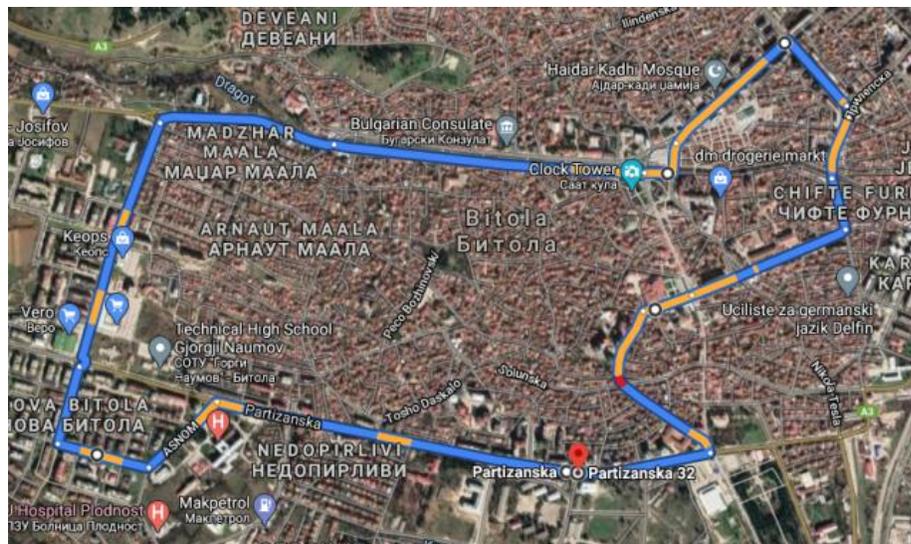


EXPERTISE

for routes and timetables of electric vehicles for passenger transport in the municipality of Bitola

Green Inter-e-Mobility – CN1 – S.0 2.1 – SC 039



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1. INTRODUCTORY NOTES, GOALS AND METHODOLOGY OF WORK

1.1. Introduction

Recently, many efforts have been made globally to support sustainable mobility, in order to address the problems of urban air pollution and fossil fuel dependence. In this regard, the application of electric vehicles is considered one of the best environmental and economic solutions.

Electric vehicles are an important part of sustainable urban transport, as they are a clean mode of transport and environmentally friendly. This type of vehicle does not emit exhaust emissions, it is quieter, more energy efficient and structurally simpler, which leads to lower maintenance costs. In addition, electric vehicles have no harmful health effects compared to fossil fuel vehicles and consume less energy, even at the same weight.

As part of the project "Integration of Green Transport in Cities" with the acronym "Green Inter-e-Mobility" in the municipality of Bitola will be procured two electric vehicles (passenger vehicle and minibus), a photovoltaic station and a charging station will be built. The two electric vehicles in the municipality of Bitola intended for passenger transport make the first step in promoting this technology and in supporting the sustainable development of urban transport in the municipality.

Electric vehicle transport is expected to boost energy efficiency and transport sustainability in the cross-border region as well. This will be achieved through the realization of trips (sports, tourism, work, research, etc.) in the cross-border region: municipalities of Bitola and Resen in the Republic of North Macedonia and municipalities of Florina and Prespa in Western Macedonia in Greece. Cross-border connection with electric vehicles will also contribute to strengthening relations between the population of the two countries.

This study was prepared within the project "Integration of Green Transport in Cities" in order to define and design the routes and timetables for electric vehicles in the municipality of Bitola.

The study propose and completely develop three urban routes and four tourist routes in the region (including the cross-border region), in order to provide comfortable, modern and clean passenger transport. The destinations of the urban routes are the following: NUI Library "St. Kliment Ohridski ", sports complex, City Market and Old Town Bazaar. The destinations of the tourist routes are the village of Trnovo, the village of Pretor, Ohrid and the cross-border towns of Bitola, Resen, Prespa and Florina.

The study describes in detail these routes and the weekly timetable. Thereby, the potential categories of passengers for which the transport with electric vehicles is intended are emphasized. The priority in the service is set primarily on the vulnerable groups of the population, in order to facilitate their daily transportation needs. So, the offered option for sustainable mobility with electric vehicles will be primarily intended for transportation of the following categories of citizens: people with disabilities, the elderly, athletes, pupils, students and tourists.

The planning of the routes is performed by observing the limitations in the driving range of the electric vehicles when the electric battery is fully charged. All proposed routes are shown on a map with certain parameters: stops, route length and duration of the trip in total on the entire route.

The study also provides a vision for the sustainability of the offered type of transport with electric vehicles for a period of 20 years, taking into account the depreciation of vehicles and batteries. In this regard, recommendations for extending battery life are provided. The selection of optimal routes that will follow the demographic and urban changes in the city and the realization of passenger transport by electric vehicles will contribute to reducing transportation costs in both regions over a period of 20 years.

Regardless of the small number with which electric vehicles will be represented for the first time in public transport in the municipality of Bitola, it is still important to emphasize their role in the development of sustainable urban transport. Transportation of passengers by electric vehicles will contribute to improving the urban quality of life, raising public awareness of "green" mobility and greater confidence in the municipality in dealing with environmental pollution problems.

1.2. Goals of the work

The main goal of the "Green Inter-e-Mobility" project is to design and implement an energy efficient, regional intelligent transportation system that will support the efficient implementation of cross-border tourism promotion, daily transportation of students and facilitate residents in their daily transportation.

Regarding the schedule of the routes, the specific goal includes defining the routes for the purchased electric vehicles according to their purpose, the technical specifications (range), the configuration of the streets and the terrain, the placement of the bus stops, etc. The definition of the routes should be done according to the national and local legislation for the current situation (immediate implementation) and a period of 20 years.

For the realization of this goal it is necessary to perform:

- defining several routes for electric vehicles according to the needs of the municipality of Bitola, the configuration of the road network, the location of the charging station, the placement of the bus stops and the technical specifications (range) of the vehicles
- forecast for the development of the routes for the next 20 years in relation to the condition of the electric vehicles, the condition of the batteries, the charging station, the bus stops, etc.

Three routes per municipality will be defined, each of the routes on a daily basis will be an average of 10 km, serving an average of 25 citizens per day. Priority will be given to vulnerable social groups, such as the elderly, people with disabilities, pupils and students, whose daily transportation needs can be alleviated, thus increasing their quality of life.

1.3. Methodology of the work

During the preparation of the study, the methodology for optimal routing and charging schedule for electric vehicles should be applied. In doing so, several components need to be considered.

- *Routing of electric vehicles.* In addition to the usual routing approaches (shortest distance and fastest travel), electric vehicles should be routed with particular attention to minimizing energy consumption. Two steps can be considered for routing electric vehicles. The first step is to find routes of minimum consumption for travel between two points. In this step, it is necessary to take into account the technical characteristics of electric vehicles. The second step consists in determining the optimal routes to meet the demand for transportation to different destinations, while minimizing energy consumption. Similar to the first step, the calculation of the optimal routes is performed considering the characteristics of the electric vehicles.
- *Charging schedule.* This process should be coordinated with the routing schedule to ensure reliable operation, whereby charging costs will be minimized and there will be no disruption to the timetable. Additionally, for the charging schedule, it is necessary to consider the time required for charging electric vehicles.
- *Battery lifespan.* The goal is to increase battery lifespan to reduce long-term operating costs. It must be taken into account that the useful life of the battery depends on the charge and discharge cycles. This aspect is relevant because the battery is the most expensive component of electric vehicles.

With the realization of the methodology for work, the following specific tasks will be realized, shown below.

- Definition of the desired destinations for electric vehicles in coordination with the municipality of Bitola.
- Proposal for optimal routes (description and visualized on a map) for each desired destination, taking into account the above components.
- Vision for the development of the routes in the next 20 years, taking into account the condition of the battery, the condition of the charging station and the changes in the bus stops.

The methodology for defining and designing the routes in the study from the University of Patras, attached to the Annex, generally follows the recommendations defined in the project concept, with the exception of the vehicle charging schedule, battery extension recommendations and the vision for development in the next 20 years.

With a detailed analysis of the routes determined in the study for the municipality of Bitola prepared by the University of Patras, incomplete definitions and omissions of some components were determined. The following are general and detailed remarks of the study by the University of Patras, compared with the changes made in this study.

General remarks:

- the study defines only two urban routes, and is more focused on tourist routes, which are proposed to be performed on weekends; the definition of only two urban routes, both of which do not serve the peripheral settlements in the town, is insufficient to meet the transport needs of the indicated categories of citizens
- the charging schedule of the electric vehicles is left out
- the vision, i.e. the forecast for development in a period of 20 years is left out
- no recommendations are given for extending the life of the batteries of electric vehicles
- the proposed urban routes do not include the peripheral settlements, i.e. the urban routes are aimed at serving the transport needs only in the wider central town area; therefore, in this study one of the urban routes serves the peripheral settlements Brusnik and Dovledzik
- the initial and final stop for each of the routes is the Sports Hall "Boro Churlevski", where there are no bus stops, which from a security and legal point of view is unacceptable; in this study, the initial and final stop for each of the routes are the bus stops near the Sports Hall "Boro Churlevski".

Detailed remarks

Route 1: destination NUI Library „St. Kliment Ohridski“

Remark 1: The route has a stop at the Primary School "Gjorgji Sugarev". However, next to this school there is no bus stop where the electric minibus would stop, which from a safety and legal point of view is unacceptable and inadmissible.

Remark 2: The route provides a stop right in front of the library itself, where there is also no bus stop. In fact, the service offered by the electric minibus is a public transport service, not a taxi transport, which makes it impractical and unsafe for passengers to be transported "door-to-door". Therefore, it is sufficient for passengers to be transported to the nearest bus stop which is within walking distance of the final destination. In this study, the electric minibus stops at the former "Epinal" bus stop, which is a 237-meter walk from the library.

Remark 3: Due to the one-way flow of traffic around the library, the electric vehicle, after stopping in front of the library, makes a larger circle on the surrounding streets to exit on Partizanska Street. With the proposal in this study, the electric vehicle, after stopping at the bus stop "Epinal", without unnecessary detours around the library, with a simple continuation of the movement is included from the street "St. Kliment Ohridski" on the street "Partizanska".

Route 2: destination City stadium

Remark 1: The final destination is the city stadium in Bitola, where there is also no bus stop, which is unacceptable from a security and legal point of view.

Remark 2: The route has a stop at the Primary School "Gjorgji Sugarev". However, next to this school there is no bus stop where the electric minibus would stop, which from a safety and legal point of view is unacceptable and inadmissible.

Remark 3: The route has a stop at the Primary School "Dame Gruev", where there is also no bus stop, which is unacceptable from a security and legal point of view.

Route 3: destination village Trnovo

Remark 1: This route is proposed to be performed on a daily basis. But it serves only stops on the streets "Partizanska" and "General Vasko Karangelevski". As a tourist route, it does not serve the stops in the central part of Bitola, where the frequency of tourists is higher. Therefore, in this study, the route has a completely new line with stops in the downtown area ("Javor" and "Scheherazada").

Remark 2: The destination in the village of Trnovo is not well defined, i.e. there is an unnecessary circular movement around the church "St. Bogorodica" and usage of unpaved roads. In this study it is proposed electric minibus to stop and turn in the wide area in front of the church.

Route 4: destination village Pretor

Remark 1: The only remark refers to the location of the destination, which is not well established - namely, the route enters and circles the village. Instead, it is proposed to use the widening of the road in front of the entrance to the village to stop the minibus.

Route 5: destination Krushevo

Remark 1: Krushevo is located at an altitude of 1350 meters. To overcome higher altitudes, the electric vehicle will consume more energy, and the amount of energy consumed can only be determined through special models and simulations, which in this case is not done. Such models that would make a very accurate analysis are not available, so the route to Krushevo is not proposed in this study.

Route 6: destination Ohrid

Remark 1: The destination in Ohrid has not been determined at all. In this study, it is proposed that it be directly next to the bus station in Ohrid, from where passengers can easily manage transportation to their final destination in Ohrid.

Route 7: destination Bitola-Resen-Prespa-Florina

Remark 1: The difference with the route proposed in this study is in the location of the initial and final stop, which according to the study of the University of Patras are located in the Sports Hall "Boro Churlevski", and in this study they are located near the Sports Hall "Boro "Curlevski".

Remarks for the timetable:

- in the timetable during the working days several hours of work are missing, i.e. the timetable from 08:24 – 09:00; 9:55 – 11:00; 11:55 – 13:00; 14:29 – 16:00; 16:54 – 18:00; 18:54 – 20:00; 20:24 – 21:00 is left out
- the timetable during the days of the weekend is made only for the first two weekends of the month, but not for the other two; it is unclear whether the proposed timetable will be repeated for the last two weekends of the month, or it is simply omitted to make a schedule for those two weekends as well.

According to the presented detailed analysis of the study prepared by the University of Patras, which identified a number of shortcomings, this study in principle follows the methodology of design defined according to the conditions in the project, but offers complete solutions that overcome all shortcomings.

2. PROCESS OF DEFINING ROUTES FOR ELECTRIC VEHICLES

This part covers the analysis of the complete process of routes definition, starting with general characteristics of the process and specific characteristics of the electric vehicles that will be procured for the municipality of Bitola. All these data have been taken into account during the preparation of the routes and timetables, including the data for the more important locations for destinations for urban and tourist trips.

2.1. General characteristics of the routing process

The process of designing the routes and defining the timetables is based on certain data, which primarily refer to the need for mobility and the mode of transport in everyday urban travel in the municipality of Bitola.

In addition, an analysis is made of the schedule of lines of the existing public transport, for which data was submitted by the Municipality of Bitola. This is necessary in order for the studied data to be thoroughly used in the route planning process, in order to offer optimal transportation alternatives.

Route planning includes data for the starting and ending point (destinations) of travel. In addition, the categories of citizens for whom electric vehicle transport is primarily intended have been identified, namely the elderly, people with disabilities, pupils, students, athletes, residents of suburban areas and tourists.

Travel, whether urban or tourist, consists of a starting point and an end point, i.e. a destination. The design of the routes is done according to an established procedure:

- determining the starting and ending point of the trip
- determining the stops for the public transport where the vehicles will stop, which are at a walking distance
- determining the public transport stop closest to the destination, which is at a walking distance
- determining the schedule for the charging time of the electric vehicles at the charging station.

Existing bus stops throughout the town will be used as stops in each of the proposed routes. During the selection of these stops while creating the routes, and in cooperation with the Municipality of Bitola, special attention was paid to their attractiveness for the journeys, which is primarily related to the daily needs of citizens for education, health, sports and recreation, for shopping, socializing, etc.

The routes defined in this study apply to the electric minibus. According to the Law on Road Transport in the part of the capacity of the vehicles for passenger transport, where the minimum number of seats for line, free and special type of transport is 8+1 (without the driver's seat), the passenger electric vehicle can not to perform public transport of passengers on defined routes and using the bus stops. Therefore, for this vehicle it is proposed to perform door-to-door taxi transport for those categories of citizens who need such transport the most, and that is people with disabilities. The passenger electric vehicle can perform daily taxi transport of pupils with disabilities at relation home - primary school "Gjorgji Sugarev" as well as urban and tourist transport of members of associations with disabilities in the municipality of Bitola.

Unlike conventional routing approaches, which determine the shortest distance or the fastest route to a destination, the analysis in this study plans the routes for electric vehicles by finding the energy optimal solution, taking into account the battery capacity. So, the goal is to define the route from the starting point to the destination point with the least amount of energy consumed. This goal is extended to determine the shortest travel time as well as the optimal route for maximum battery life in electric vehicles.

According to the requirements and conditions in the project, in the municipality of Bitola should be defined three routes, on average 10 km each, which would served an average of 25 citizens per day.

The routes and timetables proposed and developed in this study include three urban routes and four tourist routes. They are all based on a detailed analysis of previous features and data.

2.2. Specific characteristics of the electric vehicles

The fleet of electric vehicles for the municipality of Bitola, which will perform public transport of passengers, consists of one electric passenger car and one electric minibus.

The electric passenger car has five seats (4+1), and the electric minibus has 9 seats (8+1), including the driver's seat. The autonomy of the combined cycle of the passenger electric car is 270 km, and for the city cycle 389 km. As for the minibus, the autonomy of the combined cycle will be 200 km, while the autonomy of the city cycle will exceed 300 km.

To charge the two electric vehicles, an appropriate charging station will be built, and a grid-connected photovoltaic system will be installed to generate electricity. Photovoltaic panels will be installed on the roof of the Sports Hall "Boro Churlevski" in the municipality of Bitola. Figure 1 shows the location of the selected object.



Figure 1: Location of the Sports Hall "Boro Churlevski" in Bitola

Source: Google Maps

The charging station will be located in the parking lot in the yard of the Sports Hall "Boro Churlevski". Therefore, the starting and ending point of each route will be the bus stops in the immediate vicinity of the Sports Hall "Boro Churlevski", where the electric vehicles will be charged.

2.3. Definition of the routes

The location of the charging station for electric vehicles determines the beginning and the end of each trip, i.e. each route. Therefore, the bus stops that are closest to the Sports Hall "Boro Churlevski" will be the places where the trips will start, i.e. where they will end.

The basis for creating the proposed routes are the data and information provided by the Municipality of Bitola, which refer to the destinations of urban and tourist travel according to their attractiveness, the schedule of services in public transport and the characteristics of mobility of residents in daily travel.

Table 1 shows the proposed routes, which are designed according to a previous analysis.

Table 1: Routes for electric vehicles in the municipality of Bitola

Route 1		Destination: NUI Library „St. Kliment Ohridski“
Stops	1	23 „Kasarna“
	2	19 „Bolnica“
	3	47 „Ruzha Delcheva“
	4	17 „Vero 2“
	5	15 „Pedagoshka 2“
	6	35 „Muzichko“
	7	10 „Javor“
	8	31 „At-pazar“
	9	Epinal (near the library)
	10	23 „Kasarna“
Route 2		Destination: Sports complex - Sports hall "Boro Churlevski", town stadium, handball court, football and tennis courts
Stops	1	23 „Kasarna“
	2	19 „Bolnica“
	3	47 „Ruzha Delcheva“
	4	„Diskont“
	5	„Dovledzik“
	6	„Pedagoshka 1“
	7	35 „Muzichko“
	8	10 „Javor“

	9	31 „At-pazar“
	10	50 „Zeleznicka stanica 1“ (near the sports complex)
	11	24 „Rakometno“ (near the sports complex)
	12	23 „Kasarna“
Route 3		
		Destination: Town Market and Old Town Bazaar
Stops	1	23 „Kasarna“
	2	19 „Bolnica“
	3	17 „Vero 2“
	4	15 „Pedagogoshka 2“
	5	35 „Muzichko“
	6	10 „Javor“ (Town Market and Old Town Bazaar)
	7	7 „Dulie 2“
	8	31 „At-pazar“
	9	26 „Ruska Crkva“
	10	50 „Zeleznicka 1“
	11	23 „Kasarna“
Route 4		
		Destination: village Trnovo (church "St. Bogorodica") – <i>tourist route</i>
Stops	1	25 „Rakometno“
	2	30 „At-pazar“

	3	11 „Sheherezada“
	4	village Trnovo church "St. Bogorodica"
	5	10 „Javor“
	6	31 „At-pazar“
	7	24 „Rakometno“
Route 5		
		Destination: village Pretor and Lake Prespa - <i>tourist route</i>
Stops	1	23 „Kasarna“
	2	17 „Vero 2“
	3	15 „Pedagoshka 2“
	4	village Pretor and Lake Prespa
	5	14 „Pedagoshka 2“
	6	16 „Vero 2“
	7	22 „Kasarna“
Route 6		
		Destination: Ohrid – <i>tourist route</i>
Stops	1	23 „Kasarna“
	2	17 „Vero 2“
	3	15 „Pedagoshka 2“
	4	Ohrid
	5	14 „Pedagoshka 2“

	6	16 „Vero 2“
	7	22 „Kasarna“
Route 7		Destination: Bitola-Resen-Prespa-Florina <i>tourist route</i>
Stops	1	23 „Kasarna“
	2	Resen – town hall
	3	Prespa - town hall
	4	Florina – town hall
	5	23 „Kasarna“

The destination of the first route is NUI Library "St. Kliment Ohridski", which was chosen because it is a national, modern and cultural institution, with frequent visits from pupils, students, researchers and readers.

Figures 2 and 3 show the location and front view of the NUI Library "St. Kliment Ohridski".

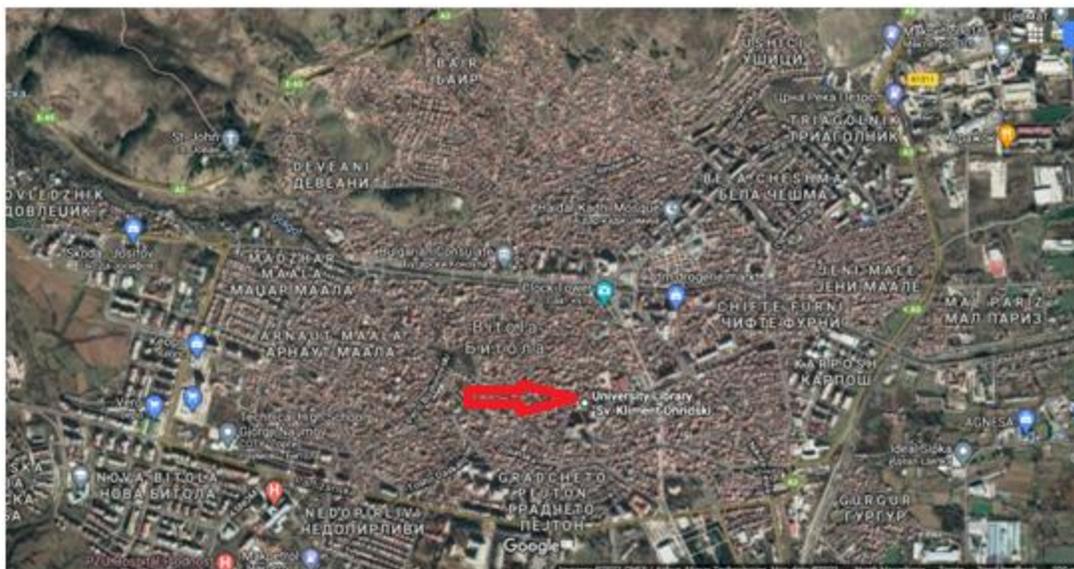


Figure 2: Location of the NUI Library "St. Kliment Ohridski" in Bitola

Source: Google Maps



Figure 3: NUI Library "St. Kliment Ohridski"

Source: [mk.wikipedia.org/wiki/Универзитетска_библиотека_„Св_Климент_Охридски“_\(Битола\)](http://mk.wikipedia.org/wiki/Универзитетска_библиотека_„Св_Климент_Охридски“_(Битола))

Stop 23 "Kasarna" which is near the Sports Hall "Boro Churlevski" is the initial and final stop on this route. This route is 7.5 km long and takes 19 minutes.

As intermediate stops the following are defined:

2. 19 „Bolnica“
3. 47 „Ruzha Delcheva“
4. 17 „Vero 2“
5. 15 „Pedagoshka 2“
6. 35 „Muzichko“
7. 10 „Javor“
8. 31 „At-pazar“
9. Epinal (near the NUI Library "St. Kliment Ohridski").

The second route leads to the destination sports complex, which includes the Sports Hall "Boro Churlevski", town stadium, handball court, football and tennis courts. This destination is attractive primarily for athletes and recreationists. The town park is located here, which attracts a large number of citizens for a walk in the greenery. Figures 4 and 5 show the location of the sports complex in Bitola and the appearance of the constituent units in this complex.



Figure 4: Location and composition of the sports complex in Bitola (1 - Sports Hall "Boro Churlevski"; 2 - handball court; 3 - tennis court; 4 - tennis courts; 5 - football field; 6 - town stadium)

Source: Google Maps



a) Sports Hall "Boro Churlevski"

Source: mk.wikipedia.org



b) town stadium

Source: https://mk.wikipedia.org/wiki/Стадион_Тумбе_Кафе



c) tennis field



d) tennis field

Source: http://www.bitola.gov.mk/asfalt_teniski_5_13/

Source: <http://www.bitola.gov.mk>

Figure 5 (a-d): Appearance of the units in the composition of the sports complex

Stop 23 "Kasarna" which is near the Sports Hall "Boro Churlevski" is the initial and final stop on this route. For this route, two stops have been determined as destinations, which are located in the immediate vicinity of the sports complex. This route is 10.3 km long and takes 25 minutes.

As intermediate stops the following are defined:

2. 19 „Bolnica“
3. 47 „Ruzha Delcheva“
4. „Diskont“
5. „Dovledzik“
6. „Pedagoshka 1“
7. 35 „Muzichko“
8. 10 „Javor“
9. 31 „At-pazar“
10. 50 „Zeleznicka 1“ (near the sports complex)
11. 24 „Rakometno“ (near the sports complex).

The destination of the third route is the Town Market and the Old Town Bazaar. This destination is attractive for the citizens of Bitola, but also for the tourists. Figures 6 and 7 show the location and layout of the Town Market and the Old Town Bazaar.

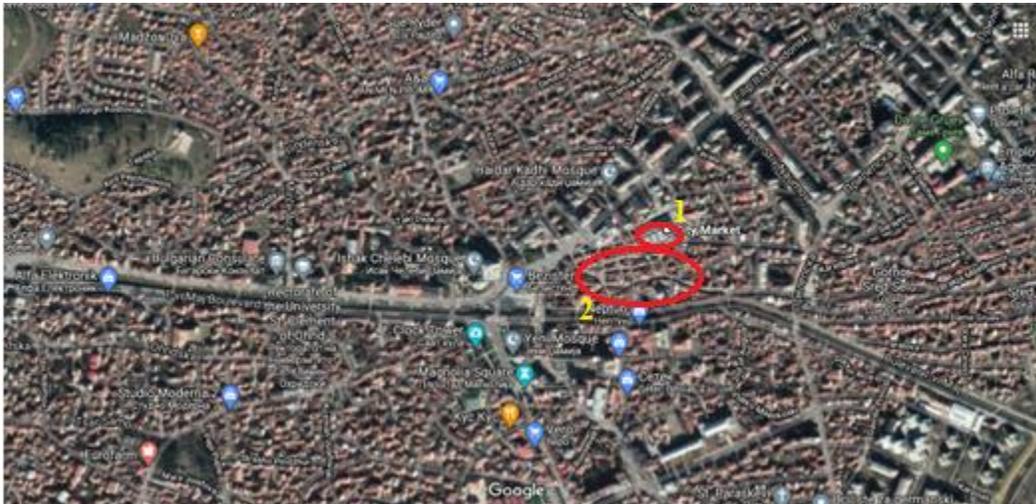


Figure 6: Location of the Town Market (1) and Old Town Bazaar (2) in Bitola

Source: Google Maps



a) Town Market



b) Town Market

Извор (a): <https://www.alamy.com/stock-photo/bitola-municipality.html>

Извор (b): <https://www.google.com/search?q=pazaar+bitola>



c) Old Town Bazaar



d) Old Town Bazaar

Source (c): <http://www.macedoniancuisine.com/2016/08/stara-bitolska-carsija-bitola-old.html>

Source (d): https://bitola.info/mk/стара_чаршија_битола/

Figure 7 (a-d): View of the Town Market and Old Town Bazaar

Stop 23 "Kasarna" which is near the Sports Hall "Boro Churlevski" is the initial and final stop on this route. This route is 8.7 km long and takes 21 minutes.

As intermediate stops the following are defined:

2. 19 „Bolnica“
3. 17 „Vero 2“
4. 15 „Pedagoshka 2“
5. 35 „Muzichko“
6. 10 „Javor“ (Town Market and Old Town Bazaar)
7. 7 „Dulie 2“
8. 31 „At-pazar“
9. 26 „Ruska Crkva“
10. 50 „Zeleznicka 1“.

The fourth route is a tourist route and is driven to the destination village Trnovo on Baba Mountain. The electric vehicle will stop at the church "St. Bogorodica". This route is 20.4 km long and lasts 38 min. Figure 8 shows the location of the village of Trnovo and Figure 9 shows the appearance of the church "St. Bogorodica".



Figure 8: Location of the village Trnovo and church "St. Bogorodica"

Source: Google Maps



Figure 9: Appearance of the church "St. Bogorodica"

Source: <https://bitola.info/mk/sv-bogorodica-trnovo-opstina-bitola/>

Stop 25 "Rakometno" which is near the Sports Hall "Boro Churlevski" is the starting point of this route. The final stop is 24 "Rakometno", also near the Sports Hall "Boro Churlevski". The following are identified as intermediate stops:

2. 30 „At-pazar“
3. 11 „Sheherezada“
4. village Trnovo село Трново church "St. Bogorodica"
5. 10 „Javor“
6. 31 „At-pazar“.

The fifth route is a tourist route and is driven to the destination village Pretor. Pretor is a village in the Municipality of Resen, on the northeast shore of Lake Prespa. The village is located 13 km south of the municipal center of Resen. Figure 10 shows the location of the village of Pretor. This route has a length of 78 km and a duration of 70 min.

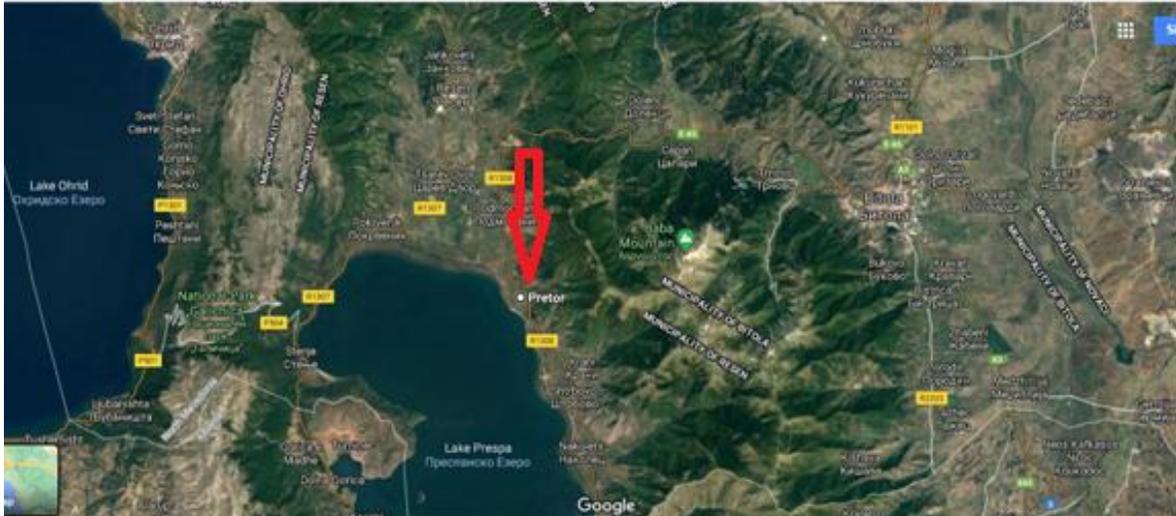


Figure 10: Location of the village Pretor

Source: Google Maps

Stop 23 "Kasarna" which is near the Sports Hall "Boro Churlevski" is the starting point of this route, and the final stop is 22 "Kasarna". The following are identified as intermediate stops:

2. 17 „Vero 2“
3. 15 „Pedagoshka 2“
4. village Pretor and Lake Prespa
5. 14 „Pedagoshka 2“
6. 16 „Vero 2“.

The sixth route is a tourist route and is driven to the destination Ohrid. Ohrid is the largest city on Lake Ohrid and the eighth largest city in the country, with over 42,000 inhabitants as of 2002. It is located west of Resen and Bitola. Ohrid is one of the 28 places that are part of the UNESCO World Heritage, which are cultural as well as natural places. Figure 11 shows the location of Ohrid, and Figure 12 shows the destination of the electric vehicle in Ohrid.

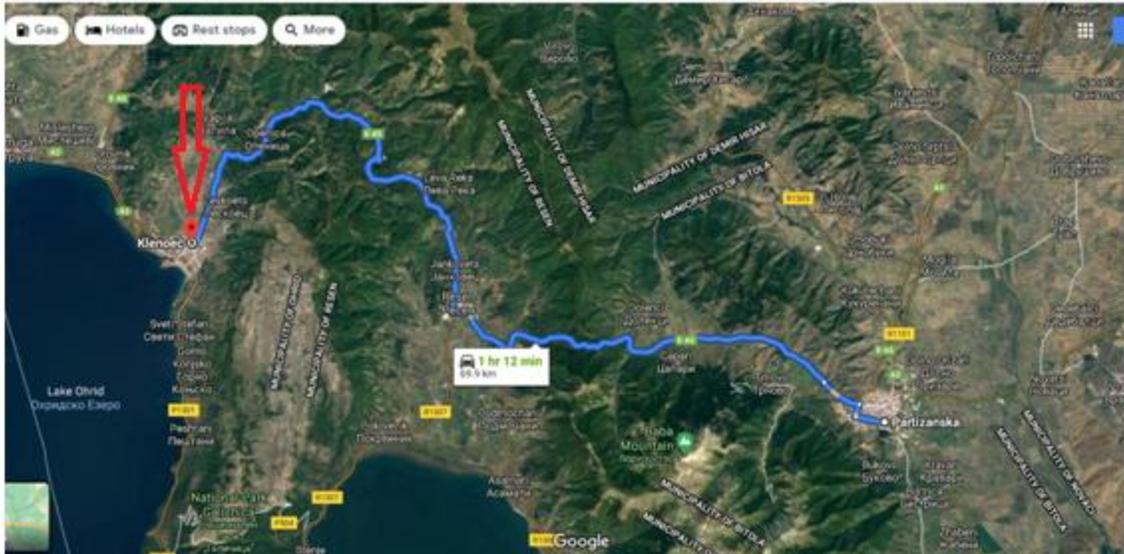


Figure 11: Location of Ohrid

Source: Google Maps

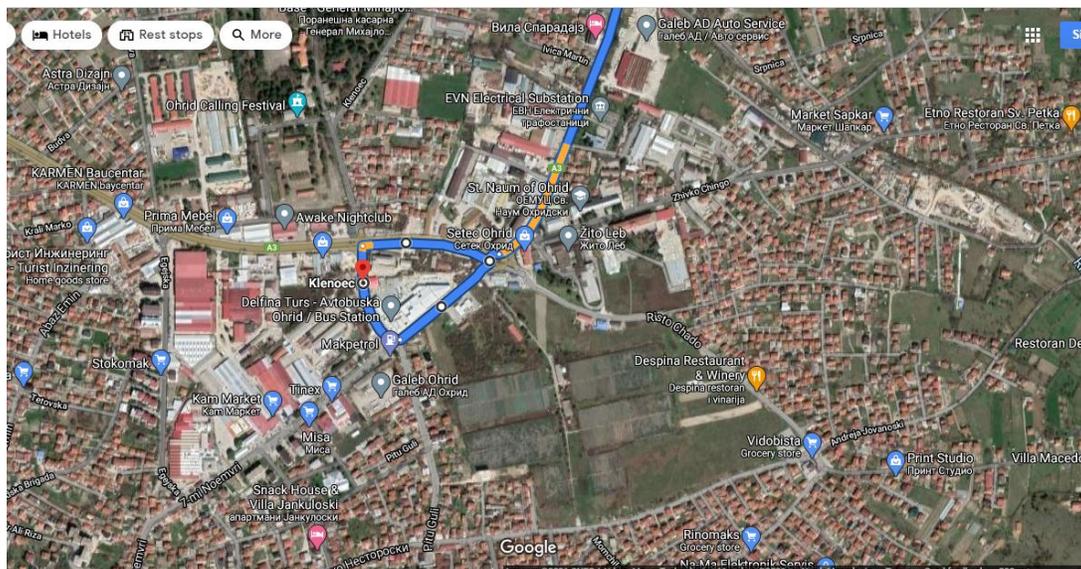


Figure 12: Location of the destination of the electric vehicle in Ohrid

Source: Google Maps

Stop 23 "Kasarna" which is near the Sports Hall "Boro Churlevski" is the starting point of this route, and the final stop is 22 "Kasarna". The route is 139.8 km long and has a duration of 2 hours and 24 minutes. The following are identified as intermediate stops:

2. 17 „Vero 2“
3. 15 „Pedagoshka 2“
4. Ohrid

5. 14 „Pedagoshka 2“
6. 16 „Vero 2“.

Route number 7 is a tourist route that serves four cities in the cross-border region - Bitola, Resen, Prespa and Florina. The stop near the Sports Hall "Boro Churlevski", i.e. 23 "Kasarna" is the initial and final stop for this route. The length of this route is 151 km and lasts 2 hours and 52 minutes. Intermediate stops in route 7 are the following:

1. Resen: town hall
2. Prespa: town hall
3. Florina: town hall.

Figure 13 shows the location of these four cities in the cross-border region.

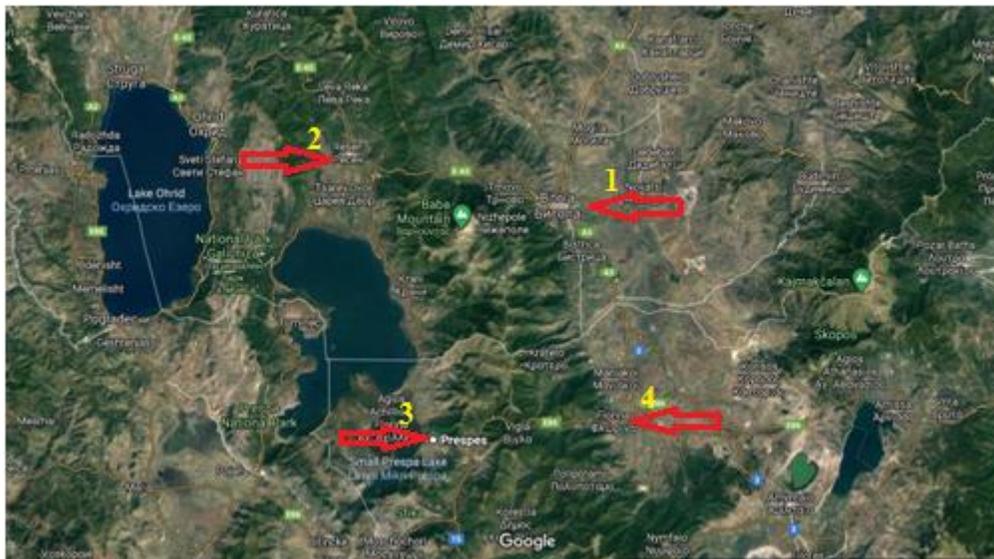


Figure 13: Location of the towns Bitola (1), Resen (2), Prespa (3) and Florina (4) in the cross-border region

Source: Google Maps

Table 2 summarizes the length and duration of each route.

Table 2: Length and duration of the routes

Route	1	2	3	4	5	6	7
Length (km)	7.5	10.3	8.7	20.4	78	139.8	151
Duration (minutes)	19	25	21	38	70	144	172

3. DESIGN OF THE ROUTES FOR ELECTRIC VEHICLES

In this part, the previously defined routes for the municipality of Bitola are developed, taking into account the characteristics of the road and traffic network in Bitola: one-way or two-way traffic, allowed turning, geometric characteristics of the roads (turning radii, slope) and traffic signalization.

3.1. Route 1: Destination NUI Library “St. Kliment Ohridski”

Figure 14 shows route 1 on the map of Bitola.

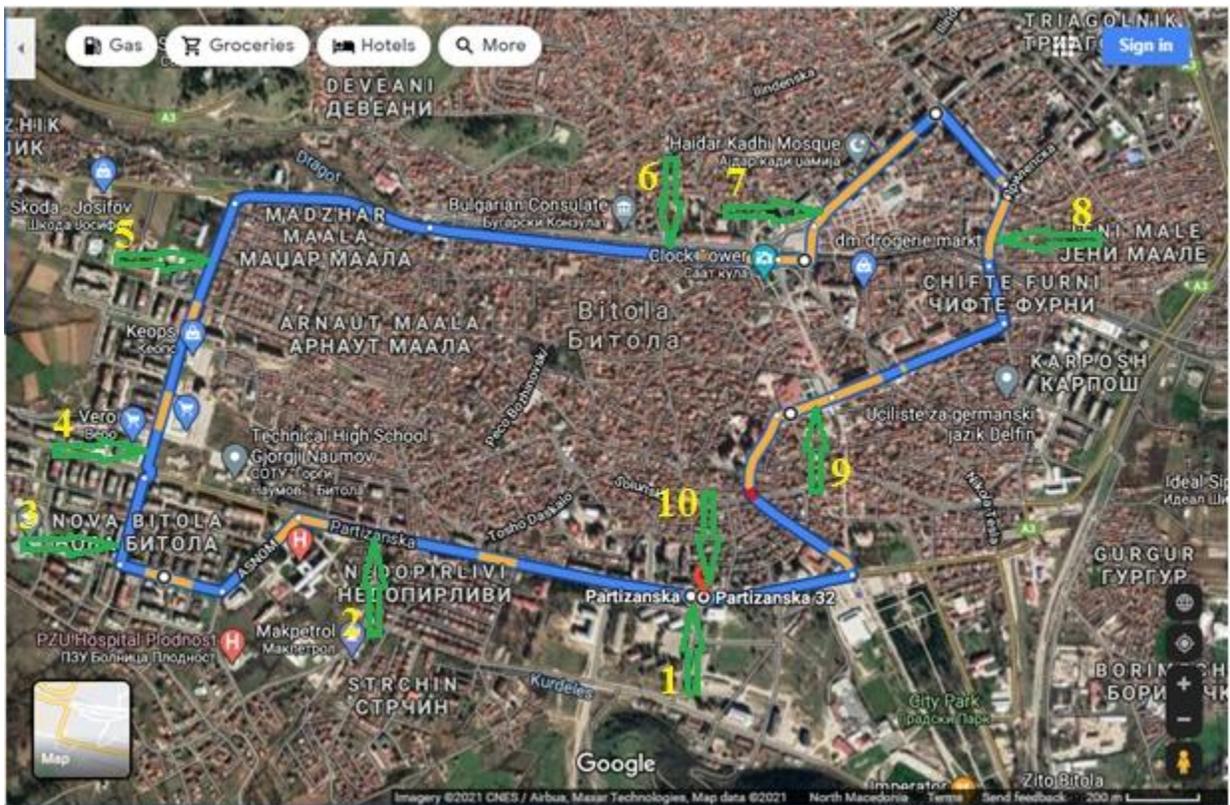


Figure 14: Route 1 with stops

The route is created with a sequential selection of road sections. The stops are defined according to the data from the municipality of Bitola for the citizens' mobility needs with a more important location as a destination. Defined in this way, route 1 can be used for daily urban travel of citizens, as it serves the more important locations (hospital, market, faculty, schools, bazaar, bus station), which are up to 5 minutes walking distance from the nearest stop. 10 stops are defined, listed below:

- stop 1: 23 „Kasarna“
- stop 2: 19 „Bolnica“
- stop 3: 47 „Ruzha Delcheva“
- stop 4: 17 „Vero 2“
- stop 5: 15 „Pedagogshka 2“
- stop 6: 35 „Muzichko“
- stop 7: 10 „Javor“
- stop 8: 31 „At-pazar“
- stop 9: Epinal (near the NUI Library “St. Kliment Ohridski”)
- stop 10: 23 „Kasarna“.

Next, the road sections of route 1 are shown.

Route 1: distance 7.5 km; travel time 19 minutes.

Electric vehicle:

1. exits the **parking lot of the Sports Hall "Boro Churlevski"** and heads northwest to the street "Partizanska" - 130.67 meters
2. turns left on "Partizanska" street and goes to **stop 23 "Kasarna"** - 394.88 meters
3. keeps the direction of the street "Partizanska" to the **stop 19 "Bolnica"** - 1 kilometer; **Clinical Hospital "Dr. Trifun Panovski"** is on the left
4. continues straight on "Partizanska" street and turns left on "Asnom" street - 129.25 meters
5. moves on "Asnom" street in the southwest direction - 289.01 meters
6. turns right on the street "Ruza Delcheva" and keeps the direction of this street - 294.30 meters
7. turns right on the street "General Vasko Karangelevski" and comes to a **stop 47 "Ruza Delcheva"** - 41.85 meters; the **primary school "St. Kliment Ohridski"** is on the left side
8. continues on the street "General Vasko Karangelevski" and at the roundabout continues at the second exit, i.e. stays on the street "General Vasko Karangelevski" and comes to **stop 17 "Vero 2"** - 304.29 meters; **Vero supermarket** is on the left, and the **shopping center** is on the right
9. keeps the direction on the street "General Vasko Karangelevski" and comes to a **stop 15 "Pedagogka 2"** - 489.69 meters; the **Faculty of Pedagogy** is on the left
10. continues on the street "General Vasko Karangelevski" and at the roundabout continues at the first exit - 247.5 meters

11. moves on the Boulevard "1st of May" and arrives at the **stop 35 "Muzichko"** - 1.25 km; the **State Music School** is on the right side, and the **Gymnasium "J.B. - Tito"** and **High School of Economics "Jane Sandanski"** are on the left
12. keeps the direction on the Boulevard "1st of May" and arrives at the crossroads in front of the bridge over the river Dragor, where it turns left - 303.41 meters
13. crosses the bridge on the river Dragor, crosses the exit to the left and continues straight, thus coming out on the street "Filip II Makedonski" - 103.56 meters
14. continues on "Filip II Makedonski", at the roundabout continues on the second exit, stays on the street "Filip II Makedonski" and arrives at the **stop 10 "Javor"** - 159.86 meters; the **Health center "Dr. Haim Abravanel"** is on the right side, and the **shopping center "Javor"** is on the right side
15. keeps the direction on "Philip II Makedonski" to the intersection with the street "Battalion Stiv Naumov" where it turns right - 380.14 meters
16. continues on the street "Battalion Stiv Naumov" to the intersection with the street "Prilepska" where it turns right - 312.12 meters
17. moves on the street "Prilepska" and arrives at the **stop 31 "At-pazar"** - 96.69 meters; the **Suburban bus station** is on the left
18. continues along the street "Prilepska", crosses the bridge over the river Dragor (Sali Most) which leads to the street "4th of November" and arrives at the intersection with the street "D. Ilievski - Muratot"- 290.63 meters
19. turns right on the street "D. Ilievski - Muratot" and continues on this street, keeping the direction of the street" D. Ilievski - Muratot" and at the crossroads with the street "Nikola Tesla", and then enters the street "Pece Maticevski" and arrives at the **stop Epinal** - 593.70 meters; The **NI Center for Culture** is on the right, and the **NUI Library "St. Kliment Ohridski"** is at a walking distance of 237 meters from this stop
20. at the crossroads with the street "St. Kliment Ohridski" turns left - 108.66 meters
21. continues along the street "St. Kliment Ohridski" and at the crossroads with the street "Solunska" continues straight on the street "St. Kliment Ohridski"- 251.73 meters
22. arrives at the intersection with "Partizanska" street and turns right on "Partizanska" street - 377.14 meters
23. moves on the street "Partizanska" to the **stop 23 "Kasarna"** - 449.56.

Electric vehicles always follow the same route (to the NUI Library "St. Kliment Ohridski") with the same start (23 "Kasarna") and the same end (23 "Kasarna"), without stopping for charging or starting another route. Based on this, the timetable for this route was prepared.

3.2. Route 2: Destination Sports complex

This route is designed to serve the transport to the sports complex in Bitola. Defined in this way, route 2 can also be used for day trips of citizens, as it serves the most important locations (hospital, market, faculty, schools, bazaar, bus stations and train station), which are up to 5 minutes walking distance from the nearest stop. 12 stops are defined, listed below:

- stop 1: 23 „Kasarna“
- stop 2: 19 „Bolnica“
- stop 3: 47 „Ruzha Delceva“
- stop 4: „Diskont“
- stop 5: „Dovledzik“
- stop 6: „Pedagoshka 1“
- stop 7: 35 „Muzichko“
- stop 8: 10 „Javor“
- stop 9: 31 „At-pazar“
- stop 10: 50 „Zeleznicka 1“ (near the sport complex)
- stop 11: 24 „Rakometno“ (near the sport complex)
- stop 12: 23 „Kasarna“.

Figure 15 shows route 2 on the map of Bitola together with the stops determined for this route.



Figure 15: Route 2 with stops

Next, the road sections of route 2 are presented.

Route 2: length of the route 10.3 km; total travel time 25 minutes.

So, the electric vehicle:

1. exits the parking lot of the **Sports Hall "Boro Churlevski"** and heads northwest to the street "Partizanska" - 130.67 meters
2. turns left on "Partizanska" street and goes to **stop 23 "Kasarna"** - 394.88 meters
3. keeps the direction on the street "Partizanska" to the **stop 19 "Bolnica"** - 1 kilometer; **Clinical Hospital "Dr. Trifun Panovski"** is on the left
4. continues straight on "Partizanska" street and turns left on "Asnom" street - 129.25 meters
5. moves on "Asnom" street in the southwest direction - 289.01 meters
6. turns right on the street "Ruzha Delcheva" and keeps the direction of this street - 294.30 meters
7. turns right on the street "General Vasko Karangelevski" and comes to a **stop 47 "Ruzha Delcheva"** - 41.85 meters; the **primary school "St. Kliment Ohridski"** is on the left side
8. continues on the street "General Vasko Karangelevski" and at the roundabout continues at the third exit, i.e. joins the street "Partizanska" - 296.08 meters
9. keeps the direction on the street "Partizanska", and at the crossroads with the street "Metodija Andonov Cento" turns right - 789 meters

10. continues on the street "Metodija Andonov Cento" and arrives at the **stop "Discount"** - 531.45 meters; this stop is located in the **peripheral settlement of Brusnik**
11. continues on the street "Metodija Andonov Cento" and at the crossroads with the street "Skoevska" turns right - 170.43 meters
12. continues on the street "Skoevska" and turns right on the street "Dovledzik" - 111.56 meters
13. keeps the direction of the street "Dovledzik" and arrives at the **stop "Dovledzik"** - 317.29 meters; this stop is in the **suburban settlement Dovledzik**
14. continues on the street "Dovledzik" and at the crossroads with the street "11th Macedonska Divizija" turns right - 33.15 meters
15. keeps the direction of the street "11th Macedonska Divizija" and arrives at the **stop "Pedagogshka 1"** - 774.49 meters; this stop is located in the **suburban settlement Dovledzik**
16. continues on the street "11th Macedonska Divizija" and at the roundabout moves to the second exit, i.e. joins the Boulevard "1st of May" - 279.57 meters
17. keeps the direction of the Boulevard "1st of May" and arrives at the **stop 35 "Muzichko"** - 1.22 km; the **State Music School** is on the right side, and the **Gymnasium "J.B. - Tito"** and **High School of Economics "Jane Sandanski"** are on the left
18. keeps the direction of the Boulevard "1st of May" and arrives at the crossroads in front of the bridge over the river Dragor, where it turns left - 303.41 meters
19. crosses the bridge over the river Dragor, crosses the exit to the left and continues straight, thus coming out on the street "Filip II Makedonski" - 103.56 meters
20. continues on "Filip II Makedonski", at the roundabout continues on the second exit, stays on the street "Filip II Makedonski" and arrives at **stop 10 "Javor"** - 159.86 meters; the **Health center "Dr. Haim Abravanel"** is on the right side, and the **shopping center "Javor"** is on the right side
21. keeps the direction of "Filip II Makedonski" to the intersection with the street "Battalion Stiv Naumov" where it turns right - 380.14 meters
22. moves on the street "Battalion Stiv Naumov" to the intersection with the street "Prilepska" where it turns right - 312.12 meters
23. moves on the street "Prilepska" and arrives at the **stop 31 "At-pazar"** - 96.69 meters; the **Suburban bus station** is on the left
24. continues along the street "Prilepska", crosses the bridge over the river Dragor (Sali Most), exits the street "4th of November" and arrives at the intersection with the street "D. Ilievski - Muratot"- 290.63 meters

25. at the crossroads keeps the direction and turns on the street "4th of November" and continues on this street until the crossroads with the street "Nikola Tesla" where it turns left on the street "Nikola Tesla" - 735.39 meters
26. keeps the direction of the street "Nikola Tesla" and arrives at the **stop 50 "Zeleznicka 1"** - 394.81 meters; the **Train station** is on the right, and part of the sports complex: **city stadium, football and tennis courts** is within walking distance of up to 350 meters
27. keeps the direction of the street "Nikola Tesla" until the intersection with the street "Makedonska Falanga" where it turns right - 137.20 meters
28. continues on the street "Makedonska Phalanga" to the intersection with the street "Partizanska", where it turns left and turns on the street "Partizanska" - 475.45 meters
29. starts moving on the street "Partizanska" and arrives at the **stop 24 "Rakometno"** - 118.61 meters; part of the sports complex - **sports hall, handball court** are located at a walking distance of up to 130 meters
30. keeps the direction of the street "Partizanska" and arrives at the **stop 23 "Kasarna"** - 515.77 meters.

Electric vehicles always follow the same route (to the sports complex) with the same start (23 "Kasarna") and the same end (23 "Kasarna"), without stopping for charging or starting another route. Based on this, the timetable for route 2 was prepared.

3.3. Route 3: Destination Town Market and Old Town Bazaar

Route 3 is designed to serve passenger transport to the Town Market and the Old Town Bazaar. The route will serve other important destinations, such as a hospital, supermarket, train station and two bus stations in Bitola within 5 minutes walking distance from the nearest stop.

So, with this stretch design, route 3 can be used for daily trips of citizens, because it serves the stops near the more important destinations in the town.

11 stops have been determined for this route, listed below:

- stop 1: 23 „Kasarna“ 23
- stop 2: 19 „Bolnica“
- stop 3: 17 „Vero 2“
- stop 4: 15 „Pedagoshka 2“
- stop 5: 35 „Muzichko“

- stop 6: 10 „Javor“ (Town Market and Old Town Bazaar)
- stop 7: 7 „Dulie 2“
- stop 8: 31 „At-pazar“
- stop 9: 26 „Ruska Crkva“
- stop 10: 50 „Zeleznicka 1“
- stop 11: 23 „Kasarna“.

Figure 16 shows route 3 on a map together with the stops determined for this route.

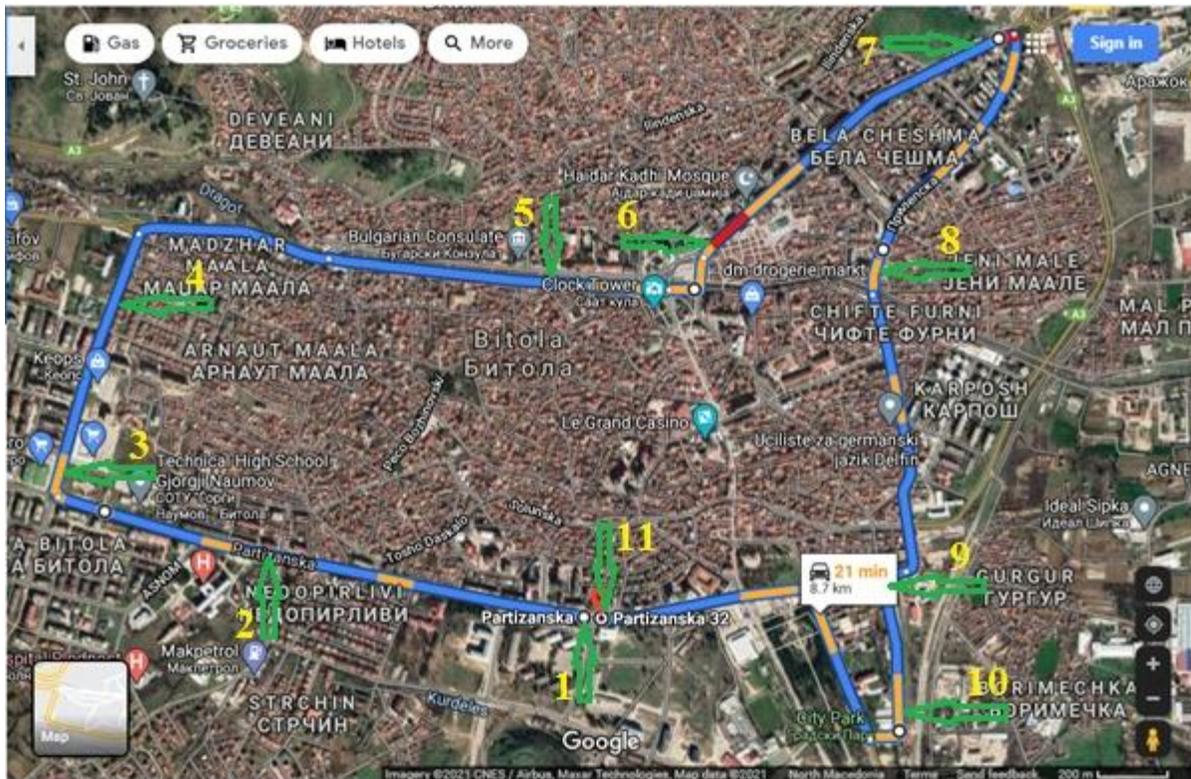


Figure 16: Route 3 with stops

The following are the road sections of route 3.

Route 3: length of the route 8.7 km; total travel time 21 minutes.

So, the electric vehicle:

1. exits the parking lot of the **Sports Hall "Boro Churlevski"** and heads northwest to the street "Partizanska" - 130.67 meters
2. turns left on "Partizanska" street and head to **stop 23 "Kasarna"** - 394.88 meters
3. keeps the direction on the street "Partizanska" to the **stop 19 "Bolnica"** - 1 kilometer; **Clinical Hospital "Dr. Trifun Panovski"** is on the left

4. keeps the direction on the street "Partizanska" until the roundabout where it takes the first exit and turns right, turning on the street "General Vasko Karangelevski" and arrives at **stop 17 "Vero 2"** - 627.9 meters; **Vero supermarket** is on the left, and the **shopping center** is on the right
5. keeps the direction on the street "General Vasko Karangelevski" and comes to a **stop 15 "Pedagoshka 2"** - 489.69 meters; the **Faculty of Pedagogy** is on the left
6. continues on the street "General Vasko Karangelevski" and at the roundabout continues at the first exit - 247.5 meters
7. moves on the Boulevard "1st of May" and arrives at the **stop 35 "Muzichko"** - 1.25 km; the **State Music School** is on the right side, and the **Gymnasium "J.B. - Tito"** and **High School of Economics "Jane Sandanski"** are on the left
8. keeps the direction of the Boulevard "1st of May" and arrives at the crossroads in front of the bridge over the river Dragor, where it turns left - 303.41 meters
9. crosses the bridge on the river Dragor, crosses the exit to the left and continues straight leading to the street "Filip II Makedonski" - 103.56 meters
10. continues on "Filip II Makedonski", at the roundabout continues on the second exit, stays on the street "Filip II Makedonski" and arrives at the **stop 10 "Javor"** - 159.86 meters; the **Health center "Dr. Haim Abravanel"** is on the right side, and the **shopping center "Javor"**, **Town Market** and the **Old Town Bazaar** are on the right side
11. keeps the direction of the street "Filip II Makedonski" and arrives at the **stop 7 "Dulie 2"** - 968.12 meters
12. continues on the street "Filip II Makedonski" and before the roundabout turns right and turns on the street "Prilepska" - 128.93 meters
13. keeps the direction of movement on the street "Prilepska" and arrives at the **stop 31 "At-pazar"** - 729.41 meters; the **Suburban bus station** is on the left
14. crosses the bridge on the river Dragor (Sali Most) and exits on the street "4th of November" and keeps the direction of this street until the intersection with the street "Solunska", where it turns right on the street "Solunska" - 802.45 meters
15. starts moving on the street "Solunska" and arrives at the **stop 26 "Ruska Crkva"** - 53.12 meters
16. continues on the street "Solunska" to the intersection with the street "Nikola Tesla" where it turns right on the street "Nikola Tesla" - 43.32 meters
17. maintains the direction of movement on the street "Nikola Tesla" and arrives at the **stop 50 "Railway Station 1"** - 544.75 meters; the **Train station** is on the left
18. keeps the direction of the street "Nikola Tesla" until the crossroads with the street "Makedonska Falanga" where it turns right - 137.20 meters

19. continues on the street "Makedonska Falanga" to the intersection with the street "Partizanska", where it turns left and turns on the street "Partizanska" - 475.45 meters
20. starts moving on the street "Partizanska", keeps the direction of this street and arrives at **the stop 23 "Kasarna"** - 634.68 meters.

Electric vehicles always follow the same route with the same start (23 "Kasarna") and the same end (23 "Kasarna"), without stopping for charging or starting another route. Based on this, the timetable for route 3 was prepared.

3.4. Route 4: Destination village Trnovo

The destination on route 4 is the village of Trnovo, more precisely the church "St. Bogorodica" in the village. The route is designed with appropriate selection of road sections, based on the needs of citizens. Then, the stops are selected, a total of 7 in number, as follows:

- stop 1: 25 „Rakometno“
- stop 2: 30 „At-pazar“
- stop 3: 11 „Sheherezada“
- stop 4: village Trnovo church "St. Bogorodica"
- stop 5: 10 „Javor“
- stop 6: 31 „At-pazar“
- stop 7: 24 „Rakometno“.

Figure 17 shows route 4 on a map, and Figure 18 shows part of this route through the city along with the stops set for that part.

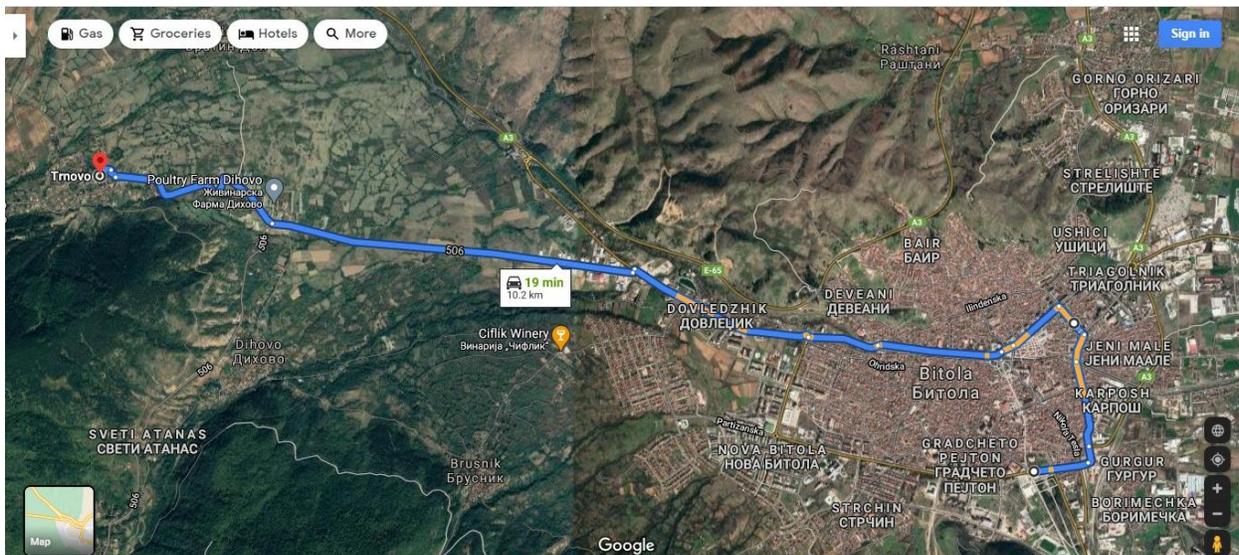


Figure 17: Route 4

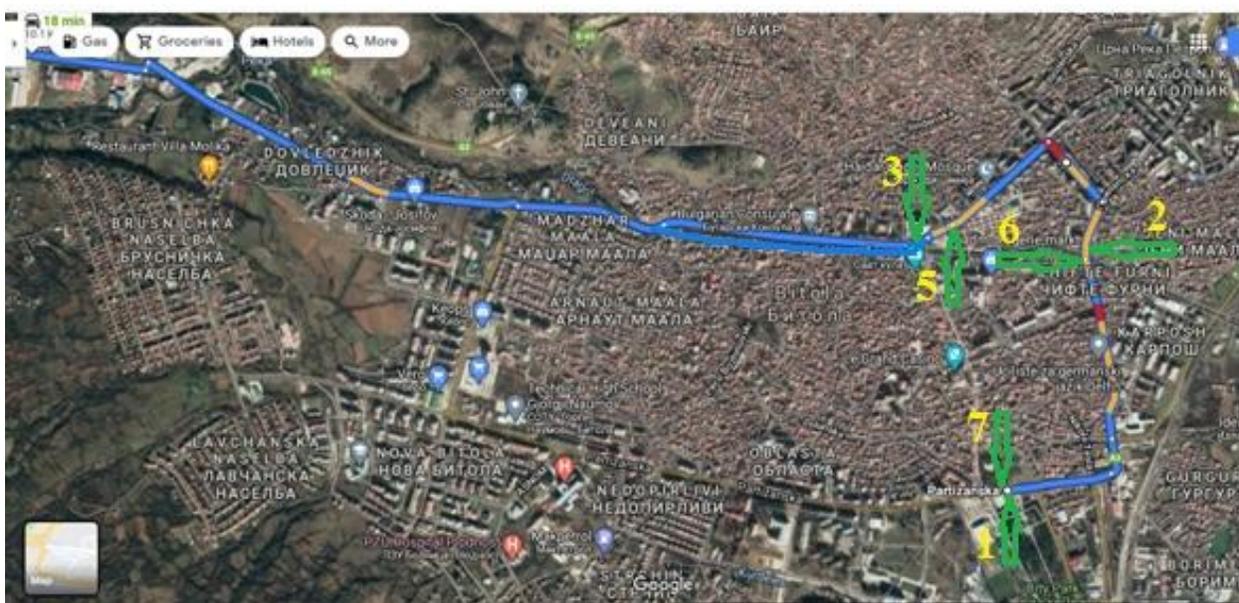


Figure 18: Route 4 with stops

Route 4: length of the route 20.4 km; total time 38 minutes.

Electric vehicles always follow the same route with start (25 "Rakometno") and final stop (24 "Rakometno"), without stopping for charging or starting another route. The start and end stops are terminal stops, where the standing time can be 30 seconds or more. Based on this, the timetable for route 4 was prepared.

3.5. Route 5: Destination village Pretor

The destination on route 5 is the village of Pretor on Lake Prespa. The route is designed with a proper selection of road sections. The stops are selected, a total of 7, as follows:

- stop 1: 23 „Kasarna“
- stop 2: 17 „Vero 2“
- stop 3: 15 „Pedagoshka 2“
- stop 4: village Pretor
- stop 5: 14 „Pedagoshka 2“
- stop 6: 16 „Vero 2“
- stop 7: 22 „Kasarna“.

Figure 19 shows route 5 on a map, and Figure 20 shows part of the route through Bitola together with the stops determined for this route on that part.

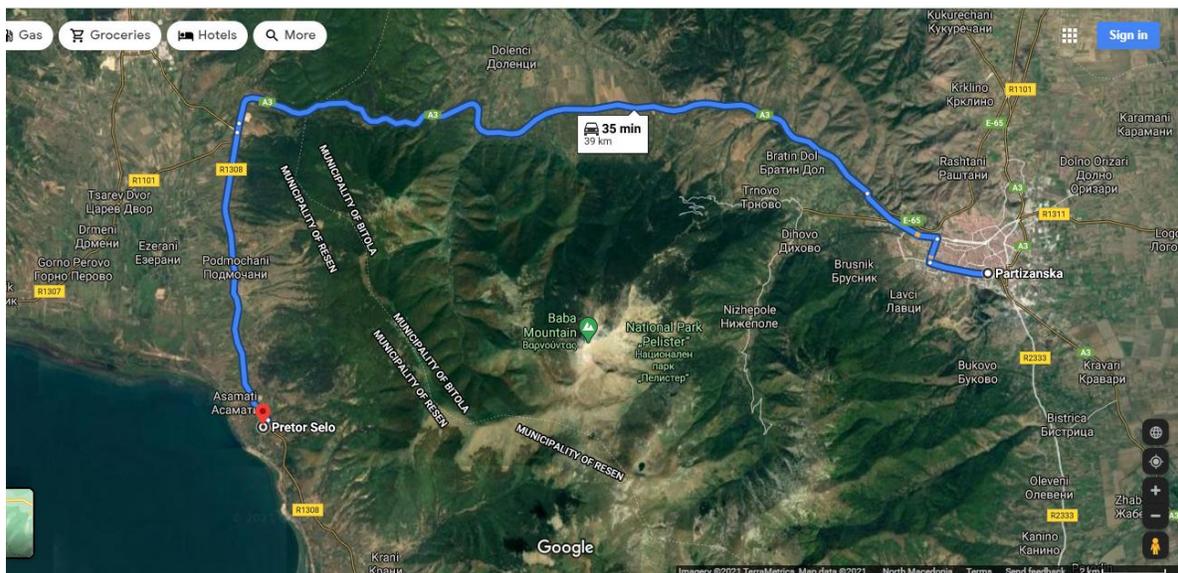


Figure 19: Route 5



Figure 20: Route 5 with stops in Bitola

Route 5: length of the route 78 km; total time 70 minutes.

Electric vehicles always follow the same route with the same starting point (23 "Kasarna") and the same final stop (22 "Kasarna"), without stopping for charging or starting another route. The start and end stops are terminal stops, where the standing time can be 30 seconds or more. Based on this, the timetable for route 5 was prepared.

3.6. Route 6: Destination Ohrid

The destination of route 6 is Ohrid. The route is designed with a proper selection of road sections. The stops are selected, a total of 7, as shown:

- stop 1: 23 „Kasarna“
- stop 2: 17 „Vero 2“
- stop 3: 15 „Pedagoshka 2“
- stop 4: Ohrid
- stop 5: 14 „Pedagoshka 2“
- stop 6: 16 „Vero 2“
- stop 7: 22 „Kasarna“.

Figure 21 shows route 6 on the map.

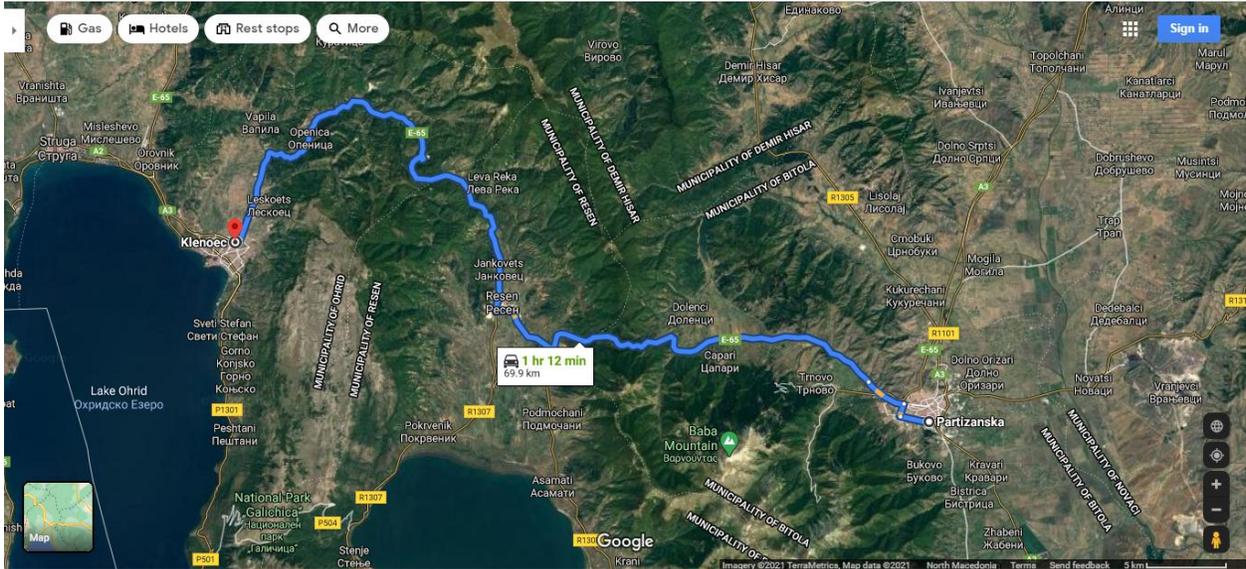


Figure 21: Route 6

Figure 22 shows a part of route 6 that passes through Bitola together with the stops determined on that part.



Figure 22: Route 6 with stops in Bitola

Route 6: Length of the route 139.8 km; total time 2 hours and 12 minutes.

Electric vehicles always follow the same route with the same starting point (23 "Kasarna") and the same final stop (22 "Kasarna"), without stopping for charging or starting another route.

The start and end stops are terminal stops, where vehicles can stand for 30 seconds or more. Based on this, the timetable for route 6 was prepared.

3.7. Route 7: Destination Bitola-Resen-Prespa-Florina

This tourist route includes the towns in the cross-border region: Bitola, Resen, Prespa and Florina. The route is created with an appropriate selection of road sections in each of the municipalities. Then, a total of 5 stops are defined:

- stop 1: 23 „Kasarna“
- stop 2: Resen: town hall
- stop 3: Prespa: општинска зграда
- stop 4: Florina: town hall
- stop 5: 23 „Kasarna“.

Figure 23 shows route 7 for the four municipalities in the cross-border region.

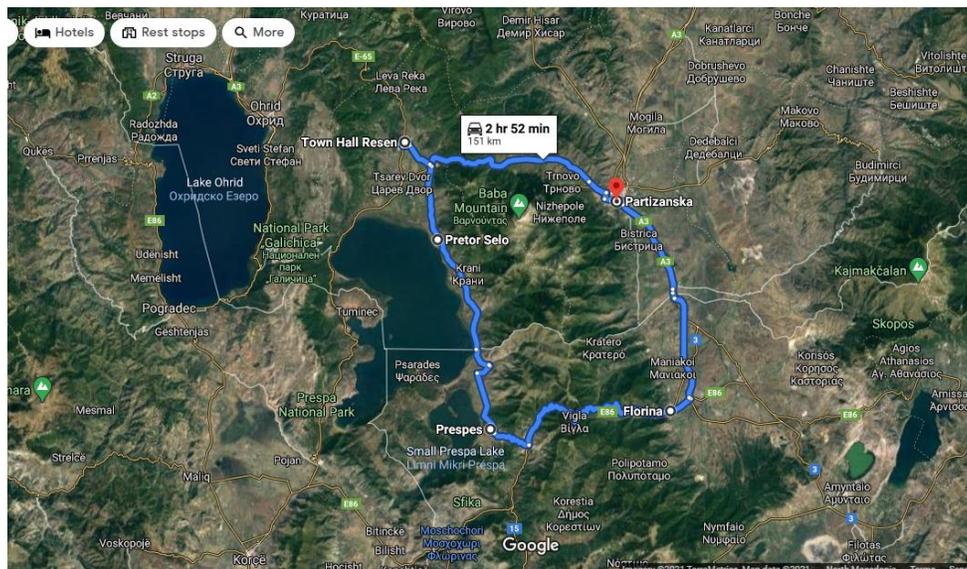


Figure 23: Route 7 for the four municipalities in the cross-border region

Route 7: length of the route 151 km; total time 172 minutes.

Electric vehicles always follow the same route with the same starting and ending point (23 "Kasarna"), without stopping for charging or starting another route. Based on this, the timetable for route 7 was developed.

4. TIMETABLE

The timetable of the proposed routes is made in order to provide optimal capacity utilization in relation to the mileage and optimal level of service to the citizens of the municipality of Bitola.

To begin with, this section will briefly summarize the basic features.

The bus stops near the Sports Hall "Boro CHurlevski" are the starting and ending points of each of the proposed routes. The main limitation is the range of mileage with the electric vehicle - minibus, for which no charging is provided during the day. The combined cycle autonomy for this vehicle is about 200 km, while the city cycle autonomy exceeds 300 km.

The average charging time of electric vehicles is about 4 hours / vehicle, due to which it is inefficient to charge electric vehicles during the day. Therefore, the charging of the electric vehicles will be during the night period (from 21:30), and during the day the service of the passengers will be performed.

The next table 3 shows the proposed schedule for the electric minibus for the first three routes which are urban routes, i.e. covering the territory of the municipality of Bitola. This schedule includes the fourth route (to the village of Trnovo), which is a tourist route, but shorter and can be performed daily. These routes are proposed to be performed during the working days, i.e. from Monday to Friday.

The route numbers are displayed in different colors: route 1 is green, route 2 is red, route 3 is yellow and route 4 is blue.

Table 3: Proposed timetable for route 1, route 2, route 3 and route 4

Time	Stops	Route No
07:00	23 „Kasarna“	1
07:02	19 „Bolnica“	1
07:03	47 „Ruzha Delcheva“	1
07:04	17 „Vero 2“	1
07:05	15 „Pedagogshka 2“	1
07:08	35 „Muzichko“	1

07:10	10 „Javor“	1
07:13	31 „At-pazar“	1
07:16	Epinal (near the library)	1
07:19	23 „Kasarna“	1
07:25	23 „Kasarna“	2
07:27	19 „Bolnica“	2
07:28	47 „Ruzha Delcheva“	2
07:32	„Diskont“	2
07:34	„Dovledzik“	2
07:35	„Pedagoshka 1“	2
07:38	35 „Muzichko“	2
07:40	10 „Javor“	2
07:43	31 „At-pazar“	2
07:47	50 „Zeleznicka 1“ (near the sports complex)	2
07:49	24 „Rakometno“ (near the sports complex)	2
07:50	23 „Kasarna“	2
07:55	23 „Kasarna“	3
07:57	19 „Bolnica“	3
07:58	17 „Vero 2“	3
07:59	15 „Pedagoshka 2“	3
08:02	35 „Muzichko“	3
08:04	10 „Javor“ (Town Market and Old Town)	3

	Bazaar)	
08:07	7 „Dulie 2“	3
08:09	31 „At-pazar“	3
08:12	26 „Ruska Crkva“	3
08:13	50 „Zeleznicka 1“	3
08:16	23 „Kasarna“	3
08:20	23 „Kasarna“	1
08:22	19 „Bolnica“	1
08:23	47 „Ruzha Delcheva“	1
08:24	17 „Vero 2“	1
08:25	15 „Pedagoshka 2“	1
08:28	35 „Muzichko“	1
08:30	10 „Javor“	1
08:33	31 „At-pazar“	1
08:36	Epinal (near the library)	1
08:39	23 „Kasarna“	1
08:45	23 „Kasarna“	2
08:47	19 „Bolnica“	2
08:48	47 „Ruzha Delcheva“	2
08:52	„Diskont“	2
08:54	„Dovledzik“	2
08:55	„Pedagoshka 1“	2
08:58	35 „Muzichko“	2

09:00	10 „Javor“	2
09:03	31 „At-pazar“	2
09:07	50 „Zeleznicka 1“ (near the sports complex)	2
09:09	24 „Rakometno“ (near the sports komplex)	2
09:10	23 „Kasarna“	2
09:15	23 „Kasarna“	3
09:17	19 „Bolnica“	3
09:18	17 „Vero 2“	3
09:19	15 „Pedagogoshka 2“	3
09:22	35 „Muzichko“	3
09:24	10 „Javor“ (Town Market and Old Town Bazaar)	3
09:27	7 „Dulie 2“	3
09:29	31 „At-pazar“	3
09:32	26 „Ruska Crkva“	3
09:33	50 „Zeleznicka 1“	3
09:36	23 „Kasarna“	3
09:40	25 „Rakometno“	4
09:44	30 „At-pazar“	4
09:47	11 „Sheherezada“	4
09:58	village Trnovo church “St. Bogorodica”	4
10:03	village Trnovo church “St. Bogorodica”	4

10:16	10 „Javor“	4
10:19	31 „At-pazar“	4
10:23	24 „Rakometno“	4
10:28	23 „Kasarna“	1
10:30	19 „Bolnica“	1
10:31	47 „Ruzha Delcheva“	1
10:32	17 „Vero 2“	1
10:33	15 „Pedagogshka 2“	1
10:36	35 „Muzichko“	1
10:38	10 „Javor“	1
10:41	31 „At-pazar“	1
10:44	Epinal (near the library)	1
10:47	23 „Kasarna“	1
10:52	23 „Kasarna“	3
10:54	19 „Bolnica“	3
10:55	17 „Vero 2“	3
10:56	15 „Pedagogshka 2“	3
10:59	35 „Muzichko“	3
11:01	10 „Javor“ (Town Market and Old Town Bazaar)	3
11:04	7 „Dulie 2“	3
11:06	31 „At-pazar“	3
11:09	26 „Ruska Crkva“	3
11:10	50 „Zeleznicka 1“	3

11:13	23 „Kasarna“	3
11:18	23 „Kasarna“	2
11:20	19 „Bolnica“	2
11:21	47 „Ruzha Delcheva“	2
11:25	„Diskont“	2
11:27	„Dovledzik“	2
11:28	„Pedagoshka 1“	2
11:31	35 „Muzichko“	2
11:33	10 „Javor“	2
11:36	31 „At-pazar“	2
11:40	50 „Zeleznicka 1“ (near the sports complex)	2
11:42	24 „Rakometno“ (near the sports komplex)	2
11:43	23 „Kasarna“	2
11:47	23 „Kasarna“	3
11:49	19 „Bolnica“	3
11:50	17 „Vero 2“	3
11:51	15 „Pedagoshka 2“	3
11:54	35 „Muzichko“	3
11:56	10 „Javor“ (Town Market and Old Town Bazaar)	3
11:59	7 „Dulie 2“	3
12:01	31 „At-pazar“	3

12:04	26 „Ruska Crkva“	3
12:05	50 „Zeleznicka 1“	3
12:08	23 „Kasarna“	3
12:13	23 „Kasarna“	1
12:15	19 „Bolnica“	1
12:16	47 „Ruzha Delcheva“	1
12:17	17 „Vero 2“	1
12:18	15 „Pedagogoshka 2“	1
12:21	35 „Muzichko“	1
12:23	10 „Javor“	1
12:26	31 „At-pazar“	1
12:29	Epinal (near the library)	1
12:32	23 „Kasarna“	1
12:37	23 „Kasarna“	2
12:39	19 „Bolnica“	2
12:40	47 „Ruzha Delcheva“	2
12:44	„Diskont“	2
12:46	„Dovledzik“	2
12:47	„Pedagogoshka 1“	2
12:50	35 „Muzichko“	2
12:52	10 „Javor“	2
12:55	31 „At-pazar“	2
12:59	50 „Zeleznicka 1“ (near the sports complex)	2

13:01	24 „Rakometno“ (near the sports kompleks)	2
13:02	23 „Kasarna“	2
13:07	23 „Kasarna“	3
13:09	19 „Bolnica“	3
13:10	17 „Vero 2“	3
13:11	15 „Pedagogoshka 2“	3
13:14	35 „Muzichko“	3
13:16	10 „Javor“ (Town Market and Old Town Bazaar)	3
13:19	7 „Dulie 2“	3
13:21	31 „At-pazar“	3
13:24	26 „Ruska Crkva“	3
13:25	50 „Zeleznicka 1“	3
13:28	23 „Kasarna“	3
13:33	23 „Kasarna“	1
13:35	19 „Bolnica“	1
13:36	47 „Ruzha Delcheva“	1
13:37	17 „Vero 2“	1
13:38	15 „Pedagogoshka 2“	1
13:41	35 „Muzichko“	1
13:43	10 „Javor“	1
13:46	31 „At-pazar“	1
13:49	Epinal (near the library)	1

13:52	23 „Kasarna“	1
13:57	23 „Kasarna“	3
13:59	19 „Bolnica“	3
14:00	17 „Vero 2“	3
14:01	15 „Pedagogshka 2“	3
14:04	35 „Muzichko“	3
14:06	10 „Javor“ (Town Market and Old Town Bazaar)	3
14:09	7 „Dulie 2“	3
14:11	31 „At-pazar“	3
14:14	26 „Ruska Crkva“	3
14:15	50 „Zeleznicka 1“	3
14:18	23 „Kasarna“	3
14:30	25 „Rakometno“	4
14:34	30 „At-pazar“	4
14:37	11 „Sheherezada“	4
14:48	village Trnovo church “St. Bogorodica”	4
14:53	village Trnovo church “St. Bogorodica”	4
15:06	10 „Javor“	4
15:09	31 „At-pazar“	4
15:13	24 „Rakometno“	4
15:18	23 „Kasarna“	2

15:20	19 „Bolnica“	2
15:21	47 „Ruzha Delcheva“	2
15:25	„Diskont“	2
15:27	„Dovledzik“	2
15:28	„Pedagoshka 1“	2
15:31	35 „Muzichko“	2
15:33	10 „Javor“	2
15:36	31 „At-pazar“	2
15:40	50 „Zeleznicka 1“ (near the sports complex)	2
15:42	24 „Rakometno“ (near the sports komplex)	2
15:43	23 „Kasarna“	2
15:48	23 „Kasarna“	1
15:50	19 „Bolnica“	1
15:51	47 „Ruzha Delcheva“	1
15:52	17 „Vero 2“	1
15:53	15 „Pedagoshka 2“	1
15:56	35 „Muzichko“	1
15:58	10 „Javor“	1
16:01	31 „At-pazar“	1
16:04	Epinal (near the library)	1
16:07	23 „Kasarna“	1
16:12	23 „Kasarna“	3

16:14	19 „Bolnica“	3
16:15	17 „Vero 2“	3
16:16	15 „Pedagogoshka 2“	3
16:19	35 „Muzichko“	3
16:21	10 „Javor“ (Town Market and Old Town Bazaar)	3
16:24	7 „Dulie 2“	3
16:26	31 „At-pazar“	3
16:29	26 „Ruska Crkva“	3
16:30	50 „Zeleznicka 1“	3
16:33	23 „Kasarna“	3
16:38	23 „Kasarna“	1
16:40	19 „Bolnica“	1
16:41	47 „Ruzha Delcheva“	1
16:42	17 „Vero 2“	1
16:43	15 „Pedagogoshka 2“	1
16:46	35 „Muzichko“	1
16:48	10 „Javor“	1
16:51	31 „At-pazar“	1
16:54	Epinal (near the library)	1
16:57	23 „Kasarna“	1
17:02	23 „Kasarna“	2
17:04	19 „Bolnica“	2
17:05	47 „Ruzha Delcheva“	2

17:09	„Diskont“	2
17:11	„Dovledzik“	2
17:12	„Pedagoshka 1“	2
17:15	35 „Muzichko“	2
17:17	10 „Javor“	2
17:20	31 „At-pazar“	2
17:24	50 „Zeleznicka 1“ (near the sports complex)	2
17:26	24 „Rakometno“ (near the sports komplex)	2
17:27	23 „Kasarna“	2
17:30	23 „Kasarna“	3
17:32	19 „Bolnica“	3
17:33	17 „Vero 2“	3
17:34	15 „Pedagoshka 2“	3
17:37	35 „Muzichko“	3
17:39	10 „Javor“ (Town Market and Old Town Bazaar)	3
17:42	7 „Dulie 2“	3
17:44	31 „At-pazar“	3
17:47	26 „Ruska Crkva“	3
17:48	50 „Zeleznicka 1“	3
17:51	23 „Kasarna“	3
17:55	23 „Kasarna“	1

17:57	19 „Bolnica“	1
17:58	47 „Ruzha Delcheva“	1
18:59	17 „Vero 2“	1
18:00	15 „Pedagoshka 2“	1
18:03	35 „Muzichko“	1
18:05	10 „Javor“	1
18:08	31 „At-pazar“	1
18:11	Epinal (near the library)	1
18:14	23 „Kasarna“	1
18:20	23 „Kasarna“	2
18:22	19 „Bolnica“	2
18:23	47 „Ruzha Delcheva“	2
18:27	„Diskont“	2
18:29	„Dovledzik“	2
18:30	„Pedagoshka 1“	2
18:33	35 „Muzichko“	2
18:35	10 „Javor“	2
18:38	31 „At-pazar“	2
18:42	50 „Zeleznicka 1“ (near the sports complex)	2
18:44	24 „Rakometno“ (near the sports komplex)	2
18:45	23 „Kasarna“	2
18:50	23 „Kasarna“	3

18:52	19 „Bolnica“	3
18:53	17 „Vero 2“	3
18:54	15 „Pedagogshka 2“	3
18:57	35 „Muzichko“	3
18:59	10 „Javor“ (Town Market and Old Town Bazaar)	3
19:02	7 „Dulie 2“	3
19:04	31 „At-pazar“	3
19:07	26 „Ruska Crkva“	3
19:08	50 „Zelevnicka 1“	3
19:11	23 „Kasarna“	3
19:15	23 „Kasarna“	1
19:17	19 „Bolnica“	1
19:18	47 „Ruzha Delcheva“	1
19:19	17 „Vero 2“	1
19:20	15 „Pedagogshka 2“	1
19:23	35 „Muzichko“	1
19:25	10 „Javor“	1
19:28	31 „At-pazar“	1
19:31	Epinal (near the library)	1
19:34	23 „Kasarna“	1
19:40	23 „Kasarna“	2
19:42	19 „Bolnica“	2
19:43	47 „Ruzha Delcheva“	2

19:47	„Diskont“	2
19:49	„Dovledzik“	2
19:50	„Pedagoshka 1“	2
19:53	35 „Muzichko“	2
19:55	10 „Javor“	2
19:58	31 „At-pazar“	2
20:02	50 „Zeleznicka 1“ (near the sports complex)	2
20:04	24 „Rakometno“ (near the sports komplex)	2
20:05	23 „Kasarna“	2
20:10	23 „Kasarna“	3
20:12	19 „Bolnica“	3
20:13	17 „Vero 2“	3
20:14	15 „Pedagoshka 2“	3
20:17	35 „Muzichko“	3
20:19	10 „Javor“ (Town Market and Old Town Bazaar)	3
20:22	7 „Dulie 2“	3
20:24	31 „At-pazar“	3
20:27	26 „Ruska Crkva“	3
20:28	50 „Zeleznicka 1“	3
20:31	23 „Kasarna“	3
20:35	23 „Kasarna“	1

20:37	19 „Bolnica“	1
20:38	47 „Ruzha Delcheva“	1
20:39	17 „Vero 2“	1
20:40	15 „Pedagoshka 2“	1
20:43	35 „Muzichko“	1
20:45	10 „Javor“	1
20:48	31 „At-pazar“	1
20:51	Epinal (near the library)	1
20:54	23 „Kasarna“	1
21:00	23 „Kasarna“	2
21:02	19 „Bolnica“	2
21:03	47 „Ruzha Delcheva“	2
21:07	„Diskont“	2
21:09	„Dovledzik“	2
21:10	„Pedagoshka 1“	2
21:13	35 „Muzichko“	2
21:15	10 „Javor“	2
21:18	31 „At-pazar“	2
21:22	50 „Zelesnicka 1“ (near the sports complex)	2
21:24	24 „Rakometno“ (near the sports komplex)	2
21:25	23 „Kasarna“	2

The total length traveled daily by the electric vehicle - minibus according to the proposed timetable is 285.2 km:

$$L_d^{vk} = \sum_d (L_1^{vk} + L_2^{vk} + L_3^{vk} + L_4^{vk}) = 75 + 82.4 + 87 + 40.8 = 285.2 \text{ km}$$

According to the technical specifications of the electric vehicle - minibus, this length is less than the established range for city driving, i.e. $285.2 < 300$ km.

This confirms that the proposed daily schedule will be performed without stopping, because there will be no need for daily charging of the electric vehicle - minibus.

For tourist routes (route numbers 5, 6 and 7) which are routes with a longer duration compared to urban routes (maximum duration is 2 hours and 52 minutes), a timetable is shown in Tables 4 and 5 which refers only to the days from weekend (Saturday and Sunday).

Table 4: Timetable for tourist routes 5 and 7

The first three Saturdays of the month: route 5		Last Saturday of the month: route 7	
Time	Stops	Time	Stops
09:00	23 „Kasarna“	09:00	23 „Kasarna“
09:03	17 „Vero 2“	09:33	Resen – town hall
09:04	15 „Pedagogshka 2“	10:27	Prespa - town hall
09:35	village Pretor	11:20	Florina – town hall
10:11	14 „ Pedagogshka 2“	11:52	23 „Kasarna“
10:12	16 „Vero 2“		
10:15	22 „Kasarna“		
14:00	23 „Kasarna“		

14:03	17 „Vero 2“		
14:04	15 „Pedagoshka 2“		
14:35	village Pretor		
15:11	14 „Pedagoshka 2“		
15:12	16 „Vero 2“		
15:15	22 „Kasarna“		
Lenght: 2 X 78 = 156 km		Lenght: 151 km	

Table 5: Timetable for the tourist route 6

Route 6: every Sunday of the month	
Time	Stops
09:00	23 „Kasarna“
09:03	17 „Vero 2“
09:04	15 „Pedagoshka 2“
10:13	Ohrid
11:20	14 „Pedagoshka 2“
11:21	16 „Vero 2“
11:24	22 „Kasarna“
Lenght: 139.8 km	

For tourist routes (5, 6 and 7) uninterrupted transport by electric minibus is also provided, because the daily mileage for each route (i.e., 156 km, 151 km and 139.8 km) is less than the capacity of the vehicle with charged battery, i.e. less than the autonomy of the combined cycle range which is 200 km.

5. SCHEDULE FOR CHARGING ELECTRIC VEHICLES

A particularly important aspect when planning a timetable for electric vehicles is the limitation of battery capacity. Hence the need when planning the timetable of the routes to take into account the charging schedule of electric vehicles.

The demand for electricity from the vehicles is a result of the consumed energy due to the mobility of the users with the electric vehicles on the proposed routes. The charging station should enable uninterrupted charging of both electric vehicles for uninterrupted realization of the timetable. Thus, the charging schedule determines the charging times of the two electric vehicles, in order to avoid disturbances in the timetable of the designated routes.

According to the technical characteristics of electric vehicles, the average charging period is about 4 hours. According to the timetable, the ride on the last route ends at 21:25. The start of the work is from 07:00. So, there is a total period of 9.5 hours, a period in which both electric vehicles can be charged.

The charging of the electric vehicles will be performed from 21:30 to 07:00, so that during the day, there will be no delay in the realization of the routes according to the timetable.

6. FORECAST FOR THE APPLICATION OF ELECTRIC VEHICLES AND THE DEVELOPMENT OF PASSENGER TRANSPORT FOR THE NEXT 20 YEARS

Compared to fossil fuel vehicles, electric vehicles are more energy efficient and have lower maintenance costs. Batteries for electric vehicles are a proven technology that will last for many years. The electric vehicle battery is expected to last up to 20 years before it needs to be replaced.

The battery is the most sensitive part of electric vehicles. Therefore, here are some recommendations for longer lifespan and increased battery efficiency.

1. **Avoid complete charge:** If each battery is charged 100%, its lifespan will be significantly reduced. Frequent charge of the battery to such a full capacity will lead to its degradation. To extend battery life, the vehicle needs to be charged to 80% capacity. An additional 20% of the empty space will prevent the electric vehicle from creating too much stress. In addition, this will enable regenerative braking that can convert kinetic energy into usable energy. Often, if the battery is more than 80% full, the vehicle will automatically disable this useful feature.
2. **Avoid complete discharge:** Similarly, the battery should not be consumed until it reaches 0%. This discharge will result in excessive consumption and degradation of

the battery components. As soon as the battery of the electric vehicle drops to 10% to 20% capacity, the vehicle should be switched on so that it does not run on low charge for a long period of time.

3. **Taking into account weather conditions:** Extreme weather conditions and temperature changes can also shorten battery lifespan. Therefore, care should be taken with the weather conditions when parking, storing and charging electric vehicles.
 - **Shade parking:** Excessive sun exposure and higher temperatures can cause severe damage to the battery. To minimize damage to the electric vehicle, shaded parking is recommended, especially if the vehicle needs to be parked for an extended period of time.
 - **Avoiding extreme cold:** extreme cold can affect the battery of an electric vehicle in the same way as extreme heat. In fact, a particularly cold wave can temporarily reduce battery life by more than 40% when switching on and using internal heaters. Therefore, it is best to store electric vehicles in a temperature-controlled facility during the winter months or to charge them during a very cold polar period.

4. **Moderate speed movement.** Driving at high speeds as well as driving uphill will put an unnecessary load on the battery of electric vehicles. To extend battery life, it is recommended that the vehicle be operated at moderate speeds on flat terrain.

By following the recommendations given in the exploitation of electric vehicles, the effect in extending the lifespan of the batteries will be positive. Longer battery life will mean prolonged use of electric vehicles for passenger transport in Bitola.

In the future period of 20 years, of course, there will be demographic and urban changes in the town, so it is recommended that these proposed routes in the study be changed and adapted to the future needs for transportation and demand from the citizens of Bitola. Regarding the selected places in the study for the destination of all three urban routes, the urban plans do not plan dislocation of these places (city library, sports complex and city market and bazaar). This would mean that the need for mobility will continue to be addressed to these destinations, as attractive destinations in urban travel. The urban changes in the 20-year period will refer to the expansion of the city in the peripheral areas, and especially in the immediate vicinity of the Sports Hall "Boro Churlevski", where a residential settlement is already starting to develop. These urban changes mean that there will be no major deviation from the route line - the changes would refer to the expansion of the route to the areas where increased urban development is expected. The expansion of the routes will include adding new stops for

travelers in the new urban areas of the town or defining a new route that will serve the residents of those areas to the destinations of greater attractiveness.

Such a change in the routes that will follow all urban changes in the town will mean maintaining and continuing the quality of service for passengers. The selection of optimal routes and the realization of the transport of passengers with electric vehicles on those routes will reduce the transport costs in both regions in the period of 20 years.

In the next 20-year period of operation of electric vehicles in Bitola, technological upgrades to passenger transport can be made using the benefits of advanced technology. For example, transportation can be integrated with a system for vehicle location and a real-time customer information system. Thus, passengers at a stop or at home via the Internet or on their phones will receive real-time information on the arrival times of vehicles at each stop on the route.

The implementation of the proposed solutions for the routes and the vision for development elaborated in the study will contribute the passenger transport with electric vehicles to be an important part of the modern quality way of urban living in Bitola.

7. CONCLUSION

In this study, the routes for the municipality of Bitola are defined and developed and the timetable for the electric vehicle-minibus is created, according to the requirements in the project "Integration of Green Transport in Cities" and the directions received from the municipality of Bitola. During the design of the routes, several characteristics and parameters have been taken into account: the needs of the transport users, the destinations that are attractive and that attract more citizens, the characteristics of the road and traffic network in the municipality of Bitola and the characteristics of the electric vehicles.

Routes 1, 2 and 3 are urban routes with specific destinations in Bitola: library, sports complex, town market and bazaar. These are destinations that are popular and attract a large number of daily travelers. With these created routes, certain categories of citizens of the municipality of Bitola (persons with disabilities, the elderly, athletes, pupils and students) are provided with comfortable, modern and quality transport, which is also environmentally friendly.

Routes 4, 5, 6 and 7 are tourist routes with destinations: the village of Trnovo, the village of Pretor, Ohrid and the four cross-border towns of Bitola, Resen, Prespa and Florina. Route 4 to the village of Trnovo is proposed to be realized as a daily route, due to the relatively shorter length compared to other tourist routes. The other tourist routes will be performed only during the weekends (Saturday and Sunday). Thereby, the tourist route 5 (to the village of Pretor) will be performed twice a day (Saturday), and the other tourist routes due to the longer length only once a day.

A detailed weekly timetable has been prepared for all routes. In its preparation, the limitations in the driving range of the electric minibus were taken into account, i.e. attention was taken not to exceed the daily range of kilometers traveled when the battery is fully charged.

With the practical implementation of the solutions from the study, it is expected that the transport with electric vehicles in the municipality of Bitola will contribute to the improvement of the passenger transport service in the daily urban travel of the mentioned categories of citizens.

The study provides a forecast for the development of passenger transport over a 20-year period. The routes will have to adapt to the demographic and urban changes in the town, in order to meet the needs for transportation of residents in the new residential neighborhoods in Bitola. Changes in the routes by adding new stops or defining a new route that will follow all urban changes in the town will mean maintaining and continuing the quality of service for passengers.

Passenger transportation with electric vehicles will contribute to reducing emissions, favorable opportunities for personal mobility as an alternative to using own vehicle, reducing household costs, reducing vehicle maintenance costs. These benefits apply to both cross-border regions. In addition, in combination with the way of charging with clean energy (solar energy) that will be used to obtain electricity, electric vehicles can serve as an interesting tourist attraction in the town.

In the municipality of Bitola this will be a modest start with two electric vehicles - a passenger vehicle and a minibus. Nevertheless, the municipality sets a very good example for promoting the benefits of electric vehicles in the development of sustainable mobility. In fact, the sustainability of urban transport needs solutions that will encourage the private vehicle to be a second choice, which would reduce environmental pollution and energy consumption. And electric vehicles have that potential. Therefore, the transport of passengers in urban transport by electric vehicles in the municipality of Bitola will mean active involvement in the initiatives for sustainable urban transport.

LITERATURE

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**Deliverable 3.6.3: Studies for the most efficient electric
minibuses route schedule per Municipality**

Study for Bitola Municipality

by

University of Patras

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1. Introduction

This deliverable describes the study about routing and scheduling in the Municipality of Bitola. It is part of the project “Integration of Green Transport in Cities” with acronym “Green Inter-e-Mobility”. This project proposes an intelligent green public transportation system to improve urban mobility and increase sustainability in cross-border regions. Integration of the new system with upgraded infrastructure is expected to reduce travel time, thus enhancing mobility options and supporting Vulnerable-to-Exclusion (VTE) groups, such as elderly and students. The new system is also expected to promote energy efficiency thus strengthening network sustainability in the cross-border regions. The new integrated cross-border system will support work and school trips in Western Macedonia Region of Greece (Florina and Prespes Municipalities), and Pelagonia Region of North Macedonia (Bitola and Resen Municipalities).

Main project outputs include the enhancement of the tourist stream towards the cross-border area and enhancements of the cross-border cultural relations. This is to be accomplished through the establishment of the transnational Bitola-Florina tourist route, and the facilitation of students in their daily transport and of residents (elderly, disabled, distant-residents) in their daily on-demand transport in all four Municipalities. Further, the optimal route scheduling and the realization of transport by e-vehicles will greatly reduce their transportation expenses in the two regions through a 20-year horizon.

Through the cross-border approach, including the partners’ cooperation during the development and operation phases, the Municipalities will benefit by the mutual exchange of know-how and experiences among the cross-border actors and end-users of the e-vehicles. Moreover, the public, through the partners’ joint awareness initiatives for green mobility, and by making use of the new technology, will participate to environment-friendly concepts and actions. Also, the establishment of the cross-border electric minibus route between Florina and Bitola will be combined with other cultural activities and strengthen the relations between the populations of the two countries.

The project added value is multi-faceted, as it includes the environmental conservation of the cross-border area, the touristic promotion of the region and the facilitation of the area residents in their daily transport.

From the above, long-term benefits to the two regions will include: (a) saving transport and maintenance cost; and environmental benefits through social media, conferences attendees, seminars, (b) the fact that the electric vehicles, especially when they are combined with solar charging, can serve as an important touristic attraction for the area, especially for

thematic tourists. In view of rapidly increasing environment-sensitive and thematic tourism, the EVs provide added value to the touristic development of the area.

In what follows, the deliverable will provide routes for seven main destinations, City Library St. Kliment Ohridski, City Stadium Tumba Kafe, village Trnovo-Baba Mountain, Village Pretor-Prespa Lake, Krushovo town, Ohrida city and a tourist route to all four municipalities, and one schedule (given that one e-minibus will be available) for Bitola Municipality. The e-minibus mixed cycle autonomy will be 200km, and city cycle autonomy will exceed 300km. The average time needed for charging fluctuates around 4 hours.

2. Data Collection

In this section Bitola Municipality's preferences, as well as important and busy locations of the area are listed. The routes and schedules created in the next sections take into consideration these preferences.

2.1. General Information

In order to create a route schedule for Bitola Municipality, there is a need to collect quantitative data on current mobility needs and requirements as well as the ways these are being addressed. There is a need for data about the modes that local citizens use for their daily transport, as well as the corresponding trip characteristics, schedules and itineraries. Next, it is essential to focus on the exact mode, in this case buses, and examine the best alternatives for that mode. Effective route planning and scheduling require the best possible awareness of public needs, including origins and destinations. Given that information, the designer proposes trip routes, stops and schedules.

However, public needs are not the same across the four municipalities under study. Public transit networks have their own characteristics and properties across municipalities, and these were taken into consideration when designing routes and schedules. In particular, design requirements included the positions of stops and their popularity, which are related to citizen needs and requirements for education, fitness, recreation, health and markets. Toward this objective Bitola Municipality provided a list of possible transit stops, and this is included in section 2.3.

2.2. Electric vehicle characteristics

The intelligent network of the electric vehicles for Bitola Municipality consists of one electric minibus (e-minibus) and one electric utility car that will be employed for transporting tourists and students along the routes, as well as residents, especially elderly, disabled and distant-residents, on-demand. The e-minibus will have seven seats and the electric utility car will have five seats. The combined cycle autonomy of the 5-seat utility electric car will be 270km, and for the city cycle, 389km. Regarding the 7-seat e-minibus, mixed cycle autonomy will be 200km, while city cycle autonomy will exceed 300km. Three routes per municipality, averaging 10 km each, will serve on average 25 citizens daily. Additionally, a cross border route from Bitola to Resen, Prespes and Florina will serve locals and tourists who desire to travel in the cross-border area. The following image shows the cross- border area.

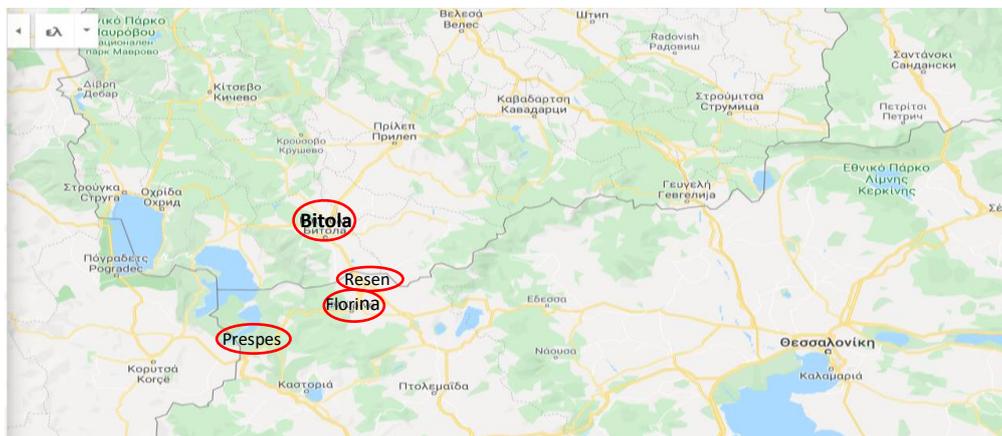


Figure 1: The cross-border area of Bitola, Resen, Prespes and Florina

To charge the two electric vehicles of the municipality of Bitola, a proper charging station will be constructed, and a grid connected photovoltaic (PV) system that produces electric energy will be installed. The photovoltaic panels will be installed in the municipality of Bitola, on the roof of the Sports Hall of the area. Figure 2 shows the location of the selected building. The starting and ending point of each route will be the Sports Hall, where the charging of the electric vehicles is feasible.



Figure 2: The Sports Hall of Bitola (top view)



Figure 3: The Sports Hall of Bitola (front view)

2.3. Collected data

Bitola Municipality provided a list of possible routes and the corresponding stops. Sports Hall is both the starting and ending point of each route because of the charging station on the

roof of the Sports Hall of the area. Table 1 shows the routes suggested by Bitola Municipality, according to the locals' needs.

Table 1: Routes suggested by Bitola Municipality

Route 1		City Library St. Kliment Ohridski
Stops	1	Sports Hall Boro Churlevski
	2	PHI Clinical Hospital Dr. Triphun Panovski Bitola
	3	Vero
	4	Pedagoshka Faculty of pedagogy
	5	Primary School Gjorgji Sugarev
	6	Javor
	7	Bitoil
	8	Selska Avtobuska Stanica
	9	Shetalishte
	10	City Library St. Kliment Ohridski
	11	Sports Hall Boro Churlevski
Route 2		City Stadium Tumbe Kafe
Stops	1	Sports Hall Boro Churlevski
	2	PHI Clinical Hospital Dr. Triphun Panovski Bitola
	3	Vero
	4	Pedagoshka Faculty of pedagogy
	5	Primary School Gjorgji Sugarev
	6	Javor
	7	Bitoil
	8	Primary School Dame Gruev
	9	Football stadium Tumbe kafe
	10	Sports Hall Boro Churlevski
Route 3		Tourist route to village Trnovo – Baba Mountain
Stops	1	Sports Hall Boro Churlevski
	2	Vero
	3	Pedagoshka - Faculty of pedagogy

	4	village Trnovo church "St. Bogorodica"
	5	Pedagoshka - Faculty of pedagogy
	6	Vero
	7	Sports Hall Boro Churlevski
Route 4		Tourist route to village Pretor - Prespa Lake
Stops	1	Sports Hall Boro Churlevski
	2	Vero Super Market
	3	Faculty of Pedagogy
	4	Pretor village-Prespa Lake
	5	Faculty of Pedagogy
	6	Vero Super Market
	7	Sports Hall Boro Churlevski
Route 5		Tourist route to Krushevo
Stops	1	Sports Hall Boro Churlevski
	2	Krushevo
	3	Sports Hall Boro Churlevski
Route 6		Tourist route to Ohrida
Stops	1	Sports Hall Boro Churlevski
	2	Ohrida
	3	Sports Hall Boro Churlevski
Route 7		Tourist route to Bitola-Resen-Prespes-Florina
	1	Sports Hall Boro Churlevski (Bitola)
	2	Resen Town Hall
	3	Prespes Town Hall
	4	Florina Town Hall
	5	Sports Hall Boro Churlevski (Bitola)

The first route drives to the destination of City Library St. Kliment Ohridski. Library "St. Kliment Ohridski" is a national, modern cultural institution, and constitutes a central spot for the city, as the majority of professors, researchers, journalists and students visits it often.

Figures 4 and 5 show the location and the front view of the City Library St. Kliment Ohridski respectively.

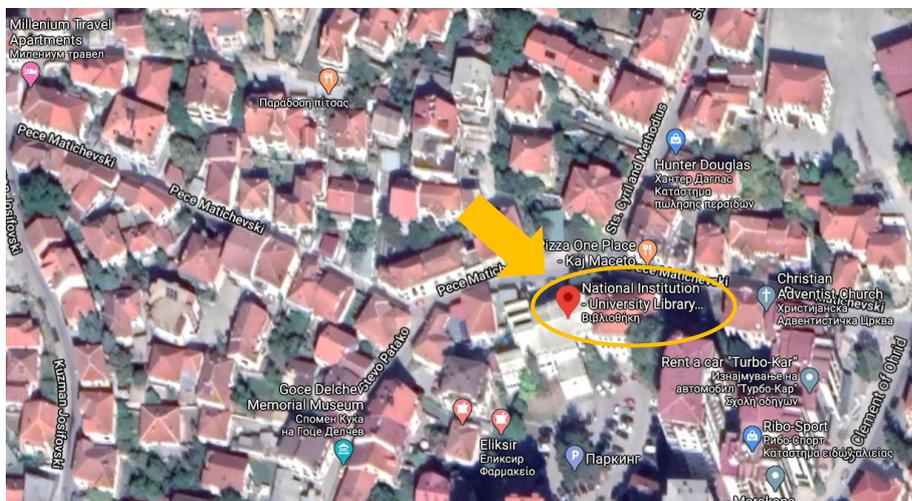


Figure 4: Location of City Library St. Kliment Ohridski in Bitola (Source: Google Maps)



Figure 5: City Library St. Kliment Ohridski in Bitola (Source: www.WhereIsMacedonia.org)

Sports Hall is both the starting and ending point of the route, where the charging of the electric vehicles is feasible. The first route is of 10.8 km length and lasts 27 minutes. The intermediate stops of this route are:

- PHI Clinical Hospital Dr. Triphun Panovski
- Vero Super Market
- Pedagogshka Faculty of pedagogy

- Primary School Gjorgji Sugarev
- Javor Trade Center
- Bitoil Gass Station
- Selska Avtobuska Stanica (station for suburban traffic)
- Shetalishte City Park

The second route drives to the destination of City Stadium Tumbe Kafe. The latter is a football stadium, a hallmark for the city, as it constitutes an attraction point for citizens and athletes. Figures 6 and 7 show the location and the view of the City Stadium Tumbe Kafe.

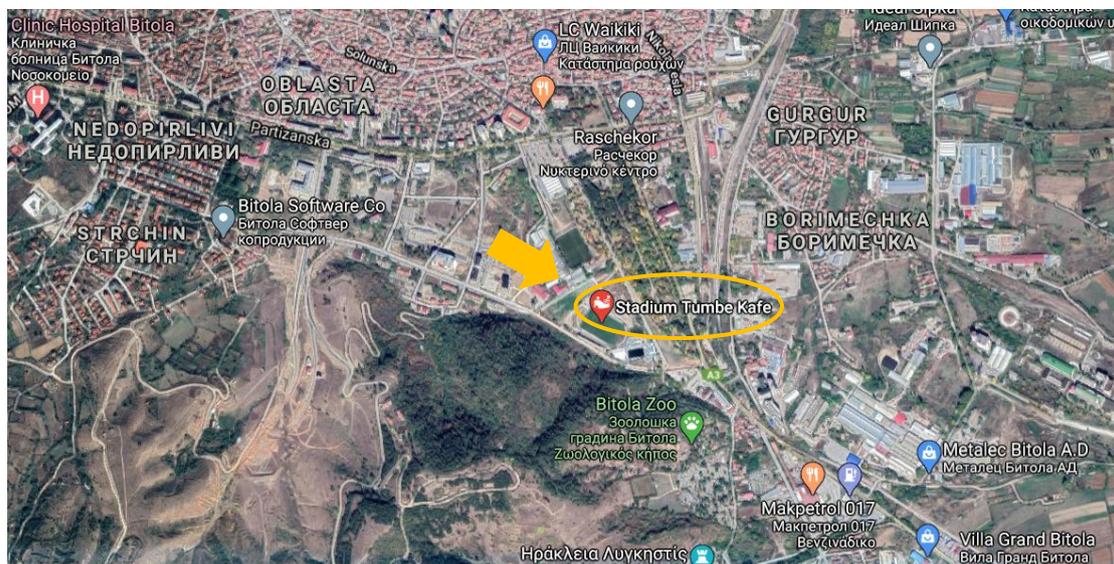


Figure 6: Location of City Stadium Tumbe Kafe in Bitola (Source: Google Maps)



Figure 7: View of City Stadium Tumbe Kafe in Bitola (Source: Wikipedia)

Sports Hall is both the starting and ending point of the route, where the charging of the electric vehicles is feasible. The second route is of 10.8 km length and of 25 min duration. The intermediate stops of this route are:

- PHI Clinical Hospital Dr. Triphun Panovski Bitola
- Vero Super Market
- Pedagogshka Faculty of pedagogy
- Primary School Gjorgji Sugarev
- Javor Trade Station
- Bitoil Gass Station
- Primary School Dame Gruev

The third route is a tourist route and drives to the destination of village Trnovo in Baba Mountain. The e-minibus will stop at church “St. Bogorodica” (Holy Virgin Mary Church). The third route is of 18 km length and of 29 min duration. Figure 8 shows the location of village Trnovo in Baba Mountain and figure 9 shows the front view of St. Bogorodica Church.

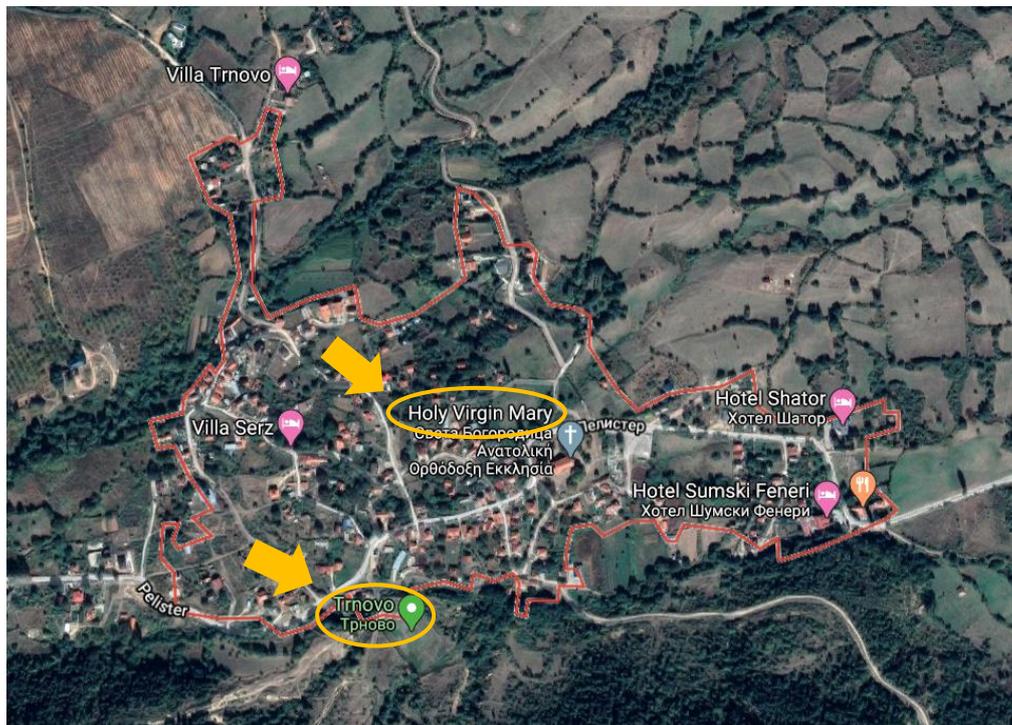


Figure 8: The location of village Trnovo in Baba Mountain in Bitola (Source: Google Maps)



Figure 9: The front view of St. Bogorodica Church in Bitola (Source: Google Maps)

The fourth route is a tourist route and drives to the destination of Pretor village. Pretor (Macedonian: Претор) is a village in the Resen Municipality, on the northeastern shore of Lake Prespa. The village is located over 13 kilometres south of the municipal centre of Resen. Figure 10 shows the location of Pretor village.

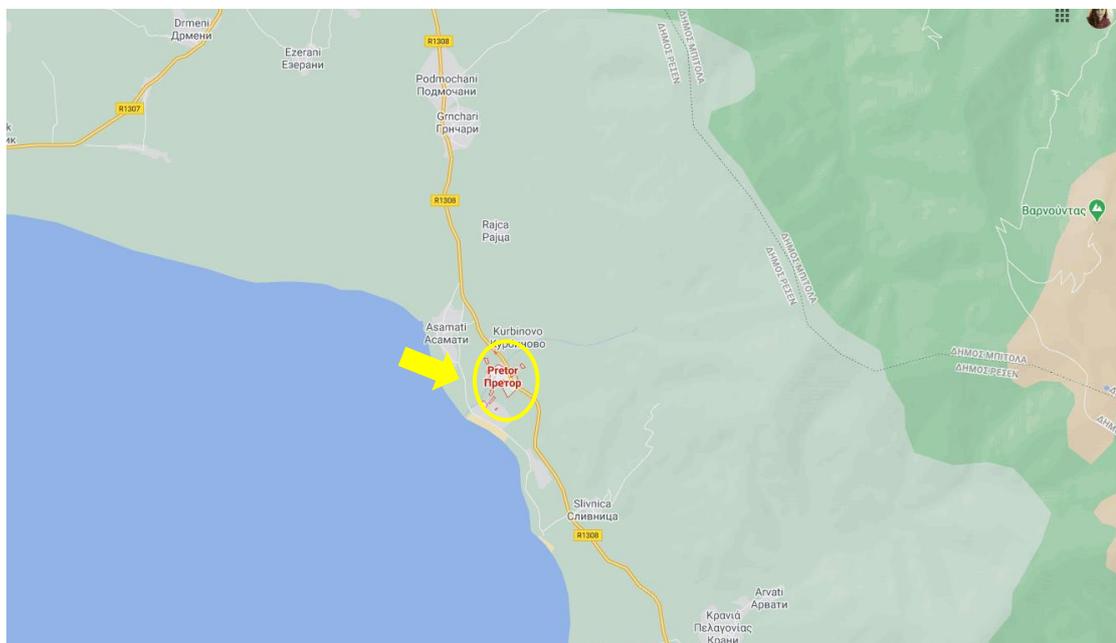


Figure 10: Location of Pretor village in Bitola (Source: Google Maps)

Sports Hall is both the starting and ending point of the route, where the charging of the electric vehicles is feasible. The fourth route is of 78.6 km length and of 25 min duration. The intermediate stops of this route are:

- Sports Hall Boro Churlevski
- Vero Super Market
- Faculty of Pedagogy
- Pretor village-Prespa Lake
- Faculty of Pedagogy
- Vero Super Market
- Sports Hall Boro Churlevski

The fifth route is a tourist route and drives to the destination of Krushevo. Krushevo is a town in North Macedonia. It is the highest town in North Macedonia and the Balkans, situated at an altitude of over 1350 m above sea level. The town of Krushevo is located in the western part of the country, overlooking the region of Pelagonia, 33 and 53 km from the nearby cities of Prilep and Bitola, respectively. Figure 11 shows the location of Krushevo.

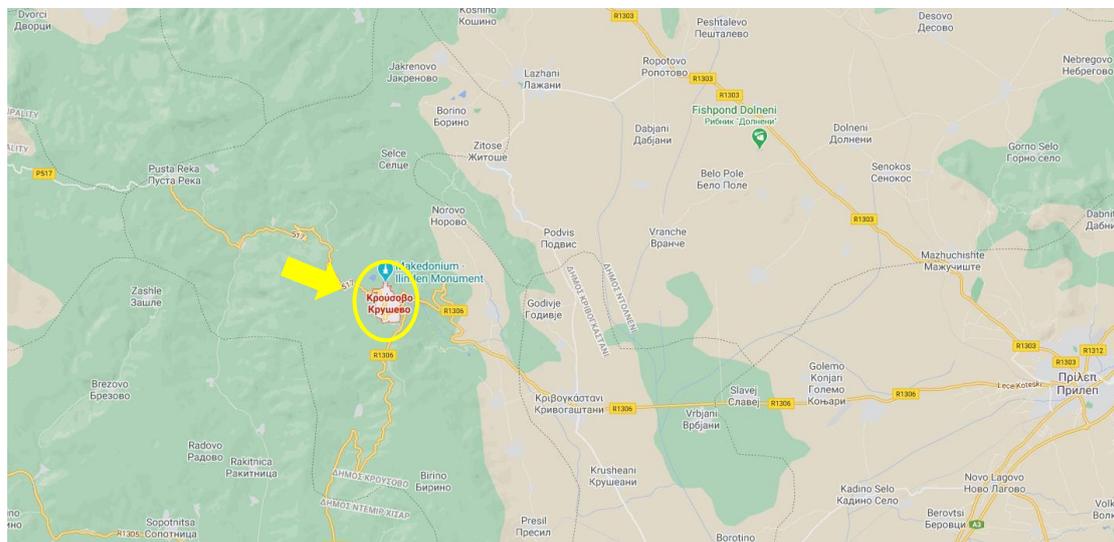


Figure 11: Location of kreshovo in Bitola (Source: Google Maps)

Sports Hall is both the starting and ending point of the route, where the charging of the electric vehicles is feasible. The fifth route is of 108 km length and of 1h and 58 min duration. The intermediate stops of this route are:

- Sports Hall Boro Churlevski

- Krushevo
- Sports Hall Boro Churlevski

The sixth route is a tourist route and drives to the destination of Ohrida. Ohrida (Macedonian: Охрид) is a city in North Macedonia and the seat of the Ohrida Municipality. It is the largest city on Lake Ohrida and the eighth-largest city in the country, with over 42,000 inhabitants as of 2002. It is located southwest of Skopje, west of Resen and Bitola. Ohrida is one of only 28 sites that are part of UNESCO's World Heritage that are Cultural as well as Natural sites. Figure 12 shows the location of Ohrida.

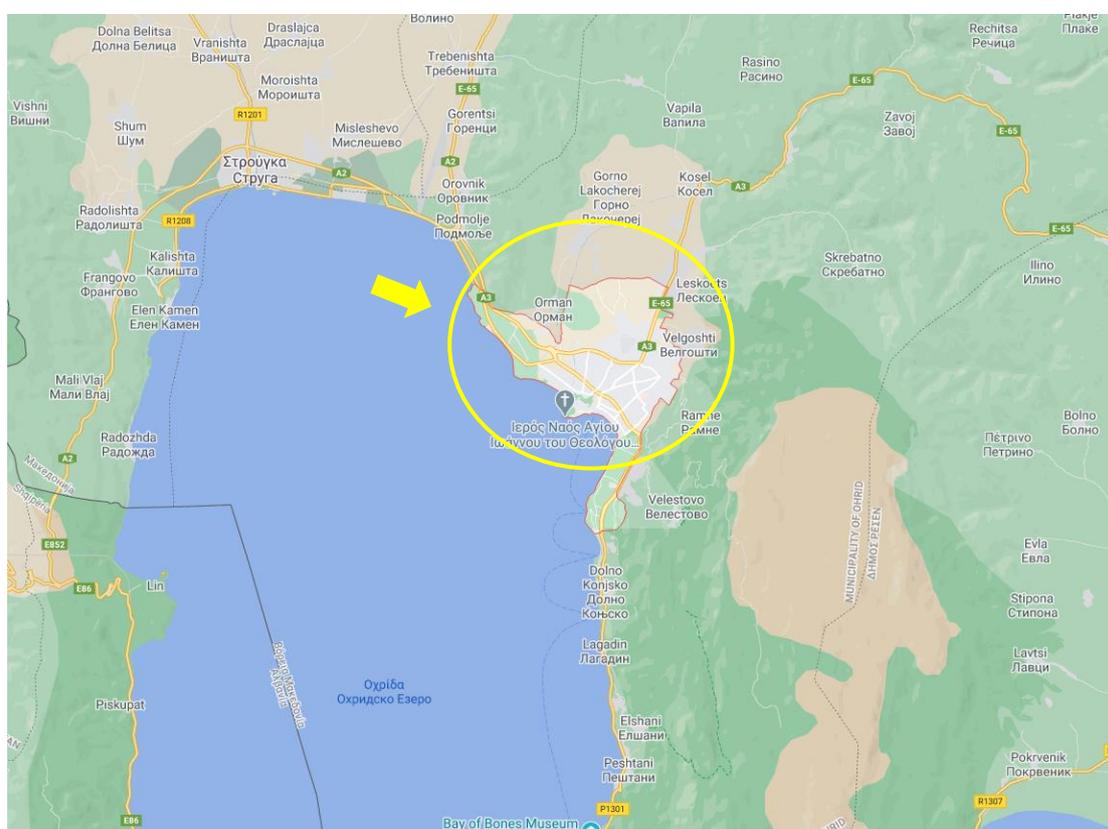


Figure 12: Location of Ohrida in Bitola (Source: Google Maps)

Sports Hall is both the starting and ending point of the route, where the charging of the electric vehicles is feasible. The sixth route is of 142 km length and of 2h and 27 min duration. The intermediate stops of this route are:

- Sports Hall Boro Churlevski
- Ohrida
- Sports Hall Boro Churlevski

The seventh route is a tourist route and drives to the destination of all 4 Municipalities: Bitola, Resen, Prespes and Florina. Sports Hall is both the starting and ending point of the route, where the charging of the electric vehicles is feasible. The seventh route is of 160 km length and of 2h and 22 min duration. The intermediate stops of this route are:

- Sports Hall Boro Churlevski (Bitola)
- Resen Town Hall
- Prespes Town Hall
- Florina Town Hall
- Sports Hall Boro Churlevski (Bitola)

Table 2 summarizes the length and duration of each route according to the collected data.

Table 2: Length and duration of the three routes

Route	1	2	3	4	5	6	7
Length (km)	10.8	10.8	18	78.6	108	142	160
Duration (min)	27	25	28	1h and 14 min	1h and 58 min	2h and 27 min	2h and 22 min

3. E-minibus routing

In this section, considering the data provided by Bitola Municipality the e-minibus routing was designed. Users' preferences and traffic rules' constraints were also considered.

3.1. Route 1 to City Library St. Kliment Ohridski

E-minibus routing was designed using Aimsun Next 8.4.0 Software considering traffic rules, i.e. allowed turns, double- or single-way roads, number of lanes and general road geometry's constraints. Figure 13 shows Bitola's center. This map was imported as a road network in Aimsun Next from *Open Street Map.org*.

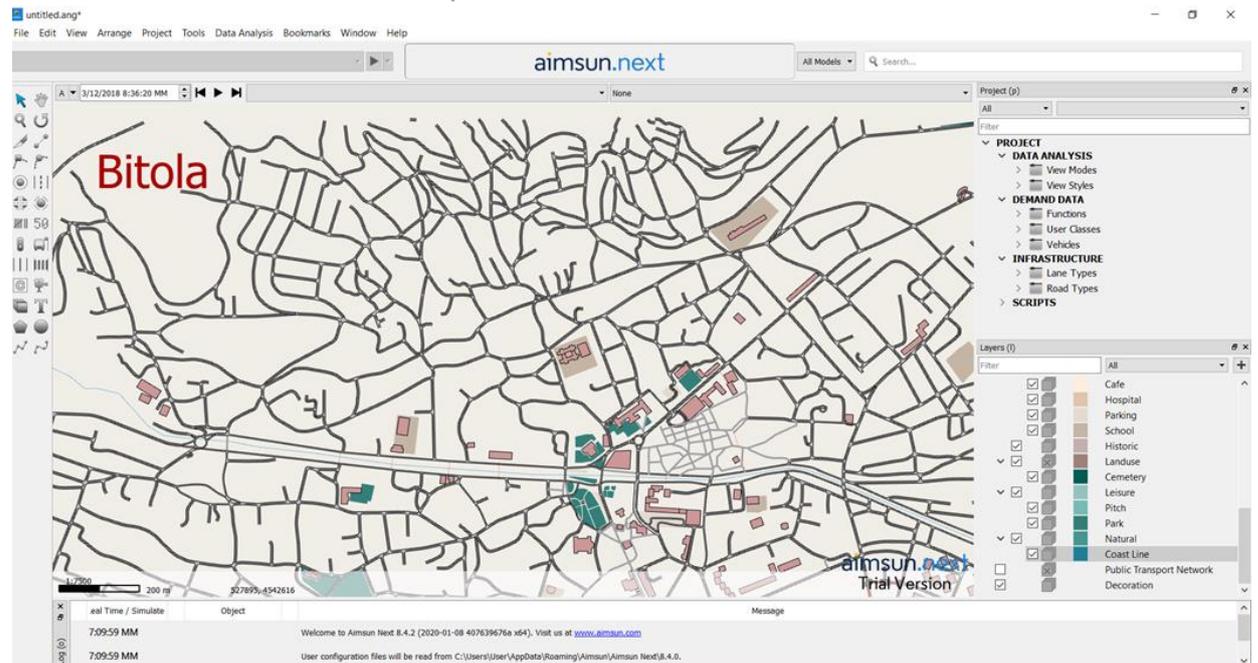


Figure 13: Bitola's center

After importing the map, including the whole center of Bitola, the best route to City Library St. Kliment Ohridski, route 1, was designed. A public transport line was created by selecting the appropriate road sections consecutively, according to data collected by Bitola Municipality. Afterwards, the stops were defined in accordance with citizens' needs. The following stops were chosen to serve the majority of Bitola citizens. Assuming that most mobility demands have as a destination an important location (hospitals, libraries, stadiums, markets etc.), the route serves most of daily citizens' travels, as most important locations are either stops or "5-minutes-on-foot" away from the nearest stop. Eleven stops were designed, as follows:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: PHI Clinical Hospital Dr. Triphun Panovski Bitola
- Stop 3: Vero Super Market
- Stop 4: Pedagogshka Faculty of pedagogy
- Stop 5: Primary School Gjorgji Sugarev
- Stop 6: Javor Trade Center
- Stop 7: Bitoil Gass Station
- Stop 8: Selska Avtobuska Stanica

- Stop 9: Shetalishte City Park
- Stop 10: City Library St. Kliment Ohridski
- Stop 11: Sports Hall Boro Churlevski

Figure 14 shows route 1 to City Library St. Kliment Ohridski. Figures 15, 16 and 17 show parts of this route, Sports Hall Boro Churlevski, Primary School Gjorgji Sugarev and City Library St. Kliment Ohridski, respectively.

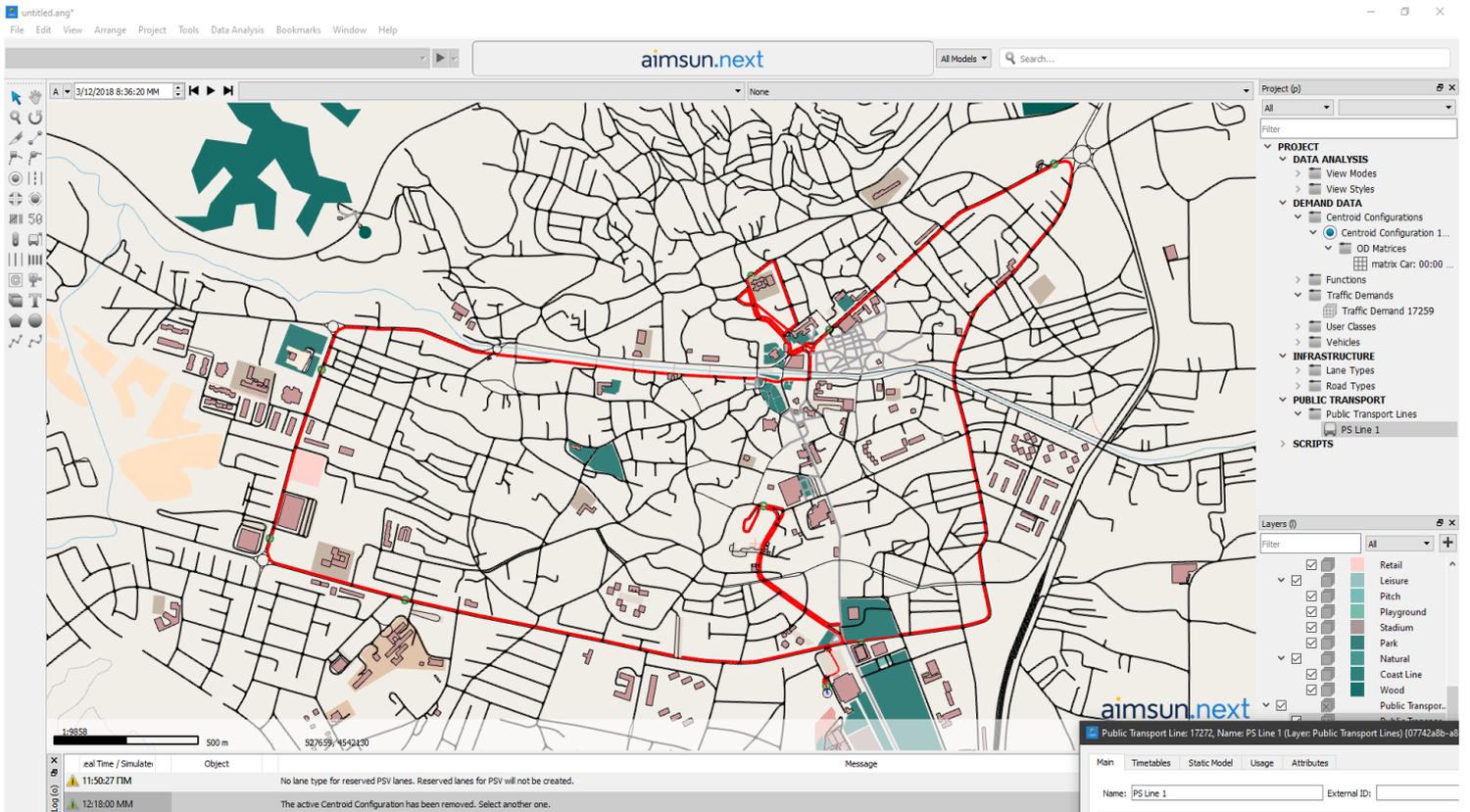


Figure 14: Route 1 to City Library St. Kliment Ohridski

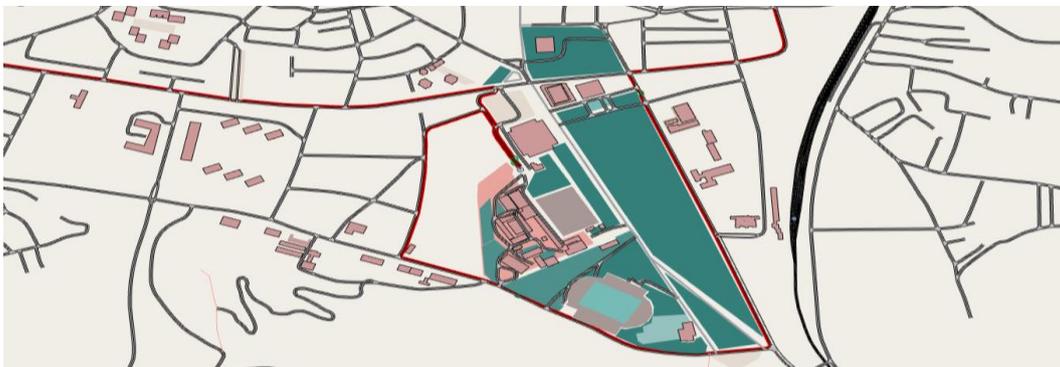


Figure 15: Sports Hall Boro Churlevski

- ❖ **Terminal stops:** Terminal stops are used to model public transport stations or bus parking. They have room for a limited number of public transport vehicles; the capacity is defined as an attribute of the stop.

Normal stop is the type that was chosen for the intermediate stops, and terminal stop is the type used for the last stop of the route. Thirty seconds were chosen as stop duration.

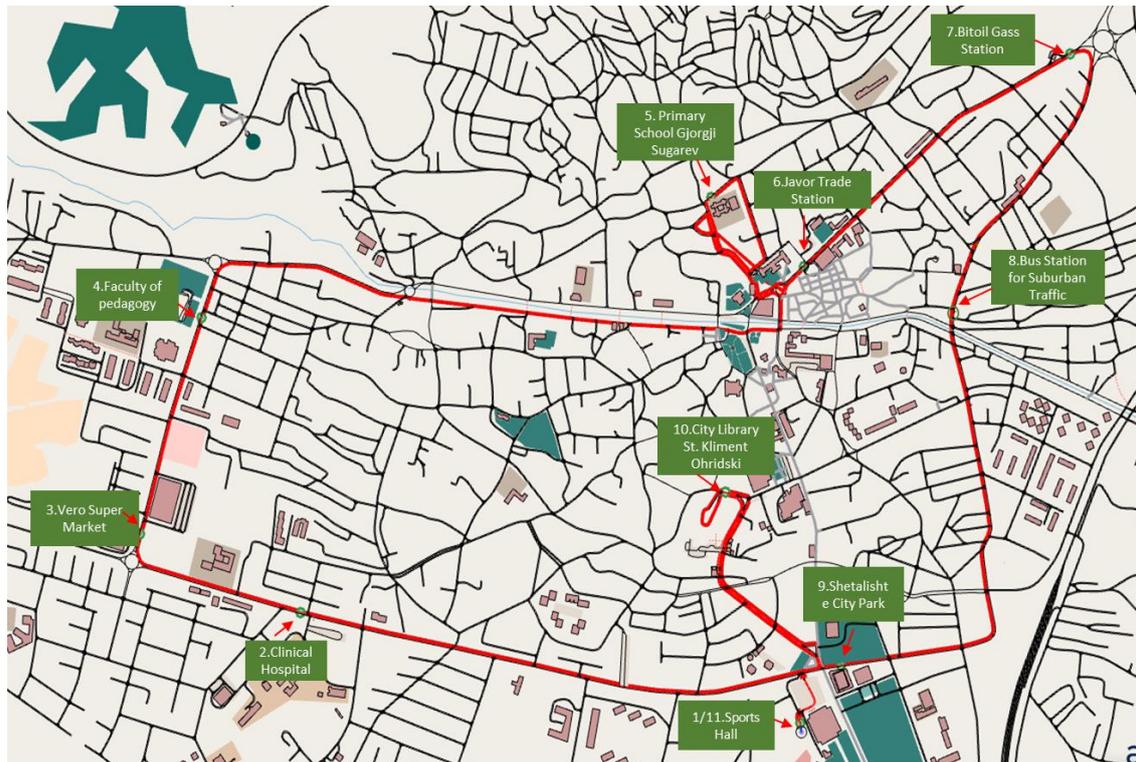


Figure 18: Route 1 (City Library St. Kliment Ohridski) and the intermediate stops

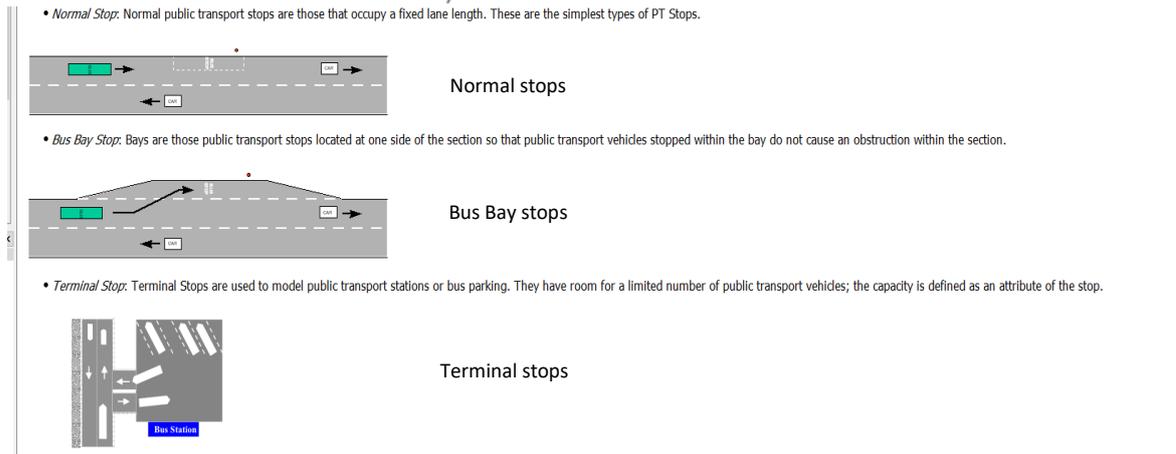


Figure 19: The three types of stop

Road sections of the first route to City Library St. Kliment Ohridski, accompanied with instructions, are presented below.

Distance: 10.8 km, Optimal Travel Time: 27 min. The e-minibus:

1. Starts from **Sports Hall**.
2. Goes northwest to Polygon Street towards Partizanshka Street - 170m
3. Turns left to Partizanshka Street - 1.4km.
4. Turns left to **Clinical Hospital Dr. Trifun Panovski** - 120m.
5. Goes northeast to Partizanshka Street – 120m.
6. Turns left to Partizanshka Street – 500m.
7. In the roundabout, takes the first exit to General Vasko Karangjelevski Street – 140m.
Vero Super Market is on the left side.
8. Goes north to General Vasko Karangjelevski Street towards Taku Dimitrovski Street– 120m. **Faculty of Pedagogy** is on the left side.
9. In the roundabout, takes the first exit to 1st May Boulevard Street –550m.
10. In the roundabout. Takes the second exit and stays in 1st May Boulevard Street- 1 km.
11. Turns left in 1st May Boulevard Street– 42m.
12. Turns left to stay in 1st May Boulevard Street– 89m.
13. Turns left to Jane Sandanski Street– 300m.
14. Turns right in Dimitar Vlahov Street– 35m. **Elementary School Gjorgji Sugare** is on the right side.
15. Goes southwest to Dimitar Vlahov Street towards Jane Sandanski Street – 35m.
16. Turns left to Jane Sandanski Street– 300m.

17. Turns left to Filip II Makedonski Street – 61m.
18. In the roundabout, takes the second exit and stays in Filip II Makedonski Street – 170m. **Javor Trade Center** is on the left side.
19. Goes northeast in Filip II Makedonski Street – 110m. **Bitoil Gass Station** is on the left side.
20. In the roundabout, takes the first exit towards Prilepska Street – 850m.
21. Turns left to stay in Prilepska Street – 25m. **Bus Station for Suburban Traffic** is on the left side.
22. Goes west to Prilepska Street – 25m.
23. Turns left in the first intersection to stay in Prilepska Street – 66m.
24. Continues towards 4th November Street – 170m.
25. Turns right to Dimal Ilevski-Murato Street – 550m.
26. Continues to Pece Matichovski Street – 280m. **National Institution - University Library "St. Kliment Ohridski"** is on the left side.
27. Goes east in Pece Matichovski – 88m.
28. Turns right towards Clement of Ohrid Street – 39m.
29. Turns right in Clement Ohrid Street – 39m.
30. Turns right in Partizanska Street – 100m. **Shatlishte City Park** is on the left side.
31. Turns right in Polygon Street – 170m. **Sports Hall** is on the left side and the route ends.

After designing the route and inserting the intermediate stops, a “Dynamic Traffic Scenario” considering this public transport route was run. “Dynamic Traffic Scenario” is an option in Aimsun software to make traffic simulations. Parameters such as public transport line, stops and traffic are included in the DTS, defining it, and affecting its final output. Using Aimsun, traffic was simulated on road sections, on which prevailing traffic conditions affect bus traffic. As there were no traffic data for these sections and for Bitola Municipality generally, “Google Maps: Traffic” was used. Google Traffic informs about speed limits using a color code. This code, described below, was used to insert traffic flow values in Aimsun. Several traffic scenarios were run, until the observed speed per section approached the expected one, according to Google traffic data. Figure 20 illustrate the ways in which typical dynamic traffic scenarios serve General Vasko Karangelevski Street (Vero Super Market stop).



Figure 20: A typical traffic dynamic scenario on General Vasko Karangjelevski Street (Vero Super Market stop- yellow color)

The colored lines representing traffic conditions on major highways or streets refer to the speed at which one can travel on that road. The dreaded red lines on the map mean highway traffic is moving at less than 40.2 km per hour and could indicate an incident or congestion on that route. Yellow lines on the map indicate that traffic is moving faster, from 40.2 to 80.46 km per hour. Green lines on the traffic map indicate zipping along at 80.46 km per hour or more. Grey lines on the map indicate that no traffic information is available. The red-black line on the map indicates extremely slow or stopped traffic. Table 3 shows the *Google Maps: Traffic* color code about speed limits, while Figure 21 shows these limits in Bitola center.

Table 3: The Google Maps: Traffic color code about speed limits

Color	Speed (km/h)
Red	<40
Yellow	40-80
Green	>80
Grey	No traffic information available
Red-Black	Extremely slow/stopped traffic

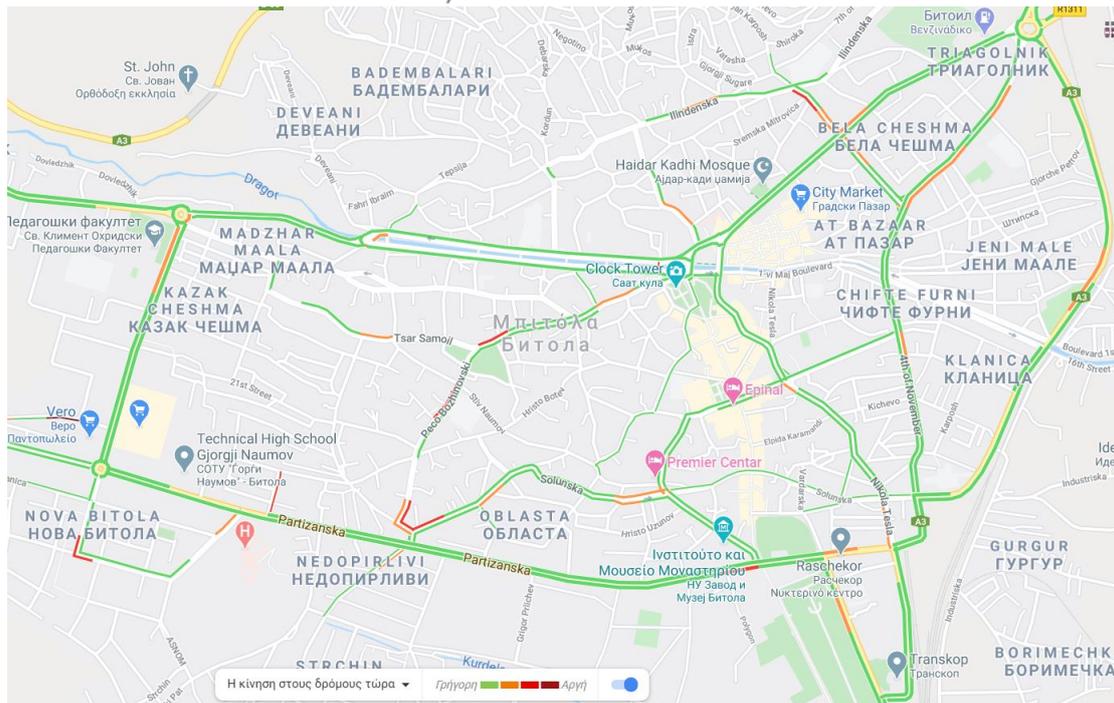


Figure 21: Speed limits in Bitola center according to "Google Maps: Traffic"

Given the public transport line (route), its stops (origin, intermediate stops and destination) and a ran simulation in Aimsun, a position-time diagram was exported. This diagram illustrates the position of the bus as a function of time. Figure 22 shows the pattern of position and time for route 1 serving City Library "St. Kliment Ohridski", including the intermediate stops:

- Stop 1: Sports Hall Boro Churlevski (start)
- Stop 2: PHI Clinical Hospital Dr. Triphun Panovski Bitola
- Stop 3: Vero Super Market
- Stop 4: Pedagogshka Faculty of pedagogy
- Stop 5: Primary School Gjorgji Sugarev
- Stop 6: Javor Trade Center
- Stop 7: Bitoil Gass Station
- Stop 8: Selska Avtobuska Stanica
- Stop 9: Shetalishte City Park
- Stop 10: City Library St. Kliment Ohridski
- Stop 11: Sports Hall Boro Churlevski (end)

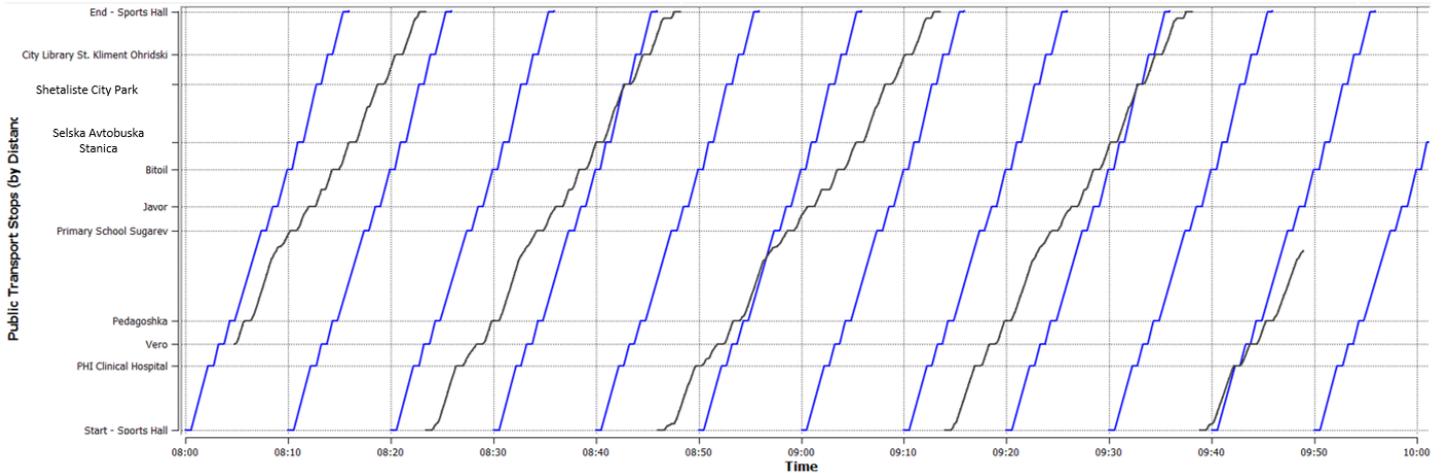


Figure 22: Position and time for route 1 to City Library St. Kliment Ohridski

In Figure 22 there are two lines, of different coloring. There is a blue line representing free flow conditions, and a black line representing real traffic conditions. For estimating travel conditions, simulations were performed using a dedicated software. The simulations were key for calculating the time for the bus to travel between stops, and to calculate overall trip time from origin to destination. The blue line stands for free flow conditions, namely road signage, road geometry and overall road traffic are not considered. These parameters exist in realistic traffic conditions causing significant latencies. Thus, the black line indicates more time for reaching the destination than the blue line. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and traffic in the network, making the simulation realistic.

As we see in Figure 22, there is a blue line (free flow conditions) and a black line (real traffic conditions). Blue lines correspond to free flow and start every 10 minutes to compare free flow with bus position, during the simulation, on the route relatively to time. The simulation was crucial for calculating the time the bus needs to travel from stop to stop, and overall time (from origin to destination). Free flow was not realistic as it assumes maximum speed for all the way. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules and other vehicles in the network. For illustrating the differences between ideal and realistic conditions, the black lines differ from blue lines, with the black ones representing the simulated (realistic) scenario. Thus free flow can be compared with simulated conditions, in terms of time and speed (slope of time-position in the figure).

The simulation started at 8:00 and we notice that the same bus follows the same route faster at the beginning, and then with longer delay (larger deviation from free-flow line). In particular, the first simulation starts at 8:00 and ends at 8:23 (duration=23 minutes), the second simulation starts at 8:23 and ends at 8:48 (duration= 25 minutes), and the third one starts at 8:48 and ends at 9:14 (duration=26 minutes). This happens because at 8:00 (start of simulation) the traffic network was empty (no vehicles), while later it was loaded. In the second case, the minibus was driving in realistic traffic conditions.

It is considered that the minibus always follows the same route (to City Library St. Kliment Ohridski) with the same start (Sports Hall) and the same end (Sports Hall), without stopping for charging or for starting another route. This assumption was considered in simulations to calculate the average duration of route 1, considering stop, road geometry, signaling and traffic conditions.

3.2. Route 2 to City Stadium Tumbe Kafe

After importing the map (see Figure 13) including the whole center of Bitola, the best route to City Stadium Tumbe Kafe, route 2, was designed. A public transport line was created by selecting the appropriate road sections consecutively, according to data collected by Bitola Municipality. Afterwards, the stops were defined, in accordance with citizens' needs. Eleven stops were designed, as follows:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: PHI Clinical Hospital Dr. Triphun Panovski Bitola
- Stop 3: Vero Super Market
- Stop 4: Pedagogshka Faculty of pedagogy
- Stop 5: Primary School Gjorgji Sugarev
- Stop 6: Javor Trade Center
- Stop 7: Bitoil Gass Station
- Stop 8: "Primary School Dame Gruev"
- Stop 9: Tennis Court
- Stop 10: "Football stadium Tumbe kafe"
- Stop 11: Sports Hall Boro Churlevski

Figure 23 shows route 2 to "Football stadium Tumbe kafe". Figures 24 and 25 show parts of this route, Football stadium Tumbe kafe and Primary School Gjorgji Sugarev, respectively.



Figure 23: Route 2 to “Football stadium Tumbe kafe”



Figure 24: Football stadium Tumbe kafe

Road sections of the second route to Football stadium Tumbe kafe, accompanied with instructions are presented below.

Distance: 10.8 km, Optimal Travel Time: 25 min. The e-minibus:

1. Starts from **Sports Hall**.
2. Goes northwest to Polygon Street towards Partizanshka Street - 170m
3. Turns left to Partizanshka Street - 1.4km.
4. Turns left to **Clinical Hospital Dr. Trifun Panovski** - 120m.
5. Goes northeast to Partizanshka Street – 120m.
6. Turns left to Partizanshka Street – 500m.
7. In the roundabout, takes the first exit to General Vasko Karangjelevski Street – 140m.
Vero Super Market is on the left side.
8. Goes north to General Vasko Karangjelevski Street towards Taku Dimitrovski Street– 120m. **Faculty of Pedagogy** is on the left side.
9. In the roundabout, takes the first exit to 1st May Boulevard Street –550m.
10. In the roundabout. Takes the second exit and stays in 1st May Boulevard Street- 1 km.
11. Turns left in 1st May Boulevard Street– 42m.
12. Turns left to stay in 1st May Boulevard Street– 89m.
13. Turns left to Jane Sandanski Street– 300m.
14. Turns right in Dimitar Vlahov Street– 35m. **Elementary School Gjorgji Sugare** is on the right side.
15. Goes southwest to Dimitar Vlahov Street towards Jane Sandanski Street – 35m.
16. Turns left to Jane Sandanski Street– 300m.
17. Turns left to Filip II Makedonski Street – 61m.
18. In the roundabout, takes the second exit and stays in Filip II Makedonski Street – 170m. **Javor Trade Center** is on the left side.
19. Goes northeast in Filip II Makedonski Street – 110m. **Bitoil Gass Station** is on the left side.
20. In the roundabout, takes the first exit towards Prilepska Street – 450m. **Primary School Dame Gruev** is on the left side.
21. Goes southwest to Prilepska Street towards 4th November Street – 1,15km.
22. Goes south to 4th November/A3/E65 towards Nicala Tesla Street – 210m.
23. Goes towards Partizanska Street – 210m.
24. Turns left to Makedonska Falanga Street – 18m. **Tennis Court** is on the right side.
25. Goes south to Makedonska Falanga Street towards Zborska Street – 750m.

26. Turns right to Kurdeles Street – 400m.
27. Goes northwest to Kurdeles Street – 400m. **Stadium Tumbe Kafe** is on the right side.
28. Turns right – 350m.
29. Turns right towards Polygon Street – 140m.
30. Turns right to Polygon Street – 130m. **Sports Hall** is on the left side.

After designing the route and inserting the intermediate stops, a “Dynamic Traffic Scenario (DTS)” considering this public transport route was run. As there were no traffic data for the road sections included in the DTS, and for Bitola Municipality generally, “Google Maps: Traffic” was used. Google Traffic informs about speed limits using a color code. This code, described above, was used to insert traffic flow values in Aimsun. Figure 27 shows a typical dynamic traffic scenario on 1st May Boulevard (Javor Trade Station).

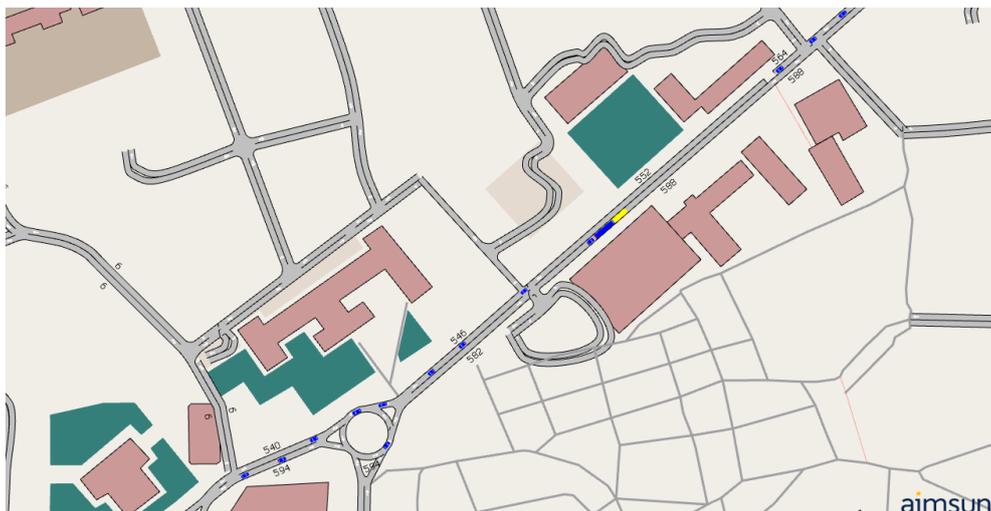


Figure 27: A typical traffic dynamic scenario on 1st May Boulevard (Javor Trade Station)

Given the public transport line (route), its stops (origin, intermediate stops and destination) and a ran simulation in Aimsun, a position-time diagram was exported. This diagram illustrates the position of the bus as a function of time. Figure 28 shows the position-time diagram for route 2 to Stadium Tumbe Kafe, including the intermediate routes:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: PHI Clinical Hospital Dr. Triphun Panovski Bitola
- Stop 3: Vero Super Market

- Stop 4: Pedagogshka Faculty of pedagogy
- Stop 5: Primary School Gjorgji Sugarev
- Stop 6: Javor Trade Center
- Stop 7: Bitoil Gass Station
- Stop 8: “Primary School Dame Gruev”
- Stop 9: Tennis Court
- Stop 10: “Football stadium Tumbe kafe”
- Stop 11: Sports Hall Boro Churlevski

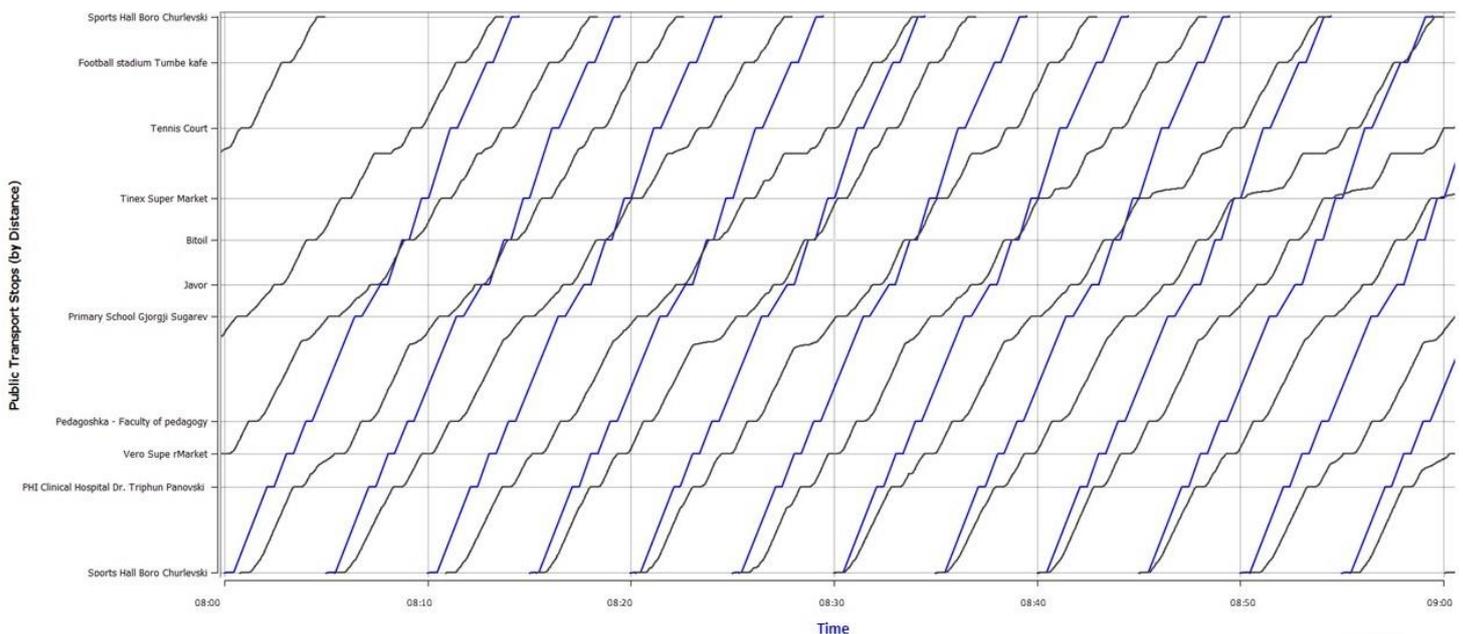


Figure 28: The position-time diagram for route 2 to Stadium Tumbe Kafe

In Figure 28 there are two lines, of different coloring. There is a blue line representing free flow conditions, and a black line representing real traffic conditions. For estimating travel conditions, simulations were performed using a dedicated software. The simulations were key for calculating the time for the bus to travel between stops, and to calculate overall trip time from origin to destination. The blue line stands for free flow conditions, namely road signage, road geometry and overall road traffic are not considered. These parameters exist in realistic traffic conditions causing significant latencies. Thus, the black line indicates more time for reaching the destination than the blue line. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and traffic in the network, making the simulation realistic.

Programme co-funded by the European Union and national funds of the participating countries

As seen in Figure 28, there is a blue line (free flow conditions) and a black line (real traffic conditions). Blue lines correspond to free flow and start every 5 minutes to compare free flow with the simulated position on the route with time. This was necessary to compare free flow with simulated conditions, not only relative to time, but also relative to speed (slope of time-position diagram). The simulation started at 8:02 and we notice that the same bus follows the same route faster at the beginning, and then with a longer delay (larger deviation from free-flow line). In particular, the first simulation starts at 8:02 and ends at 8:24 (duration=22 minutes), the second simulation starts at 8:12 and ends at 8:35 (duration= 23 minutes), and the third one starts at 8:20 and ends at 8:44 (duration=24 minutes). This happens because at 8:02 (start of simulation) the traffic network had no vehicles, while later it was loaded. In the second case, the minibus was driving in realistic traffic conditions.

It is considered that the minibus always follows the same route (to Football Stadium Tumba Kafe) with the same start (Sports Hall) and the same end (Sports Hall), without stopping for charging or for starting another route. This assumption was considered in simulations to calculate the average duration of route 2, considering stop, road geometry, signaling and traffic conditions.

3.3. Route 3 to village Trnovo - Baba Mountain

After importing the map (see Figure 13) including the whole center of Bitola, the best route to village Trnovo - Baba Mountain, route 3, was designed. A public transport line was created by selecting the appropriate road sections consecutively, according to data collected by Bitola Municipality. Afterwards, the stops were defined, in accordance with citizens' needs. Eight stops were designed, as follows:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: Vero Super Market
- Stop 3: "Pedagoshka - Faculty of pedagogy"
- Stop 4: village Trnovo church "St. Bogorodica "(4)
- Stop 5: village Trnovo church "St. Bogorodica "(5)
- Stop 6: "Pedagoshka - Faculty of pedagogy"
- Stop 7: Vero Super Market
- Stop 8: Sports Hall Boro Churlevski

Figure 29 shows route 3 to village Trnovo - Baba Mountain. Figures 30 and 31 show parts of this route, church “St. Bogorodica in Pelister Street and a part of route 3 - Pelister Street, respectively.



Figure 29: Route 3 to village Trnovo - Baba Mountain

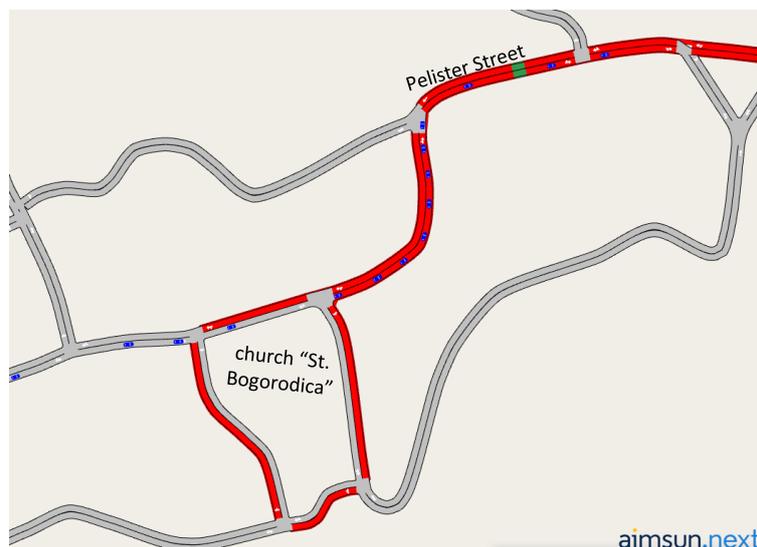


Figure 30: Village Trnovo church “St. Bogorodica” in Pelister Street

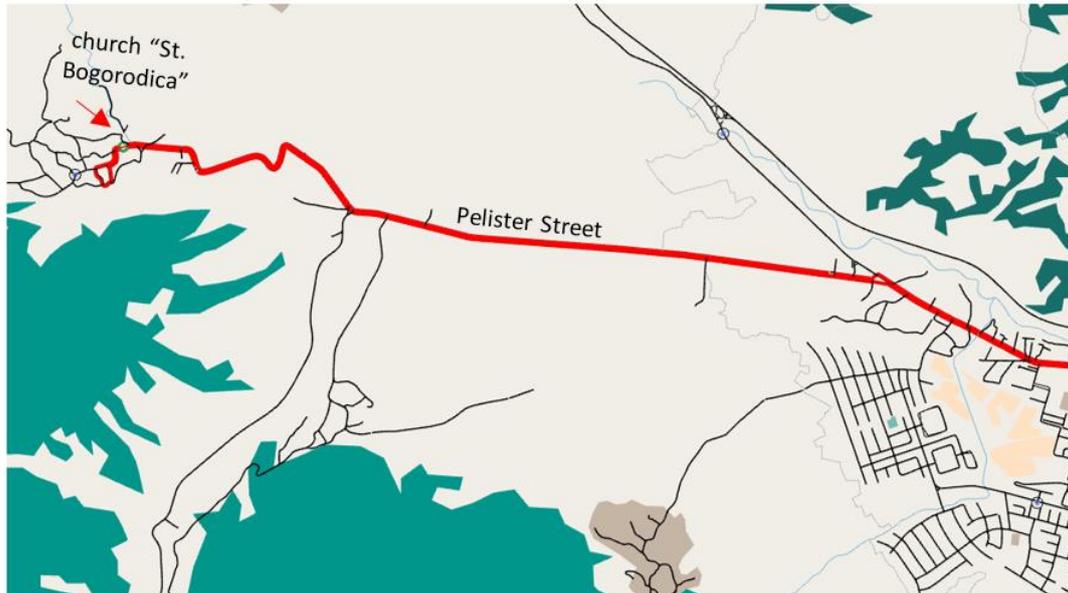


Figure 31: Part of Route 3- Pelister Street

Figure 32 shows route to Village Trnovo church “St. Bogorodica” and the intermediate stops. The stops have yellow color when they are designed in Aimsun and green color when they are imported in road sections, becoming, in this way, part of the public transport line. Normal stop is the type that was chosen for the intermediate stops and terminal stop is the type used for the last stop of the route. Thirty seconds were chosen as stops’ duration.



Figure 32: Route 3 to church “St. Bogorodica” and the intermediate stops

Road sections of the third route to Village Trnovo “St. Bogorodica”, accompanied with instructions, are presented below.

Distance: 18 km, Optimal Travel Time: 29 min. The e-minibus:

1. Starts from **Sports Hall**.
2. Goes northwest to Polygon Street towards Partizanshka Street - 170m
3. Turns left to Partizanshka Street - 2.14km.
4. In the roundabout, takes the first exit to General Vasko Karangjelevski Street – 140m.
Vero Super Market is on the left side.
5. Goes north to General Vasko Karangjelevski Street towards Taku Dimitrovski Street– 120m. **Faculty of Pedagogy** is on the left side.
6. Goes on General Vasko Karangjelevski Street towards Bosanska Street – 110m.
7. In the roundabout, takes the second exit to 11th Makedonska Divizija Street – 1.5km.
8. Turns right to 506 – 2.9km.
9. Turns right towards Pelister Street – 1.5km. **Village Trnovo- church “St. Bogorodica”** is on the right side.
10. Goes west to Pelister Street – 220m.
11. Goes southwest to Pelister Street – 58m.
12. Turns left – 44m.
13. Goes southeast – 5m and turns left – 100m towards Pelister Street. **Village Trnovo- church “St. Bogorodica”** is on the right side.
14. Turns left in Pelister Street – 1.58km.
15. Turns left in 506 Street – 3km.
16. Turns right to 11th Makedonska Divizija Street – 1.4km.
17. In the roundabout, takes the first exit towards General Vasko Karangjelevski Street – 750m. **Faculty of Pedagogy** is on the right side.
18. Goes south to towards General Vasko Karangjelevski Street – 62m. **Vero Super Market** is on the right side.
19. In the roundabout, takes the third exit towards Partizanska – 2km.
20. Turns left to Polygon Street – 170m. **Sport Hall** is on the left side. This is the end if the route.

After designing the route and inserting the intermediate stops, a “Dynamic Traffic Scenario (DTS)” considering this public transport route was run. As there were no traffic data for the road sections included in the DTS, and for Bitola Municipality generally, “Google Maps: Traffic” was used. Google Traffic informs about speed limits using a color code. This code, described

above, was used to insert traffic flow values in Aimsun. Figure 33 shows a typical dynamic traffic scenario on Pelister Street (village Trnovo- church “St. Bogorodica” Station).



Figure 33: A typical traffic dynamic scenario in Pelister Street (Village Trnovo- church “St. Bogorodica” Station)

Given the public transport line (route), its stops (origin, intermediate stops and destination) and a ran simulation in Aimsun, a position-time diagram was exported. This diagram illustrates the position of the bus as a function of time. Figure 34 shows the position-time diagram for route 3 to Vilage Trnovo “St. Bogorodica”, including the intermediate routes:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: Vero Super Market
- Stop 3: “Pedagoshka - Faculty of pedagogy”
- Stop 4: vilage Trnovo church “St. Bogorodica “(4)
- Stop 5: vilage Trnovo church “St. Bogorodica “(5)
- Stop 6: “Pedagoshka - Faculty of pedagogy”
- Stop 7: Vero Super Market
- Stop 8: Sports Hall Boro Churlevski

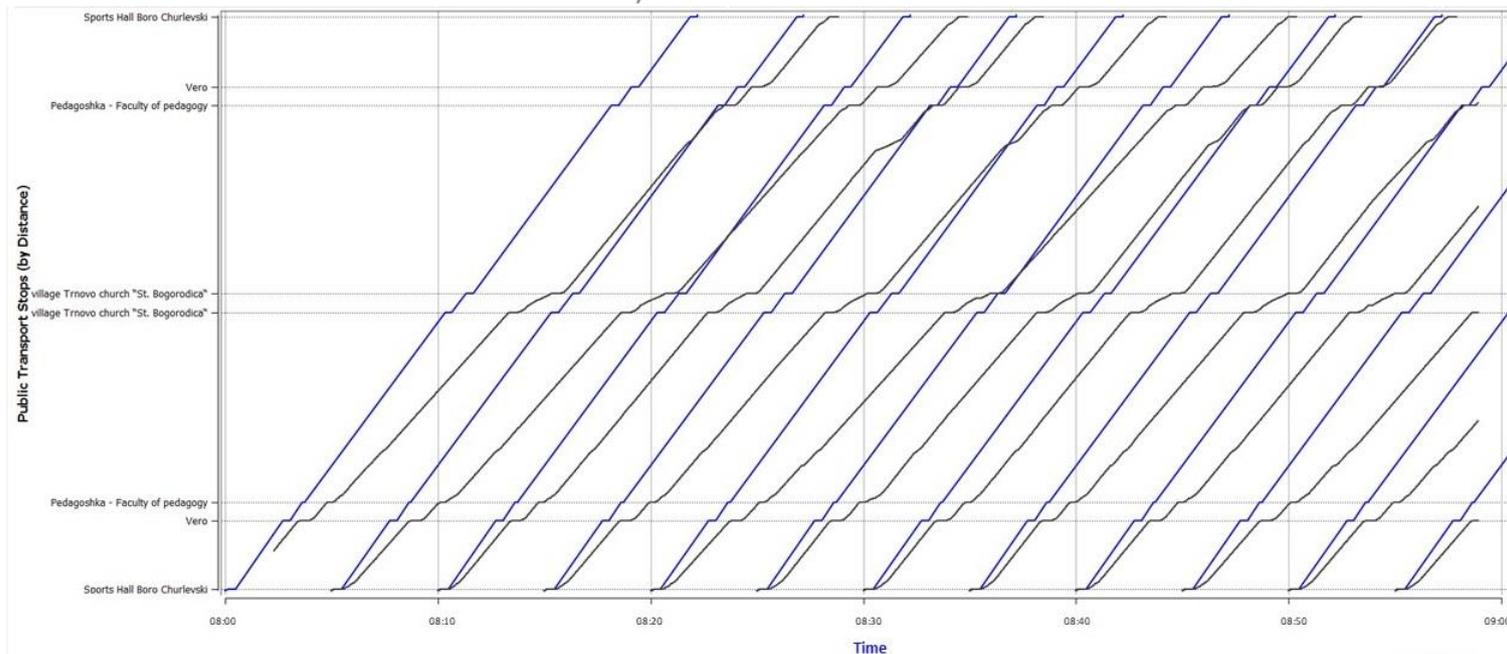


Figure 34: Position-time diagram for route 3 to Village Trnovo "St. Bogorodica"

In Figure 34 there are two lines, of different coloring. There is a blue line representing free flow conditions, and a black line representing real traffic conditions. For estimating travel conditions, simulations were performed using a dedicated software. The simulations were key for calculating the time for the bus to travel between stops, and to calculate overall trip time from origin to destination. The blue line stands for free flow conditions, namely road signage, road geometry and overall road traffic are not considered. These parameters exist in realistic traffic conditions causing significant latencies. Thus, the black line indicates more time for reaching the destination than the blue line. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and traffic in the network, making the simulation realistic.

As we see in Figure 34, there is a blue line (free flow conditions) and a black line (real traffic conditions). Blue lines correspond to free flow and start every 5 minutes in order to compare free flow with the simulated position on the route with time. This was needed in order to compare free flow with simulation, not only relative to time, but also relative to speed (slope of time-position diagram). The simulation started at 8:00 and we notice that the same bus follows the same route faster at the beginning, and then with longer delay (larger deviation from free-flow line). In particular, the first simulation starts at 8:00 and ends at 8:28 (duration=28 minutes), the second simulation starts at 8:05 and ends at 8:33 (duration= 28

minutes), the third one starts at 8:10 and ends at 8:39 (duration=28 minutes), and the fourth starts at 8:15 and ends at 08:44 (duration=29 minutes). This happens because at 8:02 (start of simulation) the traffic network was empty (no vehicles), while later it was loaded. In the second case, the minibus was driving in realistic traffic conditions.

It is assumed that the minibus always follows the same route (to village Trnovo church “St. Bogorodica) with the same start (Sports Hall) and the same end (Sports Hall), without stopping for charging or for starting another route. This assumption was considered in simulations in order to calculate the average duration of route 3, considering stop, road geometry, signaling and traffic conditions.

3.4. Route 4 to village Pretor - Prespa Lake

E-minibus routing was designed using Aimsun Next 8.4.0 Software. Figure 35 shows the new map imported in Aimsun software for the other four routes' simulation.

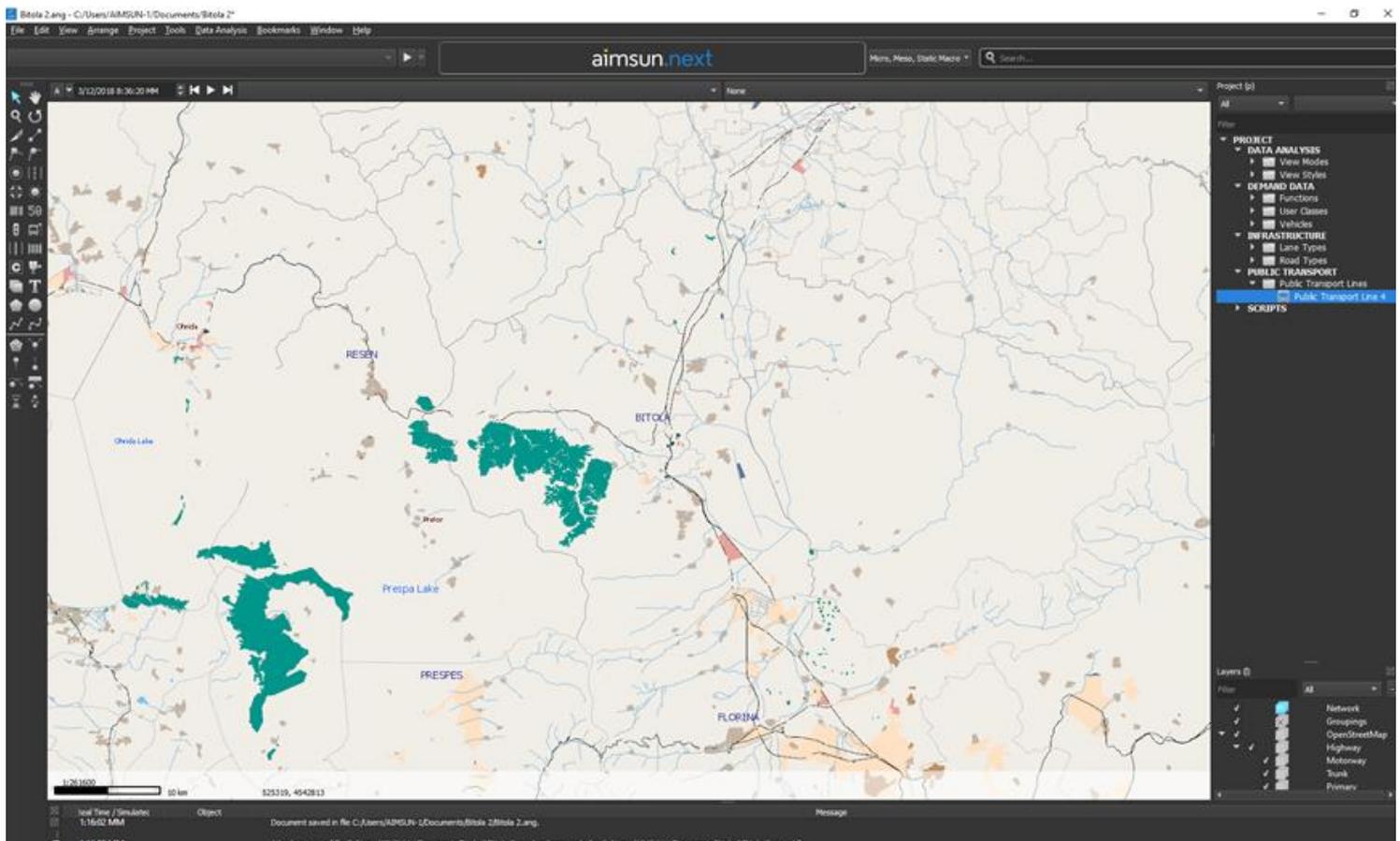


Figure 35: The new map imported in Aimsun Software for the other four routes' simulation

After importing the new map (see Figure 35) including the whole cross-border region (Bitola, Resen, Prespes, Florina), the best route to village Pretor, route 4, was designed. A public transport line was created by selecting the appropriate road sections consecutively, according to data collected by Bitola Municipality. Afterwards, the stops were defined, in accordance with citizens' needs. Seven stops were designed, as follows:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: Vero Super Market
- Stop 3: Faculty of Pedagogy
- Stop 4: Pretor village-Prespa Lake
- Stop 5: Faculty of Pedagogy
- Stop 6: Vero Super Market
- Stop 7: Sports Hall Boro Churlevski

Figure 36 shows route 4 to village Pretor while Figure 37 shows the location of Pretor.

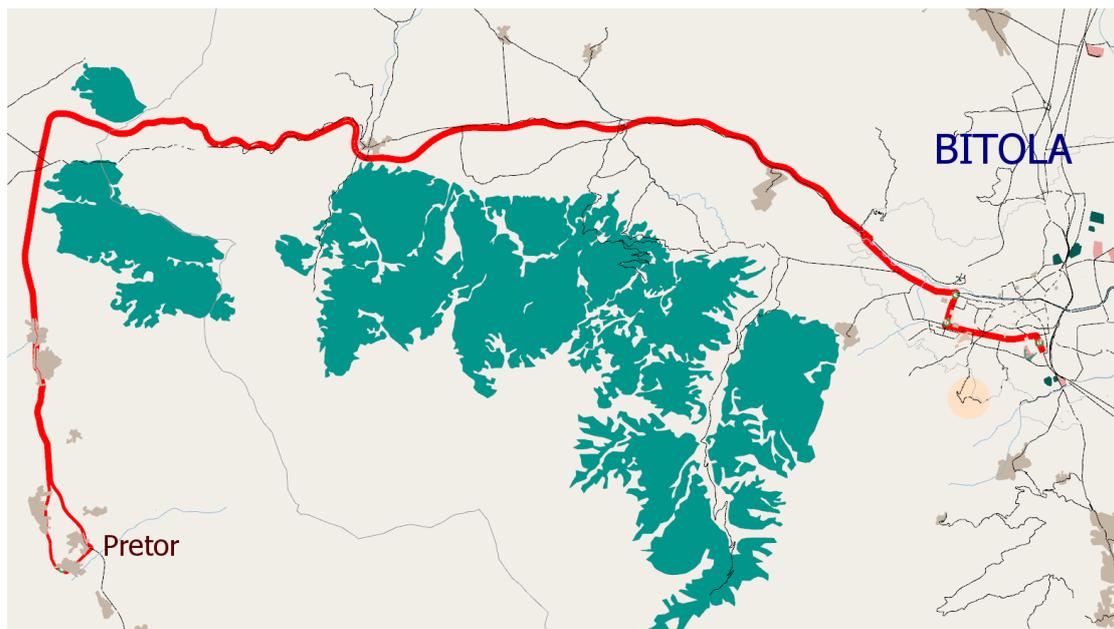


Figure 36: Route 4 to village Pretor



Figure 37: The location of Pretor village

Figure 38 shows route to Pretor village and the intermediate stops. The stops have yellow color when they are designed in Aimsun and green color when they are imported in road sections, becoming, in this way, part of the public transport line. Normal stop is the type that was chosen for the intermediate stops and terminal stop is the type used for the last stop of the route. Thirty seconds were chosen as stops' duration.



Figure 38: Route 4 to Pretor village and the intermediate stops

After designing the route and inserting the intermediate stops, a “Dynamic Traffic Scenario (DTS)” considering this public transport route was run. As there were no traffic data for the road sections included in the DTS, and for Bitola Municipality generally, “Google Maps: Traffic” was used. Google Traffic informs about speed limits using a color code. This code, described above, was used to insert traffic flow values in Aimsun. Figure 39 shows a typical dynamic traffic scenario serving Vero Super Market.

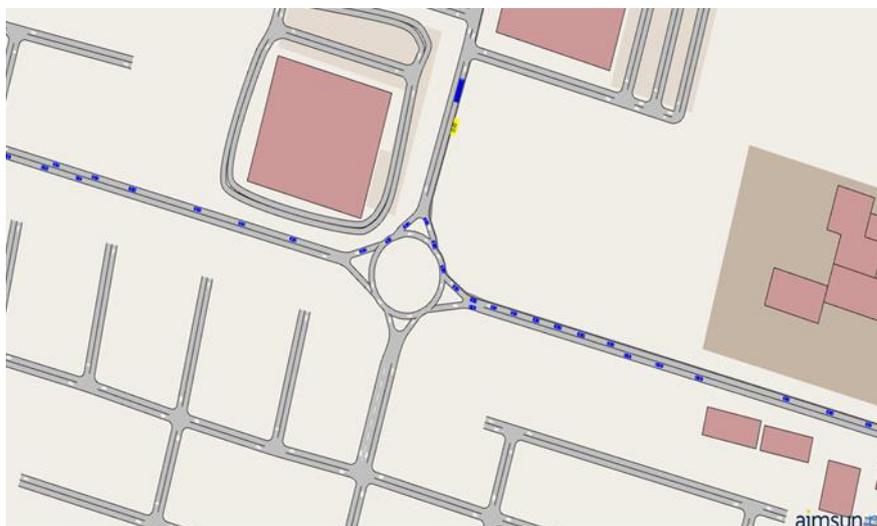


Figure 39: A typical traffic dynamic scenario in Vero super Market

Given the public transport line (route), its stops (origin, intermediate stops and destination) and a ran simulation in Aimsun, a position-time diagram was exported. This diagram illustrates the position of the bus as a function of time. Figure 29 shows the position-time diagram for route 4 to Pretor village, including the intermediate stops:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: Vero Super Market
- Stop 3: Faculty of pedagogy
- Stop 4: Pretor village
- Stop 5: Faculty of pedagogy
- Stop 6: Vero Super Market
- Stop 7: Sports Hall Boro Churlevski

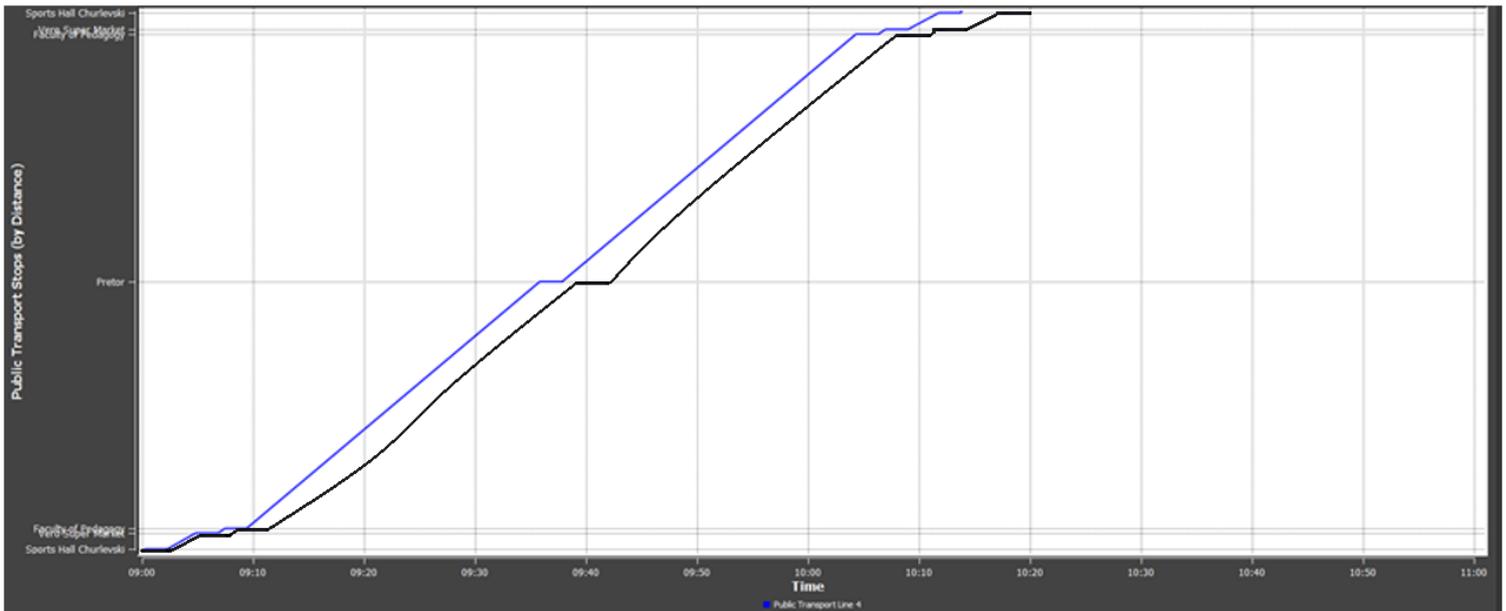


Figure 40: Position-time diagram for route 4 to Pretor village

In Figure 40 there are two lines, of different coloring. There is a blue line representing free flow conditions, and a black line representing real traffic conditions. For estimating travel conditions, simulations were performed using a dedicated software. The simulations were key for calculating the time for the bus to travel between stops, and to calculate overall trip time

from origin to destination. The blue line stands for free flow conditions, namely road signage, road geometry and overall road traffic are not considered. These parameters exist in realistic traffic conditions causing significant latencies. Thus, the black line indicates more time for reaching the destination than the blue line. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and traffic in the network, making the simulation realistic.

In Figure 40 there is a blue line (free flow conditions) and a black line (real traffic conditions). The simulation was crucial for calculating the time for the bus to travel between stops, and to calculate overall time (from origin to destination). Free flow was not realistic as it assumes maximum speed for the whole trip. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and other vehicles in the network. Black lines differ from blue lines, as the black ones represent the simulated (realistic) scenario. Thus, it is possible to compare free flow with simulated conditions, not only with respect to time, but also speed (slope of time-position figure). The simulation started at 09:00 and there is a deviation from free-flow line. In particular, the simulation starts at 09:00 and ends at 10:20 (duration= 1 hour and 20 minutes), while in free flow conditions the bus starts at 09:00 and ends at 10:14 (duration= 1 hour and 14 minutes). It is assumed that the minibus always follows the same route (to Pretor village) with the same start (Sports Hall) and the same end (Sports Hall), without stopping for charging or for starting another route. This assumption was considered in simulations in order to calculate the average duration of route 4, considering stop, road geometry, signaling and traffic conditions.

3.5. Route 5 to Krushovo town

After importing the new map (see Figure 35) including the whole cross-border region (Bitola, Resen, Prespes, Florina), the best route to Krushovo town, route 5, was designed. A public transport line was created by selecting the appropriate road sections consecutively, according to data collected by Bitola Municipality. Afterwards, the stops were defined, in accordance with citizens' needs. Three stops were designed, as follows:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: Krushovo town
- Stop 3: Sports Hall Boro Churlevski

Figure 41 shows route 5 to Krushovo town, while Figure 42 shows the location of Krushovo.

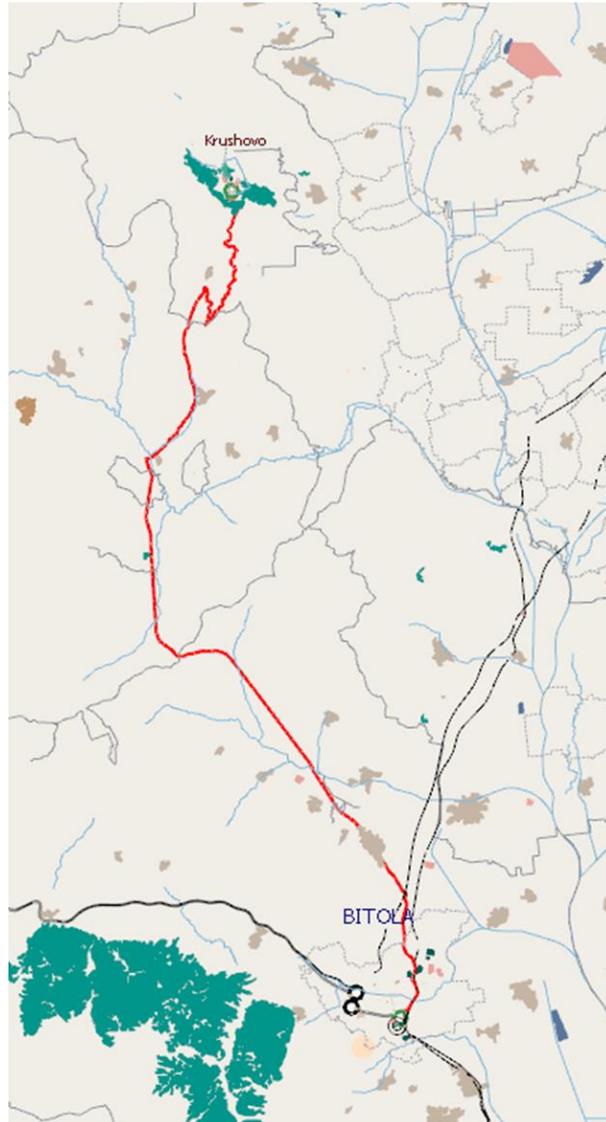


Figure 41: Route 5 to Krushovo



Figure 42: The location of Krushovo

Figure 43 shows route to Krushovo town and the intermediate stops. The stops have yellow color when they are designed in Aimsun and green color when they are imported in road sections, becoming, in this way, part of the public transport line. Normal stop is the type that was chosen for the intermediate stops and terminal stop is the type used for the last stop of the route. Thirty seconds were chosen as stops' duration.

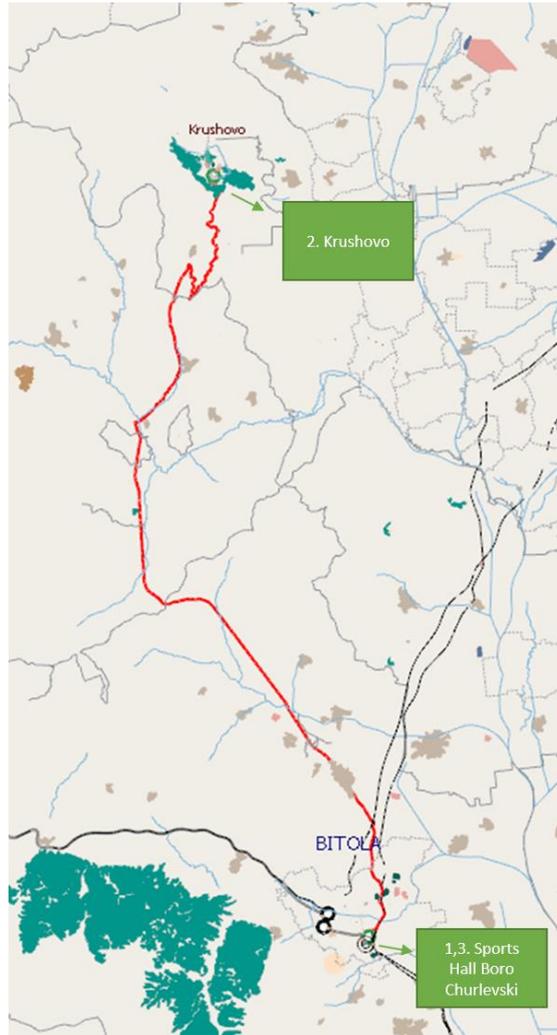


Figure 43: Route 5 to Krushovo town and the intermediate stops

After designing the route and inserting the intermediate stops, a “Dynamic Traffic Scenario (DTS)” considering this public transport route was run. As there were no traffic data for the road sections included in the DTS, and for Bitola Municipality generally, “Google Maps: Traffic” was used. Google Traffic informs about speed limits using a color code. This code, described above, was used to insert traffic flow values in Aimsun. Figure 44 shows a typical dynamic traffic scenario serving Vero Super Market.



Figure 44: A typical traffic dynamic scenario in Vero super Market

Given the public transport line (route), its stops (origin, intermediate stops and destination) and a ran simulation in Aimsun, a position-time diagram was exported. This diagram illustrates the position of the bus as a function of time. Figure 45 shows the position-time diagram for route 5 to Krushovo town, including the intermediate stops:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: Krushovo town
- Stop 3: Sports Hall Boro Churlevski

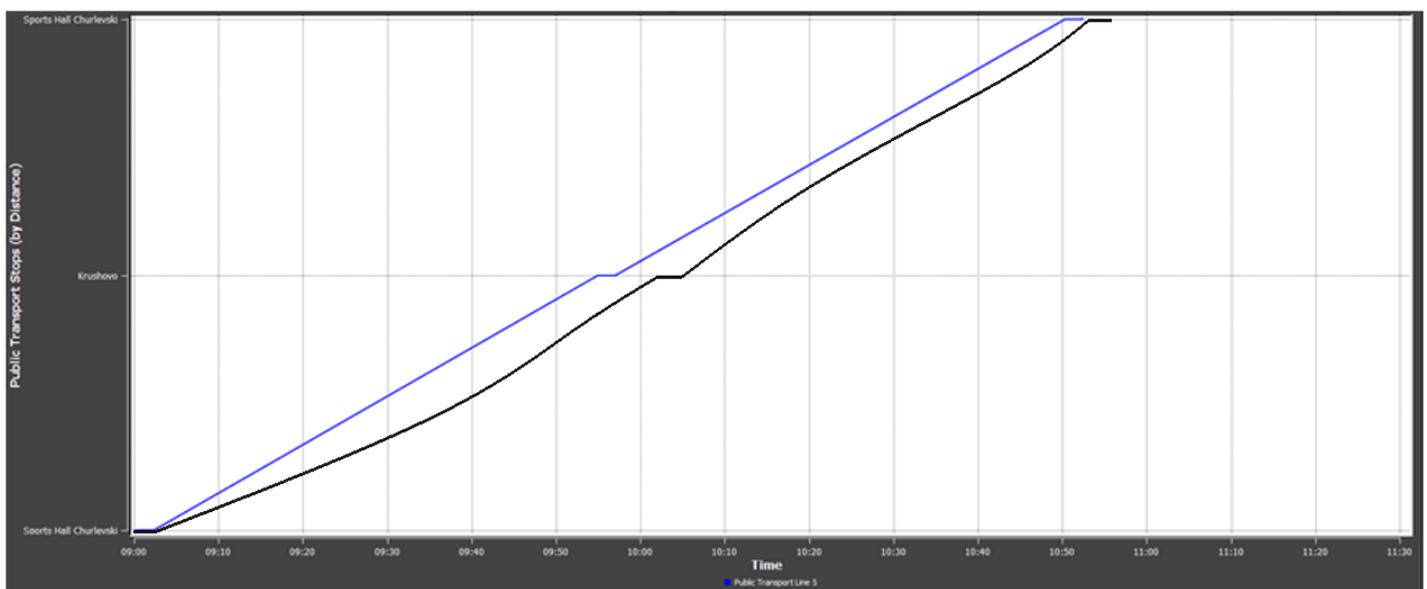


Figure 45: Position-time diagram for route 5 to Krushovo town

In Figure 45 there are two lines, of different coloring. There is a blue line representing free flow conditions, and a black line representing real traffic conditions. For estimating travel conditions, simulations were performed using a dedicated software. The simulations were key for calculating the time for the bus to travel between stops, and to calculate overall trip time from origin to destination. The blue line stands for free flow conditions, namely road signage, road geometry and overall road traffic are not considered. These parameters exist in realistic traffic conditions causing significant latencies. Thus, the black line indicates more time for reaching the destination than the blue line. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and traffic in the network, making the simulation realistic.

In Figure 45 there is a blue line (free flow conditions) and a black line (real traffic conditions). The simulation was crucial for calculating the time for the bus to travel between stops, and to calculate overall time (from origin to destination). Free flow was not realistic as it assumes maximum speed for the whole trip. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and other vehicles in the network. Black lines differ from blue lines, as the black ones represent the simulated (realistic) scenario. Thus, it is possible to compare free flow with simulated conditions, not only with respect to time, but also speed (slope of time-position figure).

The simulation started at 09:00 and there is a deviation from free-flow line. In particular, the simulation starts at 09:00 and ends at 10:56 (duration= 1 hour and 56 minutes), while in free flow conditions the bus starts at 09:00 and ends at 10:52 (duration= 1 hour and 52 minutes). It is assumed that the minibus always follows the same route (to Krushovo) with the same start (Sports Hall) and the same end (Sports Hall), without stopping for charging or for starting another route. This assumption was considered in simulations in order to calculate the average duration of route 5, considering stop, road geometry, signaling and traffic conditions.

3.6. Route 6 to Ohrida city

After importing the new map (see Figure 35) including the whole cross-border region (Bitola, Resen, Prespes, Florina), the best route to Ohrida city, route 6, was designed. A public transport line was created by selecting the appropriate road sections consecutively, according

to data collected by Bitola Municipality. Afterwards, the stops were defined, in accordance with citizens' needs. Three stops were designed, as follows:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: Ohrida city
- Stop 3: Sports Hall Boro Churlevski

Figure 46 shows route 6 to Ohrida city, while Figure 47 shows the location of Ohrida.



Figure 46: Route 6 to Ohrida

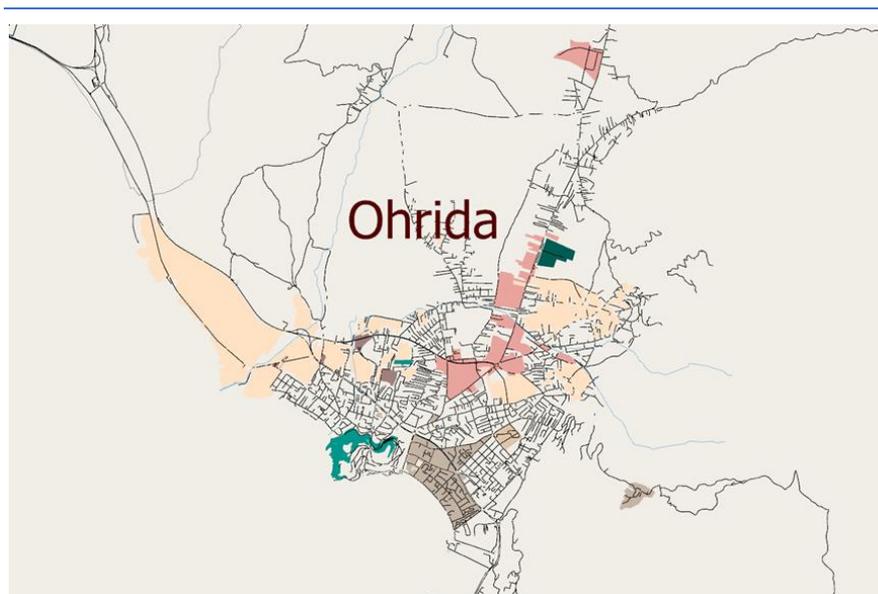


Figure 47: The location of Ohrida

Figure 48 shows route to Ohrida city and the intermediate stops. The stops have yellow color when they are designed in Aimsun and green color when they are imported in road sections, becoming, in this way, part of the public transport line. Normal stop is the type that was chosen for the intermediate stops and terminal stop is the type used for the last stop of the route. Thirty seconds were chosen as stops' duration.



Figure 48: Route 6 to Ohrida city and the intermediate stops

After designing the route and inserting the intermediate stops, a “Dynamic Traffic Scenario (DTS)” considering this public transport route was run. As there were no traffic data for the road sections included in the DTS, and for Bitola Municipality generally, “Google Maps: Traffic” was used. Google Traffic informs about speed limits using a color code. This code, described above, was used to insert traffic flow values in Aimsun. Figure 49 shows a typical dynamic traffic scenario serving Vero Super Market.

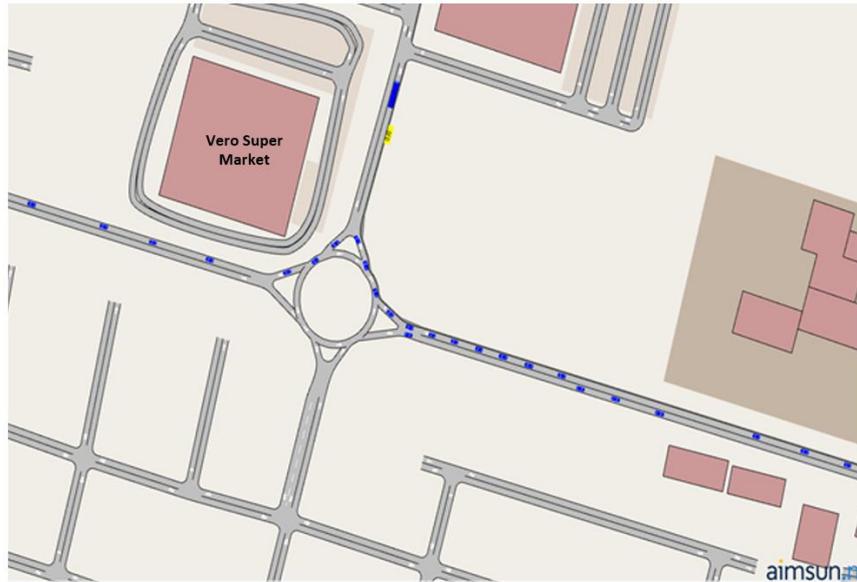


Figure 49: A typical traffic dynamic scenario in Vero super Market

Given the public transport line (route), its stops (origin, intermediate stops and destination) and a ran simulation in Aimsun, a position-time diagram was exported. This diagram illustrates the position of the bus as a function of time. Figure 50 shows the position-time diagram for route 6 to Ohrida city, including the intermediate stops:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: Ohrida city
- Stop 3: Sports Hall Boro Churlevski

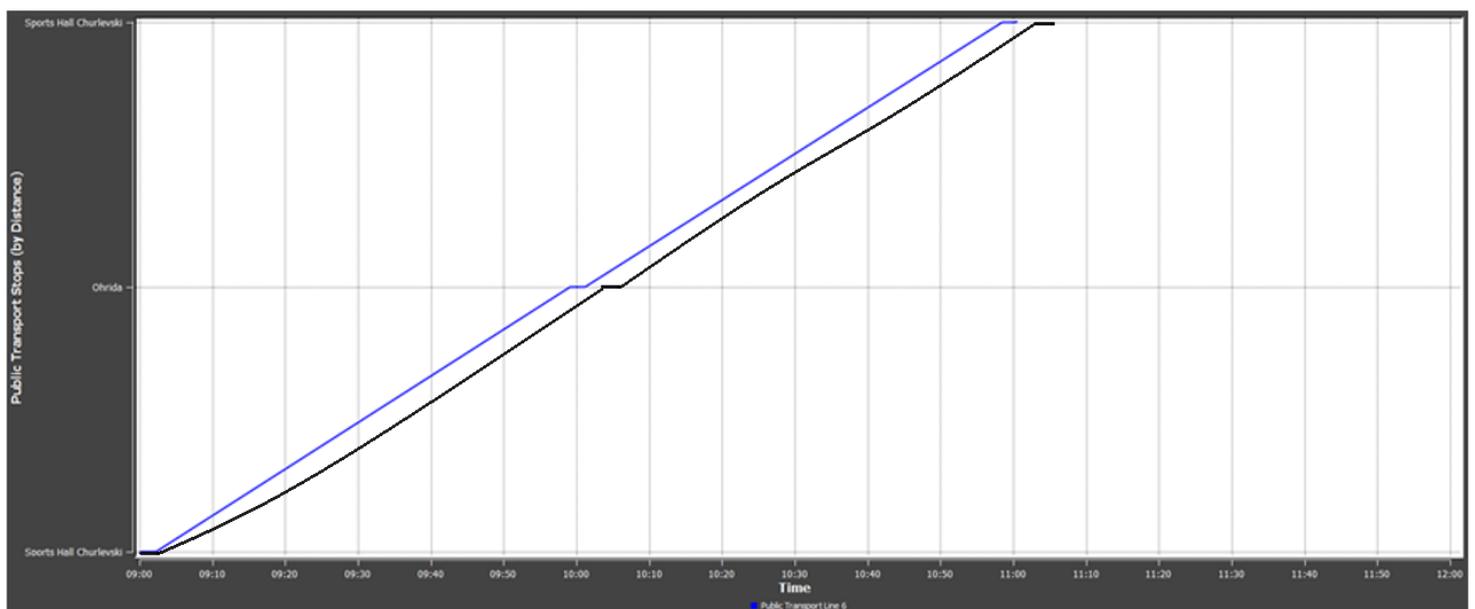


Figure 50: Position-time diagram for route 6 to Ohrida city

In Figure 50 there are two lines, of different coloring. There is a blue line representing free flow conditions, and a black line representing real traffic conditions. For estimating travel conditions, simulations were performed using a dedicated software. The simulations were key for calculating the time for the bus to travel between stops, and to calculate overall trip time from origin to destination. The blue line stands for free flow conditions, namely road signage, road geometry and overall road traffic are not considered. These parameters exist in realistic traffic conditions causing significant latencies. Thus, the black line indicates more time for reaching the destination than the blue line. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and traffic in the network, making the simulation realistic.

In Figure 50 there is a blue line (free flow conditions) and a black line (real traffic conditions). The simulation was crucial for calculating the time for the bus to travel between stops, and to calculate overall time (from origin to destination). Free flow was not realistic as it assumes maximum speed for the whole trip. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and other vehicles in the network. Black lines differ from blue lines, as the black ones represent the simulated (realistic) scenario. Thus, it is possible to compare free flow with simulated conditions, not only with respect to time, but also speed (slope of time-position figure).

The simulation started at 09:00 and there is a deviation from free-flow line. In particular, the simulation starts at 09:00 and ends at 11:06 (duration= 2 hours and 6 minutes), while in free flow conditions the bus starts at 09:00 and ends at 11:00 (duration= 2 hours). It is assumed that the minibus always follows the same route (to Ohrida) with the same start (Sports Hall) and the same end (Sports Hall), without stopping for charging or for starting another route. This assumption was considered in simulations in order to calculate the average duration of route 6, considering stop, road geometry, signaling and traffic conditions.

3.7. Route 7 to Bitola-Resen-Prespes-Florina

After importing the new map (see Figure 35) including the whole cross-border region (Bitola, Resen, Prespes, Florina), the best route to the four municipalities, route 7, was designed. A public transport line was created by selecting the appropriate road sections

consecutively, according to data collected by Bitola Municipality. Afterwards, the stops were defined, in accordance with citizens' needs. Five stops were designed, as follows:

- Stop 1: Sports Hall Boro Churlevski
- Stop 2: Resen Town Hall
- Stop 3: Prespes Town Hall
- Stop 4: Florina Town Hall
- Stop 5: Sports Hall Boro Churlevski

Figure 51 shows route 7 to the four municipalities of the cross-border region.

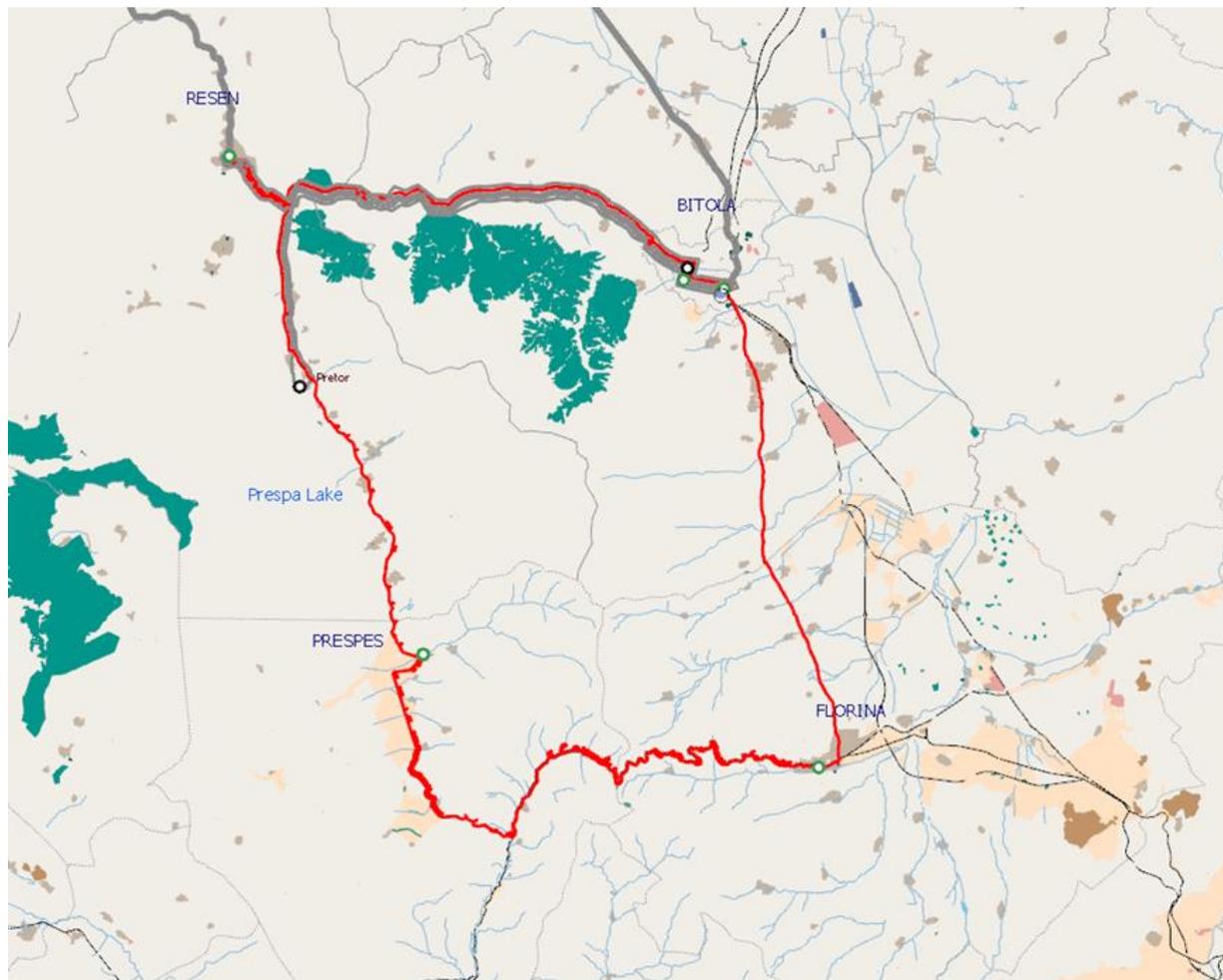


Figure 51: Route 7 to the four municipalities of the cross-border region

Figure 52 shows route to the four municipalities and the intermediate stops. The stops have yellow color when they are designed in Aimsun and green color when they are imported in road sections, becoming, in this way, part of the public transport line. Normal stop is the

type that was chosen for the intermediate stops and terminal stop is the type used for the last stop of the route. Thirty seconds were chosen as stops' duration.

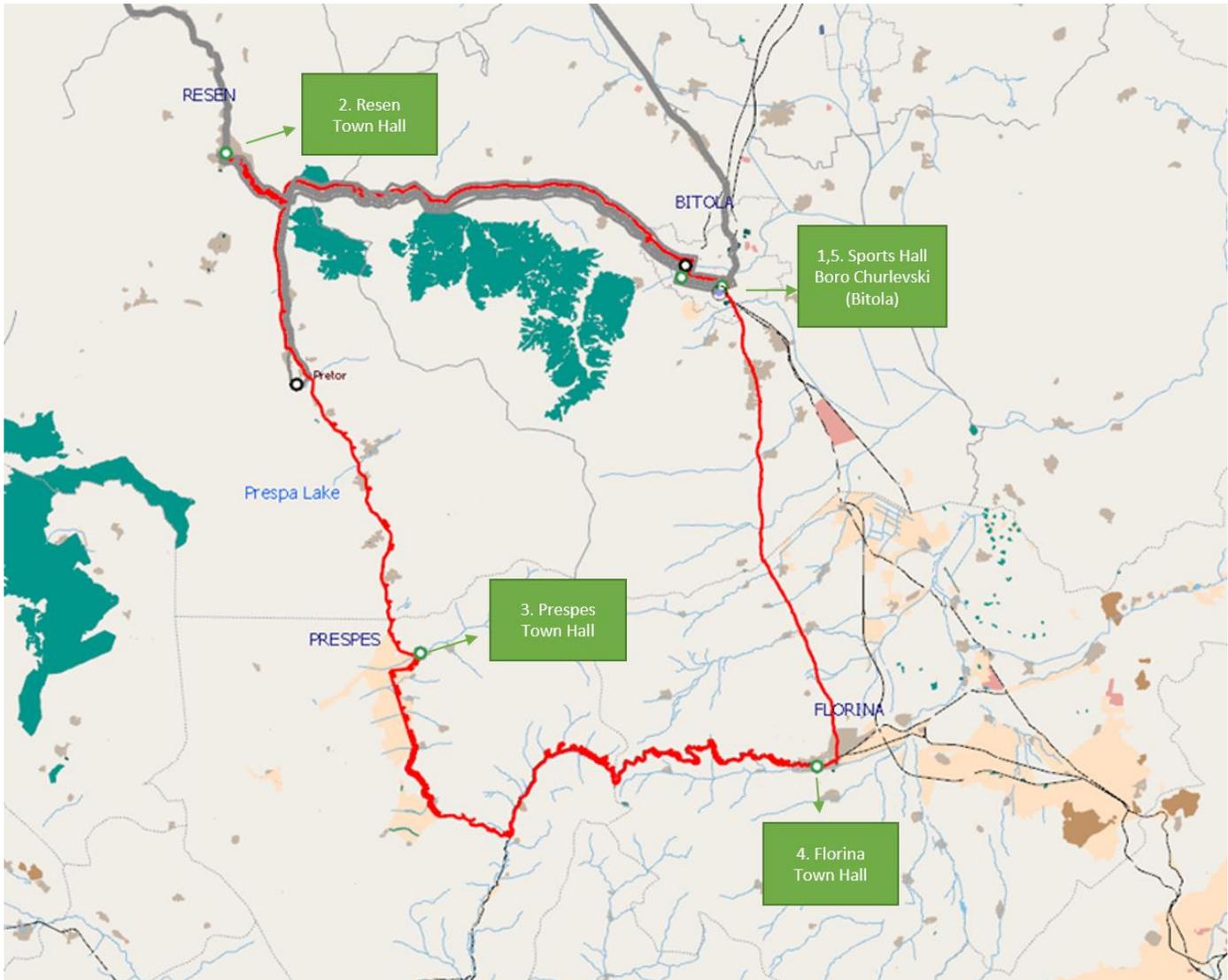


Figure 52: Route 7 to the four municipalities and the intermediate stops

After designing the route and inserting the intermediate stops, a “Dynamic Traffic Scenario (DTS)” considering this public transport route was run. As there were no traffic data for the road sections included in the DTS, and for Bitola Municipality generally, “Google Maps: Traffic” was used. Google Traffic informs about speed limits using a color code. This code, described above, was used to insert traffic flow values in Aimsun. Figures 53, 54 and 55 show a typical dynamic traffic scenario serving Florina Municipality Multipurpose Hall, Prespes Town Hal and Resen Town Hall, respectively.

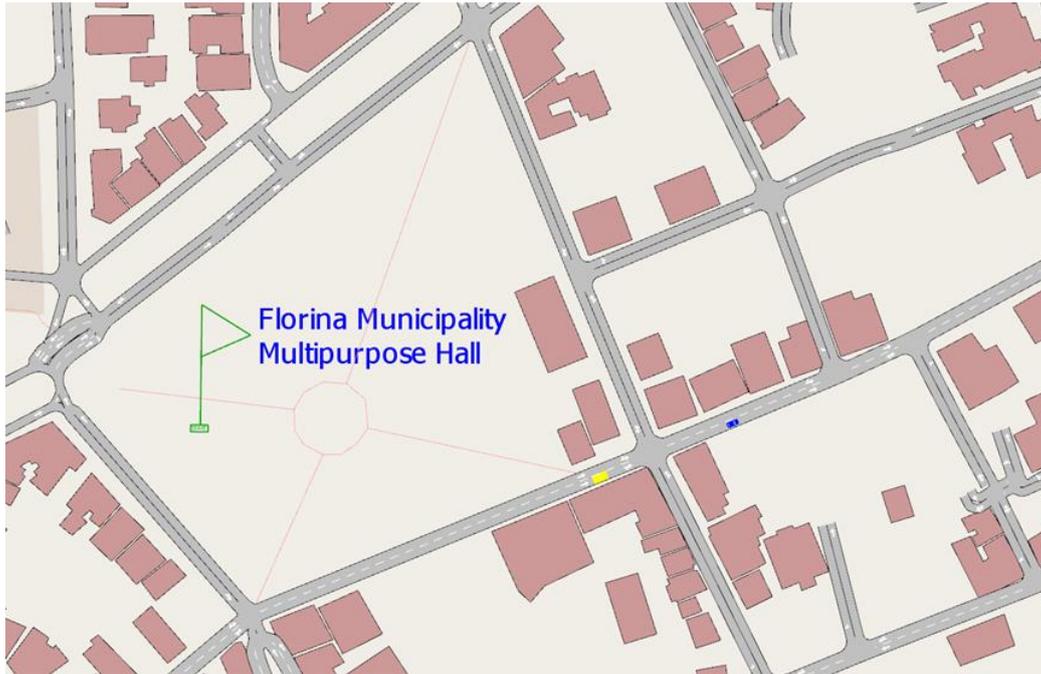


Figure 53: A typical traffic dynamic scenario in Florina Municipality Multipurpose Hall

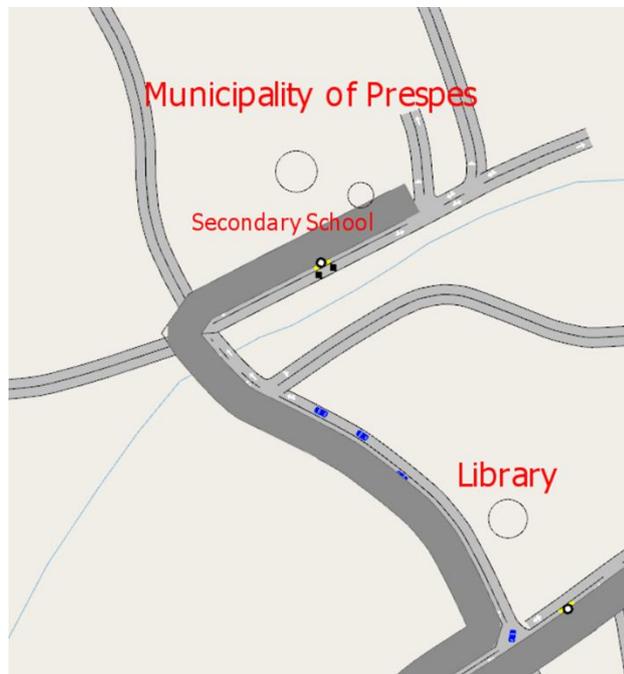


Figure 54: A typical traffic dynamic scenario in Prespes Town Hall (Agios Germanos)

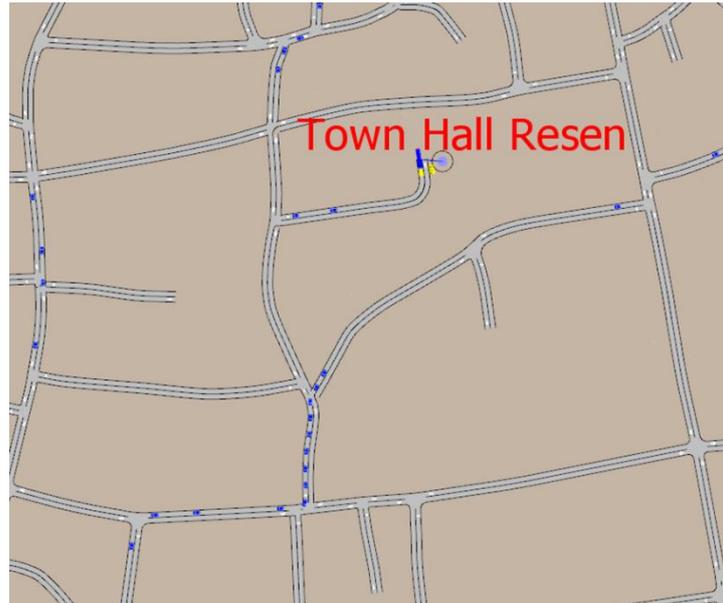


Figure 55: A typical traffic dynamic scenario in Resen Town Hall

Given the public transport line (route), its stops (origin, intermediate stops and destination) and a ran simulation in Aimsun, a position-time diagram was exported. This diagram illustrates the position of the bus as a function of time. Figure 56 shows the position-time diagram for route 7 to the four municipalities, including the intermediate stops:

- Stop 1: Sports Hall Boro Churlevski (Bitola)
- Stop 2: Resen Town Hall
- Stop 3: Prespes Town Hall
- Stop 4: Florina Town Hall
- Stop 5: Sports Hall Boro Churlevski (Bitola)

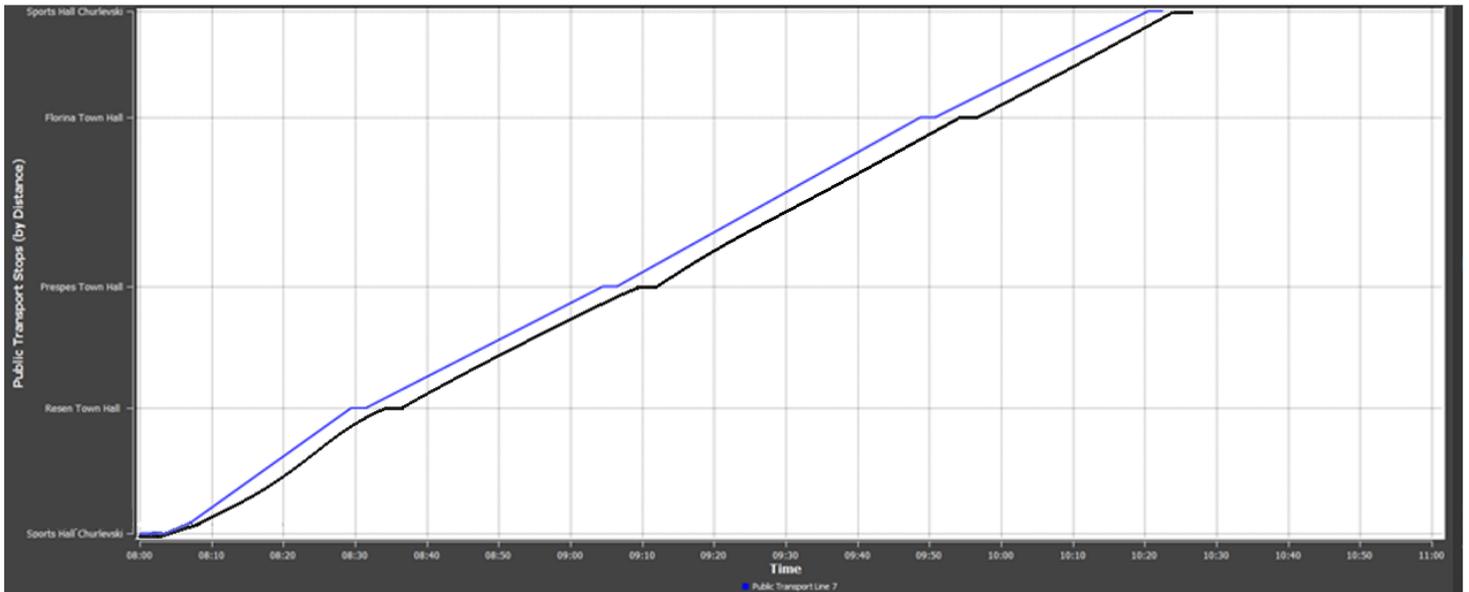


Figure 56: Position-time diagram for route 7 to the four municipalities

In Figure 56 there are two lines, of different coloring. There is a blue line representing free flow conditions, and a black line representing real traffic conditions. For estimating travel conditions, simulations were performed using a dedicated software. The simulations were key for calculating the time for the bus to travel between stops, and to calculate overall trip time from origin to destination. The blue line stands for free flow conditions, namely road signage, road geometry and overall road traffic are not considered. These parameters exist in realistic traffic conditions causing significant latencies. Thus, the black line indicates more time for reaching the destination than the blue line. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and traffic in the network, making the simulation realistic.

In Figure 56 there is a blue line (free flow conditions) and a black line (real traffic conditions). The simulation was crucial for calculating the time for the bus to travel between stops, and to calculate overall time (from origin to destination). Free flow was not realistic as it assumes maximum speed for the whole trip. On the other hand, Aimsun simulation considered bus accelerations and decelerations after and before stops, road geometry, traffic signaling and rules, and other vehicles in the network. Black lines differ from blue lines, as the black ones represent the simulated (realistic) scenario. Thus, it is possible to compare free flow with simulated conditions, not only with respect to time, but also speed (slope of time-position figure). The simulation started at 08:00 and there is a deviation from free-flow line.

In particular, the simulation starts at 08:00 and ends at 10:28 (duration= 2 hours and 28 minutes), while in free flow conditions the bus starts at 08:00 and ends at 10:22 (duration= 2 hours and 22 minutes). It is assumed that the minibus always follows the same route (to the four municipalities) with the same start (Sports Hall) and the same end (Sports Hall), without stopping for charging or for starting another route. This assumption was considered in simulations in order to calculate the average duration of route 7, considering stop, road geometry, signaling and traffic conditions.

4. E-minibus scheduling

In this section, one of the best alternatives for scheduling is presented. Sports Hall is the origin and destination of all seven routes; thus any sequence of routes is possible. One serious constraint is that e-minibus mixed cycle autonomy will be 200km, while city cycle autonomy will exceed 300km. Moreover, the average time needed for charging fluctuates around 4 hours, making it impossible and inefficient to charge the e-minibus during the day. So, the itineraries were spread during the day according to users' needs with respect to time.

Table 4 shows the suggested scheduling for the first three routes, which are the shortest (near Bitola's center). The itineraries of these three routes are suggested to be carried out from Monday to Friday. Route 1 is in orange, route 2 in red and route 3 in blue color.

Table 4: The suggested e-minibus scheduling for the first three routes (near Bitola's center)

Time	Stop	
07:00:00 AM	Sports Hall Boro Churlevski (start)	1
07:03:00 AM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	1
07:04:00 AM	Vero Super Market	1
07:05:00 AM	Pedagoshka Faculty of pedagogy	1
07:10:00 AM	Primary School Gjorgji Sugarev	1
07:12:00 AM	Javor Trade Center	1
07:14:00 AM	Bitoil Gas Station	1
07:17:00 AM	Selska Avtobuska Stanica	1
07:20:00 AM	Shetalishte City Park	1

07:23:00 AM	City Library St. Kliment Ohridski	1
07:27:00 AM	Sports Hall Boro Churlevski (end)	1
07:30:00 AM	Sports Hall Boro Churlevski (start)	2
07:33:00 AM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	2
07:34:00 AM	Vero Super Market	2
07:35:00 AM	Pedagoshka Faculty of pedagogy	2
07:40:00 AM	Primary School Gjorgji Sugarev	2
07:42:00 AM	Javor Trade Center	2
07:44:00 AM	Bitoil Gas Station	2
07:47:00 AM	Primary School Dame Gruev	2
07:50:00 AM	Tennis Court	2
07:53:00 AM	Footbal Stadium Tumbe kafe	2
07:55:00 AM	Sports Hall Boro Churlevski (end)	2
07:55:00 AM	Sports Hall Boro Churlevski (start)	3
07:58:00 AM	Vero Super Market	3
07:59:00 AM	Pedagoshka Faculty of pedagogy	3
08:08:00 AM	village Trnovo church"St. Bogorodica" (1)	3
08:11:00 AM	village Trnovo church"St. Bogorodica" (2)	3
08:20:00 AM	Pedagoshka Faculty of pedagogy	3
08:21:00 AM	Vero Super Market	3
08:24:00 AM	Sports Hall Boro Churlevski (end)	3
09:00:00 AM	Sports Hall Boro Churlevski (start)	1
09:03:00 AM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	1
09:04:00 AM	Vero Super Market	1
09:05:00 AM	Pedagoshka Faculty of pedagogy	1
09:10:00 AM	Primary School Gjorgji Sugarev	1
09:12:00 AM	Javor Trade Center	1
09:14:00 AM	Bitoil Gas Station	1
09:17:00 AM	Selska Avtobuska Stanica	1
09:20:00 AM	Shetalishte City Park	1
09:23:00 AM	City Library St. Kliment Ohridski	1
09:27:00 AM	Sports Hall Boro Churlevski (end)	1

09:30:00 AM	Sports Hall Boro Churlevski (start)	2
09:33:00 AM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	2
09:34:00 AM	Vero Super Market	2
09:35:00 AM	Pedagoshka Faculty of pedagogy	2
09:40:00 AM	Primary School Gjorgji Sugarev	2
09:42:00 AM	Javor Trade Center	2
09:44:00 AM	Bitoil Gas Station	2
09:47:00 AM	Primary School Dame Gruev	2
09:50:00 AM	Tennis Court	2
09:53:00 AM	Footbal Stadium Tumbe kafe	2
09:55:00 AM	Sports Hall Boro Churlevski (end)	2
11:00:00 AM	Sports Hall Boro Churlevski (start)	1
11:03:00 AM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	1
11:04:00 AM	Vero Super Market	1
11:05:00 AM	Pedagoshka Faculty of pedagogy	1
11:10:00 AM	Primary School Gjorgji Sugarev	1
11:12:00 AM	Javor Trade Center	1
11:14:00 AM	Bitoil Gas Station	1
11:17:00 AM	Selska Avtobuska Stanica	1
11:20:00 AM	Shetalishte City Park	1
11:23:00 AM	City Library St. Kliment Ohridski	1
11:27:00 AM	Sports Hall Boro Churlevski (end)	1
11:30:00 AM	Sports Hall Boro Churlevski (start)	2
11:33:00 AM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	2
11:34:00 AM	Vero Super Market	2
11:35:00 AM	Pedagoshka Faculty of pedagogy	2
11:40:00 AM	Primary School Gjorgji Sugarev	2
11:42:00 AM	Javor Trade Center	2
11:44:00 AM	Bitoil Gas Station	2
11:47:00 AM	Primary School Dame Gruev	2
11:50:00 AM	Tennis Court	2
11:53:00 AM	Footbal Stadium Tumbe kafe	2

11:55:00 AM	Sports Hall Boro Churlevski (end)	2
01:00:00 PM	Sports Hall Boro Churlevski (start)	1
01:03:00 PM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	1
01:04:00 PM	Vero Super Market	1
01:05:00 PM	Pedagoshka Faculty of pedagogy	1
01:10:00 PM	Primary School Gjorgji Sugarev	1
01:12:00 PM	Javor Trade Center	1
01:14:00 PM	Bitoil Gas Station	1
01:17:00 PM	Selska Avtobuska Stanica	1
01:20:00 PM	Shetalishte City Park	1
01:23:00 PM	City Library St. Kliment Ohridski	1
01:27:00 PM	Sports Hall Boro Churlevski (end)	1
01:30:00 PM	Sports Hall Boro Churlevski (start)	2
01:33:00 PM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	2
01:34:00 PM	Vero Super Market	2
01:35:00 PM	Pedagoshka Faculty of pedagogy	2
01:40:00 PM	Primary School Gjorgji Sugarev	2
01:42:00 PM	Javor Trade Center	2
01:44:00 PM	Bitoil Gas Station	2
01:47:00 PM	Primary School Dame Gruev	2
01:50:00 PM	Tennis Court	2
01:53:00 PM	Footbal Stadium Tumbe kafe	2
01:55:00 PM	Sports Hall Boro Churlevski (end)	2
02:00:00 PM	Sports Hall Boro Churlevski (start)	3
02:03:00 PM	Vero Super Market	3
02:04:00 PM	Pedagoshka Faculty of pedagogy	3
02:13:00 PM	village Trnovo church"St. Bogorodica" (1)	3
02:16:00 PM	village Trnovo church"St. Bogorodica" (2)	3
02:25:00 PM	Pedagoshka Faculty of pedagogy	3
02:26:00 PM	Vero Super Market	3
02:29:00 PM	Sports Hall Boro Churlevski (end)	3

04:00:00 PM	Sports Hall Boro Churlevski (start)	2
04:03:00 PM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	2
04:04:00 PM	Vero Super Market	2
04:05:00 PM	Pedagoshka Faculty of pedagogy	2
04:10:00 PM	Primary School Gjorgji Sugarev	2
04:12:00 PM	Javor Trade Center	2
04:14:00 PM	Bitoil Gas Station	2
04:17:00 PM	Primary School Dame Gruev	2
04:20:00 PM	Tennis Court	2
04:23:00 PM	Footbal Stadium Tumbe kafe	2
04:25:00 PM	Sports Hall Boro Churlevski (end)	2
04:27:00 PM	Sports Hall Boro Churlevski (start)	1
04:30:00 PM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	1
04:31:00 PM	Vero Super Market	1
04:32:00 PM	Pedagoshka Faculty of pedagogy	1
04:37:00 PM	Primary School Gjorgji Sugarev	1
04:39:00 PM	Javor Trade Center	1
04:41:00 PM	Bitoil Gas Station	1
04:44:00 PM	Selska Avtobuska Stanica	1
04:47:00 PM	Shetalishte City Park	1
04:50:00 PM	City Library St. Kliment Ohridski	1
04:54:00 PM	Sports Hall Boro Churlevski (end)	1
06:00:00 PM	Sports Hall Boro Churlevski (start)	2
06:03:00 PM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	2
06:04:00 PM	Vero Super Market	2
06:05:00 PM	Pedagoshka Faculty of pedagogy	2
06:10:00 PM	Primary School Gjorgji Sugarev	2
06:12:00 PM	Javor Trade Center	2
06:14:00 PM	Bitoil Gas Station	2
06:17:00 PM	Primary School Dame Gruev	2
06:20:00 PM	Tennis Court	2
06:23:00 PM	Footbal Stadium Tumbe kafe	2

06:25:00 PM	Sports Hall Boro Churlevski (end)	2
06:27:00 PM	Sports Hall Boro Churlevski (start)	1
06:30:00 PM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	1
06:31:00 PM	Vero Super Market	1
06:32:00 PM	Pedagoshka Faculty of pedagogy	1
06:37:00 PM	Primary School Gjorgji Sugarev	1
06:39:00 PM	Javor Trade Center	1
06:41:00 PM	Bitoil Gas Station	1
06:44:00 PM	Selska Avtobuska Stanica	1
06:47:00 PM	Shetalishte City Park	1
06:50:00 PM	City Library St. Kliment Ohridski	1
06:54:00 PM	Sports Hall Boro Churlevski (end)	1
08:00:00 PM	Sports Hall Boro Churlevski (start)	2
08:03:00 PM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	2
08:04:00 PM	Vero Super Market	2
08:05:00 PM	Pedagoshka Faculty of pedagogy	2
08:10:00 PM	Primary School Gjorgji Sugarev	2
08:12:00 PM	Javor Trade Center	2
08:14:00 PM	Bitoil Gas Station	2
08:17:00 PM	Primary School Dame Gruev	2
08:20:00 PM	Tennis Court	2
08:23:00 PM	Footbal Stadium Tumbe kafe	2
08:25:00 PM	Sports Hall Boro Churlevski (end)	2
08:30:00 PM	Sports Hall Boro Churlevski (start)	1
08:33:00 PM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	1
08:34:00 PM	Vero Super Market	1
08:35:00 PM	Pedagoshka Faculty of pedagogy	1
08:40:00 PM	Primary School Gjorgji Sugarev	1
08:42:00 PM	Javor Trade Center	1
08:44:00 PM	Bitoil Gas Station	1
08:47:00 PM	Selska Avtobuska Stanica	1
08:50:00 PM	Shetalishte City Park	1

08:53:00 PM	City Library St. Kliment Ohridski	1
08:57:00 PM	Sports Hall Boro Churlevski (end)	1
08:59:00 PM	Sports Hall Boro Churlevski (start)	2
09:02:00 PM	PHI Clinical Hospital Dr. Triphun Panovski Bitola	2
09:03:00 PM	Vero Super Market	2
09:04:00 PM	Pedagoshka Faculty of pedagogy	2
09:09:00 PM	Primary School Gjorgji Sugarev	2
09:11:00 PM	Javor Trade Center	2
09:13:00 PM	Bitoil Gas Station	2
09:16:00 PM	Primary School Dame Gruev	2
09:19:00 PM	Tennis Court	2
09:22:00 PM	Footbal Stadium Tumbe kafe	2
09:24:00 PM	Sports Hall Boro Churlevski (end)	2

Figure 57 shows the e-minibus' energy reserve, in kilometers remaining during a day.

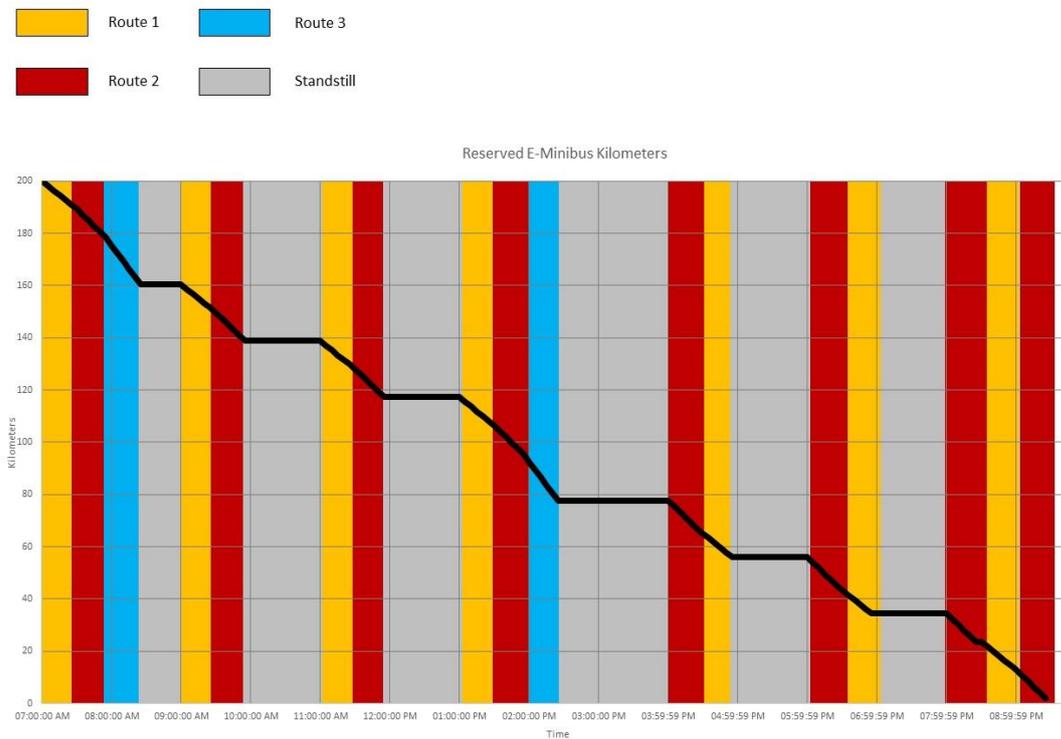


Figure 57: The e-minibus' energy reserve, in kilometers remaining during a day

The other four routes (4, 5, 6 and 7) are tourist routes and they have duration of approximately 2 hours. So, the following schedule is suggested for these routes (see Table 5). Table 6 shows the e-minibus' energy reserve, in kilometers remaining during a day for the tourist routes.

Table 5: The suggested e-minibus scheduling for the other four (tourist) routes

1st Saturday of the month			2nd Saturday of the month		
Time	Stop		Time	Stop	
09:00 PM	Sports Hall Boro Churlevski	4	09:00 PM	Sports Hall Boro Churlevski	6
09:05 PM	Vero Super Market	4	10:03 PM	Ohrida	6
09:08 PM	Faculty of Pedagogy	4	11:02 PM	Sports Hall Boro Churlevski	6
09:39 PM	Pretor village-Prespa Lake	4			
10:08 PM	Faculty of Pedagogy	4			
10:11 PM	Vero Super Market	4			
10:17 PM	Sports Hall Boro Churlevski	4			
1st Sunday of the month			2nd Sunday of the month		
Time	Stop		Time	Stop	
09:00 PM	Sports Hall Boro Churlevski	5	08:00 PM	Sports Hall Boro Churlevski	7
10:02 PM	Krushevo	5	09:34 PM	Resen Town Hall	7
10:52 PM	Sports Hall Boro Churlevski	5	09:11 PM	Prespes Town Hall	7
			09:54 PM	Florina Town Hall	7
			10:23 PM	Sports Hall Boro Churlevski	7

Table 6: The e-minibus energy reserve (for routes 4, 5, 6 and 7), in kilometers remaining during a day

1st Saturday of the month		2nd Saturday of the month	
Stop	km	Stop	km
Sports Hall Boro Churlevski		Sports Hall Boro Churlevski	
Vero Super Market		Ohrida	
Faculty of Pedagogy		Sports Hall Boro Churlevski	
Pretor village-Prespa Lake			
Faculty of Pedagogy			
Vero Super Market			
Sports Hall Boro Churlevski			
Sum	78.6		142
	<300		<300

1st Sunday of the month			2nd Sunday of the month	
Stop	km		Stop	km
Sports Hall Boro Churlevski			Sports Hall Boro Churlevski	
Krushevo			Resen Town Hall	
Sports Hall Boro Churlevski			Prespes Town Hall	
			Florina Town Hall	
			Sports Hall Boro Churlevski	
Sum	108		Sum	160
	<300			<300

5. Summary

Given Bitola's suggestions and preferences, University of Patras designed the routes and created the schedules for the e-minibus of Bitola. Using Aimsun, the routes were designed in detail with respect to users' needs, road and minibus geometry and traffic rules. Creating a realistic traffic simulation, the time needed from stop to stop and the overall time (from origin to destination) were calculated. Considering these times, as well as e-minibus kilometers autonomy, the scheduling was designed to satisfy users' needs in terms of space and time.