BRĂILA

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Traffic Analysis and Redesign of Main Junction in Brăila, Romania

Bachelor's Thesis

Civil Engineering

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Preface

This thesis is written as part of the third year of the bachelor program of Civil Engineering at University of Twente (UT), Enschede, Netherlands. It is an external project commissioned by the Municipality of the city of Brăila, Romania (Primaria Brăila).

The Municipality was interested in conducting research to identify strategies and ways to relieve congestion in a key area of the city that is often utilized by vehicles due to the rising number of automobiles in Romania and in Brăila in recent years. They were also interested in looking forward and identifying measures that would stand the test of time and the existing trends in traffic and transportation in Europe. Safety, accessibility, and the environment were the project's main priorities.

Special thanks go out to Dr. Ing. Bălănică Dragomir Mariana Carmelia, my external supervisor from the Municipality of Brăila, and Prof. Dr. Ir. Eric C. van Berkum, my internal supervisor from the UT, who both dedicated considerable time in regularly supervising me. Both of them continuously raised the bar and made sure to mentor me as I developed my job. I also appreciated the flexibility they both offered me to pursue the interests and issues I felt were relevant and fascinating.

Additionally, I want to thank Municipality of Brăila for providing me the chance to work on this project and for not imposing any restrictions on what may be accomplished. I also like to thank the University of Twente and its employees for always offering assistance when problems arose.

I always valued the support of my colleagues and friends at the UT who were there to exchange thoughts and viewpoints. Finally, I want to express my gratitude to my family for supporting me during my Bachelor's program.

Executive Summary

The number of vehicles in the city of Brăila has been rising annually for the last 20 years, and at this time, one of its major intersections, called "Bariera Călărașilor," is experiencing an alarming degree of congestion as a consequence of regular bottlenecks. If intervention is not taken soon, the situation might worsen and lead to even more dangerous conditions.

The goal of this study was to provide some solutions or measures for improving the situation in this heavily traveled location while also taking the near future into consideration. The major boulevard "Calea Călărașilor" and the large roundabout, which constitute the most important components of the junction, were the focus of the improvement efforts to increase accessibility, safety, and reduce environmental effects.

The baseline model was developed using local manual counting, data from the Municipality of Brăila and PTV VISSIM software. After that, three solutions were created, examined, and contrasted to the baseline model for both the present state and two potential future situations using VISSIM, statistical computations, and an assessment framework. The three solutions are traffic signaling optimization, implementation of bicycle lanes and installing an underground or overpass pedestrian passage.

Considering the ten congestion indices that were selected for the project, the underground or overpass pedestrian passage ultimately proved to be the most effective measure out of the three, but it does not represent a very eco-friendly solution as it promotes more vehicle use. However, combining the development of bicycle lanes, pedestrian passages, and traffic signal optimization has shown to be quite advantageous in all situations, even the pessimistic future scenario.

This research demonstrates that there are certainly measures that may be taken within a high-intensity road network utilizing a micro-simulation traffic modeling program and methodology to lessen the current congestion and also to stop the approaching traffic congestion of the near future.

Table of Contents

1. Introduction

For thousands of years, transportation played one of the most relevant roles in the daily lives of human beings. Especially since the invention of the wheel and of human settlements, the necessity for things to be moved around increased steadily and significantly in time. Nowadays, the importance of transportation can be observed in how people, businesses and governments depend on it to access, deliver and move resources and goods. Transportation stands at the foundation of any society (Impoff, 2020).

In order for transportation to be done efficiently and safely, the right infrastructure needs to exist. This means modern airports, harbors and land infrastructure such as: proper road links between cities (highways or express roads) and well-designed, suitable roads and junctions inside the cities. Unfortunately, especially in Europe because of the historical background and the difference culturally and economically between the countries, the development of land infrastructure has not advanced symmetrically.

On the other hand, the ownership of private cars has increased steadily in the last decade in all countries in Europe at similar paces. The EU passenger car fleet grew from 2016 to 2020 from 220 million to almost 250 million, which means a steady 1,2% increase every year. An outlier of this study is Romania for whom, in the same period of time, the cars increased with a rate of 5,4%, from 5,5 million to 7,3 million passenger cars. It represents the highest rate of increase in whole Europe (ACEA, 2022).

Because of this rapid increase of cars all over the country and the slowly developing infrastructure, the traffic congestions are dangerously evolving in all the cities and towns in Romania. Solutions need to be found in order to cope with the situation at the moment and to support the local governments especially until new roadways are created or the existing ones are developed to be suitable for the future. This can be done by analyzing the current situation in the largest bottlenecks of the cities and redeveloping them by smart solutions, new technologies and if possible, enhancing the use of alternative ways of transport.

One such bottleneck may be discovered in the study case of this Bachelor Thesis in Brăila, Romania, which has been examined in further detail later in the report. The remaining structure of the report is based on the design cycle. The report contains large chapters such as the “Context” of the situation at hand; “Methodology”, which includes the formulas and approaches that the project uses for evaluating the initial scenario and the solutions; “Setup of the Simulation Model” and “Baseline Model and Current Situation” which explain how the input data for the model that was used throughout the project has been generated and how the model itself was constructed based on the initial situation; “Potential Measures and Scenarios”, “Future Scenarios” and “Combination of Measures” which tackle how to handle the congestion and how the solutions are handling the near future. Finally, there are a " Discussion and future recommendations" chapter and a “Conclusion” at the end of the report, which summarizes the study's major findings and discusses the research as a whole.

2. Context

2.1. Study Area

In the Romanian city of Brăila, there is a bottleneck caused by heavy traffic. As background, people traveling to or from Moldova and Ukraine, which are both less than 30 km distant, pass through the city. At addition, travelers from the north-east of Romania who are headed to the seaside or the Danube Delta stop in Brăila during the summer months. Figure 1 shows the city's layout, and the junction's position may be seen in the black circle. (OpenStreetMap, Braila , 2022). The numbering on the graphic makes it easy to identify and understand the five ways that converge at the intersection where the bottleneck exists. The junction is crucial for ensuring that traffic engaged in traversing the city, for the objectives described above, is occurring as well as connecting major neighborhoods with the rest of the city.
In Figure 2, the junction itself and the bottleneck are presented, with the assigned vehicle inputs (OpenStreetMap, Bariera Calarasilor-Braila, 2022). The junction is composed of two roundabouts, one which includes traffic lights (Northeast) and one which does not include traffic lights (Southwest), and the connection between them. During the peak hours of the day, the bottleneck is congested and that has consequences on all the directions that are joined into the junction because they become congested as well. Regarding the traffic flow arrows, in the afternoon peak hour, the most relevant ones are the “Calea Călărașilor” arrows (highlighted with blue circles), because the highest flow is coming from those directions in a normal day. Following upon that, the other two arrows are equally important. The ones with orange are not as relevant during the day, but during 4:00 and 6:00 in the afternoon they may become congested as well with people coming home from work. A really important aspect of the junction is also the tram which is represented on the map by the two grey parallel lines. Also, the pedestrians are an essential factor that needs to be considered, with predominance in the large roundabout.

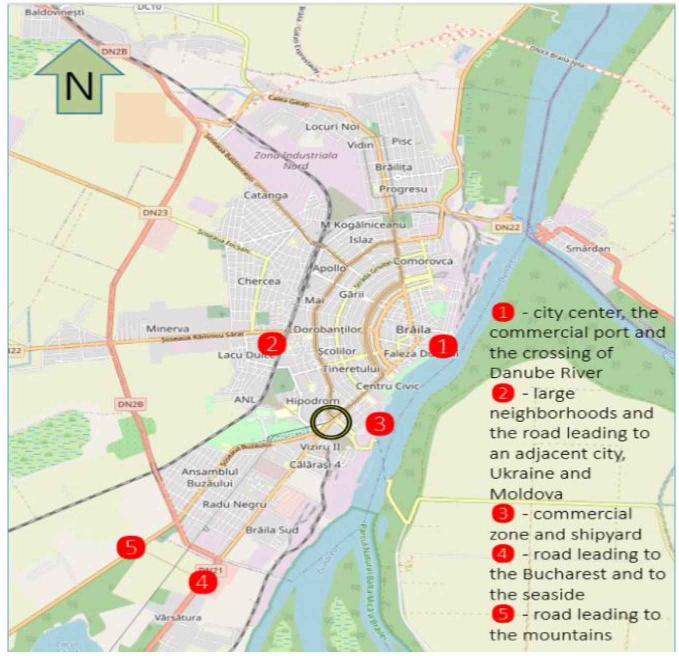

Figure 1 - Location of study area within Brăila (OpenStreetMap, Braila , 2022)

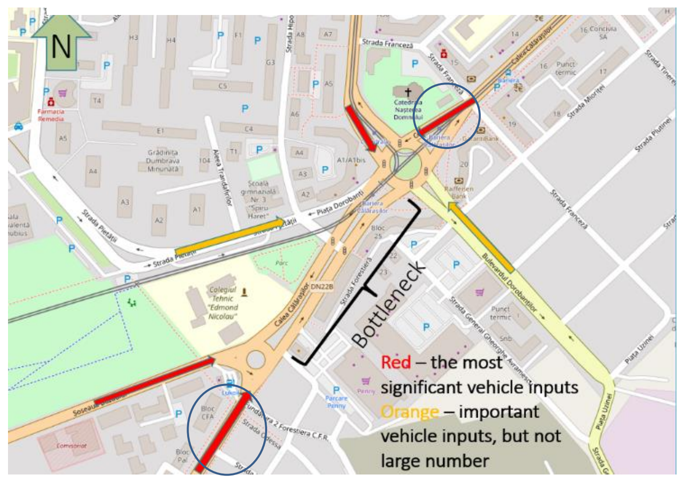

Figure 2 - Presentation of the study area - inputs (OpenStreetMap, Bariera Calarasilor-Braila, 2022)

Specifically, on the city's main boulevard, "Calea Călărașilor," and inside the large roundabout, where most of the congestion is located, the project in question aims to find measures or a set of solutions to alleviate traffic-related problems, such as congestion, accessibility, and environmental issues.

2.2. Involved Parties

2.2.1. Municipality

The Municipality of Brăila, Romania, is the party that hosted the project and the most important stakeholder. The Municipality represents the main governmental body of the city of Brăila. According to the “Law of local public administration” nr.215, it performs its duties with the following principles: decentralization, local autonomy, deconcentration of public services, eligibility of local public administration authorities, legality and consultation of citizens in solving school problems of public interest (Romanian-Government, 04.11.2014). Also, according to the Romanian Administrative Code, which represents the main guideline for local administration, a few extra principles can be seen, besides the one presented above: cooperation, responsibility and budgetary constraint (Romanian-Legislation, n.d.).
The Municipality has administrative and financial local autonomy, which gives them the right to take initiatives in all the domains in their jurisdiction and within the limits of the law. Their interest in the initiated project is to improve accessibility and safety, decrease congestion and enhance the environmental aspects of the area.

2.2.2. Other Actors

The outcome of the project is relevant for a couple of other actors such as:

- The traffic police, the actor who approves or denies the results of the project if they consider it is not in conformity with the emergency rules that they follow. Their interest is the safety of the drivers and pedestrians and also, they need to make sure that if an emergency occurs, the ambulance, firetruck and police cars can easily pass the area.
- The residents, visitors and businesses who are affected regularly during the peak hours by the bottleneck in the junction. Their interest is to have a smooth transition through the study area without large delays on their home, to work etc. This category can be as well divide into pedestrians and drivers. They both have the interest of crossing the junction but conflicts may occur between the two categories
    - Residents who are directly impacted by environmental factors in the region are interested in improving the air quality by reducing local emissions. Easy access to other parts of the city is another priority of theirs, hence the area's decongestion is crucial for them.
    - Accessibility and safety within the region and to other areas of the city is important to tourists and travelers, therefore decongestion is required as well as the improvement of various forms of transportation within the road network.
    - The accessibility and safety of the automobiles are the most important concerns for the companies who have trucks or cars crossing the intersection since they want to have quick and simple access across the neighborhood.

2.2.3. Possible conflicts of opinions

The conflicts which need to be considered during the project are:

- Municipality vs traffic police: The decisions that the Municipality may seem favorable for themselves might interfere with the interests of the traffic police. A compromise needs to be found in order keep everyone satisfied as much as possible and to enhance the accessibility and safety of the area.
- Pedestrians vs drivers: The junction contains a lot of pedestrian crosses and a lot of car lanes. If a balance between the times for automobiles to drive and for pedestrians to cross the street is not established, accidents may happen and one of the groups may get more irritated.

2.2.4. My contribution

My role in this project was to find solutions and practical measures to improve the situation in the road network of this project. The main objective of the Municipality is to improve the "Calea Călărașilor'" boulevard section of the road network, as it is the most used boulevard in the city (it can be seen in figure 2), as well as the large roundabout condition. Also, they are interested in bicycle lane implementation in this road network. The improvement of the other adjacent roads and boulevards was a secondary target. The simulation took into consideration also the other participants of the traffic: the tram and the pedestrians.

The processes conducted during the project included reviewing the bottleneck's existing situation, identifying the issues, developing a list of requirements, creating a set of viable solutions, and assessing the solutions using a framework for assessment and statistical calculations. The tool employed was the VISSIM program, which allowed me to evaluate the measures, obtain results, and create scenarios. The intersection was created from scratch in the PTV VISSIM software where all the inputs were inserted. The methods used and the solutions that were developed, could be able to be used in other areas where similar traffic problems occur and the technologization of the infrastructure is not yet up to date.

2.3. List of requirements

A list of requirements for the redesign of the road network was established based on the Municipality's demands, the needs of other stakeholders, and my contribution.

- Accessibility of main boulevard and large roundabout: When it comes to decongesting the region, the congestion on "Calea Călărașilor" boulevard and the large roundabout take precedence to the other roads.
- Maintaining the tram network: The tram lines should be kept in the network for maintaining the public transport use

- Pedestrian experience enhanced: Pedestrian crossings traffic signal phases should be balanced with the vehicles traffic signal phases
- Bicycle lanes implementation: Bicycle lanes should be considered in the area, especially from the "Monument" park towards the city center (from Șoseaua Buzăului towards Calea Călărașilor)
- Future proof: The solutions identified should be as realistic and valuable as possible in the near future (for example, in 5 years), not just for the current circumstances.

2.4. Studies conducted in the past

There is a vast number of articles, books and reports present online and in the literature about tackling traffic congestion. In the section below, some articles about previous studies of VISSIM-based traffic analysis were discussed. Unfortunately, there are no published studies done in the past in the location of the project so inspiration will be found in studies from around the world.

Lin et al. studied the traffic effect of the road network in Beijing CBD area using VISSIM in 2013. In VISSIM, the road network was modeled and four traffic organization alternatives were examined. Because of the differences in driving behavior in China compared to Europe or the United States, behavioral studies were also done to calibrate the model's parameters. The analysis had as inputs the design of a road network, a traffic demand estimate, an OD matrix with vehicle inputs and route options, and a traffic signal timing plan. To conduct the comparison, they employed travel time, travel speed, queue length, and delay as output evaluation indicators. One flaw in the study is the absence of pedestrians, who are an important component of crossings. (Lin, Yang, & Gao, 2013).

In the year 2020, Utomo et al used VISSIM to examine a congested highway network in Bandung, Indonesia. They calibrated the model similarly to the Beijing study in order to represent the distinct traffic behavior of Indonesian drivers. They utilized the existing traffic statistics in the network during the daily peak hour as input for the VISSIM model (vehicle inputs, routes and signal timing). The primary network was separated into three portions, with a new condition recommended for each section. For the comparison between the present and new traffic conditions, trip time, travel speed, and queue length were used as assessment markers. The report's main flaw is that it ignores pedestrians. (Utomo, Ramadhan, & Imran, 2020).

Shah et al used VISSIM in 2021 to assess the effectiveness of an existing roundabout in Peshawar, Pakistan. They used five scenarios: a standard roundabout and four others that turned the roundabout into a signalized roundabout (each scenario used different cycle length of the traffic lights). The vehicle inputs for each roundabout entry were gathered as input for the model, and the cycle duration for each scenario was determined. The degree of service, fuel consumption, traffic delay, queue length, carbon monoxide emissions, and nitrogen oxide emissions were all examined as output parameters. The lack of specifics, methodology, and the fact that it is quite generic are the report's drawbacks. (Shah, Khan, Ullah, & Khan, 2021).

Gutierrez and Hernandez constructed two models in VISSIM in 2021 with the goal of reorganizing traffic control equipment on one of Valdivia's busiest routes (Chile). Vehicle counting has been done at specific control points for the model's inputs, as well as the arrival of buses and line taxis. Frequencies and synchronizations of traffic signals were also measured. The aggregate journey time and aggregate delay time have been taken into account for the output data. The authors' recommended remedy was to increase the number of bus stations along the avenue while eliminating taxi lines, which resulted in a nearly 40% reduction in travel times and a nearly 50% reduction in wait times in the upgraded scenario model. Again, the lack of pedestrians is the main flaw of the model (Gutierrez & Hernandez, 2021).

Kutlimuratov et al used VISSIM to investigate the impact of a roadway intersection in 2021. They compare and contrast the operational performance of a standard four-legged junction versus a roundabout. They created two models in VISSIM for each case, and then used the models and methodology to come up with realistic traffic junction planning options. In order to determine the future consequences of the junctions, they also took into account the expected traffic increase between 2020 and 2025. Video cameras were used to collect data for the model, which included vehicle inputs, routes, compositions. The road geometry was taken from the current scenario until 2020 (four-legged junction) and the projected condition after 2020 (roundabout). They used Level of Service, Average Queue Length, Maximum Queue Length, Delays, Number of Stops, Number of Vehicles (Capacity), Fuel Consumption, Carbon Monoxide, Nitrogen Oxide, and Volatile Organic Compound Values as output and assessment criteria for the comparison. This study has the benefit of comparing the two alternatives while also taking into account the road network's future demands. They discovered that, while four-legged crossroads are currently able to handle traffic demands, by 2025, they would no longer be able to do so. (Kutlimuratov, Khakimov, Mukhitdinov, & Samatov, 2021).

In summary, the program is an internationally utilized tool for optimizing and reconstructing congested road networks and traffic intersections, according to the major principles from the previously stated scientific publications concerning VISSIM aided studies. The models can simulate every traffic condition in the globe if it is calibrated and validated. The vehicle inputs, compositions, and routes, as well as the signal timings and phases, were all gathered as inputs in the articles. Travel times and delay times are the common evaluation criteria utilized by all of them for the output. The emissions values are another helpful result that was mentioned in one of the articles. If it decreases, this element can help the network's environmental sustainability. Pedestrians were not included in any of the articles, despite the fact that they are an important part of regular traffic. Pedestrians and public transportation, in my opinion, should be included in the study because the simulation would be inaccurate without them.

3. Problem Statement and Research Objective

In this chapter, the problem statement was mentioned as well as the research objective, which describes the goal that should be achieved at the end of the project.

3.1. Problem Statement

Keeping the traffic flow stable during peak hours in the city of Brăila, Romania became difficult when the number of cars is increasing rapidly every year and the infrastructure and the travel options are not updated at the same pace. This unbalanced equation between these factors produces traffic congestion in the road networks. Analyzing the current situation, finding alternatives and proposing feasible present and future solutions would improve the experience of all types of participants to the traffic.

3.2. Research Objective

The objective of this study is to develop solutions for a congested traffic junction in a high-traffic metropolitan area in Brăila, Romania for the situation at the moment and for near future scenarios.

4. Research Questions

One key research question has emerged as a result of the context, problem statement, and research objective. To properly address the main research topic, four sub-questions must be answered.

- **Can solutions derived from micro-simulation traffic analysis and methodology improve the congestion situation in a high-intensity road network during peak hours in Brăila, Romania at the moment and in the near future?**

  - What are the indices of congestion that should be chosen as evaluation indicators and output of the model and what are their values?
  - Is the model validated and does it accommodate all modes of traffic?
  - What measures/solutions can be generated to decrease the indices of congestion?
  - What recommendations can be proposed based on the results for an even further mitigation of traffic congestion in the near future?

5. Methodology

It is necessary to develop a research approach that can be utilized to answer the research questions. A flow chart was shown first, which give a clear picture of the steps that were taken. The flowchart depicts the processes that must be completed in order to answer the main research question and obtain the intended outcomes. The blue rectangles depict the report's major sections. The yellow boxes represent the sub-questions of this research report. All the boxes of the methodology flow were discussed in detail in the following sections.

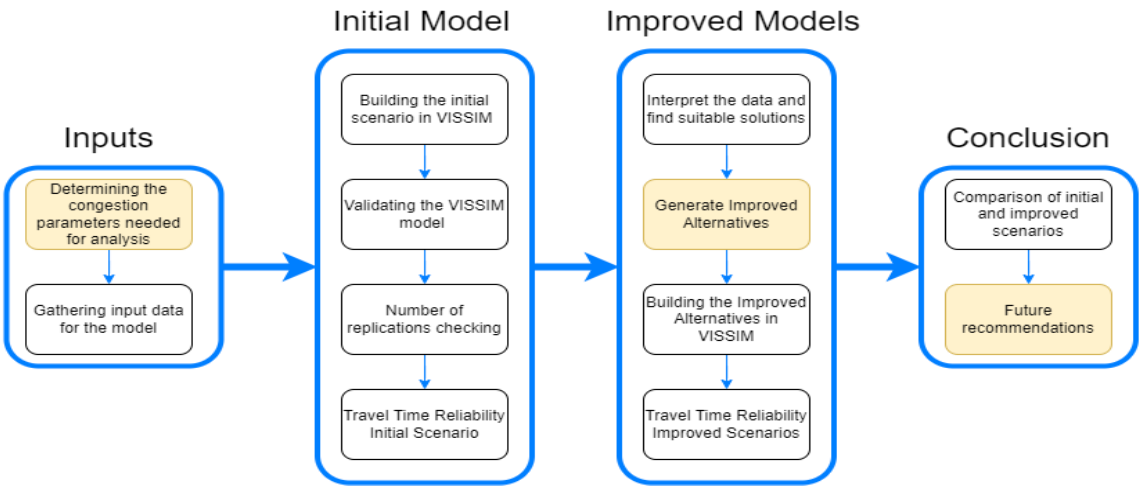

Figure 3 - Flowchart Methodology

5.1. Inputs

The first blue box in Figure 3 was covered in this sub-chapter, together with the Congestion parameters (how they are obtained and what values may be used) and how the data for the model's vehicle inputs will be acquired.

5.1.1. Congestion Parameters

In 1997, in "Quantifying Congestion", Lomax et al were investigating ways of developing methods to measure congestion on roadway systems. One of the definitions that they came up regarding congestions is "Unacceptable congestion is travel time or delay in excess of an agreed-upon norm". The agreed-upon norm may vary depending on the context of each project. For the measures of traffic congestion, several options were found by the authors and they can be seen in Figure 4 opposite to the level of Analysis. Considering that the project involves "Individual Locations" and a "Short Roadway section", the selected measures of congestion are Travel Time and Total Delay. The formulas for each one of them can be seen in

Table 1 (Lomax, Turner, & Shunk, 1997). Other congestion parameters or indices as they were called in the latter stages are the travel time reliability (TTI, PTI and Buffer Index), the Level-Of-Service (LOS), three types of emissions (CO, NOx, VOC) and the average fuel consumption of the vehicles.

Level or Scale of Analysis	Measures of Congestion										
	Travel Time	Travel Time Difference	Travel Rate	Delay Rate	Total Delay	Relative Delay Rate	Delay Ratio	Corridor Mobility Index	Congested VMT/ PMT	Congested Roadway	Accessibility
Individual Locations	S	S			P						
Short Roadway Sections	P		P	P	S	S					
Long Roadway Sections or Routes		S	P	P	P	S	S				
Corridors			S	S	P	P	P	S			S
Sub-Areas					P			S	P	P	P
Regional Networks					P			S	P	P	P
Modal Analyses		P	S	S	P	P	P	P			P

Note: P = Primary measure of congestion
S = Secondary measure of congestion
VMT = Vehicle-miles of travel
PMT = Person-miles of travel

Figure 4 - Indices of Congestion (Lomax, Turner, & Shunk, 1997)

Measure of Congestion	Formula	Explanation of terms
Travel time	TT	TT = Travel time (minutes)
Segment delay	$Ds = (TT_{actual} - TT_{acceptable}) \times V_{peak}$	Where, TT_{actual} = actual travel time (minutes) $TT_{acceptable}$ = acceptable travel time (minutes) V_{peak} = vehicle volume in the peak-period (vehicles)

Table 1 - Indices of Congestion Formulas (Lomax, Turner, & Shunk, 1997)

5.1.2. Gathering the Data

The method for collecting data for the model's inputs, such as data regarding automobile traffic flows, traffic signal timings, and other variables, was addressed thoroughly in Chapter 6 as it was a very complex step of the project.

5.2. Initial model and Improved models

The second and third blue boxes from Figure 3 were covered in this sub-chapter. Both use the same software and follow identical formulas, which is why they are in the same chapter.

5.2.1. Model background

As it can be almost impossible to test the measures that were taken during the project first in real life, a simulation was chosen for this project to check measures and obtain results. Simulation has certain advantages as stated in (Rodrigues, 2014):

- In terms of time, resources, and cost, simulation is less expensive than various types of field testing and analytical modeling;
- Simulation is an effective method for contrasting the effects of several alternative plans and methods;
- Simulation models are "transparent," in that anyone wishing to understand how they operate may look right through the model;

PTV VISSIM is the program that was utilized for this research study. It is a microscopic multifunctional traffic simulator that lets you analyze all kinds of transportation, including pedestrians. It has the ability to increase the capacity of current infrastructure and is displayed in a fully editable visual format. VISSIM is the industry standard traffic simulation program, with over 2500 cities and 120 nations using it (PTV-GROUP, 2022). There are recorded examples of effective VISSIM simulations all across the world, as the chapter "prior literature" indicates. On the program brochure, there are two more comparable examples from across the world: The city of Copenhagen is mimicking bicycle traffic in and the Government of Western Australia is putting in place the world's first signalized roundabout (PTV-GROUP, 2022).

VISSIM's fields of application are quite valuable in relation to the research subject in question. VISSIM can construct a digital twin of a city's current junctions and corridors, allowing for the identification and understanding of congestion concerns. It assists in the optimization of solutions prior to any real-world application, hence reducing construction costs and dangers. All actions may be designed and simulated, and the impacts on total traffic flow can then be assessed (PTV-GROUP, 2022).

5.2.2. Building the model

The actions that were performed for the building of the "initial scenario" model were detailed in this portion of the model chapter. In Figure 5, the whole process can be seen including the steps, the source of the step and the elements involved in the steps. Following upon the figure, the steps are explained afterwards.

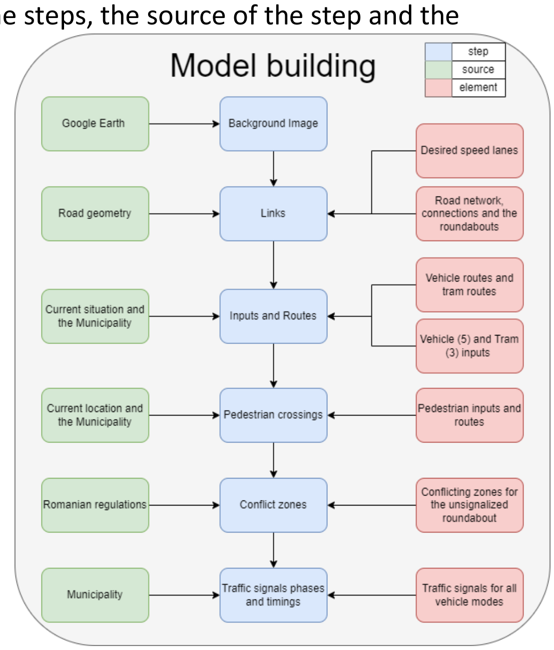

Figure 5 - Model building steps

First and foremost, the model's background image needed to be created. The background picture was created using Google Earth maps because the map in the VISSIM program is not up to speed with the situation in the region (one of the roundabouts is still a normal junction; a scenario that existed a couple of years ago in the area). Afterward, it was scaled to match the actual measurements of reality.

The road network was then built utilizing links in the second stage. The VISSIM connections' default lane width is 3,5 meters, however for this project, the lane will be adjusted to 2,75 meters after measuring the width of the lane in the network with Google Maps. Although this had no effect on the model's behavior, it is worth mentioning. Following that, tram lines were constructed utilizing the specific public transportation option, with the lane dedicated just to tram traffic.

Furthermore, the vehicle inputs (5 vehicle inputs and 3 tram inputs) were included at the start of every network entry, followed by the vehicle routes, which should examine any path that a vehicle can take when it joins the network. The tram station was placed in its original location, as depicted by Google.

The pedestrian lanes were incorporated into the roadway as the following stage. There are seven pedestrian crossings in the network, two of which are unsignalized and five of which are. The places where pedestrians cross from, the pedestrian inputs, and the routes were all included (by pedestrian routes it is meant crossing from one side

to the other of the street).
Finally, conflict zones for the unsignalized roundabout were determined, and traffic lights were built in the model with the phases and timings being entered later on during the project. The basic model was considered complete after the preceding phases were completed and real values were entered into the model.

5.2.3. Calibration

Because the driver behavior is different than the ones that the model is calibrated for, a calibration was done for the models that were simulating traffic from areas outside of Europe (Lin, Yang, & Gao, 2013) under the prior research section. Because VISSIM is a German-made program, it incorporates features that improve simulation in European settings. As a result, because the study project is being carried out in Romania, no calibration was done towards the driver behavior parameters (i.e., lane change frequency, distance to car in front etc.) that are already in VISSIM simulation, as it is considered that the software's regular driving behavior is comparable to that of Romanian drivers.

5.2.4. Validation

The morning peak data for the cars was utilized for validation because the primary computations and analysis of this report were done using the afternoon peak hours' data for the vehicles. Since there was no information available for the pedestrian intakes during the morning, the inputs for pedestrians were reduced by 25%. This section is extended further in Chapter 7's "Validation" sub-chapter.

5.2.5. Relevance of output data

The following calculations were carried out for both the initial and revised scenarios in order to determine how relevant the output data is and to gain a better understanding of travel times and delay periods. 95% confidence level was chosen for this project because it is the most common one used in statistical calculations and it is not as wide as 99% and not as narrow as 90% (GraphPad, 2022).

Number of repetitions

For the number of repetitions, a formula derived from the Confidence Interval was used. The Confidence interval equation can be seen below.

$$CI = mean \pm \boldsymbol{z} * \frac{\boldsymbol{std}}{\sqrt{\boldsymbol{n}}}$$

Where:

- $\boldsymbol{z} * \frac{\boldsymbol{std}}{\sqrt{\boldsymbol{n}}}$ represents the half-width interval of the confidence interval
- $\boldsymbol{z}$ represents the confidence level value
- $\boldsymbol{std}$ represents the sample standard deviation
- $\boldsymbol{n}$ represents the sample size

The simulation was chosen to run five times, so the mean and the standard deviation can be estimated. The number of repetitions were calculated using the formula below derived from the confidence Interval equation. The purpose of this calculation is to keep the half-width of the confidence interval to be less than 5% of the mean with 95% confidence.

$$n = (\frac{t^{95} * std_5}{0.05 * mean_5})^2$$

Where:

- where t^{95} is the t-value of the confidence interval for 95% depending on the degrees of freedom (2,776 for 5 repetitions)
- std_5 is the estimated standard deviation based on the 5 samples
- $mean_5$ is the estimated average based on the 5 samples

Travel time reliability

After setting the number of times the model has to run, the travel time reliability was checked using 3 indices (SMARTTRAFFIC, 2022):

1. The travel time index (TTI) measures how much longer a trip takes at peak hours compared to how long it takes in a non-traffic situation. The index value should be as close to 1 as possible.

$$TTI = \frac{mean\ travel\ time}{free\ flow\ travel\ time}$$

Where:

- free flow travel time is the time it takes for cars to pass the specific road corridor if the free flow is possible

2. The buffer index (BI) is the amount of time that travelers should plan for unforeseen delays. The value should be as close to 0% as possible

$$BI = \frac{travel\ time_{95} - mean\ travel\ time}{mean\ travel\ time} * 100$$

Where:

- travel $time_{95}$ is mean travel time to be on-time 95 percent of the time

3. The planning time index (PTI) is the ratio of the 95th percentile to the free-flow travel time, and it represents the total time required for on-time arrival in 95% of all journeys. The distinction between the Buffer Index and the Planning Time Index is that the BI reflects the additional delay time that must be added to the average journey duration, whereas the PTI represents the entire trip time (average travel time + buffer time). The value should be as close to 1 as possible.

$$PTI = \frac{travel\ time_{95}}{free\ flow\ travel\ time}$$

All 3 parameters give insight into the travel times and the delay times. If the values of the indices are satisfactory and realistic, then the analysis can continue. If the values are too unrealistic, then adjustments need to be done on the simulation.

5.3. Conclusion

This sub-chapter focused on the last blue box in Figure 3. There are two sorts of scenario comparisons mentioned. One used an assessment framework built throughout the project, while the other compared output data using a statistical formula. Finally, some future recommendations were provided.

5.3.1. Comparison of scenarios with assessment framework

The list of requirements (from Chapter 2.3) was used to create an assessment framework for comparing the initial and revised scenarios. The cases were tested using the VISSIM as the tool to evaluate if they meet the requirements better or worse based on the model's output figures. In addition, if some requirements were distant from being met according to the assessment framework, a scenario was automatically ruled out.

5.3.2. Comparison of scenarios with confidence interval

For the comparison between the scenarios data, another statistical formula was used. Confidence interval (C.I.) for a difference between means is a range of values that is likely to contain the true difference between two population means with a certain level of confidence (STATOLOGY, 2020). The Confidence Interval for the Difference between two means with 95% confidence level was the equation chosen for this project’s final comparison. The equation can be seen below.

$$CImean = (\bar{x}_1 - \bar{x}_2) \pm t_{95,n-1} * \sqrt{\frac{{std_1}^2 - {std_2}^2}{n}}$$

6. Setup of the Simulation Model

The generation of the input data for the VISSIM model were fully explored in this chapter. This covers road layout, traffic signal phases, and all traffic type inputs and routes (vehicles, pedestrians and tram).

6.1. Road layout

On-site measurements and observations were done to become more familiar with the region's characteristics in order to estimate the street layout and lane width. It was necessary to understand the road's geometry in order to avoid relying just on how Google Maps or Earth displayed the road

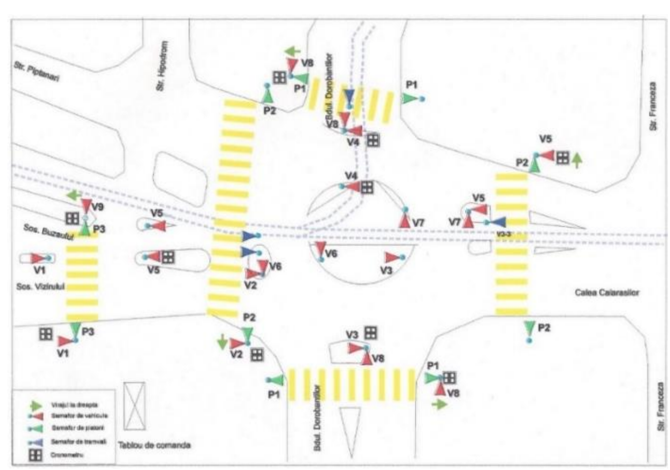

Figure 6 - Traffic Signaling of Main Roundabout

online. The lanes looked to be between 2,5 and 3 meters wide, depending on where they were on the road and how the road curves at particular corners. As a result, the center point was chosen and the lanes were set at 2.75 meters wide. The lanes on the tiny roundabout were roughly 4,5 meters wide, while the lanes on the bigger roundabout were around 3,5 meters wide. The lane width figures are purely for the purpose of being exact, even though they have no impact on how the model behaves or what outcomes it produces.

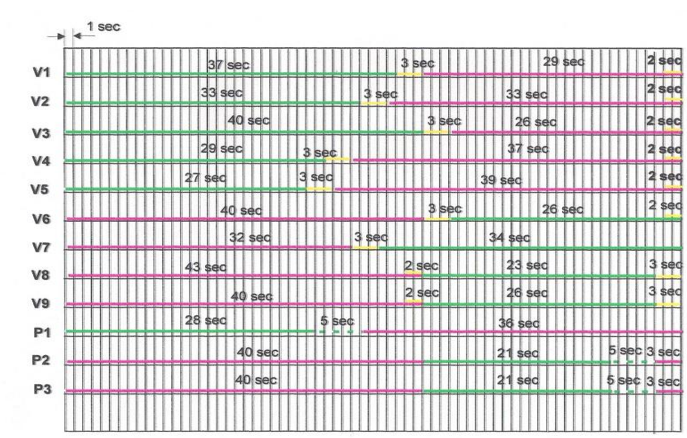

Figure 7 - Full traffic signaling cycle

6.2. Traffic signal phases

The Municipality provided the phases and timings of the traffic signals. Figures following show the locations (Figure 6) and phases (Figure 7) of the traffic lights for the large roundabout. The first image depicts traffic signal installation, while the second image depicts a whole cycle of traffic signals, including people. A cycle takes 71 seconds to complete, therefore 52 cycles of traffic signals occur every hour. Check Appendix 2: Traffic Signaling Cycle for the traffic signals between the two roundabouts.

Figure 8 - The six vehicle inputs (OpenStreetMap, Bariera Calarasilor-Braila, 2022)

6.3. Traffic inputs

6.3.1. Cars

There are six traffic inputs in the network, as shown in Figure 8 from OpenStreetMap, and as discussed in the Context chapter (OpenStreetMap, Bariera Calarasilor-Braila, 2022). Unfortunately, the municipality lacked statistics on automobile influxes in this region, as well as any OD matrix.

To identify the model's inputs, manual counting was necessary. Manual counting has various drawbacks, including significant variability in the data set and the possibility of human mistake and fatigue, depending on the time interval and the analysis' objective. Manual counts, on the other hand, are efficient for small data samples, short count intervals, and the goals of direction of travel, turning motions, pedestrian movements, and vehicle occupancy, according to the literature (Kusimo & Okafor, 2016). Another article on the accuracy of hand counting demonstrates that counting mistakes are minor, generally less than 1% for brief counting intervals (Zheng & Mcdonald, 2012). According to another source, when the total number of cars is the focus of the investigation, the difference between a manual and an automatic counter is between 2% and 3% (Palo, Caban, Kiktova, & Cernicky, 2019).

In consideration of the entire amount of working hours for this project, it was concluded with the internal supervisor that two weeks of manual counting would be suitable. Consequently, manual counting was done for the first two weeks of the study (18th to 29th of April) for both morning (7:30-9:30) and afternoon (16:00-18:00) peak hours on weekdays. The hour intervals were chosen based on what the Municipality suggested as the peak hours in Brăila, as well as articles about peak traffic hours, such as one from Romania-Insider, which suggests that the peak hours in Bucharest (no other article about another city in Romania was found online) are from 7 to 9 and from 16 to 18 (Romania-Insider.com, 2015).

Another difficult issue was the positioning of the manual counting since it would have been impossible to count all directions at the same time. For the sake of simplicity, the six directions were assigned numbers from ❶ to ❻.

Input	Number
Șoseaua Buzăului	❶
Șoseaua Viziru	❷
Strada Pietății (Hipodrom)	❸
Bulevardul Dorobanților (Șantier Naval, Lidl)	❹
Calea Călărașilor	❺
Bulevardul Dorobanților	❻

Table 2 - Assigned numbers for each input

So, for points ❹, ❺ and ❻, I took measurements from a 7th-floor apartment balcony. As can be seen in Figure 9, there was a good view of the large roundabout, which made counting simple. To decrease the risk of human mistake, I usually had another person assist me with the counting. For points ❶, ❷, ❸, with the Municipality's assistance, I was able to look at the video recordings of the Local Police from those locations and count for the day and hour intervals I required. The numbers were converted into Excel once the physical counting was completed for easier display and comprehension of the data. Appendix 1: Manual Counting contains the data tables. The data has two noteworthy features:

Figure 9 - Location of the manual counting for points ❹, ❺, ❻

- Because it was Easter Weekend in Romania from April 22nd to 25th, there was a slight decline in the usage of automobiles on Friday (22nd) and Monday (25th).
- Additionally, both weeks were student vacation weeks, so there was less traffic in the morning peak hour than typical. During typical working days in Brăila, parents frequently drive their children to school or kindergarten, resulting in increased traffic. Given this, the morning peak hour does not accurately reflect reality.

Basic statistics and histograms were created in Excel for each direction data set for both morning and afternoon data. They are also included in Appendix 1: Manual Counting. Because the distribution of data values is asymmetrical and there are outliers (Easter days), it was thought that using the median rather than the mean would be more appropriate, based on the information discovered in theory between mean and median (STATOLOGY, 2021). The median vehicle inputs for all six directions for both peaks are shown in Figure 10 and Figure 11 below. As can be observed, the afternoon peak has higher numbers, thus it was utilized for analysis, with the morning data serving as validation.

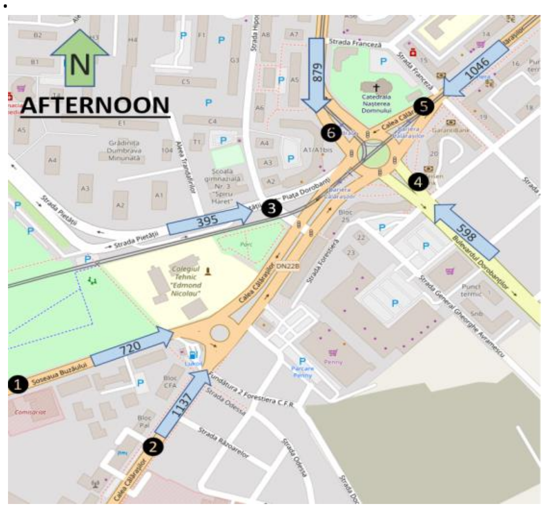

Figure 10 - Afternoon peak inputs

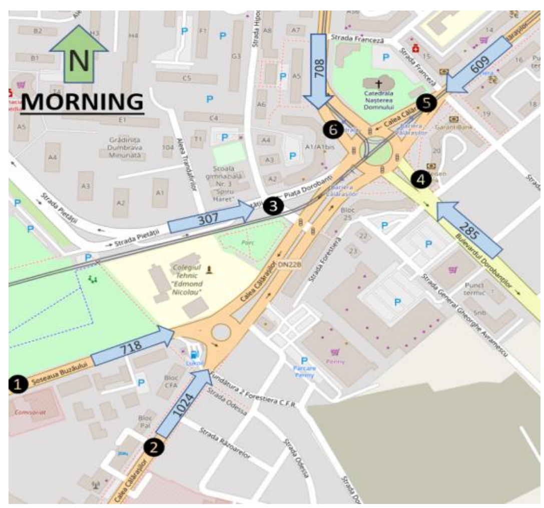

Figure 11 - Morning peak inputs

6.3.2. Pedestrians

According to hand counting done during an afternoon peak hour, the number of pedestrians per each traffic signal cycle for signalized crossings is generally the same. As a consequence, for each crossing, an average per cycle was calculated and multiplied by the number of cycles each hour (52 cycles). The external supervisor assisted in estimating the unsignalized crossings. For the morning peak unfortunately, there was no counting but it was decided to decrease the numbers by 25%. Figure 12 and Table 3 display the location of each crossing, as well as which ones are signalized and which are not, as well as the afternoon peak data for each one, including total and per-side pedestrian numbers. The following sections' crossings have been numbered from ① to ⑧ for simplicity's purpose.

Figure 12 - Pedestrian crossing locations

Crossing	Total Pedestrians Afternoon Peak	Pedestrians Per Side Afternoon Peak
①	40	20
②	60	30
③	100	50
④	300	150
⑤	300	150
⑥	200	100
⑦	300	150
⑧	300	150

Table 3 - Pedestrian crossings input numbers

6.3.3. Tram

The tram was established suitably for all four directions the tram may travel in this network, as can be seen in Figure 13, as well as where the tram stops are placed, thanks to the Municipality providing the public transportation schedule in the region. Each tram cycle is every 15 minutes, with a 100-seconds wait between trams, and in the order shown in the diagram.

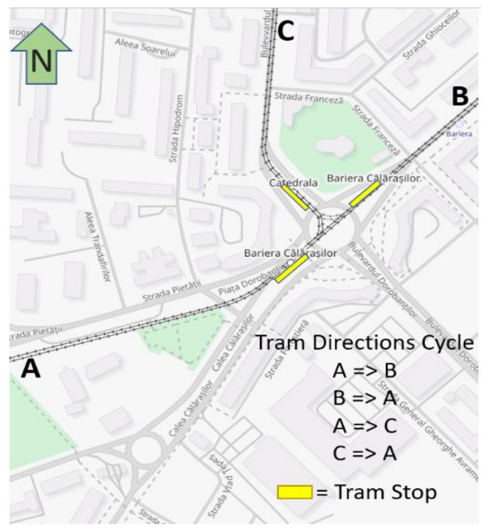

Figure 13 - Tram directions cycle

6.4. Vehicle Routes Ratios

After completing the inputs, all possible directions/routes that automobiles might take from each starting point, as well as the ratios they could take in each direction, had to be evaluated. The procedure was followed at the same time as the manual counting. Table 4 displays the ratios at which autos can travel from one beginning place to another for afternoon peak hour. The figures have also been double-checked with the external supervisor to ensure that they are accurate. For each origin point, they must add up to one. One assumption worth highlighting is that automobiles with the same origin and destination, essentially turning around from where they came from (example: ❶=>❶), are ignored since their numbers are small.

❶ => ❷	0,1 (10%)	❷ => ❶	0,05 (5%)
❶ => ❸	0,15 (15%)	❷ => ❸	0,15 (15%)
❶ => ❹	0,1 (10%)	❷ => ❹	0,1 (10%)
❶ => ❺	0,45 (45%)	❷ => ❺	0,47 (47%)
❶ => ❻	0,2 (20%)	❷ => ❻	0,23 (23%)
❸ => ❶	0,25 (25%)	❹ => ❶	0,14 (14%)
❸ => ❷	0,3 (30%)	❹ => ❷	0,18 (18%)
❸ => ❹	0,04 (4%)	❹ => ❸	0,02 (2%)
❸ => ❺	0,4 (40%)	❹ => ❺	0,33 (33%)
❸ => ❻	0,01 (1%)	❹ => ❻	0,33 (33%)
❺ => ❶	0,35 (35%)	❻ => ❶	0,28 (28%)
❺ => ❷	0,4 (40%)	❻ => ❷	0,32 (32%)
❺ => ❸	0,1 (10%)	❻ => ❸	0,05 (5%)
❺ => ❹	0,05 (5%)	❻ => ❹	0,15 (15%)
❺ => ❻	0,1 (10%)	❻ => ❺	0,2 (20%)

Table 4 - Vehicle route ratios afternoon peak

The numerical ratios for morning peak hour have been kept nearly similar to the afternoon ones, with just minor modifications. To illustrate the fact that individuals are travelling to work, just 5% have been transferred from a modest destination to a more essential road. The modifications are shown below.

❶ => ❸	0,1 (10%)	❺ => ❶	0,4 (40%)	❷ => ❸	0,1 (10%)
❶ => ❻	0,25 (25%)	❺ => ❸	0,05 (5%)	❷ => ❻	0,28 (28%)

Table 5 - Differences for morning vehicle route ratios

7. Baseline Model and Current Situation

7.1. Construction of the model

After all of the data was collected, the model was built in VISSIM to match the real-life condition. The backdrop image is a satellite image from Google Earth that has been scaled to approximate real-world distances and road networks (Figure 14).

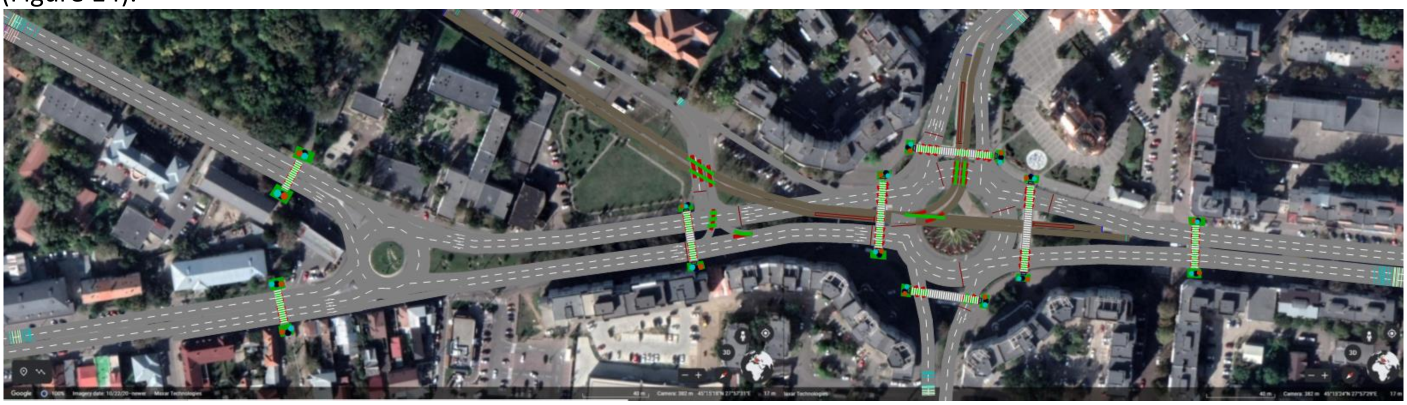

Figure 14 - Baseline Model

- The grey roads are clearly car roadways, the brown roads are tram lines, and the pedestrian crossings are marked with green and white zebra.
- The traffic signals have been set according to the real-life cycle of 71 seconds. The traffic signals are represented by the red/green/amber lines on the street. Can be seen in Figure 16 and Figure 18. The representation of the traffic signal cycle can be seen in Figure 15 below.

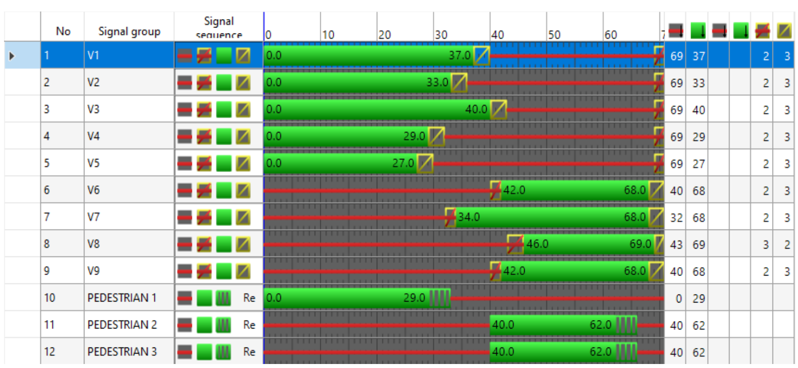

Figure 15 - Traffic signaling cycle

- The green rectangles at the end of the pedestrian crossings symbolize "pedestrian zones," or the starting and ending points for walkers. Also, the points inside the green zones represent input (black), origin (red), destination (blue)
- The tram stops have been placed in their correct place and they are marked with rectangles with red outline. They can be seen barely in Figure 18.
- The conflict zones can be seen in Figure 17 or in Figure 18 at the large roundabout. Priority is represented by green, and stop by red. Figure 17, for example, demonstrates which vehicle has precedence: the tram always has priority, while automobiles turning left must wait for cars turning straight. Inside the blue circle in Figure 17 is a conflict zone that should be included in the model but is intentionally excluded after seeing how the model performs. Normally, the tram should take precedence and autos should come to a complete stop

before the tram tracks. However, during the afternoon rush hour, when traffic is at its worst, drivers cannot wait because the congestion is too large, so they wait for the green light while driving on the tram track, when the tram is not incoming. It was thought to be a reasonable omission in this model.

Figure 16 - 3D view, Running 2D view and Steady 2D view of Small Roundabout

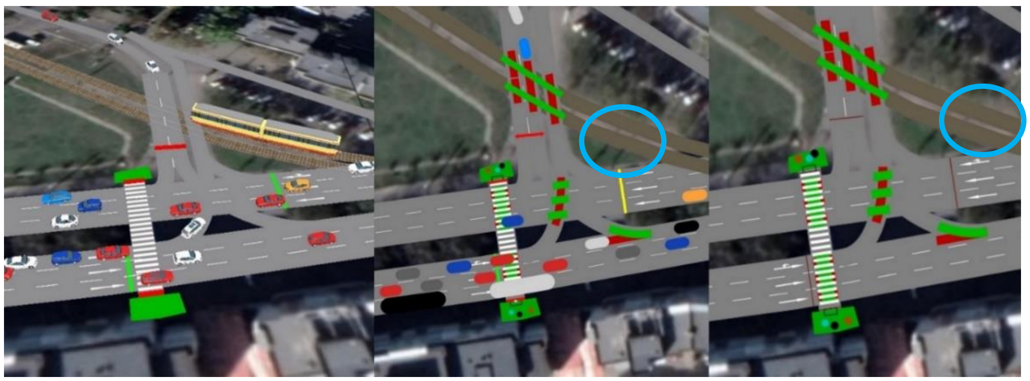

Figure 17 - 3D view, Running 2D view and Steady 2D view of between the roundabouts

Figure 18 - 3D view, Running 2D view and Steady 2D view of Large Roundabout

• In the software, the vehicle routes have been built as "static vehicle routes" (they do not change throughout the simulation). The ratios that are found in Chapter 6 have been allocated to them. Figure 19 depicts how all of the routes for automobiles departing from Șoseaua Buzăului appear (❶).

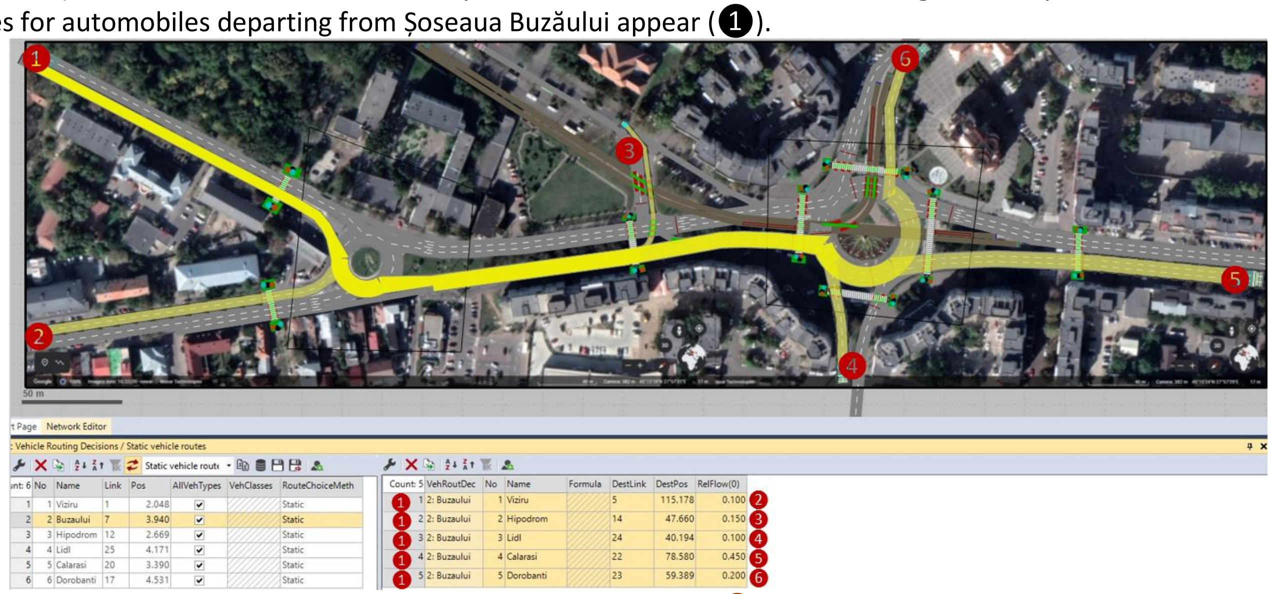

Figure 19 - Route ratios for Șoseaua Buzăului ❶ representation in VISSIM

The people and trams have been positioned according to Chapter 6 for the inputs. There were some minor changes to the automobiles, as well as some assumptions about the quantity of cars that are worth addressing:

1. To begin with, the vehicle composition varies by origin. The vehicle mixes for points ❶, ❷ and ❺ (Buzăului, Viziru, and Călărași) is 94% automobiles, 5% buses, and 1% HGV (heavy goods vehicle). Buses and HGVs do not utilize the other routes, thus there are just vehicles. It can be seen in Figure 20 as well.
2. The model was simulating unrealistic congestion using the input cars from Chapter 6, since the network became blocked at several spots, which is incorrect. It was decided to reduce some of the inputs that appeared to be causing the issues by at most 100 cars. The original and adjusted values may be found in Table 6 below.

Count: 6	No	Name	Link	Volume(0)	VehComp(0)	
1	1	Buzaului	7	720.0	1: Default	❶
2	2	Viziru	1	1050.0	1: Default	❷
3	3	Hipodrom	12	400.0	4: Only cars	❸
4	4	Lidl	25	520.0	4: Only cars	❹
5	5	Calarasi	20	940.0	1: Default	❺
6	6	Dorobanti	17	830.0	4: Only cars	❻

Figure 20 - Inputs in VISSIM model

Input	Original	Adjusted
❶	720	720
❷	1137	1050
❸	400	400
❹	598	520
❺	1046	940
❻	879	830

Table 6 - Difference between initial and adjusted values

3. At the advice of the external supervisor, the speed of the automobiles was increased to better resemble reality. It was raised from 50 km/h to 60 km/h, which is the highest legal speed that automobiles in that region may reach.

7.2. Output

Certain operations that are implemented in the model must be utilized to retrieve data from it, and parameters must be specified for the simulation. After the program has completed 5 runs, the output data is shown as "Results" in the software, based on the time intervals specified.

Simulation Interval and initial number of runs

One hour of running should be included in the simulation. The challenge with traffic simulations is that they must account for warm-up (cars gradually join the model until a continuous flow of automobiles develops) and cool-down (cars gradually exit the model until no cars remain). Regarding the cool down duration, nothing was found in the VISSIM developer's forum, and as the simulation ends immediately once the time interval is completed, the cool down period is ignored. Warm-up time should be between 15 and 30 minutes, according to the developer (PTV-GROUP, n.d.). As a result, 15 minutes (900 seconds) were ignored by the model. After 15 minutes, the output data was recorded, resulting in a 4500-second simulation with only results from the interval 900-4500.
In terms of the initial number of runs, 5 was picked as the best amount to start with. After that, using the formula from the Methodology chapter, the proper number was determined.

Setup

As the model has quite an extensive set of operations that can be used for getting results, only a handful of them are relevant for this simulation. So, the “Vehicle Travel Time” and the “Nodes” operations were used in the model.

- "Vehicle Travel Times" are markers inserted at the beginning and end of a route of interest, and the model will provide results depending on the parameters you select. These points were chosen for this study to provide statistics for traffic flow, average vehicle travel time, and total delay time along that route. All 30 paths that the automobiles can take were considered and marked with this operation.
- "Nodes" are polygons positioned around an area of focus that provide results for all of the linkages inside the region as well as the total of the chosen area. The nodes were put around both roundabouts, and the data will include the roundabouts' Level-of-Service (LOS), three types of pollutants (NOx, CO, and VOC), and fuel usage (in US gallons, which will be afterwards transformed into liters). The nodes in the model are marked in yellow in Figure 21 below.

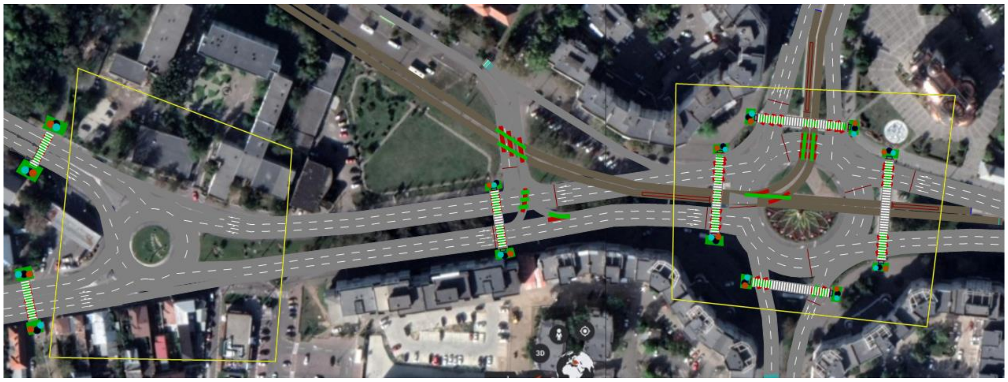

Figure 21 - VISSIM Nodes operation representation

7.3. Validity of baseline model

After the first five runs were finished and the data was translated into excel, the number of runs needed to be calculated. Because only a small number of cars travel certain routes, not all 30 are relevant to the study, hence a smaller number was chosen for verification. As a result, the formula was applied to the 10 most important routes (based on traffic flow), and the correct number of runs had to be greater than all of the "n" values in the computations. The average travel time was used as the basis for the calculation since it was thought to be the most meaningful indicator of congestion. Based on the computation, the n figures for average travel time for all 10 routes are shown in the Table 7. Because the maximum number of runs identified was approximately 23 (❶ => ❻), a round number of 25 was chosen as the ideal number of runs for a 95 percent confidence level. From this point, all computations were based on 25 runs (validation, solutions etc.).

Route	Number of runs necessary
❷ => ❺	17,97
❺ => ❷	13,79
❶ => ❺	17,67
❺ => ❶	11,88
❻ => ❷	20,85
❷ => ❻	16,73
❻ => ❶	10,45
❶ => ❻	22,48
❸ => ❺	7,03
❹ => ❻	7,66

Table 7 - Number of runs

7.4. Results

The 25 runs were carried out in the model using all of the above-mentioned parameters and assumptions. The data has been saved in an Excel spreadsheet. Calculations were done for the same 10 routes as in sub chapter 7.3. So, for these 10 routes, the mean and standard deviation for all average travel time, traffic flow, and delay time were determined, taking into account all 25 experiments. After that, the TTI, PTI, and Buffer index for each of the ten routes were determined. Appendix 3: Results contains all of these tables and computations. For the sake of readability, only three route outcomes are included in Table 8 below. The routes were picked at random, with the only criterion being that each one's origin and destination should be distinct from the others.

Results	❻ => ❷	❺ => ❶	❹ => ❻
Average Travel Time (s)	90,47	95,08	40,15
Average Traffic Flow (nr)	266	326	171
Average Delay (s)	57,41	50,93	27,64
TTI	2,63	2,09	1,63
PTI	3,1	2,32	1,94
Buffer Index	18%	11%	19%

Table 8 - Baseline model results routes

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1319,13	256,65	305,72	71,43
Large	LOS D	7108,48	1383,05	1647,46	384,92

Table 9 - Baseline model results roundabouts

As can be seen from the findings, the delay is greater than half of the travel time, implying that the delay is larger than free flow. The time they lose while the red traffic signal is also included in the delay, which is worth mentioning. In terms of trip time reliability factors, the values are mostly not big, but they are also not little, since TTI and PTI in a free flow condition would both be 1, while the buffer index should be 0%. It is worth noting that the traffic signal is interfering with the amount of time they are losing.

The simulation results for the nodes are also for 25 runs, and the entire result of each roundabout will be shown because it is deemed more important than choosing routes or linkages inside the node. The small roundabout is properly optimized with a maximum Level-of-Service (LOS A), however the larger roundabout may be improved with a Level-of-Service below the average and roughly 5,4 times higher emissions and fuel consumption.

7.5. Validation

Validation was done using the morning peak data, as indicated in the Data Generation chapter. Because there were no normal working days at the time, the traffic was in a near-free flow state. In comparison to the main model, the tram timetable, traffic-signal cycle, and vehicle compositions have all remained unchanged. Only the vehicle routes illustrated and discussed in Table 5 in chapter 6 have been altered. The amount of pedestrian input has been reduced by a quarter. The vehicle inputs are shown in Figure 22, and the deviations from the basic model are shown in Table 10. Inputs ❸, ❹, ❺, ❻ have been greatly reduced. The traffic from ❶, ❷, on the other hand, was very comparable to the main model.

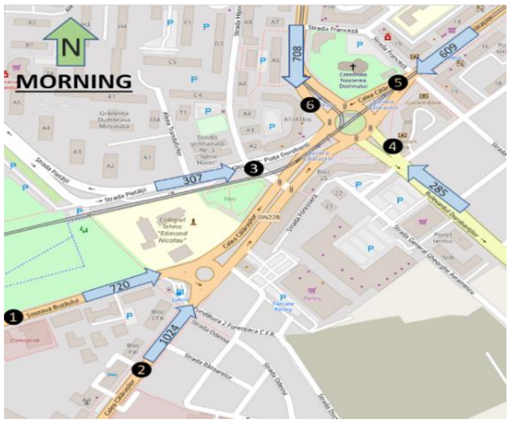

Figure 22 - Morning peak hour inputs

Input	Main	Validation
❶	720	720
❷	1050	1024
❸	400	307
❹	598	285
❺	1046	609
❻	879	708

Table 10 - Comparison between baseline model and validation model inputs

The validation results for the same routes as the main model may be seen in Table 11 below. All of the figures have declined, demonstrating a decrease in the quantity of automobiles in the network. In addition, the travel time reliability factors reduced dramatically, particularly the buffer index, which is now below 10% for all of them. Green color near the number indicates the percentages of how much the index declined. The full results for the validation can be seen in Appendix 3: Results.

Results	❻ => ❷	❺ => ❶	❹ => ❻
Average Travel Time (s)	73,2 (19%↓)	75,01 (21%↓)	32,76 (18%↓)
Average Traffic Flow (nr)	227 (15%↓)	243 (25%↓)	92 (46%↓)
Average Delay (s)	40,15 (30%↓)	30,84 (39%↓)	20,27 (27%↓)
TTI	2,12 (19%↓)	1,65 (21%↓)	1,33 (18%↓)
PTI	2,22 (28%↓)	1,73 (25%↓)	1,45 (25%↓)
Buffer Index	4% (78%↓)	5% (55%↓)	9% (53%↓)

Table 11 – Validation model results routes

The outcomes for the nodes have also improved, with the major roundabout receiving a Level of Service of C, putting it above average, and emissions and fuel consumption dropping by nearly a third for the large roundabout and a quarter for the small one. The percentages of how much the index fell are indicated by the green color near the number.

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	999,46 (24%↓)	193,46 (24%↓)	231,64 (24%↓)	54,12 (24%↓)
Large	LOS C	4837,72 (32%↓)	941,25 (32%↓)	1121,19 (32%↓)	291,96 (32%↓)

Table 12 - Validation model results roundabouts

The validation went well, and the model is operating on point, given that it behaves appropriately for a modified input circumstance and produces fair results when compared to the main model.

8. Potential Measures and Scenarios

Solutions for the current scenario are discovered in the following chapter, which were implemented into the model, were evaluated using the assessment framework and the output data was compared to the initial model data using confidence interval of means for three indices (delay time, CO emissions and Fuel consumption).

8.1. Assessment framework

The assessment framework was introduced first. This framework was used to examine all of the answers, followed by the determination of the confidence interval of means. A solution will pass if it meets the target for the requirements

to which it is linked, or if it does not weaken the present condition for the others. Any solution that harms any of the aims for any condition is not considered optimal.
The very first requirement is the most important (Accessibility of main boulevard and large roundabout). For all of the primary solutions shown, the green highlighted component is mandatory, however the yellow highlighted element is optional because it can be difficult to implement for all of the options. The next three requirements are quite particular to individual solutions, and the bicycle lanes implementation requirement, for example, is required for the cycling solution that will be provided. They must, however, be taken into account by all of the solutions given. The final need, future proof, was explored in detail in the chapter 9 as it can be quite difficult to quantify.

Requirement	Definition	Measurement	Current value	Target value
Accessibility of main boulevard and large roundabout	Congestion on "Calea Călărașilor" ❺ up until point ❷ and on the large roundabout take precedence to other roads	-Avg Delay T -Emissions (NOx, CO, VOC) -Fuel Consumption -TTI -PTI	100%	A decrease of at least 5% on all of them, preferably 10%
		LOS	LOS D	At least LOS C
		Buffer Index	-	Below 10%
Maintaining the tram network	Tram lines should be kept in the network for enhancing the use of public transport	The measurement lines	4 routes	At least 4 routes
The pedestrian's experience must be protected	Pedestrian crossing signal periods should not be shortened and, if at all feasible, should be lengthened.	The signal time	28 seconds for crossings❺, ❼ and 21 seconds for crossings ❸, ❹, ❻	The numbers should be at least the same, if not bigger
Bicycle lanes implementation	Bicycle lanes should be installed for the route ❶=>❺	Location of bicycle lane	0	At least on route ❶=>❺, if possible, on other routes as well

Table 13 - Assessment framework

8.2. Comparison to initial scenario

For the final part of the analysis, the one with the confidence interval of means: the delay, the CO emissions grams and the fuel consumed were chosen for the analysis. Only the delay was shown because the travel time and the delay are connected and they gave the same results for this part of the analysis. And for the CO emissions and fuel consumption, only the large roundabout results were presented as the large roundabout is relevant for this project and it has much more influence on the network compared to the other roundabout. The difference between the initial scenario average and the revised scenario average is reflected in the interval between the CI1 and CI2 figures discovered in this part of the analysis.

8.3. Large Solutions

All of the large solutions that were discovered to be suitable for this road network were described, implemented in the model, assessed using the evaluation framework, and compared to the starting model in this sub-chapter. Because the road network is already in place and large adjustments would interfere too much with the area's infrastructure, built environment, and urban land planning, the majority of the solutions are simple and traditional ones that can be found across the literature as universal congestion remedies.

8.3.1. Optimizing the Traffic Signaling

Presentation of the solution

This solution focuses on adjusting traffic signal timings to offer additional time to directions that are experiencing traffic congestion. Because the difficulties occur inside the roundabout and the research is aimed at improving the situation on the major boulevard "Calea Călărașilor" (points ❺ and ❷ from the vehicle inputs maps), extra time was allocated to traffic signals along the main boulevard's routes. Additionally, if feasible, extra time should be provided to pedestrians in order to ameliorate their position, as crossings ④ and ⑥ do not allow pedestrians to pass at a reasonable pace from one side to the other.
Normally, traffic signal optimization is done using software, but because no such program is available in this circumstance, the adjustment of timings will have to be done manually. The disadvantage of performing the analysis manually in this scenario is the computation time of VISSIM, as running the model 25 times to check if each step of the optimization improves or worsens the situation takes a lengthy time.
Initially, a few "optimistic" scenarios were attempted, such as giving nearly every traffic light associated to the points listed above an extra second, even 5 or 6 seconds for some of them. Those scenarios did not produce the desired

results, as the delay and travel times grew even larger than in the initial situation, or when they improved, more than 5 of the 25 runs would be outliers, indicating that the scenario is unreliable and can produce far more dangerous congestions than desired.
So, in the end, a solution that was quite similar to the real situation was developed, signaling that the real situation is very near to the best-case scenario for the region and the current traffic situation. Figure 23 and Table 14 show the improved traffic light cycle as well as what has changed from the original situation.

Figure 23 - Improved traffic signaling cycle

Input	Original Green Time	New Green Time
V2	33 s	35 s
V4	29 s	33 s
V5	27 s	31 s
P2	26 s (including intermittent green)	30 s (Including intermittent green)
P3	26 s (Including intermittent green)	30 s (Including intermittent green)

Table 14 - Comparison between original and new traffic signaling cycles

Results

Following that, the output results of the 25 VISSIM runs may be found in Table 15 for the routes and Table 16 for the nodes. It is worth noting that one of the 25 runs was an outlier, thus it was not included in the analysis.

Results	❻ => ❷	❺ => ❶	❹ => ❻
Average Travel Time (s)	88,42 (2%↓)	83,71 (12%↓)	36,98 (8%↓)
Average Traffic Flow (nr)	267 (0%↓)	326 (0%↓)	172 (0%↓)
Average Delay (s)	54,37 (5%↓)	39,56 (22%↓)	24,48 (11%↓)
TTI	2,57 (2%↓)	1,84 (12%↓)	1,5 (8%↓)
PTI	2,96 (4%↓)	2 (14%↓)	1,66 (14%↓)
Buffer Index	15% (15%↓)	9% (20%↓)	11% (44%↓)

Table 15 - Traffic Signaling Optimization model results routes

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1619,05 (23%↑)	315,01 (23%↑)	375,23 (23%↑)	87,67 (23%↑)
Large	LOS C	6511,38 (8%↓)	1266,88 (8%↓)	1509,08 (8%↓)	352,58 (8%↓)

Table 16 - Traffic Signaling Optimization model results roundabouts

Assessment framework checking

Using the assessment framework, we can see that this solution is fulfilling the targets of the first requirement for two of the routes (❺ => ❶ and ❹ => ❻) from the network:

- the decrease for all mandatory parameters being more or at least 5 % for all indices from the first target
- the LOS updated from a D to a C level for the large roundabout

Even if the TTI and PTI for route ❻ => ❷ are not above 5%, this route is not substantially affected by traffic light optimization, therefore it makes reasonable for the statistics to not be reduced as much. In terms of pollution, the little roundabout has seen an increase in emissions as traffic has transferred partially from the large roundabout to the small one. However, when the total is calculated, there is a reduction in emissions and fuel usage.
Regarding the other requirements, the tram network and the bicycle lanes implementation have been not interfered with, so it fulfilled the target, the pedestrian's experience is protected by giving them even more time to pass.

Comparison to initial scenario

The findings of the Confidence interval (C.I.) for a difference between means for a 95 percent Confidence level and 25 replications may be seen in Table 17. Only the delay time for the three routes, as well as CO emissions and fuel consumption for the major roundabout, have been shown, as previously stated. Appendix 4: Comparison using confidence interval of the means" contains the rest of the findings. Except for route ❻ => ❷, where the delay can be longer by at most 0,23 seconds in some runs compared to the baseline scenario, both CI values are positive for all of the indices presented below, indicating that the decrease of these indices is real and the solution is useful.

Congestion Index	Route/Roundabout	Initial Scenario		Improved Scenario 1		Confidence Interval	
Delay Time	❻ => ❷	Mean	57,41 s	Mean	55,37 s	CI1	4,32 s
		STD	9,91	STD	8.23	CI2	- 0,23 s
	❺ => ❶	Mean	50,93 s	Mean	39,56 s	CI1	13,24 s
		STD	6,36	STD	4,5	CI2	9,52 s
	❹ => ❻	Mean	27,64 s	Mean	24,48 s	CI1	4,8 s
		STD	4,64	STD	2,41	CI2	1,53 s
Emissions CO	Large	Mean	7108 g	Mean	6511 g	CI1	724,5 g
		STD	432	STD	303	CI2	469,7 g
Fuel Consumption	Large	Mean	385 g	Mean	352,5 g	CI1	39,23 g
		STD	23,43	STD	16,42	CI2	25,44 g

Table 17 - Comparison between baseline model and Signal Optimization measure

8.3.2. Underground or Overpass Pedestrian Passage Large Roundabout

Presentation of the solution

This solution is comprised of replacing the existing signalized pedestrian crossings with an underground or overpass pedestrian crossing ④, ⑤, ⑥, ⑦. Considering how much time automobiles waste on the roundabout waiting for people to cross safely on the opposite side, especially for crossing number ④, this method would effectively end the dispute between pedestrians and vehicles. By redirecting pedestrian traffic below or above the roundabout, pedestrians' safety would be greatly enhanced, and their journey times would be dramatically reduced, since they would no longer have to wait for their green lights.

In the two possible approaches shown in Figure 26 and Figure 25 below, the underground pedestrian crossing would involve underground passages from each corner of the junction and tunnels till the other sides. It is not clear which one of the two is the better, easiest to implement or safest option. That is the focus of a different study that can be performed.

Figure 24 - Pedestrian crossings location

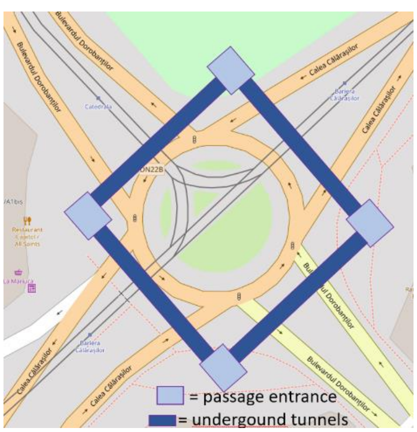

Figure 25 - Alternative 1 Underground Passage

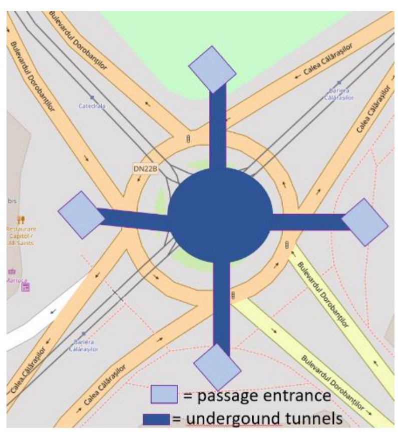

Figure 26 - Alternative 2 Underground Passage

Figure 27 - Entrances to the Underground Passage Idea

Because there is space on the pavement at each of the corners to build an entry like the one in Figure 27, the entrances can seem like metro entrances.

In Figure 28, a few possible designs for the overpass pedestrian crossing are illustrated. This solution would give the roundabout intersection a new image and may become an attraction point as people may come and visit it, if it is built with a certain design. It may enhance the beauty of the intersection as well as the safety of the pedestrians and most importantly for the project it would decongest the road network.

Figure 28 - Ideas for overpass pedestrian passage

Results

The implementation of both underground and overpass pedestrian crossings is identical in the VISSIM software: the existing pedestrian crossings are eliminated from the model itself. The results of the 25 simulation runs after the implementation in VISSIM can be seen below in Table 18 for the three selected routes and in Table 19, the node results for the two roundabouts.

Results	❻ => ❷	❺ => ❶	❹ => ❻
Average Travel Time (s)	71,32 (21%↓)	72,25 (24%↓)	32,62 (19%↓)
Average Traffic Flow (nr)	268 (1%↑)	328 (0%↓)	171 (0%↓)
Average Delay (s)	38,27 (33%↓)	28,06 (45%↓)	20,11 (27%↓)
TTI	2,07 (21%↓)	1,59 (24%↓)	1,32 (19%↓)
PTI	2,16 (30%↓)	1,63 (30%↓)	1,44 (25%↓)
Buffer Index	4% (76%↓)	3% (75%↓)	9% (52%↓)

Table 18 – Underground or Overpass pedestrian passage model results routes

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1192,31 (10%↓)	231,98 (10%↓)	276,33 (10%↓)	64,56 (10%↓)
Large	LOS C	4667,04 (34%↓)	908,04 (34%↓)	1081,63 (34%↓)	252,71 (34%↓)

Table 19 - Underground or Overpass pedestrian passage model results roundabouts

Assessment framework checking

Using the assessment framework, we can see that this solution is fulfilling the targets of the first requirement, even the optional ones:

- the decrease for all parameters being more or at least 10 % for all indices from the first target
- the LOS updated from a D to a C level for the large roundabout
- the buffer index is below 10% for the checked routes

Regarding the other requirements, the tram network and the bicycle lanes implementation has been not interfered with, so it fulfills the target, the pedestrian's experience is protected at all costs by constructing them specific paths through the network.

Comparison to initial scenario

Table 20 shows the results of the Confidence interval (C.I.) for a difference in means with a 95 percent confidence level and 25 replications. As previously indicated, only the delay time for the three routes, as well as CO emissions and fuel consumption for the major roundabout, were displayed. The rest of the findings are in Appendix 4: Comparison using confidence interval of the means. For all of the indices listed below, both CI values are positive, showing that the drop is genuine and significant, and that the solution is beneficial.

Congestion Index	Route/Roundabout	Initial Scenario		Improved Scenario 1		Confidence Interval	
Delay Time	❻ => ❷	Mean	57,41 s	Mean	38,27 s	CI1	23,15 s
		STD	9,91	STD	1,93	CI2	15,13 s
	❺ => ❶	Mean	50,93 s	Mean	28,06 s	CI1	25,45 s
		STD	6,36	STD	1,2	CI2	20,29 s
	❹ => ❻	Mean	27,64 s	Mean	20,11 s	CI1	9,3 s
		STD	4,64	STD	1,78	CI2	5,76 s
Emissions CO	Large	Mean	7108 g	Mean	4667 g	CI1	2613 g
		STD	432	STD	121	CI2	2270 g
Fuel Consumption	Large	Mean	385 g	Mean	253 g	CI1	141,5 g
		STD	23,43	STD	6,55	CI2	123 g

Table 20 - Comparison between baseline model and Pedestrian Passage measure

8.3.3. Bicycle Lanes Implementation

Presentation of the solution and Implementation

The last large solution involves implementing bicycle lanes for the main boulevard routes. The municipality desires as stated in the requirements and the assessment framework that a bicycle lane would be implemented between points ❶ and ❺, for the people to cycle through the "Monument Park" and from the "Buzăului Neighborhood" to the city center on this route. In this solution situation, I decided to consider not only that route but also route ❷ => ❺, in order to make the whole section of the main boulevard to be bicycle friendly.

The main challenge was to find a suitable location for the bicycle lanes in order to keep the cyclists safe from the vehicle traffic and especially from turning inside the roundabout which would be very dangerous especially in the large one, with so much car influx. Another issue was to find suitable space for the lanes in the vicinity of the main car road. For example, lanes would not fit on the incoming direction of point ❶, as the pavement is already very narrow and it would mean that no space for the pedestrians would be left on that side.

In the end, a viable solution was identified, and input ❸ was also integrated, as seen in Figure 29 below. The lanes are designed to run in both directions and will be separated from the automobiles by an elevated curb. It is implemented over the whole span, from input ❷ to point ❺, and is connected to another lane leading to the park in point ③. Unfortunately, the pedestrian crossing at that location will be removed, and the existing traffic signals will be used with the same cycle timings. People arriving from both points ❶ and ❸ would benefit from this vertical bicycle lane leading to the park. The bicycle lane was installed next to the pedestrian crossing number ③ in the large roundabout, and it utilizes the same traffic signals as the pedestrians. The bicycle lane crosses four additional pedestrian crossings perpendicularly (②, ④, ⑥, ⑧) and, to minimize conflicts, pedestrians would be given priority so that they may cross from one side to the other without having to wait for automobiles or bikes.

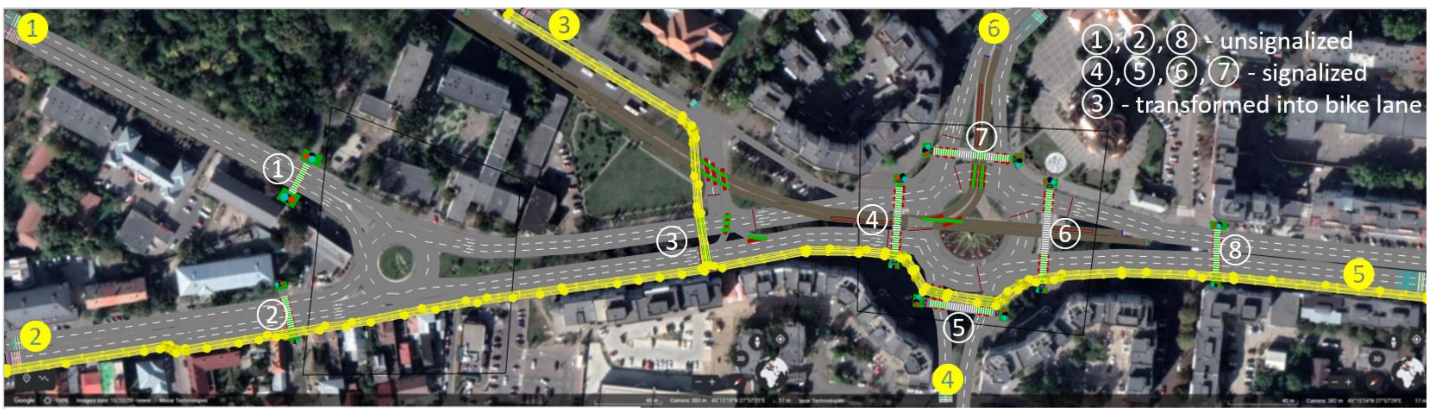

Figure 29 - Bicycle Implementation Measure

The width of the lanes, bike speeds, routes, and inputs all had to be established when it came to the lane configuration in the model. According to the European Union's "Integrated Cycling Planning Guide" announced in 2020, the minimum width of a cycle track that is part of a shared-use path should be 1,5 meters (Buczynski, Kolczynska, & Kuster, 2020). Because the pavement is now not particularly broad in any part of the road network, the width will be maintained at 1,5 meters in each direction of the track, for a total of 3 meters (considering there are two connected directions inside the cycle track).

According to one report, the average commuting bike speed for inexperienced cyclists is 16 kilometers per hour (Gavin, n.d.). According to another report, urban cycling has an average speed of 19 to 26 kilometers per hour (Sustainability-Info, n.d.). Given that Brăila is a flat town with no hills and that speed is solely determined by the cyclist's fitness, an average speed of 20 kilometers per hour was chosen as the network's average speed.

For the routes of the bikes, it was assumed that most of the bikes coming from inputs ❷ and ❸ would predominantly cycle towards point ❺. Between themselves it was assumed that more would come from point ❷ towards ❸, as people would come to the park. From origin point ❺, no difference between the two destinations could be assumed. So, in Table 21 below, the route ratios can be seen.

Route	❷ => ❸	❷ => ❺	❸ => ❷	❸ => ❺	❺ => ❷	❺ => ❸
Ratio	0,2 (20%)	0,8 (20%)	0,1 (10%)	0,9 (90%)	0,5 (50%)	0,5 (50%)

Table 21 – Bicycle routes ratios

Shift towards bike use

The inputs for the bikes have to be based on assumptions about the transition from vehicles to bikes. Two concerns were discovered: what proportion of persons who drive private vehicles become cyclists, and how many bikes does a one-car reduction represent. Because no paper or study describing any computation or estimation for resolving those two problems could be discovered, two assumptions were made:

- On average, one automobile equates to two cyclists.
- Three scenarios were examined: Cars were reduced by 10%, 15%, and 20%, respectively, and their translation into cyclists was incorporated into the model.

The input number of bikes for each of the three cases can be seen in Appendix 5: Switch from cars to bicycles and increase of cars for future scenarios. It is worth mentioning that only the input points that contain bikes were decreased (points ❹, ❻ remained the same)

Results

The results were surprising and fascinating to examine, as the congestion indices showed no significant variation between the three situations. Furthermore, none of them was the optimal choice for all of the routes. In most circumstances, 20% was the best option, which may seem logical, but in a few cases, 10% and 15% were better, particularly in the emissions and fuel consumption sections of the findings, where 10% was better than 20%. This can be explained by the fact that with a 10% decrease in cars, the cyclists' numbers are not large enough to influence the delay of the cars when the bikes cross in front of them, whereas with a 20% increase in bicycles, the cars must wait much, resulting in higher emissions and more fuel consumption.
Only the findings for the 10% will be shown below, as this number is reasonable for a scenario where bike lanes are being constructed for the first time. It would be a bit naive to anticipate that 20 percent of automobiles will convert to bikes in such a short period of time. Appendix 3: Results contains the results for 15 percent, 20 percent and the rest of the results for 10 percent.

Results	❻ => ❷	❺ => ❶	❹ => ❻
Average Travel Time (s)	85,87 (5%↓)	92,35 (24%↓)	30,16 (0%↓)
Average Traffic Flow (nr)	268 (1%↑)	293 (10%↓)	172 (0%↓)
Average Delay (s)	52,81 (8%↓)	48,2 (5%↓)	27,65 (0%↓)
TTI	2,49 (5%↓)	2,03 (3%↓)	1,63 (0%↓)
PTI	2,79 (10%↓)	2,3 (5%↓)	1,83 (6%↓)
Buffer Index	12% (34%↓)	8% (24%↓)	12% (36%↓)

Table 22 - Bicycle Lane Implementation model results routes

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1243,63 (6%↓)	241,77 (6%↓)	287,99 (6%↓)	67,29 (6%↓)
Large	LOS D	6755,75 (5%↓)	1314,15 (5%↓)	1567,3 (5%↓)	364,74 (5%↓)

Table 23 - Bicycle Lane Implementation model results roundabouts

Assessment framework checking

Using the assessment framework, we can see that this solution is quite divisive: it meets all of the mandatory requirements for one of the routes (❻ => ❷), it meets all of the mandatory requirements for another route except the TTI, but the buffer index is below 10% (❺ => ❶), and it meets some of the indices for the last route (❹ => ❻). Because the last route does not include the cycling track and its input vehicle numbers are the same as the initial scenario, it makes sense to have the same results.
In terms of the other requirements, the tram network has not been harmed, hence the approach meets the objective. The pedestrian experience is preserved since pedestrians have precedence over all other means of transportation in the region, and traffic signals stay unchanged. The implementation of bicycle lanes was done in a wider approach than desired; hence the goal was met.

Comparison to initial scenario

Table 24 shows the results of the Confidence interval (C.I.) for a difference in means with a 95 percent confidence level and 25 replications. As previously indicated, only the delay time for the three routes, as well as CO emissions and fuel consumption for the major roundabout, were displayed. The rest of the findings are in Appendix 4: Comparison using confidence interval of the means. Except for the route that is not heavily associated with the bike lanes, both CI values are positive for all of the indices given below, indicating that the decline is legitimate and that the solution is beneficial.

Congestion Index	Route/Roundabout	Initial Scenario		Improved Scenario 1		Confidence Interval	
Delay Time	❻ => ❷	Mean	57,41 s	Mean	52,81 s	CI1	7,8 s
		STD	9,91	STD	6,21	CI2	1,42 s
	❺ => ❶	Mean	50,93 s	Mean	48,2 s	CI1	4,5 s
		STD	6,36	STD	4,71	CI2	0,97 s
	❹ => ❻	Mean	27,64 s	Mean	27,65 s	CI1	1,46 s
		STD	4,64	STD	2,97	CI2	-1,48 s
Emissions CO	Large	Mean	7108 g	Mean	6805 g	CI1	412 g
		STD	432	STD	342	CI2	194 g
Fuel Consumption	Large	Mean	385 g	Mean	369 g	CI1	22,3 g
		STD	23,43	STD	18,55	CI2	10,5 g

Table 24 - Comparison between baseline model and Bicycle Lane Implementation measure

9. Future Scenarios

Two future possibilities, one optimistic and the other pessimistic, were examined in this chapter. After discussing each one, the initial condition, as well as the three enhanced situations from the previous chapter, were ran through both scenarios to see how they manage it, in order to determine how well each one would withstand the test of time in the near future and if they fulfill the last requirement of the assessment framework. The term "near future" refers to a five-year period in the future in this analysis.

9.1. Pessimistic Scenario

For the pessimistic scenario, it is projected that people's behavior would remain focused on the use of personal automobiles, and that the number of cars would continue to rise. The rate of increase of private vehicles in Romania is roughly 5% per year in Romania, as indicated in the introduction as well (ACEA, 2022). No data was available online about how much the increase of the vehicle fleet is in Brăila, but considering that the population of Brăila is decreasing in the last 10 years and the population is aged, it is assumed that this 5% represents an unrealistic rate. A maximum of 3% per year seemed fit as it fits somewhere in the middle between a massive increase of 5% and no increase at all. The 3% increase in vehicles every year would represent a 16% increase in the cars in 5 years.

Input	Actual	Increased
❶	720	914
❷	1050	1333
❸	400	508
❹	520	660
❺	940	1193
❻	830	1054

Table 25 - Difference between baseline and pessimistic inputs

The input numbers for the vehicles after this increase can be seen in Table 25 compared to the ones used for the actual situation. Also, there would be no rise in the use of public transportation, and the switch from using cars towards the usage of bicycles for the cycle track solution would be limited at a maximum of 10%.

The road network became crowded on the complete length of the road network in three of the four scenarios: the initial situation, the optimization of traffic signals solution, and the bicycle lane implementation solution, as shown in Figure 30. No results are shown because they would not be useful at all with such congestion in all the 25 runs.

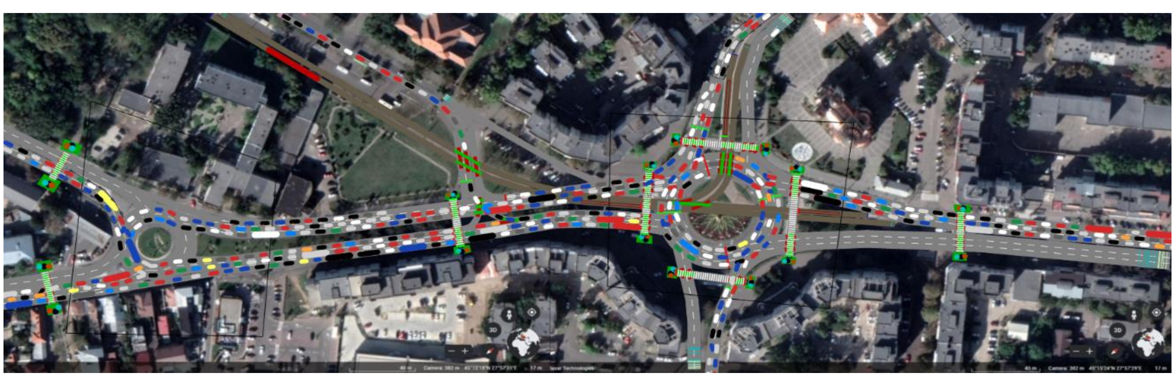

Figure 30 - Crowded network

For the implementation of an underground or overpass pedestrian passage, the road network was handling the extra vehicles well. The results can be seen below in Table 26 and Table 27 for the three chosen routes and for the two roundabouts. The rest of the results can be seen in Appendix 3: Results. It is worth mentioning that 3 out of the 25 runs were outliers where the network got stuck at certain points. They were ultimately eliminated from the results.

Results	❻ => ❷	❺ => ❶	❹ => ❻
Average Travel Time (s)	75,71 (16%↓)	75,74 (20%↓)	33,24 (17%↓)
Average Traffic Flow (nr)	310,32 (17%↑)	379,41 (16%↑)	198,45 (16%↑)
Average Delay (s)	42,66 (26%↓)	31,57 (38%↓)	20,71 (25%↓)
TTI	2,2 (16%↓)	1,67 (20%↓)	1,35 (17%↓)
PTI	2,31 (25%↓)	1,71 (26%↓)	1,42 (27%↓)
Buffer Index	5% (71%↓)	3% (75%↓)	5% (73%↓)

Table 26 - Pedestrian Passage Pessimistic Scenario results routes

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1771,55 (34%↑)	344,68 (34%↑)	410,57 (34%↑)	95,93 (34%↑)
Large	LOS C	5722,45 (19%↓)	1113,38 (19%↓)	1326,23 (19%↓)	302,91 (19%↓)

Table 27 - Pedestrian Passage Pessimistic Scenario results roundabouts

The findings show that this solution handles the substantial increase in automobile inputs from each direction pretty effectively. Even with this rise, the indices are still significantly lower than the starting condition. Only the traffic flow, as well as the little roundabout pollution and fuel consumption, have gotten worse. This can be explained by the fact that traffic migrated from the large to the small roundabout. When the emissions are totaled, the result is still a decrease, because the huge roundabout numbers are far more important.
In terms of the assessment framework's final criterion, the first three scenarios examined do not meet the goal of managing the pessimistic scenario's vehicle inputs. However, based on the findings presented above, the last option, the one with the subterranean or overpass pedestrian tunnel, appears to handle the pessimistic scenario very well, even if three of the 25 tests had troubles, which is quite noteworthy.

9.2. Optimistic Scenario

In the more optimistic scenario, it is projected that people will begin using other modes of transportation in place of private automobiles, leading to a sustained increase in the number of cars but one that is declining year after year. As a result, every year the percentage of private automobiles increasing would be 0,5% lower than the year before (2,5 percent first year; 2 percent second year etc.). Public transportation would grow, adding bus lines for all inputs (at the moment, only 3 inputs have buses), and the proportion of buses in the vehicle composition would rise from 5% to 6%. In accordance with the suggested method for bike lane implementation, 20% of individuals would give up their cars in favor of bicycles. The input numbers for the vehicles after this increase can be seen in Table 28 compared to the ones used for the actual situation.

Input	Actual	Increased
❶	720	778
❷	1050	1134
❸	400	432
❹	520	561
❺	940	1015
❻	830	896

Table 28 - Difference between baseline and optimistic inputs

In two of the four situations—the initial situation and the traffic signal optimization solution, as illustrated in Figure 30 from the preceding sub-chapter—the road network grew congested over its entire length. No results are displayed since, with such congestion in all 25 runs, they would be of absolutely no value. The road network responded better for the other two proposed solutions.

Underground or overpass pedestrian passage

The road network was capable of accommodating the increased traffic for the development of an underground or overpass pedestrian crossing. The outcomes for the three selected routes and the two roundabouts are shown in Table 29 and Table 30 below. Appendix 3: Results contains the remaining results. It is important to note that 1 of the 25 tests was an outlier in which the network became stopped at various places. In the end, it was taken out of the analysis.

Results	❻ => ❷	❺ => ❶	❹ => ❻
Average Travel Time (s)	75,86 (16%↓)	74,73 (21%↓)	33,61 (16%↓)
Average Traffic Flow (nr)	289,79 (9%↑)	352,88 (8%↑)	184,17 (8%↑)
Average Delay (s)	42,42 (26%↓)	30,5 (40%↓)	20,94 (24%↓)
TTI	2,2 (16%↓)	1,64 (21%↓)	1,37 (16%↓)
PTI	2,35 (24%↓)	1,71 (26%↓)	1,46 (25%↓)
Buffer Index	7% (62%↓)	4% (65%↓)	7% (62%↓)

Table 29 - Pedestrian Passage Optimistic Scenario results routes

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1354,86 (3%↑)	263,61 (3%↑)	314 (3%↑)	73,36 (3%↑)
Large	LOS C	5235,71 (26%↓)	1022,18 (26%↓)	1217,6 (26%↓)	284,48 (26%↓)

Table 30 - Pedestrian Passage Optimistic Scenario results roundabouts

The results demonstrate how well this solution manages the significant increase of automotive inputs coming from all directions. The index results are still far below the initial scenario even with this growth in the future. Only the traffic flow has become worse, along with the little roundabout pollution and fuel use. The movement of traffic from the large to the little roundabout may be used to demonstrate this. Because the large roundabout numbers are significantly more relevant, the total emissions nevertheless show a decline.

Bicycle lanes implementation

The road network performed suitably for the goals of the bicycle lane deployment approach. It is important to note that 20% of the inputs in Table 28, for the ones where bicycle lanes are placed, were reduced and converted into bikes using the same reasoning as in chapter 8, when it was considered that each automobile reduced equals two cyclists. The total numbers for each input for vehicles and bikes can be seen in Appendix 5: Switch from cars to bicycles and increase of cars for future scenarios. Table 31 and Table 32 below display the results for the three chosen routes and the two roundabouts. The remaining results are in Appendix 3: Results. It is also important to keep in mind that 1 of the 25 experiments was an outlier in which the network experienced many stops. It was ultimately removed from the analysis.

Results	❻ => ❷	❺ => ❶	❹ => ❻
Average Travel Time (s)	100,14 (11%↑)	96,08 (1%↑)	44,56 (11%↑)
Average Traffic Flow (nr)	263,88 (1%↓)	278,75 (14%↓)	171,71 (0%↑)
Average Delay (s)	66,67 (16%↑)	51,85 (2%↑)	31,91 (15%↑)
TTI	2,91 (11%↑)	2,11 (1%↑)	1,81 (11%↑)
PTI	3,56 (15%↑)	2,28 (2%↓)	2,16 (11%↑)
Buffer Index	22% (24%↑)	8% (30%↓)	19% (0%↑)

Table 31 - Bicycle Lane Implementation Optimistic Scenario model results routes

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1546,39 (17%↑)	300,87 (17%↑)	358,39 (17%↑)	83,73 (17%↑)
Large	LOS D	8506,94 (20%↑)	1655,14 (20%↑)	1971,57 (20%↑)	460,64 (20%↑)

Table 32 - Bicycle Lane Implementation Optimistic Scenario model results roundabouts

The outcomes demonstrate that the congestion is still being handled by this method at a reasonable rate. Additionally, the majority of the traffic is caused by vehicles waiting for bikes to pass in front of them; this is the same problem that led to the outcomes in chapter 8's solution results. This strategy is ecologically beneficial, hence it is fine to discourage driving by providing preference to bikes, even though the outcomes are currently poorer for the majority of indices compared to the starting state.

9.3. Future Situation

The option with the building of an underground or overpass pedestrian tunnel, which handled both the pessimistic and optimistic scenarios exceptionally well, may be stated to be the most problem-free after watching all four cases proceed through the two future scenarios. Although it is a highly useful and efficient solution, it does promote the use of private automobiles hugely, thus it is not a very green option on its own. The most ecologically friendly approach, which also handles the optimistic scenario on the limit and aims to discourage the use of private automobiles even if in the pessimistic scenario the road was already excessively congested with cars, is to incorporate bicycle lanes into the road network. Currently, the road network may be relatively less congested for the real factors by optimizing traffic signals, the third measure. But, without a doubt, on its own, it cannot be a future answer.

10. Combination of Measures

It is important to consider how the network would improve if all measures were adopted at once after assessing the results of each measure separately for the baseline scenario and two future situations. It may be said that the measures have synergy and are not at odds with one another if the outcomes are better than the individual results. Therefore, all three of the measures were incorporated into the network for all three scenarios: the baseline scenario, the pessimistic scenario, and the optimistic scenario.
Each relevant index decreased considerably and by considerable amounts in each of the three conditions that were examined. The two future scenarios only had two growing indices: traffic flow, which was clear given the rising

number of automobiles per input, and emissions for the small roundabout, but they were both countered by the significant drop in the large roundabout, which is more important. Only the findings for the most difficult case (pessimistic scenario) are displayed here, so if this one seems appealing, the others are undoubtedly at least as excellent. Additionally, Appendix 3: Results has the remaining results.

Results	❻ => ❷	❺ => ❶	❹ => ❻
Average Travel Time (s)	74,26 (18%↓)	68,96 (27%↓)	33,12 (18%↓)
Average Traffic Flow (nr)	311,92 (17%↑)	340 (4%↑)	198,4 (16%↑)
Average Delay (s)	41,22 (28%↓)	24,78 (51%↓)	20,61 (25%↓)
TTI	2,16 (18%↓)	1,52 (27%↓)	1,35 (17%↓)
PTI	2,24 (28%↓)	1,56 (33%↓)	1,44 (26%↓)
Buffer Index	4% (79%↓)	3% (72%↓)	7% (64%↓)

Table 33 - Combination of Measures Pessimistic Scenario results routes

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1526,49 (16%↑)	297(16%↑)	353,78 (16%↑)	82,66 (16%↑)
Large	LOS C	5465,97 (23%↓)	1063,48 (23%↓)	1266,79 (23%↓)	295,98 (23%↓)

Table 34 - Combination of Measures Pessimistic Scenario results roundabouts

It may be stated that the measures are not in contradiction to one another and that they can peacefully coexist since when taken collectively, they provide outcomes that are appealing and are more effective than when taken alone. They may thus be gradually adopted in this study case and even applied to other projects of a similar nature.

11. Discussion and future recommendations

The primary component of this project required me to use VISSIM, which I had never used to analyze such a large road network, to apply the inputs, build the baseline model, analyze the situation, and test measures. Initially, it was rather difficult to include all of the real-life factors and components into the model, such as the precise road structure and all of the traffic participants.

Because they were unrelated to one another and, more crucially, did not involve conflicts between one another, the three major solutions were all intriguing to evaluate. Given that it fully removes pedestrians from the road network, it was immediately clear that the "pedestrian passage" would be the most effective option in terms of the 11 congestion indices that were checked. One of the major issues in the region was noted to be autos waiting even though they had a green signal and people not having enough time to cross. Even if it is the most practical of the three ideas, it still promotes the use of vehicles, thus in my view it should be linked to another initiative that would continue to promote the use of less and fewer private autos.

The manual optimization of traffic signals was initially fairly challenging since it required verifying 25 runs each time a traffic light changed for a few seconds. However, in the end, it was successful because the indices decreased as expected. However, it is a current measure for the actual situation, it would not be useful still in 5 years.

The last option is the one that I am most pleased of since the Municipality was really interested in coming up with a plan for how to establish bicycle lanes across the road system. The study's findings were particularly intriguing to observe since they were somewhat counterintuitive—a 20% transfer from vehicles to bikes resulted in more emissions than a 10% switch. This problem however would be in time less and less relevant if the car fleet starts becoming more and more electric. Long-term, it is a highly environmentally beneficial option that would encourage individuals to commute by bike to work or school.

The bicycle lane implementation was managing the optimistic scenario still at a manageable rate, and the traffic signaling optimization was not working properly under the congestion for both future scenarios, proving that it is only a solution for the current situation. For the two future scenarios, the "pedestrian passage" handled both of them really well, demonstrating once again that it is the most efficient. The network's implementation of all measures together produced very hopeful outcomes, even for the two future scenarios, indicating that the solutions may be applied gradually over time without encountering any problems.

I have accomplished my aim of adding all traffic modes into the model, as opposed to earlier studies that were carried out using the VISSIM program for comparable reasons, which mostly included vehicles, motorbikes, and almost never pedestrians. Regarding the measures discovered, they were not always derived from documents; rather, they were created with input from the Municipality and were not particularly unique scenarios that could not be used in other places. The creation of bicycle lanes and traffic signal optimization are both well-known methods for reducing congestion. The "pedestrian passage" is a little unconventional since it is more widespread in Asia than

Europe but has the potential to spread to other regions as well.
If the duration of the thesis would be longer than the time allocated, I would have implemented bicycle lanes throughout the entire road network, checked for sure a measure regarding more bus implementation in the area, and used, if available, a program for traffic signal optimization to be as close to the optimal traffic signal cycle as possible. In addition, actuated signalization, as opposed to the present fixed signals, would be a more contemporary and efficient technique to take into account when it comes to traffic signaling.
The absence of data on vehicle inputs and routes for an extended length of time is undoubtedly one of this project's disadvantages that has to be mentioned. Furthermore, the absence of earlier research studies in the field and the lack of studies on the wide variety of traffic modes contained in VISSIM indicated that some of the things were done by trial and error at various stages, limiting the time available to be utilized, for instance, for verifying another measure. The project's future scenarios section also has limitations since another future scenario might probably occur in five years and not the two scenarios that were developed. Additionally, a tiny proportion of the outcomes of the model may have been harmed by some assumptions I made, such as reducing the vehicle inputs since the circumstance did not accurately reflect reality. Overall, based on the data that could be gathered or was already at the Municipality, I think the findings are as accurate as they can be.

12. Conclusion

The appropriate infrastructure must be present for efficient and secure transportation. When the number of automobiles increases significantly every year and the infrastructure and transport choices are not upgraded at the same rate, maintaining a steady traffic flow during peak hours in Brăila, Romania, proved challenging in recent years and in the future, it can get even worse. This study's goal was to provide solutions for a congested traffic intersection in a busy urban region of Brăila, Romania, for both the current condition and potential situations in the near future. Returning to the research question at the conclusion, for the first sub-question, eleven congestion indices were selected and are utilized throughout the whole report. All types of traffic in the region are supported by the model, which has been verified (chapter 7). According to VISSIM software and the assessment framework, three measures were created and examined that may lower the congestion indices (chapter 8). The latter chapters (9 and 10) include recommendations for what can be done and what the future effects will be, and the Discussion chapter has some suggestions for more study.
It can be concluded that the current situation definitely calls for changes because the baseline model as it is in reality right now will reach a congestion level that cannot be handled sooner than expected. Because they would solve concerns with safety, accessibility, and the environment, all the measures suggested may be adopted gradually. Additionally, extra research should undoubtedly be conducted to discover fresh concepts for further congestion reduction and for additional future circumstances.

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Appendix

All the tables that were utilized throughout the research but were not essential to include in the report may be found in this section. The appendix is divided into four sections:

- The first is manual counting, in which each of the translations for the 10 days of manual counting were collected from an excel spreadsheet for each input of the road network. Each sub-chapter concludes with a list of all the sums for each day, a table of descriptive statistics, and a histogram of the sums.
- The second part is about the traffic signaling cycles
- The third section discusses the index results for all simulations that were performed, including the baseline model, validation, initial results for the three measures, results for future scenarios, and results for the combination of measures. It is worth mentioning that only the 10 out of 30 most important routes have results as the other 30 were not as relevant.
- The fourth section is about the comparison results between the baseline model and the three solutions that were verified using confidence interval of the means.
- The last section is about the switch from cars to bikes for the baseline measure and for both pessimistic and optimistic scenarios. Also it includes the increase of cars explanation for both future scenarios.

A legend has been included since several of the notations used here, particularly for the first segment of manual counting, are not always clear. The first four, CW, CS, CN, and CE, reflect the four simple directions of the huge roundabout at the time the counting was done, they can be seen in the figure below.

CW	**Combination of four inputs ❶ (Șoseaua Buzăului), ❷ (Șoseaua Viziru), ❸ (Strada Pietății/Hipodrom)**
CS	❹ Bulevardul Dorobanților (Șantier Naval, Lidl)
CE	❺ Calea Călărașilor
CN	❻ Bulevardul Dorobanților
DESCRIPTIVE STATISTICS	Explains or summarizes the features of a data collection. In this case summarizes the 10 sums of each input
❷ => ❺	Viziru-Călărași
❺ => ❷	Călărași -Viziru
❶ => ❺	Buzăului- Călărași
❺ => ❶	Călărași - Buzăului
❻ => ❷	Dorobanți-Viziru
❷ => ❻	Viziru- Dorobanți
❻ => ❶	Dorobanți - Buzăului
❶ => ❻	Buzăului - Dorobanți
❸ => ❺	Hipodrom- Călărași
❹ => ❻	Lidl- Dorobanți

Appendix 1: Manual Counting

Appendix 1A: CW+CS MORNING

Date	18-04-22	MON
Interval	07:14-08:14	
Direction	CW	CS
	39	6
	35	10
	40	8
	34	6
	39	10
	32	8
	31	9
	22	12
	21	8
	21	8
	21	4
	22	6
	20	5
	31	2
	27	8
	29	1
	31	2
	31	6
	20	2
	26	15
	34	8
	25	5
	29	8
	32	8
	27	6
	29	6
	27	1
	28	5
	33	2
	23	4
	32	7
	31	4
	26	10
	8	8
	25	4
	20	6
	33	4
	18	7
	19	6
	22	6
	21	9
	22	12
	21	7
	21	17
	21	10
	22	11
	20	10
	31	12
	27	5
	29	5
	31	16
	31	14
	37	11
Total	1427	390

Date	19-04-22	TUE
Interval	07:18-08:18	
Direction	CW	CS
	28	8
	24	6
	31	15
	35	11
	34	9
	34	12
	32	10
	28	6
	31	7
	33	6
	35	6
	32	8
	26	7
	29	7
	24	5
	28	4
	32	4
	26	5
	30	7
	35	9
	25	2
	30	4
	36	7
	27	2
	26	4
	20	7
	22	4
	25	10
	28	8
	27	4
	29	6
	32	4
	31	7
	37	6
	29	6
	26	8
	30	6
	37	5
	29	4
	40	4
	36	4
	34	3
	30	8
	35	3
	25	5
	30	5
	36	13
	20	3
	29	4
	31	10
	34	13
	33	11
	37	10
Total	1603	352

Date	20-04-22	WED
Interval	07:15-08:15	
Direction	CW	CS
	22	4
	16	3
	23	8
	28	5
	35	2
	32	6
	24	3
	31	6
	35	1
	28	3
	26	5
	26	2
	26	10
	32	6
	21	7
	28	6
	27	6
	28	8
	32	7
	35	7
	41	5
	39	4
	40	4
	41	5
	37	7
	36	9
	26	2
	36	4
	32	7
	28	6
	37	5
	32	7
	35	6
	28	5
	35	4
	29	10
	39	4
	37	7
	42	6
	37	5
	23	12
	30	7
	22	8
	33	6
	30	6
	40	6
	33	7
	34	4
	34	6
	29	8
	25	6
	30	9
	29	7
Total	1654	309

Date	21-04-22	THU
Interval	07:17-08:17	
Direction	CW	CS
	24	10
	19	4
	23	2
	30	2
	38	8
	23	4
	27	6
	43	5
	20	2
	22	8
	25	1
	28	2
	27	6
	29	2
	32	4
	31	5
	37	8
	29	8
	26	6
	30	6
	35	1
	38	5
	39	2
	28	4
	28	7
	33	4
	31	10
	20	8
	39	4
	27	6
	31	4
	28	7
	17	6
	20	6
	19	8
	33	6
	31	5
	32	4
	37	4
	31	4
	31	3
	31	8
	31	3
	26	6
	23	4
	34	5
	34	0
	28	6
	36	3
	30	3
	25	5
	23	12
	37	13
Total	1549	275

Date	22-04-22	FRI
Interval	07:14-08:14	
Direction	CW	CS
	34	14
	31	8
	33	2
	38	7
	32	4
	31	10
	37	8
	29	4
	26	6
	30	4
	35	7
	38	6
	39	6
	28	8
	28	6
	33	5
	31	4
	20	4
	39	4
	27	3
	31	8
	28	3
	17	6
	20	4
	26	5
	33	3
	31	6
	33	5
	30	2
	37	4
	29	2
	32	3
	28	6
	22	3
	32	5
	18	3
	33	2
	32	4
	25	2
	36	8
	26	4
	26	6
	36	6
	24	3
	24	2
	27	5
	22	6
	27	3
	23	8
	26	4
	29	9
	34	11
	29	18
Total	1565	289

Date	25-04-22	MON
Interval	07:15-08:15	
Direction	CW	CS
	31	7
	33	10
	28	11
	26	6
	16	5
	22	3
	26	7
	28	7
	27	3
	26	7
	34	1
	31	7
	28	4
	26	3
	16	9
	22	8
	26	8
	28	7
	27	1
	26	11
	34	5
	20	5
	27	7
	30	5
	33	4
	26	5
	26	10
	36	4
	24	4
	24	2
	27	7
	35	8
	32	8
	29	6
	25	9
	27	8
	25	6
	21	8
	19	6
	23	5
	26	6
	20	8
	20	6
	29	5
	31	4
	34	4
	22	4
	27	3
	23	8
	26	3
	29	6
	34	4
	29	5
Total	1420	313

Date	26-04-22	TUE
Interval	07:15-08:15	
Direction	CW	CS
	21	5
	18	2
	18	3
	8	2
	25	5
	20	0
	33	4
	18	3
	19	2
	22	4
	21	6
	22	8
	21	5
	21	3
	21	3
	22	4
	20	1
	31	5
	27	3
	29	4
	31	5
	31	4
	20	8
	26	4
	34	4
	25	4
	29	3
	32	4
	27	2
	29	8
	27	6
	28	4
	33	8
	23	6
	33	2
	20	4
	30	3
	32	4
	26	3
	21	3
	33	7
	14	3
	25	4
	24	11
	22	6
	18	8
	22	3
	23	6
	18	3
	27	5
	24	7
	28	7
	24	6
Total	1296	237

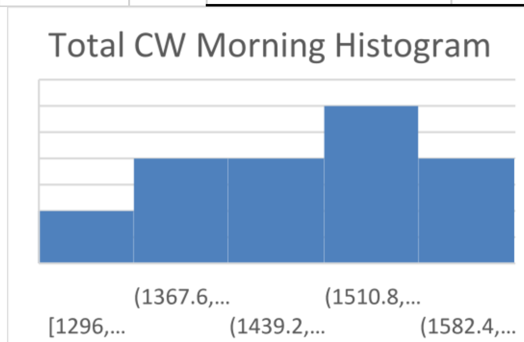
Date	27-04-22	WED
Interval	07:20-08:20	
Direction	CW	CS
	22	6
	26	4
	28	5
	27	10
	27	6
	27	0
	28	6
	23	5
	20	3
	28	7
	22	7
	32	3
	18	7
	26	1
	36	5
	31	7
	30	2
	29	3
	26	4
	40	2
	36	6
	25	4
	32	5
	33	10
	33	7
	28	5
	35	5
	30	5
	26	8
	26	7
	28	6
	33	9
	27	2
	37	7
	26	6
	27	7
	24	3
	32	5
	30	6
	27	6
	30	2
	23	6
	26	5
	27	5
	26	4
	28	6
	23	3
	20	2
	28	1
	29	1
	25	2
	35	0
	31	7
	30	4
	25	8
Total	1547	268

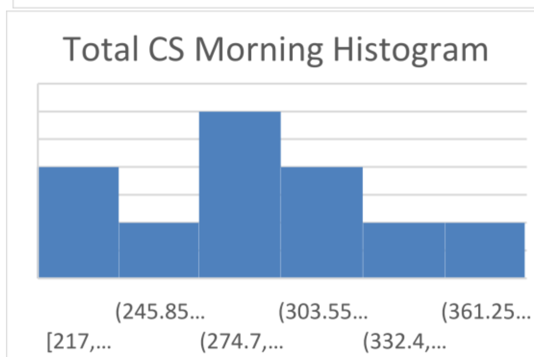
Date	28-04-22	THU
Interval	07:25-08:25	(
Direction	CW	CS
	24	6
	23	3
	23	6
	23	2
	25	7
	24	6
	20	3
	29	2
	33	5
	38	6
	27	4
	29	3
	31	3
	25	3
	32	7
	34	7
	32	2
	33	3
	42	2
	33	4
	28	1
	26	4
	33	3
	32	5
	25	6
	36	4
	26	5
	26	2
	36	4
	24	2
	24	3
	27	6
	35	3
	42	5
	29	3
	25	2
	27	4
	25	2
	21	8
	19	4
	23	6
	26	6
	20	3
	20	2
	32	5
	29	6
	23	3
	17	8
	24	4
	22	4
	22	4
	35	1
	27	5
Total	1466	217

Date	29-04-22	FRI
Interval	07:25-08:25	(
Direction	CW	CS
	26	1
	31	4
	28	6
	26	8
	16	3
	22	9
	26	8
	28	8
	27	7
	26	1
	34	11
	20	5
	27	5
	30	7
	33	5
	33	4
	28	5
	31	10
	34	4
	36	4
	32	2
	33	7
	32	8
	33	8
	34	6
	20	9
	27	8
	33	6
	26	3
	29	6
	29	6
	30	2
	30	4
	17	8
	20	5
	34	3
	20	8
	23	5
	31	2
	33	3
	25	3
	24	4
	33	8
	30	2
	16	4
	22	4
	20	4
	30	4
	24	6
	21	3
	21	3
	33	6
	24	7
Total	1451	282

TOTAL CW		*CW*	
1427			
1603		Mean	1497.8
1654		Standard Error	33.3356
1549		Median	1506.5
1565		Mode	#N/A
1420		Standard Deviation	105.4164
1296		Sample Variance	11112.62
1547		Kurtosis	0.038246
1466		Skewness	-0.43232
1451		Range	358
		Minimum	1296
		Maximum	1654
		Sum	14978
		Count	10

TOTAL CS		*CS*	
390			
352		Mean	293.2
309		Standard Error	16.17392
275		Median	285.5
289		Mode	#N/A
313		Standard Deviation	51.14641
237		Sample Variance	2615.956
268		Kurtosis	0.259457
217		Skewness	0.496792
282		Range	173
		Minimum	217
		Maximum	390
		Sum	2932
		Count	10





Appendix 1B: CW+CS Afternoon

Date	4/18/2022	MON
Interval	16:02-17:02	
Direction	CW	CS
	39	6
	35	10
	40	8
	34	6
	39	10
	32	8
	31	9
	31	12
	37	8
	31	14
	37	13
	32	11
	38	13
	37	17
	38	11
	33	13
	36	9
	39	11
	38	11
	37	15
	35	8
	40	9
	38	6
	36	14
	39	10
	33	12
	27	16
	39	12
	29	12
	32	16
	32	14
	31	16
	26	17
	33	11
	36	17
	34	11
	25	17
	29	8
	32	12
	32	8
	29	9
	28	12
	43	7
	32	17
	31	10
	29	11
	33	10
	29	12
	31	5
	31	5
	26	16
	33	14
	37	11
Total	1784	600

Date	4/19/2022	TUE
Interval	16:07-17:07	
Direction	CW	CS
	28	8
	24	6
	31	15
	35	11
	34	9
	34	12
	32	6
	28	6
	31	10
	33	12
	35	16
	32	12
	34	15
	31	15
	43	14
	37	14
	36	9
	31	13
	41	17
	40	17
	37	19
	39	16
	33	23
	37	16
	37	12
	39	12
	39	15
	39	15
	29	13
	32	14
	32	12
	31	14
	26	19
	33	9
	31	7
	33	4
	30	9
	37	5
	29	6
	28	5
	43	10
	33	7
	40	5
	36	10
	34	5
	25	5
	29	13
	32	3
	32	4
	31	10
	26	13
	33	11
	37	10
Total	1772	588

Date	4/20/2022	WED
Interval	16:00-17:00	
Direction	CW	CS
	32	14
	30	13
	35	17
	31	17
	35	19
	33	16
	39	23
	36	16
	38	12
	35	12
	35	17
	35	15
	41	13
	34	14
	37	12
	39	14
	35	19
	40	14
	34	11
	39	15
	32	8
	31	9
	31	6
	37	14
	31	17
	37	11
	32	17
	38	15
	32	15
	29	14
	34	10
	31	8
	38	14
	37	10
	30	12
	25	14
	31	9
	37	11
	38	10
	35	8
	32	9
	37	7
	42	7
	33	17
	39	10
	38	12
	37	10
	40	12
	32	10
	34	12
	24	16
	27	14
	37	11
Total	1831	682

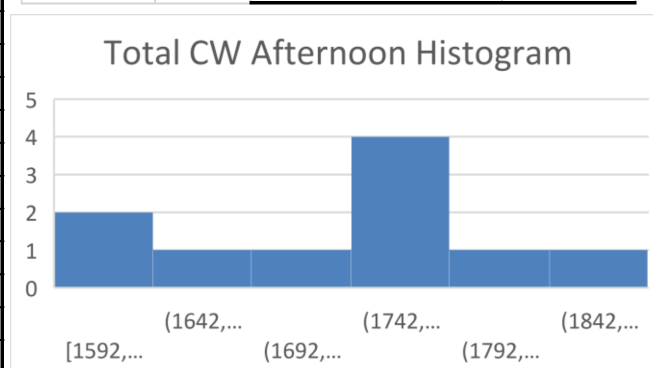
Date	4/21/2022	THU
Interval	16:06-17:06	
Direction	CW	CS
	34	10
	34	12
	38	21
	31	12
	35	18
	39	15
	30	13
	33	14
	37	13
	40	13
	38	11
	34	11
	40	9
	35	10
	41	11
	36	8
	41	12
	39	10
	39	16
	39	15
	29	11
	32	9
	32	14
	31	13
	26	17
	33	13
	31	10
	33	11
	30	8
	37	6
	29	9
	28	12
	43	11
	33	8
	40	10
	36	10
	34	18
	34	10
	36	9
	35	8
	40	9
	41	4
	39	8
	35	8
	33	6
	37	7
	41	13
	34	15
	37	13
	30	9
	33	14
	28	13
	30	7
Total	1853	597

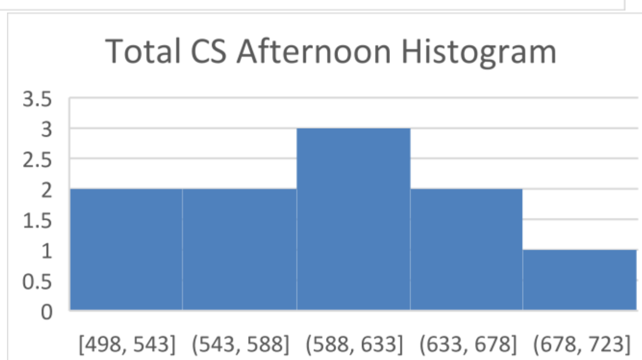
Date	4/22/2022	FRI	Date	4/25/2022	MON	Date	4/26/2022	TUE	Date	4/27/2022	WED
Interval	15:55-16:55		Interval	15:58-16:58		Interval	15:50-16:50		Interval	15:49-16:49	
Direction	CW	CS	Direction	CW	CS	Direction	CW	CS	Direction	CW	CS
	34	14		34	7		30	7		29	14
	31	8		40	10		34	10		35	8
	33	6		38	11		21	11		28	6
	38	15		34	13		21	8		24	15
	28	11		40	10		25	6		31	11
	24	9		35	14		24	10		35	9
	36	12		41	12		25	8		34	12
	31	6		36	16		23	6		34	6
	35	6		41	14		31	10		32	6
	39	11		20	10		22	8		28	10
	30	11		32	8		31	9		31	12
	33	11		27	10		26	12		33	16
	37	13		35	9		37	8		35	12
	40	13		37	10		37	14		32	19
	38	12		21	17		37	13		34	16
	34	14		23	11		38	12		31	14
	40	11		30	11		33	16		43	16
	35	13		28	11		36	17		37	17
	41	13		27	10		39	13		36	22
	26	11		26	9		38	14		31	17
	29	11		29	4		37	9		41	14
	24	9		24	6		35	11		40	17
	28	10		28	10		40	9		37	8
	32	11		32	6		38	7		39	12
	26	8		26	9		36	10		33	8
	33	12		30	7		39	9		37	9
	31	10		35	4		33	4		36	12
	33	16		25	9		27	6		36	14
	30	15		30	5		38	10		41	9
	37	11		36	6		28	6		32	12
	29	9		27	5		27	9		35	12
	28	14		26	10		26	7		39	9
	43	13		29	7		29	4		36	10
	33	17		24	5		24	9		39	6
	40	13		28	6		28	5		38	10
	36	6		32	8		32	6		36	8
	34	5		26	5		26	5		39	9
	30	10		30	10		30	10		34	12
	35	7		35	7		35	7		31	10
	25	10		25	5		25	5		33	7
	30	8		30	6		30	6		38	16
	36	9		36	8		36	8		28	8
	20	7		20	9		20	9		24	11
	29	7		29	10		29	10		36	16
	31	10		31	9		31	9		27	11
	34	18		34	12		34	12		26	8
	22	7		22	10		22	10		20	10
	27	15		27	13		27	13		43	12
	23	12		23	11		23	11		32	11
	26	12		26	10		26	10		35	9
	29	9		29	11		29	11		35	15
	34	11		34	14		34	14		28	8
	29	18		29	18		29	18			
Total	1689	580	Total	1592	498	Total	1611	501	Total	1757	601

Date	4/28/2022	THU	Date	4/29/2022	FRI
Interval	16:03-17:03		Interval	15:56-16:56	
Direction	CW	CS	Direction	CW	CS
	39	17		36	10
	31	17		29	10
	35	17		36	12
	30	18		33	16
	31	19		35	12
	39	17		26	14
	43	18		26	10
	35	11		34	12
	29	4		36	14
	36	13		21	16
	40	10		41	12
	39	14		34	12
	36	12		34	12
	34	16		30	19
	38	14		35	18
	38	10		42	16
	39	8		36	19
	34	10		30	19
	30	9		34	16
	37	10		27	12
	30	17		30	12
	34	11		31	10
	29	11		35	14
	38	11		27	15
	28	13		35	8
	28	13		30	9
	35	12		24	10
	34	16		16	13
	32	14		33	11
	40	13		33	7
	35	9		37	13
	35	11		22	9
	27	11		33	13
	32	5		36	12
	27	10		33	17
	35	12		32	16
	37	18		30	6
	21	14		36	10
	23	12		33	13
	30	8		35	13
	29	10		22	11
	31	12		34	13
	33	8		33	9
	37	10		36	9
	39	18		32	12
	29	7		31	17
	27	15		18	8
	36	12		34	9
	36	12		38	13
	39	9		39	11
	34	11		37	11
	39	7		40	9
	31	7		34	11
Total	1783	643	Total	1704	655

TOTAL CW		*CW*	
1784			
1772		Mean	1737.6
1831		Standard Error	27.594766
1853		Median	1764.5
1689		Mode	#N/A
1592		Standard Deviation	87.2623121
1611		Sample Variance	7614.71111
1757		Kurtosis	-0.6617276
1783		Skewness	-0.5592066
1704		Range	261
		Minimum	1592
		Maximum	1853
		Sum	17376
		Count	10

TOTAL CS		*CS*	
600			
588		Mean	594.5
682		Standard Error	18.8722312
597		Median	598.5
580		Mode	#N/A
498		Standard Deviation	59.6792352
501		Sample Variance	3561.61111
601		Kurtosis	-0.1971757
643		Skewness	-0.4661869
655		Range	184
		Minimum	498
		Maximum	682
		Sum	5945
		Count	10





Appendix 1C: CN+CE Morning

Date	18-04-22	MON
Interval	07:14-08:14	
Direction	CN	CE
	12	26
	20	27
	22	15
	10	10
	10	13
	15	19
	17	7
	14	18
	15	13
	15	13
	14	3
	14	11
	7	10
	12	12
	6	12
	6	6
	9	16
	7	8
	9	12
	7	15
	7	5
	16	8
	9	9
	13	8
	22	11
	15	11
	16	13
	10	14
	16	9
	12	14
	13	13
	12	10
	17	11
	19	7
	12	12
	21	14
	23	7
	7	9
	11	10
	17	10
	14	17
	13	6
	19	6
	15	18
	6	5
	16	28
	11	25
	7	18
	10	10
	18	14
	18	11
	16	11
	16	13
Total	708	653

Date	19-04-22	TUE
Interval	07:18-08:18	
Direction	CN	CE
	12	16
	12	15
	17	14
	12	7
	13	25
	13	13
	17	18
	9	16
	9	21
	23	26
	20	28
	10	8
	10	15
	18	8
	19	16
	15	11
	7	12
	13	16
	18	8
	11	5
	6	16
	9	8
	11	14
	13	9
	9	5
	14	9
	5	5
	15	10
	10	10
	7	14
	11	12
	12	8
	14	13
	11	6
	13	18
	11	7
	10	7
	16	18
	12	5
	18	9
	13	13
	15	7
	18	16
	18	13
	16	14
	9	15
	15	10
	13	10
	8	15
	13	4
	16	9
	16	11
	16	12
Total	691	650

Date	20-04-22	WED
Interval	07:15-08:15	
Direction	CN	CE
	15	4
	10	7
	11	16
	17	19
	21	4
	20	2
	13	5
	14	13
	15	4
	20	10
	18	12
	22	4
	21	15
	14	11
	16	11
	25	12
	16	2
	16	13
	14	11
	24	17
	10	11
	11	14
	13	15
	13	11
	22	7
	15	14
	16	12
	10	9
	16	19
	12	4
	13	7
	12	9
	17	8
	19	7
	12	5
	21	9
	23	15
	7	3
	11	14
	17	7
	14	9
	13	16
	13	12
	14	6
	18	16
	12	6
	6	8
	14	12
	10	13
		20
		9
		13
		15
Total	746	547

Date	21-04-22	THU
Interval	07:17-8:17	
Direction	CN	CE
	10	11
	15	10
	12	12
	14	17
	13	12
	13	9
	10	18
	10	11
	17	17
	14	11
	17	15
	23	10
	13	13
	17	12
	14	12
	24	14
	16	19
	21	13
	17	8
	13	13
	10	11
	16	13
	11	17
	17	16
	12	15
	18	12
	12	12
	13	20
	19	12
	15	10
	6	12
	16	7
	11	8
	7	15
	10	11
	9	16
	12	11
	9	14
	15	9
	14	6
	14	9
	7	9
	12	12
	6	11
	6	13
	9	10
	7	8
	9	13
	7	8
	7	7
	16	8
	9	9
	10	10
Total	674	631

Date	22-04-22	FRI
Interval	07:14-08:14	
Direction	CN	CE
	18	15
	12	11
	20	13
	14	12
	18	12
	16	11
	19	15
	20	17
	15	13
	20	11
	16	16
	17	11
	14	14
	8	9
	13	6
	14	9
	15	9
	6	12
	17	11
	15	13
	8	10
	6	8
	16	4
	16	17
	18	10
	8	8
	17	14
	15	12
	8	8
	12	19
	11	6
	13	5
	11	7
	10	7
	16	18
	12	5
	18	9
	13	13
	7	7
	8	16
	15	13
	16	15
	9	15
	15	15
	13	10
	8	15
	13	4
	16	9
	14	6
	12	15
	21	10
	15	23
	12	16
Total	729	609

Date	25-04-22	MON
Interval	07:15-08:15	
Direction	CN	CE
	18	11
	13	16
	19	11
	12	14
	19	9
	18	6
	15	9
	13	9
	14	12
	5	11
	15	13
	10	10
	7	8
	11	12
	12	8
	14	13
	11	6
	13	18
	11	7
	10	7
	16	18
	12	5
	18	9
	13	13
	7	7
	18	16
	18	13
	16	14
	9	15
	15	10
	13	10
	8	15
	13	4
	16	9
	17	10
	17	17
	5	6
	10	10
	17	15
	12	11
	12	15
	13	20
	9	14
	12	12
	14	17
	10	15
	16	10
	18	17
	14	25
	15	8
	21	15
	15	17
	12	10
Total	711	632

Date	26-04-22	TUE
Interval	07:15-8:15	
Direction	CN	CE
	15	22
	5	4
	8	7
	9	9
	6	5
	6	9
	9	8
	15	5
	15	10
	19	7
	8	2
	14	15
	14	4
	5	17
	15	10
	10	8
	7	14
	11	12
	12	8
	14	13
	11	6
	13	18
	11	7
	10	7
	16	18
	12	5
	18	9
	13	13
	7	7
	18	15
	18	8
	16	16
	9	11
	15	12
	13	16
	8	8
	13	5
	16	16
	13	8
	11	14
	15	9
	10	5
	17	9
	13	5
	13	10
	11	10
	14	12
	5	13
	12	3
	16	16
	13	9
	11	11
	30	14
Total	658	534

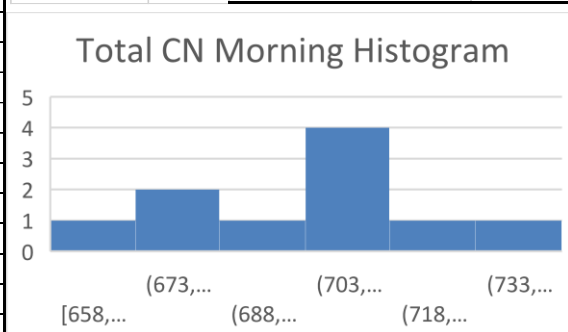
Date	27-04-22	WED
Interval	07:20-8:20	
Direction	CN	CE
	9	8
	12	8
	14	9
	14	7
	13	10
	18	16
	17	5
	16	11
	14	11
	21	8
	14	9
	15	10
	12	8
	19	18
	15	14
	12	18
	12	13
	17	5
	12	16
	13	5
	13	9
	17	15
	9	8
	9	16
	23	11
	20	12
	10	16
	10	8
	18	5
	19	16
	15	8
	7	14
	13	9
	18	5
	11	9
	6	5
	9	10
	11	10
	12	10
	12	15
	10	12
	12	19
	16	15
	15	9
	16	14
	13	15
	6	11
	12	11
	11	11
	7	6
	12	13
	20	14
	13	11
Total	714	581

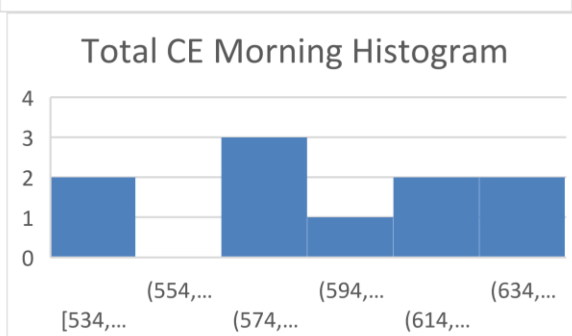
Date	28-04-22	THU
Interval	07:25-8:25	(
Direction	CN	CE
	13	5
	10	14
	20	9
	13	4
	16	19
	8	7
	16	18
	17	13
	14	13
	8	3
	13	11
	14	10
	15	12
	6	12
	17	6
	15	16
	8	8
	6	22
	16	15
	16	5
	18	8
	8	9
	17	8
	15	11
	8	11
	12	13
	20	14
	16	9
	9	14
	15	13
	12	10
	16	11
	11	7
	17	12
	14	14
	14	7
	12	9
	12	10
	20	10
	11	17
	10	6
	13	6
	16	18
	6	5
	7	16
	16	11
	14	5
	14	16
	7	10
	11	14
	10	14
	11	3
	13	14
Total	686	577

Date	29-04-22	FRI
Interval	07:25-8:25	(
Direction	CN	CE
	22	10
	16	12
	12	12
	13	12
	21	11
	17	10
	7	6
	18	20
	12	9
	15	7
	10	13
	15	6
	15	20
	4	11
	14	4
	12	17
	14	9
	13	8
	23	12
	10	3
	21	20
	10	13
	12	5
	14	14
	18	14
	12	17
	14	16
	19	6
	13	8
	10	13
	10	3
	13	12
	13	14
	9	15
	14	17
	11	7
	10	12
	10	11
	13	9
	15	11
	14	7
	9	18
	14	9
	12	5
	13	12
	9	11
	5	1
	17	10
	9	11
	14	11
	16	15
	16	6
	16	22
Total	708	587

TOTAL CN		*CN*	
708			
691		Mean	702.5
746		Standard Error	8.203319
674		Median	708
729		Mode	708
711		Standard Deviation	25.94117
658		Sample Variance	672.9444
714		Kurtosis	-0.11206
686		Skewness	-0.11053
708		Range	88
		Minimum	658
		Maximum	746
		Sum	7025
		Count	10

TOTAL CE		*CE*	
653			
650		Mean	607.3
547		Standard Error	15.47259
631		Median	609
609		Mode	#N/A
632		Standard Deviation	48.92863
534		Sample Variance	2394.011
581		Kurtosis	-1.2373
577		Skewness	-0.07763
587		Range	147
		Minimum	534
		Maximum	681
		Sum	6073
		Count	10





Appendix 1D: CN+CE Afternoon

Date	4/18/2022	MON	Date	4/19/2022	TUE	Date	4/20/2022	WED	Date	4/21/2022	THU
Interval	17:02-18:02		Interval	16:07-17:07		Interval	16:00-17:00		Interval	16:06-17:06	
Direction	CN	CE	Direction	CN	CE	Direction	CN	CE	Direction	CN	CE
	12	26		22	16		18	29		19	32
	20	27		18	15		19	25		12	19
	22	18		16	14		15	26		20	24
	10	19		19	7		11	24		22	23
	10	17		11	25		18	21		18	17
	15	17		15	13		19	16		16	26
	17	20		14	18		20	19		19	27
	18	21		15	16		13	23		20	18
	14	21		14	21		17	25		24	19
	16	20		22	26		15	21		20	17
	18	13		10	28		16	28		15	17
	12	21		19	8		20	26		14	20
	19	15		18	18		14	22		15	21
	14	13		18	11		18	30		20	21
	21	19		14	25		21	23		17	14
	18	18		15	28		17	19		14	20
	5	12		15	25		21	16		14	21
	12	13		15	16		16	13		16	18
	18	17		10	21		15	22		23	11
	12	18		15	19		11	18		19	16
	17	25		17	16		22	16		17	19
	15	11		17	26		23	22		16	25
	16	20		14	25		18	19		22	14
	25	15		15	14		12	28		21	20
	20	8		18	20		14	25		20	30
	26	16		25	15		19	16		16	19
	15	17		18	21		19	28		20	20
	17	10		16	25		20	12		17	29
	23	8		18	10		21	27		7	16
	19	15		21	20		10	27		15	21
	19	25		20	19		19	17		18	19
	13	18		14	14		22	20		15	16
	15	20		18	12		15	21		15	26
	16	15		17	14		23	25		10	25
	10	18		15	18		15	18		12	14
	13	20		14	20		17	21		17	19
	14	22		17	23		17	23		10	13
	15	27		15	24		14	26		11	22
	19	25		21	20		18	18		14	12
	22	25		15	18		18	19		17	8
	10	23		20	21		25	17		18	20
	19	27		12	25		12	26		11	15
	18	30		21	22		21	23		10	21
	18	24		19	24		19	25		19	25
	14	16		15	22		18	23		23	10
	15	28		14	17		14	24		18	20
	15	25		15	25		15	18		14	19
	18	18		15	22		15	18		20	14
	15	20		15	17		20	20		18	12
	18	14		21	25		21	14		19	14
	18	23		18	8		18	23		16	18
	16	21		16	24		16	21		10	17
	16	20		16	20		16	20		18	20
Total	862	1014	Total	877	1016	Total	920	1146	Total	881	1013

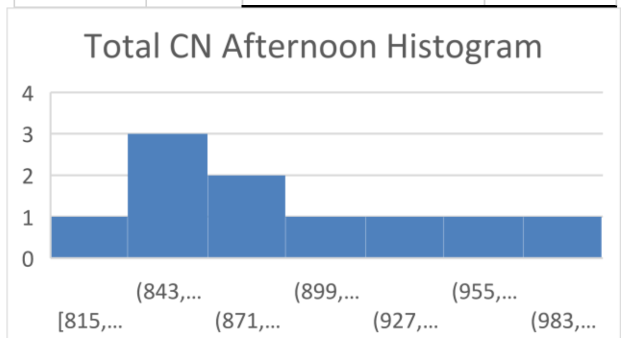
Date	4/22/2022	FRI	Date	4/25/2022	MON	Date	4/26/2022	TUE	Date	4/27/2022	WED
Interval	15:55-16:55		Interval	15:58-16:58		Interval	15:50-16:50		Interval	15:49-16:49	
Direction	CN	CE	Direction	CN	CE	Direction	CN	CE	Direction	CN	CE
	18	26		18	26		18	26		10	20
	12	19		13	19		13	19		10	21
	20	28		19	28		19	28		15	15
	22	18		12	23		12	23		17	19
	18	25		19	18		19	18		18	15
	16	11		18	11		18	16		24	15
	19	20		15	24		23	24		16	25
	20	18		13	21		13	13		18	17
	15	25		12	26		14	15		12	18
	20	11		19	28		11	14		19	25
	14	20		14	12		5	7		14	11
	16	24		21	19		22	25		21	20
	17	25		18	20		18	13		18	24
	19	22		18	21		12	18		18	25
	18	15		18	25		17	16		18	22
	15	28		17	22		15	21		17	15
	20	8		23	24		19	26		23	24
	16	18		19	22		22	28		19	19
	12	22		22	8		10	8		22	21
	18	8		15	18		19	18		15	28
	17	18		15	11		18	11		15	16
	23	11		19	25		18	25		19	24
	21	25		10	28		14	28		10	20
	14	28		23	25		15	25		23	17
	21	25		18	24		15	24		18	28
	16	24		18	14		18	14		16	27
	13	14		15	24		15	24		18	18
	17	24		18	25		18	25		21	26
	14	25		13	18		13	18		20	18
	17	18		17	15		17	15		14	23
	12	20		10	18		14	18		18	24
	6	15		17	11		17	11		17	20
	21	21		15	14		22	24		24	18
	10	25		5	11		6	21		14	14
	19	10		17	16		17	26		17	20
	11	20		17	18		17	28		15	28
	11	19		5	12		16	12		21	21
	14	14		10	10		10	19		22	19
	17	12		17	15		17	20		21	26
	15	14		12	11		20	21		16	12
	21	26		12	15		12	25		17	26
	22	25		13	20		13	22		9	7
	12	29		9	14		14	24		20	26
	16	22		12	12		12	22		19	26
	17	22		14	17		14	17		16	25
	9	20		10	15		23	25		20	32
	20	14		16	10		16	22		16	29
	19	12		18	17		18	17		15	25
	14	17		14	25		14	25		20	22
	12	15		15	8		24	8		15	21
	21	10		21	15		21	24		23	28
	15	23		15	17		15	27		17	29
	12	16		12	10		12	25		20	27
Total	864	1024	Total	815	955	Total	844	1068	Total	930	1141

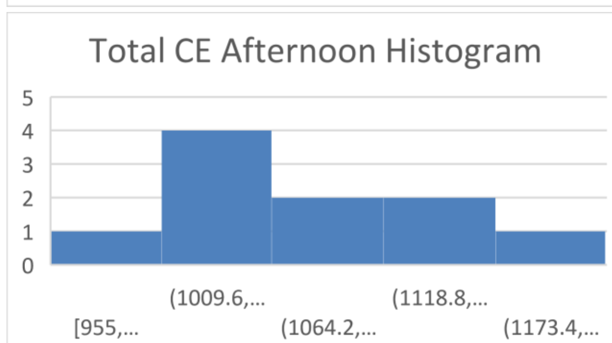
Date	4/28/2022	THU
Interval	16:03-17:03	
Direction	CN	CE
	16	25
	15	18
	16	20
	16	15
	16	18
	17	20
	19	22
	18	27
	22	25
	20	25
	16	23
	12	27
	18	30
	17	24
	23	16
	21	28
	14	25
	21	24
	16	25
	17	25
	17	20
	21	17
	15	22
	25	24
	24	10
	14	23
	20	30
	22	14
	18	32
	19	23
	16	23
	18	27
	24	26
	21	25
	19	29
	17	22
	20	22
	16	25
	25	26
	20	34
	26	28
	29	27
	17	10
	23	21
	19	26
	19	27
	13	14
	15	26
	16	28
	10	21
	13	22
	18	18
	26	24
Total	985	1228

Date	4/29/2022	FRI
Interval	15:56-16:56	
Direction	CN	CE
	12	30
	25	13
	23	21
	18	20
	14	22
	21	30
	15	12
	8	18
	17	26
	14	18
	15	27
	17	29
	14	24
	17	26
	18	21
	24	24
	18	19
	19	23
	26	26
	23	14
	9	17
	14	20
	23	10
	18	26
	20	25
	15	10
	13	29
	19	14
	16	21
	28	28
	21	16
	16	20
	16	18
	23	10
	18	22
	13	16
	19	13
	14	22
	19	17
	20	19
	25	18
	19	11
	16	16
	22	23
	17	22
	19	22
	24	22
	19	24
	21	27
	19	20
	12	23
	18	23
	19	16
Total	962	1083

CN		*CN*	
862			
877		Mean	894
920		Standard Error	16.99673171
881		Median	879
864		Mode	#N/A
815		Standard Deviation	53.74838499
844		Sample Variance	2888.888889
930		Kurtosis	-0.69729947
985		Skewness	0.400117568
962		Range	170
		Minimum	815
		Maximum	985
		Sum	8940
		Count	10

CE		*CE*	
1014			
1016		Mean	1068.8
1146		Standard Error	25.94472757
1013		Median	1046
1024		Mode	#N/A
955		Standard Deviation	82.04443241
1068		Sample Variance	6731.288889
1141		Kurtosis	0.011858365
1228		Skewness	0.710462113
1083		Range	273
		Minimum	955
		Maximum	1228
		Sum	10688
		Count	10



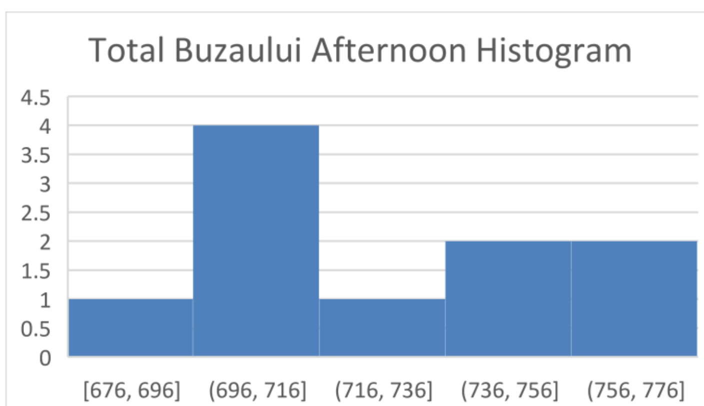


Appendix 1E: BUZAULUI

Date	4/18/2022	Date	4/19/2022	Date	4/20/2022	Date	4/21/2022	Date	4/22/2022
Day	MON	Day	TUE	Day	WED	Day	THU	Day	FRI
Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00
	62		60		87		75		79
	69		60		59		62		47
	62		66		42		45		56
	61		69		60		55		69
	65		71		50		61		67
	62		55		69		59		67
	54		56		55		67		51
	62		68		56		54		50
	68		62		58		72		45
	71		50		62		51		68
	60		64		72		60		55
	62		63		68		64		49
Total	758	Total	744	Total	738	Total	725	Total	703

Date	4/25/2022	Date	4/26/2022	Date	4/27/2022	Date	4/28/2022	Date	4/29/2022
Day	MON	Day	TUE	Day	WED	Day	THU	Day	FRI
Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00
	55		65		65		71		49
	58		57		57		53		61
	55		59		60		60		47
	65		69		69		72		60
	58		50		55		64		60
	63		55		55		64		44
	50		50		50		74		59
	60		62		65		61		57
	51		55		55		49		62
	52		50		54		63		74
	53		66		70		59		68
	56		59		61		67		61
Total	676	Total	697	Total	716	Total	757	Total	702

Buzaului		*Buzaului*	
758			
744		Mean	721.6
738		Standard Error	8.696359
725		Median	720.5
703		Mode	#N/A
676		Standard Deviation	27.5003
697		Sample Variance	756.2667
716		Kurtosis	-1.0543
757		Skewness	-0.10395
702		Range	82
		Minimum	676
		Maximum	758
		Sum	7216
		Count	10

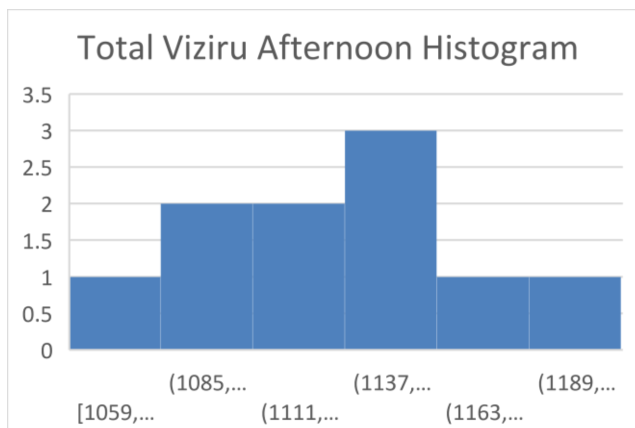


Appendix 1F: VIZIRU

Date	4/18/2022	Date	4/19/2022	Date	4/20/2022	Date	4/21/2022	Date	4/22/2022
Day	MON	Day	TUE	Day	WED	Day	THU	Day	FRI
Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00
	90		91		115		90		80
	130		110		96		130		110
	95		115		103		95		115
	101		107		88		101		96
	99		103		98		89		103
	95		91		97		75		80
	90		86		98		90		75
	80		87		107		80		87
	95		98		94		95		98
	79		107		92		69		107
	92		74		130		92		74
	98		82		95		98		82
Total	1144	Total	1151	Total	1213	Total	1104	Total	1107

Date	4/25/2022	Date	4/26/2022	Date	4/27/2022	Date	4/28/2022	Date	4/29/2022
Day	MON	Day	TUE	Day	WED	Day	THU	Day	FRI
Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00
	93		83		107		133		120
	95		143		129		103		97
	120		103		90		97		89
	75		107		123		100		102
	74		100		95		65		86
	102		65		109		94		88
	79		94		100		70		100
	88		70		75		99		90
	100		99		100		99		88
	90		79		69		79		85
	68		87		101		87		103
	75		100		79		88		97
Total	1059	Total	1130	Total	1177	Total	1114	Total	1145

Viziru		*Viziru*	
1144			
1151		Mean	1134.4
1213		Standard Error	13.44470156
1104		Median	1137
1107		Mode	#N/A
1059		Standard Deviation	42.51587939
1130		Sample Variance	1807.6
1177		Kurtosis	0.701884341
1114		Skewness	0.15116646
1145		Range	154
		Minimum	1059
		Maximum	1213
		Sum	11344

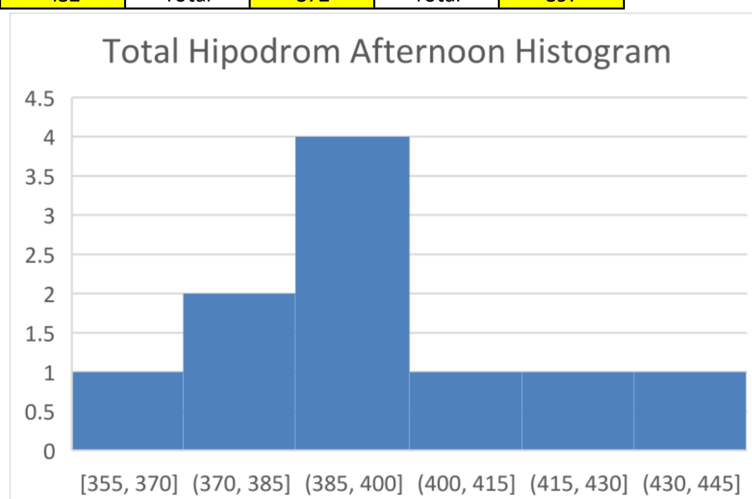


Appendix 1G: HIPODROM

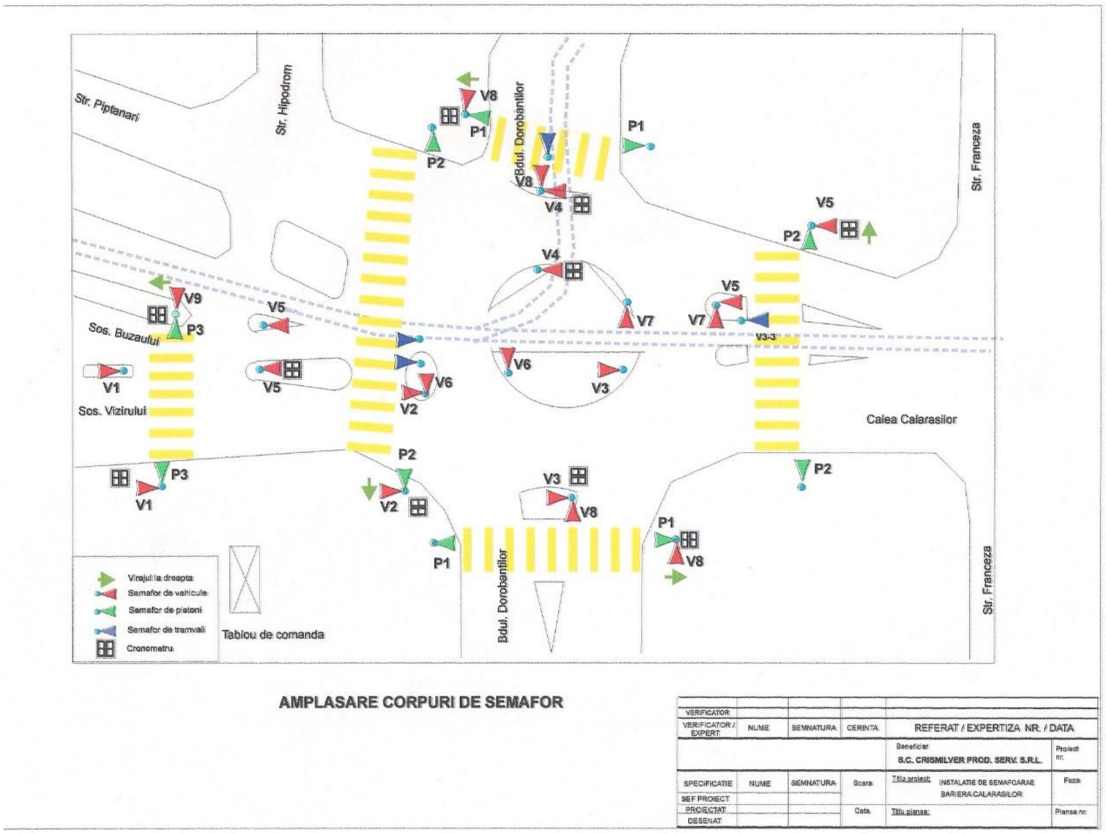
Date	4/18/2022	Date	4/19/2022	Date	4/20/2022	Date	4/21/2022	Date	4/22/2022
Day	MON	Day	TUE	Day	WED	Day	THU	Day	FRI
Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00
	25		39		41		38		30
	34		39		39		42		25
	21		25		35		25		25
	37		29		41		29		32
	27		41		31		34		23
	27		31		36		49		33
	36		36		30		50		31
	45		49		24		22		45
	38		25		42		23		38
	29		22		39		41		28
	38		23		36		31		35
	37		41		35		27		35
Total	394	Total	400	Total	429	Total	411	Total	380

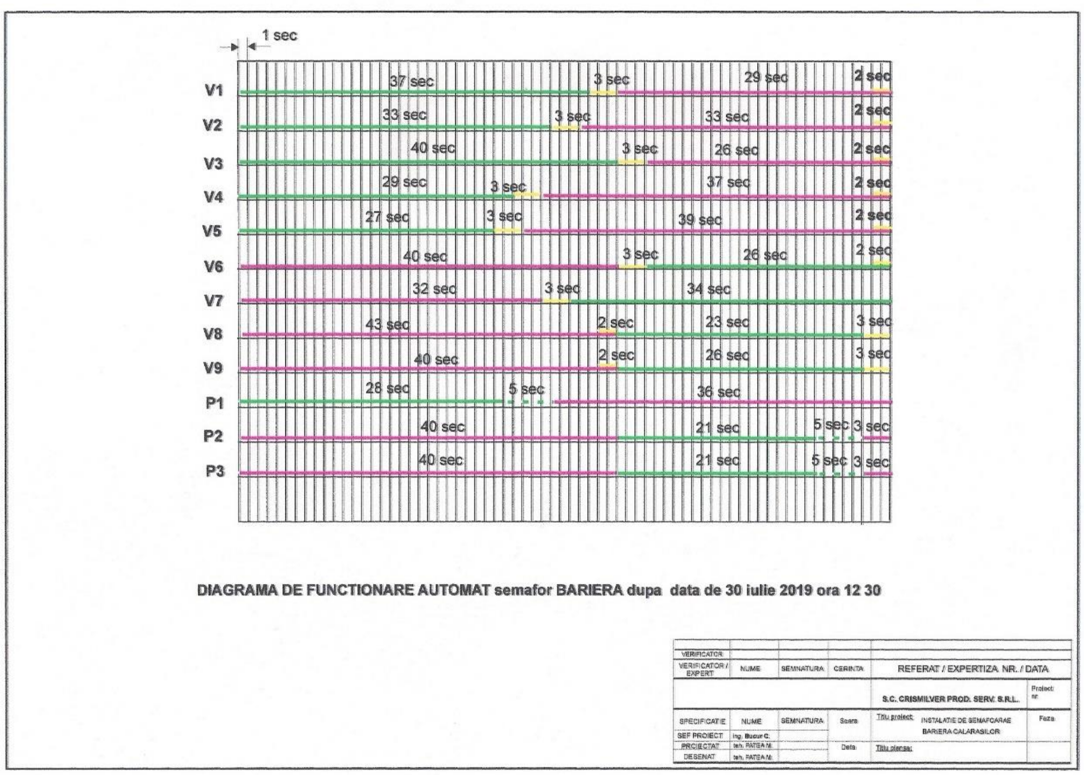
Date	4/25/2022	Date	4/26/2022	Date	4/27/2022	Date	4/28/2022	Date	4/29/2022
Day	MON	Day	TUE	Day	WED	Day	THU	Day	FRI
Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00	Interval	16:00-17:00
	30		29		43		35		41
	25		26		37		32		41
	25		30		33		27		27
	24		30		47		25		40
	28		21		29		35		27
	33		35		33		32		27
	31		36		27		23		30
	35		49		34		47		31
	31		32		38		29		29
	28		29		37		28		32
	32		36		34		34		32
	33		34		40		25		40
Total	355	Total	387	Total	432	Total	372	Total	397

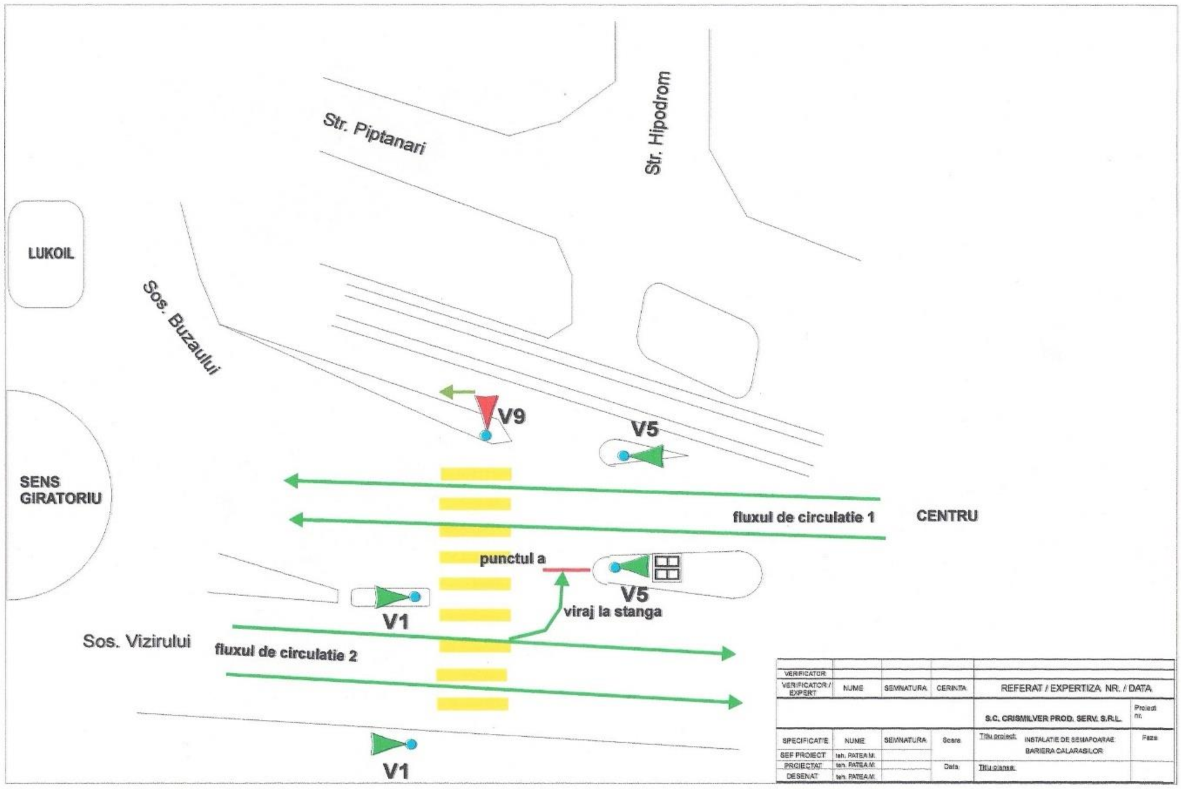
Hipodrom		*Hipodrom*	
394			
400		Mean	395.7
429		Standard Error	7.618763
411		Median	395.5
380		Mode	#N/A
355		Standard Deviation	24.09265
387		Sample Variance	580.4556
432		Kurtosis	-0.35739
372		Skewness	0.031353
397		Range	77
		Minimum	355
		Maximum	432
		Sum	3957
		Count	10



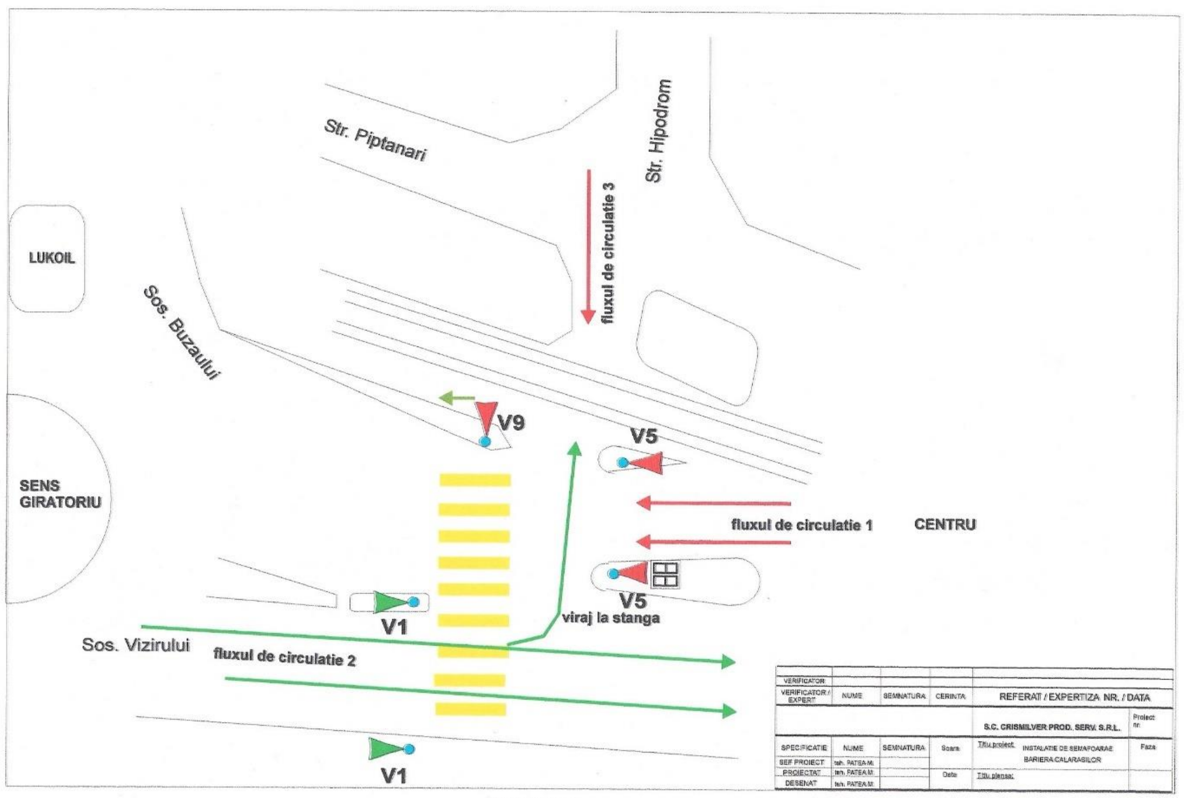
Appendix 2: Traffic Signaling Cycle



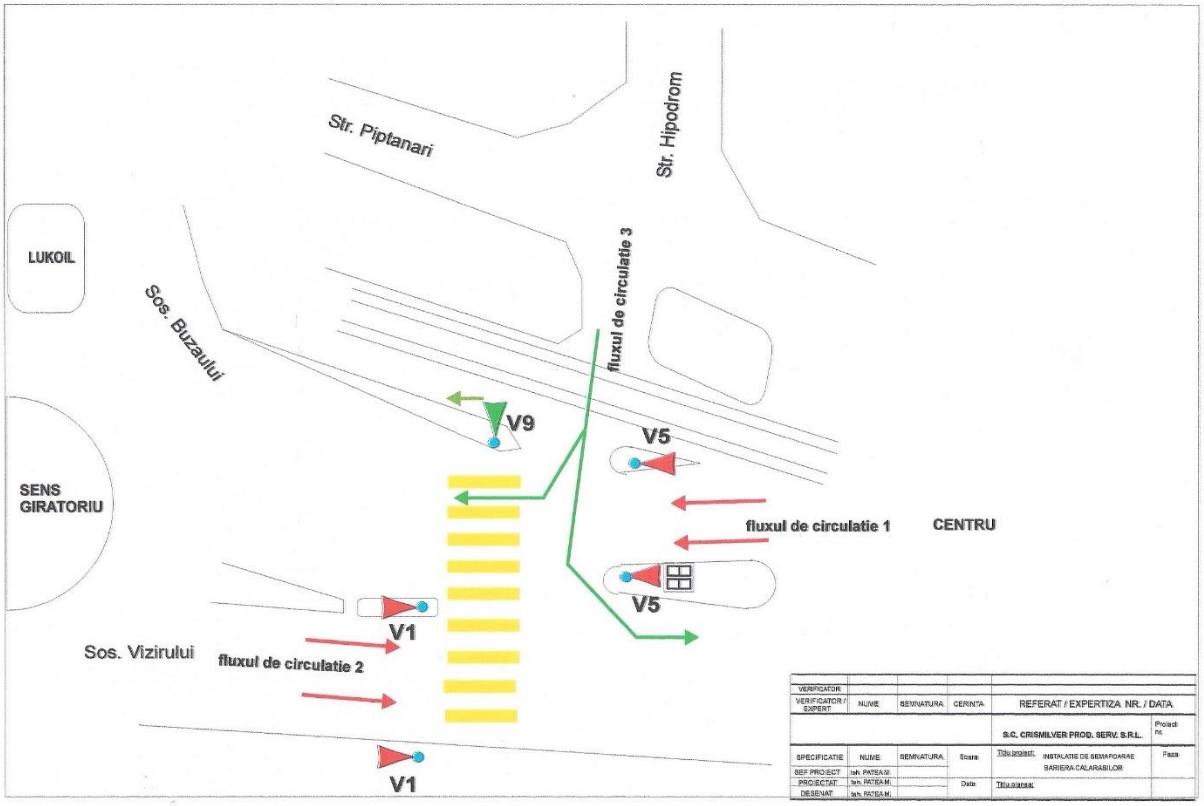




SECVENTA 1



SECVENTA 2



SECVENTA 3

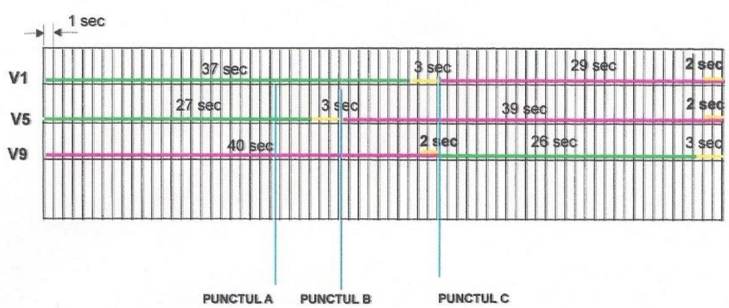


DIAGRAMA DE FUNCTIONARE FORMAT REDUS, AUTOMAT semafor BARIERA

VERIFICATOR
VERIFICATOR / EXPERT | NUME | SEMNATURA | CERINTA | REFERAT / EXPERTIZA NR. / DATA
S.C. CRISMILVER PROD. SERV. S.R.L. | Proiect nr.
SPECIFICATIE | NUME | SEMNATURA | Scara | Titlu proiect: INSTALATIE DE SEMAFOARAE BARIERA CALARASILOR | Faza
SEF PROIECT teh. PATEA M.
PROIECTAT teh. PATEA M. | Data | Titlu plansa:
DESENAT teh. PATEA M.

Appendix 3: Results

Appendix 3A: Initial Situation

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	74,95	93,53	80,31	95,08	90,47
Average Traffic Flow (nr)	491	368	322	326	266
Average Delay (s)	38,91	50,16	41,96	50,93	57,41
TTI	2,02	2,09	2,03	2,09	2,63
PTI	2,25	2,38	2,28	2,32	3,10
Buffer Index	12%	14%	12%	11%	18%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	91,34	97,60	94,68	77,84	40,15
Average Traffic Flow (nr)	236	228	142	158	171
Average Delay (s)	58,55	64,52	59,75	52,26	27,64
TTI	2,70	2,83	2,62	2,91	1,63
PTI	3,03	3,27	2,99	3,16	1,94
Buffer Index	12%	15%	14%	9%	19%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1319,13	256,65	305,72	71,43
Large	LOS D	7108,48	1383,05	1647,46	384,92

Appendix 3B: Validation

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	66,46	73,85	70,39	75,01	73,20
Average Traffic Flow (nr)	468	241	324	243	227
Average Delay (s)	30,42	30,42	32,06	30,84	40,15
TTI	1,79	1,65	1,78	1,65	2,13
PTI	1,90	1,72	1,90	1,73	2,22
Buffer Index	6%	4%	7%	5%	4%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	81,56	77,54	83,98	73,32	32,76
Average Traffic Flow (nr)	274	195	177	139	92
Average Delay (s)	48,77	44,48	49,03	47,74	20,27
TTI	2,41	2,25	2,33	2,74	1,33
PTI	2,62	2,41	2,57	2,94	1,46
Buffer Index	8%	7%	8%	7%	9%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	999,46	194,46	231,64	54,12
Large	LOS C	4837,72	941,25	1121,19	261,96

Appendix 3C: Traffic Optimization Base Scenario

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	74.16	83.59	80.47	83.71	88.42
Average Traffic Flow (nr)	492	368	321	326	267
Average Delay (s)	38.11	40.21	42.12	39.56	55.37
TTI	1.99	1.86	2.03	1.84	2.56
PTI	2.22	2.10	2.35	2	2.96
Buffer Index	11%	13%	16%	9%	15%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	87.19	94.13	91.83	76	36.98
Average Traffic Flow (nr)	236	228	143	158	172
Average Delay (s)	54.40	61.05	56.90	50.41	24.48
TTI	2.58	2.73	2.54	2.84	1.50
PTI	2.86	3.06	2.94	3.05	1.66
Buffer Index	11%	12%	16%	8%	11%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1619.05	315.01	375.23	87.67
Large	LOS D	6511.38	1266.88	1509.08	352.58

Appendix 3D: Underground or Overpass Pedestrian Passage Base Scenario

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	59.75	70.99	64.04	72.25	71.32
Average Traffic Flow (nr)	493	369	323	328	268
Average Delay (s)	23.65	27.57	25.65	28.06	38.27
TTI	1.6	1.59	1.62	1.59	2.07
PTI	1.66	1.63	1.7	1.63	2.16
Buffer Index	3%	2%	5%	3%	4%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	73.39	75.34	75.69	68.21	32.62
Average Traffic Flow (nr)	237	230	143	158	171
Average Delay (s)	40.57	42.27	40.73	42.62	20.11
TTI	2.17	2.19	2.1	2.55	1.32
PTI	2.28	2.28	2.21	2.69	1.44
Buffer Index	5%	4%	5%	5%	9%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1192.31	231.98	276.33	64.56
Large	LOS C	4667.04	908.04	1081.63	252.71

Appendix 3E: Bicycle Lane Implementation 10%

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	72.91	91.3	75.44	92.35	85.87
Average Traffic Flow (nr)	441	333	291	293	268
Average Delay (s)	36.87	47.91	37.09	48.20	52.81
TTI	1.96	2.04	1.90	2.03	2.49
PTI	2.16	2.19	2.12	2.2	2.79
Buffer Index	10%	7%	11%	8%	12%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	84.73	92.23	85	76.49	40.16
Average Traffic Flow (nr)	213	229	129	143	172
Average Delay (s)	51.96	59.15	50.05	50.91	27.65
TTI	2.5	2.68	2.35	2.86	1.63
PTI	2.77	3.03	2.6	3.05	1.83
Buffer Index	10%	13%	11%	7%	12%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1242.63	241.77	287.99	67.29
Large	LOS D	6755.75	1314.15	1567.30	364.74

Appendix 3F: Bicycle Lane Implementation 15%

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	72.19	90.33	74.3	91.01	85.83
Average Traffic Flow (nr)	415	314	277	276	267
Average Delay (s)	36.14	46.94	35.97	46.85	52.77
TTI	1.94	2.02	1.88	2	2.49
PTI	2.1	2.16	2.03	2.15	2.78
Buffer Index	8%	7%	8%	7%	11%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	83.08	91.98	84.2	78.3	40.08
Average Traffic Flow (nr)	202	229	121	135	171
Average Delay (s)	50.33	58.90	49.27	52.72	27.57
TTI	2.46	2.67	2.33	2.93	1.63
PTI	2.68	3.03	2.51	3.12	1.83
Buffer Index	9%	13%	8%	7%	12%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1280.29	249.10	296.72	69.33
Large	LOS C	6823.59	1327.62	1581.43	369.49

Appendix 3G: Bicycle Lane Implementation 20%

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	72.9	88.21	74.53	89.39	85.57
Average Traffic Flow (nr)	391	296	262	259	267
Average Delay (s)	36.85	44.82	36.20	45.23	52.50
TTI	1.96	1.97	1.88	1.97	2.49
PTI	2.13	2.11	2.05	2.1	2.83
Buffer Index	8%	7%	9%	7%	14%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	82.34	91.74	83.5	78.76	39.10
Average Traffic Flow (nr)	191	229	114	127	172
Average Delay (s)	49.58	58.66	48.56	53.18	26.59
TTI	2.44	2.66	2.31	2.95	1.59
PTI	2.65	3.05	2.48	3.2	1.75
Buffer Index	9%	15%	7%	9%	10%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1356.35	263.90	314.35	73.44
Large	LOS C	6957.72	1353.72	1612.52	376.75

Appendix 3H: Pessimistic Scenario Pedestrian Passage

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	67,65	74,81	76,32	75,74	75,71
Average Traffic Flow (nr)	572	427	366	379	310
Average Delay (s)	31,56	31,39	37,94	31,57	42,66
TTI	1,82	1,67	1,93	1,67	2,20
PTI	1,97	1,74	2,20	1,71	2,31
Buffer Index	8%	4%	14%	3%	5%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	84,02	79,99	87,59	73,64	33,24
Average Traffic Flow (nr)	280	272	163	181	198
Average Delay (s)	51,23	46,90	52,62	48,03	20,71
TTI	2,49	2,32	2,43	2,76	1,35
PTI	2,69	2,45	2,66	2,94	1,42
Buffer Index	8%	5%	10%	7%	5%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1771,55	344,68	410,57	95,93
Large	LOS C	5722,45	1113,38	1326,23	302,91

Appendix 3I: Optimistic scenario Pedestrian Passage

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	63,77	73,66	69,33	74,73	75,86
Average Traffic Flow (nr)	533	399	349	353	290
Average Delay (s)	27,60	30,17	30,85	30,50	42,42
TTI	1,72	1,65	1,75	1,64	2,20
PTI	1,78	1,71	1,85	1,71	2,35
Buffer Index	4%	3%	5%	4%	7%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	77,99	80,74	81,53	74,34	33,61
Average Traffic Flow (nr)	256	249	153	170	184
Average Delay (s)	45,13	47,28	46,49	48,45	20,94
TTI	2,31	2,34	2,26	2,78	1,37
PTI	2,40	2,55	2,36	3,04	1,46
Buffer Index	4%	9%	5%	9%	7%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1354,86	263,61	314,00	73,36
Large	LOS C	5253,71	1022,18	1217,60	284,48

Appendix 3J: Optimistic scenario 20% bikes

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	91,36	94,91	93,18	96,08	100,14
Average Traffic Flow (nr)	420	320	281	279	264
Average Delay (s)	55,27	51,44	54,79	51,85	66,67
TTI	2,46	2,12	2,35	2,11	2,91
PTI	2,95	2,31	2,89	2,28	3,56
Buffer Index	20%	9%	23%	8%	22%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	104,66	107,49	105,10	94,72	44,56
Average Traffic Flow (nr)	205	228	124	136	172
Average Delay (s)	71,85	74,03	70,10	68,85	31,91
TTI	3,10	3,12	2,91	3,54	1,81
PTI	3,77	3,80	3,53	4,26	2,16
Buffer Index	22%	22%	21%	20%	19%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1546,39	300,87	358,39	83,73
Large	LOS D	8506,94	1655,14	1971,57	460,64

Appendix 3K: Complete Model Baseline Conditions

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	56,56	66,25	59,61	66,86	71,28
Average Traffic Flow (nr)	441	332	292	292	268
Average Delay (s)	20,46	22,81	21,21	22,65	38,24
TTI	1,52	1,48	1,51	1,47	2,07
PTI	1,58	1,52	1,57	1,50	2,15
Buffer Index	4%	3%	4%	2%	4%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	68,93	74,31	70,62	65,87	32,59
Average Traffic Flow (nr)	214	230	129	143	171
Average Delay (s)	36,12	41,25	35,63	40,28	20,08
TTI	2,04	2,16	1,96	2,46	1,32
PTI	2,11	2,25	2,04	2,56	1,45
Buffer Index	3%	4%	4%	4%	9%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1244,54	242,14	288,44	67,39
Large	LOS C	4524,53	880,31	1048,60	245,00

Appendix 3L: Complete Model Pessimistic

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	60.61	68.27	65.06	68.96	74.26
Average Traffic Flow (nr)	514	384	336	340	312
Average Delay (s)	24.49	24.85	26.64	24.78	41.22
TTI	1.63	1.53	1.64	1.52	2.16
PTI	1.73	1.57	1.81	1.56	2.24
Buffer Index	6%	3%	10%	3%	4%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	73.08	78.61	76.08	69.68	33.12
Average Traffic Flow (nr)	247	270	149	164	198
Average Delay (s)	40.26	45.53	41.10	44.07	20.61
TTI	2.16	2.28	2.11	2.61	1.35
PTI	2.29	2.41	2.27	2.77	1.44
Buffer Index	6%	6%	7%	6%	7%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1526.49	297.00	353.78	82.66
Large	LOS C	5465.97	1063.48	1266.79	295.98

Appendix 3M: Complete Model Optimistic

Results	❷ => ❺	❺ => ❷	❶ => ❺	❺ => ❶	❻ => ❷
Average Travel Time (s)	58.22	67.09	61.22	67.75	74
Average Traffic Flow (nr)	422	319	281	279	290
Average Delay (s)	22.05	23.59	22.75	23.47	40.57
TTI	1.57	1.5	1.55	1.49	2.15
PTI	1.63	1.54	1.6	1.55	2.27
Buffer Index	4%	2%	3%	4%	6%
Results	❷ => ❻	❻ => ❶	❶ => ❻	❸ => ❺	❹ => ❻
Average Travel Time (s)	69.28	77.74	70.94	71.16	33.25
Average Traffic Flow (nr)	206	248	124	137	184
Average Delay (s)	36.43	44.30	35.89	45.27	20.59
TTI	2.05	2.26	1.97	2.66	1.35
PTI	2.12	2.39	2.06	2.96	1.45
Buffer Index	3%	6%	5%	11%	7%

Roundabout	LOS	Emissions CO (g)	Emissions NOx (g)	Emissions VOC (g)	Fuel consumption (liters)
Small	LOS A	1486.13	289.15	344.43	80.47
Large	LOS C	5384.80	1047.69	1247.98	291.58

Appendix 4: Comparison using confidence interval of the means

Appendix 4A: Comparison-traffic signal optimization

Congestion Index	Route/Roundabout	Initial Scenario		Improved Scenario 1		Confidence Interval	
Travel Time	❻ => ❷	Mean	90,47 s	Mean	88,42 s	CI1	4,33 s
		STD	9,9	STD	8,22	CI2	-0,22 s
	❺ => ❶	Mean	95,08 s	Mean	83,71 s	CI1	13,21 s
		STD	6,33	STD	4,50	CI2	9,54 s
	❹ => ❻	Mean	40,15 s	Mean	36,98 s	CI1	4,79 s
		STD	4,63	STD	2,41	CI2	1,53 s
Delay Time	❻ => ❷	Mean	57,41 s	Mean	55,37 s	CI1	4,32 s
		STD	9,91	STD	8.23	CI2	- 0,23 s
	❺ => ❶	Mean	50,93 s	Mean	39,56 s	CI1	13,24 s
		STD	6,36	STD	4,5	CI2	9,52 s
	❹ => ❻	Mean	27,64 s	Mean	24,48 s	CI1	4,8 s
		STD	4,64	STD	2,41	CI2	1,53 s
Emissions CO	Large	Mean	7108 g	Mean	6511 g	CI1	724,5 g
		STD	432	STD	303	CI2	469,7 g
NOx	Large	Mean	1383 g	Mean	1266 g	CI1	140,96 g
		STD	84,20	STD	58,99	CI2	91,39 g
VOC	Large	Mean	1647 g	Mean	1509 g	CI1	167,91 g
		STD	100,30	STD	70,27	CI2	108,86 g
Fuel Consumption	Large	Mean	385 g	Mean	352,5 g	CI1	39,23 g
		STD	23,43	STD	16,42	CI2	25,44 g

Appendix 4B: Comparison-no pedestrian

Congestion Index	Route/Roundabout	Initial Scenario		Improved Scenario 1		Confidence Interval	
Travel Time	❻ => ❷	Mean	90,47 s	Mean	71,32 s	CI1	23,15 s
		STD	9,9	STD	1,90	CI2	15,14 s
	❺ => ❶	Mean	95,08 s	Mean	72,25 s	CI1	25,40 s
		STD	6,33	STD	1,19	CI2	20,26 s
	❹ => ❻	Mean	40,15 s	Mean	32,62 s	CI1	9,28 s
		STD	4,63	STD	1,80	CI2	5,76 s
Delay Time	❻ => ❷	Mean	57,41 s	Mean	38,27 s	CI1	23,15 s
		STD	9,91	STD	1,93	CI2	15,13 s
	❺ => ❶	Mean	50,93 s	Mean	28,06 s	CI1	25,45 s
		STD	6,36	STD	1,20	CI2	20,29 s
	❹ => ❻	Mean	27,64 s	Mean	20,11 s	CI1	9,30 s
		STD	4,64	STD	1,78	CI2	5,76 s
Emissions CO	Large	Mean	7108 g	Mean	4667 g	CI1	2612,89 g
		STD	432	STD	120,95	CI2	2270 g
NOx	Large	Mean	1383 g	Mean	908 g	CI1	508,37 g
		STD	84,20	STD	23,53	CI2	441,66 g
VOC	Large	Mean	1647 g	Mean	1081 g	CI1	605,56 g
		STD	100,30	STD	28,03	CI2	526,09 g
Fuel Consumption	Large	Mean	385 g	Mean	253 g	CI1	141,49 g
		STD	23,43	STD	6,55	CI2	122,93 g

Appendix 4C: Comparison-bicycle 10%

Congestion Index	Route/Roundabout	Initial Scenario		Improved Scenario 1		Confidence Interval	
Travel Time	❻ => ❷	Mean	90,47 s	Mean	85,87s	CI1	7,78 s
		STD	9,9	STD	6,21	CI2	1,42 s
	❺ => ❶	Mean	95,08 s	Mean	92,35 s	CI1	4,48 s
		STD	6,33	STD	4,70	CI2	0,98 s
	❹ => ❻	Mean	40,15 s	Mean	40,16 s	CI1	1,45 s
		STD	4,63	STD	2,98	CI2	-1,47 s
Delay Time	❻ => ❷	Mean	57,41 s	Mean	52,81 s	CI1	7,79 s
		STD	9,91	STD	6,21	CI2	1,42 s
	❺ => ❶	Mean	50,93 s	Mean	48,20 s	CI1	4,5 s
		STD	6,36	STD	4,71	CI2	0,97 s
	❹ => ❻	Mean	27,64 s	Mean	27,65 s	CI1	1,46 s
		STD	4,64	STD	2,97	CI2	-1,48 s
Emissions CO	Large	Mean	7108 g	Mean	6805 g	CI1	411,82 g
		STD	432	STD	342,60	CI2	193,63 g
NOx	Large	Mean	1383 g	Mean	1324 g	CI1	80,13 g
		STD	84,20	STD	66,66	CI2	37,67 g
VOC	Large	Mean	1647 g	Mean	1577 g	CI1	95,44 g
		STD	100,30	STD	79,40	CI2	44,88 g
Fuel Consumption	Large	Mean	385 g	Mean	369 g	CI1	22,30 g
		STD	23,43	STD	18,55	CI2	10,49 g

Appendix 5: Switch from cars to bicycles and increase of cars for future scenarios

Appendix 5A: 10% Switch from cars to bicycles

B	C	D	E	F	G	H	I
Input	Initial	10% Decrease (90%*C)	Difference (C-D)	Total Cars (SUM E)	Ratio (E/$F$3)	Total People (F*2)	Total Bikes (G*$H$3)
Buzaului	720	648	72	311	0.232	622	144
Hipodrom	400	360	40		0.129		80
Viziru	1050	945	105		0.338		210
Lidl	520	520	0		0		0
Calarasi	940	846	94		0.302		188
Dorobanti	830	830	0		0		0

Appendix 5B: 15% Switch from cars to bicycles

B	C	D	E	F	G	H	I
Input	Initial	15% Decrease (85%*C)	Difference (C-D)	Total Cars (SUM E)	Ratio (E/$F$3)	Total People (F*2)	Total Bikes (G*$H$3)
Buzaului	720	612	108	467	0.232	933	216
Hipodrom	400	340	60		0.129		120
Viziru	1050	892.5	157.5		0.338		315
Lidl	520	520	0		0		0
Calarasi	940	799	141		0.302		282
Dorobanti	830	830	0		0		0

Appendix 5C: 20% Switch from cars to bicycles

B	C	D	E	F	G	H	I
Input	Initial	20% Decrease (80%*C)	Difference (C-D)	Total Cars (SUM E)	Ratio (E/$F$3)	Total People (F*2)	Total Bikes (G*$H$3)
Buzaului	720	576	144	622	0.232	1244	288
Hipodrom	400	320	80		0.129		160
Viziru	1050	840	210		0.338		420
Lidl	520	520	0		0		0
Calarasi	940	752	188		0.302		376
Dorobanti	830	830	0		0		0

Appendix 5D: Pessimistic Scenario (3% constant 5 years increase of cars and 10% switch to bicycles)

Two tables are included in this section. The first one shows the switch from cars to bikes including the formulas. The second one includes the increase for the 5 years taken into consideration. In this case for a 3% increase every year, it accounts to 116% (yellow highlighted section) which is used in the formula from column D.

B	C	D	E	F	G	H	I	J
Input	Initial	3% Increase for 5 years (c*116%)	10% Decrease (90%*D)	Difference (D-E)	Total Cars (SUM F)	Ratio (F/$G$3)	Total People (H*2)	Total Bikes (H*$I$3)
Buzaului	720	835.2	751.68	83.52	361	0.232	721.52	167.04
Hipodrom	400	464	417.6	46.4		0.129		92.8
Viziru	1050	1218	1096.2	121.8		0.338		243.6
Lidl	520	603.2	603.2	0		0		0
Calarasi	940	1090.4	981.36	109.04		0.302		218.08
Dorobanti	830	962.8	962.8	0		0		0

	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Total increase %	100	103	106.09	109.2727	112.5509	115.9274
Increase %/year	3%	3%	3%	3%	3%	3%

Appendix 5E: Optimistic Scenario (constant lower increase of cars for 5 years and 20% switch to bicycles)

Two tables are included in this section. The first one shows the switch from cars to bikes including the formulas. The second one includes the increase for the 5 years taken into consideration. In this case a smaller increase every year (0,5% smaller increase every year), accounts to 108% (yellow highlighted section) which is used in the formula from column D.

B	C	D	E	F	G	H	I	J
Input	Initial	Increase for 5 years (c*108%)	20% Decrease (80%*D)	Difference (D-E)	Total Cars (SUM F)	Ratio (F/$G$3)	Total People (H*2)	Total Bikes (H*$I$3)
Buzaului	720	777.6	622.08	155.52	672	0.232	1343.52	311.04
Hipodrom	400	432	345.6	86.4		0.129		172.8
Viziru	1050	1134	907.2	226.8		0.338		453.6
Lidl	520	561.6	561.6	0		0		0
Calarasi	940	1015.2	812.16	203.04		0.302		406.08
Dorobanti	830	896.4	896.4	0		0		0

	YEAR 0	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5
Total increase %	100	102.5	104.55	106.1183	107.1794	107.7153
Increase %/year	3%	2,5%	2%	1,5%	1%	0,5%