4.Transport model

Transport models are essential tools for mobility planning and transport as well as optimized/improved management of both infrastructure and services. The transport model is essentially a mathematical model of actual traffic, usually individual and public passenger transport. By modelling a transport system, we can both understand aggregated phenomena arising from complex interactions and predict the behavior of the transport system in the near or far future, depending on the application.

By integrating the supply of transport networks with demand from users, a model can show the relationship between costs (in terms of travel times and other elements of generalized cost) and transport demand. It also shows the point at which equilibrium is reached (a balance between traffic demand and available capacity).

With the help of the transport model, it is possible not only to qualify but also to quantify the traffic indicators of the existing transport system as well as the scenarios for the development of the transport system in the future. Furthermore, the developed transport model enables testing of certain traffic policies, such as changes in tariffs, changes in timetables, etc.

Based on all available relevant and data collected through surveys synthetic transport model was developed for individual and public traffic. The model is based on socio-economic data and road traffic data and is developed as a classic 4-step model of demand. The research area included in the transport model is Lika-Senj County. The scope of the transport model is shown in the following picture.

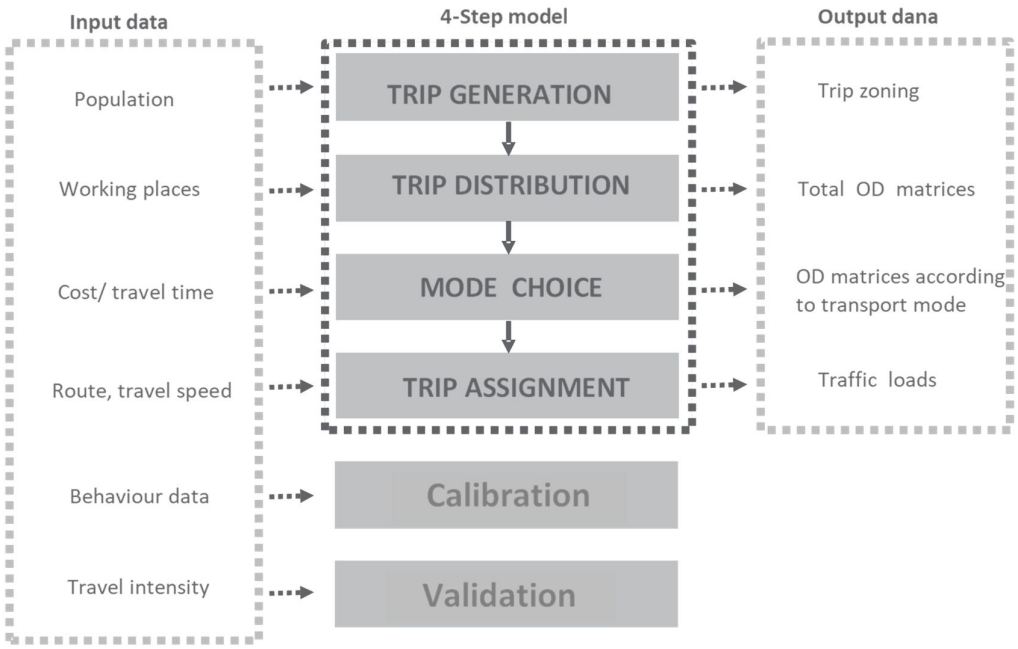


Picture 5: The scope of the transport model (Source: https://visit-lika.com/page/karta)

Socio-economic data was collected from various sources, in great amount as source data processed at the level of traffic zones. The specific characteristics of the travel habits within the project are taken from the Surveys of Travel Habits of population within the development of the National transport model for the Republic of Croatia and transport Masterplan for the functional region North Adriatic. The stated empirical data were used for calibration and validation of the transport model.

4.1 Data

To develop this multimodal transport model, data describing traffic demand (socio-economic and population travel patterns), data describing the traffic supply (traffic network) and traffic indicators have been collected.
All spatial data was collected for the lowest available level of statistical space unit. The data that was not available was developed through additional research conducted by the authors of this Study.



Picture 6. Ratio of input and output data in the development of traffic supply model (Source: Authors)

4.1.1 Socio-economic data

Socio-economic data are the basic data for the calculation of the demand model. These data are the basis for calculating the trip generation at the source of the trips, and for calculating the trip attraction at the potential trip destination. The origin and destination of the trip is in the traffic zone. Traffic zones are geographical units that describe the modelled area. Therefore, a detailed socio-economic data is needed of the traffic zones of the transport model.

The following socio-economic data were collected for the demand model development:

- Population data from the Population Census 2011 (data source: Central Bureau of Statistics),
- Number of employed residents according to NKD07 (data source: Croatian Pension Insurance Institute),
- Data on secondary school students (source: Ministry of Science and Education),
- Data on higher education students (source: Ministry of Science and Education).

Population

The basis for trip generation is the population, that is, depending on the trip purpose the relevant group to which the trip refers to. The data source describing the population is the latest population census dating from 2011. To develop the transport model, data on total population, number of residents older than 14 years and, number of students in high schools, number of students in higher education, and number of employed people. The overview of the population at the municipality/town level, is shown in the following table.

Table 2. Population in the Lika-Senj County (Source: CBS)

City / Municipality	Population	Population 14+	Employed	High School Students	Higher education students
Brinje	3256	2817	702	97	66
Donji Lapac	2113	1935	397	44	30
Gospić	12745	10726	4183	572	620
Karlobag	917	830	204	28	26
Lovinac	1007	879	195	25	18
Novalja	3663	3123	1134	137	160
Otočac	9778	8458	2877	427	386
Perušić	2638	2346	600	84	66
Plitvička Jezera	4373	3617	1435	186	176
Senj	7182	6326	2251	267	292
Udbina	1874	1671	530	58	21
Vrhovine	1381	1281	157	25	19

Employment

The number of jobs per traffic zone is based on the data on the number of insured according to the records of the Croatian Pension Insurance Institute (HZMO). The overview of jobs is shown by settlements in the areas covered by the transport model in the following table:

Table 3. Jobs in the scope zone of the transport model (Source: Authors)

City / Municipality	Total	Leisure/Holiday	Trade
Brinje	57	8	5

Donji Lapac	18	1	1
Gospić	187	15	19
Karlobag	35	3	3
Lovinac	41	2	4
Novalja	244	50	58
Otočac	85	11	15
Perušić	53	3	19
Plitvička Jezera	78	41	5
Senj	78	11	10
Udbina	30	2	6
Vrhovine	27	2	-

Schools and higher education facilities

In the Lika-Senj County, more precisely in the towns of Gospić, Otočac, Senj and Korenica, there are 5 high schools attended by a total of 1,361 students. Furthermore, in the town of Gospić, the administrative seat of Lika-Senj County, is located the Polytechnic "Nikola Tesla" which is attended by 375 students. An overview of the number of students and students by facilities is shown in the following tables:

Table 4. High schools within the project scope (Source: MZO)

Facility	Town	Address	Number of students
Strukovna škola Gospić	Gospić	Budačka 24	419
Gimnazija Gospić	Gospić	Budačka 24	228
Srednja škola Otočac	Otočac	Ćirila i Metoda 2	368
Srednja škola Pavla Rittera Vitezovića u Senju	Senj	Vjenceslava Novaka 2	150
Srednja škola Plitvička jezera	Korenica	Zagrebačka 2	196

Table 5. Higher Education facilities within the project zone

Facility	Town	Address	Number of Students
Veleučilište "Nikola Tesla" u Gospiću (Gospić)	Gospić	Ulica bana Ivana Karlovića 16	375

Tourism

The data on accommodation capacities are taken from the *eVisitor* database, information system for monitoring the arrival and departure of individual tourists. The accommodation capacities by specific traffic zones are determined by geo- referencing of tourist accommodation according to the

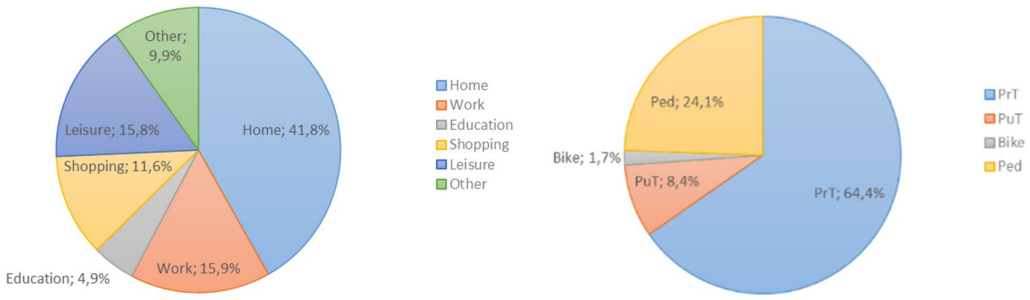
address. The overview of the accommodation by settlements within the zone of the transport model is shown in the following table.

Table 6. Tourist capacities in the project zone (Source HTZ)

City / Municipality	Beds
Brinje	2
Donji Lapac	5
Gospić	26
Karlobag	1.087
Lovinac	26
Novalja	6.201
Otočac	27
Perušić	6
Plitvička Jezera	238
Senj	612
Udbina	7
Vrhovine	23

4.1.2 Travel behavior

A survey on travel habits was conducted in the functional region of the North Adriatic (the area that includes Counties Lika-Senj, Primorsko Goranska and Istra) from 1 March to 20 May 2018.
Most of the respondents, about 72% of them, travelled on an assigned day, i.e. changed their location due to performing some activity; respondents who travelled made an average of 3 trips per day and spent 55 minutes travelling.
The breakdown of trips by trip purpose reveals that returning home individually is the most common purpose of travel with a share of 42%, in second place were trips to go to work (16%), while in third place were trips to go to regular shopping (12%). The analysis showed that given the basic modalities of transport in the area of the project, of all the trips, by far the most was done by car, in total, 64%. 24% of all recorded trips were made by walking, 8% by public transport, and 2% by bicycle. Compared to the situation at the national level, a higher share of total car traffic was recorded (64.2% vs. 53.8%), while slightly lower shares were recorded in walking (24.6% vs. 28.5%), public transport (7 .8% vs. 11%) and bicycles (2% vs. 5.3%).



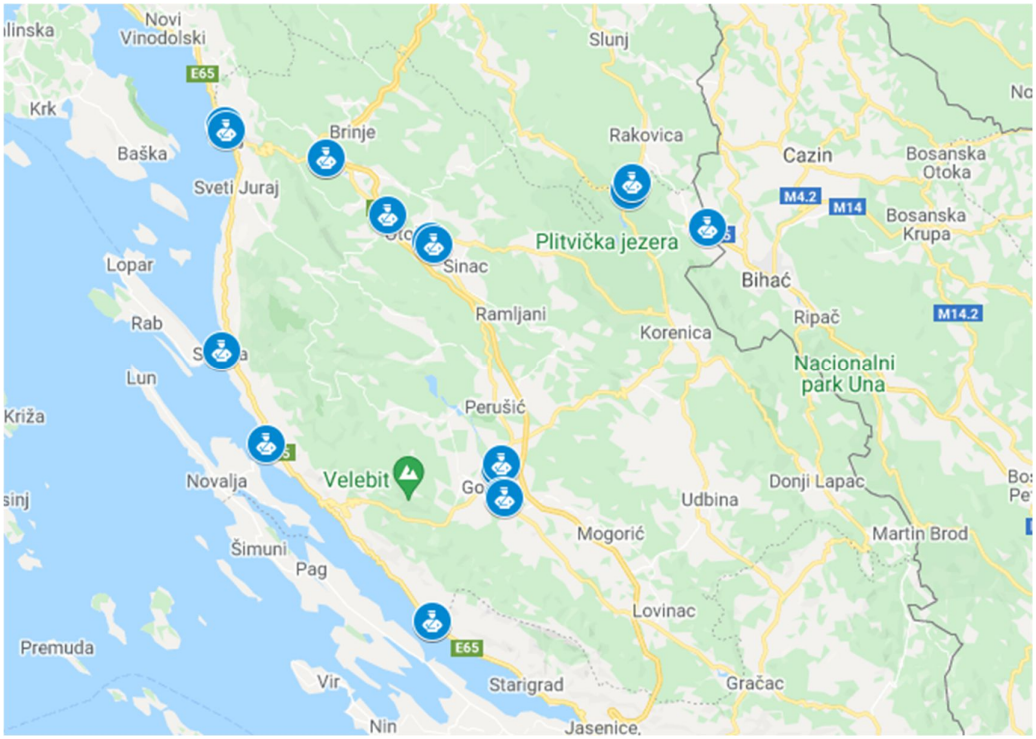
Picture 7: Trip distribution by purpose (left) and modal split (right) (Source: MP functional region Northern Adriatic)

Analysis of the distance of the nearest bus stop as the most common form of public transport shows that about 58% of respondents are within a zone of up to 5 minutes walk between the residential address and the bus stop, about 28% live 6 to 10 minutes walk to the nearest bus stop. 8% at a distance of 11 to 15, and about 6% of them need more than 15 minutes to the bus stop. When asked about the expediency of using public transport to travel to their most frequent destination, about 19% of respondents said that their most common destination is not available at all with the use of public transport, for 57% of respondents it is somewhat, and for them about 24% with the use of public transport.

When it comes to details that currently make it difficult for residents of their settlements to use public transport, most respondents believe that each of these elements can be linked to the unattractive use of public transport. However, given the share of ratings "extremely difficult" two elements stand out a little on this list - about 31% of respondents believe that the use of public transport residents of their settlements is extremely difficult high ticket price, and about 25% of respondents attribute this to rare departures on public transport. Between 15% and 18% of respondents believe that irregularity, slow driving and frequent on-board congestion or crowding (within the Public Transport vehicles) are elements that make it extremely difficult to use public transport in their neighborhood.

4.1.3 Roadside interview

The cordon survey was conducted in the presence of police officers in a way that random information on travel was obtained by stopping the vehicle at random in the shortest possible time. The roadside interviews in the Lika-Senj County were conducted at a total of 12 survey locations (both directions) from April 10 to April 12, 2018 at the following locations.



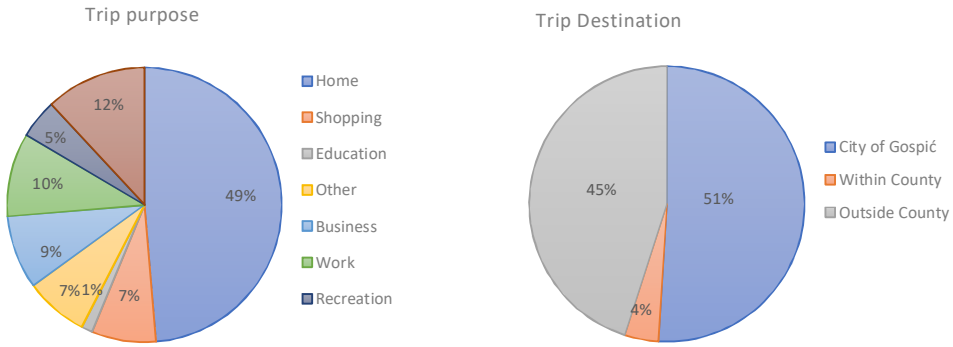
Picture 8: Locations of roadside interviews in LSŽ (Source: MP functional region Northern Adriatic)

Table 7. Locations and dates of roadside interviews in LSŽ (Source: MP functional region Northern Adriatic)

No	Location	Date
1	Senj 1 – D8 – Camp Bunica - smjer jug	April 10, 2018
	Senj 1 – D8 Vrataruša – smjer sjever	
2	Senj 2 – Žuta Lokva – D23 – smjer zapad	April 11, 2018
	Senj 2 – Žuta Lokva – smjer istok	
3	Otočac – raskrižje kod Benzinske postaje Adria Oil (oba smjera)	April 12, 2018
4	Otočac 2 – kod Zračne luke Otočac – D50 (oba smjera)	April 10, 2018
5	Camp Borje – Raskrižje D1 – D52 – oba smjera	April 12, 2018
6	Raskrižje D504 - D217 - Ličko Petrovo Selo (oba smjera)	April 11, 2018

7	Gospić 1 – Raskrižje D534 - Budačka ulica – oba smjera	April 10, 2018
8	Novoselo Bilajsko – D50 – smjer sjever	April 11, 2018
	Novoselo Bilajsko – D50 – smjer jug	
9	Lukovo Šugarje – D8 – smjer sjever	April 12, 2018
	Lukovo Šugarje – D8 – smjer jug	
10	Trajektno pristanište Rab – Stinica (oba smjera)	April 26, 2018
11	Trajektno pristanište Prizna – Žigljen (oba smjera)	
12	Plitvička jezera – Parking na samim Plitvicama	

The survey on road crossings and external cordons Gospići-Budačka Street included **1,083 vehicles**. As a summary of the results of this research, it is possible to state that the largest traffic of all survey locations was recorded at the location Gospić - Budačka ulica - D534 and that through this survey location the largest number of vehicles ended the trip in Gospić (location Kaniška Ulica). The city of Gospić, the largest number of vehicles ended the trip in Lički Osik. The largest number of recorded trips was for the purpose of going to work and returning home (49%), which can be seen in the chart below.



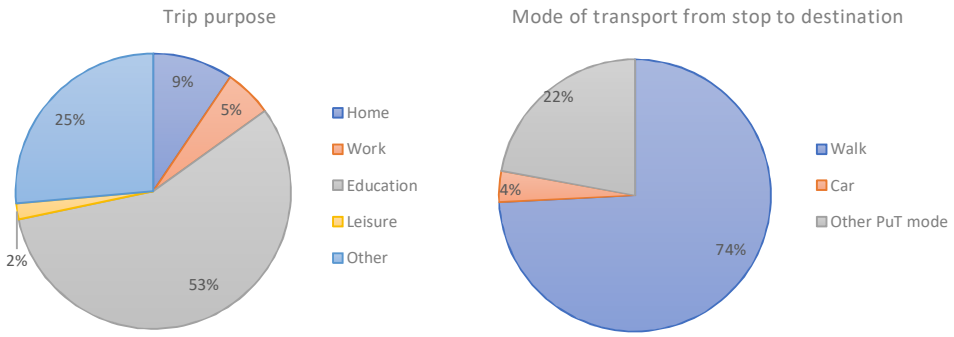
Picture 9. Trip purpose and destination at Gospić-Budačka street (Source: MP functional region Northern Adriatic)

4.1.4 Public transport survey

In order to determine daily movements by public transport on typical working days (Tuesday/ Wednesday/Thursday), a survey and counting of passengers at bus stations and stops was conducted. The survey was conducted in the period from March 1 to April 26, 2018 with a total of

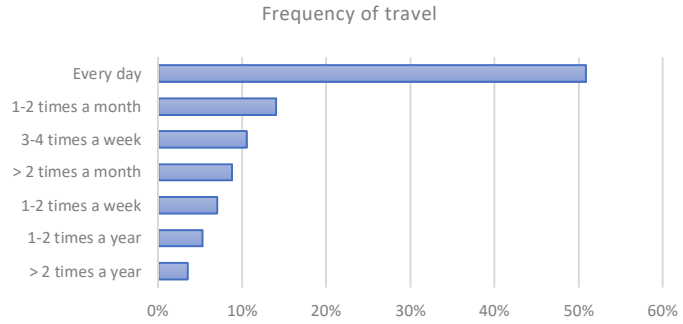
500 surveyed passengers. The survey collected data on the current state of mobility in the Lika-Senj County. The survey contained information on the origin and destination of trips, trip purpose, previous and next mean of transport, frequency of travel, suggestions for improving public transport services, travel habits and reasons for choosing a particular mean of transport and suggestions to stimulate more frequent use of public transport.

The results of the survey show that bus transport is most often used for educational purposes (about 53%) and other purposes, of which the respondents most often stated going to the doctor, performing administrative tasks related to the household and going on home visits. According to the mode of travel from the public transport stop to the destination of the respondents, the respondents most often walked, 74% of them, 22% travelled by another JP line, and about 4% by car.



Picture 10. Trip purpose and mode of transport from stop to the respondent's destination at the bus station in Gospić (Source: MP functional region Northern Adriatic)

According to the frequency of travel for the same purpose at the bus station in Gospić, about 50% of respondents travel every working day, while about 14% of respondents travel once or twice a month.



Picture 11. Frequency of travel at the bus station in Gospić (Source: MP functional region Northern Adriatic)

From the conducted research it can be concluded that there is a demand for public transport, and the users are most often students, and travel is most often every working day and there is a possibility for additional investment in the supply of public transport.

4.1.5 Public transport passenger counting

The survey was conducted with the aim of determining daily movements by public transport on typical working days (Tuesday/Wednesday/Thursday). The survey was conducted in the period from March 1 to April 26, 2018. A mobile application was developed that automatically records the location, and counters/students entered the number of passengers who board/alight at the stops. On the county lines, the counters were in buses while the inter-county lines were recorded at the stations/stops that were on the itinerary of the inter-county line.
In Lika-Senj County, about 500 trips of county bus lines were recorded, and most of them were recorded at the stations in Gospić and Otočac. Gospić does not have public city transport, but the surrounding settlements are connected by existing county lines. A total of 6.507 boarding and alighting events were counted.

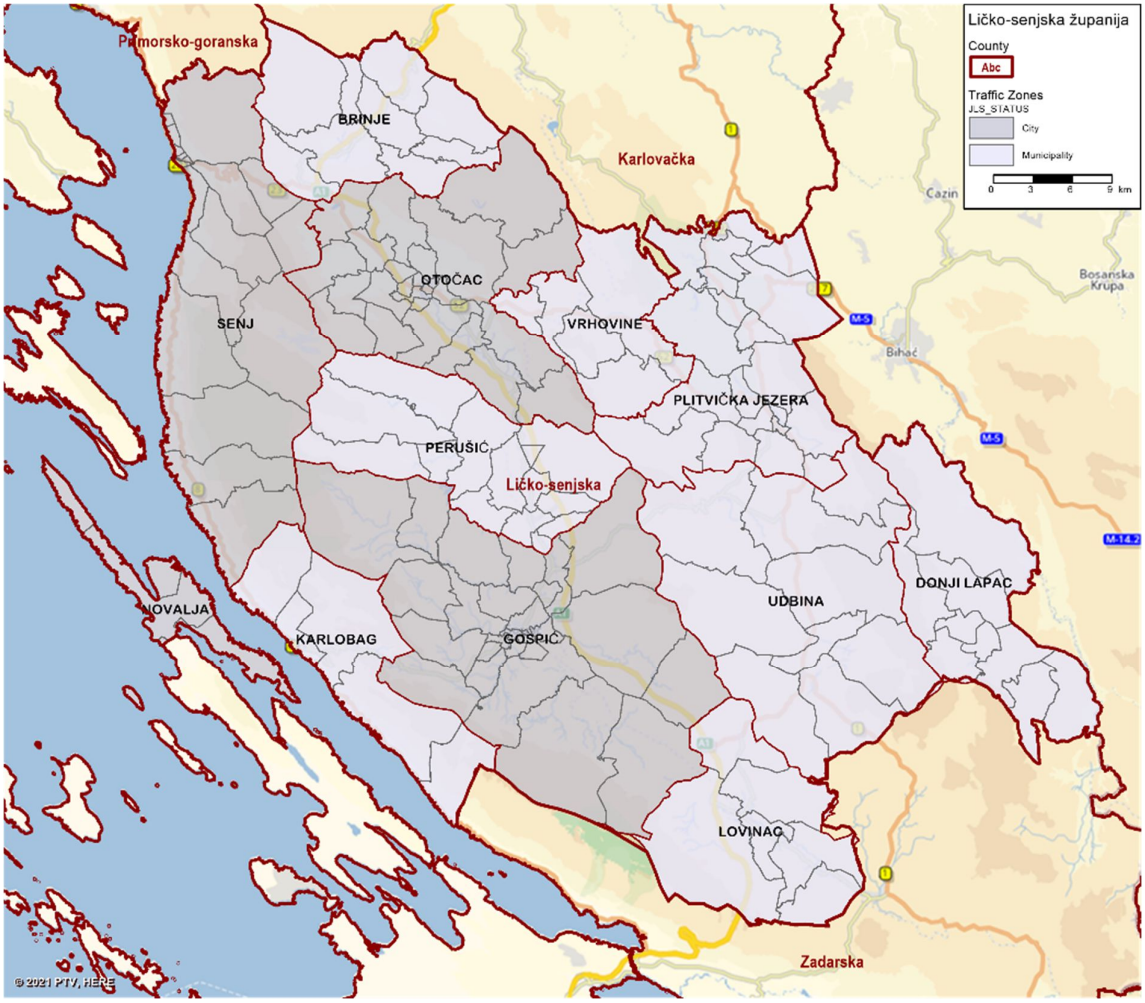
4.2 Traffic zones

The demand model is described in traffic zones, or the source and destination zones of the trip. The zoning is based on appropriate administrative and statistical units that depend on data availability. The transport model has a total of 164 traffic zones, of which:

- 151 internal traffic zones;
- 13 external traffic zones[1].

External zones represent the main traffic routes to neighboring counties and to the Republic of Bosnia and Herzegovina.

[1] External zones represent the main traffic routes to neighbouring counties and to the Republic of Bosnia and Herzegovina.



Picture 12. Traffic zones in the scope of the transport model

4.3 Transport Network

The transport network is described in the supply model, for individual and public urban and suburban traffic with their characteristics as well as related services. The modelled road network is divided by categories into motorways, state roads, county roads and local roads, as well as main city, access, and residential roads. The total length of the existing network is slightly more than 7,000 km.

Picture 13. Traffic network in the scope of the transport model

The model free flow speed corresponds to the administrative limit. Capacity values of the road network have been determined for each type of road based on international guidelines (HBS[2], HCM[3]). The free flow speed and capacity values associated to each road type in the transport model are shown in the following table.

[2] Handbuch fur die Bemessung von Strassenverkehrsanlagen, Ausgabe 2015

[3] HCM 2010, Highway Capacity Manual

Table 8. Characteristics of the network sections

LinkType	Classification	Speed (km/h)	Capacity (vehicles/h)
10	Motorway, 2 lanes, 130 km/h	130km/h	3.900
18	Motorway-ramp, 1 lane, 40 km/h	40km/h	1.700
30	State road, 1 lane, 90 km/h	90km/h	1.300
31	State road, 1 lane, 70 km/h	70km/h	1.300
32	State road, 1 lane, 50 km/h	50km/h	1.300
35	State road, 2 lanes, 80 km/h	80km/h	2.600
38	State road ramp, 1 lane, 40 km/h	40km/h	1.300
39	State road ramp, 2 lanes, 50 km/h	50km/h	2.600
41	County road, 1 lane, 70 km/h	70km/h	1.200
42	County road, 1 lane, 60 km/h	60km/h	1.200
43	County road, 1 lane, 50 km/h	50km/h	1.200
44	County road, 1 lane, 40 km/h	40km/h	1.200
50	Local road, 1 lane, 50 km/h	50km/h	900
51	Local road, 1 lane, 40 km/h	40km/h	900
53	Unclassified road, 1 lane, 40 km/h	40km/h	800
70	Main local road and/or street, 1 lane, 50 km/h	50km/h	1.200
71	Main local road and/or street, 1 lane, 40 km/h	40km/h	1.200
72	Main local road and/or street 2 lanes, 50 km/h	50km/h	2.400
80	Access road, 1 lane, 50 km/h	50km/h	800
81	Access road, 1 lane, 40 km/h	40km/h	800
85	Other street, 30 km/h	30km/h	500

The public transport network consists of railway, ferry, suburban and coach bus transport with corresponding routes and timetables. The public transport lines serve 242 stops. The overview of the public transport lines is given in the following picture.

Picture 14. Public transport lines

4.4 Developing the passenger demand model

The passenger demand model was developed as a synthetic model with the PTV Visum 2021. PTV Visum is the world's leading software package for creating a transport model, creating traffic impact analyses, creating forecasts, and managing GIS data.

The approach to modelling is macroscopic, stochastically sorted, multimodal model in 4 steps. The model is based on the balance between demand and supply, which consists of trip generation, travel distribution, mode choice and assignment to the network. Demand calculation was carried out using

the EVA[4] method, which provides a great advantage with simultaneous calculation of travel distribution and travel mode choice.

4.4.1 Trip generation

The first step is the trip generation, i.e. calculating the number of trips produced/ attracted from each traffic zone. This calculation will be carried out separately for each demographic group and trip purpose based on socio-economic parameters and spatial parameters.

Passenger model was set up for an average working day for the period off summer season and for the period in the summer season. The calculation of production and attraction was carried out for homogeneous source- target groups that represent the purpose of travelling “work”, "school", "shop", "leisure time", "vacation" and "other".

By combining the mentioned purposes 13 source-target groups were developed: “Home-work“, ”home-school”, “home-shop”, "home-leisure”, “home-other”, “work-home”, “school-home”, “shop-home”, “leisure-home”, “other-home”, “work-other”, “other-work” and “other-other”.

For each of the thirteen (13) source-target groups, based on the household survey, the number of daily trips per person was determined. For most groups, the relevant person is the "resident" in the specific traffic zone. For the groups "home-work", "work-home", "work-other" and "other-work" groups, the relevant person is "the employee", while for the groups "home-school" and "school-home" it is the “student” for secondary schools and "higher-education student" for faculties.

External traffic is modelled by a simplified gravity model, according to the following procedure:

- The production of external zones is determined by traffic at the locations of automatic traffic counting;
- Distribution of transit trips is a function of the number of trips and the distance travelled;
- Distribution of destinating/originating trips is a function of the number of residents;
- In the end of the calculation of the external traffic matrix is made symmetric.

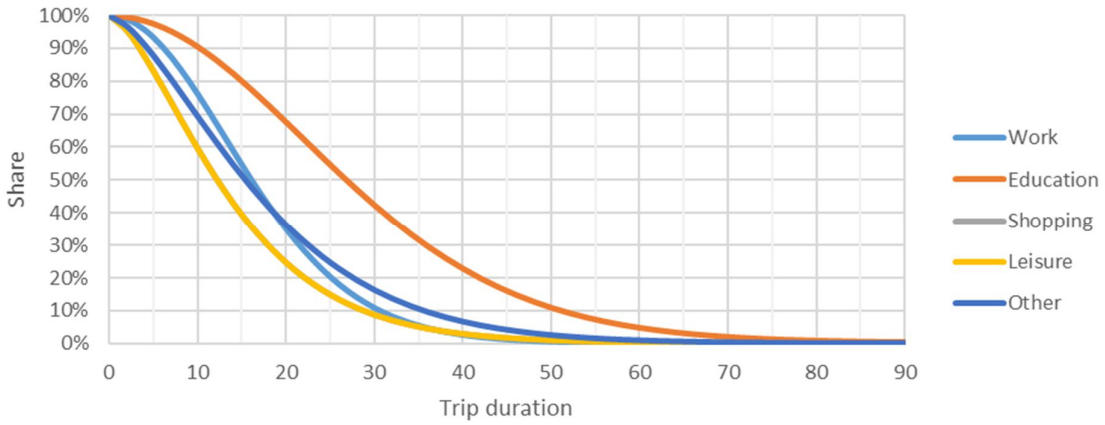
[4] The EVA model developed by Lohse at Dresden Technical University constitutes an alternative approach to the first three stages of the classical traffic planning model (Lohse 1997).

4.4.2 Trip distribution and mode choice

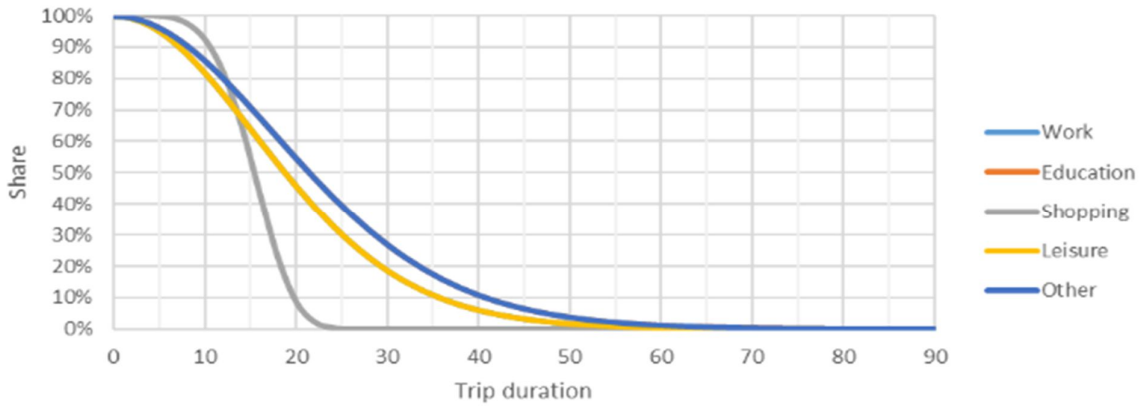
Trip distribution and mode choice are determined by the simultaneous EVA model. These are probabilistic functions that differ between various source-target groups for various transport modes and for various types of impedance. These functions (in addition to attractions) determine which destinations will be chosen by which means of transport at the same time.

The basic parameters of the model are determined according to conducted researches, recommendations of software manufacturers and previous experience in modelling of national and regional models. Based on these data and the EVA function, within multiple iterations travel matrices for travels by private car, public transport, bicycle, and walking were calculated.

An overview of the probability functions for each travel purpose for individual transport by private vehicle and public transport are shown in the following diagrams.



Picture 15. Probability functions for different trip purposes by private car- individual transport (Legend: work, school, shopping, leisure, other)

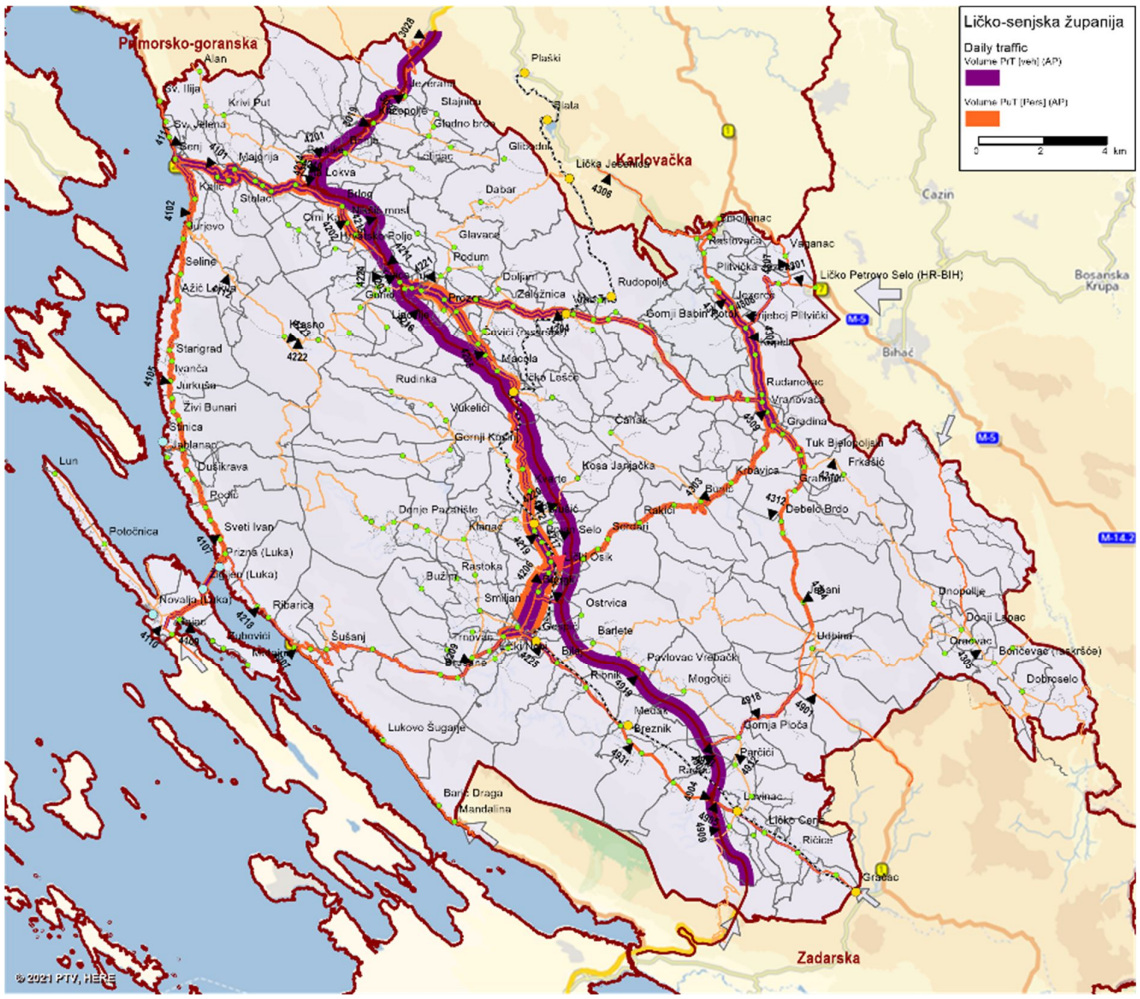


Picture 16. The probability function for different travel purposes by public transport

4.4.3 Trip assignment

The last step in the demand transport model development is the assignment to the multimodal transport network. For private traffic stochastic teaching method was used (Lohse). The public transport was assigned using the intermodal procedure based on the public transport timetable. Both, private and public traffic, internal and external traffic have been assigned simultaneously.
The assignment to the traffic network was implemented in several iterations according to the equilibrium network loading methodology. Based on data obtained from previous iteration, users find new optimal routes in the next iteration. In the iterative procedure of optimum route search is continued to the network balance until the corresponding resistance matrix convergence is achieved. Assignment to the network is based on the function of generalized costs or generalized time. In the search for optimal route, the effects of traffic congestion, i.e., the consequences of driving speed reduction have been taken into account. For this purpose, a BPR[5] function was used, which reflects the travel time dependency on the traffic load and road capacity.

[5] The Bureau of Public Roads (BPR) function, relating the travel time to the flow. It is based on the travel time under free-flow conditions and the practical capacity of the link under consideration.



Picture 17. ADT of private and public transport in the project zone (ADT= average daily traffic)

4.5 Model calibration and validation

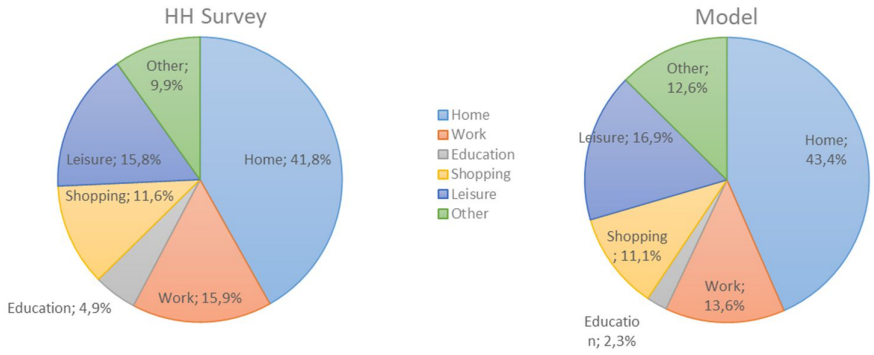
The transport model represents one of the key basis for decision-making on transport and spatial policy, on investments in the infrastructure that requires time and financial resources, on the shape and dimensions of roads and their impacts, etc. It is therefore important that the model results are reliable.

Reliability and credibility are the key characteristics of good and useful transport models. The necessary precision of the model is achieved by calibration, whilst the reliability and credibility required are confirmed by validation.

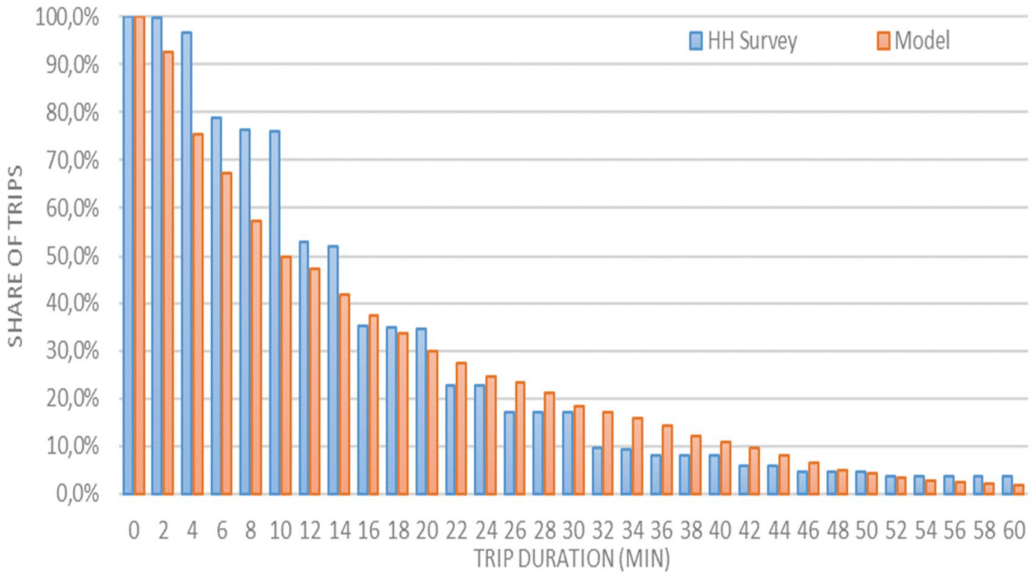
Calibration and validation are two very important steps, independent of each other, yet related. Calibration is the procedure of more detailed definition of model parameters (the mobility rate, the distribution function, the modal distribution…) so that the model results correspond to the observed conditions in the studied areas as much as possible.
Validation is a verification and confirmation of the validity and usability of the calibrated model as well as credibility of its forecasts. To assure the model validity, all the steps of the 4-phase approach have been calibrated and confirmed.

4.5.1 Model calibration

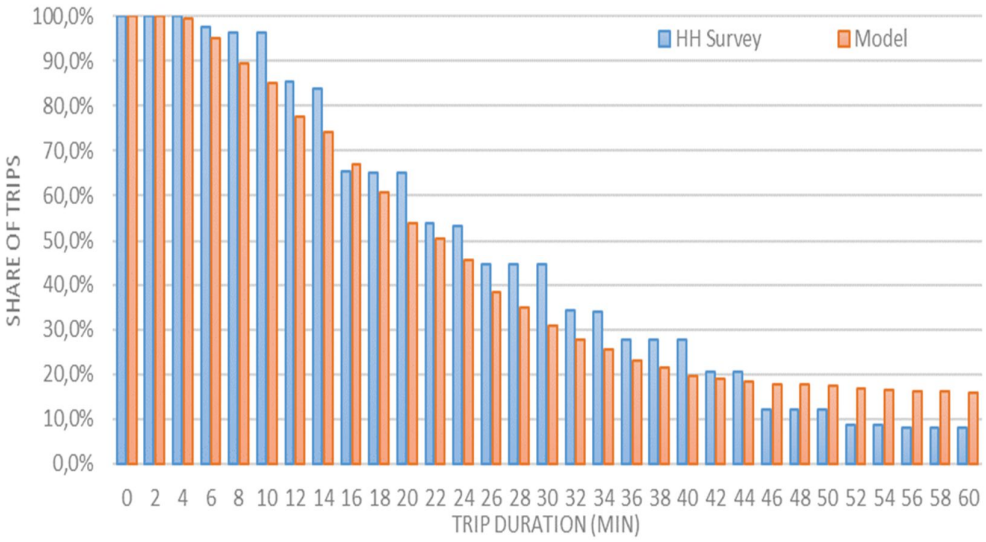
The trip generation was validated by comparing the production and attraction results to the results from the household survey.
The model has modelled a total of 90,916 journeys resulting in a mobility rate of 2.55 trips per capita. The activities with the attraction purpose home, i.e. activities work-home, school-home, shop-home and other-home make a total of 43,4% trips altogether. The next is the activity home-leisure with the share of 16,9% of trips. Then there are activities „home- work“ and “other- work“ with the share of 13,6%, the activity „home-other“ with the share of 12,6% of trips and the activity home-shopping with the share of 11,1%. The least was generated by the activity home-school with the share of 2,3% of all trips. The calibration result of the travel generation process is shown in the following picture.



Picture 18. Distribution of all trips according to the purpose



Picture 19. Individual trip distribution by private car (blue- household survey, red- model)

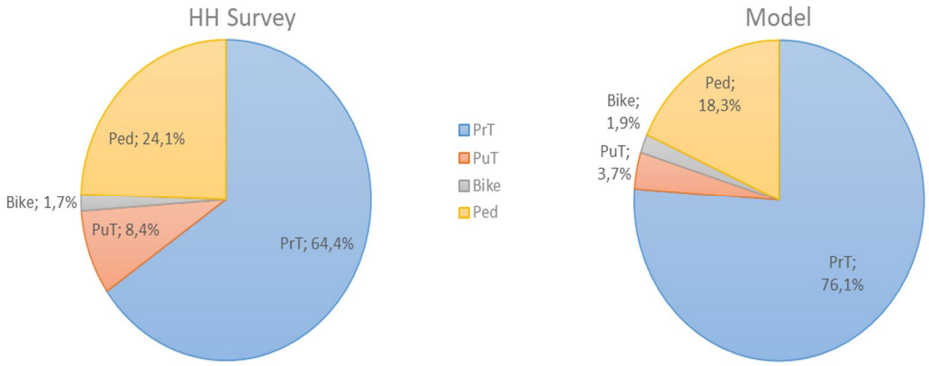


Picture 20. Trip distribution by public transport (blue- household survey, red- model)

The trip distribution was verified by comparing the source-target matrix volumes calculated using trip patterns observed in the research at different cross sections, outer cordons and the public

transport system. Furthermore, a comparison was performed between model results and observation data for trip distance and time travel distribution.

To verify the choice of the trip mode, the shares of transport mode according to the trip purpose derived from model calculation have been compared to indicators from the household survey. From the total number of trips, 76,1% of trips are done by private car. The next is walking with 18,3%, trips by public transport with 3,7% and bicycle travel with 1,9% of travels.



Picture 21. Travel distribution according to the means of transport

4.5.2 Model validation

The trip assignment for the road traffic is validated by comparing calculated vehicle volume at road cross sections of main national links, at cross sections and cordon lines according to the observed traffic data. Regarding the traffic volumes, the assignment validation is made according to the following four criteria:

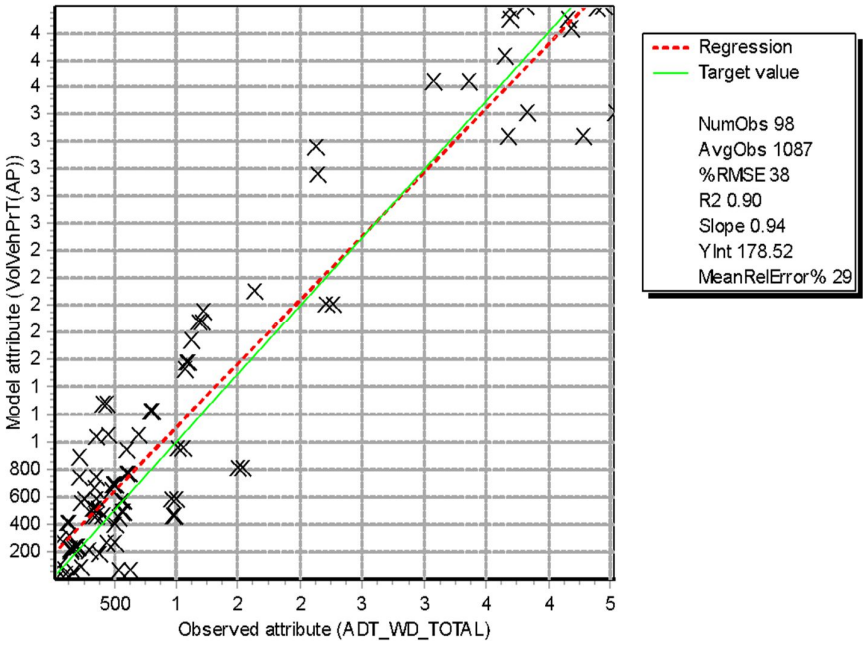
- by the correlation analysis (R2> 0.9),
- by the analysis of standard deviation of RMSE[6],
- by statistical analysis of GEH[7] values at all cross sections, cordons and control lines (GEH <5 at minimum of 85% locations, GEH <10 at minimum of 95% locations)

Using the analysis of observed and modelled traffic flows at 86 locations for the period off-season we calculated the correlation coefficient of 0,950, i.e. the determination coefficient R2=0,903 and

[6] RMSE - Root Mean Square Error (https://www.statisticshowto.com/probability-and-statistics/regression-analysis/rmse-root-mean-square-error/)

[7] GEH - The GEH Statistic (https://en.wikipedia.org/wiki/GEH_statistic)

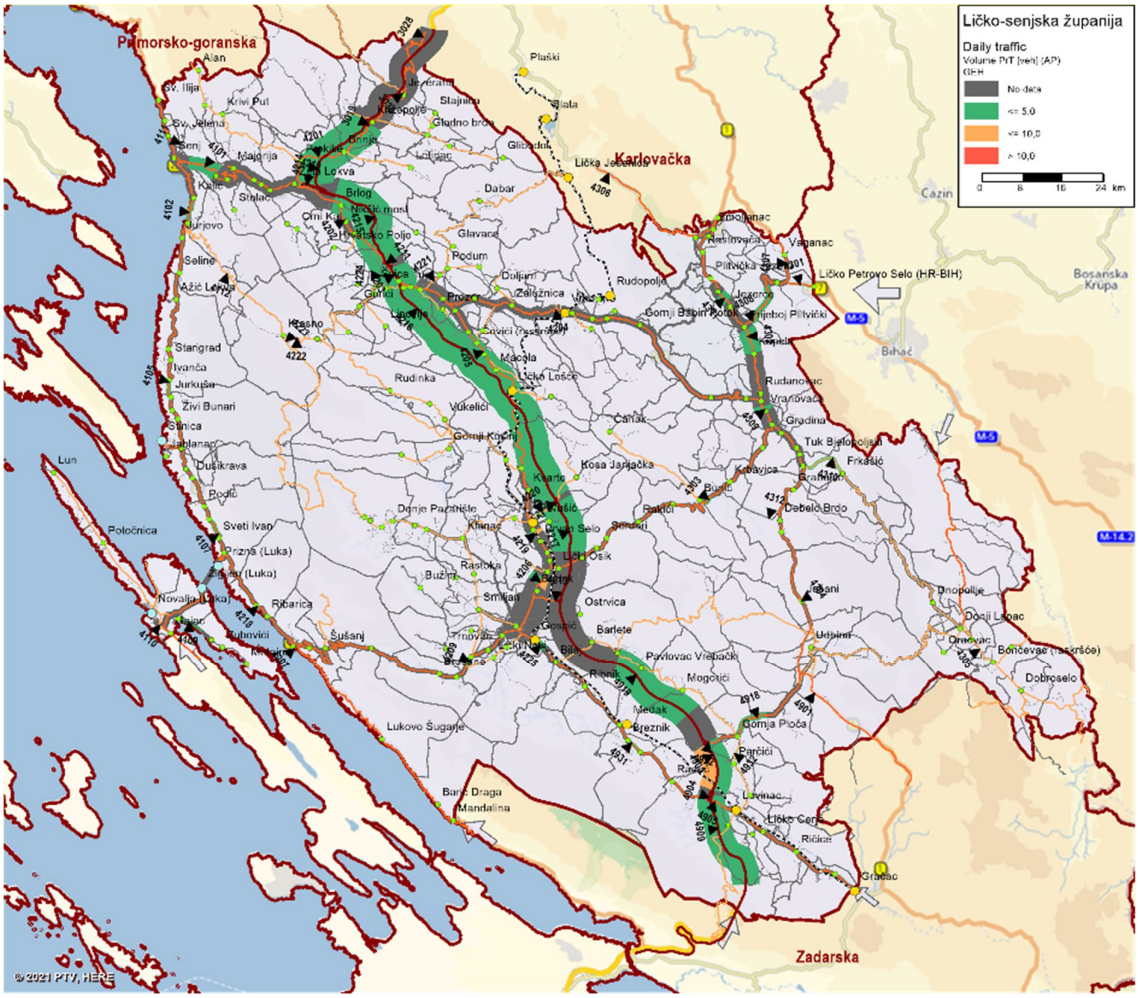
the standard error estimate RMSE=37,8%. This analysis includes the comparison of modelled traffic flows and the observed traffic flows in four different sources and timelines, i.e. the data from continuous and occasional automatic traffic counting by HC, continuous automatic counting and toll counting by HAC, and the traffic counting done within the Master Plan of the functional region Northern Adriatic.



Picture 22. The correlation between the observed and modelled traffic flows, off-season

For the model off-season, according to the statistical analysis of GEH values at all counting locations, 82/98, i.e. 84% of counting locations have GEH value less than 5, while 100% of counting locations have GEH value less than 10. The traffic load validation according to the statistical analysis of GEH values is shown in the following picture.

Calibrated and validated model is the basic tool for analysis of the current state of the traffic system and is the basis for creating future scenarios and the implementation of future cost-benefit analysis.



Picture 23. The validation of traffic load according to the statistical GEH values analysis, off-season

4.6 Annual daily traffic analysis

Based on an analysis of the annual hourly traffic distribution at the automated traffic count location 4206 Budak between Gospić and Lički Osik, three typical classes have been determined:

1. Class, representing the maximum of 300 hours and which usually represents dimensioning criteria
    - hour is 9,9 % AADT[8];

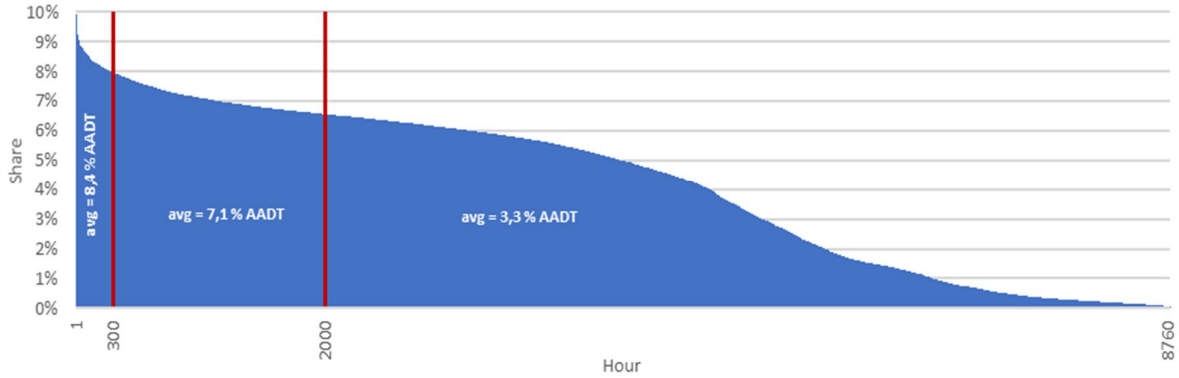
[8] AADT – Annual Average Daily Traffic

- 30. hour is 8,9 % AADT;
- 100. hour is 8,5 % AADT.

On average, the first 300 hundred hours make 8,4% of AADT.

2. Class represents 301. to 2000. hour according to the volume. The majority of these hours occur in summer months (June, July, August).
   On average 301. to 2000. hour make 7,1% of AADT.

3. Class is represented by other hours, where there is little time loss due to congestion, since the traffic share is below 6,6% of AADT.
   Other average hours make 3,3% of AADT.



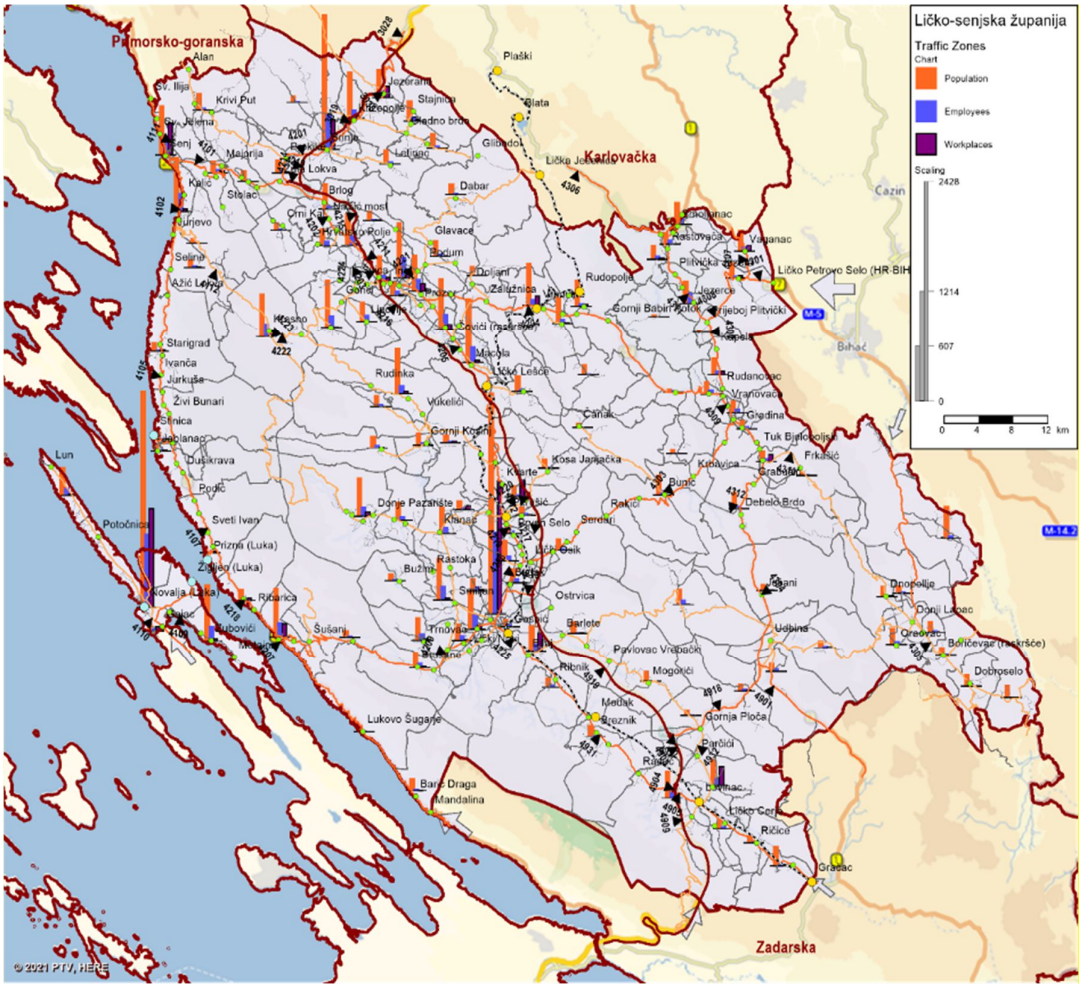
Picture 24. Annual hourly traffic distribution at the automatic traffic counting location 4206 Budak

4.7 Functional analysis of traffic in the observed area

The functional analysis includes analysis of socio-economic variables (population, employees and jobs in general) that have a direct impact on traffic demand, i.e. the generation and distribution of traffic flows. Furthermore, the functional analysis includes the analysis of the traffic network through demonstration of accessibility, saturation and reduction of the traffic flow speed at the traffic network.

4.7.1 Functional analysis for regional and local needs

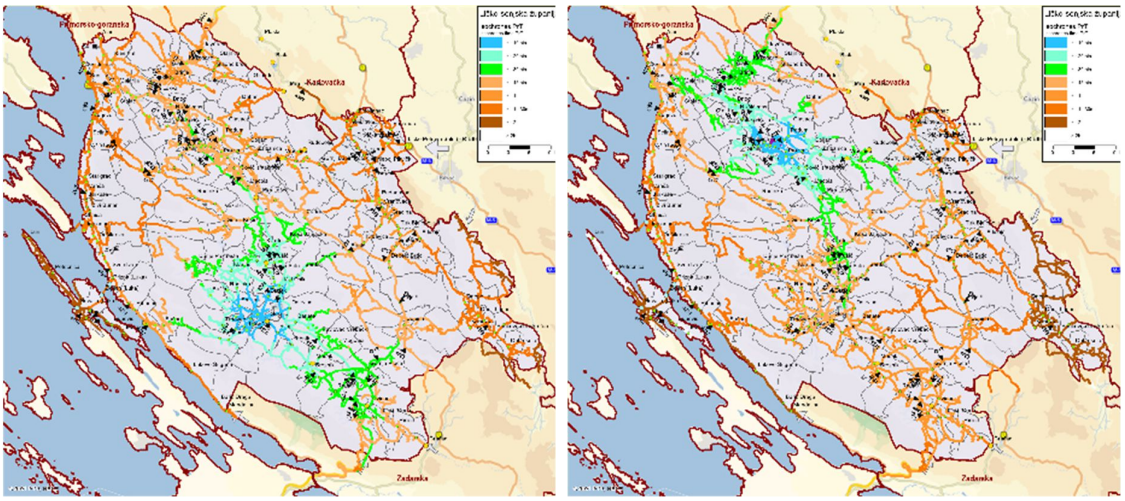
With only 50,927 inhabitants according to the 2011 Census, the area of Lika-Senj County is the least populated area in the Republic of Croatia. The population lives mainly in urban areas, slightly less than 13 thousand residents in the town of Gospić, the administrative seat of the county, almost 10 thousand in Otočac and slightly more than 7 thousand in Senj. The remaining local self-government units have a population of just over 20,000 residents.
According to the data from the 2020 the majority of the total 13.5 thousand jobs are in the cities. In the town of Gospić alone, there are almost 5 thousand jobs, 2 thousand in the area of Otočac, and 1.5 each in the area of Senj, Plitvice Lakes and Novalja.



Picture 25. Spatial distribution of socio-economic components (population, employees, workplaces)

The County area is intersected by several important traffic corridors. The most important road corridor is the A1 Zagreb - Split motorway, which passes through the central area of the County, connecting the towns of Gospić and Otoče, and the entire county to the north and south with the rest of the Republic of Croatia. The motorway network is supplemented by the network of state roads, of which D1 Gornji Macelj (A2) - Krapina - Zagreb - Karlovac - Gračac - Knin - Brnaze - Split (D8), D8 G.P. Pasjak (gr. R. Slovenije) - Šapjane - Rijeka - Zadar - Split - G.P. Klek (gr. BiH) - G.P. Zaton Doli (gr. BiH) - Dubrovnik - G.P. Karasovići (town of Montenegro), D50 Žuta Lokva (D23) - Otočac - Gospić - Gračac (D27), D23 Duga Resa (D3) - Josipdol - Žuta Lokva - Senj (D8) and D25 Korenica (D1) - Bunić - Lički Osik - Gospić - Karlobag (D8).

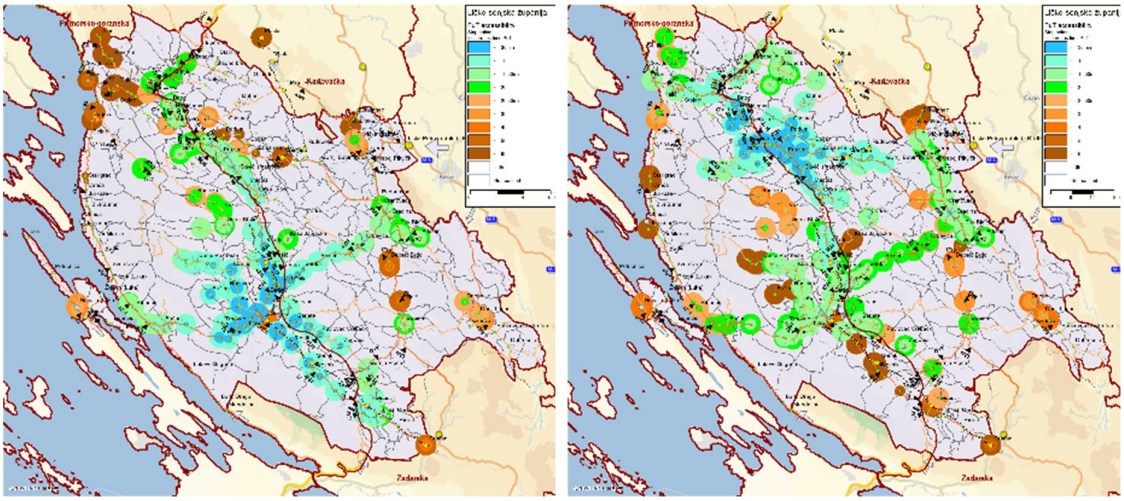
The existing road network enables very good interconnection of the central parts of the county, especially the parts located along the motorway, while the peripheral areas, especially the coastal ones, are relatively poorly connected. For example, the most remote areas from Gospić or Otočac are accessible by motor vehicles for up to 2 hours. Also, the motorway network enables a very good connection of parts of the county to the counties with the rest of the Republic of Croatia.



Picture 26. Accessibility by private transport (Gospić left, Otočac right)

The M604 Oštarije - Gospić - Knin - Split railway crosses the Lika-Senj County and connects the county with the rest of the Republic of Croatia. Unfortunately, only two passenger trains on the route Zagreb GK - Split pass on the daily line, more precisely one in each direction. The situation is

similar with the inter-county bus transport of passengers, which mainly on the routes between the City of Zagreb and larger cities in Dalmatia, only pass through the Lika-Senj County.
Therefore, the backbone of public passenger transport in the county is the county bus passenger transport. Due to the county's demand, bus lines are organized mainly with routes and timetables suitable for transport of pupils to primary or secondary schools. Such an organized public transport network results in long journeys and poor accessibility of certain parts of the county.
An example of the accessibility of the city centres of the City of Gospić and Otočac by public passenger transport is shown in the following figure.



Picture 27. Accessibility by public transport (Gospić left, Otočac right)

4.7.2 Usage of the transport model results in development of the new sustainable mobility solutions

Results of the developed transport model are providing clear insights which will contribute to the improvement of the public transport passenger flows in the analysis area of Lika-Senj County. From the data collected throughout various researches, counts and surveys, and then used in the development of the transport model, it is clearly seen that there is plenty of the Lika-Senj County citizens that are living in rural areas with very limited availability of the public transport, and limited availability of personal cars, which is affecting the quality of the life and availability of the life existing services like health and social services. Developed transport model provided insights that city of Gospić, where most of the social and health institutions are placed, is not very well connected with

public transport with rural areas of the Lika-Senj County. It is recommended that mentioned transport model is continuously updated and used in future period where results of the implemented improvements and measures should be assessed through it.

Performed analysis and developed transport model results clearly show that Lika-Senj County is a very large area to be covered efficiently with traditional public transport services. Implementation of the traditional public transport lines and services would not be efficient given the fact that there is a small number of inhabitants spread across very large area throughout the Lika-Senj County. In that sense, the only possible way to address the challenges that Lika-Senj County and its inhabitants are facing, is the usage of new sustainable and smart mobility solutions, with the goal of improving the public transport passenger flows. This analysis and developed transport model are clearly showing that people are living in rural areas and that accessibility to those rural areas with public transport is not good, and also that most of the region gravitates toward the centre of the Lika-Senj County, which is Gospić. Since the analysis has shown that traditional public transport would not be an efficient option, it is clear that there should be tested and implemented some kind of public transport on demand that is supported throughout usage of new sustainable and smart mobility solutions. In this study alternative and smart mobility solutions that could solve the main problem mentioned above (low accessibility for rural inhabitants to health and social services) have been assessed and analyzed. We have analyzed potential new sustainable and smart mobility solutions that could be adopted among which we have selected the most feasible one. Services assessed which could be adopted were small electric busses or mini vans which would be serving newly defined public transport network covering rural areas, but this analysis has brought to conclusion that there is plenty of the small villages with just a few citizens which would this kind of service make very expensive. Also, it was assessed how the railway network could be used more efficiently, but this option was also defined as not feasible one given the fact that the railway network is not developed. The third and the most feasible solution that was assessed was the development of an application for mobile phones throughout which citizens from the rural areas, that are not connected with the City of Gospić with public transport, will be able to order transport on demand which will allow them to access health and social services.

Table 9. Lika-senj county new sustainable and smart mobility option analysis

No.	Option	Pros	Cons
1.	Traditional public transport using CNG or electricity	Environmentally friendly service known to the wider public	Financially non-feasible since there is plenty of dispersed rural places with very small number of older inhabitants which are not traveling often

2.	Small electric buses or mini vans	Environmentally friendly service known to the wider public	Fairly financially non feasible if there is plenty of dispersed rural places with very small number of inhabitants which are not traveling often
3.	Use of the railways	Environmentally friendly service known to the wider public	There is no established railways network that would support commuting of the inhabitants from dispersed rural places
4.	On-demand transport using apps on smart phones for demand and supply of the service	Cost-efficient and environmentally friendly transport service	Risk of not having enough interested subjects to provide this kind of transport service

Since in the Lika-Senj County there are no available smart solutions that would solve public transport challenges that inhabitants are facing, logical way would be development of an application (App) for mobile phones which will cover relevant commuting needs. In order to define clear processes and functional requirements of the App it was required to assess current state, understand the challenges that citizens of the county face today. Based on the developed transport model results, covering availability of the public transport in rural areas and defined transport zones, there was assessed and defined optimal model for the public transport on demand for the people in need for the health and social services. Results of this analysis were taken in consideration as a relevant input during the phase of development of the business model and functional specification of the future mobile App that should serve as an new sustainable mobility solution. Smart mobility solution will consist of the front-end and back-end. Front-end will be mobile App available for download from App stores and all citizens will be able to download it and use it on their mobile phones. Throughout this front-end, citizens will be able to easily order on demand public transport service which will be provides to them by approved transport providers which will also have the mobile App on their phones throughout which they will track orders and deliver transport services. Throughout back-end, LIRA and Lika-Senj County will manage the providers of the service, fees related to the specific routes, define zones and manage payments to the providers of the service. Analysis performed throughout WP4 has provided inputs in defining which model and solution of the new sustainable mobility is the most appropriate for Lika-Senj County, and based on the transport model developed in this study, **optimal tariff zones** were defined. These tariff zones will be used in the new service and App foreseen in the MIMOSA WP5.