EVALUATION OF THE EFFICIENCY OF MAINLINE AND RAMP METERING IN HIGHWAY TRAFFIC MANAGEMENT

GÜZEM YARAN
B.S., Civil Engineering, IŞIK UNIVERSITY, 2017

Submitted to the Graduate School of Science and Engineering
in partial fulfillment of the requirements for the degree of
Master of Science
in
Civil Engineering

IŞIK UNIVERSITY
2020

IŞIK UNIVERSITY
GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

EVALUATION OF THE EFFICIENCY OF MAINLINE AND RAMP METERING IN HIGHWAY TRAFFIC MANAGEMENT

GÜZEM YARAN

APPROVED BY:

Assist. Prof. Ali Sercan KESTEN (Thesis Supervisor)	Işık University	________________
Prof. Dr. Ali Osman ATAHAN	I.T.U.	________________
Assist. Prof. Önder UMUT	Işık University	________________

APPROVAL DATE: .../.../2020

EVALUATION OF THE EFFICIENCY OF MAINLINE AND RAMP METERING IN HIGHWAY TRAFFIC MANAGEMENT

Abstract

In the study, the effects of the mainline and ramp control theories on the highway traffic flow are investigate. In order to eliminate to alleviate the traffic congestion problem, which has become a problem in high-population cities, the mainline and ramp controls are considered as a solution, and control networks are emphasized. Examples of applications and results in the world are given. The applicability of the methods to be used by examining the previous studies was first examined on a general model and then on a selected highway network. In the models prepared, vehicle speeds, travel times, flow (volume) concepts, and relationships between them are mentioned. In addition, general information about highway management was also provided before. Control models were examined with the Microscopic Simulation Program, the purpose and types of models applied were compared. The traffic simulation model of the region between K-8 and K-11 on the O-2 highway from Asia to Europe has been created and the effects created by the control have been examined by applying both ramp and mainline metering. Analysis results; It has been observed that the control of ramp and mainline scenarios provides benefits compared to uncontrolled situations. Among the benefits provided; when the analysis of the basic model and mainline metering is applied, it is seen that there is an increase of 20.76% in travel times and an increase of 19.78% in vehicle speeds. Nevertheless, the implications of these control scenarios should be thoroughly investigated. Simulation results show that Ramp Metering (RM) and Mainline Metering (MM) controls can be an effective method in the management of highway-highway connections. In this regard, it is recommended that the control strategies mentioned in intensive highway-to-highway participations be tested in real life in order to increase efficiency.

Keywords: Ramp Metering, Mainline Metering, Traffic Congestion

EVALUATION OF THE EFFICIENCY OF MAINLINE AND RAMP METERING IN HIGHWAY TRAFFIC MANAGEMENT

Özet

Hazırlanan çalışmada ana yol ve katılım kontrol teorilerinin otoyol trafik akımı üzerindeki etkileri araştırılmıştır. Yüksek nüfuslu şehirlerde bir problem haline gelen trafik tıkanıklığı sorunu, geçiş sırasında oluşan tıkanıklığın ortadan kaldırılması ya da hafifletilmesi amacıyla ana yol ve katılım kontrolleri bir çözüm olarak görülmekte olup kontrol şebekeleri üzerinde durulmuştur. Dünyadaki uygulamalar ve sonuçlarından örnekler verilmiştir. Önceki çalışmalar incelenerek kullanılacak metotların uygulanabilirliği öncelikle genel bir model üzerinde sonrasında da seçilmiş bir otoyol ağı üzerinden uygulanarak incelenmiştir. Hazırlanan modellerde yol ağı ile ilgili araç hızlarına, seyahat sürelerine, akım (hacim) kavramlarına ve aralarındaki ilişkilere değinilmiştir. Ayrıca otoyol yönetimi ile ilgili genel bilgiler de öncesinde sunulmuştur. Kontrol modelleri Mikroskobik Simülasyon Programı ile incelenmiş, amacı, uygulanan model çeşitleri kıyaslamalı olarak anlatılmıştır. Asya Avrupa yönünde O-2 otoyolunda K-8 ile K-11 arasında kalan bölgenin trafik benzetim modeli oluşturulmuş ve hem katılım hem de ana yol kontrolü uygulaması yapılarak, kontrolün yarattığı etkiler incelenmiştir. Analiz sonuçları katılım ve ana yol senaryolarının kontrolünün, kontrolsüz durumlara göre fayda sağladığı görülmüştür. Sağlanan faydalar arasında temel model ve ana yol kontrolünün uygulandığı analizler karşılaştırıldığında; ana yol kontrolünün seyahat sürelerinde % 20,76 kazanç ve araç hızlarında ki % 19,78'lik yükseliş sağladığı görülmektedir. Bununla birlikte, bahsi geçen kontrol senaryoları uygulandığında doğuracağı sonuçlar kapsamlı bir şekilde araştırılmalıdır. Yapılan simülasyon sonuçları katılım (RM) ve anayol (MM) kontrollerinin Otoyol-otoyol bağlantılarının yönetiminde etkili bir yöntem olabileceğini göstermektedir. Bu doğrultuda, verimlilik artışı sağlamak üzere yoğun otoyol-otoyol katılımlarında bahsi geçen kontrol stratejilerinin etkinliğinin gerçek hayatta da sınanması önerilmektedir.

Anahtar kelimeler: Katılım Kontrolü, Ana Yol Kontrolü, Trafik Tıkanıklığı

Acknowledgements

During the execution of this study, my advisor, who has a very special place since the undergraduate period, is Assist. Prof. Ali Sercan KESTEN, thank you for the help and support. I would like to thank my mother Suna Berrin, my father İrfan, my brother Ph.D. Candidate Mehmet Özgür YARAN and my aunt Sevim ODABAŞ who supported me in my intensive and stressful graduate education process and Dr. Sinan SARGIN who was with me both in academic and business life, also Dr. Ehsan ETMİNAN, who has supported this entire graduate process and played a role in completing this process without giving up. Finally, representing the family of EMAY Engineering Consulting Inc. which prioritizes the training of its staff; I would like to thank the Superstructures Coordinator Ali BOZ and my unit supervisors Tülay ŞENGEZER and Ahmet YÜCESOY.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

Q_{MD}	Mainline Downstream Volume
Q_M	Mainline Volume
Q_R	Ramp Volume
G_{TRamp}	Green Time Ramp
C_{TRamp}	Cycle Time Ramp
C_{TM}	Cycle Time Mainline
BC	**B**ase **C**ase
RMC	**R**amp **M**etering **C**ontrol
MLC	**M**ain-**L**ine Metering **C**ontrol
EDS	Turkish translation for "Electronic Violation Detection System"
O-2	Istanbul Outer Bellway
AIMSUN	The Integrated Transport Modelling Software
VSL	**V**ariable **S**peed **L**imit
HCM	**H**ighway **C**apacity **M**anual
ALINEA	French for "Linear Utilization for Highway Entrances"
ITS	**I**ntelligent **T**ransportation **S**ervices
LOS	**L**evel **o**f **S**ervice

Chapter 1

Introduction

The massive development of human communities, the growth, and crowd of cities cause a numerical and temporal increase in the daily commute, which means business and commercial centers from the city's surroundings to the city center. There are many metropolises that do not have correct signaling at junctions or connecting roads. These signaling problems cause many problems such as high travel times, delayed appointments and time losses, harmful emission gases emitted to the environment due to psychological disturbances for drivers, noise, stopping and starting and pause.

NUMBEO publishes statistical reports every year about the quality of life of cities. According to the research in the global quality of life 2019 report, Bursa, Izmir, Ankara, and Istanbul are included in this report [1]. The cities subject to the study are examined in terms of traffic, purchasing power, and cost of life and air pollution. Istanbul, which ranks 183rd among 226 cities in terms of quality of life, is the 12th city with the most traffic index.

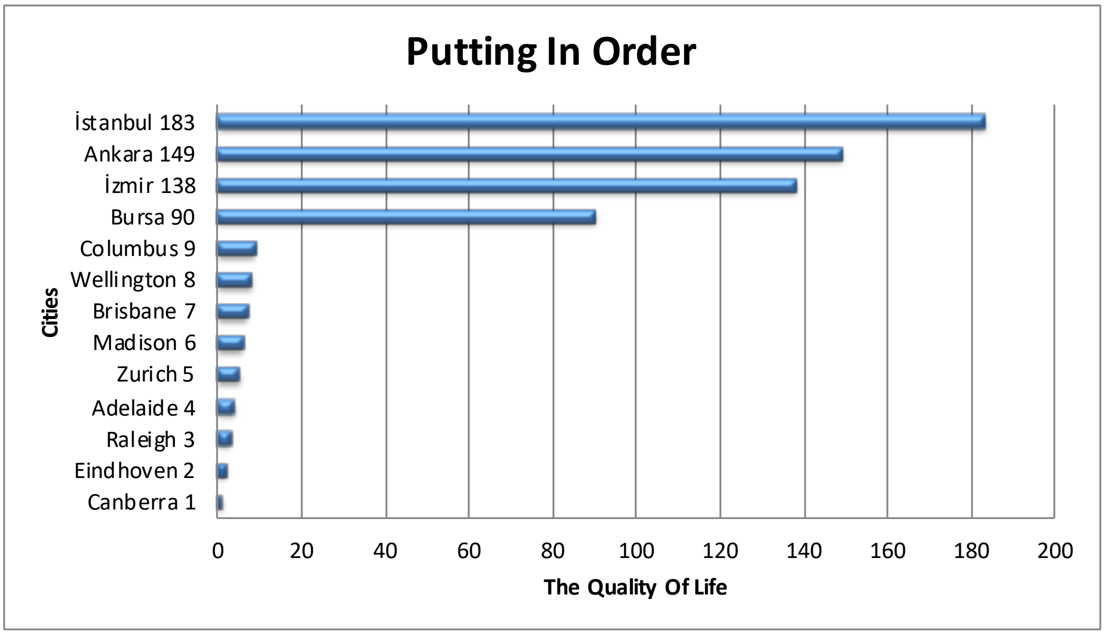

Figure 1.1: NUMBEO, Statistical Report Data On The Quality Of Life Of Cities [1].

Rank	Country	Traffic Index	Time Index	Time Exp. Index	Inefficiency Index	CO2 Emission Index
1	Nigeria	308,03	61,08	17169,05	521,62	8664,11
2	Sri Lanka	293,36	59,01	14627,68	495,15	8308,2
3	Kenya	274,71	56,65	12039,3	290,75	8332,78
4	Bangladesh	255,21	56,73	12120,25	320,18	4969,07
5	Egypt	240,72	49,78	6207,28	295	9021,61
6	Iran	220,43	48,01	5086,37	240,39	7325,43
7	Peru	214,86	48,33	5274,72	263,59	6032,61
8	India	207,52	46,99	4499,49	243,01	6062,42
9	Philippines	198,84	44,63	3314,83	248,96	6538,48
10	Colombia	198,41	47,49	4781,38	213,61	4509,33
11	Jordan	196,77	42,03	2263,9	222,67	8507,33
12	Turkey	195,21	44,65	3322,85	213,33	6133,12

Table 1.1: NUMBEO, Statistical Report Data On The Quality Of Traffic Index [1].

In addition, when the travel time between the home and work or school for the traffic index is calculated by taking into account the surveys made with individuals, the average time for 'one way' for Istanbul is determined as 52 minutes and ranks 11th. In this ranking, several main methods have come to the fore in order to be in better places and to improve traffic. Ramp metering is one of these methods that aim to correct the flow by controlling the ramp with a signal. Another is speed control, which is widely applied to prevent shock waves in traffic. There may be some doubts that speed restrictions will not work in Istanbul because there is a tendency to violate speed restrictions in Istanbul. However, there are some studies showing that the use of EDS significantly reduces the violation [2].

Traditional traffic solutions such as geometric arrangements and static solutions based on static counts are among the most important solutions on a daily basis. On the other hand, computer simulation is the main method used to conduct scientific research and solve really difficult problems. Traffic simulation is an important application of computer simulation technology in the field of traffic engineering. In this thesis, traffic theories are introduced on a macro scale that is basically the basis of most simulation studies and control strategies.

Then, the relationship between the traffic variables is shown and the flow theories based on the hydraulic model are analyzed and shock waves, the main cause of traffic jams, are shown analytically. In addition, in this study, the description of macro-micro-mesoscopic simulation models has been made and the general literature summary of the control structure that makes the model prediction used in the application is summarized. Then, by introducing ramp metering control approaches, the vehicle combinations that will be entered in the simulation program for participation and the mainland are tried to be determined.

In order to achieve success in this field, With "AIMSUN" software, I first determined different joining capacities and service levels and identified 3 different densities and different green time control designs. As a result, alternative solutions that provide the necessary conditions have revealed methods with an optimum solution. and the highest applicability, and then I applied it to the O-2 region, a region I always use and know.

A fact well known to have Turkey has an emerging economy in recent years and in parallel with this situation, there is a rapid increase in the number of vehicles. According to the 2019 data, the number of vehicles registered to traffic has scaled up to 20 million 456 thousand 556 and this circumstance causes some important problems especially about local traffic [3]. Istanbul is the 9th most traffic-congested city of the world and 2nd most traffic-congested city of the Europe.

TOMTOM Traffic Index 2019

#	World rank	City	Country	Congestion level
1	6	**Moscow region (oblast)**	Russia	**59%** ↑ 3%
2	9	**Istanbul**	Turkey	**55%** ↑ 2%
3	12	**Kyiv**	Ukraine	**53%** ↑ 7%
4	14	**Bucharest**	Romania	**52%** ↑ 4%
5	16	**Saint Petersburg**	Russia	**49%** ↑ 2%
6	17	**Dublin**	Ireland	**48%** ↑ 3%
7	18	**Odessa**	Ukraine	**47%**
8	19	**Lodz**	Poland	**47%** ↑ 3%
9	22	**Krakow**	Poland	**45%** ↑ 5%
10	23	**Novosibirsk**	Russia	**45%** ↑ 1%

Figure 1.2: TomTom Traffic Index, Congestion Level Table [4].

Also, Istanbul's congestion level is 55% It means people spend the time that half of the time in travel is the lost time in traffic. This is such an amazing for traffic data [4]. Considering the fact that almost 250,000 vehicles travel daily from O-2 path on average, the general purpose of this project is to determine the bottleneck of this corridor, to analyze the current level of service and establish better for a trip that making ramp metering control design. Although the benefits to be achieved in this area are limited to a local control zone, I think the proposed control approach can be applied in other parts of the network.

Chapter 2

Literature Review

Increasing transportation demand and the traffic problems it brings are among the most important problems of today's world metropolises. Even if the solution to these problems should be used efficiently of the urban roads that will be built in the first place, how to use the roads in the second phase most efficiently is a much more prominent solution. When junction areas on highways are associated with major traffic jams and traffic collapse sources and cause turbulence to increase due to lane change; starting these problems from the right side of the mainline causes the ramp vehicles to produce excessive weaving maneuvers and then spread over the entire lane. After encountering a problem, shock waves and long tails will appear. This situation will arise in environmental problems. Given all the problems and tails, it can be considered that a low-cost effective can save a lot of money.

2.1 Traffic Congestion

Traffic congestion is a severe and growing problem. Traffic congestion is a condition of transport that is characterized by slower speeds, longer trip times, and increased vehicular queuing. Traffic congestion on urban road networks has become increasingly problematic since the 1950s.

In the states of many countries (Ex: Minnesota and California), some examples of highway to highway ramp metering are examined and the advantages and disadvantages of highway to highway ramp metering are discussed. To reduce increased congestion and improve road safety, state transport departments have developed some innovative strategies to optimize the efficiency of congested highway sections. Such strategies are highway-to-highway ramp metering and mainline metering.

In Sun [5], a new switching traffic sensitive ramp metering controller that adapts to different features is presented using the multi-rate LQI approach. In addition, a PI tail length regulator design was used to prevent the queue during ramp from exceeding storage capacity and to provide improved performance on the "queue override" scheme. The proposed strategy has been developed to reduce congestion space and time coverage using available information. In this context, while total vehicle delay decreased by 7.7%, total vehicle delay was observed to decrease by 5.7% in-vehicle time in CTM traffic simulator.

The research of Hampton Roads Bridge-Tunnel, one of Southeast Virginia's most important facilities, has been conducted, by Stairs [6]. And this tunnel says that Hampton Roads Port provides the only interstate connection, until July 1983, delays of up to 2 hours is experienced. This means that cars overheat and increase carbon monoxide (CO) levels in the tunnel. Therefore, in August 1983, a hand-controlled baseline metering was initiated. This type of metering consists of stopping traffic and is designed by releasing traffic when the tunnel is cleared from the traffic and when the CO level decreases when the vehicles in the tunnel slow down to 24.2 km / h (15 mph) or less. In any case, the detained vehicles were caught on vehicles that were not detained before reaching the opposite shore. In reality, drivers who were detained 5 to 8 minutes before entering the tunnel reached the time they had if they were not detained. Various benefits were obtained from the mainline metering. Such as Lower CO levels and less ventilation required, lower tunnel temperatures and less downtime caused by overheated vehicles, free-flow traffic for longer periods and shorter time and length traffic backups with better efficiency. This type of mainline metering considers the author to be one of the most effective methods of managing bridge-tunnel-bridge traffic during periods of intense congestion. It was also stated by the author that the manual metering of the mainline metering could not be continued due to complaints of the driver stopping before entering the tunnel [6].

2.2 Demand Control

In many countries, traffic emissions have gained great importance due to the increasing number of vehicles over the past two decades. Therefore, traffic emissions have become the main source of air pollution in urban areas where violations of European Union (EU) limit values often occur. To reduce these emissions, local traffic measures can be implemented to complement regional and national measures. Measures include traffic demand control, Heavy Duty Vehicles (HDV) prohibition, speed limitation and Adaptive Cruise Control (ACC). According to the research conducted by Mahmod [7], it was found that reducing the traffic demand by 20% caused a decrease of 23% in terms of CO2, NOx and PM10 emissions. Banning HDVs led to a significant reduction in NOx and PM10 emissions. Although the speed restriction reduces CO2 emissions by 7%, both NOx and PM10 emissions increased, especially from HDVs. ACC reduced both CO2 and NOx by 3%, but it was found to increase PM10 by 3% [7].

Ghiasi [8]; He performed a series of simulation analyzes on a section of the I-35 highway in Kansas City, KS, using a calibrated VISSIM network to evaluate algorithm performance under different traffic conditions and parameter settings. It states that it has developed a dynamic signal control algorithm that can be applied for an integrated ramp and mainline metering strategy. He talks about the problems caused by the merger of a highway and how he can solve the traffic jam in the mainline with the dynamic signal control algorithm. In the main signaling models, for security reasons, the proposed algorithm argues that signal control cannot be activated unless the traffic speed on all the main lines falls below a safe speed threshold (set to 10 kilometers/hour in our experiments). As a result of his analysis, he concluded that there was a maximum 15: 7% improvement in average speed, a 20: 9% reduction in average delay and a 13: 7% reduction in CO emissions. Finally, he suggested that with some future improvements in the Forecast algorithm, better results can be achieved with fewer traffic sensors to achieve more cost-effective solutions.

2.3 Traffic Control Strategies

2.3.1 Control Logic

Control logic of the approach used in the research:

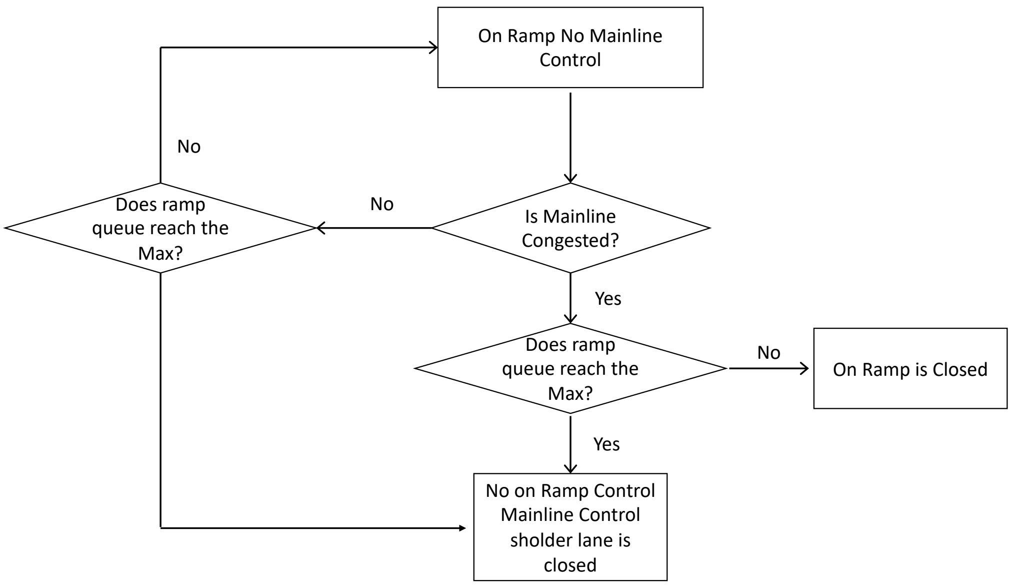

Figure 2.1: Control Logic of the on Ramp and Mainline [9].

In particular, it starts by evaluating whether the baseline is blocked. For this, data is collected from the detectors located in the upstream mainline. From this data, it allows us to see the occupancy rate and travel speed and whether the queue on the ramp has reached the queue. In addition, these values differ according to the data collected by the detectors at the end of the ramp.

While there is a blockage in the mainline, the queue during the ramp may not reach its maximum value. In this case, it is temporarily closed on the ramp to eliminate the main blockage. If the tail on the ramp reaches the maximum level, the shoulder strap of the mainline is closed. This action is considered to have a larger capacity for storing tails in the mainline, and pouring it over the queue on the ramp can cause serious problems for ground streets. But this method is done to eliminate the ramp tail. This process can be repeated if a long tail appears on the ramp and there is no blockage in the mainline. In this control logic, the time it takes to repeat processes, that is, the repeated loop is not constant. Cycle time calculated as a variable. When a cycle has ended, a new cycle will be calculated, starting a new process, and control action accordingly so that real-time traffic status and feedback can be received.

The above control logic and algorithm are realized through the AIMSUN program. Using simulation, the performance of the highway corridor under two control strategies is compared to the control approach not only on the ramp but on both the mainline and the ramp. While performing the ramp control, a local feedback ramp metering strategy, ALINEA algorithm, was used. This is an extremely simple, highly efficient and easily implemented simulation algorithm. While controlling both the mainline and the ramp, the algorithm designed by this study was applied. AIMSUN data entry instructions and default model parameters are provided. The data collected includes highway traffic volume, speed, travel time and congestion, etc. contains data. Finally, the simulation network has been installed and calibrated. System performance values were obtained after adding the signal control module. The volume results and movement behavior parameters calibrated in AIMSUN are examined in the conclusion section, respectively.

2.3.2 Metering

It is observed in studies that a potentially cost-effective solution to the highway joining bottleneck problem is to develop an effective signal control strategy to reduce friction between the mainline and the junction traffic, and one of the well-known approaches in this category is to use ramp metering using input ramp traffic [8, 10].

Even if the work is done is successful in reducing the weaving, the friction that can occur between the mainline and the ramp traffic can be such a measure that some over-saturated traffic conditions in the mainline may require a more effective approach to maintain the approach. Improvements that may occur as soon as traffic flows into the current downstream queue and when the bottleneck traffic speed is allowed to improve are revealed as a result of many studies [8]. Numerous studies have been conducted to design and implement ramp metering approaches to mitigate freeway bottlenecks.

Considering that in the research supported by the Chinese National Science Fund [9], the highway mainline not only has high speed but can also store a large number of vehicles, this research proposes a new approach to control both the ramp and the highway on the mainline. This approach is based on the Local ramp metering strategy ALINEA, using the Traffic simulation software VISSIM. It controls the vehicles of the ramp and the mainline, thereby aiming to optimize the vehicle storage capacity of the mainline and also reduce the highways travel time and ramp sequence. This strategy is particularly useful for situations where there is no large gap between the ramp and the importance of the mainline. This is the average travel time of the algorithm proposed by this study, the average delay of the mainline and ramp vehicles, the average tail length on the ramp and the number of stops on the ramp on the mainline and ramp (real lines in any way), network performance, especially ramp vehicles. For its delay and tail, it was found to be better only when controlled on the ramp (dashed lines in any way). In simulations, it uses the capacity of the mainline to accommodate a large number of vehicles to reduce the loss of vehicles on the ramp, therefore it is concluded that it is particularly suitable for use in situations where the ramp's position in the entire traffic network is very important compared to the mainline [9].

2.3.2.1 Ramp Metering

Ramp Metering is a control mechanism to optimize traffic downstream of a highway with a signal on the ramp. There are three main purposes of using ramp metering. Controlling the number of vehicles allowed on the highway, reducing downhill highway demand and reducing congestion by reducing the likelihood of vehicle weaving.

Local ramp metering is a control system that deals with an isolated highway section rather than the entire network. Some local ramp metering strategies are summarized in four types. Demand Capacity In the control system, the metering speed is determined by upstream volume and downstream capacity. The difference between band flow volume and downstream capacity determines the metering rate for the next cycle. In the Upstream Occupancy Control system, real-time occupancy on the ramp is used to determine the metering rate for the next cycle. For Gap Acceptance Control; the occupancy metering's from the upstream of the ramp are measured to determine the metering rate. For Closed Circuit Local Control Strategies, the system output is fed back and the input is changed according to the output [11, 12] .

One of the two lanes at the facility at the location shown in I5-I110 southbound interchange in Los Angeles had to be closed due to regular rocks. In Los Angeles, where many typical ramp metering installations were operated during this period and beyond, a serious bottleneck was avoided despite the fact that there were highway ramps measured at only a few intersections, and it is obvious that they played a big role in the absence of long queues and waiting times [5].

The system is a control system that takes into account a network with wide ramp metering, various consecutive or coordinated ramps. Improving traffic at a highway junction may not be sufficient for relaxation across the entire network. It may also be harmful to other consecutive segments. Therefore, the entire network should be considered when optimizing traffic.

2.3.2.2 Mainline Metering

Highway mainline metering involves checking the amount of traffic entering a highway segment to allow better movement downstream of the control area. Generally, this method appears to have been successfully applied to bridges and tunnels. However, there are not many studies that apply this application to a typical urban highway system. It is being explored whether regulation of major vehicle movements can also improve highway operations without a bottleneck. The mainline metering evaluation is based on various mainline volume and control conditions on the ramp. The results will show how mainline metering affects highway operations downstream of the mainline counter. The main factor will show how it will affect the total delay for vehicles resulting from the upstream of the measuring location. The main goal here is that it can be achieved without increasing. In addition, it is aimed that the vehicles accessing the highway from the measured ramps downstream of the meter to the mainline do not enter a congested highway mainline, thus reducing the total travel time [10].

Chapter 3

Methodology

3.1 Traffic Flow Modelling

In the basic model simulation project that is the subject of my study, ramp and mainline metering control of the literature related to the microscopic simulation design of traffic flow control has been done. This study is for the subject area K-9 and K-10 intersections of the O-2 road. Trying to find a solution to the problem of congestion, this is the main purpose of the study, by assigning different scales and different control algorithms to the model during the researches. To achieve this goal, intensity flow, speed management approaches, different green time periods, and the tasks assigned to the main route routes with connections were tried. These control approaches are made dynamically based on traffic data. Performance indices such as total travel time, flow in one segment, the density of one segment, the average delay of vehicles, and the number of stops per vehicle were shown to see the effectiveness of the approaches.

In the 1970s, a project titled "Traffic Flow Study in a Restricted Facility" was launched and the Baltimore Harbor Tunnel was used to analyze the concepts of traffic flow theory. One of the control strategies was the effects of a predetermined baseline measurement system above the entrance to the tunnel and below the tunnel-through plaza. Traffic signals are positioned above the tunnel portal and predetermined metering scenarios for 2, 3, and 4-minute cycle lengths are evaluated. When measured, the red time ranged from 7 to 10 seconds, and the amber time ranged from 3 to 5 seconds. And the vehicle speeds when passing through the measurement point of the Drivers are determined as 32 to 40 km / h (20 to 25 mph). (Footnote: Signals are always green when no measurement is taken.) This application has caused the speeds to increase in the tunnel bottleneck and also the flow rate in the tunnel to increase. Based on the velocity flow curves developed before and after the metering process, it was stated that the study did not continue the baseline metering operation due to the lack of support for this study, which has been found to have the potential to increase the capacity per strip of the metering system by approximately 10 percent of the uncontrolled condition [13].

3.1.1 Traffic Flow- Variables- Density-Flow-Speed

Traffic density is the number of vehicles on the highway per unit distance. They interact with factors such as traffic variables and driving behavior, weather, and information technology. A brief description of the traffic variables is required to explain the traffic flow. Traffic flow can be defined in two main types. Understanding what kind of flow occurs in a given situation will help you decide which analysis methods and descriptions are most relevant.

The first type is a continuous flow and is regulated by vehicle-vehicle interactions and interactions between vehicles and the road. Vehicles traveling on an interstate highway are examples of uninterrupted flow. The other type of traffic flow is intermittent flow. The interrupted flow is regulated in an external way, such as a traffic signal. Under intermittent flow conditions, vehicle-vehicle interactions and vehicle-road interactions play a role in defining traffic flow.

Generally, traffic flows vary both by area and time. Therefore, the measurement of the relevant variables for the traffic flow theory is actually sampling a random variable. In traffic engineering, these are called the trajectories of vehicles [14]. On the other hand, in LWR Theory, these are the features of the solution of the wave function [15]. These variables are important in defining macroscopic variables with traffic density, speed, and flow.

The average number of vehicles, expressed by vehicles per mile or kilometer, occupying one mile or one kilometer road area, defines us the density. Due to the level of difficulty that may occur during the metering of the density, the fullness of the detector in a certain area or using this ratio will give better results.

Flow rates are generally expressed in terms of vehicles per hour, although the actual measuring range is much less. Flow rates are collected directly through point measurements and, by definition, require metering over time. They cannot be predicted from the image of the road length taken in a single moment. Flow rates and time titles are related to each other as in the formula. Flow rate, q, is obtained by dividing the number of vehicles counted by the elapsed time [16].

3.1.1.1 Traffic Simulation (Macro-Micro-Meso Simulation)

Simulation plays an important role in traffic modeling and planning. Traffic simulations are based on three basic models and classified according to the given input. If traffic does not change over time, such simulations model the steady-state average traffic conditions with a statically dispersed state; If traffic changes over time, it models the variant structure of such traffic and is dynamically expressed. Another classification of traffic models is defined as statistical perspectives. If the simulations show the same output on each run, this is called deterministic modeling of traffic. The last and most important classification of traffic is detail classification.

Based on two assumptions that no cars were lost or suddenly appeared on a conservative road. Various models are then proposed, which are similar to gas dynamics and represent multiple regimes. Simulations based on these theories are called macroscopic simulations. In these simulations, the level of detail is limited, and since the traffic parameters are roughly handled, the need arises for the separation of time and space [17, 18].

Unlike macro models, microscopic traffic models are related to individual vehicle movements. In this study, it is necessary to emphasize that a microscopic simulation environment is used to test macroscopic theories related to traffic flow. The fact that control algorithms are based on macroscopic theories results from the field applications of control algorithms on a macro scale. Because there is no solution for controlling individual vehicles for today. The most known microscopic traffic model is the linear car tracking model. The answer is based on the basic Newtonian theory of physics law, which is equal to the stimulus. In reality, however, there is a sense of sensitivity between the stimulus and the response that makes the word "equal" in this theoretical proposition "proportional" [19]. In meso simulations, vehicles are modeled individually. However, unlike the microscopic simulation, the overall behavior of the tools is considered on the links. It is based on the spread of the vehicles shown in Figure 3.1 through the cells.

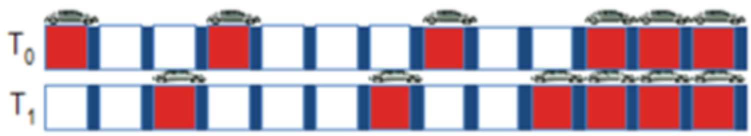

Figure 3.1: Vehicle Propagation based on Cell Automata Traffic Flow Model [20].

3.1.2 Simulation Model Methodology

Methodologically, simulation is a useful technique to provide an experimental test-bed to compare alternative system designs, and experiments on the representation of a computer in terms of a simulation model are used instead of experiments in the physical system. The results of the computer experiment thus provide decision-makers with a basis for quantitative support. The simulation model aims to draw valid conclusions for the real system. And it can give the impression of a computer lab by experimenting on a system model and can be used to answer questions. So, assuming that the System model over time accurately mimics the evolution of the system model over time, information is collected about the relevant observational variables that can draw conclusions about system behavior using statistical analysis techniques. Figure 3.2 illustrates this methodology conceptually.

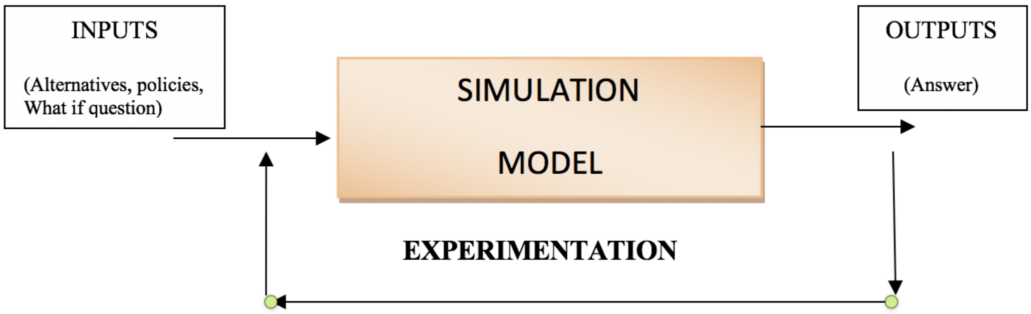

Figure 3.2: System Behavior Model [21].

Reliability in the decision-making process depends on the ability to produce a simulation model that represents system behavior in order to use the model for experimental purposes for real purposes. It also applies to traffic simulation, which is valid for simulation analysis. The process of determining whether the simulation model is close enough to the real system is usually achieved through an iterative process that involves the calibration of the model parameters and compares the model with the actual system behavior. To develop the model, discrepancies between the two and those obtained are used until the accuracy is considered acceptable.

Validation of a simulation model is a concept that needs to be taken into account during the model duration created. As a first step, the problem is formulated, and requirements are determined to find the solution. Necessary controls are made. When it is assumed that the designed computer program is working properly and without errors, experimental sampling procedures are determined. Finally, simulation experiments are carried out and analyses are obtained.

Methodological process diagram;

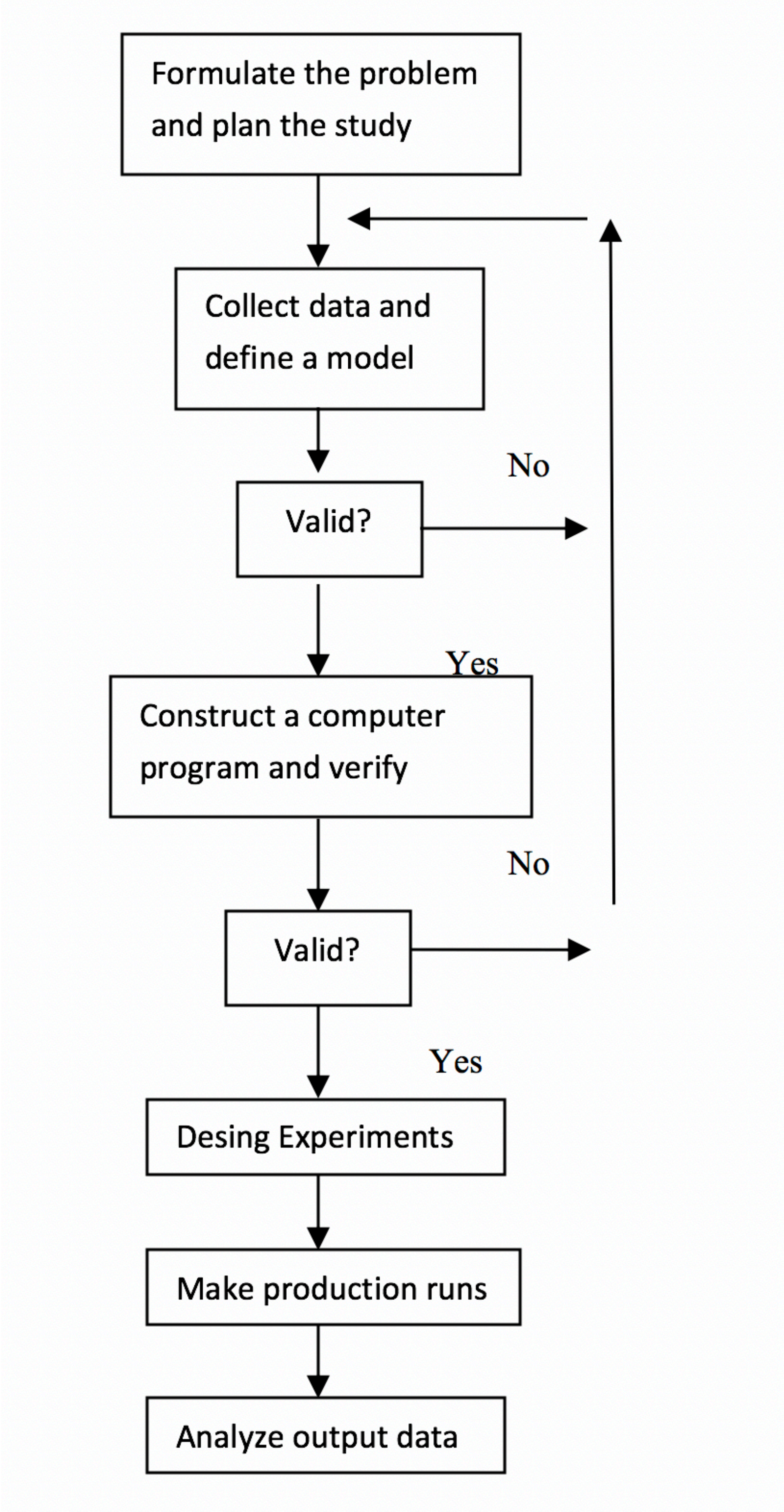

Figure 3.3: Methodological Process Diagram [22].

The abstraction of reality, the natural system under study, is the process of acquiring knowledge of the primary system or conceptual model first.

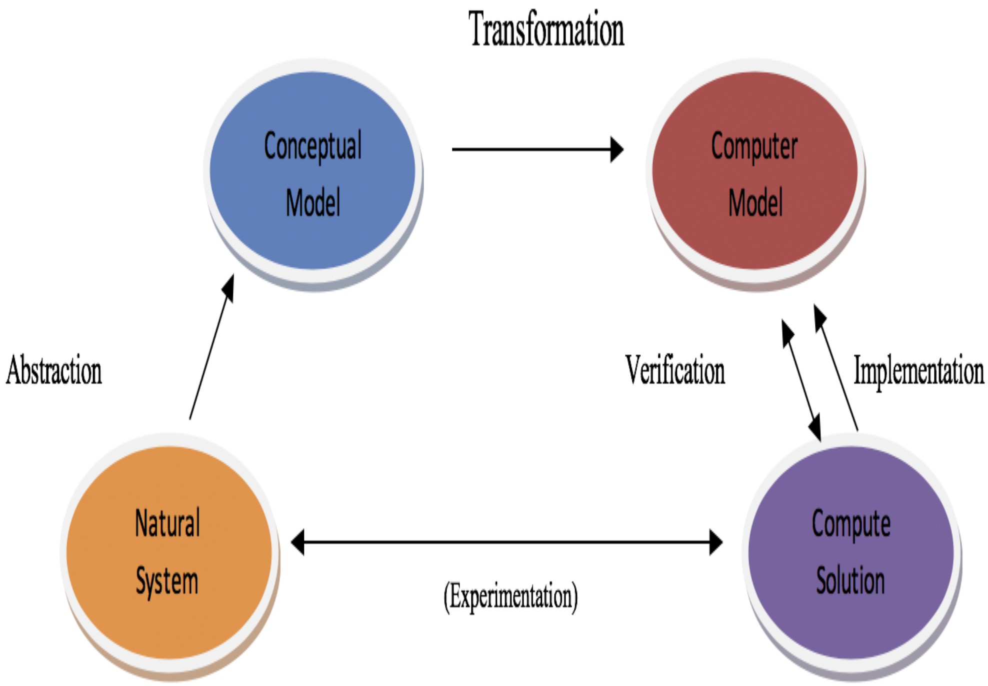

Figure 3.4: Basic conceptual steps in model building and using process [22].

Thus, creating error-free computer models can be implemented and executed to provide solutions that will later become the object of the final verification. The final verification exercise often includes a comparison with the observed reality. The approved computer model can then be used to perform simulation experiments that will answer questions about system behavior under various design alternatives that configure experimental scenarios.

3.1.2.1 Simulation Modeling and Software (Calibration)

First, a section is created in the desired model from the toolbar on the left.

Figure 3.5: The First Stage Creating Model.

While creating detectors; It is necessary to place the detector in the network as shown in the picture.

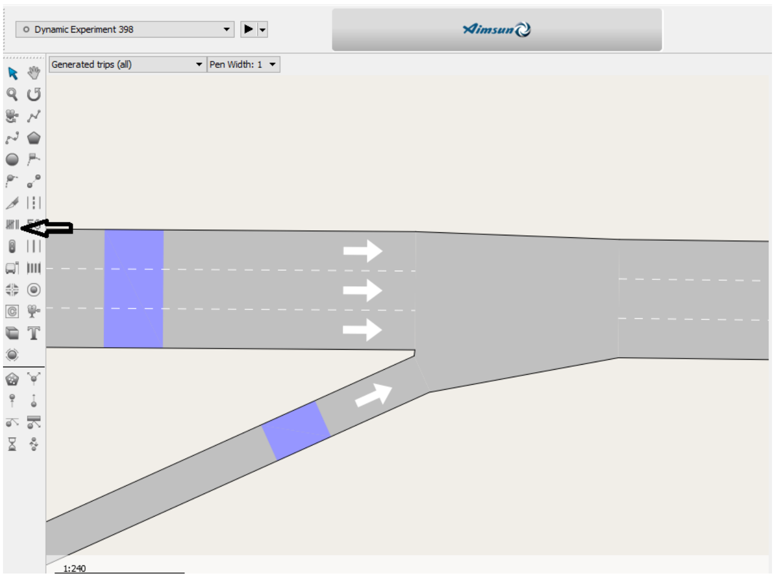

Figure 3.6: Creating Detector.

Press the icon to place a detector and pressed it to the desired place in the desired section again. Then double click on the detector to set its name and properties as shown in the next picture.

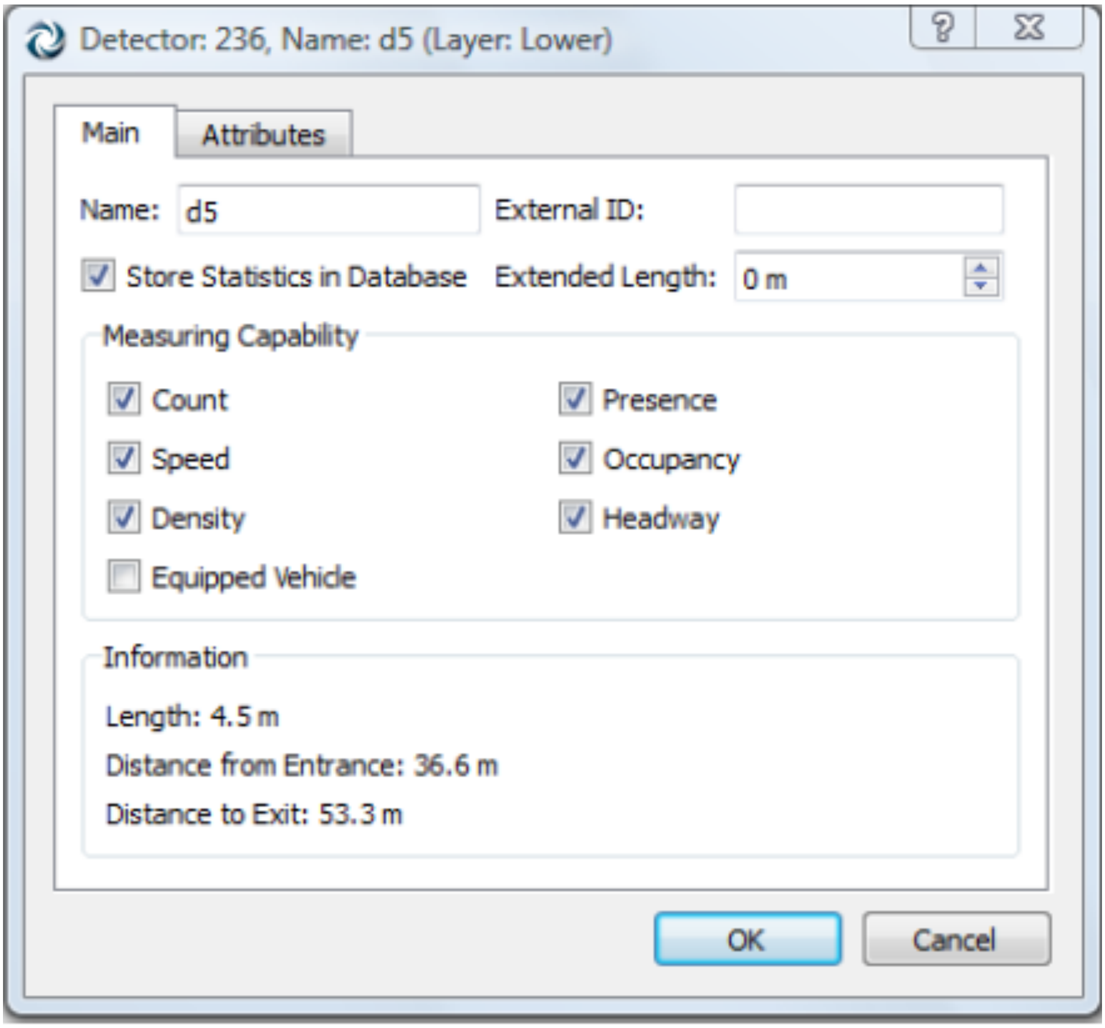

Figure 3.7: Set Names on Detectors.

When creating the centroids if the traffic demand is given as an OD Matrix, the first step will be to identify the centroids that the matrix corresponds to. Press the icon to place a centroid on the network and then click the location that needs to be placed on the network. After defining a centroid, double click on it to display the Centroid editor, and its called Centroid under the "Main" tab. And finally, a connection from the center to the network and vice versa should be established. This is done by pressing the new button and selecting the input or output section. OK, the button is pressed when all connections are ready.

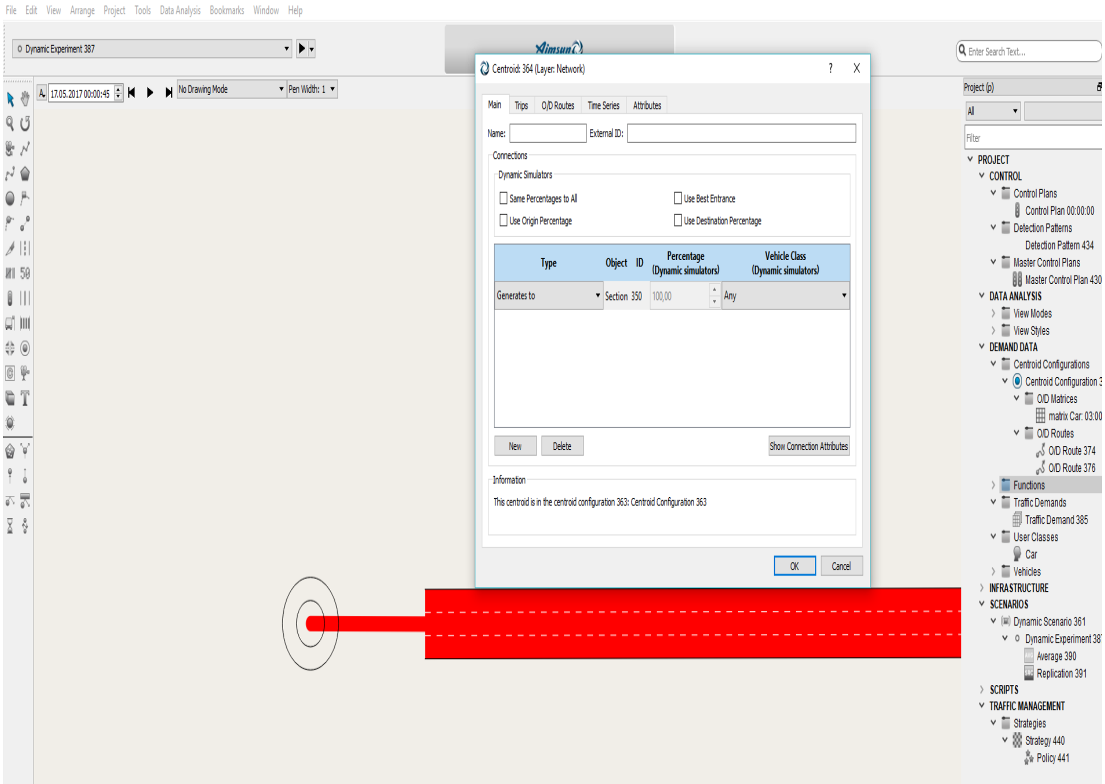

Figure 3.8: Creating Centroid.

Afterward, Defining, how many km, how many lanes, lane widths, speed and lane capacity features of the section established. After these processes are completed, centroids are created to determine the data entry and display points of vehicles. The detector is then assigned to the parts deemed appropriate in the project and creates a measurement. These commands are assigned the O / D path and O / D matrices respectively, and the data obtained through the search are entered into the system. As for normal entry centroids, it is possible to define routes starting at a public transport stop by selecting the linked entry centroid as O / D route origin centroid. These are mainly road speed limits, number of vehicles per lane, vehicle lanes, vehicle types, and lane number [23]). After the information is entered into the system, the settings are made;

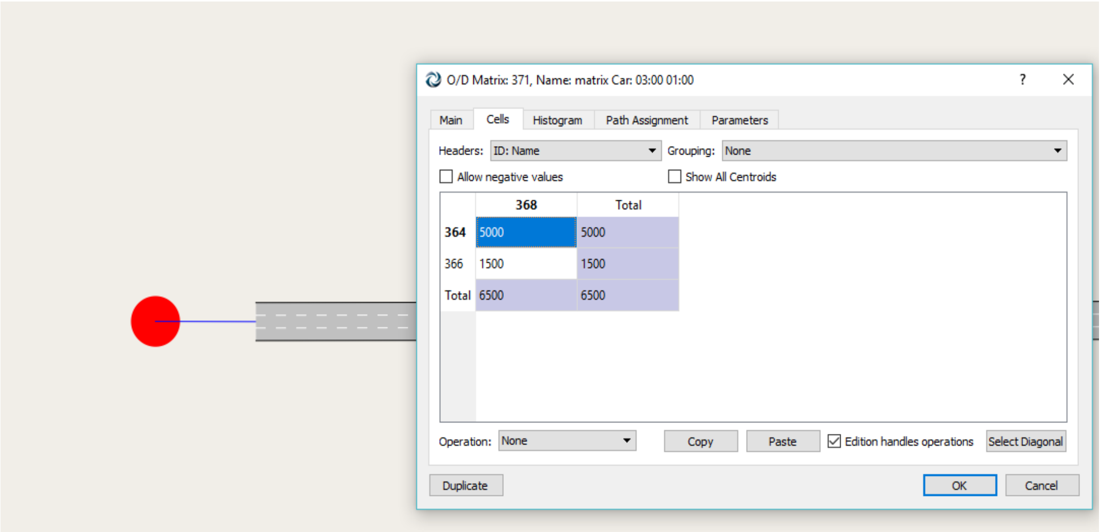

Figure 3.9: Enter Values Centroid.

- Traffic demand: the user can select whether the traffic demand will be composed of matrices or traffic states. The time interval where this traffic demand will be applicable can be defined modifying the Initial Time and Duration.

- Dynamic scenario: The scenarios for the microscopic, mesoscopic and hybrid simulators are Dynamic Scenarios, while the scenario for the static traffic assignment is called Macro Assignment Scenario and the one for the static demand adjustment is the Macro Adjustment Scenario. A scenario is composed of several parameters. For the ones mentioned above, the main parameters are a traffic demand (a group of O/D matrices or traffic states), and optionally, a public transport plan, and a master control plan (a group of control plans) for micro, meso and hybrid.

- Control plan: For each possible turn, this interface assigns to it a signal group, so when a phase contains a turn; automatically it adds the related signal group, avoiding barred turns [24].

Traffic Demands can be created when OD Matrices and Traffic Status are ready. Traffic Status is ready. It is created by selecting the Project / New / Demand

Data / Traffic Demand menu which will cause a new Traffic Demand to appear in the Project window.

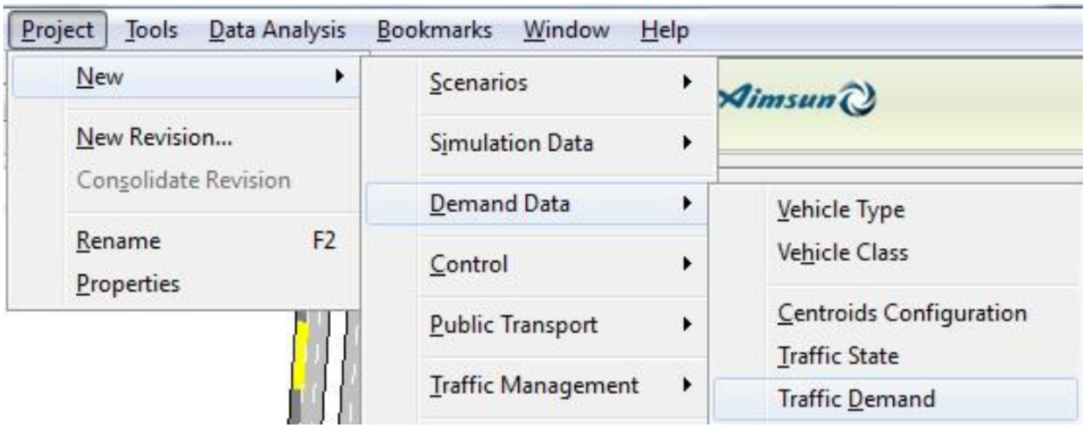

Figure 3.10: Created Since OD Matrices And Traffic Status.

The Demand for Traffic with OD Matrices is renamed to the 'Traffic Demand Matrix', by double-clicking and following steps; Type is fixed; Matrices. Click Add Dem Demand Item and the prepared car matrices are placed. End Press OK to end.

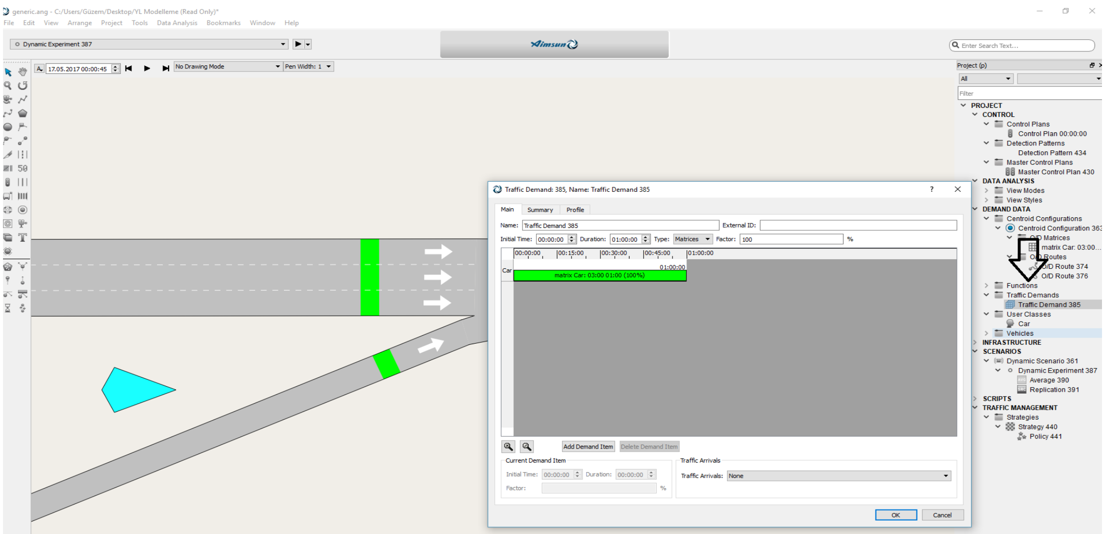

Figure 3.11: Assign Traffic Demand.

To test the geometry created so far, it can run initial simulations, although no control plan or public transport is still specified. To do this, he needs to create a script and an experiment. A Scenario must be created first. It is created with the Project / New / Scenarios / Dynamic Scenario menu and will be displayed in the Project window in its Scenarios folder. It should create an experiment related to the scenario and to do this, move the mouse over the scenario in the Project window and press the right mouse button to access the scenario context menu, New Experiment is selected. Select the type of experiment for Microscopic Simulator and Stochastic Route Selection. Then the scenario editor can be opened and the demand to be used for the scenario can be selected. To open the scenario dialog window, double-click on the scenario and select the previously created claim item under the Main tab.

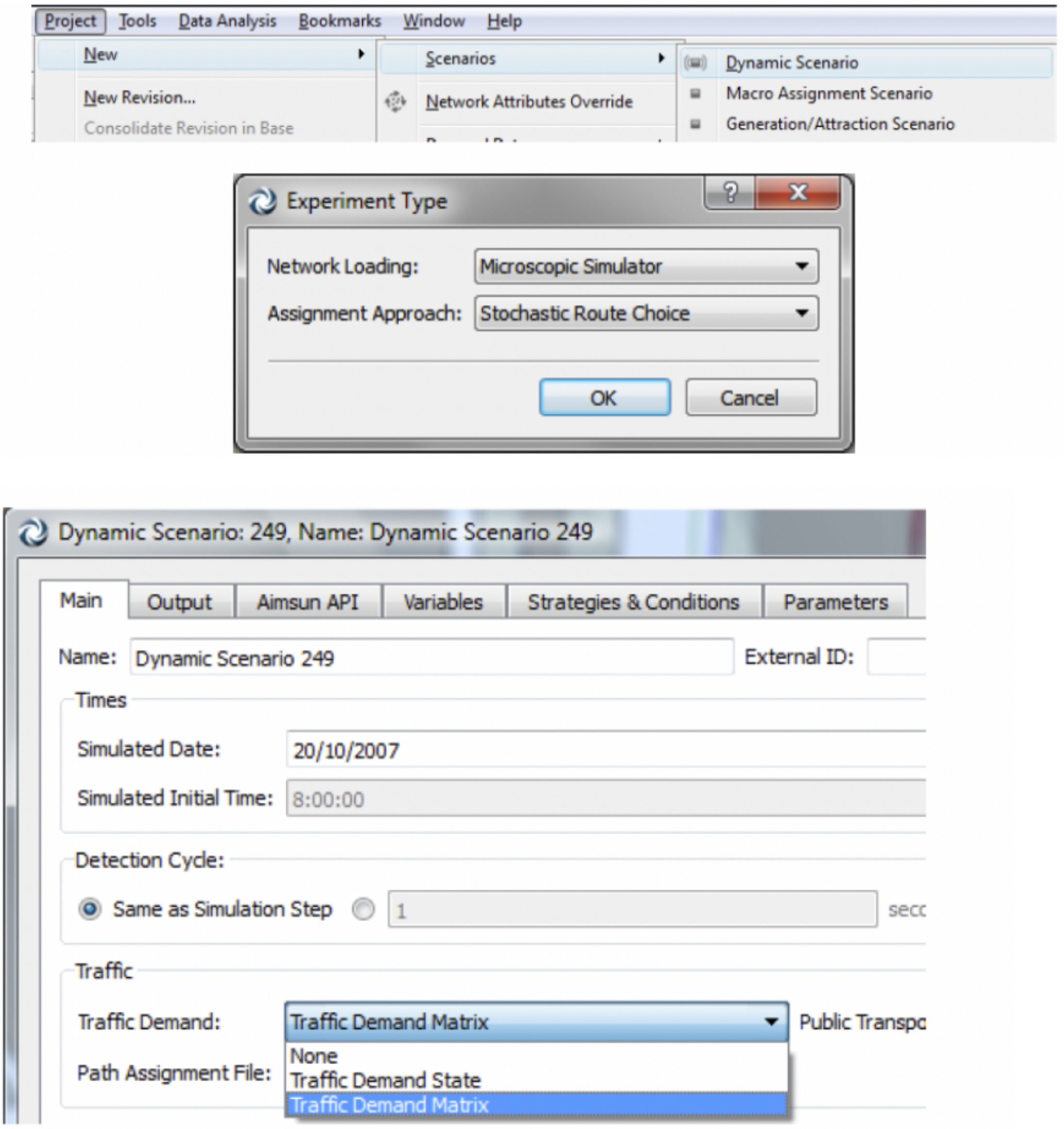

Figure 3.12: Create An Experiment About The Scenario.

Finally, after all the information and analysis methods are processed, simulate the exercise by clicking the run button (▶) in the simulation task box.

3.1.3 Generic Network Simulation and Scenario Testing

At this stage, the loading of the strips at different densities is determined and the density that creates the most ideal behavior is determined. The number of flows from the accession control was 3000 vehicles / s and the number of flows from the mainline was 8000 vehicles / s. In the model, the ramp is designed as a 1-lane road. The mainline is a 3-lane highway. The lane widths were set at 3.5 m and create a shoulder with a distance of 1.5 m from the right and 0.5 m from the left. The most ideal results are obtained after basic modeling is created in the simulation program and by applying various speed and lane changes. Then, this application scenario is modeled as 3 different scenarios (No Control, Ramp Metering, Mainline Metering), and analysis results are obtained.

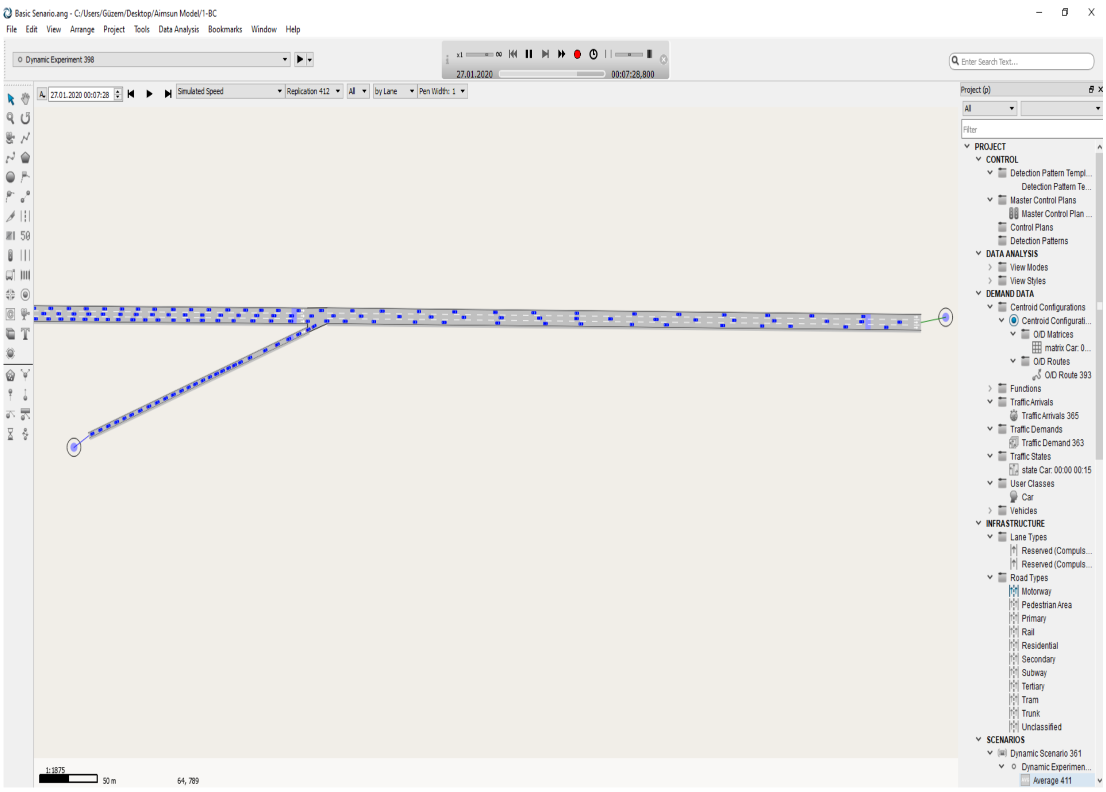

Figure 3.13: Running the Basic Scenario.

3.1.3.1 Base Case (BC)(No Control)

When implementing the basic scenario, a path is designed as shown in 3.13. The lane width was initially set to 3 m when designing the road. No changes were made to the currents assigned, and the assigned speeds, lane widths, and shoulders were designed as indicated above the Tables (3.1-3.4) . In the first stage, a basic model was designed and operated without any scenario effect. The purpose of this is to analyze the ordinary data and to see the gains obtained by comparing the results of the different scenarios applied later.

The speed of 20km / h, which is one of the data accessed at the top of all tables, is remarkable (Table 3.3). The reason for setting the speed assignment to 20km / h for the part of the highway speed after the junction point was made to analyze the situation that the highway might have reached saturation. Because we are usually in a city where there is saturation on the parts of the highways above the ramp. For this reason, it is thought that it can reach more realistic results by analyzing this stage.

The difference between Table 3.1 and Table 3.2 is that the strip width has changed and the safety strip has been added. In addition, when compared with the first model, it can be concluded that all values show a positive acceleration. Although the IEM Emission - VOC - Intercity - Car value may seem negative at first, it can be understood that the reason for this is the excess of vehicle passage without a 0.35% improvement in Travel Time.

Basic Scenario (BS)(Line 3 m)

Performance Measure	Value	Standart Deviation	Units
Delay Time	246,42	245,55	sec/km
Density	66,48	N/A	veh/km
Flow	6880	N/A	veh/h
Fuel Consumption	0	N/A	l
Harmonic Speed	28,81	4,46	km/h
IEM Emission - CO2 - Interurban	388979,76	N/A	g/km
IEM Emission - CO2	1061555,36	N/A	g
IEM Emission - NOx - Interurban	1072,07	N/A	g/km
IEM Emission - NOx	2925,76	N/A	g
IEM Emission - PM - Interurban	291,72	N/A	g/km
IEM Emission - PM	796,12	N/A	g
IEM Emission - VOC - Interurban	197,15	N/A	g/km
IEM Emission - VOC	538,04	N/A	g
Input Count	1127	N/A	veh
Input Flow	6776	N/A	veh/h
Max Virtual Queue	1243	N/A	veh
Mean Queue	16,99	N/A	veh
Mean Virtual Queue	829,79	N/A	veh
Missed Turns	0	N/A	
Number of Stops	1,77	N/A	veh /km
Speed	29,5	4,32	km/h
Stop Time	166,21	256,68	sec/km
Total Travel Time	229,98	N/A	h
Total Travelled Distance	3868,68	N/A	km
Travel Time	279,61	245,48	sec/km
Vehicles Inside	500	N/A	veh
Vehicles Lost Inside	0	N/A	veh
Vehicles Lost Outside	0	N/A	veh
Vehicles Outside	1720	N/A	veh
Vehicles Waiting to Enter	1242	N/A	veh

Table 3.1: 1.Base Case (DNS Do Nothing Scenario).

BS(Line 3,5m - Shoulder right-1,5 left-0,5) Speed All Line 120km/h

Performance Measure	Value	Standard Deviation	Units
Delay Time	245,06	235,97	sec/km
Density	66,33	N/A	veh/km
Flow	6820	N/A	veh/h
Fuel Consumption	0	N/A	l
Harmonic Speed	28,79	4,63	km/h
IEM Emission - CO2 - Interurban	382748,05	N/A	g/km
IEM Emission - CO2	1044291,98	N/A	g
IEM Emission - NOx - Interurban	1046,08	N/A	g/km
IEM Emission - NOx	2854,14	N/A	g
IEM Emission - PM - Interurban	279,68	N/A	g/km
IEM Emission - PM	763,08	N/A	g
IEM Emission - VOC - Interurban	200,81	N/A	g/km
IEM Emission - VOC	547,9	N/A	g
Input Count	1131	N/A	veh
Input Flow	6816	N/A	veh/h
Max Virtual Queue	1230	N/A	veh
Mean Queue	13,66	N/A	veh
Mean Virtual Queue	825,2	N/A	veh
Missed Turns	0	N/A	
Number of Stops	1,82	N/A	veh /km
Speed	29,54	4,51	km/h
Stop Time	163,91	244,66	sec/km
Total Travel Time	227,83	N/A	h
Total Travelled Distance	3816,61	N/A	km
Travel Time	278,25	235,94	sec/km
Vehicles Inside	518	N/A	veh
Vehicles Lost Inside	0	N/A	veh
Vehicles Lost Outside	0	N/A	veh
Vehicles Outside	1705	N/A	veh
Vehicles Waiting to Enter	1230	N/A	veh

Table 3.2: 2.Base Case (DNS Do Nothing Scenario).

BS(Line 3,5m - Shoulder right-1,5 left-0,5) Speed DS-Main Line 20km/h

Performance Measure	Value	Standard Deviation	Units
Delay Time	352,53	235,97	sec/km
Density	104,78	N/A	veh/km
Flow	4936	N/A	veh/h
Fuel Consumption	0	N/A	l
Harmonic Speed	14,6	4,63	km/h
IEM Emission - CO2 - Interurban	268446,87	N/A	g/km
IEM Emission - CO2	732431,99	N/A	g
IEM Emission - NOx - Interurban	544,48	N/A	g/km
IEM Emission - NOx	1485,57	N/A	g
IEM Emission - PM - Interurban	199,57	N/A	g/km
IEM Emission - PM	544,5	N/A	g
IEM Emission - VOC - Interurban	325,23	N/A	g/km
IEM Emission - VOC	887,36	N/A	g
Input Count	823	N/A	veh
Input Flow	4916	N/A	veh/h
Max Virtual Queue	1951	N/A	veh
Mean Queue	210,76	N/A	veh
Mean Virtual Queue	1307,16	N/A	veh
Missed Turns	0	N/A	
Number of Stops	6,42	N/A	veh /km
Speed	15,9	4,51	km/h
Stop Time	236,01	244,66	sec/km
Total Travel Time	256,57	N/A	h
Total Travelled Distance	2741,52	N/A	km
Travel Time	423,14	235,94	sec/km
Vehicles Inside	809	N/A	veh
Vehicles Lost Inside	0	N/A	veh
Vehicles Lost Outside	0	N/A	veh
Vehicles Outside	1234	N/A	veh
Vehicles Waiting to Enter	1951	N/A	veh

Table 3.3: 3.Base Case (DNS Do Nothing Scenario).

Performance Measure	Delay Time (sec/km)	Density (veh/km)	Flow (veh/h)	Speed (km/h)	Travel Time (sec/km)
Basic Scenario (BS)(Line 3 m)	246,42	66,48	6880	29,5	279,61
BS(Line 3,5m - Shoulder right-1,5 left-0,5/Speed All Line 120km/h)	245,06	66,33	6820	29,54	278,25
BS(Line 3,5m - Shoulder right-1,5 left-0,5/Speed DS-Main Line 20km/h)	352,53	104,78	4936	15,9	423,14

Table 3.4: Comparison of Baseline Scenarios Within Themselves.

All parameters are applied to scenarios in the same way. The important part of this model is to change the velocity values in the flow direction after ramp participation. (120 km /h, 20 km/h). These details can be found in Table 3.1 , Table 3.2 and Table 3.4. In the scenario run at 2 different speed parameters, it can be seen that the results get worse. (For 20 km/h). This gives the impression that the mainline should be intervened to reduce the density of a saturated motorway downstream.

(Line 3,5m - Shoulder right-1,5 left-0,5)	Main-US	Ramp	Main-DS
All Line Speed 120km/h			
Simulated Travel Time	404,8	496	21,3
Simulated Speed	26,3	8,2	86,9
Simulated Flow	5790	1044	6864
Simulated Density	74,7	127,3	26,3
Simulated Delay Time	210	83,3	4,3
Speed Downstream-Main Line 20km/h			
Simulated Travel Time	611	656,8	99,1
Simulated Speed	16,4	5,7	18,6
Simulated Flow	4140	798	4932
Simulated Density	108	88,5	142,7
Simulated Delay Time	412,2	121,9	14,7

Table 3.5: Base Case Scenario-Values of Roads As A Result of Analysis.

As a result of basic modeling, only models that differ in highway speeds were compared. In the comparative graphs made, total results are shown, not per each road segment. The values (Simulated Travel Time, Speed, Flow, Density and Delay Time) shown by the results from the speed differences on the roads in each road section are shown in Table 3.5. It is also seen that all the values deteriorate with the decrease in speed on the highway.

3.1.3.2 Ramp Metering Control (RMC)

The goal of the ramp metering scenario is to allow a certain number of vehicles to enter the meter per hour. The parameters are Tool Length and Traffic Flow. Each time the counter is opened to release vehicles; the lengths are made so that tools with the parameter "Tool Length" can pass. If the control of the measurement is constant, there will be only one parameter to specify the number of vehicles per hour to be released. The specific flow measurement applying the ramp metering strategy is not available in the mesoscopic simulator. The metering flow during the time interval used in this scenario is calculated as follows:

$$G_{TRamp} = \left(1 - \left(\frac{|Q_{Mdc} - (Q_M + Q_R)|}{Q_R}\right)\right) \tag{3.1}$$

Ramp Capacity	Q_R	1200	
Mainline Capacity	Q_M	6200	0,00
Downstream Capacity (Main)	Q_{DC}	800	0,67
Cycle Time	C_T	15	
Green Time	G_T	10	

Table 3.6: Calculation Green Time Equations.

In formula 3.1, G_{TRamp} represents Green type ramp, Q_{Mdc} represents Mainline downstream volume, Q_R represents ramp volume. Using these calculations, the scenario was run by setting the control type as Fixed, assigning a 50% red percentage, green time 7 seconds and cycle time 15 seconds, and Tables (3.5, 3.7, 3.8) were created with the results.

(RMS)(Line 3,5m -Shoulder right-1,5 left-0,5) Speed All Line 120km/h

Performance Measure	Value	Standard Deviation	Units
Delay Time – Car	174,1	325,99	sec/km
Density – Car	45,63	N/A	veh/km
Flow – Car	7700	N/A	veh/h
Fuel Consumption – Car	0	N/A	l
Harmonic Speed – Car	44,19	18,44	km/h
IEM Emission - CO2 - Interurban – Car	359182	N/A	g/km
IEM Emission - CO2 – Car	979995	N/A	g
IEM Emission - NOx - Interurban – Car	1184,14	N/A	g/km
IEM Emission - NOx – Car	3230,82	N/A	g
IEM Emission - PM - Interurban – Car	221,39	N/A	g/km
IEM Emission - PM – Car	604,04	N/A	g
IEM Emission - VOC - Interurban – Car	137,56	N/A	g/km
IEM Emission - VOC – Car	375,32	N/A	g
Input Count – Car	1291	N/A	veh
Input Flow – Car	7736	N/A	veh/h
Max Virtual Queue – Car	1020	N/A	veh
Mean Queue – Car	25,89	N/A	veh
Mean Virtual Queue – Car	727,39	N/A	veh
Missed Turns – Car	0	N/A	
Number of Stops – Car	1,39	N/A	#/veh /km
Speed - Car	51,89	11,83	km/h
Stop Time - Car	142,24	325,36	sec/km
Total Travel Time - Car	175,76	N/A	h
Total Travelled Distance - Car	4523,09	N/A	km
Travel Time - Car	207,32	326,08	sec/km
Vehicles Inside - Car	359	N/A	veh
Vehicles Lost Inside - Car	0	N/A	veh
Vehicles Lost Outside - Car	0	N/A	veh
Vehicles Outside - Car	1925	N/A	veh
Vehicles Waiting to Enter - Car	1020	N/A	veh

Table 3.7: Control Scenario 1.Ramp Metering.

(RMS) (Line 3,5m - Shoulder right-1,5 left-0,5) Speed DS-Main Line 20km/h

Performance Measure	Value	Standard Deviation	Units
Delay Time – Car	340,49	349,92	sec/km
Density – Car	101,81	N/A	veh/km
Flow – Car	4904	N/A	veh/h
Fuel Consumption – Car	0	N/A	l
Harmonic Speed – Car	14,54	4,74	km/h
IEM Emission - CO2 - Interurban – Car	236718,49	N/A	g/km
IEM Emission - CO2 – Car	645864,08	N/A	g
IEM Emission - NOx - Interurban – Car	477,85	N/A	g/km
IEM Emission - NOx – Car	1303,78	N/A	g
IEM Emission - PM - Interurban – Car	166,7	N/A	g/km
IEM Emission - PM – Car	454,82	N/A	g
IEM Emission - VOC - Interurban – Car	321	N/A	g/km
IEM Emission - VOC – Car	875,83	N/A	g
Input Count – Car	832	N/A	veh
Input Flow – Car	4932	N/A	veh/h
Max Virtual Queue – Car	1998	N/A	veh
Mean Queue – Car	155,07	N/A	veh
Mean Virtual Queue – Car	1352,96	N/A	veh
Missed Turns – Car	0	N/A	
Number of Stops – Car	4,93	N/A	#/veh /km
Speed - Car	16,09	4,32	km/h
Stop Time - Car	218,53	376,38	sec/km
Total Travel Time - Car	253,12	N/A	h
Total Travelled Distance - Car	2815,48	N/A	km
Travel Time - Car	408,39	369,27	sec/km
Vehicles Inside - Car	788	N/A	veh
Vehicles Lost Inside - Car	0	N/A	veh
Vehicles Lost Outside - Car	0	N/A	veh
Vehicles Outside - Car	1226	N/A	veh
Vehicles Waiting to Enter - Car	1998	N/A	veh

Table 3.8: Control Scenario 2.Ramp Metering.

In all circumstances, it is seen that 20 km / h at mainline speed gives worse results than 120 km / h. However, the important point here is how much change the data received when the ramp control was applied according to the scenario where no control was applied.

(Line 3,5m - Shoulder right-1,5 left-0,5)	Main-US	Ramp	Main-DS
All Line Speed 120km/h			
Simulated Travel Time	236,4	772	22
Simulated Speed	51,3	4,7	83,9
Simulated Flow	7020	696	7716
Simulated Density	45,9	151,5	30,8
Simulated Delay Time	73,4	148,4	5
Speed Downstream-Main Line 20km/h			
Simulated Travel Time	584	821,6	100,1
Simulated Speed	16,8	3,7	18,4
Simulated Flow	4308	600	4896
Simulated Density	102,9	158,1	88,9
Simulated Delay Time	392,4	192,6	15,8

Table 3.9: Ramp Metering Scenario-Values of Roads As A Result Of Analysis.

3.1.3.3 Main-Line Metering Control (MLC)

According to the design of the road network, the highway mainline can be added to another highway mainline as a participation arm. Connections from the highway to highway when needed can be taken under. The purpose of the mainline metering scenario is that, depending on the traffic conditions available, to regulate current. It is to regulate the demand on the mainline and try to keep this demand below capacity by controlling the volume of traffic participating in the mainline. Each time the meter is turned on to release vehicles; if the control of the metering is constant, there will be only one parameter to specify the number of vehicles per hour to be released.

The measurement flow during the time interval used in this scenario is calculated as follows: (Making use of Table 3.6 Calculation Green Time Equations)

$$G_{TMain} = \left(\left(\frac{|Q_{Mdc} - (Q_M + Q_R)|}{Q_R}\right)\right) * C_{C_{TM}} \tag{3.2}$$

The formulas that are written are calculated by considering the maximum road capacity as 1800 vehicles per lane in a classical scenario, and the values are determined by proportioning the volumes given in the direction of the coefficient. As a result of the calculations, the control types are selected Fixed again for both the mainline and ramp. Assigned values for main line Cycle = 30 s, Green Duration = 27 s, Offset = 24s, Red Percentage = %50; values assigned for ramp Cycle = 30 s, Green Duration = 6 s, Red Percentage=%50. The data from the simulations modeled with these conditions are listed in Tables (3.10,3.11,3.12).

(MLC) (Line 3,5m -Shoulder right-1,5 left-0,5) Speed All Line 120km/h

Performance Measure	Value	Standard Deviation	Units
Delay Time – Car	171,54	291,09	sec/km
Density – Car	55,65	N/A	veh/km
Flow – Car	6648	N/A	veh/h
Fuel Consumption – Car	0	N/A	l
Harmonic Speed – Car	32,43	16,01	km/h
IEM Emission - CO2 - Interurban – Car	343331,49	N/A	g/km
IEM Emission - CO2 – Car	936747,62	N/A	g
IEM Emission - NOx - Interurban – Car	1059,92	N/A	g/km
IEM Emission - NOx – Car	2891,88	N/A	g
IEM Emission - PM - Interurban – Car	229,28	N/A	g/km
IEM Emission - PM – Car	625,58	N/A	g
IEM Emission - VOC - Interurban – Car	169,5	N/A	g/km
IEM Emission - VOC – Car	462,46	N/A	g
Input Count – Car	1103	N/A	veh
Input Flow – Car	6752	N/A	veh/h
Max Virtual Queue – Car	1430	N/A	veh
Mean Queue – Car	48,23	N/A	veh
Mean Virtual Queue – Car	1014,31	N/A	veh
Missed Turns – Car	0	N/A	
Number of Stops – Car	1	N/A	#/veh /km
Speed - Car	40,33	7,5	km/h
Stop Time - Car	122,94	298,21	sec/km
Total Travel Time - Car	185,15	N/A	h
Total Travelled Distance - Car	4051,49	N/A	km
Travel Time - Car	204,79	291,17	sec/km
Vehicles Inside - Car	438	N/A	veh
Vehicles Lost Inside - Car	0	N/A	veh
Vehicles Lost Outside - Car	0	N/A	veh
Vehicles Outside - Car	1662	N/A	veh
Vehicles Waiting to Enter - Car	1430	N/A	veh

Table 3.10: Control Scenario 1. Mainline Metering.

(MLC) (Line 3,5m-Shoulder right-1,5 left-0,5) Speed DS-Main Line 20km/h

Performance Measure	Value	Standard Deviation	Units
Delay Time – Car	285,01	295,69	sec/km
Density – Car	98,02	N/A	veh/km
Flow – Car	4752	N/A	veh/h
Fuel Consumption – Car	0	N/A	l
Harmonic Speed – Car	14,09	5	km/h
IEM Emission - CO2 - Interurban – Car	283718,61	N/A	g/km
IEM Emission - CO2 – Car	774099,49	N/A	g
IEM Emission - NOx - Interurban – Car	676,27	N/A	g/km
IEM Emission - NOx – Car	1845,14	N/A	g
IEM Emission - PM - Interurban – Car	224,61	N/A	g/km
IEM Emission - PM – Car	612,84	N/A	g
IEM Emission - VOC - Interurban – Car	291,2	N/A	g/km
IEM Emission - VOC – Car	794,5	N/A	g
Input Count – Car	805	N/A	veh
Input Flow – Car	4808	N/A	veh/h
Max Virtual Queue – Car	2112	N/A	veh
Mean Queue – Car	124,27	N/A	veh
Mean Virtual Queue – Car	1450,27	N/A	veh
Missed Turns – Car	0	N/A	
Number of Stops – Car	4,72	N/A	#/veh /km
Speed - Car	15,86	3,25	km/h
Stop Time - Car	164,79	316,23	sec/km
Total Travel Time - Car	239,51	N/A	h
Total Travelled Distance - Car	2871,02	N/A	km
Travel Time - Car	348,41	309,26	sec/km
Vehicles Inside - Car	760	N/A	veh
Vehicles Lost Inside - Car	0	N/A	veh
Vehicles Lost Outside - Car	0	N/A	veh
Vehicles Outside - Car	1188	N/A	veh
Vehicles Waiting to Enter - Car	2112	N/A	veh

Table 3.11: Control Scenario 2. Mainline Metering.

(Line 3,5m - Shoulder right-1,5 left-0,5)	Main-US	Ramp	Main-DS
All Line Speed 120km/h			
Simulated Travel Time	322,1	994,6	20,9
Simulated Speed	36,5	1,5	88,4
Simulated Flow	6348	276	6600
Simulated Density	59,6	184,4	25
Simulated Delay Time	130,4	482,5	3,9
Speed Downstream-Main Line 20km/h			
Simulated Travel Time	579,7	1044,2	95,7
Simulated Speed	15,7	1,3	19,3
Simulated Flow	4488	252	4758
Simulated Density	99,1	186,4	81,9
Simulated Delay Time	394,3	548,1	11,4

Table 3.12: 2. Mainline Metering Control-Values Of Roads As A Result Of Analysis.

3.1.3.4 BC-RMC-MLC Explication and Comparison

When the tables in which the results of the BC and RMC conditions are written are compared, a few different situations are encountered. One of the encountered situations is that the values in the table with 120km / h speed and 20km / h speed are not directly proportional. According to the uncontrolled scenario in ramp control, some important results are obtained as seen in table 3.13.

For 120 km / h:		For 20km / h:	
Delay Time %28,95	↘	Delay Time %3,41	↘
Density %31,21	↘	Density %2,83	↘
Flow %11,43	↗	Flow %0,58	↘
Speed %42,74	↗	Speed %1,18	↗
Travel Time %25,49	↘	Travel Time %3,48	↘

Table 3.13: Proportionality variables.

When comparing the tables in which the results of the RMC and MLC metering are written, different situations are encountered. The main point in this comparison is that it gives better results than ramp control as seen in table 3.14.

For 120 km / h:		For 20km / h:	
Delay Time %1,47	↘	Delay Time %16,29	↘
Density %18,01	↗	Density %3,72	↘
Flow %13,66	↘	Flow %3,10	↘
Speed %22,28	↘	Speed %1,43	↘
Stop Time %13,57	↘	Stop Time %24,59	↘
Travel Time %1,22	↘	Travel Time %14,69	↘

Table 3.14: Proportionality variables of RMC and MLC.

Stop Time, Delay Time, and Travel Times decreasing give impressions that the work done will provide useful results. For this reason, applying the models made in line with the results of the analysis to a real highway network is considered as a way to solve the traffic problems of the countries.

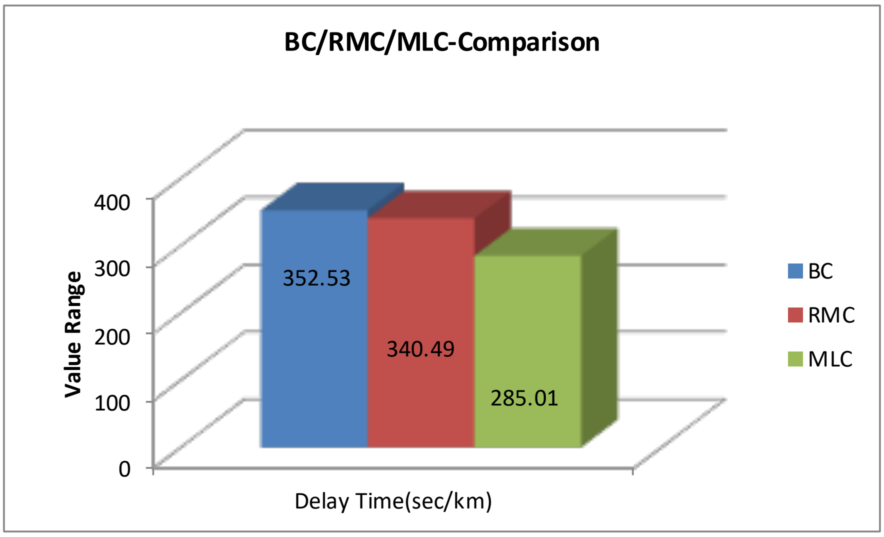

Figure 3.14: Comparison Of The Delay Time (20km/h).

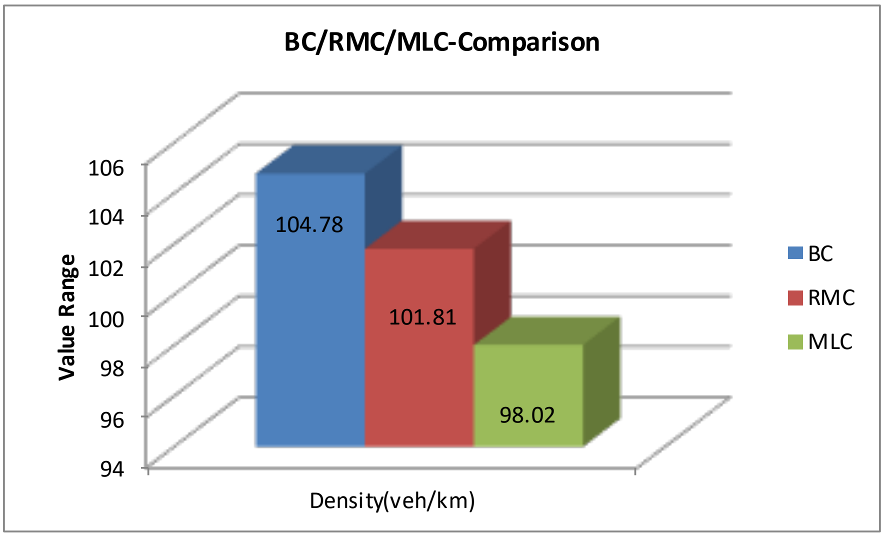

Figure 3.15: Comparison Of The Density (20km/h).

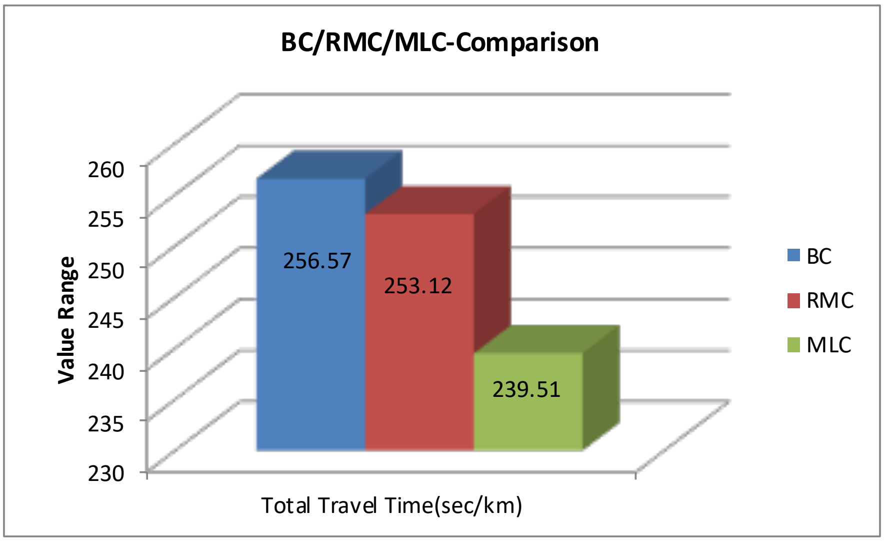

Figure 3.16: Comparison Of The Total Travel Time (20km/h).

The graphical results of the analysis are available in Figure 3.14, 3.15, 3.16 and remarkable results are observed. The biggest visible change is travel times and drops in delay times. As a result of the scenario in which the mainline control is applied, the results of analysis supporting the defense that there is a much more useful control model than the scenario where the ramp control is applied are found.

Chapter 4

Traffic Control Simulation

Modeling steps of the simulation program used in this section are explained. As a result of these steps, a simulation is summarized. Different metering control methods are designed in the program. Analysis of the data entered at the end of the design is made. Thus identified the most suitable option for highway access control arrangements are made necessary analysis and advice.

4.1 Study Area

As a study field, K-9, and K-10 intersections of the O-2 road are determined. The satellite view of the study area is shown in Figure 4.1.

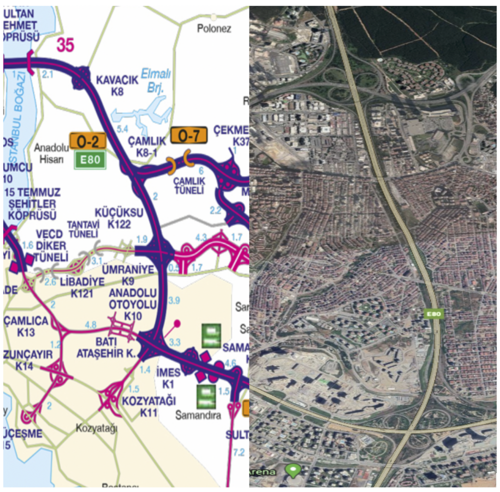

Figure 4.1: Satellite Image of the Study Field.

4.2 Network Building

Multiple scenarios can be defined in AIMSUN and multiple attempts can be created for each. Each scenario and experiment will have their own values. AIMSUN will keep all defined scenarios (and thus experiments, replications, and results) in the network. The workspace was modeled using this infrastructure of the program. AIMSUN software is a program that has network connection in itself and can obtain geometrical modeling data from all over the world using this connection. For this reason, the design I used in the project was selected from the list of window templates that appeared on the screen after running the program (Figure 4.2).

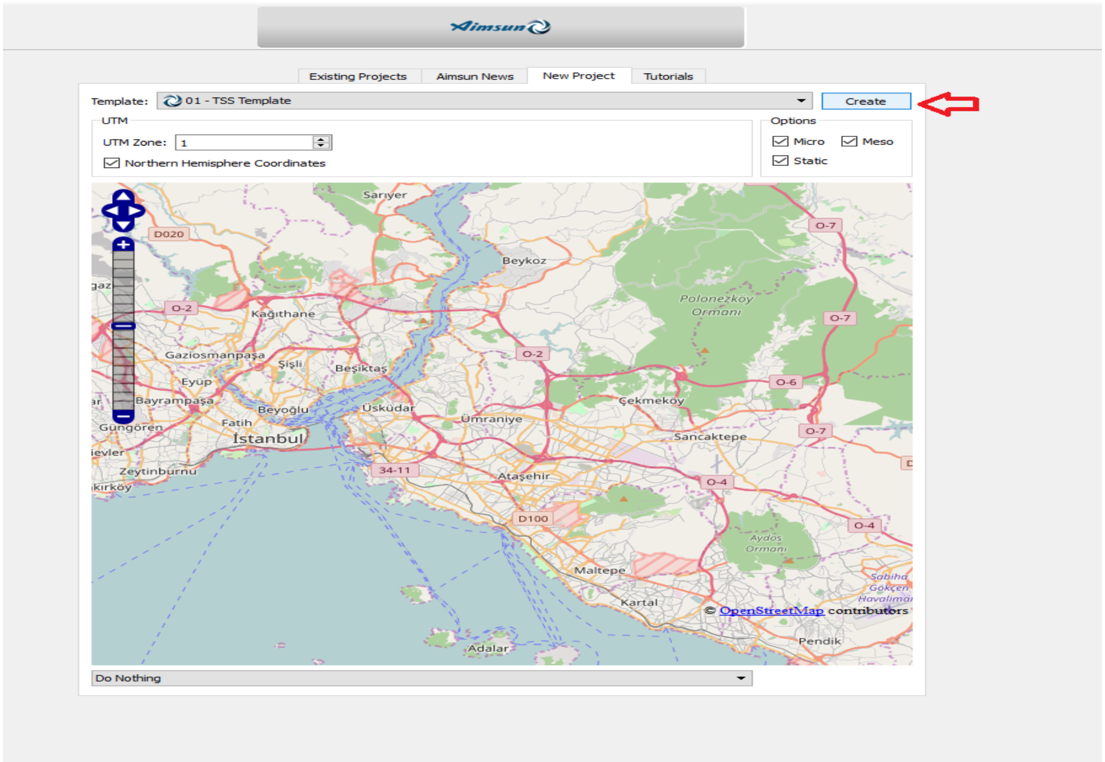

Figure 4.2: Template Chooser Window.

The part to be modeled first is selected by selecting the world map. Unrelated parts are removed from the selected part (buildings, green areas, parking spaces, lighting, etc.). After that, the intersections of the roads and the weaving lengths at the joints are measured on any online map and necessary adjustments are made and if there are mistakes, corrections are made. After these processes are completed, centroids are created to determine the data entry and viewing points of the vehicles. Then the detector is assigned to the parts that are deemed appropriate in the project, and create metering. These commands are assigned O/D route and O/D matrices respectively, and the data obtained by searching are entered into the system. As for normal entrance centroids, it is possible to define routes starting in a public transport stop by selecting the linked entrance centroid as the O/D route origin centroid. These are mainly road speed limits, the number of vehicles per lane, the lanes of vehicles, vehicle types, and a number of lanes.

4.3 Scenarios (For Study Area)

Scenarios compared and applied in the general network are applied to the workspace with the same logic. General details about the scenario applied can be found in Table 4.1 and Figure 4.3. Table 4.3 shows the number of cars assigned to the centroid point in the system. Figure 4.3 shows the centroid of these points. Model, take the highway network in the verbatim, get real data it is desired to affect the analysis results match exactly. In this way, the most accurate results in the analysis are obtained.

⊗	37141	37146	37152	37155	37159	Total
37133	7	10	500	30	50	1097
37134	10	65	750	30	70	1875
37140	-	-	4750	35	3200	7985
37147	-	3	4500	55	75	4633
37156	-	-	8500	-	4500	13000
37160	-	-	4500	80	50	4630
37339	15	40	6750	55	90	6950
Total	32	118	31700	285	8035	40170

Table 4.1: O / D Matrix Editor - Assign Tools from One Centroid.

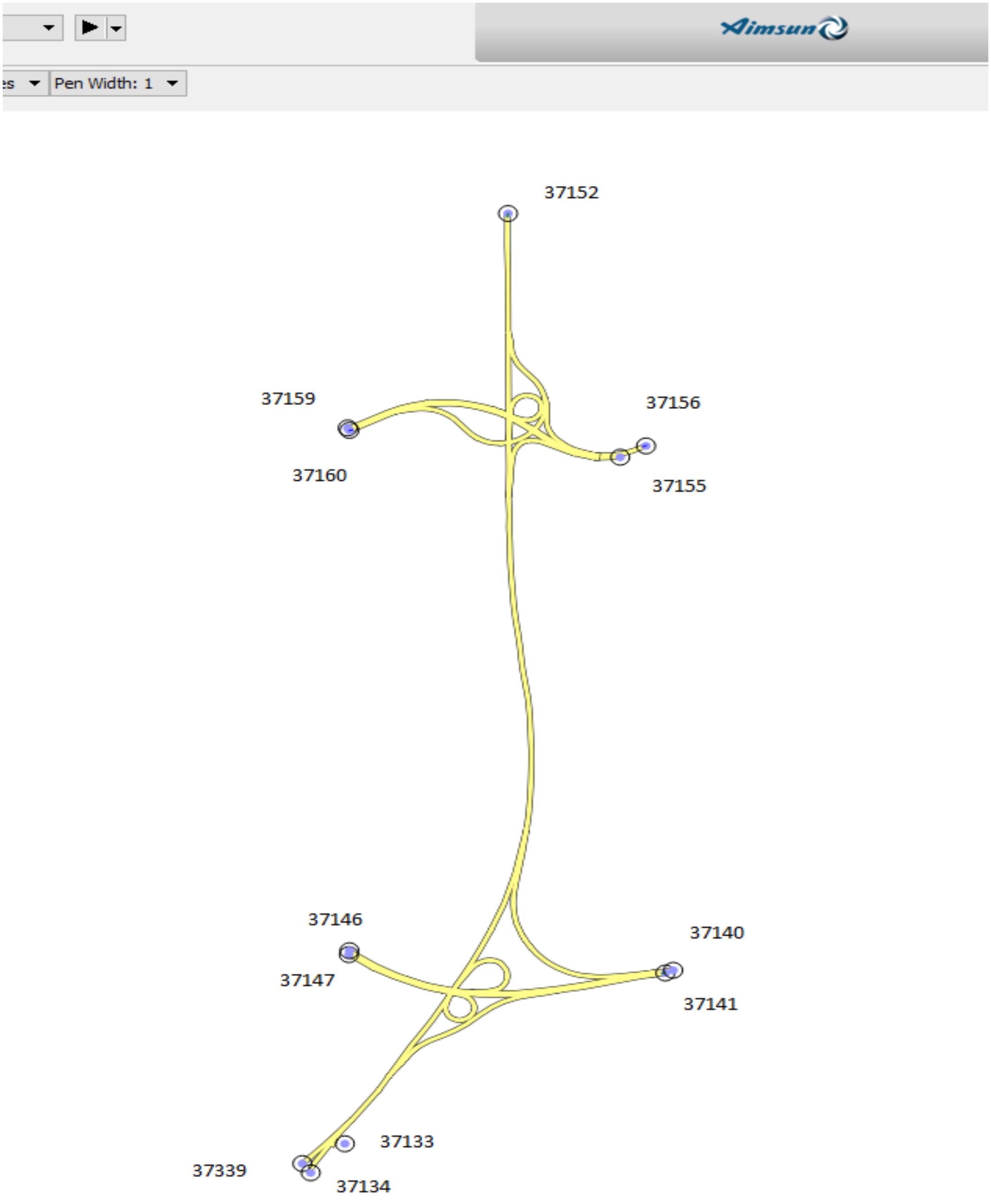

Figure 4.3: O/D Routes for a Centroid Configuration.

4.3.1 Base Case (BC)(No Control)

For the applied control scenarios to be comparable, a basic model should be designed first. Thus, it can be interpreted how successful other scenarios are to mitigate traffic. The basic case is given as a result of the simulation and the density map image is as in Figure 4.4. Analysis data in the area where the control scenario is not applied are presented in tables 4.2 and 4.3. It will then be used to compare the analysis in the results section.

Performance Measure	Value	Standard Deviation	Units
Delay Time - Car	57,18	56,67	sec/km
Density - Car	1,2	N/A	veh/km
Flow - Car	7740	N/A	veh/h
Harmonic Speed - Car	57,45	15,55	l
Input Count - Car	3106	N/A	km/h
Input Flow - Car	18636	N/A	g/km
Max Virtual Queue - Car	35639	N/A	g
Mean Queue - Car	325,67	N/A	g/km
Mean Virtual Queue - Car	17583,87	N/A	g
Missed Turns - Car	12	N/A	g/km
Number of Stops - Car	0,81	N/A	g
Speed - Car	61,65	15,55	g/km
Stop Time - Car	41,85	52,04	g
Total Travel Time - Car	126,5	N/A	veh
Total Travelled Distance - Car	5660,99	N/A	veh/h
Travel Time - Car	98,76	61,26	veh
Vehicles Inside - Car	1816	N/A	veh
Vehicles Lost Inside - Car	6	N/A	veh
Vehicles Lost Outside - Car	6	N/A	
Vehicles Outside - Car	1290	N/A	#/veh/km
Vehicles Waiting to Enter - Car	35639	N/A	km/h

Table 4.2: Analysis Results For Base Case.

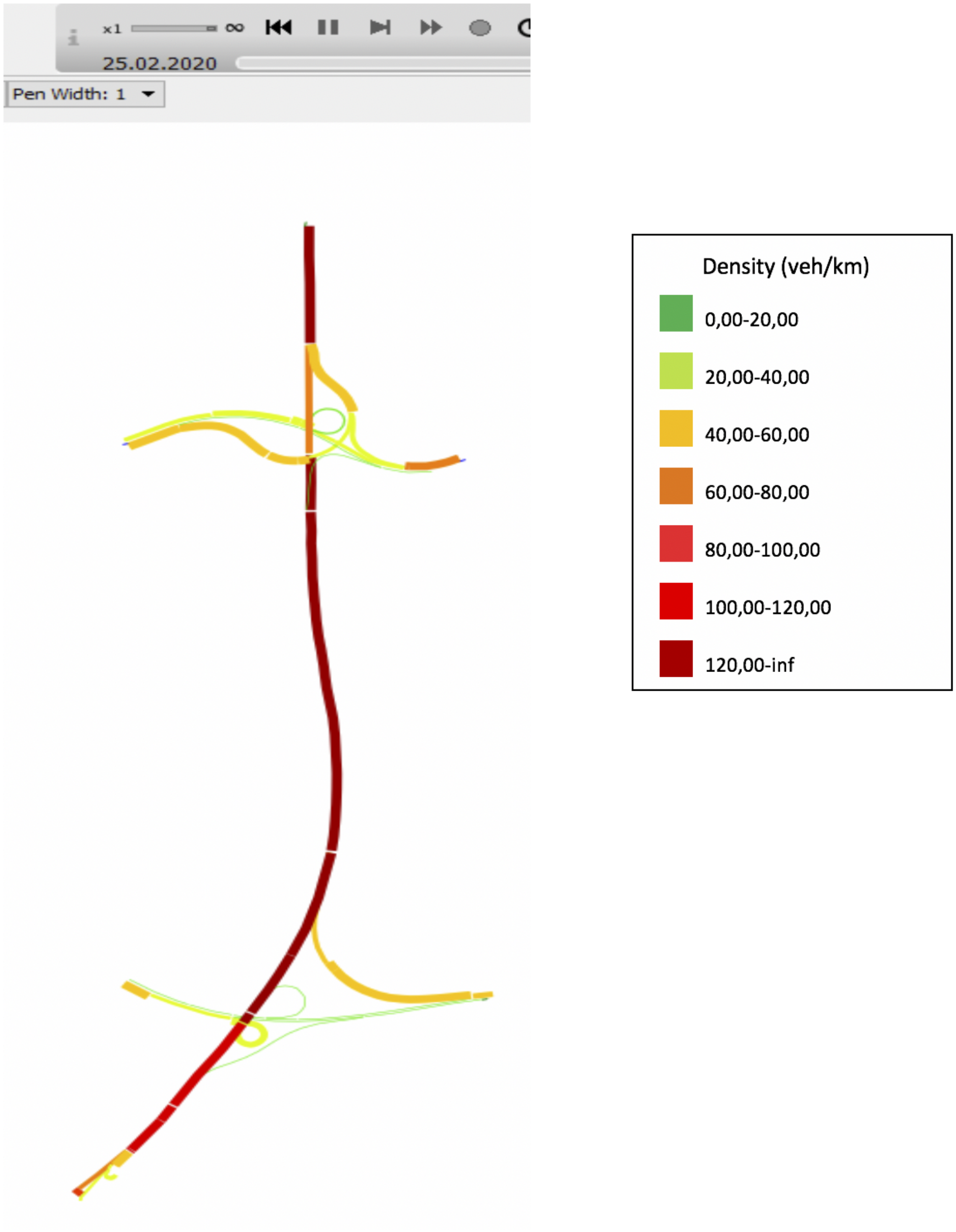

Figure 4.4: Base Case Road Condition (For Density).

Origin	Destination	Vehicles Assigned	Vehicles Entered	Vehicles Exited	Volume	Distance	Travel Time
37339	37159	86	4	4	90	6780,48	488,272
37339	37155	55	3	3	55	5696,3	410,231
37339	37152	6772	244	244	6750	6613,48	476,17
37339	37146	36	3	3	40	2858,1	205,829
37339	37141	11	3	3	15	2462,93	177,392
37160	37155	64	6	6	80	1604,23	115,504
37160	37152	4489	201	201	4500	2627,68	189,317
37156	37159	4441	153	153	4500	1762,61	126,955
37156	37152	8631	227	227	8500	2064,24	148,687
37147	37159	67	2	2	75	6542,79	471,158
37147	37155	42	2	2	55	5458,61	393,117
37147	37152	4584	113	113	4500	6375,79	459,057
37147	37146	4	1	1	3	2620,41	188,715
37140	37159	3138	74	74	3200	5878,93	423,36
37140	37155	34	1	1	35	4794,75	345,32
37140	37152	4776	94	94	4750	5711,93	411,259
37134	37159	81	5	5	70	6805,35	490,062
37134	37155	37	4	4	30	5721,17	412,022
37134	37152	728	73	73	750	6638,35	477,961
37134	37146	53	10	10	65	2882,97	207,619
37134	37141	7	1	1	10	2487,8	179,182
37133	37159	54	2	2	50	6692,57	481,942
37133	37155	33	8	8	30	5608,39	403,902
37133	37152	503	48	48	500	6525,57	469,841
37133	37146	8	2	2	10	2770,19	199,499
37133	37141	11	0	0	7	2375,03	171,062

Table 4.3: Analysis Table from Point Origin to Destination in The Base Case.

4.3.2 Ramp Metering Control (RMC)

The implementation of the ramp metering is controlled by a traffic signal that turns cyclically red and green. The control cycle and green time values for the metering are displayed in the control editor. In cases other than metering control, Minimum and Maximum green areas can be accepted. The formulas in table 3.6 are based on on-ramp metering in this study. On the mainline, a rate is established by accepting the number of vehicles assigned per lane as 1800 and the number of vehicles coming from the ramp per lane as 1200 and continues accordingly. There are 4 ramp points in the modeled one-way road network. The implementation of the ramp controls is controlled by a traffic signal that turns cyclically red and green. The control cycle and green time values for the metering are displayed in the control editor. In cases other than metering control, Minimum and Maximum green areas can be accepted. The formulas in table 3.6 are based on on-ramp metering in this study. On the mainline, a rate is established by accepting the number of vehicles assigned per lane as 1800 and the number of vehicles coming from the ramp per lane as 1200 and continues accordingly. There are 4 ramp participation points in the modeled one-way road network. Various cycle times and green times are assigned, taking into account the individual density of each ramp and the vehicle density from the main road. Various cycle times and green times are assigned, the results of the analysis are taken over and over and simulation is used, which provides the most ideal image from the analysis results. Besides, in the comparison made as a result of the specific time determinations made for each ramp, the best result was determined by these times were determined as Green Time 8 sec, Cycle Time 12 sec, and Offset 2 sec. When different time variations are tried, for example, when a specific value is assigned to each ramp, it is seen that the density in the ramps decreases to a minimum. But at the same time, total travel time and total flow are significantly reduced. In this direction, it is concluded that the density in the mainline has increased significantly and this situation does not give the desired.

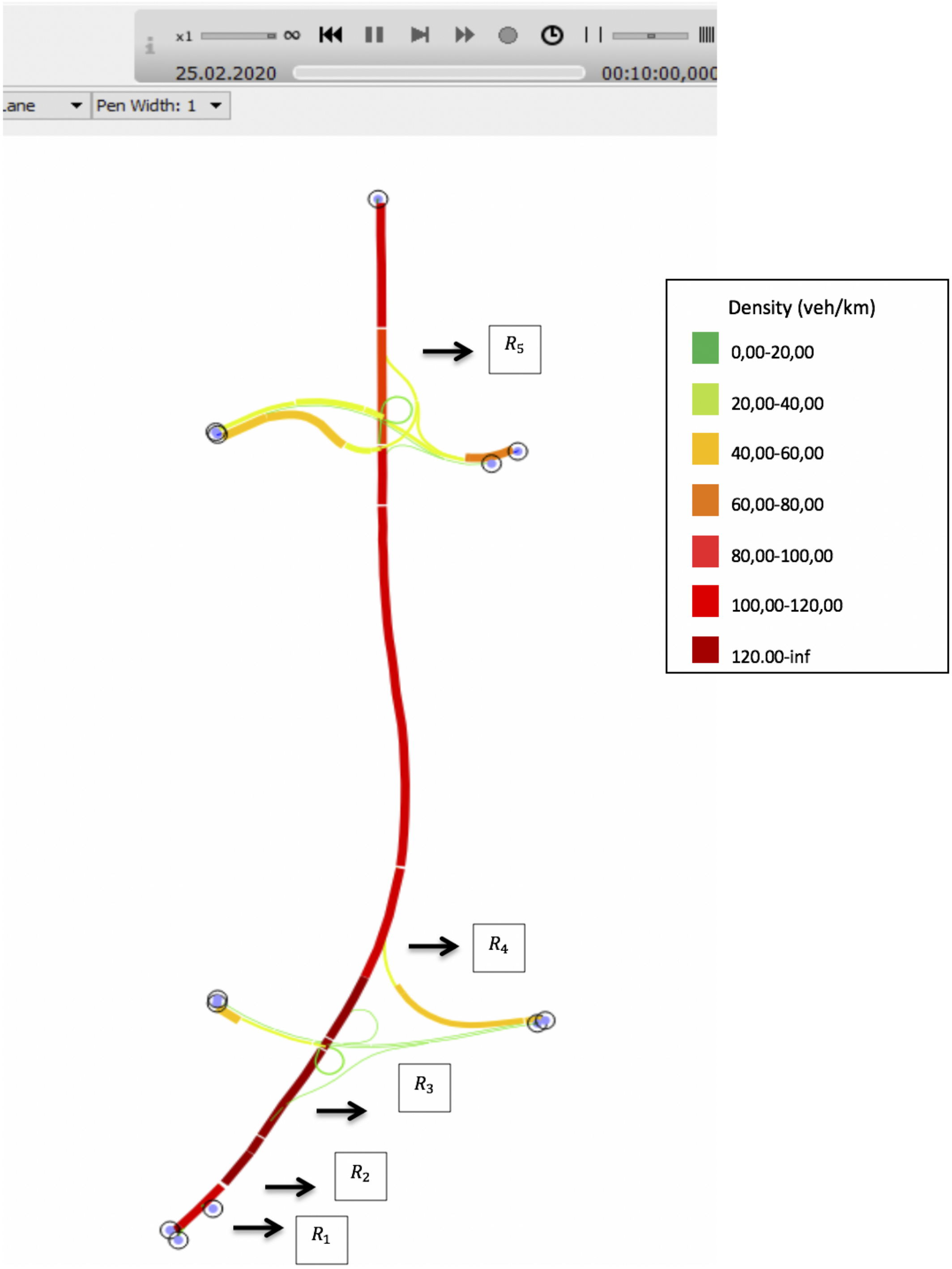

Figure 4.5: Ramp Metering Road Condition (For Density).

Performance Measure	Value	Standard Deviation	Units
Delay Time - Car	53,75	58,55	sec/km
Density - Car	1,39	N/A	veh/km
Flow - Car	7218	N/A	veh/h
Harmonic Speed - Car	54,93	22,82	km/h
Input Count - Car	3359	N/A	veh
Input Flow - Car	20154	N/A	veh/h
Max Virtual Queue - Car	35894	N/A	veh
Mean Queue - Car	653,73	N/A	veh
Mean Virtual Queue - Car	17698,24	N/A	veh
Missed Turns - Car	14	N/A	
Number of Stops - Car	0,82	N/A	#/veh/km
Speed - Car	64,4	20,31	km/h
Stop Time - Car	40,94	55,55	sec/km
Total Travel Time - Car	122,24	N/A	h
Total Travelled Distance - Car	5981,78	N/A	km
Travel Time - Car	91,66	62,96	sec/km
Vehicles Inside - Car	2156	N/A	veh
Vehicles Lost Inside - Car	3	N/A	veh
Vehicles Lost Outside - Car	10	N/A	veh
Vehicles Outside - Car	1203	N/A	veh
Vehicles Waiting to Enter - Car	35894	N/A	veh

Table 4.4: Analysis Results For Ramp Control.

Origin	Destin-ation	Vehicles Assigned	Vehicles Entered	Vehicles Exited	Volume	Distance	Travel Time
37339	37159	86	3	3	90	6780,48	272259
37339	37155	55	3	3	4500	1762,61	115963
37339	37152	6772	343	343	75	6542,79	265194
37339	37146	36	2	2	3200	5878,93	249452
37339	37141	11	1	1	70	6805,35	273005
37160	37155	64	6	6	50	6692,57	269657
37160	37152	4489	140	140	55	5696,3	209,63
37156	37159	4441	171	171	80	1604,23	103911
37156	37152	8631	152	152	55	5458,61	202565
37147	37159	67	1	1	35	4794,75	186823
37147	37155	42	0	0	30	5721,17	210376
37147	37152	4584	84	84	30	5608,39	207028
37147	37146	4	0	0	6750	6613,48	198404
37140	37159	3138	73	73	4500	2627,68	790358
37140	37155	34	1	1	8500	2064,24	630516
37140	37152	4776	129	129	4500	6375,79	191339
37134	37159	67	2	2	4750	5711,93	175598
37134	37155	30	4	4	1000	6638,35	199,15
37134	37152	993	79	79	750	6525,57	195803
37134	37146	70	6	6	40	2858,1	144834
37134	37141	17	2	2	3	2620,41	137769
37133	37159	47	1	1	65	2882,97	145,58
37133	37155	38	2	2	10	2770,19	142232
37133	37152	744	65	65	15	2462,93	146079
37133	37146	9	2	2	10	2487,8	146825
37133	37141	8	0	0	7	2375,03	143477

Table 4.5: Analysis Table from Point Origin to Destination In The Ramp Control.

4.3.3 Main-Line Metering Control (MLC)

Under normal circumstances, the demand to impose restrictions on the mainline can be reconciled with the decisions made as a result of an erroneous analysis. However, it is considered that ramp metering will not be sufficient to shorten long travel times on highways that are above the mainline density capacity. It is believed that the congestion occurring on the mainline on the highway can be prevented from forming long queues with the mainline metering. It is believed that the signaling placed on the mainline can be opened and closed at certain time intervals, relieving the obstruction in the downstream direction and then rapidly discharging the vehicle density in the upstream direction. It is thought that this form of signaling can be a useful method to open the blockages that will occur as a result of traffic accidents. Modeling was carried out by accepting the number of vehicles allocated per lane on the mainline and the number of vehicles per lane coming from the ramp in this same scenario type. There are 4 mainline participation points in the modeled one-way road network [Figure 4.6]. Various cycle times and green time scenarios have been tried by considering the individual vehicle densities of each ramp and mainline. By making small fluctuations in different values assigned, the results of the analysis are taken over and over and simulation is used that provides the most ideal image from the analysis results. Therefore, the times assigned to the model; In the mainline, Green Time is 27 seconds, Cycle Time is 30 seconds, Offset is 24 seconds; In the ramp Green Time 6 seconds, Cycle Time 30 seconds. The results of the analysis made in this direction are as follows;

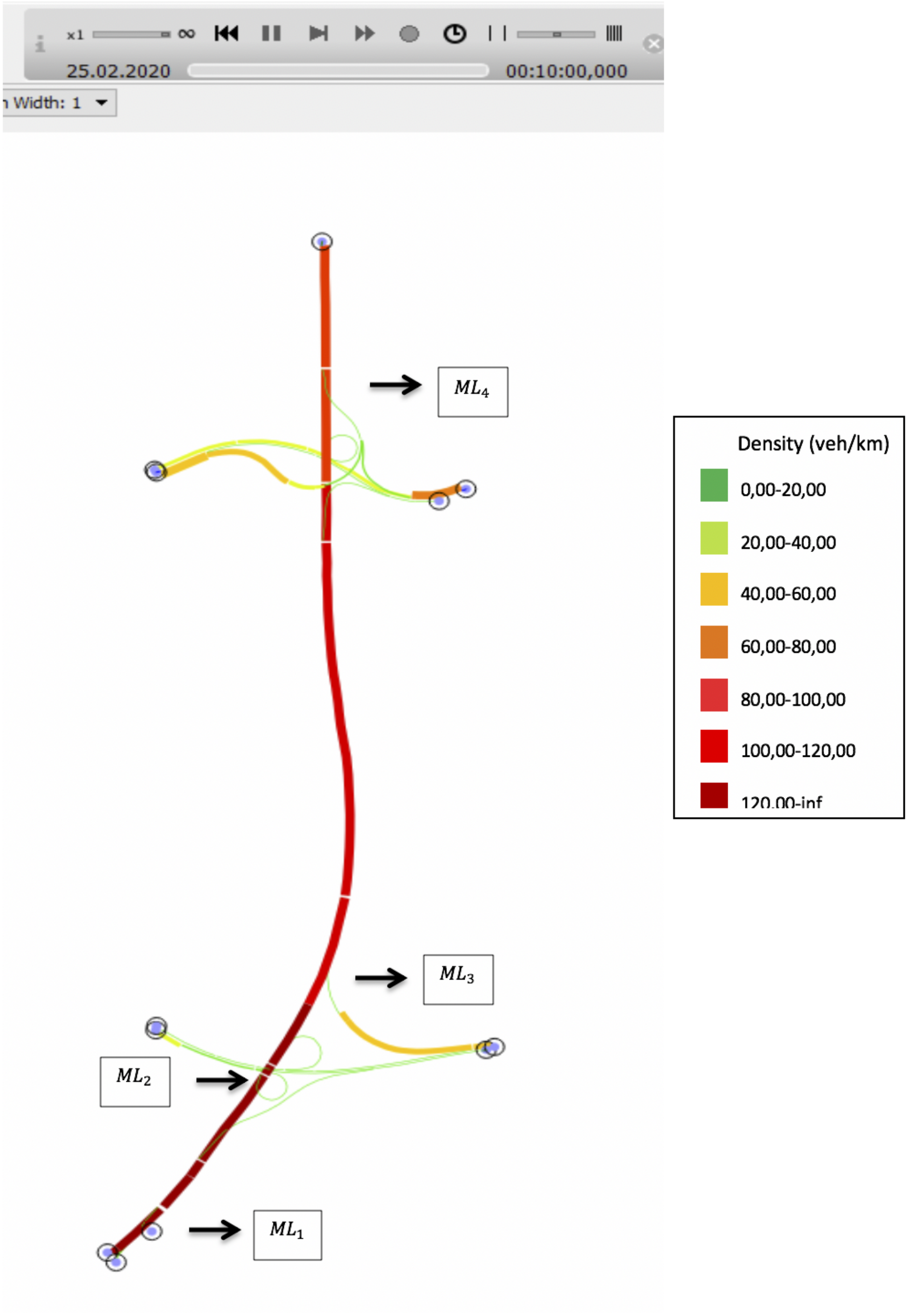

Figure 4.6: Mainline Metering Road Condition (For Density).

Performance Measure	Value	Standard Deviation	Units
Delay Time - Car	47,44	55,26	sec/km
Density - Car	1,46	N/A	veh/km
Flow - Car	5880	N/A	veh/h
Harmonic Speed - Car	63,78	25,35	km/h
Input Count - Car	3267	N/A	veh
Input Flow - Car	19602	N/A	veh/h
Max Virtual Queue - Car	35478	N/A	veh
Mean Queue - Car	871,5	N/A	veh
Mean Virtual Queue - Car	17469,02	N/A	veh
Missed Turns - Car	9	N/A	
Number of Stops - Car	0,33	N/A	#/veh/km
Speed - Car	73,85	21,13	km/h
Stop Time - Car	39,34	54	sec/km
Total Travel Time - Car	100,24	N/A	h
Total Travelled Distance - Car	5238,79	N/A	km
Travel Time - Car	85,96	61,43	sec/km
Vehicles Inside - Car	2287	N/A	veh
Vehicles Lost Inside - Car	2	N/A	veh
Vehicles Lost Outside - Car	6	N/A	veh
Vehicles Outside - Car	980	N/A	veh
Vehicles Waiting to Enter - Car	35478	N/A	veh

Table 4.6: Analysis Results For Mainline Control.

Origin	Destin-ation	Vehicles Assigned	Vehicles Entered	Vehicles Exited	Volume	Distance	Travel Time
37339	37159	86	5	5	90	6780,48	272,259
37339	37155	55	4	4	55	5696,3	209,63
37339	37152	6772	603	603	6750	6613,48	198,404
37339	37146	36	4	4	40	2858,1	144,834
37339	37141	11	2	2	15	2462,93	146,079
37160	37155	64	6	6	80	1604,23	103,911
37160	37152	4489	28	28	4500	2627,68	790,358
37156	37159	4441	169	169	4500	1762,61	115,963
37156	37152	8631	40	40	8500	2064,24	630,516
37147	37159	67	0	0	75	6542,79	265,194
37147	37155	42	0	0	55	5458,61	202,565
37147	37152	4584	23	23	4500	6375,79	191,339
37147	37146	4	0	0	3	2620,41	137,769
37140	37159	3138	16	16	3200	5878,93	249,452
37140	37155	34	1	1	35	4794,75	186,823
37140	37152	4776	29	29	4750	5711,93	175,598
37134	37159	81	1	1	70	6805,35	273,005
37134	37155	37	1	1	30	5721,17	210,376
37134	37152	728	33	33	750	6638,35	199,15
37134	37146	53	4	4	65	2882,97	145,58
37134	37141	7	1	1	10	2487,8	146,825
37133	37159	54	0	0	50	6692,57	269,657
37133	37155	33	0	0	30	5608,39	207,028
37133	37152	503	4	4	500	6525,57	195,803
37133	37146	8	0	0	10	2770,19	142,232
37133	37141	11	0	0	7	2375,03	143,477

Table 4.7: Analysis Table from Point Origin to Destination In The Mainline Control.

4.4 Results and Discussion

Comparative figures of the results from the prepared analyzes are shown in tables 4.8, 4.9 and in figures 4.8 to 4.18.

Performance Measure	BC	RMC	MLC	Units
Delay Time - Car	57,18	53,75	47,44	sec/km
Density - Car	1,2	1,39	1,46	veh/km
Flow - Car	7740	7218	5880	veh/h
Harmonic Speed - Car	57,45	54,93	63,78	km/h
Input Count - Car	3106	3359	3267	veh
Input Flow - Car	18636	20154	19602	veh/h
Max Virtual Queue - Car	35639	35894	35478	veh
Mean Queue - Car	325,67	653,73	871,5	veh
Mean Virtual Queue - Car	17583,87	17698,24	17469,02	veh
Missed Turns - Car	12	14	9	-
Number of Stops - Car	0,81	0,82	0,33	#/veh/km
Speed - Car	61,65	64,4	73,85	km/h
Stop Time - Car	41,85	40,94	39,34	sec/km
Total Travel Time - Car	126,5	122,24	100,24	h
Total Travelled Distance - Car	5660,99	5981,78	5238,79	km
Travel Time - Car	98,76	91,66	85,96	sec/km
Vehicles Inside - Car	1816	2156	2287	veh
Vehicles Lost Inside - Car	6	3	2	veh
Vehicles Lost Outside - Car	6	10	6	veh
Vehicles Outside - Car	1290	1203	980	veh
Vehicles Waiting to Enter - Car	35639	35894	35478	veh

Table 4.8: Compare Control Scenarios.

%	BC-RMC	BC-MLC	RMC-MLC	Change
Delay Time (sec/km)	6,00	17,03	11,74	↘
Density (veh/km)	15,83	21,67	5,04	↗
Flow(veh/h)	6,74	24,03	18,54	↘
Speed (km/h)	4,46	19,79	14,67	↗
Stop Time (sec/km)	2,17	6,00	3,91	↘
Total Travel Time (h)	3,37	20,76	18,00	↘
Travel Time (sec/km)	7,19	12,96	6,22	↘

Table 4.9: Compare Control Scenarios (%).

When the delay times in the analyzes are taken into consideration, it is seen that the ramp metering decreases this time by 6,00%. But the main thing is the result of the mainline metering. As a result of the mainline metering applied, the delay times of 17.03% decreased.

When the ramp metering scenario is applied, the results of the analysis are improved. This level increases exponentially when the mainline metering scenario is applied. In the scenario where ramp metering was applied, the vehicle speed was 4.46%; In the scenario applied by combining the mainline and ramp metering, the vehicle speed increases by 19.79%.

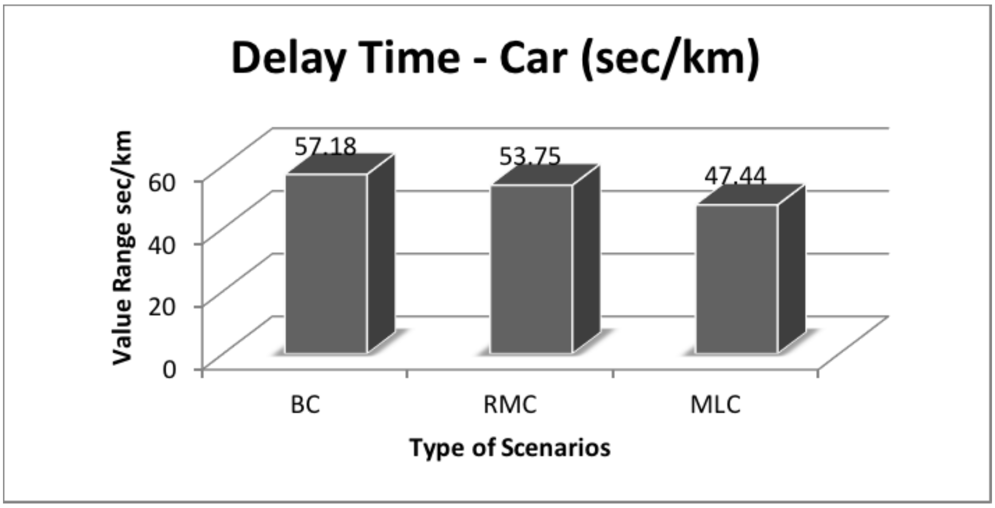

Figure 4.7: Comparing Scenario Types For Delay Time.

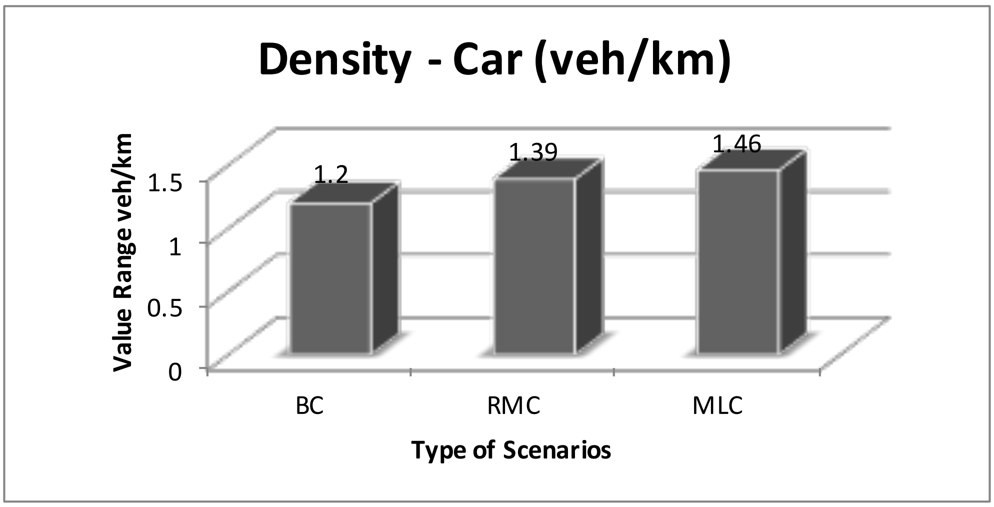

Figure 4.8: Comparing Scenario Types For Density.

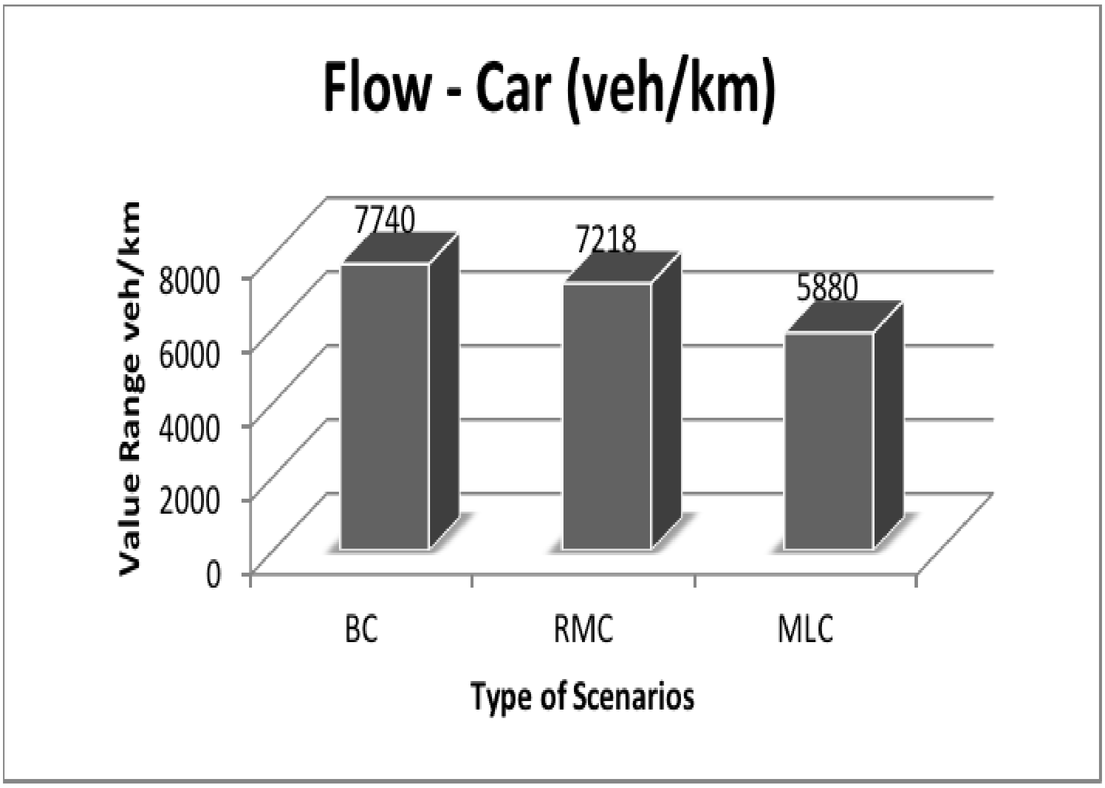

Figure 4.9: Comparing Scenario Types For Flow.

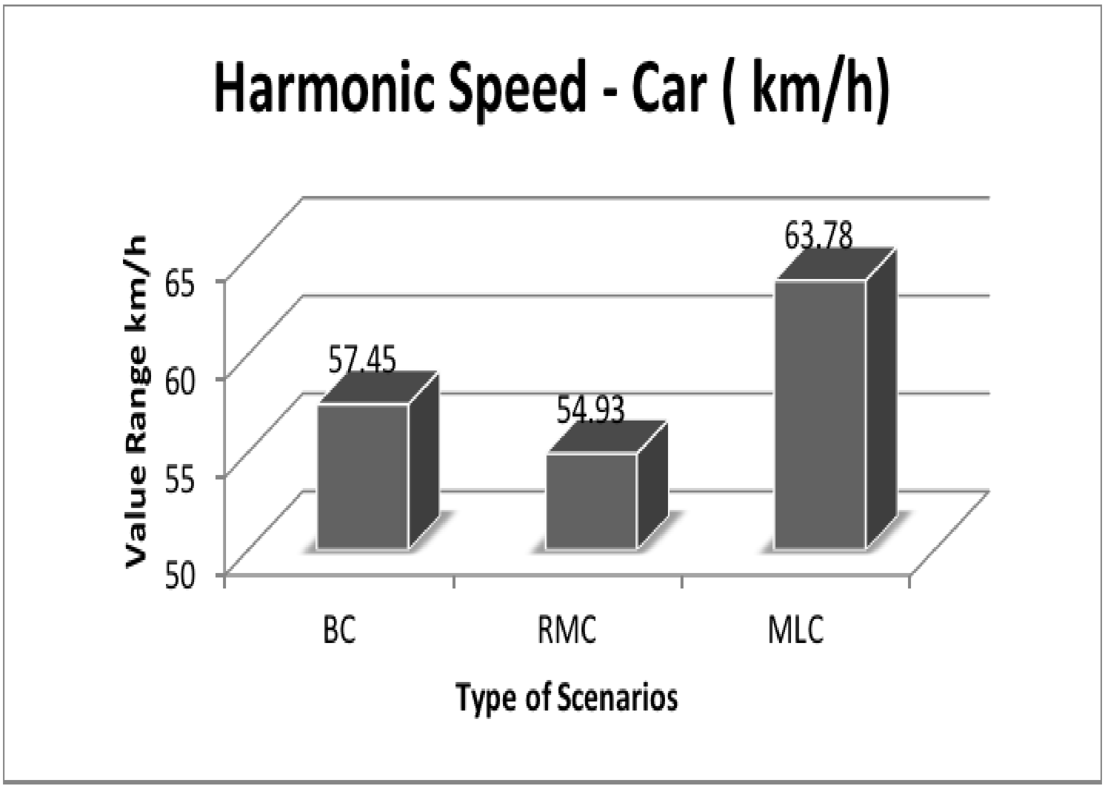

Figure 4.10: Comparing Scenario Types For Harmonic Speed.

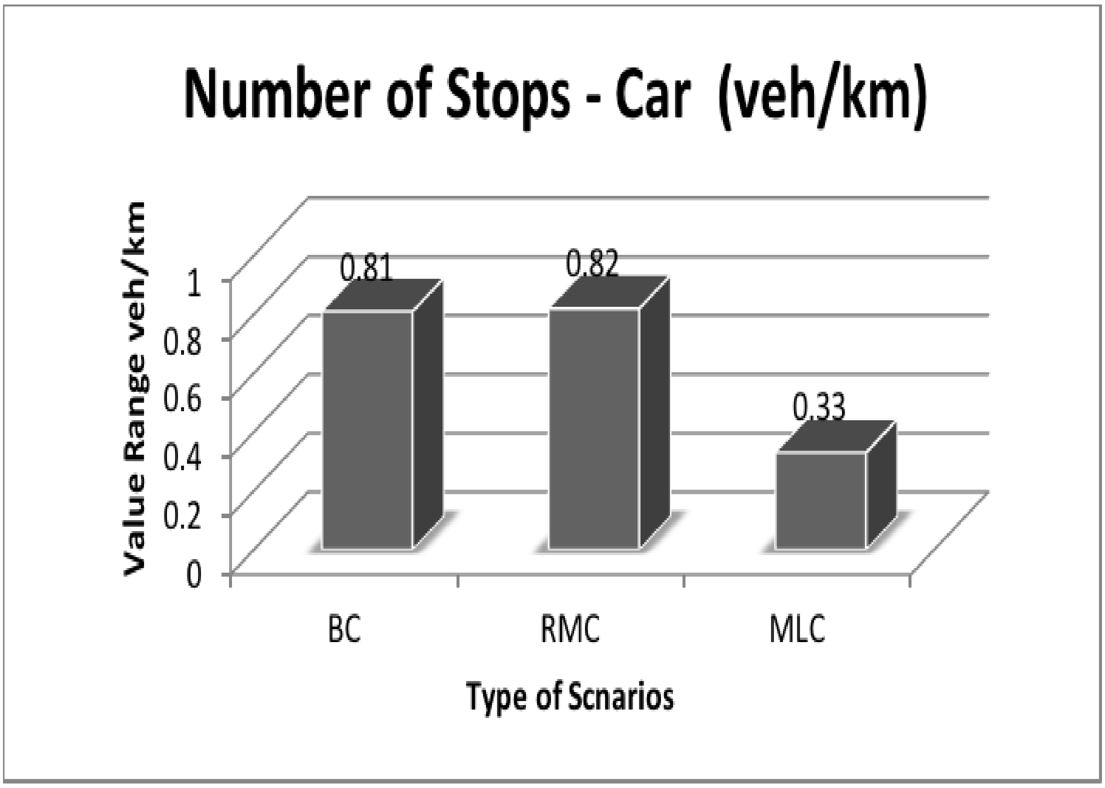

Figure 4.11: Comparing Scenario Types For Number Of Stops.

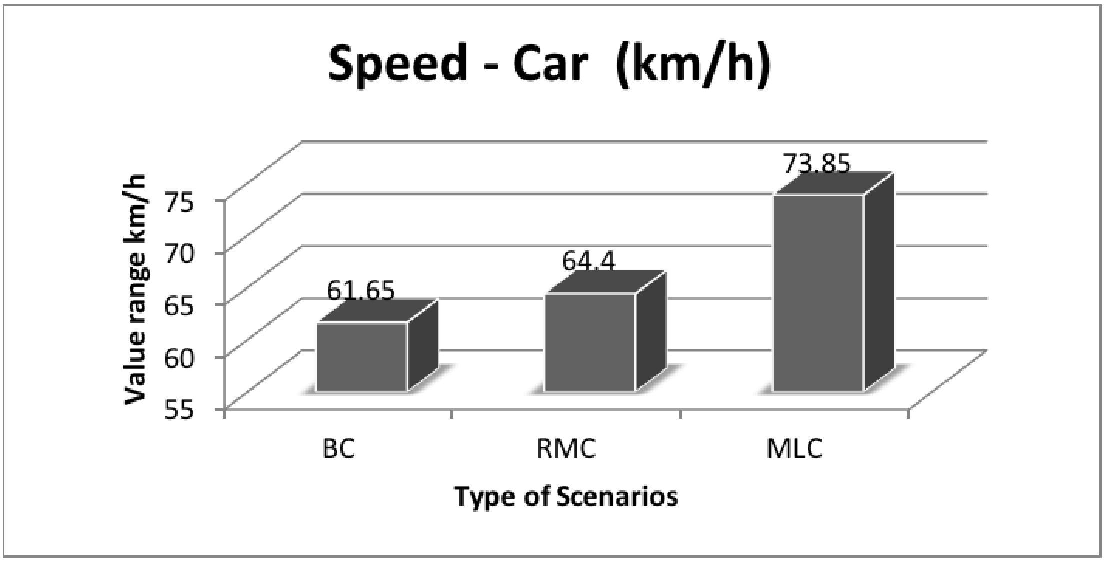

Figure 4.12: Comparing Scenario Types For Speed.

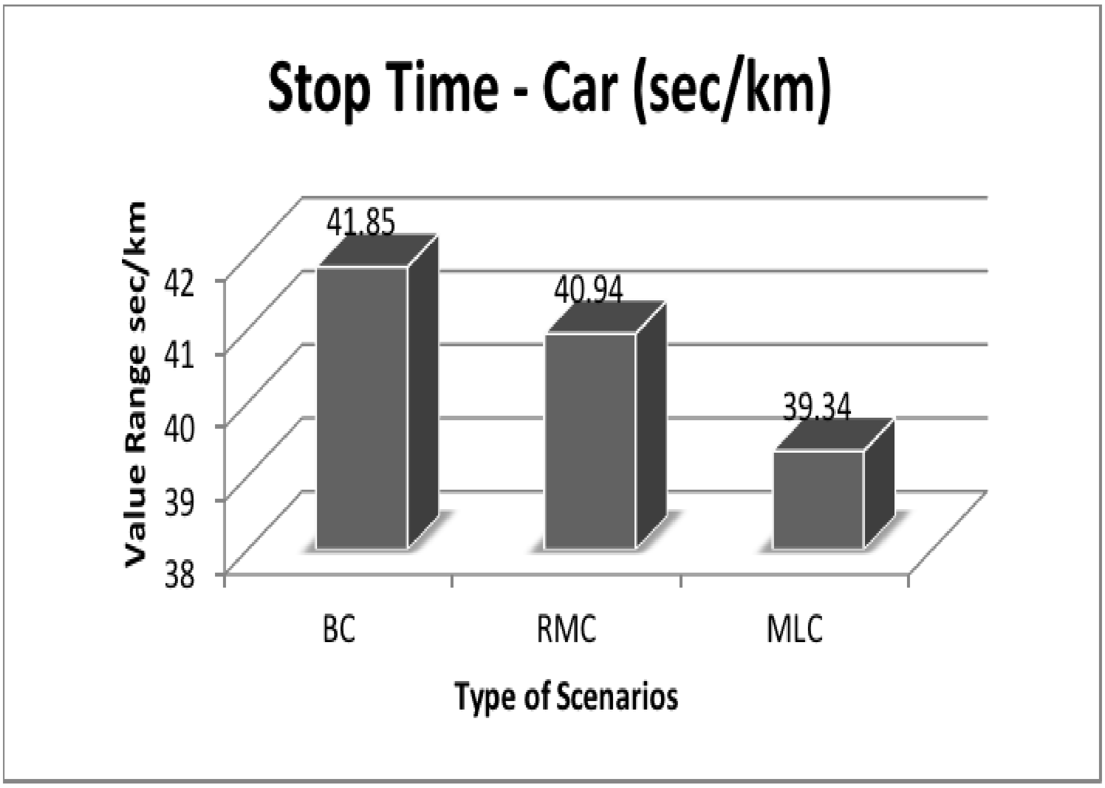

Figure 4.13: Comparing Scenario Types For Stop Time.

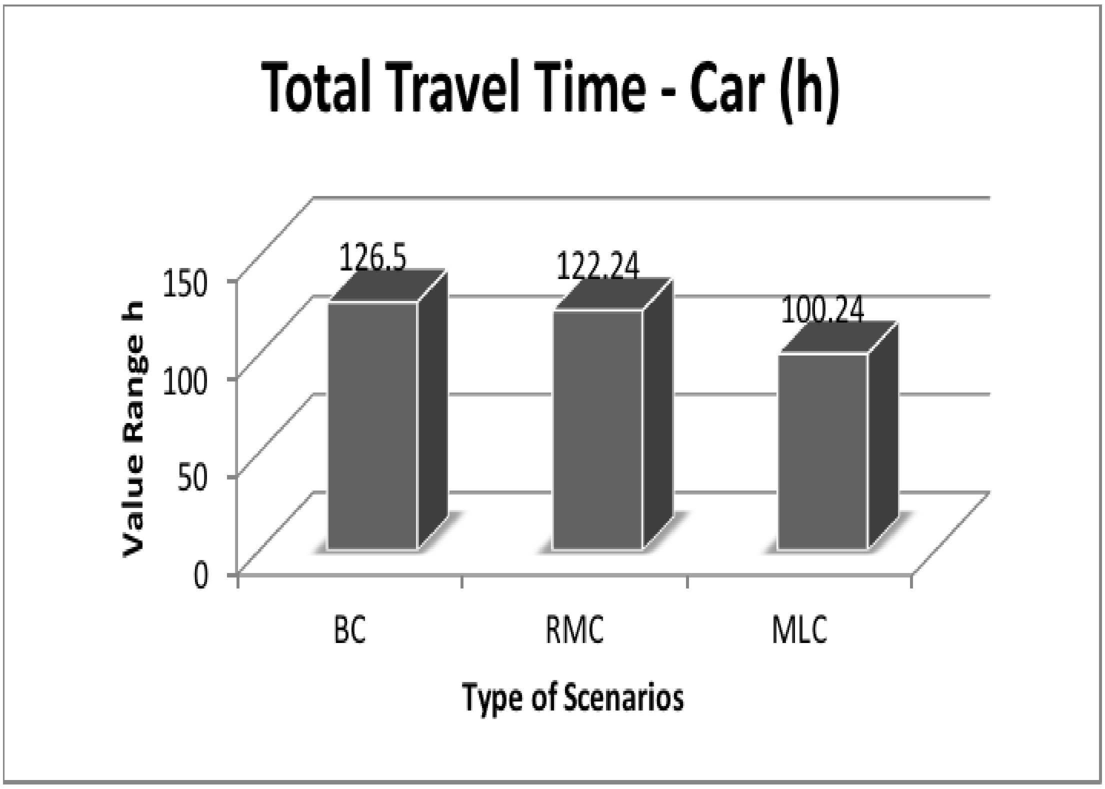

Figure 4.14: Comparing Scenario Types For Total Travel Time.

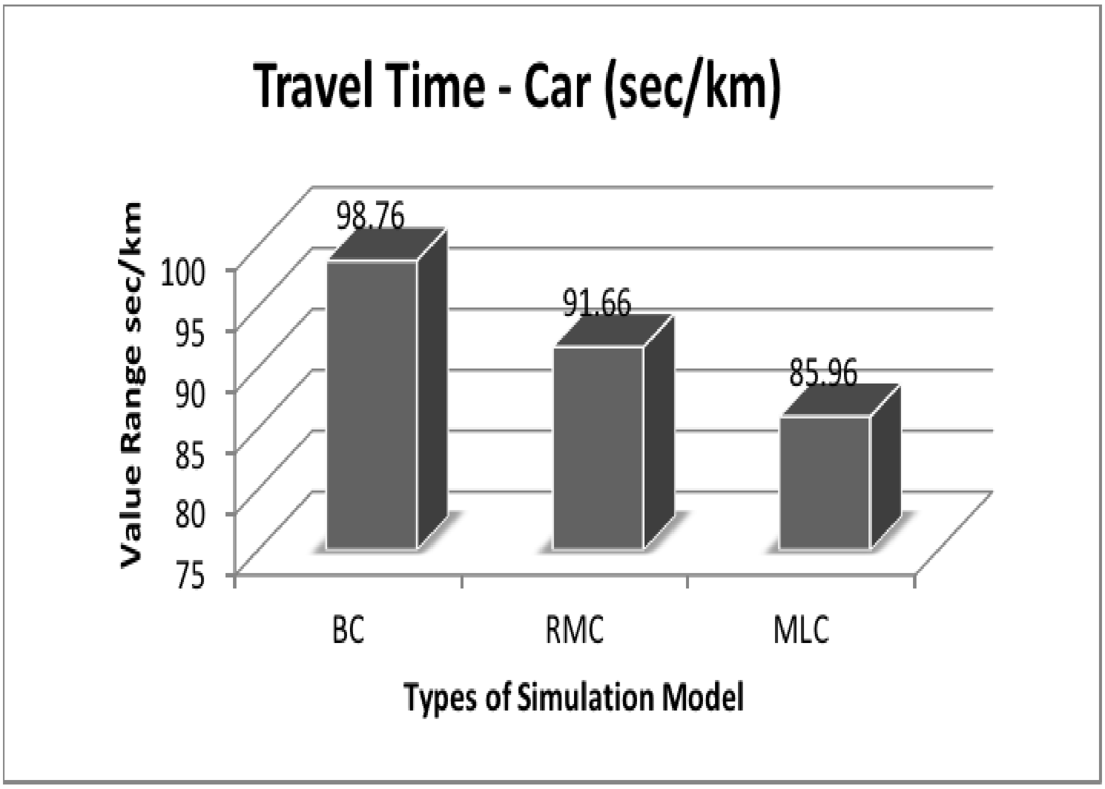

Figure 4.15: Comparing Scenario Types For Travel Time.

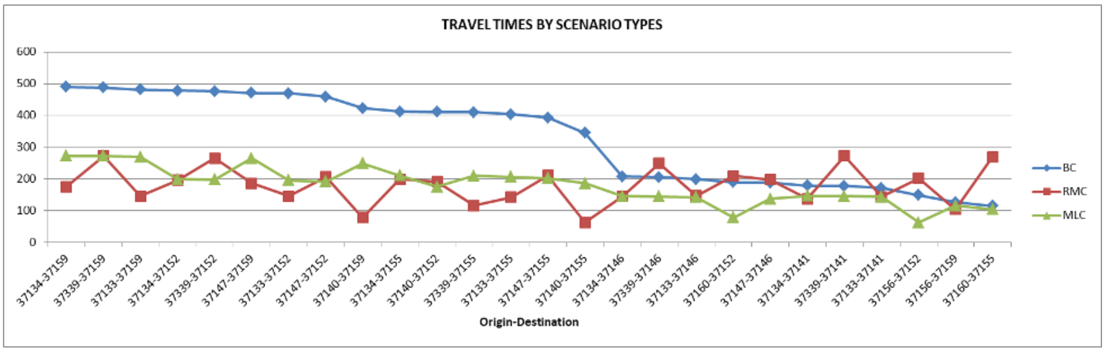

Figure 4.16: Travel Time Change Between Departure And Arrival Points.

Origin-Destination	Distance (m)	Origin-Destination	Distance (m)
37134-37159	6805,35	37147-37155	5458,61
37339-37159	6780,48	37140-37155	4794,75
37133-37159	6692,57	37134-37146	2882,97
37134-37152	6638,35	37339-37146	2858,1
37339-37152	6613,48	37133-37146	2770,19
37147-37159	6542,79	37160-37152	2627,68
37133-37152	6525,57	37147-37146	2620,41
37147-37152	6375,79	37134-37141	2487,8
37140-37159	5878,93	37339-37141	2462,93
37134-37155	5721,17	37133-37141	2375,03
37140-37152	5711,93	37156-37152	2064,24
37339-37155	5696,3	37156-37159	1762,61
37133-37155	5608,39	37160-37155	1604,23

Table 4.10: Volume Change Between Departure And Arrival Points.

Figure 4.16 shows the variations in travel times of scenarios resulting from applied restrictions and not restricted (in OD matrix ranges). Table 4.10 displays the distances between OD matrices. When these two outputs are examined together, the results are as follows;

- O: 37160 – D: 37152; These points come from the ramp and join the main road. At this point, travel time increases when ramp restriction is made, because the flow of vehicles in this line is limited. However, travel time is reduced when the main line restriction is applied. This reduces the time by increasing the vehicle flow here, along with the constraints on the mainline.
- O: 37339- D: 37146; It appears that it does not benefit when the ramp metering is applied. However, it seems that travel times are reduced when the mainline metering is applied.
- O: 37160 – D: 37155; In the lowest value rotation of BC, MLC is aligned in the same way, while RMC shows one of the highest values. There are no restrictions affecting these points. However, when the ramp restriction is applied, it is seen that the blockages occurring backward cause the section that will go to 37152.

- When the parameters in Figure 4.16 and Table 4.10 are evaluated together, the effects of RMC and MLC increase as the distance between the OD pair increases. In short distance OD pairs, it is seen that it has almost no effect. This brings to mind the effects of traffic control on equality and the optimum conditions of Pareto.

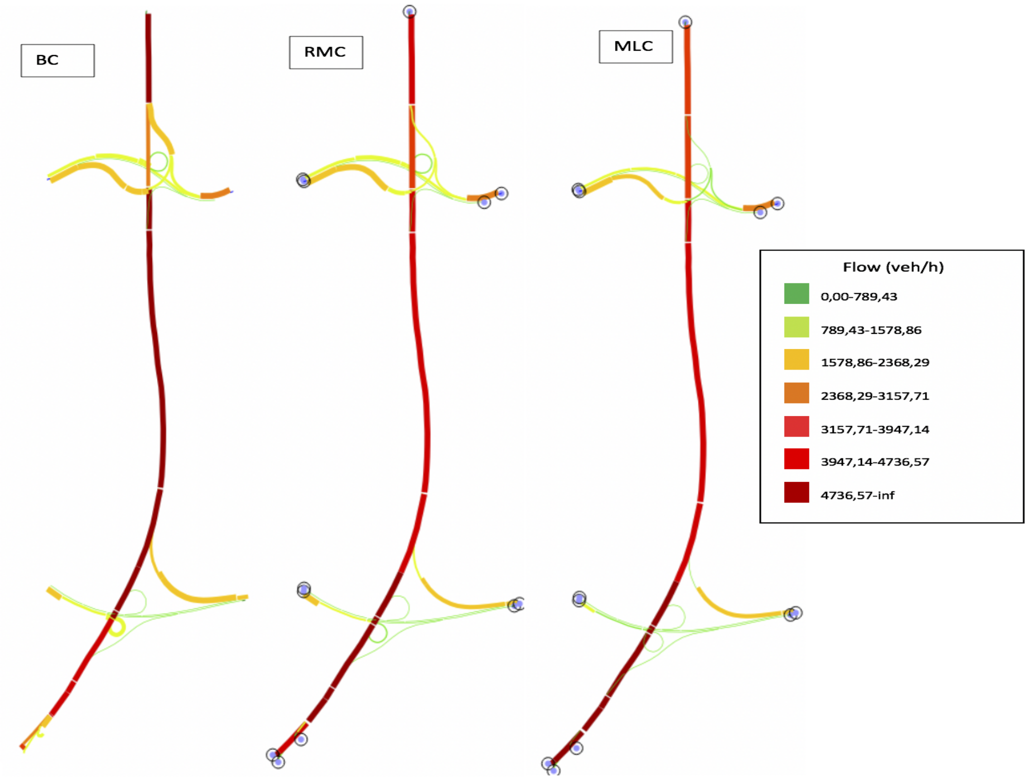

Figure 4.17: Flow Views Of Scenario Types.

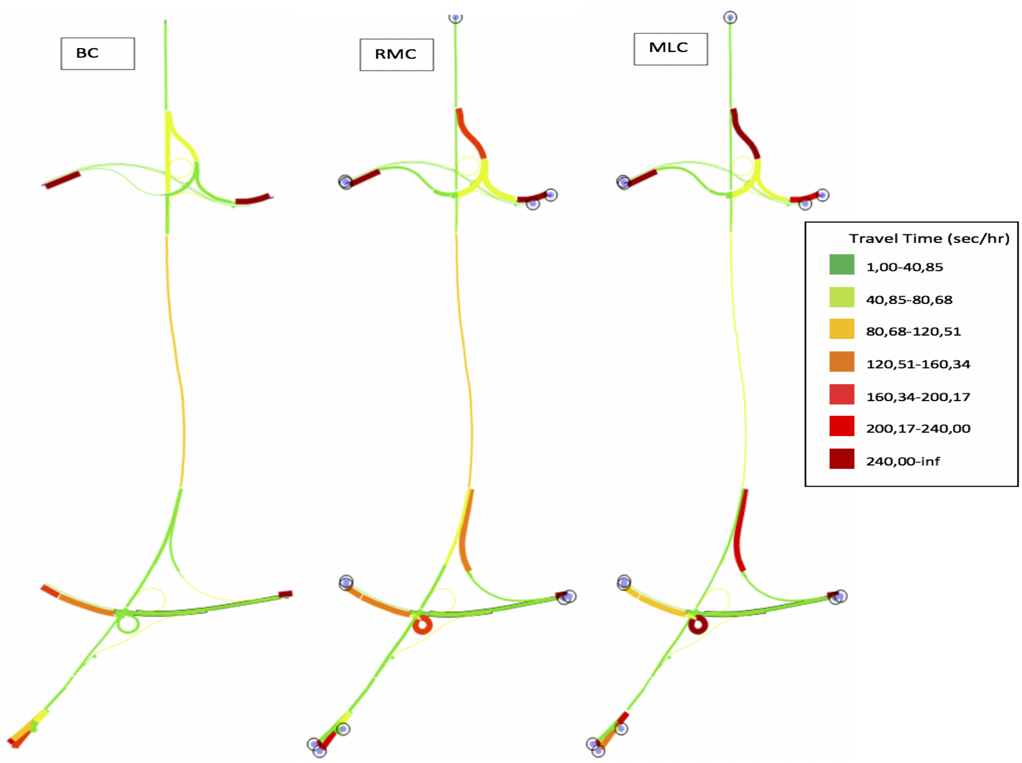

Figure 4.18: Travel Time Views Of Scenario Types.

A few observations from the results of the analysis can be listed as follows:

- As the mainline volume increases, it appears that the downstream vehicle efficiency increases in ramp metering. This result is consistent with current experience with ramp metering so far.
- Combining mainline metering with ramp metering gives lower downstream values (Figure 4.15).
- Adding signaling for the mainline provides very advanced highway conditions downstream. These conditions positively affect the travel time upstream of the main meter.
- Combining the mainline metering with the ramp metering, the total travel times for the total network are shown. Figure 4.13 shows that this time reduction may be as low as 22 s.

Chapter 5

Conclusion and Further Studies

In this study, the AIMSUN highway simulation module is used and two main dynamic traffic control approaches are proposed for the Istanbul Ring Road (E-8) traffic jam. These approaches are ramp and mainline metering within the scope of highway traffic management. The aim of the study is to determine whether the conducted analyzes provide any highway operational benefits. Although the model is not based on real-time counts, the analysis was carried out using real simulation techniques. A road network suitable for the geometrical features of the road has been created and the network has been calibrated. Network calibration was then arranged for two access control (Ramp Metering, Mainline Metering) and one uncontrolled network. After all the scenarios were created, firstly, experiments were carried out on the generic network simulation. After obtaining the desired results, the highway design network prepared for the working network was started. Simulation times, road speed limits, road widths were selected and simulation was applied for uncontrolled, ramp metering, and mainline metering. Simulation results show that the application of ramp metering and mainline metering together increases speeds on the main road and decreases intensities. In other words, improvement in operating conditions has been achieved. Thus, it was seen that the desired benefit could be obtained. Ramp metering is 3.37% decrease reduction in total travel time, 4.46% increase in speeds; mainline metering was observed resulted in a 20.76% decrease and a 19.79% increase in the same values. Ramp metering or mainline metering applications also have some negative effects. Since the purpose of the controls is to ensure the continuous flow of the main road traffic, it will be to limit the number of vehicles coming from the participation point. In this case, the length of the tail formed by the vehicles accumulated in the participation arms and Pareto optimal rule should not be ignored. It should be noted that while the lines with long travel times save time, the lines on short travel times do not extend. In the current uncontrolled state, the queues in these participations extend to urban roads and can block traffic not related to the highway. It should not be forgotten that if the controls are applied in these attendances, the possibility that the queues may become longer. Therefore, a design road with a length that can store the tail to be formed is a desired feature in the participation to be controlled. Since AIMSUN is not a program running on a strip basis, the results obtained in the study are considered as the average of the general road network. It is also mentioned in the resource research that the analyzes to be made in other programs that can form a more detailed model can give more detailed results. Simulation practice results suggest that participation control may benefit, but more detailed studies should be done before field application. After the current situation has been created with sufficient accuracy in the computer environment, it is thought that more effective results can be obtained with various improvement strategies and applications in the field. Especially when more comprehensive data are obtained. There are situations where the simulation application causes problems. It is experienced during the preparation of the thesis. One of them is that it is necessary to purify the system from its initial state effects. Especially in non-terminated models, the time spent by the system until it reaches a steady-state, i.e. the warming-up period statistics, should not be included in the calculations in order to eliminate the biased effects on the performance output values. However, the program used does not respond to the application of long analysis times. In this context, a participation control model is a tool that will provide significant benefits in terms of average delay, operating cost, travel time, travel speed, tail length in vehicles, and tail length in distance.

References

[1] Q. Life and I. Rate, "Current Quality Of Life Index By City." 2020. [Online]. Available: https://www.numbeo.com/quality-of-life/rankings_current.jsp

[2] S. Ulucay, "Traffic management in an intercontinental city: Istanbul," in *1st International Conference on Access Management,*, Athens, Greece, 2011.

[3] K. T. K. İstatistikleri, "Ankara: Türkiye istatistik kurumu trafik istatistik bülteni (2016)," 2016.

[4] Comittee, "index2019tomtom," 2019. [Online]. Available: https://www.tomtom.com/en_gb/traffic-index/ranking/

[5] X. Sun and R. Horowitz, "A localized switching ramp-metering controller with a queue length regulator for congested freeways," in *Proceedings of the 2005, American Control Conference, 2005.* Portland, OR, USA: IEEE, 2005, pp. 2141–2146.

[6] F. H. Stairs, "The Hampton Roads Bridge-tunnel Control System," *Transportation Engineering*, vol. 47, no. 9, 1977.

[7] M. M. Mahmod, B. van Arem, R. Pueboobpaphan, and M. Igamberdiev, "Modeling reduced traffic emissions in urban areas: the impact of demand control, banning heavy duty vehicles, speed restriction and adaptive cruise control," Tech. Rep., 2010.

[8] A. Ghiasi, D. Hale, J. Bared, A. Kondyli, and J. Ma, "A Dynamic Signal Control Approach for Integrated Ramp and Mainline Metering," in *2018*

21st International Conference on Intelligent Transportation Systems (ITSC). IEEE, 2018, pp. 2892–2898.

[9] N. Jiang and S. Tang, "An Approach of Controlling Both Freeway On-ramp and Mainline," in *2009 International Joint Conference on Artificial Intelligence.* Hainan Island: IEEE, 2009, pp. 683–686.

[10] K. A. Haboian, "A case for freeway mainline metering," *Transportation research record*, no. 1494, 1995.

[11] N. A. Chaudhary, Z. Tian, C. J. Messer, and C.-L. Chu, "Ramp metering algorithms and approaches for Texas," *Texas Transportation Institute Technical Report*, 2004.

[12] G. B. Whitham, *Linear and nonlinear waves.* John Wiley & Sons, 2011, vol. 42.

[13] E. C. Carter and S. P. Palaniswamy, "Study of traffic flow on a restricted facility," 1973.

[14] C. Daganzo and C. F. Daganzo, *Fundamentals of transportation and traffic operations.* Pergamon Oxford, 1997, vol. 30.

[15] P. Kachroo and K. Ozbay, *Feedback ramp metering in intelligent transportation systems.* Springer Science & Business Media, 2011.

[16] Comittee, "degisecek." [Online]. Available: http://www.fhwa.dot.gov/publication/research/operation/tft

[17] B. D. Greenshields, J. R. Bibbins, W. S. Channing, and H. H. Miller, "A study of traffic capacity," in *Highway research board proceedings*, vol. 1935. National Research Council (USA), Highway Research Board, 1935.

[18] C. Daganzo, "The cell transmission model. Part I: A simple dynamic representation of highway traffic," 1992.

[19] N. Ghariani, S. Elkosantini, S. Darmoul, and L. B. Said, "Assessment of public transport control systems: a comparative analysis of platforms and a new platform architecture," *International Journal of Shipping and Transport Logistics*, vol. 8, no. 5, pp. 509–530, 2016.

[20] K. M. Collins, "Professional Mentor David H. Roper, PE Roper and Associates, Inc." 1994.

[21] M. Pidd *et al.*, *Computer simulation in management science.* Wiley Chichester, 1998, vol. 4.

[22] A. M. Law, W. D. Kelton, and W. D. Kelton, *Simulation modeling and analysis.* McGraw-Hill New York, 2000, vol. 3.

[23] J. Barceló and J. Casas, "Dynamic network simulation with aimsun," in *Simulation approaches in transportation analysis.* Springer, 2005, pp. 57–98.

[24] A. Ghiasi, J. Ma, F. Zhou, and X. Li, "Speed harmonization algorithm using connected autonomous vehicles," in *96th Annual Meeting of the Transportation Research Board*, no. 17–02568, Washington DC, United States, 2017.